Feasibility Study Report
Cadet Manufacturing Company and Swan Manufacturing Company Portions, Vancouver Port of NuStar Cadet Swan Site

Prepared for
Port of Vancouver, USA

Port of Vancouver USA

September 13, 2023

Prepared by
Parametrix

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Cadet Manufacturing Company and Swan Manufacturing Company Portions, Vancouver Port of NuStar Cadet Swan Site

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CERTIFICATION

The technical material and data contained in this document were prepared under the supervision and direction of the undersigned, whose seal, as a professional hydrogeologist licensed to practice as such, is affixed below.

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ACRONYMS AND ABBREVIATIONS

AMEC	AMEC Earth and Environmental, Inc.
AO	Agreed Orders
ARAR	Applicable or relevant and appropriate requirements
AS	Air sparging
BNSF	Burlington Northern Santa Fe
CAMP	Comprehensive Vapor Intrusion Evaluation and Indoor Air Monitoring Plan
CLARC	Cleanup levels and risk calculation
COC	Contaminant of concern
COPC	Chemical of potential concern
CPU	Clark Public Utilities
DOH	Department of Health
ELCR	Excess lifetime cancer risk
EPA	U.S. Environmental Protection Agency
FS	Feasibility study
FVN	Fruit Valley Neighborhood
GPTIA	Groundwater pump and treat interim action
GWM	Great Western Malting
IAMP	Indoor air monitoring plan
MCL	Maximum contaminant level
MNA	Monitored natural attenuation
MTCA	Model Toxics Control Act
NFVN	North Fruit Valley Neighborhood
NGVD	National Geodetic Vertical Datum
NPDES	National Pollutant Discharge Elimination System
PCE	Tetrachloroethylene
POC	Point of compliance
RAO	Remedial action objective
RGRW	Recirculating groundwater remediation wells
RI	Remedial investigations
SFVN	South Fruit Valley Neighborhood

ACRONYMS AND ABBREVIATIONS (CONTINUED)

SMC	Swan Manufacturing Company
SVE	Soil vapor extraction
SVV	Soil vapor vacuum
TCE	Trichloroethylene
TGA	Troutdale gravel aquifer
USGS	U. S. Geological Survey
VLL	Vancouver Lake lowland
VOC	Volatile organic compound

EXECUTIVE SUMMARY

This feasibility study (FS) has been prepared to address residual dissolved trichloroethylene (TCE) and associated compounds contamination associated with the Cadet Manufacturing Company (Cadet) and former Swan Manufacturing Company (SMC) sites located in Vancouver, Washington. The Cadet and former SMC sites are part of a larger cleanup site referred to in the Washington State Department of Ecology (Ecology) database as the "Vancouver Port of NuStar Cadet Swan" site (the "Site"). The FS has been conducted in accordance with the Model Toxics Control Act (MTCA) as defined in Washington Administrative Code (WAC) 173-340 and pursuant to requirements established in the October 8, 2020, Agreed Order (AO) DE 18152 between Ecology and the Port of Vancouver, USA.

Based on the findings of the FS, preferred cleanup actions for the SMC source area and the residual groundwater concentrations include:

SMC Source Area

The recommended cleanup action for the SMC source area is Institutional Controls, Engineering Controls, and Monitored Natural Attenuation (MNA). Together, these cleanup actions include the following technologies:

- Institutional Controls
  - Implementation of groundwater use restrictions (restrictive covenant, contaminated media management plan, or equivalent) for the SMC property to prevent groundwater from being used and/or to prevent other potential exposure to hazardous substances at SMC.
  - Regular reporting of monitoring results to support institutional control requirements.
- Engineering Controls (Future)
  - Based on the elevated groundwater concentrations of volatile organic compounds (VOCs; TCE and PCE) remaining in the source area, vapor intrusion to indoor air of an overlying building is a potential future complete exposure pathway (no current occupied building exists). A restrictive covenant for future use of the site will be established. The site is currently zoned and utilized for industrial purposes. This land use will be maintained; no residential development will be allowed.
  - Future development of the site could include office space or other occupied building use. Potential site worker exposure to indoor air via vapor intrusion will be managed by completion of a vapor intrusion assessment and evaluating if implementation of mitigation (i.e., engineering controls) is necessary for occupied buildings on the property.
- MNA (in coordination with sitewide selected remedy)
  - This alternative utilizes the sitewide MNA approach to reduce the dispersed residual groundwater contamination associated with the SMC and Cadet sites. Focused monitoring of the SMC source area will be incorporated into the overall site compliance monitoring plan to ensure that the compliance objectives are being met and contingency measures can be employed, as needed.

These cleanup actions were selected for the following reasons:

- The cleanup actions meet the following threshold requirements: protecting human health and the environment, complying with cleanup standards and applicable or relevant and appropriate requirements (ARARs), and providing for compliance monitoring.
- This alternative meets the requirement for a permanent solution with respect to eliminating the exposure pathway. Institutional controls can remain in place indefinitely through the sitewide cleanup action restoration timeframe and beyond, as needed.
- Restoration of the site will be achieved in a reasonable timeframe.
- The cleanup actions address the source area risk by isolation.

The final design of the source area cleanup actions will be determined at the time of development of the cleanup action plan and will be based on the conditions present at the time of design.

Dispersed Residual Groundwater Contamination

The recommended cleanup action for the dispersed residual groundwater contamination is MNA. This cleanup action includes the following technologies:

- Source Control
  - ➢ As described above.
- MNA
  - ➢ Development of an MNA implementation plan, which includes establishing points of compliance, sampling methodology, locations, and frequency, and MNA evaluation criteria.
  - ➢ Monitoring of the Site groundwater wells to verify that groundwater cleanup levels are achieved in a reasonable timeframe.
  - ➢ Regular reporting of monitoring results.
  - ➢ Development of a cleanup action contingency plan. The intent of the contingency plan is to develop methods and procedures for further assessment or actions if the cleanup action is not performing as expected.
- Institutional Controls
  - ➢ Implementation of groundwater use restrictions (restrictive covenant, contaminated media management plan, or equivalent) to prevent groundwater from being used and/or to prevent any other potential exposure to hazardous substances at the site.

These cleanup actions were selected for the following reasons:

- The cleanup actions meet the following threshold requirements: protecting human health and the environment, complying with cleanup standards and ARARs, and providing for compliance monitoring.

- There is evidence that natural biodegradation or chemical degradation is occurring and will continue to occur at a reasonable rate at the site. Therefore, MNA meets the requirement for a permanent solution.
- Groundwater modeling and contaminant trends suggest that MTCA Method B cleanup levels will be achieved in the intermediate zone within 5 to 10 years and in the deep zone generally within 20 years. This meets the reasonable timeframe criterion.
- Groundwater modeling shows that at current conditions, public drinking water receptors will not be impacted above the maximum contaminant level (MCLs).

The final design of the cleanup action will be determined at the time of development of the cleanup action plan and will be based on the conditions present at the time of design.

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1. INTRODUCTION

On behalf of the Port of Vancouver, U.S.A. (the Port), Parametrix has conducted a feasibility study (FS) to address residual contamination associated with the Cadet Manufacturing Company (Cadet) and former Swan Manufacturing Company (SMC) sites located in Vancouver, Washington (Figures 1-1 and 1-2). The Cadet and former SMC sites are part of a larger cleanup site referred to in the Washington State Department of Ecology (Ecology) database as the "Vancouver Port of NuStar Cadet Swan" site (the "Site"). For ease of reading, we will continue to refer to the "SMC site" and the "Cadet site" but with the understanding that they are portions of the Site and no longer exist as separate cleanup sites.

The FS has been conducted in accordance with the Model Toxics Control Act (MTCA) as defined in Washington Administrative Code (WAC) 173-340 and pursuant to requirements established in the October 8, 2020, Agreed Order (AO) DE 18152 between Ecology and the Port. AO DE 18152 requires the Port to prepare an FS and draft cleanup action plan regarding certain hazardous substances on and in the vicinity of the Cadet and SMC portions of the Site. This generally includes the area north of NW Harborside Drive (Figure 1-3). AO DE 18152 is in addition to, and does not supersede, AO 07-TC-S DE 5189, AO 07-TC-S DE 3938, and AO DE 15806.

This FS report was completed to present proposed final remedy(s) to address residual dissolved trichloroethylene (TCE), tetrachloroethylene (PCE), and associated compounds from the Cadet and SMC sites. Remedial investigations (RI) have been conducted on and in the vicinity of the SMC and Cadet sites. The RIs included collection of multimedia data (soil, soil gas, groundwater, indoor air, and outdoor air) and a quantitative evaluation of the potential risk to human health and the environment. Results of the RIs are summarized in the SMC (Parametrix 2009b) and Cadet (Parametrix 2010a) RI reports. Five interim actions have been completed, and one interim action is active to clean up soil, groundwater, and air contamination associated with historical operations at the Cadet and SMC sites.

Information from the RIs and interim actions has been used to develop the cleanup action(s) proposed in this FS report, which primarily focuses on residual contamination in groundwater at the SMC source area and the underlying aquifer. All media (soil, groundwater, and air) have been addressed by previous interim actions or will be addressed by the remedial actions recommended in this FS report. Remedial investigations and continued groundwater monitoring indicate surface water is not a complete pathway for the SMC and Cadet sites and therefore not addressed in this FS. Therefore, this FS report constitutes the final evaluation of remedial actions for all media for both sites, including dispersed residual groundwater contamination remaining after interim actions that have been completed to clean up the sitewide dissolved-phase groundwater plume.

As part of the Cadet and SMC RIs, the Port developed a numeric groundwater model in 2008 to simulate groundwater movement and evaluate the effectiveness of cleanup action alternatives for the FS. The groundwater model was updated in 2021 and used by the Port as part of the FS evaluation of the cleanup action for the dispersed residual groundwater contamination, as well as to support the selection of cleanup actions for the source area at the SMC site.

1.1 Definition of Site and Regulatory Context

As defined in the recent AO (DE 18152), the Site is generally located in the southern half of Section 21 and northern half of Section 28 in Township 1 North, Range 1 East, Willamette Meridian in Vancouver, Washington (Figure 1-2). For administrative convenience, the Site is identified by four portions: (1) the Swan portion between 2001 and 2501 West Fourth Plain Boulevard; (2) the Cadet portion at 2500 West Fourth Plain Boulevard; (3) the NuStar portion at 2565 NW Harborside Drive; and (4) Kinder Morgan Operating Area portion at 2701 NW Harborside Drive). The four portions are shown on Figure 1-2. This FS addresses the SMC and Cadet portions of the Site; however, some aspects of the overall Site, including Site-wide geology and hydrogeology, are discussed throughout this FS report to provide context and setting of the SMC and Cadet sites and applicable remedial action alternatives.

As defined in previous AOs, the Site is defined consistent with MTCA to include the area where a hazardous substance from a release has “come to be located.” This primarily included the Cadet, SMC, and NuStar facilities, and the area underlain by the maximum historical extent of the combined groundwater plume. In 2019, the Kinder Morgan Operating Area was added to the Site after the discovery of metals contamination commingled with volatile organic compounds (VOCs). Therefore, the four portions (Cadet, Swan, NuStar, and Kinder Morgan) are now collectively referred to as the Site (Figure 1-2).

1.2 Purpose

The purpose of the FS is to develop and evaluate cleanup action alternatives so that final cleanup actions can be selected for the source area and dispersed residual groundwater contamination for the SMC and Cadet portion of the Site. Procedures for conducting an FS under MTCA are described in WAC 173-340-350(8). WAC 173-340-350(8)(c)(i)(A) requires an FS to include cleanup action alternatives that protect human health and the environment by eliminating, reducing, or otherwise controlling risks posed through each exposure pathway and migration route. Each alternative may consist of one or more cleanup action components. Alternatives may include remediation levels to define when particular cleanup action components will be used. Each alternative shall be evaluated on the basis of the requirements stated in WAC 173-340-360:

- Protection of human health and the environment
- Compliance with cleanup standards
- Compliance with applicable state and federal laws
- Provision for compliance monitoring

The selected cleanup action(s) shall also use permanent solutions to the maximum extent practicable, provide for a reasonable restoration timeframe, and consider public concerns.

Cleanup standards under MTCA (WAC 173-340-700(3)) include:

- Cleanup levels for hazardous substances present at the site
- The location where the cleanup levels must be met (point of compliance [POC])
- Other regulatory requirements applicable to the Site

MTCA specifies three methods (Methods A, B, and C) that can be used to develop cleanup standards for contaminated media. Method A, B, and C cleanup standards for groundwater are addressed in WAC 173-340-720. Cleanup levels for the Site have been developed and are presented in Section 5.

1.3 Report Organization

This report is organized as follows:

Section 1: Introduction – Provides the regulatory context and purpose and describes the content of the report.

Section 2: Site Background – Describes the location and historical uses of the Cadet and SMC facilities. This section also summarizes the initial activities leading to the discovery of releases at the properties, previous investigations, interim actions conducted at the properties, and the risk assessment findings.

Section 3: Groundwater Model – Summarizes the model and its use in this FS.

Section 4: Applicable Federal, State, and Local Laws – Summarizes laws applicable to cleanup levels, remedial approaches, and process.

Section 5: Development of Cleanup Standards – Describes the requirements and procedures for selecting a cleanup standard for remediation of impacted groundwater.

Section 6: Cleanup Action Evaluation Criteria – Summarizes criteria that affected the development of remedies in this FS report.

Section 7: SMC Source Area Feasibility Evaluation – Identifies and screens technologies for remediation of each medium that incorporates the interim actions, as well as combines the technologies into remedial alternatives, allowing evaluation of the alternatives.

Section 8: Dispersed Residual Groundwater Contamination Feasibility Evaluation – Incorporates the interim actions completed to date, as well as screens technologies and approaches into remedial alternatives, allowing evaluation of the alternatives.

Section 9: Recommended Cleanup Actions – Provides a summary of the preferred remedial actions described in Sections 7 and 8 and shows how the actions meet the cleanup requirements and standards.

Appendices are included that provide technical and supporting information. The appendices are referenced throughout the report.

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2. BACKGROUND

This section provides background information on the Cadet and SMC facilities, as well as summaries of the respective RI and risk assessments for the Cadet and SMC sites. Section 2.1 describes the geology and hydrogeology for the overall Site to provide the setting for physical conditions at the SMC and Cadet sites. Sections 2.2 and 2.3 provide background information on each of the sites, focusing on the source areas and the nature and extent of impacts to soil and shallow groundwater, and they summarize the risk assessments performed on the collected RI data. Historically, impacted groundwater migrated vertically to the intermediate zone and deeper groundwater and has been identified as a dispersed plume underlying the Site. The chemical fate and extent of the residual groundwater plume is discussed in Section 2.4.

2.1 Geology and Hydrogeology

The following sections summarize the geology and hydrogeology at the overall Site. Geologic and hydrogeologic conditions in the areas of the SMC and Cadet sites are detailed in their respective RI reports (Parametrix 2009a, 2010b). A detailed description of regional geologic and hydrogeologic conditions is presented in the Vancouver Lake Lowlands Groundwater Model Summary Report (Parametrix et al. 2008).

2.1.1 Geologic Conditions

The regional geologic framework and associated groundwater system detailed in the final RI reports are based on the geologic setting described and the nomenclature used in the U.S. Geological Survey (USGS) water resources investigation report, *A Description of Hydrogeological Units in the Portland Basin, Oregon and Washington* (Swanson et al. 1993). The Vancouver Lake Lowlands Groundwater Model Summary Report (Parametrix et al. 2008) presents a regional conceptual model and detailed discussion of geologic and hydrogeologic units in the region and their presence in the project area. The groundwater model was developed using regional and site-specific geologic and hydrogeologic data collected throughout the Vancouver Lake lowlands.

There are three regional geologic units (Quaternary alluvium, catastrophic flood deposits, Troutdale formation) in the project area, as indicated on Figure 2-1. Figure 2-2 shows the orientation of three cross sections in the project area. The geology along these cross sections is shown on Figures 2-3, 2-4, and 2-5.

Regionally, groundwater in the Quaternary alluvium and catastrophic flood deposits is associated with the Unconsolidated Sedimentary Aquifer (USA), while groundwater in the upper section of the Troutdale formation is associated with the Troutdale gravel aquifer (TGA). Locally, groundwater in the Quaternary alluvium is associated with the recent alluvial aquifer while catastrophic flood deposits are associated with the Pleistocene alluvial aquifer. The relationship between the regional, local, and site area geologic and hydrogeologic units is shown on Figure 2-1. The three geologic units are described in the following sections.

2.1.1.1 Alluvial Deposits

The Quaternary alluvial deposits in the project area primarily consist of two main subunits: a lower sand and an upper silt. In the area adjacent to the Columbia River, two localized subunits have been identified; these represent overbank flood deposits and dredge fill. The variability in fines present in the Quaternary alluvial deposits can notably influence the rate at which groundwater passes through the material. The four alluvial subunits shown on Figure 2-1 are described below.

Dredge Fill (Sand 2) – Dredge fill deposits are present in the southern portion of the Site and generally within 1,500 feet of the Columbia River. Dredge fill consists predominantly of sand but can include lenses of silt and gravel. Extensive dredge filling has occurred in the southern portion of the Site, particularly adjacent to the river where the thickness of the fill can reach up to 50 feet. Depending upon location, dredge fill can be saturated or situated above the water table.

Overbank Deposits (Silt 2) – This alluvial subunit is present along the Columbia River and is associated with the historical riverbank. The overbank deposits represent the historical riverbank and seasonal overbank flood deposits, consist of silt and clayey material, and are thickest adjacent to the historical river channel. The overbank deposits are thicker and contain more clayey material than the lowland area silt subunit (Silt 1). The water table is generally found within the basal portion of the overbank deposits. Consequently, its lower section is usually saturated, and its upper section is within the vadose zone. Beginning in the mid-1930s, filling was completed along the historical riverbank in the project area as part of the Port's terminal developments that resulted in the river being displaced approximately 500 feet south of its historical river channel.

Lowland Area Silt (Silt 1) – The lowland area silt is the same as the upper alluvium subunit and is generally present throughout the Site. However, the lowland area silt does not appear to be present south of Lower River Road. The lowland area silt is generally described as brownish silt and appears to have been deposited throughout most of the Vancouver Lake lowlands area.

Lowland Area Sand (Sand 1) – The lowland area sand is present throughout the Site. The lowland area sand contains variable amounts of fines and is described in places as silty sand. This subunit overlies the catastrophic flood deposits, and in the area of the SMC site, appears to be contemporaneous with lowland area silt deposits. The lowland area sand can be differentiated from catastrophic flood deposits by its lack of gravel. The lowland area sand is present under the overbank deposits on the north side of the historical riverbank. The water table is usually situated within the lowland area sand and silt subunit where overbank deposits are not present. Under these conditions, its lower section is saturated and its upper section in the vadose zone.

2.1.1.2 Catastrophic Flood Deposits

This unit consists predominantly of medium- to coarse-grained sand with gravel. The gravel can be coarse, ranging up to cobbles 6 inches or greater in diameter. These deposits are associated with the Late Pleistocene catastrophic floods of the Columbia River. This material was deposited throughout the Site and underlies the Quaternary alluvium. Due to the generally coarse nature of these deposits and the general lack of fines, these deposits are highly transmissive.

As shown on Figure 2-1, three catastrophic flood deposit subunits units have been identified at the Site; these subunits are described below.

Sand and Gravel – This subunit consists of sand with gravel to gravel with sand that consists of basaltic material. It underlies the alluvium deposits and is present throughout the Site. The sand and gravel subunit is not cemented and is usually loose, with little to no fines present in the unit.

Channel Fill – This subunit consists of sand with typically only trace amounts of gravel. When present, this subunit underlies the sand and gravel subunit. Sand in the channel fill subunit ranges from fine to coarse-grained. Channel fill deposits are usually well graded but can also be poorly graded with silt zones and can include small lenses of gravel. The channel fill subunit is located in an erosional trough in the Troutdale formation located beneath the SMC and Cadet sites.

Reworked Troutdale Formation Material – This sandy gravel subunit overlies the Troutdale formation and is interpreted to be reworked Troutdale formation material. It is usually described as gravel with sand or sand with gravel. The type and range of material in this subunit is variable. The size of clasts ranges from small gravels up to cobbles; its matrix can range from sand to silt, and it is generally described as well graded. It consists mostly of basalt clasts and sand, but in places contains quartzite clasts and/or a micaceous matrix. The sandy gravel subunit is generally not cemented, but indications of cementation can be observed prior to encountering the underlying Troutdale formation. The sandy gravel subunit is not consolidated like the Troutdale formation. Reworked Troutdale formation material is less prevalent in the area just north of the NuStar Terminal and east of Kotobuki Way.

2.1.1.3 Troutdale Formation

The Troutdale formation encountered at the Site consists of well-graded, cemented to semi-consolidated sandy gravel with varying amounts of sand, silt, and clay. The gravel clasts range up to 8 inches in diameter (i.e., cobble) and generally consist of basalt and quartzite. The matrix usually consists of brown to green fine-grained silty sand with varying amounts of silt and clay and is usually abundant with mica. The Troutdale formation underlies the catastrophic flood deposits throughout the Site. It is distinguished from the catastrophic flood deposits by the presence of cementation, consolidation, quartzite clasts, and a silty matrix containing mica. In certain places, it can be difficult to distinguish the Troutdale formation from the reworked Troutdale formation material subunit. A noticeable reduction in water production is another characteristic that can be used to distinguish the Troutdale formation from the overlying catastrophic flood deposits.

The elevation of the top of the Troutdale formation varies substantially at the Site. Mapping the top of the Troutdale formation at the Site indicates the presence of an erosional trough or low area beneath the SMC and Cadet sites. The deepest portion of the erosional trough appears to occur beneath the SMC and Cadet sites. The top of the Troutdale formation rises very steeply directly east of the SMC site and rises relatively steeply to the southwest of the SMC site. The highest elevation of the Troutdale formation at the Site occurs just east of Kotobuki Way. The erosional trough located beneath the SMC and Cadet sites was filled by channel fill deposits, which pinch out in the areas where the elevation of the top of the Troutdale formation is higher.

2.1.2 Hydrogeologic Units

Consistent with the USGS Portland Basin (Swanson et al. 1993) nomenclature, there are two regional hydrogeologic units at the Site: the USA and the underlying TGA. The USA occurs in the Quaternary alluvium and catastrophic flood deposits while the TGA occurs in the Pleistocene-aged Troutdale formation. As shown on Figure 2-1, locally in the Vancouver Lake lowlands area the USA consists of two aquifers, including the recent alluvial aquifer located in Quaternary alluvial deposits and the Pleistocene alluvial aquifer located in the catastrophic flood deposits.

The distinction between the USA and the TGA is based on differences in the geologic units and resulting hydrogeologic conditions. The overall permeability of the USA is at least one order of magnitude greater than the permeability of the TGA (McFarland and Morgan 1996). Consequently, primarily due to pumping, groundwater flow conditions in the USA differ from conditions in the TGA. In addition, groundwater flow conditions within the three zones of the USA differ due to permeability contrasts between the alluvium and the catastrophic flood deposits.

The following sections describe the hydrogeologic conditions of the three USA groundwater zones and the TGA at the Site.

2.1.2.1 Unconsolidated Sedimentary Aquifer

Regionally, the USA receives recharge primarily from precipitation. Within the Site, the USA also receives recharge from the Columbia River or discharges to the river, depending upon relative river stage conditions and pumping stresses. The flow of groundwater in the USA has historically been dominated by pumping at the Great Western Malting (GWM) site. Water levels in the USA respond quickly to changes in the Columbia River stage, indicating that the river is in direct hydraulic connection with the USA. This rapid response is attributed to the proximity of the river and the high hydraulic conductivity of the USA. These dynamic conditions make it difficult to define groundwater flow direction based on water level measurements collected during short periods of time. Water level measurements indicate very low hydraulic gradients with small-scale and local variations in apparent groundwater flow direction due in part to river stage changes. Groundwater flow model results indicate that the operation of high-volume continuous-rate pumping of production wells in the USA is possible and sustainable due to high hydraulic conductivity and relative thickness (i.e., high transmissivity) and the presence of a substantial recharge source (i.e., the Columbia River). Groundwater recharge from the Columbia River due to high volume production well pumping primarily occurs in the intermediate zone.

Three groundwater zones have been established for the USA based on observed geologic and hydrogeologic conditions (Figure 2-1). Groundwater zones were delineated during the SMC and Cadet RI efforts to evaluate and describe groundwater quality and groundwater flow trends. These zones are used to facilitate understanding of the hydrogeologic system and were originally defined by groundwater quality conditions observed during early phases of the SMC RI. Based on the presence and distribution of the alluvial and catastrophic flood deposits in the project area, the groundwater zone classification system has been retained, but it has been modified and is now applied only to the USA. As shown on Figure 2-1, the groundwater zones for the USA are as follows:

- Shallow USA groundwater zone – This zone extends from the ground surface to -10 feet mean sea level (msl), which is approximately 40 feet bgs. The shallow groundwater zone of the USA primarily corresponds to the alluvial deposits.

- Intermediate USA groundwater zone – This zone extends from the bottom of the shallow zone (-10 feet msl to -25 msl, depending upon location within the Site) to -100 feet msl (approximately 130 feet bgs). The intermediate groundwater zone of the USA primarily corresponds with the catastrophic flood sand and gravel deposits. This zone can also include a portion of the channel fill deposits and reworked Troutdale formation material.
- Deep USA groundwater zone – This zone extends below -100 feet msl (approximately 130 feet bgs). The deep groundwater zone of the USA primarily corresponds with the channel fill deposits and reworked Troutdale formation material. The deep zone generally corresponds to those portions of the aquifer that are less influenced by groundwater pumping.

The elevations of these zones continue to serve as general guidelines and have been adjusted slightly in certain areas based on encountered geologic conditions or other hydrogeologic observations. Characteristics of the three groundwater flow zones within the USA are described below.

2.1.2.2 Shallow USA Zone

The shallow USA zone consists primarily of the alluvial deposits. Depending on the thickness of the alluvial deposits, the shallow USA zone can extend into the upper part of the sand and gravel subunit of the catastrophic flood deposits. The alluvial deposits contain greater amounts of finer material than the underlying catastrophic flood deposits. Consequently, the transmissivity of the alluvial deposits is notably lower than the underlying sand and gravel deposits. Due to the overall presence of finer material with notably lower permeability, the distribution of contaminants in the shallow USA zone can differ from the distribution of contaminants in the underlying catastrophic flood deposits.

Prior to operation of the SMC groundwater pump and treat interim action (GPTIA), groundwater flow in the shallow USA zone at the SMC and Cadet sites was toward the southeast. This flow direction was reflected by contaminant distribution where high concentrations of solvents in groundwater at the two source areas decreased with distance southeast of the source area. Groundwater flow model results indicated that prior to starting the Port's GPTIA, flow in the shallow USA zone was primarily influenced by pumping occurring at the GWM site and City of Vancouver (COV) water station pumping. The flow direction at the Cadet site was similar, based on the distribution of contaminants, potentiometric contour maps, and modeling. Since startup of the GPTIA at the SMC site in 2009, groundwater flow in the shallow zone beneath Cadet has continued to be to the south-southeast but primarily influenced and controlled by the GPTIA pumping well at SMC.

2.1.2.3 Intermediate USA Zone

The intermediate USA zone corresponds to the catastrophic flood deposits. The catastrophic flood deposits are more permeable than the overlying alluvial deposits or the underlying TGA. Based on well log descriptions, the sand and gravel subunit is the most permeable sedimentary unit in the USA (Mundorff 1964). Consequently, the rate of groundwater movement is highest in the intermediate USA zone where it is greatly influenced by pumping at high-volume production wells located in the lower terrace and Vancouver Lake lowlands area, including wells operated by COV, Clark Public Utilities (CPU), GWM, and the Port of Vancouver. In response to high-volume pumping, recharge of the intermediate USA zone is primarily from the river.

Prior to operation of the GPTIA, groundwater flow in the intermediate zone near the SMC, Cadet, and NuStar sites was to the north/northeast (from the river) and curving to the east, and then toward the GWM production wells, which have been in operation since the 1940s. These flow patterns are supported by the distribution of contaminants from the SMC, Cadet, and NuStar sites; isotope data; and groundwater flow model results. After startup of the GPTIA in 2009, overall flow in the intermediate zone is toward the GPTIA. The gradient in the area between the SMC/Cadet and NuStar properties (former Carborundum pond area) is typically flat, although it does vary during periods of rapid river stage change.

2.1.2.4 Deep USA Zone

This zone of the USA includes the deeper area of the USA where the rate of groundwater flow is lower; it is less influenced by groundwater pumping and more regionally influenced. Groundwater flow in the deep USA zone has not substantially changed due to operation of the GPTIA. The deep USA zone at the Site is primarily present in the Troutdale formation erosional trough, an oblong-shaped bowl with a partial opening on its western side. At the SMC and Cadet sites, the deep USA zone corresponds to channel fill deposits and reworked Troutdale formation material. At the NuStar site, the deep USA also appears to contain reworked Troutdale formation material that is situated on top of the Troutdale formation. The channel fill deposit and the reworked Troutdale formation material are permeable, but not as permeable as the sand and gravel subunit of the intermediate USA zone. The channel fill deposits and reworked Troutdale formation material are more permeable than the underlying consolidated to semi-consolidated Troutdale formation that makes up the TGA. The rate of groundwater movement is less in the deep USA zone due to the zone's location primarily in an erosional trough or historical channel beneath the Cadet and SMC sites; the lower influence from pumping stresses by GWM and POV production wells and other pumping centers; and its lower overall material permeability compared to that of the overlying USA deposits.

Stable oxygen isotope data indicate that deep USA water is a mixture of Columbia River water and local precipitation. Potentiometric contour maps based on water level measurements from the deep wells do not indicate a clear or consistent groundwater flow direction. Rather, these maps suggest that groundwater in the deep USA zone flows in different directions at different times and usually does not flow consistently at all measurement points.

2.1.2.5 Troutdale Gravel Aquifer

The TGA is associated with the Troutdale formation that underlies the catastrophic flood deposits and alluvial deposits that make up the USA. The top of the Troutdale formation varies noticeably in depth below ground surface in the Site area, and the presence of an erosional trough has been identified. The permeability of the TGA is at least one order of magnitude lower than the USA (McFarland and Morgan 1996). This is due to the presence of more fines in the Troutdale formation and the extent of its lithification/cementation, which ranges from consolidated to semi-consolidated. The combination of lower permeability and lack of groundwater extraction from the TGA at the Site produces much lower flow rates in the aquifer than in the overlying USA. There is hydraulic connection with the USA due to a lack of a confining layer. Water level measurements collected from TGA and deep zone USA wells do not indicate a noticeable vertical gradient difference, which also suggests that the two aquifers are hydraulically connected. It is anticipated that the TGA would exhibit similar river response behavior as the USA, but would be more attenuated due to its lower permeability and the fact that it appears not to be in direct contact with the river (i.e., the USA is situated between the river and the TGA).

Based on water level measurements, the flow pattern in the TGA is variable. Groundwater flow modeling completed prior to startup of the GPTIA in 2009 indicated the overall flow pattern in the TGA is similar to the flow pattern observed in the USA, toward GWM production wells. However, stable oxygen isotope data indicate that the source of TGA water is local precipitation. This suggests that the TGA discharges to the Columbia River rather than receiving recharge from the river. The lack of pumping in the TGA in the project area is likely the primary reason that stable oxygen isotope data indicate no river water presence in the aquifer. These observations indicate that groundwater flow in the TGA is primarily influenced by regional conditions.

2.1.2.6 Hydrogeologic Characteristics

Wells completed in the USA have maximum yields between 1,000 and 6,000 gallons per minute (gpm). The most productive area of the USA is in the lower floodplain area of the Columbia River where the SMC and Cadet sites are located. In contrast, wells completed in the consolidated TGA commonly have yields that do not exceed 1,000 gpm (Swanson et al. 1993).

The USA's ability to transmit and yield large quantities of groundwater is the result of its relatively high intrinsic permeability and saturated thickness. The USA can sustain high production pumping due to receiving recharge from the Columbia River. Mundorff (1964) estimated that the transmissivity of the USA ranges from 1,900,000 to 3,500,000 gallons per day per foot (gpd/ft), based on aquifer tests completed at the former ALCOA facility located west of the project area. The aquifer tests indicate that the aquifer's transmissivity is fairly uniform throughout that facility's wellfield. The calculated transmissivities for COV Water Stations 1, 3, and 4, all producing from the USA, are 2,000,000 gpd/ft, 878,900 gpd/ft, and 586,000 gpd/ft, respectively (Robinson, Noble and Carr, Inc., 1980).

Several regional studies have estimated hydraulic conductivity of the USA. Based on a review of transmissivities calculated by consultants for the COV water stations, and transmissivities estimated from reported pump test yields and drawdown, Swanson and Leschuk (1991) assigned a hydraulic conductivity of 1,000 feet per day (ft/day) to the aquifer. McFarland and Morgan (1996) assigned storage coefficients to the USA and TGA based on aquifer tests and published information. The storage coefficients for the USA and the TGA are 0.003 and 0.0008 (unitless), respectively. Based on specific capacity data, McFarland and Morgan (1996) estimated a median hydraulic conductivity for the USA across the Portland basin of 200 ft/day with a range of 0.03 to 70,000 ft/day and the TGA with a range of 7 to 16 ft/day. Site-specific aquifer testing of the intermediate zone was performed by the Port in 2008 to better assess the anticipated range in hydraulic conductivity in the project area. On November 20, 2008, a step-rate pump test was conducted on the GPTIA extraction well to examine the well's performance. Analysis of the extraction well drawdown data suggested that the transmissivity is likely in the range of 1,500,000 to 1,870,000 gpd/ft. If it is assumed that the effective aquifer thickness at the extraction well location is 210 feet, the estimated range of horizontal hydraulic conductivity is between 950 and 1,200 ft/day. Analysis of drawdowns observed at observation wells indicated the transmissivity is likely in the range of 1,500,000 to 3,000,000 gpd/ft. Assuming an effective aquifer thickness of 210 feet, yields a range of horizontal hydraulic conductivity of between 950 and 1,900 ft/day (Parametrix 2009d).

2.2 Cadet Facility

This section provides a summary of the Cadet site including the facility history, RIs, and completed cleanup actions. The Cadet RI report (Parametrix 2010a) includes a detailed discussion of the site and past activities, including data evaluation and interim remedial actions that comprise the basis for the FS. Ecology approved the Cadet RI report in 2011 (Ecology 2011). Section 2.3 includes a similar discussion of the former SMC site.

2.2.1 Location, Description, and History

The Cadet site is a rectangular parcel located at 2500 Lower River Road in Vancouver, Washington (Figure 1-2). The Cadet site is currently occupied by an electric-heater manufacturing facility and includes a single building (15,750 square feet) with associated asphalt and gravel parking areas, as well as landscaping. In addition to the Cadet parcel, significant Cadet-related investigations were conducted on two adjacent areas, including (1) an L-shaped parcel of undeveloped land located adjacent to the Cadet site's northern and western boundaries and (2) the North Fruit Valley Neighborhood (NFVN), which is defined here as the area of single-family residences located north and east of the Cadet site. The NFVN is bounded on the east by the Burlington Northern Santa Fe Railroad (BNSF), on the south by West Fourth Plain Boulevard, to the west by Yeoman Avenue, and on the north by West 39th Street and La Frambois Road (Figure 1-2). The Cadet site is surrounded predominantly by residential and industrial properties.

Prior to the mid-1960s, the site was an undeveloped field, sometimes cultivated, with an orchard present in the northwest portion for an unknown length of time. In the mid-1960s, a single building was constructed in the same location as the present-day building. Swan Manufacturing occupied this building until 1972, at which time Cadet acquired Swan Manufacturing Company and assumed ownership of the property. Cadet continues to operate at the site, but in May 2006, ownership of the property was transferred to the Port as part of a settlement agreement.

Investigations have been at conducted at or in the vicinity of the Cadet site to delineate the nature and extent of subsurface VOCs since 1998. In January 2000, Cadet entered into an AO with Ecology to conduct investigations and interim remedial actions for VOCs in the subsurface at the Cadet site. Cadet documented its investigations in a Draft Remedial Investigation Report (AMEC 2003) and a Remedial Investigation Update Report (AMEC 2005). TCE and PCE were detected in groundwater samples at maximum concentrations of 78,000 micrograms per liter (µg/L) and 70,000 µg/L, respectively. Interim remedial actions implemented by Cadet included the installation of an air sparging and soil vapor extraction (AS/SVE) system under the Cadet manufacturing building, with operation beginning in October 2003. In 2004 and 2005, Cadet installed eight recirculating groundwater remediation wells (RGRWs) at the Cadet facility and in the NFVN to treat impacted shallow groundwater. In addition, Cadet installed in-home soil vapor vacuum (SVV) systems in six NFVN houses to mitigate VOCs detected in indoor air. A summary and current status of these interim actions is included in Section 2.2.7.

The Port acquired the Cadet property on May 29, 2006, as part of a settlement agreement, and has assumed responsibility for cleanup. Additional historical information for the Cadet site is included in the final Cadet RI report (Parametrix 2010a).

2.2.2 Property Operations

At the time Cadet took over the property in 1972, Swan Manufacturing reportedly used TCE as a degreaser in its parts cleaning process. This process involved a large dip tank or vault into which parts would be lowered on a rack. Parts were lowered to just above the liquid TCE level, the lid of the tank was closed, and the tank was heated to produce TCE vapor. Once cleaning was complete, the temperature of the tank was lowered so the TCE would return to a liquid phase. Excess TCE was shaken off the parts inside the tank. The TCE tank was approximately 10 feet long by 5 feet wide by 12 feet deep, with 8 feet of the tank set below surface level inside a concrete containment bunker. Spent TCE from the tank was removed by pumping the product into drums placed next to the tank; the drums were subsequently placed outside for recycling pickup. Fresh TCE was pumped into the tank from new drums of TCE. No remote pumping of TCE was performed (such as from outside the building), and no underground piping was in place for the remote delivery or removal of TCE (AMEC 2003).

Cadet continued to use TCE and the vapor degreasing process until approximately 1976 when they changed to a water soak cleaning process that used hot water and an alkaline cleaner, with discharge of wastewater to the City's sanitary sewer system. In 1987, Cadet switched to a powder-coating system for painting metal that includes a three-stage cleaning system. Rinse water from the cleaning system is continuously discharged to the sanitary sewer. The powder-coating system continues to be used.

In the early 1990s, a break was identified in the sanitary sewer line at the Cadet facility. In the mid-1990s, a second break in the sanitary sewer line was discovered during construction of a 20,000-square-foot addition to the original building. The second break, at approximately the same location as the first break, was discovered during installation of water and sewer line extensions to the north end of the building. Contaminated wastewater was believed to have been released to the subsurface as a result of the pipeline breaks.

2.2.3 Agreed Orders

Cadet entered into an AO DE 00-TCPVA-847 prior to the Port acquiring the site. Ecology prepared a new AO (07-TC-S DE 5189) for future work being conducted by the Port. As specified by Ecology, the AO was a new instrument that replaced the existing AOs: DE 98-TC-S337 and DE 01-TCPVA-3257 to which the Port is a party (SMC site) and AO DE 00-TCPVA-847 to which Cadet is a party. This AO (07-TC-S DE 5189) required the Port to complete an RI and implement interim action cleanup at the SMC and Cadet sites. The current AO DE 18152 replaced all previous AOs.

2.2.4 Surface Water and Surface Water Drainage

There is no surface water present in the immediate vicinity of the Cadet facility that could be impacted by site contaminants. Vancouver Lake, located more than 1.5 miles to the northwest of the Cadet facility, is located significantly outside the historical groundwater contaminant plume, and has not been impacted by releases from Cadet (or SMC) due to groundwater flow gradients away from the Lake area. The Columbia River is also not a complete pathway for the Cadet (and SMC) site based on data from remedial investigations and groundwater monitoring. Stormwater drainage occurs at the site and is directed to on-site drywells. The drywells are not a complete pathway for Cadet-related contaminants due to lack of VOCs in stormwater and absence of stormwater directed through a contaminated soil zone. Surface water and stormwater are not media of concern or potential receptors of site contaminants and therefore are not discussed further in this FS report.

2.2.5 Aquatic and Terrestrial Habitat

The Cadet site is an upland property with no surface water in the immediate vicinity; thus, aquatic habitat was not a consideration for the Cadet site in this FS. Terrestrial habitat is also limited due to the developed nature of the Cadet property. An ecological risk evaluation was completed as part of the RI and is discussed in the risk assessment summary in Section 2.2.8.

2.2.6 Summary of Remedial Investigations

Since 1998, approximately 20 investigations and/or phases of investigation have been conducted at or in the vicinity of the Cadet site to delineate the nature and extent of subsurface TCE, PCE, and other VOCs. Most of the investigations were completed by AMEC, an environmental consulting firm hired by Cadet. Investigations conducted after 2006 were completed by the Port. The details of the investigations and results are included in the Cadet RI report (Parametrix 2010a). Specific RI activities included:

- Source area investigation and soil interim action
- Installation and sampling of groundwater monitoring wells
- Depth-specific groundwater sampling during drilling of monitoring wells
- Groundwater interim action
- Geologic and hydrogeologic evaluation
- Stable isotope analysis and evaluation of groundwater samples
- Groundwater elevation measurements
- Installation of soil gas wells and soil gas monitoring
- Monitoring of indoor air and ambient air

The findings from these investigations are detailed in the Cadet RI report (Parametrix 2010a) and are summarized below by medium.

2.2.6.1 Soil Investigations

Since 1998, seven soil sampling events have been conducted at the Cadet site. Based on these soil investigations, the distribution of VOCs in soil was determined to be limited in extent. No VOCs were detected in soil samples collected in the NFVN, and very low concentrations of VOCs were detected in samples collected on the eastern portion of the Cadet site where the highest groundwater VOC concentrations were detected. This indicated the source for the contamination was not a surface release on the east side of the Cadet property or in the NFVN.

The highest concentrations of PCE and TCE were detected in soil samples collected beneath the Cadet building. The soil contamination was determined to be limited in extent to the area under the Cadet building. The source of VOCs in groundwater was determined to be the result of spills and releases in the Cadet building and in the subsurface along the sewer line breakage. Concentrations of VOCs in soil samples were not detected above regulatory cleanup levels. It is expected that the low concentrations of VOCs beneath the Cadet building were further reduced by operation of the AS/SVE system from 2003 through 2012 (see Section 2.2.7).

2.2.6.2 Soil Gas Investigations

In June and November 2000, soil gas samples were collected from subsurface borings drilled through the floor of the Cadet building and in the NFVN along the sanitary sewer easement east of the Cadet facility. Additional samples were collected in August 2001 along the existing sewer line locations. The highest concentrations of VOCs were detected in the soil gas probes completed in the NFVN along the sewer line beneath W 28th Street and Unander Avenue (Figure 1-2). Based on the preliminary soil gas investigation, it was determined that there was a potential to impact indoor air. The Washington State Department of Health (DOH) prepared a health consultation (DOH 2002) and recommended indoor air sampling in the NFVN.

Based on the preliminary soil gas results and initial indoor air sampling results obtained in January and September 2002, Ecology required additional soil gas sampling in the NFVN to further evaluate potential vapor intrusion issues. In January 2004, Cadet installed soil gas monitoring wells in the NFVN and initiated a soil gas monitoring program. The intent of the program was to try to establish a site-specific correlation between soil gas and indoor air and to delineate the extent and distribution of VOCs in soil gas in the NFVN. Soil gas wells were sampled during 19 sampling events between January 2004 and March 2011.

VOCs were detected in soil gas near the Cadet site and in the NFVN. In general, the presence of VOCs in soil gas was correlated with the occurrence of VOCs in groundwater. In most cases, concentrations of VOCs in soil gas increased with depth, which was expected due to volatilization of the groundwater source material into the overlying vadose zone. The concentrations of VOCs in soil gas decreased significantly following the installation of soil gas wells in 2004. Soil gas sampling, primarily conducted to supplement the vapor intrusion (indoor air) investigation, was discontinued in 2011 after resolution of indoor air issues (see Section 2.2.6.4). There are no Ecology cleanup levels associated with soil gas. Final remedial actions implemented in the project area to address cleanup of groundwater are sufficient to address any residual soil gas concerns.

2.2.6.3 Groundwater

Groundwater investigations have been conducted at the Cadet site since 1998. The Cadet groundwater monitoring well network is a component of the project area well network and includes wells monitored by the Port on a regular basis for groundwater quality. The Cadet site monitoring well network currently consists of 69 monitoring locations: 65 shallow, intermediate, and deep USA monitoring wells (3 are inactive) and 4 TGA monitoring wells. Specific monitoring wells associated with the Cadet site have been sampled on a regular basis since mid-1998.

Analytical results for groundwater samples have been documented in quarterly, semi-annual, and/or annual monitoring reports since 1999. The distribution of groundwater contaminants at Cadet was described in detail in the Cadet RI report (Parametrix 2010a). The 2020 distribution of groundwater contaminants in the project area is included on Figures 2-6 through 2-14. A summary of 2020 conditions is included below.

Shallow USA Zone

VOC concentrations in all Cadet shallow wells have declined significantly since startup of the GPTIA in June 2009. Cadet well CM-MW-01d-040, which has historically had the highest concentrations of TCE in the shallow zone, was generally the only Cadet shallow well with VOC concentrations above 10 µg/L in recent years.

By 2020, limited residual contamination remains, but the shallow plume associated with the Cadet site (as defined by the 4 µg/L and 5 µg/L MTCA Method B cleanup level for TCE and PCE, respectively) has been eliminated by the interim actions (Figures 2-6 and 2-7). The comparison of the groundwater plume from 2009, 2013, and 2020 is shown on Figure 2-8.

Intermediate USA Zone

VOC concentrations in all Cadet intermediate wells have declined significantly since startup of the GPTIA in June 2009. TCE and PCE isoconcentration maps for intermediate wells during 2020 are presented on Figures 2-9 and 2-10. The comparison of the groundwater plume from 2009, 2013, and 2020 is shown on Figure 2-11. By 2020, limited residual contamination remains to the northeast of the Cadet source area (CM-MW-23i). The intermediate zone plume associated with the Cadet site has been eliminated by the interim actions.

Deep USA Zone

Isoconcentration maps for TCE and PCE in the deep USA zone during 2020 are presented on Figures 2-12 and 2-13. Overall, concentrations of TCE and PCE detected in deep zone wells have slowly decreased since startup of the GPTIA in 2009. The comparison of the groundwater plume from 2009, 2013, and 2020 is shown on Figure 2-14.

TGA

Cadet well CM-MW-29TGA is the only TGA well where VOCs have been detected and the only TGA well currently included in the groundwater monitoring program. In 2020, TCE and PCE were detected in TGA well CM-MW-29TGA at concentrations of 12 µg/L and 6.48 µg/L, respectively. Concentrations of TCE and PCE detected in CM-MW-29TGA have been stable following a declining trend that ended in 2012 (Parametrix 2021)

2.2.6.4 Indoor Air

In January 2002, an indoor air investigation was initiated by Cadet in the NFVN. The investigation included the collection of indoor air samples in selected homes, primarily in the southern portion of the NFVN where VOC levels in groundwater and soil gas were highest. In 2009, the Port prepared a Comprehensive Vapor Intrusion Evaluation and Indoor Air Monitoring Plan (CAMP; Parametrix 2009e), which was subsequently approved by Ecology. The following provides a brief overview of the indoor air issues at the Cadet site.

Indoor air sampling within the NFVN was conducted from January 2002 to September 2011. At Ecology's request, the DOH conducted a health consultation to evaluate whether residents of the NFVN were being exposed to solvent vapors migrating from groundwater into indoor air. The health consultation indicated that the cancer risk from VOCs detected in samples from the initial sampling event at six NFVN homes was approximately one to two orders of magnitude greater than would be expected in background air. Ecology required that action be taken to eliminate exposure in the six residences. SVV systems were installed in the six homes in October 2003 and operated through approximately 2010 (see Section 2.2.7.3).

In addition to the SVV remedial action, Ecology required a comprehensive indoor air investigation to be completed. Between 2002 and 2008, approximately 700 residential indoor air samples (living space, basement, and crawlspace) were collected from more than 120 homes in the NFVN. The indoor air data were compiled and evaluated in the final CAMP, which was submitted to Ecology and DOH in December 2009 (Parametrix 2009e). Based on previous investigations completed at the Cadet site, it was determined that vapor intrusion represented a complete exposure pathway at some residences in the NFVN, and that the indoor air quality in some homes had exceeded MTCA ambient air cleanup levels (some cleanup levels have since been revised by Ecology). However, it was also determined that there was some contribution from sources other than groundwater contamination (e.g., outdoor air, indoor use of chemicals).

The CAMP concluded that the potential risk from vapor intrusion was low, but that additional monitoring in select homes would support a decision to conclude vapor intrusion analysis and meet all Ecology requirements. The indoor air monitoring plan (IAMP) was initiated in September 2009 and was completed in September 2011.

Evaluation of indoor air data for each of 15 homes included in the IAMP indicated that vapor intrusion was not an issue of continued concern in the NFVN. Except for one residence (2113 W 28th Street), PCE and TCE in indoor air at the residences evaluated in the IAMP were below the MTCA indoor air cleanup levels which were adopted in September 2012.

Indoor air concentrations at the 2113 W 28th Street residence were above the MTCA cleanup level (primarily for TCE). However, this home was the subject of many previous investigations, and it was determined that contamination in the home was significantly related to chemical products stored in the basement or other in-home activities (cleaning, painting, use of glues, etc.). The elevated concentrations in the home were not the result of vapor intrusion from groundwater contamination; thus, as approved by Ecology (Ecology 2013), no further investigation or sampling was conducted.

Based on the data collected during the IAMP, as well as all data collected at the Cadet site since 2002, vapor intrusion impacts resulting from VOC-contaminated groundwater beneath the NFVN are not a current or future issue of concern in the NFVN. No further indoor air investigations were conducted in the NFVN. Ecology approved the results and recommendations of the IAMP in 2013 (Ecology 2013).

2.2.7 Interim Actions

Several interim actions have been conducted at the Cadet site and in the NFVN to reduce or mitigate the presence of VOCs. These actions are summarized below.

2.2.7.1 Air Sparging/Soil Vapor Extraction System

One air sparging (AS) and two soil vapor extraction (SVE) systems were installed at the Cadet site in 2002 and 2003 to address VOCs in source area soil and groundwater and to prevent further migration of VOCs to the east toward the NFVN. The first SVE system installation is documented in the Soil Vapor Extraction System Installation and Startup Report (AMEC 2002), and the AS/SVE installation and startup is described in the Air Sparging and Soil Vapor Extraction Remediation System Installation and Startup Report (AMEC 2004b).

The completed AS/SVE remediation system began operation in October 2003 as an interim groundwater source control measure. The influence of the AS/SVE system included the area beneath the Cadet building and the areas of the property to the north and east of the building. The AS portion of the system included 73 AS wells, and the SVE portion of the system included 41 vapor extraction wells.

The AS/SVE system operated continuously from 2003 through approximately 2007. A performance evaluation of the AS/SVE system was conducted between August 2007 and April 2008 to summarize its effectiveness and recommend an operational strategy for future use of the system, if appropriate. The evaluation consisted of a rebound test (also known as pulsing), which was conducted in a manner consistent with the AS/SVE performance evaluation plan (Parametrix 2007c). Details of the evaluation are included in the AS/SVE performance evaluation report (Parametrix 2009a).

Full-time operation of the AS/SVE system was not recommended. Based on the evaluation, it was determined that periodic pulsing of the system provided benefit to remove persistent contamination in soil gas and groundwater. This method provided the most cost-efficient way of operating the AS/SVE system in the interim and phasing out its operation in the long term. Parametrix proposed pulsing and then shutdown of the AS/SVE system. In October 2009, Ecology approved the AS/SVE operating and sampling plan, which included changing system operation from full time to a pulsing schedule.

The AS/SVE system was put into a pulsing mode on November 11, 2009. After 2 years of pulsing, the AS/SVE system was permanently shut down with Ecology approval in January 2012.

2.2.7.2 Recirculating Groundwater Remediation Wells

The RGRWs were designed by AMEC to reduce concentrations of VOCs in shallow groundwater in the source area beneath the Cadet building and in the NFVN. The shallow groundwater contamination was the primary source of VOCs detected in the indoor air of homes located in the NFVN. Between February 2004 and July 2005, eight RGRWs (labeled RGRW-1A and RGRW-1 through RGRW-7) were installed by Cadet in the vicinity of the Cadet facility and the NFVN (see locations on Figure 2-2).

In 2007, a contaminant reduction analysis was completed by the Port to evaluate the effectiveness of the RGRWs in reducing concentrations of contaminants in various media at the Cadet site. The results of this analysis are discussed in detail in the final RGRW operation plan (Parametrix 2007a). Operation of the RGRWs was determined to be effective at reducing VOC concentrations in groundwater in the NFVN. A relatively large "clean" zone developed in the vicinity of the RGRWs starting in 2006, indicating that a significant portion of the source material had been removed. As VOC concentrations were reduced, the efficiency of the RGRWs decreased. Operation of the RGRWs did not significantly impact the overall extent of the TCE plume greater than 5 µg/L; i.e., the overall geographic extent of the contaminated shallow groundwater did not change significantly. It was determined that continued use of the RGRWs was unnecessary given the planned installation of the Port's GPTIA, which would treat groundwater contamination associated with the Cadet site. Therefore, the Port recommended that the RGRWs be decommissioned. Ecology approved the decommissioning in 2010.

Four of the eight RGRWs, including RGRW-1, RGRW-1A, RGRW-2, and RGRW-7, were decommissioned in 2010 (Parametrix 2010b). The remaining RGRWs, including RGRW-3, RGRW-4, RGRW-5, and RGRW-6, were decommissioned in April and May of 2012 (Parametrix 2012). Decommissioning of the RGRWs consisted of removing the well string from the well, grouting of each boring, filling and paving over of utility vaults, and removal of associated utilities.

2.2.7.3 Residential Soil Vapor Vacuum Systems

In 2002, Cadet initiated indoor air sampling in the NFVN. Based on the initial indoor air sample results, several of the residences had elevated concentrations of TCE (i.e., significantly above the average) or other VOCs in indoor air. Due to elevated levels, Ecology required the installation of SVV systems in six homes in the NFVN in October 2003. The SVVs were continuously operated through January 2010. The residences with the SVV systems were:

- 2809 Unander Avenue
- 2805 Unander Avenue
- 2206 W 28th Street
- 2202 W 28th Street
- 2105 W 28th Street
- 2103 W 28th Street

SVV systems were installed and activated in the basement and/or crawlspaces of the six residences between August 26, 2003, and September 3, 2003. The SVV systems in each of the six residences were fully operational by the end of October 2003. The equipment for each SVV system included a blower and soundproof enclosure, intake and discharge piping, electrical conduit and wiring, gauges, and filter units containing granulated activated carbon.

Cadet's Residential Soil Vapor Vacuum Installation and Startup Report (AMEC 2004a) includes details of the SVV system design and installation in the six residences. Additional information is included in the Cadet Remedial Investigation Update Report (AMEC 2005). In addition, the Port prepared a letter entitled Evaluation of SVV System Performance (Parametrix 2007b), which summarizes the construction of the systems, influent/effluent concentrations, and status of indoor air quality.

By 2009, VOCs had been reduced in indoor air in all homes to very low levels. In November 2009, the Port requested that Ecology approve temporary shutdown of the SVV systems to allow evaluation of potential VOC rebound and/or to determine whether the SVV systems could be permanently decommissioned. Ecology approved the rebound evaluation and indoor air sampling schedule in December 2009 (Ecology 2009). The SVV rebound evaluation was conducted between February and December 2010.

At the conclusion of the SVV rebound evaluation in December 2010, it was determined that systems in five of the six homes should be permanently shut down and that no further indoor air sampling was necessary for these homes. Additional indoor air sampling was recommended for the 2809 Unander Avenue residence to determine if the concentrations detected during December 2010 were an anomaly.

Decommissioning of three SVVs (2103 W 28th, 2105 W 28th, and 2206 W 28th) was completed by the Port in accordance with the Final Soil Vapor Vacuum System Rebound Evaluation in July 2011. The residents at 2805 Unander and 2202 W 28th chose to keep the SVV systems in place. However, in September 2013, decommissioning of the system at 2805 Unander was requested by the estate representative and was completed after approval by Ecology. Decommissioning of the SVV at 2809 Unander was conducted in December 2013 after approval from Ecology that indoor air was no longer an issue in that home (Ecology 2013). Ecology approved the overall findings and determined that no further indoor air investigation or remedial activities were required.

2.2.8 Summary of Risk Assessment

This section presents a summary of the human health risk assessment presented in the Cadet RI report. The risk assessment was completed in 2009 and primarily focused on the risk to applicable receptors from groundwater exposure and associated pathways. The potential human health risks from the release of TCE at the Cadet site were examined by evaluating soil, soil gas, indoor air, and groundwater data collected within the project area. Exposure to VOCs was estimated for workers and residents within the project area for the following pathways:

- Inhalation exposure to indoor air or vapor intrusion via groundwater
- Ingestion or skin contact with groundwater used for potable purposes
- Skin (dermal) contact with or incidental ingestion of groundwater from digging or trenching activities

The risk assessment was completed prior to installation and operation of several of the interim actions discussed in previous sections, including the Port's GPTIA. Use of data collected prior to the interim actions significantly overstates the current potential risk associated with remaining contamination. However, the risk assessment is primarily being used to establish potential complete exposure pathways rather than a strict evaluation of risk. Therefore, the discussions below include additional information and updates where it impacts the FS evaluation and/or potential remedial actions as of December 2020.

2.2.8.1 Land and Beneficial Water Use

Land use and beneficial water use were evaluated to support the risk assessment completed for the site, primarily to establish the applicable potential exposure pathways.

Land use for the Cadet property is industrial in nature. This is supported by the City of Vancouver zoning for the property: Industrial. The use and designation of the Cadet property is not expected to change in the future. Residential properties are located to the north and east of the Cadet site. The residential use was considered during evaluation of exposure pathways in these areas (groundwater, indoor air, etc.).

Groundwater on the Cadet site is not currently used as a potable water source. However, the intermediate groundwater zone in the vicinity of the project area is used as a productive aquifer for municipal and industrial water supplies, including by COV, GWM, the Port, and CPU. In general, shallow groundwater is not a source of potable water but does have limited potential for potable water extraction. In addition, the aquifer in the project area is designated as a sole source aquifer (which includes all zones). There is no confining layer that distinctly separates the shallow and intermediate zones. Therefore, all groundwater in the project area is considered to have a beneficial use in the form of a potential drinking water source and/or connection to a drinking water source.

2.2.8.2 Chemicals of Potential Concern

Chemicals of potential concern (COPCs) were evaluated based on potential exposure routes and analytical data in various media at the site. The selection of indicator hazardous substances (i.e., COPCs) was conducted in accordance with WAC 173-340-703. VOCs further evaluated in the risk assessment were determined based upon (1) the frequency of detection; (2) the potential for adversely affecting human health; (3) the chemical and physical characteristics of the contaminants; and (4) the identification of potential degradation byproducts of TCE.

COPCs for groundwater included 1,1,1-trichloroethane, 1,1-dichloroethene (1,1-DCE), 1,1-dichloroethane (1,1-DCA), chloroform, cis-1,2-dichloroethene (cis-1,2-DCE), PCE, toluene, TCE, trichlorofluoromethane, and vinyl chloride.

COPCs for soil included 1,1,1-trichloroethane, cis-1,2-DCE, methylene chloride, PCE, and TCE.

COPCs for indoor and outdoor air included 1,1,1-trichloroethane, 1,1-DCA, 1,1-DCE, 1,2-DCA, chloroethane, cis-1,2-DCE, PCE, trans-1,2-DCE, TCE, and vinyl chloride.

2.2.8.3 Summary of Chemical Fate and Extent

The extent of soil and groundwater contamination at the Cadet site is summarized in Section 2.2.6. Figures 2-6 through 2-14 show the extent of groundwater contamination at the site in 2020. The primary COPCs remaining at the site include TCE and PCE.

2.2.8.4 Human Health Risk Assessment

An exposure assessment is conducted to estimate the magnitude, frequency, duration, and route of exposure of a receptor to a contaminant source. Information about waste sources, exposure pathways, and receptors at the Cadet site was used to develop a conceptual understanding in order to evaluate potential risks to human health.

Receptors are defined as persons who may come into contact with site chemicals. Receptors in the analysis are individuals who work or live within the project area. “Workers” include individuals who work regularly at the Cadet facility or other Port-owned or non-owned property downgradient of the Cadet site. Temporary workers were also evaluated, such as excavation workers. Residents include people who live east of the Cadet site in the NFVN and South Fruit Valley Neighborhood (SFVN) where groundwater containing VOCs had migrated.

Cadet Site Workers

Exposure and risk estimates prepared in 2009 for Cadet site workers suggested that VOC contaminants in indoor air (Cadet building) posed a slightly elevated risk if workers are chronically exposed (maximum excess lifetime cancer risk [ELCR] $5.4x10^{-6}$). However, since the time of the indoor air risk assessment, the U.S. Environmental Protection Agency (EPA) has changed the toxicity factor that must be used to calculate risk for TCE and PCE. Because of EPA's change (and subsequently Ecology-adopted values), the potential risk is substantially lower than originally calculated. Further evaluation conducted subsequent to the RI and CAMP indicated no potential risk to workers. The indoor air issue has been completely addressed, and Ecology has indicated that no further investigation or remedial actions are required (Ecology 2013). In addition, as of December 2020, the groundwater concentrations beneath the Cadet facility that could impact vapor intrusion have been significantly reduced (see Figure 2-8 for comparison of 2009, 2013, and 2020 groundwater data); thus, the assessment that there is no potential risk to workers from vapor intrusion remains valid.

Exposure and risk estimates for source area workers suggest that VOC contaminants in groundwater pose a potential risk if workers are chronically exposed via drinking water (maximum ELCR $5.2x10^{-4}$). As of December 2020, the groundwater concentrations near the Cadet facility have been significantly reduced (see Figures 2-8 and 2-11 for comparison of 2009, 2013, and 2020 shallow and intermediate zone groundwater data). 2020 data indicate groundwater at the Cadet site does not exceed MTCA cleanup levels; thus, there is no unacceptable risk to potential users of shallow groundwater.

Cadet Site Excavation Worker

Outdoor air and soil concentrations pose minimal risk to Cadet excavation workers at 2020 concentrations. Exposure and risk estimates completed in 2009 for on-site excavation workers suggested that VOC contaminants in groundwater posed a slight potential risk if workers are chronically exposed (maximum ELCR $4x10^{-6}$). However, groundwater is not currently used at the Cadet site for domestic purposes at the levels evaluated in the risk assessment, and concentrations have been significantly reduced since that time. Therefore, when considering only air and soil pathways, estimated risks to Cadet excavation workers are considered negligible.

NFVN Residents

Exposure and risk estimates for NFVN residents were completed in 2009 and suggested that VOC contaminants in indoor air had the potential to cause risk if residents were chronically exposed (ELCRs ranging from $7.2x10^{-7}$ to $2.7x10^{-4}$). However, since the time of the indoor air risk assessment, EPA has changed the toxicity factor that must be used to calculate risk for TCE and PCE. Because of EPA's change (and subsequently Ecology-adopted values), the potential risk is substantially lower than originally calculated. Further evaluation conducted subsequent to the RI and CAMP indicated no potential risk to residents. The indoor air issue has been completely addressed, and Ecology has indicated that no further investigation or remedial actions are required (Ecology 2013). As of December 2020, the groundwater concentrations beneath the NFVN that could impact indoor air have been reduced significantly (see Figure 2-8 for comparison of 2009, 2013, and 2020 groundwater data); thus, the assessment that there is no potential risk to NFVN residents from vapor intrusion remains valid.

Exposure and risk estimates for NFVN residents suggest that VOC contaminants in groundwater pose a potential risk if residents are chronically exposed via drinking water. As of December 2020, the groundwater concentrations in the NFVN have been significantly reduced (see Figures 2-8 and 2-11 for comparison of 2009, 2013, and 2020 shallow and intermediate zone groundwater data). 2020 data indicate that with the exception of MW-23i at a maximum concentration of 5.85 µg/L, groundwater in the NFVN does not exceed the MTCA cleanup level of TCE at 4 µg/L; thus, there is no current unacceptable risk to potential users of shallow groundwater.

2.2.8.5 Ecological Risk Assessment

As required under MTCA (WAC 173-340-7490), a terrestrial ecological evaluation must be considered to:

- Determine whether a release of hazardous substances to soil may pose a threat to the terrestrial environment;
- Characterize existing or potential threats to terrestrial plants or animals exposed to hazardous substances in soil; and
- Establish site-specific cleanup standards for the protection of terrestrial plants and animals.

Exposure pathways to sediments, surface water, or wetlands are not considered complete for the Cadet site because these media do not exist at this location. Therefore, the terrestrial ecological evaluation did not include an evaluation of potential threats to ecological receptors in these media or habitat areas. Because the residual contaminated soil is located on an area designated for industrial or commercial use only, the evaluation focused only on exposure to soil contamination for terrestrial wildlife protection (per WAC 173-340-7490-03b).

A simplified terrestrial ecological evaluation was conducted for the Cadet site in accordance with WAC 173-340-7492. The soil contamination on the Cadet site is generally limited to a confined area, thus there does not appear to be a substantial potential threat of significant adverse effects to terrestrial ecological receptors. The terrestrial wildlife evaluation consisted of calculating ecological indicator soil concentrations for the COPCs at the Cadet site. The methods for obtaining information and calculating ecological soil concentrations followed methodologies developed in MTCA. A comparison of the ecological indicator soil concentrations to the reasonable maximum soil concentrations found at the Cadet site indicated that no chemical exceeded its respective indicator soil concentration. Thus, contaminant concentrations in soil at the Cadet site do not pose an unacceptable threat to terrestrial ecological receptors. Therefore, based on the size of the contaminated area, the land use at the site, and the relatively low contaminant concentrations (compared to ecological indicator soil concentrations), the Cadet site was excluded from further ecological assessment per WAC 173-340-7492.

2.2.8.6 Risk Assessment Conclusions

The risk assessment for the Cadet site was conducted in accordance with MTCA risk assessment guidance. Potential risks to human health from exposure to contaminants in groundwater, soil, indoor air, and outdoor air were examined. Based on the results of the risk assessment, Parametrix reached the following conclusions for each medium at the Cadet site.

1. Groundwater – The potential risk associated with groundwater was evaluated for a Cadet site worker, a Cadet site excavation worker, and an NFVN resident. Although potential risks were identified during the RI process in 2009, significant remedial actions implemented have reduced the groundwater concentrations associated with the Cadet site to levels below the MTCA cleanup levels.

The only exception in 2020 was a small area near MW-23i, which contained TCE slightly above the 4.0 µg/L cleanup level. Therefore, there is no elevated risk from shallow groundwater in the Cadet area. In addition, drinking water for the NFVN is currently supplied by the City of Vancouver; in areas located within the urban growth boundary and the public agency is able to provide a safe and reliable service, connection to the public water source is required as a condition of the building permit. Therefore, there is a little potential that a drinking water well would be approved and installed within the NFVN. Thus, the absence of groundwater contamination above the conservative MTCA cleanup levels for drinking water in the NFVN and the presence of a reliable public drinking water source indicates that there is no current or future risk associated with drinking water.

2. Soil – The potential risk associated with soil was evaluated for a Cadet site worker and a Cadet excavation worker. Based on the human health risk assessment, the risk associated with COPCs in soil in the source area is within the acceptable risk range. Further remediation of soil is not warranted, based on the potential receptor scenarios evaluated.
3. Indoor Air – The potential risk associated with indoor air was evaluated for Cadet site workers and NFVN residents. The results suggested that VOC contaminants in indoor air had the potential to cause risk if residents were chronically exposed (ELCRs ranging from $7.2x10^{-7}$ to $2.7x10^{-4}$). However, further evaluation conducted subsequent to the RI and CAMP indicated that no potential risk is present to residents. The indoor air issue has been completely addressed, and Ecology has indicated that no further investigation or remedial actions are required. No further evaluation of indoor air in this FS is necessary.
4. Outdoor Air – The risk from outdoor air was evaluated for a Cadet site worker and an NFVN resident (child and adult). Based on the human health risk assessment, the risk associated with COPCs in outdoor air is negligible.

2.3 SMC Facility

This section provides a summary of the SMC facility including the site history, remedial investigations, and cleanup actions. The SMC RI report (Parametrix 2009b) was approved by Ecology (Ecology 2009) and includes a detailed discussion of the site and past activities including data evaluation and interim remedial actions that comprise the basis for the FS.

2.3.1 Location, Description, and History

The SMC site is adjacent to and west of the intersection of Fourth Plain Boulevard and Mill Plain Boulevard in Vancouver, Washington (Figure 1-2). The building formerly occupied by SMC was located between 2001 and 2501 West Fourth Plain Boulevard and was demolished by the Port in 1986, 11 years prior to the contaminant discovery. The northern portion of the site is currently occupied by a pump building associated with the GPTIA system. The remainder of the property is vacant or used periodically for storage (it has been used to store rebar products).

TCE was first discovered by the City of Vancouver in 1997 as part of the Mill Plain Boulevard Extension Project. The project involved the extension and rerouting of Mill Plain Boulevard, a major arterial road in Vancouver, Washington. In 1998, the Port initiated an RI and FS at the SMC site to address TCE and other related VOCs in soil and groundwater in the project area. From 1998 to 1999, the Port completed an interim action for soil that included the excavation and treatment of approximately 13,800 cubic yards of VOC-contaminated soil from the SMC source area. From 2002 to 2004, the Port completed an interim action for groundwater that included injecting Fenton's Reagent and potassium permanganate to treat VOCs in groundwater in the SMC source area.

In June 2009, the Port completed construction and startup of the groundwater pump and treat system at the SMC site. The groundwater pump and treat system was designed to provide hydraulic containment of groundwater in the project area and treat dissolved-phase VOCs in extracted groundwater through the use of an air stripping process. Additional historical information for the SMC site is included in the final RI report (Parametrix 2009b).

2.3.2 Property Operations

From 1956 to 1964, electric heaters were manufactured by SMC at the site. Sheet metal was formed, cleaned, painted, and assembled into heaters. The sheet metal parts were cleaned using a TCE vapor degreasing tank prior to painting. The degreasing tank was set into a concrete pit in the floor of the building. After degreasing, the metal parts were transferred to two rinse tanks where the parts were rinsed to remove any remaining TCE. The parts were then dried and painted.

Occasionally, TCE was spilled while the degreasing tank was being refilled. This spilled TCE would accumulate in a sump below the degreasing tank. In order to remove the spilled TCE, water was added to the sump, and the mixture of water and TCE was pumped into barrels. In 1964, SMC transferred its operations to a new facility at 2500 Fourth Plain Boulevard, discontinuing operations at the SMC site. Cadet purchased SMC in 1972 and continues to operate at the 2500 Fourth Plain facility.

2.3.3 Agreed Orders

This FS has been conducted pursuant to requirements established in the October 8, 2020, AO DE 18152 between Ecology and the Port. AO DE 18152 requires the Port to prepare an FS and draft cleanup action plan regarding certain hazardous substances on and in the vicinity of the Cadet and SMC portions of the Site. This order is in addition to, and does not supersede, AO 07-TC-S DE 5189, 07-TC-S DE 3938, or DE 15806. AO 07-TC-S DE 5189 replaced AOs DE 98-TC-S337 and DE 01-TCPVA-3257, to which the Port is a party, and AO DE 00-TCPVA-847 to which Cadet is a party.

2.3.4 Summary of Remedial Investigations

Since 1998, numerous investigations have been conducted at or in the vicinity of the SMC site to delineate the nature and extent of TCE and other VOCs. The details of the investigations and results are included in the SMC RI report (Parametrix 2009b). Specific RI activities included:

- Source area investigation and soil interim action
- Installation and sampling of groundwater monitoring wells
- Depth-specific groundwater sampling during drilling of monitoring wells
- Groundwater interim action
- Geologic and hydrogeologic evaluation
- Development of a regional groundwater hydrogeologic model

- Stable isotope analysis and evaluation of groundwater samples
- Groundwater elevation measurements
- Installation of soil gas wells and soil gas monitoring
- Monitoring of indoor air and ambient air

The findings from these investigations are detailed in the SMC RI report (Parametrix 2009b) and summarized below by medium.

2.3.4.1 Soil Investigations

Soil investigations associated with the SMC source area were initiated in 1998. The distribution of VOCs in soil was determined to be limited in extent and confined to the source area. TCE-impacted soil (maximum concentration of 17,000 micrograms per kilogram [µg/kg] in the vadose zone) was detected in the vicinity of the SMC site. The TCE-impacted soil was the primary source material for impacting groundwater. Therefore, the Port completed an interim action in 1998 to remove the source material. Approximately 13,800 cubic yards of TCE-impacted soil were excavated from the area and treated using enhanced SVE. After the soil was treated and confirmed to meet cleanup standards, the clean soil was used as fill material under bridge abutments for a new Port entrance overpass that crosses the railroad tracks southwest of the SMC site or as fill material at Parcel 1A, located at Terminal 4.

Overall, interim actions have successfully treated VOC-contaminated soil in the unsaturated zone beneath the SMC site. Analytical results for groundwater samples collected from wells in the SMC site source area suggest that residual TCE may be present in areas of the fine-grained sand layer located in the saturated zone beneath the SMC site. VOCs were not detected at concentrations above the Method B cleanup levels in samples of the soil remaining in place after the interim actions. It is expected that the residual concentrations of VOCs in soil beneath the former SMC facility were further reduced by the interim actions completed to date.

2.3.4.2 Soil Gas Investigations

Evaluation of the distribution of soil gas is based on soil gas sampling from probe borings and soil gas wells during the RI. TCE and other VOCs were expected to be present in soil gas as a result of volatilization of contaminants from groundwater. In general, VOC concentrations were higher in soil gas closer to the groundwater and decreased as soil gas moved upward through the vadose zone to the surface. Results of the soil gas investigations are included in the SMC RI report (Parametrix 2009b).

In the SMC area, the highest concentrations of TCE in soil gas were detected in soil gas well POV-SG-04, immediately adjacent to monitoring wells MW-7s and MW-7i. These monitoring wells typically had relatively high TCE concentrations in groundwater. Between July 2005 and November 2006, TCE was detected at 10 feet bgs in soil gas well POV-SG-04 at concentrations between 16,000 micrograms per meter cubed (µg/m^3) and 23,000 µg/m^3. Concentrations of TCE were higher in the soil gas samples collected from 15 feet bgs (maximum concentration of 33,000 µg/m^3) and 20 feet bgs (maximum concentration of 46,000 µg/m^3) in POV-SG-04. The vertical profile of TCE in soil gas in this area was consistent with a groundwater source (i.e., the highest soil gas concentrations are closest to groundwater). The distribution of impacted soil gas in the remaining wells is also consistent with a groundwater source.

VOCs were detected in soil gas near the SMC site, within the Port property, and in the SFVN. In general, the presence of VOCs in soil gas could be correlated with the occurrence of VOCs in groundwater. In most cases, concentrations of VOCs in soil gas increased with depth, which is expected due to volatilization of the groundwater source material into the overlying vadose zone. The concentrations of VOCs in soil gas decreased significantly since initial soil gas wells were installed in 2004. Soil gas sampling has been discontinued as it was being used to supplement the vapor intrusion (indoor air) issue at the Site, which has since been resolved (see Section 2.3.4.4). There are no Ecology cleanup levels associated with soil gas. Soil gas is not directly addressed as part of this FS because indoor air issues at the site have been resolved and final remedial actions implemented in the project area to address cleanup of groundwater are sufficient to address any residual soil gas concerns.

2.3.4.3 Groundwater

Groundwater investigations have been conducted at the SMC site since 1998. The SMC groundwater monitoring well network is a component of the project area well network and currently consists of 67 monitoring locations: 63 shallow, intermediate, and deep USA monitoring wells; and 4 TGA monitoring wells. Specific monitoring wells associated with the SMC site have been sampled on a regular basis since mid-1998.

Analytical results for groundwater samples have been documented in quarterly, semi-annual, and/or annual monitoring reports since 1999. The distribution of groundwater contaminants at SMC was described in detail in the SMC RI report (Parametrix 2009b). The 2020 distribution of groundwater contaminants in the project area is included on Figures 2-6 through 2-14. A brief summary of 2020 conditions is included below.

Shallow USA Zone

VOC concentrations in SMC shallow source area wells continue to decline. TCE is the primary contaminant associated with the SMC source area. TCE and/or PCE were detected in all six shallow SMC source area wells in 2020. The highest concentration of TCE (559 µg/L) was detected in the third quarter sample collected from shallow source area well VMW-09. The next highest TCE concentration (547 µg/L) and the highest first quarter event detection were also detected in VMW-09.

Since initiation of GPTIA operation, the highest TCE and PCE concentrations in the shallow SMC source area wells were typically detected at MW-05, which is located closest to the extraction well EW-1. Due to a consistent concentration decrease over time at MW-05, higher concentrations of TCE and PCE were detected at VMW-09 beginning with the first quarter 2020 event. The third quarter August 2020 TCE and PCE concentrations reported for MW-05 are the lowest concentrations from a MW-05 sample since initiation of the GPTIA and the lowest TCE level detected in a MW-05 sample.

The extent of the plume in the shallow zone has continued to contract, with concentrations within the plume also significantly decreasing. The 2020 extent of TCE and PCE in the shallow zone at concentrations exceeding MTCA cleanup levels is limited to the SMC site property and extends slightly to the west side of West Mill Plain Boulevard. TCE and PCE isoconcentration maps for shallow wells during 2020 are included on Figures 2-6 and 2-7.

Intermediate USA Zone

TCE and PCE concentrations detected in intermediate wells sampled during 2020 are shown on Figures 2-9 and 2-10, respectively. Consistent with the past several years, the highest TCE concentration was detected at MW-37i (34.7 µg/L), which is located east of GWM. TCE detected in MW-37i is interpreted as coming from a source other than SMC or Cadet. The highest SMC-related concentration of TCE continues to be detected at MW-05i (12.1 µg/L), located adjacent to the GPTIA extraction well. In 2020, seven of the eight intermediate wells associated with the SMC site had concentrations of TCE slightly above 4 µg/L. PCE was detected above 5 µg/L in just one intermediate well, MW-32i (11.6 µg/L), located north of the NuStar site and outside of the Site shown on Figure 1-3. The 2020 data indicate the interim actions have essentially eliminated the dissolved-phase plume in the intermediate zone, with several small areas of residual contamination remaining.

Deep USA Zone

Concentrations of TCE and PCE detected in deep zone wells continue to slowly decrease and the extent of the plume in the deep zone continues to reduce since startup of the GPTIA in 2009, as shown on Figures 2-12, 2-13, and 2-14. Twelve deep zone samples were collected during the first quarter 2020 event. As indicated on Figure 2-12, TCE was detected at concentrations ranging from 1.79 µg/L to 21.7 µg/L. PCE was not detected at concentrations above the 5 µg/L cleanup level.

TGA

Analytical data collected from TGA monitoring wells between 1999 and 2015 indicate no concentrations above cleanup levels. No TGA wells in the SMC area are included in the current groundwater monitoring program (Figure 2-15 shows all TGA wells; only CM-MW-29TGA in the Cadet area is currently being monitored).

2.3.4.4 Indoor Air

Indoor air investigations associated with the SMC site were focused on the SFVN, and two Port tenant buildings and were relatively limited based on initial investigation results and absence of significant contamination beneath the occupied structures. As discussed above in Section 2.2.6.4, the NFVN indoor air investigations were primarily associated with the Cadet site.

Based on the data collected during the sampling for the IAMP, as well as all data collected at the site since 2002, vapor intrusion in the NFVN or SFVN is not a current or future issue of concern. No further indoor air investigation is required in the NFVN or SFVN. Ecology approved the results and recommendations of the IAMP in 2013 (Ecology 2013).

Port Tenant Buildings

In 2010, two Port tenant buildings, 2400 and 2401, were selected for indoor air sampling. Buildings 2400 and 2401 contain large open area warehouse space with no closed office space in either building. Building 2400 was selected for indoor air sampling because it was near (less than 70 feet from) soil gas well POV-SG-04, which had soil gas concentrations of TCE detected at up to 23,000 µg/m^3 in the 10-foot level. Building 2401 was selected to provide an additional sampling point and context for indoor air in the Port buildings.

PCE and TCE were detected in Building 2400 at maximum concentrations of 0.26 µg/m^3 and 1.2 µg/m^3, respectively. PCE and TCE were detected in Building 2401 at maximum concentrations of 0.13 µg/m^3 and 0.07 µg/m^3, respectively. Based on the sample results, significant concentrations of VOCs are not present in buildings 2400 and 2401. Indoor air in Port buildings was determined not to be of concern.

2.3.5 Interim Actions

Interim actions have been conducted at the SMC site to reduce or mitigate the presence of VOCs in particular media. The following provides a summary of the SMC interim actions.

2.3.5.1 Source Area Excavation

In 1998, soil interim actions were performed with oversight from Ecology and in accordance with MTCA Independent Remedial Action Program requirements. Soil cleanup activities included:

- Excavating and stockpiling TCE-impacted soil with concentrations greater than 500 µg/kg (MTCA Method A cleanup standard for TCE in soil at that time).
- Treating the stockpiled soil using enhanced SVE until TCE concentrations in the soil were below the 500 µg/kg cleanup standard.

The Port conducted the first phase of the soil interim action, which included the excavation and stockpiling of soil with TCE concentrations greater than 500 µg/kg. The work was completed under Ecology's Independent Remedial Action Program, but Ecology provided some consultation and review during the process. Building 2220 was demolished in early February 1998 to facilitate removal of the TCE-impacted soil. Excavation and stockpiling of the TCE-impacted soil began in February 1998. During soil excavation, a concrete slab was discovered directly north of former Building 2220. With the exception of a small area of TCE-impacted soil that was discovered and excavated in April 1998, excavation of the TCE-impacted soil in the vicinity of Building 2220 was completed by March 1998.

Because of the hourglass shape of the soil impacted by TCE, clean overburden also had to be removed to excavate TCE-contaminated soil down to 17 feet bgs. As it was excavated, the clean soil was separated from the TCE-impacted soil and stockpiled as "clean" soil. Approximately 13,800 cubic yards of TCE-impacted soil were excavated and stockpiled on the SMC site. Also excavated were approximately 6,300 cubic yards of clean overburden; 4,100 cubic yards of this soil and 2,200 cubic yards of dredge sands were placed as backfill in the excavation. The remaining 2,200-cubic-yard stockpile of clean overburden soil was used as fill material at other Port locations.

Sampling was conducted during the interim removal action to evaluate the effectiveness of the soil excavation. Where verification sampling indicated TCE in soil at concentrations greater than 500 µg/kg, additional soil removal was conducted and the area re-sampled. Twelve verification soil samples were collected from the two remedial excavations (under the northeast section of the SMC slab) in the vicinity of four test pits that contained soil with TCE exceeding 500 µg/kg. VOCs were not detected in any of the verification samples.

With the exception of a small area located to the south of the remedial excavation, all soil in the vadose zone that contained TCE at concentrations greater than 500 µg/kg was excavated and stockpiled for treatment.

The Port selected enhanced SVE as the most cost-effective technology to treat the stockpiled TCE-impacted soil. Philip Services Corporation was contracted by the Port to complete the soil treatment. Three treatment cells were constructed by trenching into the stockpiled soils with a trackhoe to lay the piping system. The cells were treated one at a time, with a new cell constructed upon the successful treatment of the previous cell.

The piping consisted of a series of air inlets (perforated PVC pipes) that were placed in the stockpiled soil to allow air into the soil. As needed, air was forced into the soil stockpile using these air inlets. A series of air extraction wells, also consisting of perforated PVC pipe, were also constructed to vent soil pore gases. The combined inlets and extraction wells allowed an average of approximately 362 to 377 cubic feet per minute of soil vapor to move along the induced flow path to the treatment system. The soil vapors removed from the treatment cells passed through a vapor/water separator prior to being treated using a 1,000-pound granular activated carbon unit. Captured TCE and other VOCs were destroyed during carbon regeneration. Influent and effluent air monitoring was conducted in order to evaluate the effectiveness of the treatment system.

Cell treatment was initiated in March 1999. TCE and PCE were not detected in the effluent samples taken from each cell after treatment. Soil samples collected from each of the subcells within each treatment cell were analyzed for TCE and PCE. Based on the analytical results, Ecology issued letters allowing reuse of the treated soil from each cell as fill on Port property. The treated soil from the three treatment cells was used as fill material at Parcel 1A, located at Terminal 4, or under bridge abutments for a new Port entrance overpass.

2.3.5.2 Groundwater Source Area Interim Action

A groundwater source area treatment program was initiated at the SMC site in January 2002. The treatment program consisted of introducing Fenton's Reagent below the water table using a combination of injection wells and temporary direct-push injection points. Seven treatment events were conducted between January 2002 and October 2004. Details of the various injection and monitoring events are included in the SMC RI report.

The remedial action objective (RAO) for the groundwater interim action was to destroy, to the extent possible, residual TCE from the groundwater source area. Thus, dissolved TCE concentrations less than 10,000 µg/L were deemed indicative of successful treatment and achievement of the RAO. The RAO was achieved at 28 of 30 temporary probe borings used to monitor groundwater quality in the treatment area, with the exception of the area defined by well DSI-6-40 and VMW-9 (see Figure 7-1).

Groundwater samples collected and analyzed after each treatment event consistently detected TCE at concentrations above 10,000 µg/L in VMW-9. As a result, soil conditions in the source area were evaluated to identify the source of the residual TCE. The suspected source of the residual TCE was a fine--grained layer of silty sand identified in the vicinity of VMW-9. The investigation focused on defining the extent of the fine-grained layer and evaluating residual TCE concentrations in the layer.

TCE data from the fine-grained layer also showed that, in general, the highest concentrations of TCE in soil corresponded to the locations of the highest groundwater TCE concentrations (wells DSI-6-40, VMW-9, and VMW-2).

2.3.5.3 Groundwater Pump and Treat System

The Groundwater Pump and Treatment Interim Action (GPTIA) was constructed by the Port from 2008 to 2009, with startup in June 2009. The objectives of the GPTIA were to provide hydraulic containment of the dissolved-phase plume and to remove VOCs in groundwater. Specific design details are included in the Engineering Design Report (Parametrix 2008b), and complete specifications and drawings are included in the As-Built Report for Groundwater Pump and Treat Interim Action SMC/Cadet Commingled Plume (Parametrix 2009c).

The interim action involves pumping groundwater from below the former SMC site and treating the groundwater through an air stripping process. Specifically, a groundwater extraction well is used to recover TCE-impacted water from the intermediate USA, and a forced pipeline transports the water to the treatment system. The air strippers remove the TCE and other VOCs from the water and transfer them to an air stream for discharge to the atmosphere under a Southwest Clean Air Agency permit. The clean treated water is then discharged to the Columbia River via an existing stormwater outfall under a National Pollutant Discharge Elimination System (NPDES) Permit.

Extraction Well

The interim action includes one groundwater extraction well (labeled EW-1) located on the former SMC site. EW-1 was drilled in this location for two reasons: (1) this location included the highest concentrations of VOCs associated with the SMC site; and (2) groundwater modeling indicated pumping at this location would capture the dissolved-phase plume in the overall project area.

Well construction consists of a 26-inch-diameter casing with a grout seal to approximately 40 feet bgs, a 22-inch-diameter screen from 40 to 104 feet bgs, and a 22-inch-diameter casing from 104 to 120 feet bgs as a pump chamber sump. Flow rates from the well are variable and controlled by a programmable logic controller located at the treatment plant. A flow meter was installed on the discharge line from the well to monitor and record flow continuously. The average flow rate from 2009 through 2019 was approximately 2,500 gpm. Starting in 2020, the flow rate decreased to approximately 1,000 to 1200 gpm primarily due to fouling of the well screen and other factors.

The well head and associated piping are located in the well house at the former SMC site. All piping and electrical conduits run underground from the well house to the treatment plant. Flow from the well is measured and monitored with an electronic flow meter installed on the discharge piping leading from the well to the treatment plant. The flow rate is monitored and controlled locally by the treatment plant operator from a control screen located in the control room next to the treatment plant.

Treatment System

The treatment system includes pretreatment of the water to remove iron and manganese via manganese dioxide filters. The manganese dioxide filter media operates both as a classical filter working with an oxidant and as a catalytic media due to its ability to accelerate the reaction between the oxidizing agent and with the iron and manganese present. The filters are no longer used in the operation due to low iron and manganese concentrations in the influent groundwater.

Two air strippers operate in parallel to treat the maximum flow and TCE concentration. Each air stripper is approximately 10 feet in diameter with a packing height of 40 feet. Each air stripper is equipped with a 60-horsepower blower connected to a variable frequency device. The blowers and treatment system controls are enclosed in a concrete block building for noise control and ease of maintenance. The off-gases from each air stripper are discharged to the atmosphere via a 2-foot-diameter stack.

The treatment system design was based on removing TCE from a maximum concentration of 200 µg/L down to the analytical reporting limit of 0.5 µg/L. The highest TCE concentration observed since startup was 52 µg/L in 2009. The highest PCE concentration observed since startup was 21 µg/L, also in 2009. The treatment system continues to sufficiently remove VOCs down to the analytical reporting limit of 0.5 µg/L.

Treatment Plant Discharge

The treated water is conveyed by gravity through the discharge line. The discharge line connects to the City-owned portion of a 36-inch stormwater line that runs beneath the Port/BNSF railroad tracks for approximately 333 linear feet. The flow then travels by gravity through the existing 36-inch storm line that runs beneath the rail spur and the Port Terminal 2 area. The 36-inch storm line discharges though an existing bank outfall beneath the Terminal 2 dock on the south side of the Port near Building 500. The effluent is monitored per requirements of the NPDES permit issued by Ecology.

Performance

The performance of the GPTIA has been significant with respect to the total mass of VOCs removed from the groundwater. Since startup in June 2009, the GPTIA has extracted and treated a total of 12.75 billion gallons of groundwater and removed approximately 1,298 pounds of VOCs (as of December 2020). As expected, there has been a steady decrease in the annual pounds of VOCs removed, beginning with 263 pounds during the last 6 months of 2009 to the 21 pounds removed during 2020.

The overall extent of shallow and intermediate zone contamination has been reduced significantly, as well as the concentrations in individual wells. Figure 2-8 shows the shallow dissolved-phase plume in 2009 prior to GPTIA startup, in March 2013, and 2020. Figure 2-11 shows the intermediate dissolved-phase plume in 2009, 2013 and 2020. The 2020 data indicate the interim actions have essentially eliminated the dissolved-phase plume in the intermediate zone, with several small areas of residual contamination remaining. Figure 2-14 shows the deep USA zone in 2009, 2013, and 2020.

2.3.6 Summary of Risk Assessment

This section presents a summary of the human health risk assessment for the Swan site presented in the SMC RI report. The risk assessment primarily focused on the potential risk to applicable receptors from groundwater exposure and associated pathways. The potential human health risks from the release of TCE at the SMC site were examined by evaluating soil, soil gas, indoor air, and groundwater data collected within the project area. Exposure to VOCs was estimated for workers and residents within the project area for the following pathways:

- Inhalation exposure to indoor air from soil gas or groundwater
- Inhalation exposure to outdoor air originating from soil gas or groundwater
- Ingestion or skin contact with groundwater used for potable purposes
- Skin (dermal) contact with or incidental ingestion of groundwater from (occasional) digging or trenching activities

The risk assessment was completed in 2008, prior to installation and operation of the GPTIA. Use of data collected prior to the interim actions significantly overstates the potential risk associated with remaining contamination. However, the risk assessment is primarily being used to establish potential complete exposure pathways rather than a strict evaluation of risk. Therefore, the discussions below include additional information and updates where it impacts the FS evaluation and/or potential remedial actions as of December 2020.

2.3.6.1 Land and Beneficial Water Use

Land use and beneficial water use were evaluated to support the risk assessment completed for the site, primarily to establish the applicable potential exposure pathways.

It is assumed that the Port will retain ownership of the SMC site and other properties it currently owns in the project area. It is also assumed that future use of the project area will remain as zoned (i.e., Heavy and Light Industrial at the Port and Light Manufacturing north of Fourth Plain Boulevard). In addition, Single Family Residential zoning is assumed to continue in the areas northeast of Fourth Plain Boulevard.

A beneficial water use survey was conducted to evaluate the use of water in the project area. The following conclusions are based on the information available during the RI regarding the beneficial use of groundwater and surface water in the project area. The current and potential future beneficial uses of groundwater in the project area include:

- Drinking water
- Irrigation
- Industrial

Groundwater on the SMC property is not currently used as a potable water source. However, the intermediate groundwater zone in the vicinity of the project area is used as a productive aquifer for municipal water supplies, including by COV, the Port and its tenants, and CPU. In general, shallow groundwater is not a source of potable water, but it does have limited potential for potable water extraction. In addition, the aquifer in the project area is designated as a sole source aquifer (which includes all zones). There is no confining layer that distinctly separates the shallow and intermediate zones. Therefore, all groundwater in the project area is considered to have a beneficial use in the form of a potential drinking water source and/or connection to a drinking water source.

2.3.6.2 Chemicals of Potential Concern

COPCs were evaluated based on potential exposure routes and analytical data in various media at the SMC site. The selection of indicator hazardous substances (i.e., COPCs) was conducted in accordance with WAC 173-340-703. VOCs further evaluated in the risk assessment were determined based upon: (1) the frequency of detection; (2) the potential for adversely affecting human health; (3) the chemical and physical characteristics of the contaminants; and (4) the identification of potential degradation byproducts of TCE (e.g., 1,1-DCA, 1,2-DCE, and cis-1,2-DCE).

COPCs for groundwater included 1,1-DCE, 1,1-DCA, 1,2-DCA, bromodichloromethane, carbon tetrachloride, cis-1,2-DCE, dibromochloromethane, methylene chloride, PCE, and TCE.

COPCs for soil included methylene chloride, PCE, and TCE.

COPCs for indoor and outdoor air included 1,1,1-trichloroethane, 1,1-DCA, 1,1-DCE, chloroethane, cis-1,2-DCE, PCE, trans-1,2-DCE, and TCE.

2.3.6.3 Summary of Chemical Fate and Extent

The extent of soil and groundwater contamination at the SMC site is summarized in Section 2.3.4. Figures 2-6 through 2-14 show the extent of groundwater contamination at the site as of 2020. The primary COPCs remaining at the site include TCE and PCE.

2.3.6.4 Human Health Risk Assessment

An exposure assessment is conducted to estimate the magnitude, frequency, duration, and route of exposure of a receptor to a contaminant source. Information about waste sources, exposure pathways, and receptors at the SMC site were used to develop a conceptual understanding in order to evaluate potential risks to human health.

Receptors are defined as persons who may come into contact with site chemicals. Receptors in this analysis are individuals who work or live within the project area. “Workers” include individuals who work regularly at Port-owned or non-owned property located in areas of impacted groundwater downgradient of the SMC source area. Temporary workers were also evaluated, such as excavation workers on Port property. Residents include people who live east of the SMC site in the SFVN where impacted groundwater previously migrated. Conclusions for each type of receptor evaluated in the risk assessment are discussed below.

Source Area Workers

Potential exposure routes include inhalation of contaminants in indoor and outdoor air and drinking contaminated groundwater.

Exposure and risk estimates prepared in 2008 for source area workers suggested that VOC contaminants in indoor air (Port buildings) posed a slightly elevated risk if workers are chronically exposed (maximum ELCR $2x10^{-6}$). However, since the time of the indoor air risk assessment, EPA has changed the toxicity factor that must be used to calculate risk for TCE and PCE. Because of EPA’s change (and subsequent Ecology-adopted values), the potential risk is substantially lower than originally calculated. Further evaluation conducted subsequent to the RI and CAMP indicated that no potential risk is present to workers. There is no building located over the source area where residual groundwater contamination remains. The indoor air issue has been completely addressed, and Ecology has indicated that no further investigation or remedial actions are required (Ecology 2013). In addition, as of December 2020, the groundwater concentrations near the SMC site that could impact vapor intrusion have been significantly reduced (see Figure 2-8 for comparison of 2009, 2013, and 2020 groundwater data); thus, the assessment that there is no potential risk to workers from vapor intrusion remains valid.

Risk estimates prepared in 2008 indicated VOC concentrations do not pose an elevated risk to source area workers exposed to outdoor air. 2020 concentrations are significantly less than in 2008. As a result, the risk from the outdoor air pathway is negligible.

Exposure and risk estimates prepared in 2008 for source area workers suggest that VOC contaminants in groundwater pose a potential risk if workers are chronically exposed via drinking water (maximum ELCR $1x10^{-2}$). As of December 2020, the groundwater concentrations near the SMC site have been significantly reduced (see Figures 2-8 and 2-11 for comparison of 2009, 2013, and 2020 shallow and intermediate zone groundwater data). Only a small area with VOC concentrations exceeding the MTCA cleanup levels remains and installation of a well for domestic water use is extremely unlikely as the area is serviced by the City of Vancouver. However, based on these exceedances, the potential exposure route via drinking water remains valid.

SMC Source Area Excavation Worker

Potential exposure for source area excavation workers includes soil and groundwater direct contact and vapor inhalation in outdoor air.

Direct contact with contaminated soil poses minimal risk to excavation workers because contaminated vadose zone soil has been removed. Groundwater is generally greater than 15 feet bgs (the general default depth for excavation worker exposure in risk assessments); thus, the potential risk to excavation workers from direct contact with groundwater is minimal. As noted above, outdoor air risks were negligible in the risk assessment completed in 2008. Thus, the potential risk to an excavation worker from vapors within a trench is likely negligible. The assessment of minimal risk to excavation workers remains valid and all potential risk scenarios can be mitigated through use of site health and safety procedures

Off-Site Residents

Exposure and risk estimates prepared in 2008 for SFVN residents suggested that VOC contaminants in indoor air pose a potential risk if residents are chronically exposed (ELCRs ranging from $2x10^{-6}$ to $8x10^{-5}$) (NFVN residents were assessed in the Cadet site analysis). However, since the time of the indoor air risk assessment, EPA has changed the toxicity factor that must be used to calculate risk for TCE and PCE. Because of EPA's change (and subsequently Ecology-adopted values), the potential risk is substantially lower than originally calculated. Further evaluation conducted subsequent to the RI and CAMP indicated that no potential risk is present to residents. The indoor air issue has been completely addressed, and Ecology has indicated that no further investigation or remedial actions are required (Ecology 2013). In addition, as of December 2020, the groundwater concentrations beneath the SFVN that could impact indoor air have been reduced significantly (see Figure 2-8 for comparison of 2009, 2013, and 2020 groundwater data). Thus, the assessment that there is no potential risk to SFVN residents from vapor intrusion remains valid.

Exposure and risk estimates prepared in 2008 for groundwater ingestion by SFVN residents suggested that VOC contaminants in groundwater posed a potential risk if residents are chronically exposed. However, December 2020 groundwater monitoring data indicate contaminant concentrations in the SFVN are generally below or slightly above cleanup levels (see Figures 2-8 and 2-11 for comparison of 2009, 2013, and 2020 shallow and intermediate zone groundwater data) indicating that there is very little potential risk. There are no domestic groundwater wells in use in the SFVN. Drinking water is supplied to the SFVN by the City of Vancouver.

2.3.6.5 Ecological Risk Assessment

As required under MTCA (WAC 173-340-7490), a terrestrial ecological evaluation must be considered to:

- Determine whether a release of hazardous substances to soil may pose a threat to the terrestrial environment;

- Characterize existing or potential threats to terrestrial plants or animals exposed to hazardous substances in soil; and
- Establish site-specific cleanup standards for the protection of terrestrial plants and animals.

Exposure pathways to sediments, surface water, or wetlands are not considered complete for the SMC site. Therefore, the terrestrial ecological evaluation did not include an evaluation of potential threats to ecological receptors in these media or habitat areas. Since the residual contaminated soil is located on-site the evaluation focused only on exposure to soil contamination for terrestrial wildlife protection (per WAC 173-340-7490-03b). This contamination is found in an area zoned for industrial and commercial use only.

A simplified terrestrial ecological evaluation was conducted for the SMC site in accordance with WAC 173-340-7492. The soil contamination on the SMC site is generally limited to a confined area (and at depth), and in limited access industrial and commercial area and thus does not appear to be a substantial potential for posing a threat of significant adverse effects to terrestrial ecological receptors. The terrestrial wildlife evaluation consisted of calculating ecological indicator soil concentrations for the COPCs at the SMC site. The methods for obtaining information and calculating ecological soil concentrations followed methodologies developed in MTCA.

A comparison of the ecological indicator soil concentrations to the reasonable maximum soil concentrations at the SMC site indicates that no chemical exceeded its respective indicator soil concentration. Thus, contaminant concentrations in subsurface soil at the SMC site do not pose a significant threat to terrestrial ecological receptors. Therefore, based on the size of the contaminated area, the land use at the site, and the relatively low contaminant concentrations (compared to ecological indicator soil concentrations), the SMC site was excluded from further ecological assessment per WAC 173-340-7492.

2.3.6.6 Risk Assessment Summary

The 2008 risk assessment was conducted in accordance with MTCA guidance. Potential risks to human health from exposure to contaminants in groundwater, soil, indoor air, and outdoor air were examined. Based on the results of the risk assessment, Parametrix reached the following conclusions for each medium at the SMC site.

1. Groundwater – The potential risk associated with groundwater was evaluated for source area and project area workers, an excavation worker, and SFVN residents. While previous remedial actions have significantly reduced groundwater concentrations, 2020 concentrations in the source area are still at a level that suggests potential elevated risks to human health for source area receptors only (all other receptors are below risk levels). Drinking water for the area is currently supplied by the City of Vancouver; in areas located within the urban growth boundary and where the public agency is able to provide a safe and reliable service, connection to the public water source is required as a condition of the building permit. Therefore, there is a little potential that a drinking water well would be approved and installed near or at the SMC site. Thus, the presence of a reliable public drinking water source indicates that there is no current or future risk associated with drinking water from the shallow zone.
2. Soil – The potential risk associated with soil was evaluated for a source area worker and excavation worker. Based on the human health risk assessment, the risk associated with COPCs in soil in the

source area is within the acceptable risk range. Further remediation of soil is not warranted based on the potential receptor scenarios evaluated.

3. Indoor Air – The potential risk associated with indoor air was evaluated for the source area workers and SFVN residents. Measured concentrations of VOCs at SFVN residences indicated potentially elevated cancer risks (i.e., above $1x10^{-6}$) from chronic exposure to indoor air (ELCRs ranging from $2x10^{-6}$ to $8x10^{-5}$). However, since the time of the indoor air risk assessment, EPA has changed the toxicity factor that must be used to calculate risk for TCE and PCE. Because of EPA's change (and subsequently Ecology-adopted values), the potential risk is substantially lower than originally calculated. Further evaluation conducted subsequent to the RI and CAMP indicated that no potential risk is present to residents. The indoor air issue has been completely addressed, and Ecology has indicated that no further investigation or remedial actions are required (Ecology 2013). No further evaluation of indoor air in this FS is necessary.
4. Outdoor Air – The risk from outdoor air was evaluated for a source area worker and a SFVN resident (child and adult). Based on the human health risk assessment, the risk associated with COPCs in outdoor air is negligible.

2.4 Dispersed Residual Groundwater Contamination

As noted in Section 1.1., the current AO (DE 18152) was developed to cover Cadet and SMC and the area generally encompassed by previous groundwater contamination north of NW Harborside Drive. The area covered under the current AO and the focus of this FS is shown on Figure 1-3.

Interim actions conducted at the Cadet and SMC source areas (as well as NuStar) have significantly reduced contaminant concentrations in groundwater and essentially eliminated the dissolved-phase plume associated with Cadet and SMC. In addition, there no longer is a continuous dissolved-phase plume extending from NuStar to the SMC and Cadet area (see Figures 2-6 through 2-14). Local residual areas remain near Cadet/SMC, in the NuStar area, and other limited areas of the Site. A primary focus of this FS is to evaluate remedial alternatives with respect to the dispersed residual groundwater contamination associated with Cadet and SMC (Section 8). Therefore, the summary of the existing conditions below provides a basis for the evaluation in Section 8.

2.4.1 Current (2020) Groundwater Conditions at the Site

In general, the description of the current distribution of VOCs in the project area is based on groundwater samples collected from monitoring wells during 2020. The first quarter event represents the most comprehensive event when all active SMC, Cadet, and NuStar site monitoring wells are sampled during the same period.

The examination of the distribution of VOCs in groundwater is based on the presence of TCE and PCE. These two compounds have the highest frequency of detection, are the primary contaminants released at the known source areas, are the focus of cleanup actions, and are the primary contaminants of concern in groundwater (i.e., indicator hazardous substances).

Figures 2-6 through 2-14 present isoconcentration maps for TCE and PCE in the three (shallow, intermediate, and deep) USA water quality zones described in Section 2.1. These isoconcentration maps are based primarily on first quarter 2020 sample results. The lowest isoconcentration contour shown for

TCE is 4 µg/L, which is based on its MTCA Method B cleanup level (see Section 5). Similarly, the lowest isoconcentration contour shown for PCE is 5 µg/L which is based on its MTCA Method B cleanup level (see Section 5). Higher contours are used if concentrations at those levels are present. Isoconcentration maps have not been developed for the TGA due to detections occurring in only one TGA monitoring well.

The distribution of VOCs in groundwater in the three USA water quality zones and the TGA based on 2020 results are described in the following sections. Concentrations and distribution areas continue to reduce in response to ongoing interim actions.

2.4.1.1 Shallow USA Zone

The distribution of contaminants in shallow groundwater was previously described in the Cadet and SMC background sections. Figures 2-6 and 2-7 show the 2020 distribution of TCE and PCE in the shallow USA zone across the site. Figure 2-8 shows the distribution of TCE in the shallow zone in 2009, 2013, and 2020. For completeness, a brief overview of the 2020 conditions in the shallow USA zone is provided below.

VOC concentrations in SMC shallow source area wells continue to decline in response to the interim actions. TCE is the primary contaminant associated with the SMC source area. TCE and PCE were detected in all six shallow SMC source area wells during 2020. The distributions of TCE and PCE at the former SMC site are shown on Figures 2-6 and 2-7, respectively. TCE and PCE concentrations in the shallow zone in the SMC site area do not exceed cleanup levels with exception of the SMC source area wells. The 2020 extent of TCE and PCE in the shallow zone at concentrations exceeding MTCA cleanup levels is limited to the SMC site property and extending slightly to the west side of West Mill Plain Boulevard (see Figures 7-2 and 7-3).

Since initiation of GPTIA operation, the highest TCE and PCE concentrations in the shallow SMC source area wells were typically detected at MW-05, which is located closest to the extraction well EW-1. Figure 7-5 shows the TCE concentration trend in MW-05 since 2009.

In the Cadet site area, VOC concentrations in all shallow wells have declined significantly since startup of the GPTIA in June 2009. TCE and PCE are no longer detected above 4 µg/L and 5 µg/L, respectively, in shallow wells located beyond the Cadet site boundary (see Figure 2-6)

2.4.1.2 Intermediate USA Zone

The intermediate (and deep) USA zone is the focus of the evaluation of remedial alternatives for the residual plume. Figures 2-9 and 2-10 show the 2020 distribution of TCE and PCE in the intermediate USA zone in the project area.

The highest TCE concentration detected in 2020 was at MW-37i (34.7 µg/L), located east of GWM. TCE detected in MW-37i is interpreted as coming from a source other than SMC or Cadet. The highest SMC-related concentration of TCE was detected at MW-05i (12.1 µg/L), located adjacent to the GPTIA extraction well (EW-1). In 2020, seven of the eight active intermediate wells associated with the SMC site had concentrations of TCE slightly above 4 µg/L. PCE was detected above 5 µg/L in just one intermediate well, MW-32i (12.8 µg/L), located north of the NuStar site, and outside of the site shown on Figure 1-3.

A new intermediate well, labeled MW-2i, was installed at the site in 2020 to evaluate conditions beneath and near the SMC source area. Intermediate well MW-2i initially sampled in December 2020. TCE and PCE were detected at concentrations of 1.33 µg/L and 1.11 µg/L, respectively. The SMC groundwater data indicate VOC concentrations above the cleanup levels in the intermediate zone in the SMC source area are limited to the area around MW-05i.

The highest concentration of any VOC detected in an intermediate zone Cadet well during 2020 was TCE (5.85 µg/L) in CM-MW-23i. TCE was detected at a concentration of 5.54 µg/L in intermediate well CM-MW-Ui. However, well CM-MW-Ui is near the southeast corner of the Site area and not considered a Cadet (or SMC) intermediate monitoring location and located outside of the area of Site as shown on Figure 1-3. The highest PCE concentration was detected in well CM-MW-20i (3.98 µg/L). TCE and PCE concentrations continue to decline in the Cadet intermediate wells, including CM-MW-23i.

The 2020 data indicate the interim actions have essentially eliminated the dissolved-phased plume in the intermediate zone, with a few small areas of residual contamination remaining (Figure 2-11).

2.4.1.3 Deep USA Zone

Figures 2-12 and 2-13 show the 2020 distribution of TCE and PCE in the deep USA zone. Concentrations of TCE detected in deep zone wells continue to decrease slowly since startup of the GPTIA in 2009, as shown on Figure 2-14. Twelve deep zone samples were collected during the first quarter 2020 event. As indicated on Figure 2-12, TCE was detected at concentrations ranging from 1.79 µg/L to 21.7 µg/L. PCE was not detected at concentrations above the 5 µg/L cleanup level.

2.4.1.4 TGA

Cadet well CM-MW-29TGA is the only TGA well where VOCs have been detected and the only active TGA well. Sampling of this TGA well is completed annually during first quarter events. In 2020, TCE and PCE were detected in TGA well CM-MW-29TGA at concentrations of 12 µg/L and 6.48 µg/L, respectively. TCE and PCE concentrations have been stable following a declining trend that ended in 2012 (Parametrix 2021)

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3. GROUNDWATER MODEL

This section presents an overview of the groundwater flow and transport model and its use in the FS to evaluate cleanup alternatives. Detailed discussion of model design, calibration, and verification is presented in the Vancouver Lake Lowlands Groundwater Model Summary Report (Parametrix 2008a). Discussions of previous model simulations are presented in the SMC (Parametrix 2009b) and Cadet RI Reports (Parametrix 2010a). A summary of the simulations utilized for this current FS effort is included in Section 3.3 below and results are presented in detail in Appendix A.

3.1 Background

The Port developed a three-dimensional, finite difference groundwater flow and contaminant transport model for the SMC site as part of the RI. Development of a groundwater model was proposed in the Swan Phase II Interim Data Report (Parametrix 2001) to describe groundwater flow conditions and the fate and transport processes at the SMC site. Activities at that point of the RI had found that characterization of groundwater flow beneath the SMC site was complicated by the influence of river stage elevations, tidal fluctuations, and water supply well pumping; it concluded that water level contour maps based on manual water level measurements represented over-generalizations of actual groundwater flow conditions. The combination of small-scale and local variations in groundwater flow direction, associated with local recharge characteristics, along with very low horizontal gradients, resulted in complicated water level interpretations. The distribution of the contaminant plume suggested that the flow of groundwater was heavily influenced by production well pumping. Thus, a groundwater flow model was developed to help with interpretation of groundwater flow in the project area.

Refinement, evaluation, and confirmation of the model was completed over time and facilitated through ongoing collection of hydrogeologic data in the project and active model areas during the RI effort. In 2006, the Port and CPU agreed to conduct further model calibration and validation to confirm that the model is an appropriate tool to evaluate remedial alternatives for the dispersed plume originating from the Swan, Cadet, and NuStar sites and to evaluate those alternatives with respect to proposed water supply development in the Columbia River Lowlands. CPU had developed a similar flow model to assist in its evaluation of potential water supply wellfield sites in the Vancouver Lake lowlands area. The result of the joint Port and CPU modeling effort completed in 2008 was the Vancouver Lake Lowland (VLL) groundwater flow model (Parametrix 2008a). This effort resulted in Ecology's approval to implement the 2008 VLL groundwater flow model for the SMC and Cadet cleanup site (Ecology 2008).

Hydrogeologic-related modifications to the model in the NuStar site area were made in 2011 to reflect understanding of the Site's historical river channel setting. This modification was used in modeling associated with evaluation of the Port's groundwater pump and treat system (Parametrix 2011). Other than modification of the NuStar site area to capture the Site's historical river channel setting, no additional modifications were made to the VLL groundwater flow model.

3.2 Model Description

The model consists of a groundwater flow model and a contaminant transport model. The flow model uses the USGS three-dimensional, finite difference MODFLOW code (McDonald and Harbaugh 1988).

The contaminant transport model uses the three-dimensional MT3D-99 code (Papadopulos 1999) that uses flow model results. MODFLOW and MT3D are widely used codes for groundwater modeling and are essentially the industry standard for simulation of groundwater flow and contaminant transport in groundwater.

The model computes groundwater flow and contaminant transport over an area defined by the model grid. The VLL model area includes the Vancouver Lake Lowlands and the City of Vancouver core area . The Lowlands extend approximately to the mouth of Salmon Creek to the northwest and approximately to Columbia River Mile 110 on the east. From south to north, the model extends from the south shore of the Columbia River to the top of the bluffs north of Burnt Bridge Creek. This area is needed to reach the physical boundary conditions of the USA in the project area rather than applying artificial boundary conditions. The entire model grid covers 74 square miles. The active flow model area covers 41 square miles, and the active transport model area covers 25 square miles. The transport model can be smaller than the flow model area to save computation time, as long as the active transport model area includes the contaminant plumes.

To represent the groundwater system in the VLL, the model uses a finite difference grid consisting of 16 layers extending from the water table to the base of the TGA. The model area is broken down into cells using a non-uniform grid that is oriented with a principal axis parallel to the Columbia River to minimize the number of inactive cells in the model structure. Non-uniform grid spacing was used to allow a large number of cells in the area of the three known source areas (Swan, Cadet, and NuStar) where groundwater flow and contaminant transport are of interest. In the vicinity of the known source areas, a grid spacing of 50 feet was selected. This area is referred to as the detailed model area.

The hydrogeologic units within the model area are represented by layers within the numerical model. The model includes silty recent alluvium, sandy recent alluvium, the USA, and the TGA. The bottom of the model is Confining Unit 1, so the model includes the entire thickness of the Upper Sedimentary Subsystem (see Section 2.1). The top of the TGA was used as the primary reference for building the model layers by initially setting the top of model layer 10 as top of the TGA. This provides nine model layers to define the thickness of the USA. The model layering was then modified to account for locations where the TGA, USA, and alluvial sand are at the water table by having parts of layers 1 through 9 assigned to deeper units. For instance, the TGA is generally a deep unit in the model area. However, the top of the TGA rises to the northeast and is found at the water table (model layer 1) along some parts of the northern model boundary. This layering approach improves the model's stability.

Flow model boundary conditions for the model were selected to coincide with physical (hydrologic) boundaries of the groundwater flow system wherever possible. The following boundary conditions were assigned to the regional model area:

- Specified head
- Drain
- No flow
- Specified flux

Specified head boundaries are appropriate when head in the boundary water body will not be affected by changes in head and flow in the aquifer. Specified head boundary cells were assigned to Vancouver Lake, the Columbia River, and the upgradient (northeast) portion of Burnt Bridge Creek. Drain boundary conditions were assigned to simulate groundwater discharge to Burnt Bridge Creek along the northern boundary. No flow boundaries were assumed on the south, west, east, and northwest model boundaries in layers that are not intersected by the Columbia River. The south and west no-flow boundary assumes that no flow occurs under the Columbia River from Oregon. The bottom of the model was assigned no-flow conditions based on the assumption that there is no significant flow between the TGA and the underlying Troutdale Sandstone aquifer or deeper Sand and Gravel aquifer due to the presence of Confining Units 1 and 2. Specified flux boundaries were used to simulate recharge and discharge from the groundwater system that are not a function of head. Both recharge and pumping wells were simulated as specified flux boundaries.

3.3 Feasibility Study Model Application

For this FS, the model was primarily used to evaluate the contaminant distribution in the absence of the GPTIA (i.e., under a system shut-down scenario). Pacific Groundwater Group was subcontracted by the Port to provide model application and simulations. A detailed discussion of significant model parameters, inputs, assumptions, and model results is included in Appendix A.

As described throughout this FS, the operation of the GPTIA pumping well EW-1, in addition to other interim actions completed at SMC, Cadet, and NuStar, has effectively eliminated the areal distribution of the contaminant plume and reduced concentrations within the plume. The effectiveness of the GPTIA can be seen in Figures 2-8 and 2-11 that show the substantial reduction of the plume since operation of the GPTIA began in 2009. The total amount of VOCs removed is 1,298 pounds. On an annual basis, the VOCs captured and treated has decreased from 263 pounds during the last 6 months of 2009 to the 21 pounds removed during 2020. It is apparent that the efficiency of operating the GPTIA system has been reduced as the aquifer has been cleaned up.

As described in Section 8, the remedial alternatives evaluated for the dispersed residual groundwater contamination (not source area) include (1) turning the pumping well (EW-1) off and allowing for monitored natural attenuation (MNA), or (2) continue pumping at EW-1. The groundwater model was used to evaluate the nature of groundwater contamination once the system is shut down (i.e., have the active remedial actions completed for the SMC and Cadet sites sufficiently cleaned up the aquifer?). This evaluation included using the model to assess potential receptors, including regional pumping wells.

The first step of the evaluation was to develop future pumping rate projections for the major users of groundwater in the model area. Future pumping projections were developed through discussion with COV, CPU, GWM, and the Port with the objective of establishing projections based on best understanding of probable future water demands while maintaining generally conservative assumptions (i.e., higher usage rate projections). Pump rate projections were developed for the CPU Southlake Wellfield (the Carol Curtis Wellfield), the three COC water stations (WS-1, WS-3, and WS-4), and for the GWM and Port wellfield. Future usage at the wellfields in the model area is dependent on a number of factors including actual water demands, anticipated area and regional growth, economic conditions, and long-term effectiveness of conservation measures.

Transport model boundary conditions consist of zero mass flux and concentration boundaries. Zero mass flux boundaries were defined along the edge of the active transport model area. Concentration cells were used to define the 2020 dissolved plume based on recent isoconcentration maps and to represent the SMC source area. Simulations included both a constant source and a non-constant depleting source to provide a range of conditions and results. Fate and transport of contaminants is primarily a function of dispersion through advection caused by groundwater flow. However, a conservative degradation rate was also applied.

A summary of the model scenarios, significant assumptions, relevant parameters, and results are included in Appendix A. As applicable, the results and explanation of potential impacts or effects on the residual groundwater plume are included in the individual alternatives' evaluations in Section 8.

4. APPLICABLE FEDERAL, STATE, AND LOCAL LAWS

The MTCA rules (WAC-173-340-710) require that cleanup actions comply with applicable state and federal laws, which are defined as “legally applicable requirements and those requirements that the department determines…are relevant and appropriate requirements” (i.e., ARARs). A cleanup action performed under MTCA authority (e.g., an AO) is exempt from the procedural requirements of certain state and local environmental laws; although the cleanup action must still comply with the substantive requirements of applicable federal, state, and local laws.

“Legally applicable” requirements include cleanup standards or environmental protection requirements under state or federal laws that specifically address a hazardous substance or cleanup action for a site. “Relevant and appropriate” requirements include cleanup standards or environmental requirements (e.g., cleanup standards, standards of control, environmental criteria, environmental limits, etc.) under state and federal law that, while not legally applicable to the cleanup action, address problems or situations that are considered sufficiently similar to those encountered at the site. A comprehensive list of federal, state, and local laws that may affect the development of cleanup standards and the selection and implementation of cleanup actions is presented in Table 4-1. A detailed description of these laws as they may pertain to cleanup activities is provided in Appendix B.

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5. DEVELOPMENT OF CLEANUP STANDARDS

This section summarizes the development of cleanup standards and POCs for various media at the Site. Cleanup standards were developed in accordance with WAC 173-340-720 through WAC 173-340-760. In accordance with WAC 173-340-700(3), cleanup standards were developed for hazardous substances identified at the Site and the specific areas or exposure pathways where humans or the environment could potentially become exposed to these substances. Establishing cleanup standards requires identifying the following:

- Cleanup levels – concentrations of contaminants that do not pose a risk to human health and the environment.
- Points of compliance – the location within the site where cleanup levels must be attained.
- Other regulatory requirements – requirements that apply to a site cleanup action because of the type of action and/or location of the site (i.e., ARARs).

A cleanup level is the concentration of a hazardous substance in soil, water, or air that is determined to be protective of human health and the environment under specified exposure conditions. In general, the cleanup levels and POCs were developed for the media which indicated unacceptable potential risk pathways identified in the risk assessments associated with the Cadet and SMC sites. The following sections summarize the development of cleanup levels and POCs. Potential additional regulatory requirements (i.e., ARARs) are discussed in Section 4.

5.1 Indicator Hazardous Substances

As specified in WAC 173-340-703, indicator hazardous substances may be selected for the purpose of defining cleanup requirements. COCs representing potential unacceptable baseline risks were selected as indicator hazardous substances for the specific source areas and the dispersed groundwater plume. As described in the respective RI reports and associated risk assessments, the majority of the historical risk within the Site can be attributed to PCE, TCE, and cis-1,2-DCE. The selection of a cleanup standard for human receptors will consider the applicable risk pathways (e.g., potable use of groundwater) and specific contaminants that remedial actions need to address. PCE, TCE and cis-1,2-DCE are the only compounds that have had recent concentrations exceeding cleanup levels in one or more wells across the site. Therefore, these compounds are considered the constituents of concern (COCs) at the site.

The cleanup levels for the COCs (PCE, TCE, and cis-1,2-DCE) are consistent with established MTCA procedures. MTCA specifies three methods (Methods A, B, and C) that can be used to develop cleanup standards for contaminated media. Method A, B, and C cleanup standards for impacted groundwater are addressed in WAC 173-340-720.

Method A cleanup levels can only be used at simple sites with few hazardous substances and “routine” cleanups (WAC 173-340-704). Method A cleanup levels must be at least as stringent as concentrations developed under state and federal law or the concentrations included in MTCA Table 720-1 (WAC 173-340-720(3)). Due to the complexity of this project, Method A cleanup levels are not applicable.

Method B can be used to establish cleanup levels at any site (WAC 173-340-705). Method B cleanup levels must be at least as strict as concentrations developed under state or federal law and are calculated using risk equations specified in WAC 173-340-720(4).

Method C cleanup levels are protective of human health and the environment, but are generally less restrictive than those developed using Methods A and B. Method C can be used to develop cleanup levels when the cleanup levels comply with applicable state and federal laws, all practicable treatment methods have been used, institutional controls are implemented, and Methods A and B result in cleanup levels that are below technically achievable concentrations or pose a greater overall threat to human health or the environment (WAC 173-340-706). Method C cleanup levels are calculated through the use of a risk assessment to define acceptable cleanup levels (WAC 173-340-720(5)).

The development of cleanup levels for each medium is addressed in the following sections, and where applicable, the justification for the use of MTCA Method A, B, or C is specified.

5.2 Soil

Soil cleanup standards were developed in accordance with WAC 173-340-745. As discussed in the risk assessment summaries for each site, the land use for the Cadet and SMC source areas meets the criteria for them to be categorized as industrial properties. Soil contamination within the source areas does not extend beyond any property boundaries. However, soil cleanup standards do need to protect the leaching to groundwater pathway. Therefore, soil cleanup standards were developed in accordance with MTCA Method B, . Soil cleanup standards have been developed to be protective of groundwater as drinking water and surface water; however, it is noted that when COCs in groundwater meet drinking water and surface water criteria at the specified POCs for these criteria, then the leaching to groundwater pathway is no longer considered complete.

5.2.1 Soil Cleanup Levels

Based on the protection of groundwater, MTCA Method B was deemed appropriate, and soil cleanup levels were developed in accordance with WAC 173-340-745. The following elements were considered during the development of soil cleanup levels:

- ARARs – No ARARs were identified for soils. Only cleanup levels are presented.
- Environmental Protection – No significant terrestrial habitat exists at either of the source areas – the only areas where it might be possible for shallow soil to have been impacted; therefore, development of cleanup levels for soil to protect wildlife is not necessary.
- Groundwater Protection – Potential cleanup levels to protect groundwater as a drinking water source are included in Table 5-1. All impacted groundwater zones are considered a drinking water source unless otherwise specified. The methodology for derivation of PCE and TCE cleanup levels (obtained from the Cleanup Levels and Risk Calculation [CLARC] database) is presented in Ecology CLARC guidance documents (Ecology 2012a, 2012b).
- Human Health Direct Contact – The potential cleanup levels included in Table 5-1 were obtained from the Ecology CLARC database for Method B.
- Human Health Soil Vapors – In accordance with WAC 173-340-745, if soil cleanup levels are selected to protect drinking water, the soil vapor pathway does not need to be further evaluated.

- Table 5-1 includes the soil cleanup levels screened for the Site. Table 5-2 includes the final soil cleanup levels for the Site.

5.2.2 Soil Point of Compliance

Per WAC 173-340-745(7) and -740(6)(b), the standard POC for soil cleanup levels protective of the groundwater pathway is throughout the site. However, as noted above, if COCs in groundwater meet groundwater cleanup levels, it is assumed that soil is also compliant.

5.3 Groundwater

Cleanup standards used to protect groundwater were developed in accordance with WAC 173-340-720. For groundwater, Method B was used to develop the groundwater cleanup levels. Method A was not selected because the sites have multiple hazardous substances. The Site does not qualify for use of Method C groundwater cleanup levels because it has not been demonstrated that the Method B levels are below background, will increase risk, or are below technically possible concentrations (WAC 173-340-706(1)(a)).

5.3.1 Groundwater Cleanup Levels

Under MTCA, the establishment of groundwater cleanup levels depends upon the classification of groundwater as either potable (a current or potential source of drinking water) or non-potable (WAC 173-340-700). Groundwater cleanup levels must be established based on the highest beneficial use of groundwater, assumed to be drinking water unless it can otherwise be demonstrated (WAC 173-340-720(1)(a)). Groundwater in the project area, including the Site, is classified as a drinking water resource and will likely continue to be classified as a drinking water resource in the future. Groundwater at the Site is therefore considered potable and includes all groundwater within the USA zone (i.e., shallow, intermediate, and deep zones). Groundwater has also been designated as a sole source aquifer by the EPA.

MTCA requires groundwater cleanup levels to be based on the reasonable maximum exposure expected to occur under both current and future site conditions. For potable groundwater, this means that the cleanup level must be set for COCs at concentrations that allow the water to be safely used as a source of drinking water. As identified in Section 5.1, PCE, TCE and cis-1,2-DCE are present at the Site at concentrations above the MTCA cleanup levels. In addition, groundwater cleanup levels must be established that are protective of other media including air, sediment, and surface water, as applicable.

- Groundwater Levels Protective of Air – In accordance with WAC 173-340-750(1)(a)(i), if groundwater cleanup levels are selected to protect use of groundwater as potable water, it is presumed that levels are adequate to protect the air pathway.
- Groundwater Levels Protective of Sediment – The current residual groundwater plume does not impact sediment.
- Groundwater Levels Protective of Surface Water – The current residual groundwater plume does not impact surface water.

Table 5-1 includes screening groundwater cleanup levels primarily obtained from the Ecology CLARC database associated with MTCA Method B levels. Table 5-2 includes the final groundwater cleanup levels selected for the Site. PCE and TCE, which are the primary contaminants in groundwater at the site and have been the driver of past interim action efforts and remedial action alternatives described in this FS, have cleanup levels of 5 ug/L and 4 ug/L, respectively.

5.3.2 Groundwater Point of Compliance

Per WAC 173-340-720(8)(b), the standard POC is throughout the Site and throughout the saturated zone. This POC shall correspond to the drinking water pathway cleanup level. For the purpose of this project, the saturated zone is defined as all groundwater beneath the Site within the USA zone (i.e., shallow, intermediate, and deep zones).

5.4 Air

Air cleanup standards were developed in accordance with WAC 173-340-750. An extensive indoor air evaluation was previously conducted on behalf of the Port for the residences in the FVN. The results of the evaluation were presented in the CAMP (Parametrix 2009a). As discussed in Section 2.2, residential indoor air issues in the project area have been completely addressed, and Ecology has determined that no further investigation or remedial actions are required. Therefore, air cleanup levels were developed in this FS for current or future industrial buildings only (primarily for the SMC source area).

5.4.1 Air Cleanup Levels

As specified above, air cleanup levels were developed for the industrial properties only. Method C (industrial) indoor air cleanup levels were selected from Ecology's CLARC database to assess the potential risk associated with indoor air in industrial buildings. Table 5-1 includes the screening indoor air cleanup levels developed for the Site. Table 5-2 includes the final air cleanup levels developed for the Site.

5.4.2 Air Point of Compliance

The standard POC for indoor air cleanup levels is throughout the sites, specifically in the interior of the buildings or future buildings, if any.

6. CLEANUP ACTION EVALUATION CRITERIA

Cleanup actions were evaluated and selected based on the requirements of WAC 173-340-360. The following summarizes these requirements.

- Threshold requirements:
  - Protect human health and the environment.
  - Comply with cleanup standards.
  - Comply with ARARs.
  - Provide for compliance monitoring.
- The selected cleanup action shall:
  - Use permanent solutions to the maximum extent practicable (see below).
  - Provide for a reasonable restoration timeframe (see below).
  - Consider public concerns.
  - Prevent or minimize present and future releases and migration of hazardous substances in the environment.
  - Not rely primarily on dilution and dispersion unless the incremental costs of any active remedial measures over the costs of dilution and dispersion grossly exceed the incremental degree of benefits of active remedial measures over the benefits of dilution and dispersion.
- For groundwater cleanup actions:
  - If practicable, a permanent cleanup action shall be used to achieve the cleanup levels for groundwater at the standard POC.
  - Where a permanent cleanup action is not practicable, the following measures shall be taken:
    - Conduct treatment or removal of the source.
    - To the maximum extent practicable, implement groundwater containment including barriers or hydraulic control through groundwater pumping, or both, to avoid lateral and vertical expansion of the groundwater volume affected by the hazardous substance.
    - Institutional controls shall be used if concentrations above Method A or B cleanup levels remain at the Site.

6.1 Use of Permanent Solutions

The selected cleanup action must use permanent solutions to the maximum extent practicable, as determined by the following disproportionate cost analysis. A disproportionate cost analysis is not required if a permanent solution is selected. A permanent solution is a cleanup action that achieves cleanup standards without further action being required, other than the approved disposal of residue from a treatment system (WAC 173-340-200).

The disproportionate cost analysis compares the costs and benefits of the cleanup action alternatives evaluated in the FS using the following process.

- Rank the potential alternatives from most to least permanent using the following criteria:
  - Protectiveness – Overall protectiveness of human health and the environment including the degree to which existing risks are reduced, time required to reduce risk at the facility and attain cleanup standards, on-site and off-site risks resulting from implementing the alternative, and improvement of the overall environmental quality.
  - Permanence – The degree to which the alternative permanently reduces the toxicity, mobility, or volume of hazardous substances including the adequacy of the alternative in destroying the hazardous substances, the reduction or elimination of hazardous substance releases and sources of releases, the degree of irreversibility of waste treatment process, and the characteristics and quantity of treatment residuals generated.
  - Cost – The cost to implement the alternative including the cost of construction, the net present value of any long-term costs, and agency oversight costs that are cost-recoverable. Long-term costs include operation and maintenance costs, monitoring costs, equipment replacement costs, and the cost of maintaining institutional controls. Cost estimates for treatment technologies shall describe pretreatment, analytical, labor, and waste management costs. The design life of the cleanup action shall be estimated, and the cost of replacement or repair of major elements shall be included in the cost estimate.
  - Long-Term Effectiveness – Long-term effectiveness includes the degree of certainty that the alternative will be successful, the reliability of the alternative during the period of time hazardous substances are expected to remain on site at concentrations that exceed cleanup levels, the magnitude of residual risk with the alternative in place, and the effectiveness of controls required to manage treatment residues or remaining wastes. The following types of cleanup action components may be used as a guide, in descending order, when assessing the relative degree of long-term effectiveness: reuse or recycling; destruction or detoxification; immobilization or solidification; on-site or off-site disposal in an engineered, lined and monitored facility; on-site isolation or containment with attendant engineering controls; and institutional controls and monitoring.
  - Management of Short-Term Risks – The risk to human health and the environment associated with the alternative during construction and implementation and the effectiveness of measures that will be taken to manage such risks.
  - Technical and Administrative Implementability – Ability to be implemented including consideration of whether the alternative is technically possible, availability of necessary off-site facilities, services and materials, administrative and regulatory requirements, scheduling, size, complexity, monitoring requirements, access for construction operations and monitoring, and integration with existing facility operations and other current or potential remedial actions.
  - Consideration of Public Concerns – Whether the community has concerns regarding the alternative, and if so, the extent to which the alternative addresses those concerns. This process includes concerns from individuals, community groups, local governments, tribes,

federal and state agencies, or any other organization that may have an interest in or knowledge of the site.

- The most permanent cleanup action alternative shall be the initial baseline cleanup action.
- Compare the next most permanent cleanup action alternative to the baseline cleanup alternative. The alternative whose costs are disproportionate to the benefits shall be eliminated. Costs are disproportionate to benefits if the incremental costs of the alternative over that of a lower-cost alternative exceed the incremental degree of benefits achieved by the alternative over that of the other lower-cost alternative. The comparison of benefits and costs may be quantitative but will often be qualitative and require the use of best professional judgment.
- Repeat until only one alternative remains.

6.2 Determination of Reasonable Restoration Timeframe

To determine whether a cleanup action provides for a reasonable restoration timeframe, the following factors were considered:

- Potential risks to human health and the environment.
- Practicability of achieving a shorter restoration timeframe.
- Current and potential future uses of the site, surrounding areas, and associated resources that are or may 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.

When area background concentrations would result in recontamination of the site to levels that exceed cleanup levels, that portion of the cleanup action which addresses cleanup below area background concentrations may be delayed until the off-site sources of hazardous substances are controlled. In that case, the remedial action shall be considered an interim action until cleanup levels are attained.

6.3 Qualitative Factors Considered in Evaluating Cleanup Actions

In evaluating potential cleanup actions, the following factors from WAC 173-340-370 were considered:

- Treatment technologies should 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.

- For sites with small volumes of hazardous substances, hazardous substances should be destroyed, detoxified, and/or removed to concentrations below cleanup levels throughout the site.
- For portions of sites that contain large volumes of materials with relatively low levels of hazardous substances where treatment is impracticable, engineering controls – such as containment – may be needed.
- Active measures should be taken to prevent precipitation and runoff from coming into contact with contaminated soils and waste materials.
- When hazardous substances remain on site at concentrations that exceed cleanup levels, those hazardous substances should be consolidated to the maximum extent practicable.
- For facilities adjacent to a surface water body, active measures should be taken to prevent/minimize releases to surface water via surface runoff and groundwater discharges in excess of cleanup levels. Dilution should not be the sole method for demonstrating compliance with cleanup standards in these instances.
- Natural attenuation of hazardous substances may be appropriate at sites where:
    - Source control (including removal and/or treatment of hazardous substances) has been conducted to the maximum extent practicable.
    - Leaving contaminants on site during the restoration timeframe does not pose an unacceptable threat to human health or the environment.
    - There is evidence that natural biodegradation or chemical degradation is occurring and will continue to occur at a reasonable rate at the site.
    - Appropriate monitoring requirements are conducted to ensure that the natural attenuation process is taking place and that human health and the environment are protected.

6.4 Environmental Justice Considerations

The following provides a summary of how environmental justice was incorporated as a pilot project into this FS and remedial alternatives evaluation. A detailed summary of the environmental justice procedures, evaluation, and community outreach is included in Appendix E.

6.4.1 Background

The Washington State Department of Ecology is updating the Model Toxics Control Act (MTCA) Cleanup Rule and proposing the incorporation of environmental justice (EJ) into remedy selection as part of the feasibility study process. The updates to the rule will be completed in three rulemakings over several years and is not expected to be formalized for some time. In addition, the State of Washington enacted the Healthy Environment for All (HEAL) Act, E2SSB 5141, imposing obligations on state agencies, including Ecology, to incorporate environmental justice in the administration of environmental programs. Based on this information, the port determined that it would consider EJ in the remedy selection process for this FS, before the implementation date for the HEAL Act and prior to the completion of Ecology's MTCA rulemaking and updated guidance.

Ecology issued a memorandum that outlines the general process for the rule change as a result of numerous Ecology discussions and forums (Ecology 2020). While the memorandum only includes general concepts and the methodology and implementation is likely to be modified in future policy, the Port reviewed the draft approach and concluded that the following environmental justice concepts outlined in the memorandum could be incorporated into remedy selection during this FS through the following means:

- Identify cleanup goals – Use the remedial investigation to identify cleanup standards and other goals for the cleanup action including reducing disparate impacts.
- Evaluate alternatives – Consider public concerns and highly impacted communities in the evaluation.
- Disproportionate Cost Analysis – Add a new criterion to the analysis: Reduce Disparate Impacts.

The Port and Parametrix met with Ecology on several occasions to discuss the proposed approach to environmental justice on the FS. Ecology indicated general agreement with the approach but indicated that, since there is no current requirement for environmental justice considerations, Ecology would not provide formal approval of the approach or results of the evaluation in the FS. The Port included environmental justice considerations in this FS as a pilot project that could inform Ecology and future PRPs as they work through cleanup projects and the pending regulatory policy.

6.4.2 Previous Cleanup Actions

As noted throughout this FS, previous cleanup actions at the site have reduced the extent of TCE and PCE in groundwater exceeding MTCA cleanup levels to a relatively small area near SMC (see Figures 2-8 and 2-11). As such, the focus of this FS was slightly altered from conventional practice to evaluate whether the existing GPTIA could be shut down rather than to evaluate numerous cleanup actions going forward (see Section 8). The source area was evaluated more conventionally for various remedial options (see Section 7).

As noted in the Ecology draft memorandum, environmental justice considerations should be included early in the remedial investigation stage to establish cleanup goals based on potential disparate impacts. As noted previously, the RI was previously approved by Ecology and numerous cleanup actions have been completed, or in the case of the GPTIA are ongoing, for the SMC and Cadet sites. Therefore, the focus of the current environmental justice evaluation is on the FS and potential impacts and selection of a remedial alternative(s) for final cleanup that include consideration of potential disparate impacts.

6.4.3 Evaluation of Highly Impacted Communities

One of the primary considerations in the environmental justice analysis is to determine whether the nearby community is considered a highly impacted community. Ecology defines a “highly impacted community” as likely to bear a disproportionate burden of public health risks from environmental pollution, such as minority, low-income, tribal or indigenous populations.

The Fruit Valley Neighborhood (both the NFVN and SFVN) is located near the SMC and Cadet sites (Figure 1-2). The first step of the environmental justice evaluation was to determine whether the FVN met Ecology’s definition of a highly impacted community. As discussed in the memo included in Appendix E, the EPA’s Environmental Justice Screening and Mapping tool (EJSCREEN) was utilized to obtain demographic and environmental information for the FVN. The tool provides users with a nationally consistent dataset and approach for combining environmental and demographic indicators into an "EJ Index." The EJ Index is a multi-criteria assessment based on a combination of 11 environmental indicators, such as exposure to wastewater discharge, hazardous waste proximity, and particulate matter (PM 2.5), and six demographic indicators, such as concentrations of people of color, low-income people, and linguistically isolated populations.

This tool was used to measure the presence of EJ populations and environmental exposures within the Fruit Valley Neighborhood compared to the City of Vancouver as a whole. The tool measures these differences using percentiles and also allows for comparisons between local geographies (such as the Fruit Valley Neighborhood and City of Vancouver) and state, regional, and national percentiles. For the purposes of this analysis, EJ populations and environmental exposures for the Fruit Valley Neighborhood and City of Vancouver were only compared to each other, to the region, and to the State of Washington as a whole.

The result of the EJSCREEN analysis indicated that the FVN exceeded the 75th percentile for all environmental justice indexes compared to the state and region. These findings indicate a substantial population within the FVN with higher-than-average exposure to environmental hazards (i.e., a disproportionately impacted community). Therefore, environmental justice for the FVN is considered in the FS analysis of remedial action alternatives to determine whether the actions potentially have a disproportionate impact (see Section 6.4.5).

6.4.4 Public Engagement

Based on the findings of the EJSCREEN analysis and consistent with the Port's general outreach and engagement efforts, the Port determined that the FVN should be informed of the overall cleanup progress, the FS process, and how a final remedy option will be determined. The outreach effort is detailed in Appendix E, and included a web page update, news release, online survey, and mailed postcard. The results of the community outreach are considered in the evaluation and scoring of remedial options for both the source area (Section 7) and dispersed groundwater plume (Section 8).

6.4.5 Assessment Approach and Results Incorporating EJ Findings into the FS

After completion of the EJSCREEN analysis and public engagement efforts, the results were utilized in the evaluation and scoring of all remedial alternatives. As specified in MTCA rules and discussed in Section 6.1, the disproportionate cost analysis required for evaluation of remedial alternatives has six selection criteria (see Tables 7-3 and 8-2). As proposed in the Ecology draft memorandum on environmental justice considerations, a seventh criterion (Reduce Disparate Impacts) was added to the disproportionate cost analysis to ensure that environmental justice was properly evaluated for each of the alternatives.

The Reduce Disparate Impacts criteria is intended to evaluate the remedial alternative on how it reduces, eliminates, or limits potential impacts to a particular community, and primarily includes environmental exposures such as drinking water, air emissions, contaminated soil contact, and other routes of exposure or impacts. The addition of this criteria allows for environmental justice to be a component of the remedial alternative selection with equal (and not disproportionate) weighting of the other six criteria. The relative scoring for each remedial alternative is included in Tables 7-3 and 8-2. Discussion of the environmental justice implications for each remedial alternative and basis for the associated scoring is included in Sections 7.3.3.7 and 8.5.7, respectively, for the source area and dispersed residual groundwater remedial alternatives evaluations.

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7. SMC SOURCE AREA FEASIBILITY EVALUATION

This section provides a summary of the SMC source area feasibility evaluation and selection of a preferred remedy. As summarized in Section 2.2, interim actions conducted at the Cadet site have been successful in reducing source area concentrations to near or below MTCA cleanup levels (see Figures 2-6, 2-7, and 2-8). Therefore, no additional remedial actions are required to achieve cleanup levels, and additional remedies are not being evaluated in this FS for the Cadet site source area. The following sections focus only on the SMC source area and evaluation of remedial actions to address residual contamination in that area. The FS evaluation for the dispersed residual groundwater contamination is presented in Section 8.

7.1 Extent of Impacted Media

A summary of the soil and groundwater contamination in the SMC source area is provided in the following sections. An extensive discussion of the source area is provided in the SMC RI report (Parametrix 2009b) including the past release mechanisms, fate and transport, interim actions conducted, extent of contamination through time, and site-specific geology. The FS assessment is completed using 2020 and projected future contaminant concentrations in the source area.

7.1.1 Soil

The SMC source area is southwest of the Mill Plain, St. Francis Lane, and Fourth Plain Boulevard intersection. As discussed in the SMC RI report, TCE-impacted soil (maximum concentration of 17,000 µg/kg in the vadose zone) was previously detected in the vicinity of the SMC site. The TCE-impacted soil was the primary source material for impacting groundwater at the SMC site. Therefore, in 1998 the Port completed an interim action to remove the source material. Approximately 13,800 cubic yards of TCE-impacted soil were excavated and treated using enhanced SVE. The excavation was completed to a depth of approximately 17 feet bgs, where it was terminated due to encountering groundwater. Confirmation sampling indicated that limited impacts at the soil/water interface remained after the excavation activities.

Evaluation of all data in the source area, including pre-excavation data and confirmation samples, indicates that soil samples with TCE exceeding the MTCA Method C soil cleanup level (1,800 mg/kg) were collected from the soil/water interface or below. In addition, all samples with detectable concentrations of TCE were collected at depths greater than 15 feet bgs, which is below the standard depth used for excavation/utility workers in a risk evaluation. These factors indicate little or no risk is associated with TCE above the soil/water interface at the site. Several soil samples collected below the water table contained elevated concentrations of TCE. These soil samples were saturated with contaminated groundwater, and therefore, the concentrations detected are likely representative of groundwater conditions rather than soil. Further reference to the SMC “source area” should be associated with the saturated zone including TCE bound within the fine-grained sand layer. Therefore, this FS focuses on remedial alternatives that may be appropriate for the removal of the TCE in the fine-grained sand layer from a groundwater remedy perspective. Figure 7-1 shows the estimated extent of “soil” contamination in the source area, as well as the extent of elevated groundwater concentrations. Figures 7-2 and 7-3 show the source area TCE and PCE concentrations from the 2020 groundwater monitoring events (see Section 7.1.2 below).

The thickness of the fine-grained sand layer ranges from approximately 3 feet to 12 feet thick. The depth to the top of the fine-grained sand layer ranges from 12 feet bgs (15 feet National Geodetic Vertical Datum [NGVD]) to 20 feet bgs (5 feet NGVD). The bottom of the fine-grained sand layer is relatively consistent at approximately 23 feet bgs (3 feet NGVD). The historical high-water elevation is approximately 8.6 feet NGVD, which suggests that most of the fine-grained sand layer is saturated throughout most of the year. Figure 7-4 shows a cross section of the fine-grained sand layer, which is the primary source area.

7.1.2 Groundwater

Figures 7-2 and 7-3 show the 2020 extent of the SMC source area contamination (as of December 2020). In general, the source area groundwater is represented by monitoring wells IMW-05, MW-05, VMW-08, VMW-09, VMW-10, and VMW-11. Based on the data collected from these wells, as well as the project area monitoring well network, the source area is confined to an area encompassing approximately 30 feet by 75 feet. This extent is estimated using areas where 2020 TCE concentrations exceed 25 µg/L (see Figure 7-2). TCE is used to evaluate the extent of VOC contamination as TCE concentrations are typically an order of magnitude higher than PCE and 1,2-DCE concentrations. In general, the source area extent is located beneath a gravel lot just to the east of the well house and extends east to Mill Plain Boulevard. It is generally confined to the SMC property, with some extension beneath the Mill Plain Boulevard right of way (see Figure 7-2).

Since operation of the GPTIA began in June 2009, the source area extent and concentrations have decreased significantly. Thus, the total mass available in the source area to migrate to the intermediate zone has been reduced. The remaining contamination within the source area appears to be primarily bound within the fine-grained sand layer, which is located between approximately 12 and 25 feet bgs. The tighter-grained material has slowed the cleanup of the shallow source area relative to the layers immediately below the fine-grained sand layer.

Six wells are located within the footprint of the SMC source area, including IMW-05, MW-05, VMW-08, VMW-09, VMW-10, and VMW-11 (see Figure 7-2). Over the past 2 years, TCE concentrations in three wells (IMW-05, VMW-10, and VMW-11) have generally remained below 70 µg/L. In August 2020, TCE was detected at concentrations of 10.6 µg/L, 67.6 µg/L, and 19.2 µg/L, respectively, in these three wells. TCE concentrations detected in VMW-08 have generally been below 300 µg/L, and TCE concentrations in well VMW-09 have recently ranged between 325 µg/L and 559 µg/L. In August 2020, TCE concentrations in these two wells were 252 µg/L and 559 µg/L, respectively (see Figure 7-2).

Historically, the highest concentrations of TCE in the source area have been detected in monitoring well MW-5 and have decreased significantly from a high of 21,000 µg/L (December 2009) to 216 µg/L (August 2020) during operation of the GPTIA (see Figure 7-5). Data from monitoring well MW-5 show how the contaminant plume in the source area was cleaned up over time. In June 2009, prior to operation of the GPTIA, monitoring well MW-5 had a TCE concentration of 2,700 µg/L. Once the GPTIA was operational, the TCE concentration in monitoring well MW-5 increased to a high of 21,000 µg/L in December 2009. This significant concentration increase was the result of contaminants being mobilized from the source area and flowing to extraction well EW-1. Monitoring well MW-5 is located approximately 27 feet from EW-1, between the main source area and the extraction well.

7.2 Technology Evaluation and Cleanup Action Alternative Development

This section describes the development of the cleanup action alternatives to be evaluated. The alternative development process includes identifying general response actions and corresponding technologies, screening technologies to eliminate those that are clearly not feasible and assembling remaining technologies into a list of cleanup action alternatives. In order to evaluate feasible technologies, the following RAOs have been established for the SMC source area:

- Achieve the cleanup standards for COCs.
- Protect human health and the environment.
- Use permanent solutions to the maximum extent practicable (which includes consideration of cost-effectiveness).
- Contain the source area plume from further dispersion.

The following sections provide the rationale for technology screening and the selection of remedial alternatives.

7.2.1 Technology Screening

EPA technology screening guidance provides an assessment of general classes of technologies classified by medium and type of treatment. The guidance is relatively comprehensive and was used to identify potential technologies for the SMC source area. The general technologies identified for the SMC source area include:

- Institutional controls
- Engineering controls
- Containment
- Removal/discharge
- Ex situ biological or physical/chemical treatment (used for treatment of extracted groundwater)
- In situ biological treatment or physical/chemical treatment

The specific technologies for soil and groundwater are presented on Table 7-1 and Table 7-2, respectively. For the first screening step, technologies that are not applicable to the medium of concern or the goals of the cleanup were eliminated. As discussed previously, the SMC source area is relatively complex in nature and includes soil and groundwater impacts. However, the majority of contamination remaining is bounded within a distinct and thin soil layer (i.e., the fine-grained sand layer). Based on the mean groundwater elevation, most of the fine-grained sand layer is saturated throughout most of the year. Contaminants in the vadose zone above the fine-grained sand layer were removed during a previous remedial excavation; thus, there are no significant vadose zone impacts in the source area. Therefore, the SMC source area is generally considered to be a groundwater contamination issue, and as such, soil remedies without a groundwater component were generally eliminated (the lone exception being direct excavation of source material at depth).

For the technologies identified, three criteria (effectiveness, implementability, and cost) were used to provide an initial screen (see Tables 7-1 and 7-2). After this initial screening, the specific technologies that were retained as potential alternatives are as follows:

- Groundwater use restrictions (Institutional controls)
- Monitoring (Institutional controls)
- Control of building heating, ventilation, and cooling system (Engineering controls)
- Vapor barriers (Engineering controls)
- Sub-slab depressurization or sub-floor venting (Engineering controls)
- Excavation of contaminated soil (Removal)
- Pumping/hydraulic containment (Containment)
- Pumping/pump and treat (Removal/discharge)
- Discharge to sewer/surface water (Removal/discharge)
- Discharge to reinjection wells (Removal/discharge)
- Source removal/excavation (Removal/discharge)
- Adsorption (Ex situ physical/chemical)
- Air stripping (Ex situ physical/chemical)
- Enhanced bioremediation (In situ biological)
- Aeration/air sparging (Ex situ physical/chemical)
- Injection of chemical oxidant (In situ physical/chemical)
- MNA (In situ physical/chemical)

These potential technologies were further evaluated based on site-specific conditions to develop a set of remedial alternatives that could be applied to the SMC source area. As applicable, some technologies could be combined with others for a specific remedial alternative. The development of the alternatives and site-specific conditions is summarized in the following section.

7.2.2 Development of Cleanup Action Alternatives

The identified technologies were further screened to select those that are suitable for the site conditions and COCs, as well as to determine whether the action uses permanent solutions to the maximum extent practicable. The technologies that pass this screening were assembled into remedial alternatives that will be evaluated for use at the site. Remedial alternatives were developed based on the nature and extent of contamination, potential future use of the site, technological feasibility, and engineering/logistical considerations. The following are the site-specific conditions that serve as screening criteria to determine relevant technologies from the list in Section 7.2.1 above:

- Medium – shallow groundwater flowing through a fine-grained sand layer (20 to 25 feet deep)
- Contaminants – dissolved-phase VOCs (primarily TCE and PCE)

- Site usage – light and heavy industrial usage with heavy traffic

As a result of these considerations, the potential remedial alternatives evaluated for groundwater were generally limited to the physical removal, treatment, and discharge of contaminated material or in situ treatment. Because soil in the vadose zone is generally not impacted, applicable technologies for soil were eliminated, except for removal of the source area material (in the saturated fine-grained sand layer). The saturated soil that contains most of remaining site contaminants would require in situ treatment. Engineering controls were not considered for any remedial alternatives at this time, as no building is located on the site. However, engineering controls were retained as a standby technology in the event of future property development (see Section 7.3.1). Institutional controls were considered for all options and are generally included as a viable technology for all the assembled alternatives. Enhanced bioremediation was not considered as a final alternative, as site conditions are not conducive to the decomposition of TCE and PCE. However, in situ chemical oxidation was considered.

After consideration of the nature and extent of contamination in the SMC source area, potential future use of the site, technological feasibility, and engineering/logistical considerations, the remedial alternatives were reduced to the following four for evaluation in this FS:

Alternative A – Institutional Controls and MNA

Alternative B – Remedial Excavation/Soil Mixing of Source Area

Alternative C – Air Sparging and Soil Vapor Extraction

Alternative D – In Situ Substrate Injection (Chemical Oxidation)

7.3 Screening and Evaluation of Cleanup Action Alternatives

Detailed descriptions of the alternatives and evaluation against MTCA criteria are discussed in the following sections.

7.3.1 Discussion of Common and Standby Technologies

As discussed previously, several of the retained technologies are potentially applicable to each cleanup strategy that may be selected and would be incorporated as appropriate into each of the cleanup action alternatives. Common and standby technologies area summarized below.

7.3.1.1 Common Technologies

The technologies that are common to all alternatives include:

- Contaminated media management plan – A contaminated media management plan would be prepared to ensure proper controls are implemented during future site activities. Protocols would be established for the handling and management of soil and shallow groundwater during future site work to protect workers, public health, and the environment.
- Groundwater use restriction – In accordance with WAC 173-340-440(4)(a), groundwater restrictions are required until the cleanup levels are achieved. Therefore, it is expected that some form of institutional controls (e.g., restrictive covenant, media management plan, or

equivalent) will be placed on the SMC site. Restriction of site use and groundwater usage at the site would be effective at preventing exposure to COCs.

- Monitoring – Monitoring includes the sampling and laboratory analysis of various media to assess current risks and evaluate the effectiveness of implemented cleanup actions. The site and project area have an extensive groundwater monitoring well network, which is expected to be used during and post remedial actions.
- Monitored natural attenuation – MNA involves using natural processes to reduce COC levels to acceptable concentrations. These processes include natural biodegradation, dispersion, dilution, sorption, volatilization, and chemical and biological stabilization, transformation, or destruction of hazardous substances (WAC 173-340-200). Monitoring is used to verify that these processes are actively reducing hazardous substance concentrations. An extensive monitoring well network is in place at the Site. MNA is one of the primary components evaluated and is expected to be used as part of the residual groundwater plume remedial efforts (see Section 8). In the context of the SMC source area, MNA is specifically included as part of Alternative A (see Section 7.3.2) and is coordinated with alternatives for the overall residual groundwater plume.

7.3.1.2 Standby Technologies

The site currently is not developed, and with the exception of the building associated with the groundwater extraction well and equipment, no buildings are located on the property. In the event of future site development, standby technologies could be employed for a building as part of construction requirements. The standby technologies are primarily to mitigate potential vapor intrusion into a future building resulting from contaminated groundwater and could include vapor barriers, venting, or similar technologies. An evaluation of the necessity and appropriate technologies would be conducted as part of building development options. This technology employed as part of a potential future development is included as an engineering control and is specifically added to Alternative A.

7.3.2 Evaluation of Cleanup Action Alternatives for the Source Area

MTCA established minimum requirements and procedures for selecting cleanup actions in WAC 173-340-360. MTCA requires that all cleanup actions meet the threshold requirements that are part of the minimum requirements. Any alternatives that do not meet the threshold requirements are dropped from further consideration. This section uses the threshold requirement to screen the initial list of alternatives developed. Under MTCA, remediation alternatives must meet the following threshold requirements ((WAC 173-340-360(2)(a)):

- Protection of human health and the environment
- Compliance with cleanup standards
- Compliance with ARARs
- Provision for compliance monitoring

Each alternative is evaluated individually against the threshold. Alternatives that do not meet the threshold requirements are not carried forward to the evaluation of other requirements (WAC 173-340-360(2)(b)). The other requirements were defined in Section 6 and include:

- Use of permanent solutions
- Reasonable restoration timeframe
- Consideration of public concerns
- Prevent or minimize releases and migration of hazardous substances in the environment
- Degree to which cleanup action relies on dilution/dispersion

The following sections evaluate each of the alternatives against the threshold requirements and other criteria.

7.3.2.1 Alternative A – Institutional Controls, Engineering Controls (Future) and Sitewide Monitored Natural Attenuation

Alternative A is primarily made up of controls to limit or eliminate potential exposure pathways. There are no current complete exposure pathways from the source area contaminants. However, as described in Section 2.3.6.6, the potential or reasonably likely future exposure pathways for the source area are:

- Site worker exposure to groundwater via drinking water (from a well installed on or near the SMC site)
- Construction worker exposure to soil via construction or excavation
- Site worker exposure to indoor air via vapor intrusion to an overlying building

All of these potential exposure pathways can be limited by the use of institutional or engineering controls.

Institutional controls would be placed on the site in the form of restrictive covenants to prevent potential exposure. Potential site worker exposure to groundwater via drinking water would be managed by implementing a restrictive covenant for drinking water wells on the SMC site. Since operation of the GPTIA began in 2009, the footprint of the shallow groundwater zone contamination exceeding MTCA cleanup levels has been significantly reduced and is now generally confined within the SMC site and slightly to the east. As shown on Figure 7-2, the impacted groundwater zone based on 2020 data is located in the northeast corner of the property and encompasses an area of approximately 70 by 100 feet. A small exceedance of the MTCA cleanup level is present slightly off of the SMC property beneath W. Mill Plain Boulevard. The placement of a restrictive covenant for drinking water on the SMC site would eliminate that potential pathway. In addition, drinking water wells could not be placed within the Mill Plain Boulevard right of way. A restrictive covenant would not be placed on any of the adjacent private property. However, all drinking water within the area is supplied by the City of Vancouver from production wells located outside the project area, and the potential for drinking water wells to be placed within the FVN or other areas near the site *and* targeting shallow groundwater is extremely low or negligible. Based on these considerations, the placement of a restrictive covenant on the Port-owned SMC property would effectively eliminate the drinking water exposure route as a complete pathway.

Based on the elevated groundwater concentrations of VOCs (TCE and PCE) remaining in the source area, vapor intrusion to indoor air of an overlying building is a potential future complete exposure pathway (no current occupied building exists). A restrictive covenant for future use of the site would be established. The site is currently zoned and used for industrial purposes. This land use will be maintained; no residential development will be allowed. However, future development of the site could include office space or other occupied building use. In the event of future building development, potential site worker exposure to indoor air via vapor intrusion could be managed by evaluating if vapor intrusion is an issue at that time, potential engineering controls or other mitigation plans for occupied buildings on the property. This could be in the form of a vapor barrier, passive venting systems beneath the building foundation, or building heating, ventilation, and cooling controls such as maintaining internal positive pressure or other similar technologies. Building design and use can also be considered to avoid vapor intrusion (e.g., location of parking structures versus occupied area). The requirement for evaluation of engineering controls on a future building would be included as part of the restrictive covenant. Based on these considerations, the placement of a restrictive covenant on the Port-owned SMC property and future design considerations and evaluation requirements would effectively limit the vapor intrusion exposure route as a complete pathway.

As shown on Figure 7-1 and 7-2, residual soil and groundwater contamination in the source area is present at elevated levels. There is no current exposure route to site workers. However, in the event of construction or utility work with deep excavations there is some potential for construction worker exposure to subsurface contaminated media. This potentially complete exposure pathway could be managed through the preparation of pre-construction documents and health and safety plans. A contaminated media management plan would be prepared for the site to guide future construction activities, if any. The contaminated media management plan would include health and safety protocols and measures and requirements for soil and/or groundwater encountered during construction. The requirement for health and safety measures during construction would effectively limit the construction worker exposure route as a complete pathway.

MNA uses natural processes to reduce COC levels to acceptable concentrations. These processes include natural biodegradation, dispersion, dilution, sorption, volatilization, and chemical and biological stabilization, transformation, or destruction of hazardous substances. Monitoring is used to verify that these processes are actively reducing hazardous substance concentrations. This alternative would use the sitewide MNA approach (see Section 8) to reduce the residual groundwater concentrations throughout the site, including the SMC source area. Focused monitoring of the SMC source area would be incorporated into the overall Site compliance monitoring plan to ensure that the compliance objectives are being met and contingency measures could be employed, as needed.

Costs associated with Alternative A include the preparation and filing of restrictive covenants, contaminated media management plan, engineering control plans and design documents (future, if needed), and ongoing compliance monitoring. Compliance monitoring for the SMC source area includes monitoring for approximately 20 years. Sitewide compliance monitoring is not included in the specific costs for this alternative, but it is included for the alternatives discussed in Section 8. Based on contaminant data trends, site-wide compliance monitoring for the intermediate and deep zones are likely to indicate cleanup goals will be achieved much sooner than 20 years, but compliance monitoring will remain in-place until the SMC source area wells meet all cleanup requirements. The associated costs for Alternative A are approximately $120,000 and more cost details are included in Appendix C.

Threshold Criteria

An evaluation of the institutional controls and MNA alternative indicates that it meets the threshold requirements, as summarized below:

- This alternative protects human health and the environment from the source area COCs via limiting or eliminating potential exposure. With the exception of a small aera to the east under W. Mill Plain Boulevard, source area contaminants above the applicable MTCA cleanup levels in the shallow zone do not extend beyond the boundaries of the former SMC site and outside of Port property and control. Therefore, actions or restrictions can be placed on the site by the Port to eliminate or manage the exposure pathway. In addition, the area under the adjacent roadway can be managed through notification procedures developed through agreements with the City of Vancouver, as applicable.
- The alternative complies with the MTCA cleanup standards in the source area. It relies on MNA (incorporated as the sitewide remedial alternative) to achieve long-term compliance with MTCA cleanup standards on a sitewide basis.

Use of Permanent Solutions

This alternative meets the requirement for a permanent solution with respect to eliminating exposure pathways. Institutional controls will remain in place until cleanup levels are reached, as needed.

Reasonable Restoration Timeframe

Institutional controls and MNA alone (for the source area) may not meet the requirement for a reasonable restoration timeframe. It is expected that source area reduction to MTCA cleanup levels could take approximately 20 years at present rates of decrease. However, the elimination of all potential complete exposure pathways can be completed in the near term through the implementation of a restrictive covenant that restricts groundwater use and provides for potential engineering controls in the event that an occupied building is planned for the property.

Consideration of Public Concerns

The proposed action would be submitted for public comment, and concerns raised would be addressed prior to design and implementation. It is anticipated that potential concerns of the public could be addressed as appropriate. It is not expected that public concerns that would prevent the implementation of this alternative would be received or could not otherwise be rectified. It is anticipated that potential concerns of the public would be similar among the alternatives. However, Alternative A leaves contamination in place for a significantly longer time, which is anticipated to have low to moderate public concern.

Public engagement and potential concerns related to the environmental justice evaluation are included in the disproportionate cost analysis in Section 7.3.3.7.

Prevent or Minimize Releases and Migration of Hazardous Substances in the Environment

This alternative relies on institutional controls to eliminate any potential complete exposure pathways. It is not effective at preventing or minimizing releases of hazardous substances.

Degree to Which Cleanup Action Relies on Dilution/Dispersion

This alternative relies on dilution and dispersion as part of the dispersed residual groundwater contamination remedy for the site (MNA).

7.3.2.2 Alternative B – Remedial Excavation of Source Area

This alternative primarily includes excavation and off-site disposal of impacted source area material. As discussed previously, remaining contaminants are concentrated in the fine-grained sand layer within the source area, and the contaminants continue to slowly migrate from this layer to shallow groundwater. The fine-grained sand layer is generally saturated most of the year. It is expected that much of the contaminants reside in the pore space of the soil particles and is slowly leaching to shallow groundwater.

While excavation is primarily a vadose zone soil remedial action, the relatively shallow depth and the unique complexity of this site lend themselves to consider a removal action for saturated material. Based on an evaluation of site data, the removal action area is approximately 70 feet by 100 feet and would extend to a depth of 27 feet bgs. This yields an approximate excavation volume of 7,000 cubic yards. A conceptual design of the removal action area is presented in Appendix C.

The top 17 feet is considered overburden material and is expected to be free of any contamination. Much of the overburden is clean fill (about 4,500 cubic yards) that was placed during the remedial excavation in 1998. The former excavation was terminated at approximately 17 feet bgs due to the presence of groundwater. This alternative would primarily target the 10 feet of material underlying the previous excavation; these 10 feet include the fine-grained sand layer. Due to the expected presence of groundwater at less than 20 feet bgs, this alternative would require significant shoring and dewatering. Extracted groundwater from the dewatering would be required to be treated prior to discharge to a sanitary sewer or other method of disposal.

Based on the conceptual design, approximately 2,500 cubic yards of excavated contaminated soil (saturated) would be placed into lined trucks and transported to a permitted municipal landfill (Subtitle D) for disposal under an approved permit. Confirmation sampling would be conducted in accordance with an Ecology-approved sampling and analysis plan and quality assurance project plan.

The excavation would be backfilled with a combination of imported clean fill and the stockpiled clean overburden material. The conceptual design of the alternative and estimated costs are included in Appendix C. The estimated costs are approximately $900,000. Remedial action compliance monitoring specifically for the source area is estimated for up to 5 years at a cost of $25,000. Monitoring costs do not include the comprehensive sitewide compliance monitoring, which is discussed in Section 8.

Threshold Criteria

An evaluation of the source area remedial excavation alternative indicates that it meets the threshold requirements, as summarized below:

- This alternative protects human health and the environment by directly removing COCs from the source area. The excavated soil would be placed in a permitted landfill and groundwater (dewatering) would be treated and discharged.
- This alternative complies with the MTCA cleanup standards by removing COCs from the source area.
- Numerical standard ARARs were incorporated into the cleanup level determination.

- This alternative provides for compliance monitoring, both in terms of performance monitoring during the excavation and conformation monitoring to monitor the long-term effectiveness of the remedy.

Use of Permanent Solutions

This alternative removes contaminated soil (largely saturated) through excavation and off-site landfill disposal. Therefore, it meets the requirement for a permanent solution.

Reasonable Restoration Timeframe

Due to the direct removal of contaminants, it is expected that the timeframe for cleanup would be relatively short. However, residual concentrations could remain outside the removal action area and in nearby groundwater monitoring wells. This would be addressed through continued monitoring of the area and a sitewide compliance monitoring plan and contingency plan.

Consideration of Public Concerns

The proposed action would be submitted for public comment, and concerns raised would be addressed prior to design and implementation. It is anticipated that potential concerns of the public could be addressed as appropriate. It is not expected that public concerns that would prevent the implementation of this alternative would be received or could not otherwise be rectified. It is anticipated that potential concerns of the public would be similar among the alternatives.

Public engagement and potential concerns related to the environmental justice evaluation are included in the disproportionate cost analysis in Section 7.3.3.7.

Prevent or Minimize Releases and Migration of Hazardous Substances in the Environment

This alternative provides for removal of the most impacted saturated soil; thus, it is effective at preventing or minimizing releases of hazardous substances.

Degree to Which Cleanup Action Relies on Dilution/Dispersion

Direct removal of the source area contamination does not rely on dispersion or dilution. However, dilution and dispersion are part of the dispersed residual groundwater contamination remedy for the Site (MNA).

7.3.2.3 Alternative C – Air Sparging and Soil Vapor Extraction System

This alternative includes the construction of an AS/SVE system in the source area and primarily targets the fine-grained sand layer. The AS/SVE system includes the injection of air into the groundwater to volatilize contaminants. The volatilized contaminants in the air phase rise into the vadose zone where they are captured by the SVE wells under a vacuum influence. As necessary, the volatilized contaminants are then adsorbed using a granulated activated carbon canister prior to ventilation to the atmosphere. Given ideal conditions, a typical timeframe for remediation of groundwater contaminants to below levels of concern is 2 to 4 years.

Based on the extent and depth of source area contamination (target area), the preliminary conceptual design indicates eight AS wells would be adequate to treat the SMC source area. The AS wells would be installed to the bottom of the fine-grained sand layer (approximately 25 feet bgs) with a 0.5-foot well screen at the bottom (groundwater is approximately 20 feet bgs). Seven to 10 SVE wells would be installed around the AS wells to capture soil vapors in the vadose zone. The SVE wells would be drilled to approximately 15 to 20 feet bgs, with a 10-foot well screen. A conceptual design is included in Appendix C.

The AS wells would be connected via a hose or piping to an air blower and the SVE wells connected via 2-inch PVC piping to a vacuum unit. A small equipment shed would likely be required to house the blower, vacuum, electrical unit, sound insulation, and other equipment. As necessary, the air collected by the vacuum would be discharged through a granulated activated carbon canister for treatment, prior to the air stream ventilation to the atmosphere.

Due to the complexity of the fine-grained sand layer in the source area, installation of an AS/SVE system would be extremely difficult and potentially problematic. A design study would be required to evaluate the precise geology of the fine-grained sand layer and to determine placement of AS wells effectively. The relatively thin fine-grained sand layer would make it very difficult to place the AS wells. In addition, based on past evaluation, the fine-grained sand layer is not always fully saturated, thus limiting the effectiveness of air sparging in that layer. Completion of AS wells below the fine-grained sand layer would not be effective due to the tight formation of the sand that would promote lateral movement of air at the fine-grained sand layer interface rather than vertical movement through the contaminated zone.

The conceptual design of the alternative and estimated costs are included in Appendix C. The estimated cost is approximately $280,000. Remedial action compliance monitoring specifically for the source area is estimated for up to 5 years and a cost of $25,000. Monitoring costs do not include the comprehensive sitewide compliance monitoring, which is discussed in Section 8.

Threshold Criteria

An evaluation of the AS/SVE remedial alternative indicates that it meets the threshold requirements, as summarized below:

- This alternative protects human health and the environment by removing COCs from the source area. The extracted contaminants would be removed (treated as necessary) from the air stream to prevent discharge to the air.
- This alternative complies with the MTCA cleanup standards by removing COCs from the source area.
- Numerical standard ARARs were incorporated into the cleanup level determination.
- This alternative provides for compliance monitoring, both in terms of performance monitoring during the AS/SVE remedy and conformation monitoring to monitor the long-term effectiveness of the remedy.

Use of Permanent Solutions

This alternative includes treatment of contaminated soil (largely saturated) through air sparging and vapor extraction. The extracted air stream would be treated prior to discharge. Therefore, it meets the requirement for a permanent solution.

Reasonable Restoration Timeframe

Under ideal conditions, it is expected that the timeframe for cleanup would be on the order of 2 to 4 years in the source area. This meets the reasonable timeframe criteria. However, given the complexity of the geology/hydrogeology in the source area (i.e., fine-grained sand layer), the timeframe for cleanup could be substantially increased and/or residual concentrations could remain that could impact groundwater monitoring wells. This would be addressed through continued monitoring of the area and a sitewide compliance monitoring plan and contingency plan.

Consideration of Public Concerns

The proposed action would be submitted for public comment, and concerns raised would be addressed prior to design and implementation. It is anticipated that potential concerns of the public could be addressed as appropriate. It is not expected that any public concerns that would prevent the implementation of this alternative would be received or could not otherwise be rectified. It is anticipated that potential concerns of the public would be similar among the alternatives.

Public engagement and potential concerns related to the environmental justice evaluation are included in the disproportionate cost analysis in Section 7.3.3.7.

Prevent or Minimize Releases and Migration of Hazardous Substances in the Environment

This alternative provides for removal of the most impacted zone; thus, it is effective at preventing or minimizing releases of hazardous substances.

Degree to Which Cleanup Action Relies on Dilution/Dispersion

Direct removal of the source area contamination does not rely on dispersion or dilution. However, dilution and dispersion are part of the dispersed residual groundwater contamination remedy for the Site (MNA).

7.3.2.4 Alternative D – Substrate Injection (Chemical Oxidation)

This alternative consists of injecting a chemical oxidant (likely Fenton’s Reagent) below the water table using a combination of injection wells and temporary direct-push injection points.

As is typical of in situ oxidizing treatments, the injection of Fenton’s Reagent disrupts aquifer equilibrium conditions in two ways: (1) physical agitation of the aquifer; and (2) liberation of bound TCE from the soil matrix. Both these actions can result in dissolved TCE concentrations that are initially higher after treatment than those observed prior to treatment. After mobilizing the bound TCE, subsequent treatments are aimed at destroying the resulting dissolved TCE. After the final treatment, equilibrium conditions would be re-established naturally and TCE concentrations decreased. Given ideal conditions, it is estimated that two to three treatment events would occur, followed by monthly monitoring of the wells for 1 to 3 years.

Chemical oxidation was used in the source area during previously completed interim actions (see Section 2.3) and proved to be an effective method of destroying residual TCE. This alternative includes additional injection points and direct delivery to the fine-grained sand layer, approximately 20 to 25 feet bgs.

The conceptual design of the injection system is included in Appendix C. Approximately 50 to 60 injection borings would be completed up to 30 feet bgs throughout the 70-foot by 100-foot source area. The size and shape of the source area would make implementing an effective delivery system manageable. Because of the rapid decomposition of oxidizing agents, injection points would have to be located throughout the source area in order to achieve the cleanup goals.

As documented during interim actions previously completed in the source area, the complexity of the subsurface in the source area makes it very difficult to effectively target the thin fine-grained sand layer with chemical oxidation injections. A design study would be required to evaluate the precise geology of the fine-grained sand layer and placement of injection points. The relatively thin fine-grained sand layer would create challenges for the placement of the chemical oxidant. Distribution of chemical oxidants may also be difficult in the tight formation of the fine-grained sand layer. Past experience during the source area interim action indicated that the radius of influence from injection points is limited; and therefor requiring a high number of injection points within the target area.

Costs would be moderately high due to the number of injection points needed. The conceptual design of the alternative and estimated costs are included in Appendix C. The estimated costs are approximately $400,000. Remedial action compliance monitoring specifically for the source area is estimated for up to 5 years and a cost of $25,000. Monitoring costs do not include the comprehensive sitewide compliance monitoring, which is discussed in Section 8.

Threshold Criteria

An evaluation of the chemical oxidation by injection remedial alternative indicates that it meets the threshold requirements, as summarized below:

- This alternative protects human health and the environment by treating COCs in the source area in situ.
- This alternative complies with the MTCA cleanup standards by treating COCs in the source area.
- Numerical standard ARARs were incorporated into the cleanup level determination.
- This alternative provides for compliance monitoring, both in terms of performance monitoring during the injection remedy and confirmation monitoring to monitor the long-term effectiveness of the remedy.

Use of Permanent Solutions

This includes treatment of contaminated soil (largely saturated) through injection of chemical oxidants. Therefore, it meets the requirement for a permanent solution.

Reasonable Restoration Timeframe

Under ideal conditions, it is expected that the timeframe for cleanup would be on the order of 2 to 5 years in the source area. This meets the reasonable timeframe criteria. However, given the complexity of the geology/hydrogeology in the source area (i.e., fine-grained sand layer), the timeframe for cleanup could be substantially increased and/or residual concentrations could remain that could impact groundwater monitoring wells. This would be addressed through continued monitoring of the area and a sitewide compliance monitoring plan and contingency plan.

Consideration of Public Concerns

The proposed action would be submitted for public comment, and concerns raised would be addressed prior to design and implementation. It is anticipated that potential concerns of the public could be addressed as appropriate. It is not expected that public concerns that would prevent the implementation of this alternative would be received or could not otherwise be rectified. It is anticipated that potential concerns of the public would be similar among the alternatives.

Public engagement and potential concerns related to the environmental justice evaluation are included in the disproportionate cost analysis in Section 7.3.3.7.

Prevent or Minimize Releases and Migration of Hazardous Substances in the Environment

This alternative provides for treatment of the most impacted zone; thus, it is effective at preventing or minimizing releases of hazardous substances.

Degree to Which Cleanup Action Relies on Dilution/Dispersion

Treatment of the source area contamination does not rely on dispersion or dilution. However, dilution and dispersion are part of the dispersed residual groundwater contamination remedy for the Site (MNA).

7.3.3 Disproportionate Cost Analysis

Costs are determined to be disproportionate to benefits if the incremental cost of a more expensive alternative over that of a lower-cost alternative exceeds the incremental degree of benefits achieved by the more expensive alternative. As specified in WAC 173-340-360(3)(e) and (f), the disproportionate cost analysis includes evaluation criteria that are a mix of qualitative and quantitative factors. The primary evaluation criteria include:

- Protectiveness – The overall protectiveness of human health and the environment including the degree to which existing risks are reduced, time required to reduce risk at the facility and attain cleanup standards, on-site and off-site risks resulting from implementing the alternative, and improvement of the overall environmental quality.
- Permanence – The degree to which the alternative permanently reduces the toxicity, mobility, or volume of hazardous substances including the adequacy of the alternative in destroying the hazardous substances, the reduction or elimination of hazardous substance releases and sources of releases, the degree of irreversibility of waste treatment process, and the characteristics and quantity of treatment residuals generated.
- Cost – The cost to implement the alternative including the cost of construction, the net present value of any long-term costs, and agency oversight costs that are cost-recoverable. Long-term costs include operation and maintenance costs, monitoring costs, equipment replacement costs, and the cost of maintaining institutional controls. Cost estimates for treatment technologies shall describe pretreatment, analysis, labor, and waste management costs. The design life of the cleanup action must be estimated, and the cost of replacement or repair of major elements shall be included in the cost estimate.

- Long-Term Effectiveness – This includes the degree of certainty that the alternative will be successful, the reliability of the alternative during the period of time hazardous substances are expected to remain on site at concentrations that exceed cleanup levels, the magnitude of residual risk with the alternative in place, and the effectiveness of controls required to manage treatment residues or remaining wastes. The following types of cleanup action components may be used as a guide, in descending order, when assessing the relative degree of long-term effectiveness: reuse or recycling; destruction or detoxification; immobilization or solidification; on-site or off-site disposal in an engineered, lined, and monitored facility; on-site isolation or containment with attendant engineering controls; and institutional controls and monitoring.
- Short-Term Risks – The risk to human health and the environment associated with the alternative during construction and implementation and the effectiveness of measures that will be taken to manage such risks.
- Implementability – Ability to be implemented including consideration of whether the alternative is technically possible, availability of necessary off-site facilities, services and materials, administrative and regulatory requirements, scheduling, size, complexity, monitoring requirements, access for construction operations and monitoring, and integration with existing facility operations and other current or potential remedial actions.
- Consideration of Public Concerns – Whether the community has concerns regarding the alternative and, if so, the extent to which the alternative addresses those concerns. This process includes concerns from individuals, community groups, local governments, tribes, federal and state agencies, or any other organization that may have an interest in or knowledge of the site.

As discussed in Section 6.4.5, a seventh criteria (Reduce Disparate Impacts), was added to the disproportionate cost analysis as a result of the Port's inclusion of environmental justice considerations.

- Reduce Disparate Impacts – The relative ability for the remedial alternative to reduce potential disproportionate impacts or outcomes (health, community quality, etc.) during both implementation of the remedy and continued operation on the highly impacted community. Ecology defines a highly impacted community as likely to bear a disproportionate burden of public health risks from environmental pollution, such as minority, low-income, tribal, or indigenous populations.

A comparative analysis of the alternatives was completed using these criteria. The comparative analysis allowed for each alternative to be compared relative to others with respect to the primary evaluation criteria. Each alternative was scored relative to the other alternatives. It is understood that remediation alternative ranking using relative criteria values is inherently subjective. Because the nature of the criteria is subjective, a qualitative or semi-quantitative evaluation based on currently available information and professional judgment was employed. A scale of zero (least beneficial) to 10 (most beneficial) was used for each criterion. Qualitative scoring for the criteria is appropriate and is typically conducted when the information to provide meaningful and defensible quantitative scoring is not available.

Table 7-3 presents an overall comparative summary of the four alternatives. Important differences and similarities among the alternatives are discussed below for each of the criteria.

7.3.3.1 Protectiveness

Alternative A (Institutional Controls) meets the RAOs and, thus, meets the protectiveness criterion. Alternative B (Remedial Excavation) appears to achieve protectiveness in the timeliest manner due to direct removal of the source area. Alternatives C (AS/SVE) and D (Substrate Injection) are similar in terms of protectiveness due to similar target areas and technologies.

7.3.3.2 Permanence

Alternative A (Institutional Controls) is permanent and effective against eliminating exposure and addresses the potential unacceptable risks posed by the site; however, it does not treat the contaminants and relies on institutional controls and MNA. Alternative B (Remedial Excavation) is generally permanent as it includes direct removal of contaminants; however, the contaminants are transferred to a landfill. Alternatives C (AS/SVE) and D (Substrate Injection) generally have similar permanence as they are both treating/destroying contaminants.

7.3.3.3 Long-Term Effectiveness

Alternative A (Institutional Controls) achieves long-term effectiveness to eliminate exposure but does not actively treat contaminants. Alternatives B through D are similar, relying on remedial efforts to provide continued protection. Alternative B (Remedial Excavation), however, provides a greater level of long-term effectiveness due to the complete removal of impacted soil for off-site disposal. Alternatives C (AS/SVE) and D (Substrate Injection) are scored slightly lower due to some uncertainty regarding the remedial actions.

7.3.3.4 Short-Term Risks

The implementation risk for Alternative A (Institutional Controls) is moderate due to the potentially long timeframe to achieve cleanup levels. Alternative B (Remedial Excavation) has relatively high short-term risk related to the significant construction project that must occur to implement the action. In addition, shoring and dewatering issues contribute to a high short-term risk. Alternatives C (AS/SVE) and D (Substrate Injection) have similar short-term risks due to the complexity of the source area geology. Alternative C was scored lower than Alternative D due to the infrastructure involved for the AS/SVE system.

7.3.3.5 Implementability

Alternative A (Institutional Controls) is the easiest to implement as it requires no action other than restrictive covenants (and sitewide compliance monitoring for MNA). Alternative B (Remedial Excavation) would be difficult to implement due to the significant dewatering and shoring involved, as well as available space for stockpiling and disruption of the site. Alternative C (AS/SVE) is implementable but has significant issues associated with the geology and target area; precise placement of the AS wells may not be feasible. There are similar concerns with the implementability for Alternative D (Substrate Injection) relating to the target area.

7.3.3.6 Consideration of Public Concerns

The proposed actions would be submitted for public comment and concerns raised would be addressed prior to design and implementation. It is expected that there may be public concerns associated with Alternative A as it requires no further action or cleanup. Some concerns associated with Alternative B may be realized due to disruption of the site and surrounding area for a large construction/excavation project. It is anticipated that potential concerns of the public would be similar among the remaining alternatives.

7.3.3.7 Reduce Disparate Impacts

Alternative A does little to reduce the already very low potential impacts on the nearby FVN community but does provide restriction of the SMC site from future groundwater use and provides isolation of subsurface contaminants from site workers with protection measures. All of the active alternatives (B, C and D) provide some level of contaminant removal that conceptually could reduce potential impacts to the community, although these current impacts are already very low or negligible. Alternatively, implementation of a large-scale remediation project at the SMC site has potential to impact the FVN community through increased vehicle traffic, noise, emissions such as dust (for Alternative B) and contaminants through remedial equipment emissions (for Alternative C), or remobilization (Alternative D).

7.3.3.8 Cost

Cost estimates for each alternative are included in Appendix C. Sitewide compliance monitoring costs are not included in the evaluation, as they are similar for all the alternatives. However, targeted source area monitoring costs are included for each alternative and may vary depending on the remedial action conducted. The estimated alternatives' completion costs are as follows:

Alternative A – Institutional Controls and MNA	$120,000
Alternative B – Remedial Excavation of SMC Source Area	$900,000
Alternative C – Air Sparging and Soil Vapor Extraction	$280,000
Alternative D – In Situ Substrate Injection	$400,000

Based on the cost estimate for each alternative, a relative score was assigned as is shown on Table 7-3.

7.4 Scoring and Ranking of Alternatives

The scoring for each alternative, shown in Table 7-3, was conducted using a relative basis from 0 to 10 for each of the criteria (prior to evaluation of costs). As discussed above, each of the alternatives was scored for each criterion based on professional judgment. The total score for each alternative is as follows:

Alternative A – 54

Alternative B – 43

Alternative C – 49

Alternative D – 41

After consideration of the individual screening and comparative analysis, the highest scored remedial alternative was Alternative A –Institutional Controls, Engineering Controls (Future) and MNA. Alternative A was shown to be effective, reliable, implementable, and has moderate implementation risk. Alternative A also achieves all of the RAOs established for the SMC source area. Based on these considerations, Alternative A scored higher than Alternatives B through D (Table 7-3).

7.5 Selection of Preferred Alternative

After consideration of the individual screening and comparative analysis, the preferred remedial alternative selected for the SMC source area is Alternative A – Institutional Controls, Engineering Controls (Future), and MNA.

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8. DISPERSED RESIDUAL GROUNDWATER CONTAMINATION FEASIBILITY EVALUATION

The following sections provide a summary of the feasibility evaluation for the dispersed residual groundwater concentrations remaining in the intermediate and deep USA zones of the SMC and Cadet area, and selection of a preferred remedy.

As previously discussed, the 2020 data indicate the five completed interim actions and one active interim action (GPTIA) for the Cadet and SMC sites have essentially eliminated the dissolved-phase plume in the intermediate zone, with several small areas of dispersed residual contamination remaining. The residual contamination in the deep zone is relatively low concentration, and slowly decreasing in concentration and extent. Therefore, the approach for the FS evaluation for the dispersed residual groundwater contamination was modified from a typical remedial alternatives assessment (i.e., technology screening) to focus on an evaluation of whether the existing interim actions have sufficiently cleaned up the aquifer to allow for long-term monitoring under MTCA requirements.

8.1 Current (2020) Extent of Dispersed Residual Groundwater Contamination

As described in Section 2.3, a pump and treat system (GPTIA) was installed by the Port at the SMC site in 2009 to extract and treat dissolved-phase groundwater contaminants in the project area. Operation of this system, in addition to the five other interim actions completed on and in the vicinity of the SMC and Cadet sites, has significantly reduced the overall distribution of dissolved-phase contaminants.

The intermediate and deep USA zones are the focus of the evaluation of remedial alternatives for the residual groundwater concentrations. Figures 2-9 and 2-10 show the 2020 distribution of TCE and PCE, respectively, in the intermediate USA zone in the project area. Figure 2-11 shows the intermediate dissolved-phase contamination in 2009, 2013 and 2020. A summary of the distribution of contaminants in 2020 in the intermediate zone wells is provided below.

In 2020, the highest TCE concentration (34.7 µg/L) was detected at MW-37i, located east of GWM. Based on data collected during the remedial investigations and long-term groundwater monitoring, the presence of contamination in MW-37i appears to be an anomaly. Concentrations of TCE in MW-37i have remained relatively stable, while contaminant concentrations in all wells around MW-37i have decreased to below cleanup levels. In addition, the ratio of PCE to TCE in MW-37i has been significantly different than other wells. The data suggest the contamination in MW-37i could be from a source other than SMC or Cadet. However, another source hasn't been clearly identified. Therefore, the contamination in MW-37i is included as part of the site remedy The highest SMC-related concentration of TCE in 2020 was 12.1 µg/L, detected at MW-05i located adjacent to GPTIA extraction well EW-1. As shown on Figure 2-9, only wells MW-05i, MW-15i, MW-37i, and CM-MW-23i exceeded the MTCA Method B cleanup level 4 µg/L (for TCE in the Cadet and SMC portion of the Site. PCE was not detected above 5 µg/L (the MTCA Method B cleanup level) in any of the intermediate wells within the SMC and Cadet portion of the Site (Figure 2-10).

A new intermediate well (labeled MW-2i) was installed at the site in 2020 to evaluate conditions beneath and near the SMC source area. Low concentrations of TCE (1.33 µg/L) and PCE (1.11 µg/L) were detected in a groundwater sample collected from MW-2i in December 2020. The data indicate TCE concentrations above 5 µg/L in the SMC source area intermediate zone are limited to the vicinity of MW-05i.

The highest concentration of any VOC detected in an intermediate zone Cadet well during 2020 was TCE at 5.85 µg/L in CM-MW-23i. TCE was also detected at a concentration of 5.54 µg/L in intermediate well CM-MW-Ui, located near the southeast corner of the Site (Figure 1-3). -. The highest PCE concentration was detected in well CM-MW-20i (3.98 µg/L). TCE and PCE concentrations continue to decline in the Cadet intermediate wells, including CM-MW-23i. Figure 2-11 shows the notable reduction of the TCE contamination in the intermediate zone since implementation of the GPTIA.

Figures 2-12 and 2-13 show the 2020 distribution of TCE and PCE in the deep USA zone. Concentrations of TCE detected in deep zone wells continue to decrease slowly since startup of the GPTIA in 2009, as shown on Figure 2-14. Twelve deep zone samples were collected during the first quarter 2020 event. As indicated on Figure 2-12, TCE was detected at concentrations ranging from 1.79 µg/L to 21.7 µg/L. PCE was not detected at concentrations above the 5 µg/L cleanup level. The residual contamination within the deep zone is included as part of the remedial action considerations in the following sections.

8.2 Remedial Action Objectives and Technology Screening

The following RAOs have been established for the residual groundwater concentrations:

- Achieve the cleanup standards for COCs.
- Protect human health and the environment.
- Use permanent solutions to the maximum extent practicable (which includes consideration of cost-effectiveness).
- Ensure protection of current or future public groundwater pumping wells (i.e., CPU, COV, Port, GWM) from the existing residual groundwater concentrations.

As noted above, specific technology screening is not explicitly a part of this FS effort for the dispersed residual groundwater contamination because the selected remedial action technology (pump and treat) was put into place as an interim action since June 2009. A detailed technology screening was conducted during the evaluation of remedial alternatives and subsequent design for the interim action in 2008 (Parametrix 2008b). For completeness and to satisfy FS requirements, the previous technology screening is summarized below, and the specific technologies considered are shown in Table 8-1.

EPA technology screening guidance provides an assessment of general classes of technologies classified by media and type of treatment. The guidance is relatively comprehensive and was used to identify potential technologies for the site. The general technologies identified for the project area included:

- Institutional controls
- Engineering controls
- Containment
- Removal/discharge
- Ex situ biological or physical/chemical treatment (used for treatment of extracted groundwater)

- In situ biological treatment or physical/chemical treatment

The specific technologies considered for the dissolved-phase groundwater plume are presented on Table 8-1. For the first screening step, technologies that are not applicable to the media of concern or the goals of the cleanup were eliminated. Three criteria (effectiveness, implementability, and cost) were used to complete an initial screening of the remaining technologies (Table 8-1). These potential technologies were further evaluated based on site-specific conditions to develop a set of remedial alternatives that could be applied to the dissolved-phase groundwater plume. As applicable, some technologies were combined with others to define a specific remedial alternative. Ultimately, groundwater pumping and treatment was the technology selected as the interim remedial action and was designed and constructed in 2008 (Parametrix 2008b). The GPTIA was operational by 2009 and continues to operate through the present.

The alternatives developed for this FS are summarized below and primarily consist of two alternatives: (1) termination of the pump and treatment system and MNA, and (2) continued operation of the pump and treatment system.

8.3 Cleanup Action Alternative Development

The following are the site-specific conditions that served as criteria to determine the cleanup action alternatives:

- The contaminated media include the shallow, intermediate, and deep groundwater zones of the aquifer, which is designated as a sole source aquifer.
- Contamination consists of dissolved-phase VOCs (primarily TCE and PCE).
- The site supports light and heavy industrial usage with heavy traffic. Some residential areas are located near the dispersed residual groundwater contamination.
- Known public drinking water wells are in the project vicinity (CPU, Port, and COV).
- Industrial use of groundwater in the project vicinity includes uses by Port tenants and COV at a wastewater treatment facility.
- The existing pump and treat system at the SMC source area (used as an interim action) was designed to extract and treat groundwater at the Site. Dispersed residual groundwater contamination as a result of operation of the interim action since 2009 is limited to localized areas and approaches MTCA Method B cleanup levels.
- Interim actions have been conducted in the Cadet and SMC source areas to reduce source area concentrations. The remedial action for the dispersed residual groundwater contamination should supplement and support any selected additional source area remedial action.

Using these considerations, the availability and success of the pump and treat system focused this technological evaluation on the feasibility of alternatives that support site closure. This was generally limited to continued operation of the pump and treat system and/or MNA. After consideration of the above site-specific conditions, the remedial alternatives for the residual groundwater concentrations were reduced to the following two for evaluation in this FS:

Alternative A – MNA

Alternative B – Continued Pump and Treat

Alternative A involves termination of the existing pump and treat system and then allowing MNA to address the low concentrations of dispersed residual groundwater contamination in the project area. Alternative B assumes that the pump and treat system will continue operation to contain and treat dispersed residual groundwater contamination. Detailed descriptions of the alternatives and evaluation against MTCA criteria are discussed in Section 8.4.

8.4 Evaluation of Cleanup Action Alternatives

As stated previously, MTCA established minimum requirements and procedures for selecting cleanup actions in WAC 173-340-360. The same standards and procedures were used in selection of both the SMC source area remedy and the dispersed residual groundwater contamination remedy. MTCA requires that all cleanup actions meet the threshold requirements that are part of the minimum requirements. Any alternatives that do not meet the threshold requirements are dropped from further consideration. Under MTCA, remedial alternatives must meet the following threshold requirements (WAC 173-340-360(2)(a)):

- Protection of human health and the environment
- Compliance with cleanup standards
- Compliance with ARARs
- Provision for compliance monitoring

Each alternative is evaluated individually against the threshold. Alternatives that do not meet the threshold requirements are not carried forward to the evaluation of other requirements (WAC 173-340-360(2)(b)). The other requirements are defined in Section 6 and include:

- Use of permanent solutions
- Reasonable restoration timeframe
- Consideration of public concerns
- Prevent or minimize releases and migration of hazardous substances in the environment
- Degree to which cleanup action relies on dilution/dispersion

The following sections evaluate each of the individual alternatives against the threshold requirements and other criteria.

8.4.1 Alternative A – Monitored Natural Attenuation

This alternative primarily consists of MNA and was developed to support shutdown of the existing pump and treatment system to achieve RAOs. Although evaluated independently as an MNA alternative, this remedy assumes the source area preferred alternative will be completed as described. Source control at the SMC site will include implementation of institutional controls and compliance monitoring.

Natural attenuation processes include a variety of physical, chemical, and biological processes that, under favorable conditions, act without human intervention to reduce the mass, toxicity, mobility, volume, or concentration of contaminants in groundwater. These in situ processes include biodegradation; dispersion; dilution; sorption; volatilization; and chemical or biological stabilization, transformation, and destruction of contaminants. Periodic monitoring is necessary to demonstrate that contaminant concentrations continue to decrease at a rate sufficient to ensure that they do not become a threat to human health or the environment.

According to MTCA as described under WAC 173-340-370(7), MNA as a remediation alternative is most appropriate for sites with the following characteristics:

- Source control has been conducted to the maximum extent practicable.
- Leaving contaminants on the site during the restoration timeframe does not pose an unacceptable threat to human health or the environment.
- There is evidence that natural biodegradation or chemical degradation is occurring and will continue to occur at a reasonable rate at the site.
- Appropriate monitoring is conducted to ensure that contaminant concentrations continue to decrease, the natural attenuation processes continue to occur, and human health and the environment are protected.

For the dispersed residual groundwater contamination associated with the SMC and Cadet sites, MNA technology would be applicable because:

- Various source control activities (e.g., interim actions at Cadet and SMC) have been completed that have reduced concentrations significantly in the source areas and throughout the groundwater aquifer. Only a small area of impacted saturated soil in the source area (primarily the fine-grained sand layer) remains (shown on Figures 7-1 through 7-3).
- Residual groundwater contamination does not pose a threat because potential receptors do not have direct contact with the contaminants remaining at the site and the contamination does not pose a risk to human health or the environment because there is no complete exposure pathway. Potential future exposure pathways via drinking water from regional supply wells can be demonstrated to not be impacted by contaminants (see Section 8.4.1.1). An MNA sampling program can be employed to ensure that assumptions for exposure are continually validated.
- There is evidence that natural attenuation is currently occurring and has significantly decreased contaminant concentrations. As an example, concentrations of contaminants located beyond the capture zone of the GPTIA have continued to decrease. Groundwater concentrations of all contaminants at the Site have been declining, are now only found in localized areas, and overall restoration of the groundwater aquifer is expected generally within approximately 20 years.
- Groundwater monitoring is required for the Site and has been conducted for the source areas and the dispersed groundwater plume. As part of the implementation of the FS remedy, an MNA sampling program will be developed and implemented. This will include establishing points of compliance (POCs) and sampling methodology and criteria.
- Land use restrictions will be in place to protect potential exposure through direct contact or ingestion of groundwater that exceeds cleanup levels (source area).

- The availability of the groundwater pump and treat system for the SMC source area provides a contingency element if MNA is not proceeding as expected or an additional remedial action is required to supplement MNA. This contingency will be included in the development of the MNA implementation plan in the corrective action plan, including criteria for permanently shutting down and dismantling the GPTIA system.

8.4.1.1 Use of the Groundwater Model to Support MNA

The groundwater model was updated and used in 2021 to evaluate the applicability of MNA and to support the selection of MNA as the primary component to this alternative. A detailed report of the modeling including regional supply well pumping rate assumptions, model and source area mass input parameters, uncertainty analysis, and results is included in Appendix A. A summary of the relevant findings to the MNA alternative is presented below.

Future Groundwater Conditions Analysis

The model was primarily used to evaluate whether the GPTIA and other remedial actions completed in the SMC/Cadet area have sufficiently cleaned up the aquifer based on MTCA requirements. As part of this analysis, the model was used to assess whether the residual contamination in the vicinity of the SMC and Cadet sites poses a potential unacceptable risk to water supply wells operated by CPU, COV, the Port, and Port tenants. The model simulations assumed that there was no pumping at the Port's GPTIA well (EW-1). Regional production well pumping rates (CPU, COV, the Port, and GWM) were based on information provided by those entities (see Appendix A for rates, locations, and model assumptions).

Two types of model simulations were completed in order to further assess the MNA alternative:

1. Base case simulations assessed future groundwater conditions and identify potential receptors.
2. Contaminant rebound simulations estimated source concentrations that would result in detectable TCE at identified receptors.

Base Case Simulations

Base case simulations using finite and infinite mass were completed.

Base Case Simulation – Finite Mass

This simulation used the average groundwater concentration for the dissolved plume and the SMC source area based on first quarter 2020 sampling results. These results were vertically distributed through the aquifer and averaged by model cell. A finite mass (i.e., depleting source) was assumed. The groundwater model was run for more than 100 years to assess the distribution of TCE in the project area over time and evaluate if the residual contamination in the vicinity of the SMC/Cadet poses a potential unacceptable risk to water supply wells (CPU, COV, and Port).

Particle tracking indicates that the groundwater flow from the area of the SMC and Cadet sites is generally to the north, then easterly due to pumping at COV water station #3 (COV WS3) and CPU's Carol Curtis wellfield (see Appendix A). The model results indicate that the existing concentrations in the source area and the dispersed groundwater contamination are not predicted to cause a detectable concentration (0.5 µg/L) in CPU, COV, or Port production wells**.** As shown on Figure 8-1, the maximum concentration predicted in the COV3 WS3 well is approximately 0.01 µg/L in approximately 25 years, significantly below the detection levels. All other supply wells showed even lower predicted concentrations at the well head.

Base Case Simulation – Infinite Mass

The simulation included an extremely conservative approach (non-depleting source) to provide an upper bound analysis. The starting mass in the SMC source area was approximated using the 2020 maximum concentration of TCE (560 µg/L) in the shallow zone, and the mass was assumed to be an infinite source (i.e., a non-depleting source) over a period of more than 100 years. It should be noted that no conditions have been observed at the site that suggest a non-depleting source is present and groundwater monitoring conducted from the extensive well network since the late 1990s, including those within the SMC site, indicate that the source area is indicative of a finite mass. However, the conservative approach was utilized to provide context and comparison to the finite mass simulation.

As shown on Figure 8-2, this simulation predicts that TCE will arrive at the production wells after approximately 20 years, slowly increasing over decades to concentrations that remain significantly below detection levels (0.5 µg/L). Thus, even under highly conservative assumptions, the 2020 source concentrations and residual groundwater conditions are not predicted to impact any of the regional supply wells above detection levels (0.5 µg/L).

In addition, predicted future groundwater conditions throughout the aquifer can be assessed through the two model simulations. As shown on Figures 8-3 and 8-4, the predicted plume configuration through time suggests that the intermediate zone wells could reach cleanup levels in relatively short timeframe (5 years) and that the source area does not significantly impact deeper groundwater in excess of the MTCA Method B cleanup levels. The groundwater model simulations support termination of the GPTIA and allowing natural processes to reach MTCA cleanup levels under an MNA approach. The MNA approach is protective of known drinking water receptors even under worst-case conditions.

Source Area Contaminant Rebound Simulations

Model simulations were completed to assess potential rebound conditions due to termination of pumping at EW-1. This was primarily completed by assessing the concentration needed at the SMC source to result in detectable TCE at the CPU or COV supply wells. Finite and infinite mass scenarios were evaluated. The simulations were completed by increasing the SMC source area mass in a stepwise manner until the groundwater model predicted that TCE would be detected (0.5 µg/L) at the production wells.

Source Area Contaminant Rebound Simulation - Finite Mass

Under the first base case scenario (finite mass), the groundwater model predicted that source area concentrations would need to increase by 49 times compared to the 2020 maximum concentration to cause a detectable concentration in CPU or COV production wells (see Appendix A). This information will be used in the CAP to develop the MNA compliance monitoring plan, which will include rebound criteria and potential actions.

Source Area Contaminant Rebound Simulation - Infinite Mass

Under the second highly conservative scenario (infinite mass), the groundwater model predicted that source area concentrations would need to increase by 4.3 times compared to the 2020 maximum concentration to cause a detectable concentration in CPU or COV production wells (Appendix A).

However, the assumption of an infinite mass vastly overestimates the expected conditions and was only completed to provide context with the finite mass scenario as provided above.

8.4.1.2 Additional MNA Alternative Considerations

Pump and Treatment System Efficiency

While not a prime consideration when generally evaluating remedial alternatives, the operating efficiency of the existing pump and treatment system does have some impact on how alternatives can be implemented. The MNA alternative was developed to help evaluate whether the existing remedial actions have been sufficient to meet MTCA requirements and whether operation of the GPTIA has a beneficial impact on groundwater conditions.

The GPTIA was designed to operate at approximately 2,500 gpm as containment of the groundwater plume was a primary factor in the selection of pump and treat technology (Parametrix 2008b). The GPTIA is currently operating at a reduced rate of approximately 1,200 gpm due to well screen biofouling and other factors, but still provides adequate containment and treatment based on the current extent of the dispersed residual groundwater plume. Given the state of the existing groundwater concentrations, containment is no longer a primary concern and should be considered as part of the alternatives evaluation and whether the system provides current benefit.

The effectiveness of the GPTIA has been significant with respect to the total mass of VOCs removed from the groundwater. Since startup in June 2009 through 2020, the GPTIA has extracted and treated a total of 12.75 billion gallons of groundwater and removed approximately 1,298 pounds of VOCs. Since beginning operation, there has been a steady decrease in the annual pounds of VOCs removed, starting with 263 pounds during the last 6 months of 2009 to the 21 pounds removed during 2020. Figure 8-5 shows the pounds of VOCs removed through the period of operation of the GPTIA, as well as the annual and cumulative amount of groundwater extracted and treated.

As shown on Figure 8-6, 2020 influent TCE and PCE concentrations are generally below 2 µg/L and 1.5 µg/L, respectively. It is apparent that the efficiency of the pump and treatment system, relative to the amount of groundwater pumped and VOCs recovered, has been decreasing at a steady rate and appears to be nearing its feasible limit. The cost for operation and maintenance of the system, including electrical costs, is significant relative to the benefit the GPTIA currently provides (as shown in Alternative B in Section 8.4.2). These cost considerations are included in the disproportionate cost analysis in Section 8.5 and play a significant role in the selection of a preferred alternative.

MNA Compliance and Planning Documents

The MNA approach would include planning and reporting requirements to document that MNA is meeting the RAOs. A comprehensive work plan would be prepared to outline methods for monitoring techniques and sampling events. The plan would define all POC sampling locations within the site. The monitoring program would be developed with the objective of verifying the ongoing effectiveness of recovery of contaminated groundwater by natural processes. The monitoring would be used to evaluate contaminant concentrations relative to the cleanup levels established for the site. In addition, a contingency plan would be developed to determine criteria for re-starting the pump and treatment system if compliance monitoring shows that MNA is not meeting the RAOs. These plans are expected to be part of the corrective action plan.

Estimated Costs

The estimated cost to implement the alternative is included in Appendix D. Estimated costs range from approximately $1M to $1.5M, which primarily includes monitoring requirements over an estimated 10- to 15-year timeframe (assumed starting from 2022), as well as preparation of planning documents for implementing MNA, annual MNA reporting, and preparation of closure documents. Costs associated with the SMC source area remedy are not included with this alternative, as the SMC source area remedy included in the preferred alternative described in Section 7.

8.4.1.3 Threshold Criteria

An evaluation of the MNA remedial alternative indicates that it meets the threshold requirements, as summarized below:

- This alternative protects human health and the environment by reduction of COCs to cleanup levels within a reasonable timeframe.
- This alternative complies with the MTCA cleanup standards by allowing COCs from the source area to degrade naturally. Cleanup levels will be achieved in the intermediate zone in a reasonable timeframe. Potential exposure to remaining contaminants in the source area will be managed through Institutional Controls and do not impact human health or the environment.
- Numerical standard ARARs were incorporated into the cleanup level determination.
- This alternative provides for compliance monitoring, both in terms of focused monitoring for the source area and confirmation monitoring to monitor the long-term effectiveness of MNA.

8.4.1.4 Use of Permanent Solutions

MNA relies on natural processes to reduce residual groundwater contaminant concentrations to achieve cleanup levels. Natural attenuation processes include a variety of physical, chemical, and biological processes that, under favorable conditions, act without human intervention to reduce the mass, toxicity, mobility, volume, or concentration of contaminants in groundwater. Based on the decreasing trend of groundwater concentrations beyond the capture zone of the GPTIA, there is evidence that natural attenuation is occurring and will continue to occur at a reasonable rate. Therefore, MNA meets the requirement for a permanent solution.

8.4.1.5 Reasonable Restoration Timeframe

Restoration timeframes were evaluated using the groundwater model, degradation rates, and contaminant trend data.

The groundwater model was used to predict restoration timeframes in intermediate and deep zone monitoring wells based on an MNA alternative. The model indicates cleanup levels will be achieved in intermediate and deep zone wells in approximately 2 years (Figures 8-7 and 8-8).

For comparison, three additional approaches were used to estimate the number of years until TCE concentrations in deep zone groundwater achieve the cleanup level (4.0 µg/L). These approaches included assessing with (1) a TCE half-life of 15 years, which is significantly slower than published half-lives of 4 years or less (Aronson and Howard 1997; Schaerlaekens et al. 1999); (2) an average annual decrease in TCE concentrations (percent) documented in specific site wells between 2010 and 2022; and (3) linear concentration trends. Results are summarized in Table 8-3.

Overall, MTCA Method B cleanup levels are generally expected to be achieved in the intermediate zone within 5 to 10 years and in the deep zone within 20 years. This meets the reasonable timeframe criteria.

8.4.1.6 Consideration of Public Concerns

The proposed action would be submitted for public comment, and concerns raised would be addressed prior to design and implementation. It is anticipated that potential concerns of the public could be addressed as appropriate. It is not expected that any public concerns that would prevent the implementation of this alternative would be received or could not otherwise be rectified.

Public engagement and potential concerns related to the environmental justice evaluation are included in the disproportionate cost analysis in Section 8.5.7.

8.4.1.7 Prevent or Minimize Releases and Migration of Hazardous Substances in the Environment

This alternative provides for attenuation of contamination from the most impacted zones; thus, it is effective at preventing or minimizing releases of hazardous substances. Groundwater modeling shows that at current conditions, public drinking water receptors would not be impacted above the maximum contaminant levels (MCLs).

8.4.1.8 Degree to Which Cleanup Action Relies on Dilution/Dispersion

Dilution and dispersion are integral to the MNA remedy; however, the technology does not rely on these factors alone. MNA also uses biodegradation, sorption, volatilization, and chemical or biological stabilization, transformation, and destruction of contaminants.

8.4.2 Alternative B – Continued Pump and Treat

This alternative primarily consists of continued operation of the pump and treatment system and was developed as an alternative to shutting down the system and to MNA. This remedy assumes the source area preferred alternative will be completed as described. The pump and treatment system in this alternative is assumed to be operated at the reduced rate of approximately 1,200 gpm and operated until MTCA Method B cleanup levels are achieved at all POCs in the intermediate USA zone. Increasing the pumping rate to the design rate of 2,500 gpm is unnecessary since containment of the groundwater contaminant plume is no longer necessary (plume has been essentially eliminated by interim actions). Operation at the 2,500-gpm design rate would require maintenance costs associated with the well screen biofouling and is not included at this time.

Since the source controls are the same as those described for Alternative A, this alternative is primarily an evaluation of whether additional benefits are gained by continued operation of the pump and treatment system to achieve cleanup levels in the intermediate zone versus implementation of MNA (i.e., active versus passive remedial action). The pump and treatment system will be operated until cleanup levels are obtained at all POCs throughout the intermediate USA zone. Based on the past and current groundwater contaminant trends in the intermediate zone wells, as well as the significant reduction of the groundwater plume areal footprint since operation of the GPTIA began in 2009, it is expected that cleanup levels would be achieved in less than 5 years.

The groundwater model simulations described for Alternative A were also used to evaluate the effectiveness of the pump and treat system. Key findings associated with continued pump and treatment are summarized below:

- Groundwater modeling indicates that the low concentrations of dispersed groundwater contamination in the intermediate zone will not impact regional pumping wells in the vicinity (CPU, COV, Port, etc.) above the MTCA Method B cleanup levels in the absence of EW-1 operation (i.e., turning the system off). Thus, any active alternative, such as pump and treat, is considered additionally conservative.
- Groundwater modeling shows that the SMC source area will not impact the intermediate zone above the MTCA Method B cleanup level. This can be achieved whether the pump and treatment system is on or off. Thus, the active alternative is considered additionally conservative.
- When compared to Alternative A, the timeframe to achieve cleanup levels through GPTIA pumping at the 2020 rate is likely to be similar. The GPTIA has effectively eliminated the dispersed groundwater plume, and only localized areas of residual contamination remain. It is not apparent that operation of the system would reduce those disparate areas in a significantly shorter time period.
- It is apparent that the efficiency of the pump and treatment system, relative to the amount of groundwater pumped and VOCs recovered, has been decreasing at a steady rate and appears to be nearing its feasible limit (see Figures 8-1 and 8-2). The cost for operation and maintenance of the system, including electrical costs, is significant relative to the benefit the GPTIA currently provides. The assumed additional 5 years of pumping does not appear to have substantial benefit.

The pump and treat alternative would include preparation of planning and monitoring reports to document that the remedy is meeting the RAOs. A comprehensive work plan would be prepared that would outline the pump and treat operation plan, as well as methods for monitoring techniques and sampling events. The plan would define all POC sampling locations within the site. The monitoring program would be developed with the objective of verifying the ongoing effectiveness of recovery of contaminated groundwater by operation of the pump and treat system. The monitoring would quantify the reduction in concentrations relative to the cleanup levels established for the site.

The estimated costs to implement the alternative are included in Appendix D. Estimated costs range from approximately $2M to $2.5M, which primarily include operation of the pump and treat system at the current pumping rate for a period of 5 years and monitoring requirements over an estimated 10- to 15-year timeframe, as well as planning documents for implementation of MNA after pumping is terminated. Costs associated with the SMC source area remedy are not included with this alternative, as the SMC source area is included in the preferred alternative described in Section 7. In addition, capital costs associated with the pump and treat system are not included as it has already been constructed as part of the Port's interim action.

8.4.2.1 Threshold Criteria

An evaluation of the pump and treat remedial alternative indicates that it meets the threshold requirements, as summarized below:

- This alternative protects human health and the environment by treating COCs in the source area and residual groundwater contamination via pump and treat.
- This alternative complies with the MTCA cleanup standards by treating COCs in the source area and residual groundwater contamination.
- Numerical standard ARARs were incorporated into the cleanup level determination.
- This alternative provides for compliance monitoring both in terms of performance monitoring during the pump and treat remedy and conformation monitoring to monitor the long-term effectiveness of the remedy.

8.4.2.2 Use of Permanent Solutions

Additional pumping and treatment are used for the residual groundwater contamination to achieve cleanup levels and permanently remove VOC mass from the system. Therefore, this alternative meets the requirement for a permanent solution.

8.4.2.3 Reasonable Restoration Timeframe

Groundwater modeling and monitoring well concentration trends indicate that operation of the pump and treat system for 5 years would meet cleanup standards in the intermediate zone and 20 years in the deep zone. Given that there is no interim risk to potential receptors, this meets the reasonable timeframe criteria.

8.4.2.4 Consideration of Public Concerns

The proposed action would be submitted for public comment, and concerns raised would be addressed prior to design and implementation. It is anticipated that potential concerns of the public could be addressed as appropriate. It is not expected that any public concerns that would prevent the implementation of this alternative would be received or could not otherwise be rectified.

Public engagement and potential concerns related to the environmental justice evaluation are included in the disproportionate cost analysis in Section 8.5.7.

8.4.2.5 Prevent or Minimize Releases and Migration of Hazardous Substances in the Environment

This alternative provides for treatment of the source area and residual groundwater contamination; thus, it is effective at preventing or minimizing releases of hazardous substances. Groundwater modeling shows that even at current conditions, public drinking water receptors would not be impacted above the MCLs.

8.4.2.6 Degree to Which Cleanup Action Relies on Dilution/Dispersion

This alternative does not rely on dispersion or dilution. Active remediation would be implemented and operated until the cleanup levels are achieved.

8.4.2.7 Additional Pump and Treatment Alternative Considerations

As part of the Port's overall initiative of evaluating operations relative to climate change impacts, the remedial alternatives for the groundwater cleanup were examined for potential climate change impacts and considered during the FS evaluation. In general, the primary difference between Alternative A and Alternative B is the continued operation of the pump and treatment system for Alternative B for an estimated 5 years. Therefore, all other impacts being equal between the alternatives, the electrical use for operation of the pump and treatment system appears to be the primary contributor to climate change impacts.

As noted above, Alternative B estimates that the pump and treatment system will be operated for a period of approximately 5 years, while the pump and treatment system will be shut down for Alternative A. A streamlined evaluation of potential impacts to climate change was completed, primarily in the form of estimating the emissions of greenhouse gases (GHG) in operation of the pump and treatment system for the 5-year time period (starting in 2022).

Based on past and current electricity use for operation of the pump and treatment system, an estimate of potential GHG emissions can be completed. Electricity use for the pump and treatment system was obtained from Port records, which has tracked the annual electricity use since operation began in 2009. The 2019 electricity usage rates, which represent average use rates over the operating period, were obtained from the Port and were used in the evaluation. Based on Port records, the electrical use solely associated with the pump and treatment system for 2019 was 0.89 megawatt hours (MWh).

The Port also supplied a conversion of electricity use to GHG emissions that they use for climate change analysis for all of the Port operations. The state eGRID emission factors are used and are expressed in pounds per MWh and include carbon dioxide, methane, nitrogen and carbon dioxide equivalents. The electricity rate is used along with the emission factors to estimate emissions of GHG in metric tons.

Based on this analysis the annual GHG emissions over the next 5 years solely due to the pump and treatment operation is estimated at 0.1 tons per year for a total of 0.5 tons over the 5-year period.

In addition, the treatment system itself emits VOCs through the air stripper stacks. As noted in previous sections, the total pounds of VOCs (primarily TCE, and to a lesser extent PCE) treated by the system has ranged from 263 pounds during the last 6 months of 2009 to the 21 pounds removed during 2020. It is expected that the 2020 rates are a reasonable estimate of pounds removed by operation of the treatment system over the next 5 years. Based on the greater than 99 percent treatment efficiency by the air strippers, it is expected that all treated VOCs are emitted through the stack. These emissions are also considered during the alternatives evaluation.

8.5 General Disproportionate Cost Analysis for Groundwater

Costs are determined to be disproportionate to benefits if the incremental cost of a more expensive alternative over that of a lower-cost alternative exceeds the incremental degree of benefits achieved by the more expensive alternative. As specified in WAC 173-340-360(3)(e) and (f), the disproportionate cost analysis includes evaluation criteria that are a mix of qualitative and quantitative factors. The primary evaluation criteria include:

- Protectiveness
- Permanence
- Long-term effectiveness
- Short-term risks
- Implementability
- Consideration of public concerns
- Reduce disparate impacts

As discussed in Section 6.4.5, the seventh criterion (Reduce Disparate Impacts), was added to the disproportionate cost analysis as a result of the Port's inclusion of environmental justice considerations.

A description of the evaluation criteria for analysis of disproportionate costs is provided in Section 6.4. Each alternative was scored relative to the other alternative. It is understood that remediation alternative ranking using relative criteria values is inherently subjective. Because the nature of the criteria is subjective, a qualitative or semi-quantitative evaluation based on currently available information and professional judgment was employed. A scale of zero (least beneficial) to 10 (most beneficial) was used for each criterion. Qualitative scoring for the criteria is appropriate and is typically conducted when the information to provide meaningful and defensible quantitative scoring is not available.

Table 8-2 presents an overall comparative summary of the two alternatives. Important differences and similarities between the alternatives are discussed below for each of the criteria.

8.5.1 Protectiveness

Current receptors (drinking water wells) are protected with Alternatives A (MNA) and B (Continued Pump and Treat). Alternative B is thought to provide a slightly greater level of protectiveness by incorporating a longer pump and treat timeframe into the remedy, thus potentially reducing the timeframe to achieve the MTCA cleanup levels.

8.5.2 Permanence

Alternatives A (MNA) and B (Pump and Treat) generally have similar permanence as they are both reducing residual concentrations to MTCA levels and protecting drinking water receptors. However, Alternative A relies on MNA to ultimately reach cleanup levels. Alternative B is thought to provide a slightly greater level of permanence by incorporating a longer pump and treat timeframe into the remedy, thus potentially reducing the timeframe to achieve the MTCA cleanup levels.

8.5.3 Long-Term Effectiveness

Alternatives A (MNA) and B (Pump and Treat) are similar with respect to long-term effectiveness. Each relies on remedial efforts to provide continued protection from the source areas and ultimately achieve cleanup levels in the residual groundwater plume. Alternative B, however, provides a slightly greater level of long-term effectiveness due to the removal of impacted groundwater through treatment, while Alternative A relies on the monitoring of natural processes. The effectiveness of both alternatives would be evaluated based on similar monitoring programs. Alternative B would likely require significantly more maintenance than Alternative A.

8.5.4 Short-Term Risks

There is little risk associated with Alternative A (MNA) as no construction or implementation is required and the ongoing measures of effectiveness (i.e., groundwater monitoring) are well established in the project area. There is also little risk associated with Alternative B (Pump and Treat) as the infrastructure has already been constructed and the operational process has already been implemented.

8.5.5 Implementability

Both alternatives are considered implementable and technically feasible. MNA (Alternative A) is very implementable and has been ongoing at the site for several years. Alternative B is also very implementable as the current pump and treat system at SMC would be used; it is operational and has no significant concerns. Since Alternative B uses infrastructure and mechanical equipment, with the potential for malfunction and maintenance, this technology is less implementable than Alternative A.

8.5.6 Consideration of Public Concerns

The proposed actions would be submitted for public comment and concerns raised would be addressed prior to design and implementation. It is anticipated that potential concerns of the public could be addressed as appropriate. It is not expected that any public concerns that would prevent the implementation of the alternatives would be received or could not otherwise be rectified. Alternatives A and B are generally scored the same. However, the consideration of GHGs in operation of the pump and treatment system for Alternative B, as well as off-gassing of VOCs emitted through the treatment system stack to the atmosphere, Alternative B was scored slightly less than Alternative A which have no such direct emissions nor electricity usage.

8.5.7 Reduce Disparate Impacts

As discussed in the memo in Appendix E, the FVN is considered a highly impacted community that may have disproportionate impacts due to several outlying factors, including demographics and environmental conditions. Ecology defines a "highly impacted community" as likely to bear a disproportionate burden of public health risks from environmental pollution, such as minority, low-income, tribal or indigenous populations.

However, little or no impact from the current groundwater cleanup efforts or associated residual conditions were identified. In addition, public engagement did not identify specific impacts or concerns that would affect the selection of the remedial alternative for the dispersed residual groundwater contamination. Thus, the two alternatives developed are not significantly different in terms of reducing disparate impacts to the FVN community. However, the following factors were considered in the scoring of this criteria.

Alternative A has some potential to reduce impacts to the community through reduction of GHG-equivalent emissions by eliminating large electricity usage. Shut down of the pump and treatment system will also include a potential benefit to the community due to the elimination of VOCs emitted through the air stripper from the treatment process potentially upwind of the FVN. However, this benefit may be small as all past and current emissions from the treatment system has met the Southwest Clean Air Agency (SWCAA) permit requirements. Alternative B includes continued operation of the GPTIA for 5 years, which includes additional VOC emissions from the air stripper stack that could have some impact on the nearby community. Although it appears to be low or negligible, Alternative B may have some added benefit by reducing the groundwater concentrations near the FVN in a more-timely fashion. However, Alternative A was scored higher than Alternative B primarily due to the VOCs emissions and reduction of GHGs.

8.5.8 Cost

Estimated costs for each alternative are included in Appendix D. The estimated alternatives' completion costs are as follows:

Alternative A – Monitored Natural Attenuation	\$1M – \$1.5M
Alternative B – Continued Pump and Treat	\$2M - \$2.5M

Based on the cost estimate for each alternative, a relative score was assigned as is shown on Table 8-2. The costs are assigned independent of the other criteria such that the disproportionate costs can be considered as outlined below.

8.6 Scoring and Ranking of Alternatives

The scoring for each alternative, shown in Table 8-2, was conducted using a relative basis from 0 to 10 for each of the criteria. As discussed above, each of the alternatives was scored for each criterion based on the best professional judgment. Prior to evaluation of the disproportionate costs, the score for each alternative is as follows:

Alternative A – 59

Alternative B – 56

Costs are determined to be disproportionate to benefits if the incremental cost of a more expensive alternative over that of a lower-cost alternative exceeds the incremental degree of benefits achieved by the more expensive alternative.

An evaluation of Alternative A (MNA) versus Alternative B (Pump and Treat) suggests that no significantly greater benefit is achieved through implementation of Alternative B. The timeframe for achieving cleanup of the dispersed residual groundwater contamination is similar, but it is suspected that a slight increase is gained by active operation of the pump and treat system as described for Alternative B. However, the reduction of risk and protection of human health and the environment is not any greater than with Alternative A. In addition, both alternatives are considered protective, permanent, and implementable, and have little short-term risks or public concern issues. The cost to implement Alternative B over Alternative A is significantly higher, but it does not achieve a higher incremental degree of benefit.

Thus, after consideration of the individual screening and comparative analysis and the disproportionate cost analysis, the highest scored remedial alternative was Alternative A, MNA. Alternative A was shown to be effective, reliable, implementable, and has little implementation risk.

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9. RECOMMENDED CLEANUP ACTIONS

As described previously, the feasibility evaluation primarily focused on contaminants in groundwater at the SMC and Cadet source areas and the residual groundwater concentrations. However, all applicable media (soil, groundwater, and air) have been addressed by previous remedial or interim actions or will be addressed by the remedial actions recommended in this FS report. Therefore, this FS report constitutes the final evaluation of remedial actions for all media for the SMC and Cadet sites, including the dispersed residual groundwater contamination.

The following summarizes the preferred cleanup actions for the SMC source area and the residual groundwater concentrations.

9.1 SMC Source Area

Based on the overall evaluation in Section 7, the recommended cleanup action for the SMC source area is Institutional Controls, Engineering Controls, and MNA. Together, these cleanup actions include the following technologies.

- Institutional Controls
  - Implementation of groundwater use restrictions (restrictive covenant, contaminated media management plan, or equivalent) for the SMC property to prevent groundwater from being used and/or to prevent any other potential exposure to hazardous substances at SMC.
  - Regular reporting of monitoring results to support institutional control requirements.
- Engineering Controls (Future)
  - Based on the elevated groundwater concentrations of VOCs (TCE and PCE) remaining in the source area, vapor intrusion to indoor air of an overlying building is a potential future complete exposure pathway (no current occupied building exists). A restrictive covenant for future use of the site will be established. The site is currently zoned and utilized for industrial purposes. This land use will be maintained; no residential development will be allowed.
  - Future development of the site could include office space or other occupied building use. Potential site worker exposure to indoor air via vapor intrusion will be managed by completion of a vapor intrusion assessment and evaluating if implementation of mitigation (i.e., engineering controls) is necessary for occupied buildings on the property.
- MNA (in coordination with sitewide selected remedy)
  - This alternative utilizes the sitewide MNA approach to reduce the dispersed residual groundwater contamination associated with the SMC and Cadet sites. Focused monitoring of the SMC source area will be incorporated into the overall site compliance monitoring plan to ensure that the compliance objectives are being met and contingency measures can be employed, as needed.

These cleanup actions were selected for the following reasons.

- The cleanup actions meet the following threshold requirements: protecting human health and the environment, complying with cleanup standards and ARARs, and providing for compliance monitoring.
- This alternative meets the requirement for a permanent solution with respect to eliminating the exposure pathway. Institutional controls can remain in place indefinitely through the sitewide cleanup action restoration timeframe and beyond, as needed.
- Restoration of the site will be achieved in a reasonable timeframe.
- The cleanup actions address the source area risk by isolation.

The final design of the source area cleanup actions will be determined at the time of development of the cleanup action plan and will be based on the conditions present at the time of design.

9.2 Dispersed Residual Groundwater Contamination

Based on the overall evaluation in Section 8, the recommended cleanup action for the dispersed residual groundwater contamination is MNA. This cleanup action includes the following technologies.

- Source Control
  - As described in Section 9.1 above.
- MNA
  - Development of a MNA implementation plan, which includes establishing POCs, sampling methodology, locations, and frequency, and MNA evaluation criteria.
  - Monitoring of the Site groundwater wells to verify that groundwater cleanup levels are achieved in a reasonable timeframe.
  - Regular reporting of monitoring results.
  - Development of a Cleanup Action Contingency Plan. The intent of the contingency plan is to develop methods and procedures for further assessment or actions if the cleanup action is not performing as expected.
- Institutional Controls
  - Implementation of groundwater use restrictions (restrictive covenant, contaminated media management plan, or equivalent) to prevent groundwater from being used and/or to prevent any other potential exposure to hazardous substances at the site.

These cleanup actions were selected for the following reasons:

- The cleanup actions meet the following threshold requirements: protecting human health and the environment, complying with cleanup standards and ARARs, and providing for compliance monitoring.

- There is evidence that natural biodegradation or chemical degradation is occurring and will continue to occur at a reasonable rate at the site. Therefore, MNA meets the requirement for a permanent solution.
- Groundwater modeling and contaminant trends suggest that MTCA Method B cleanup levels will be achieved in the intermediate zone within 5 to 10 years and in the deep zone generally within 20 years. This meets the reasonable timeframe criterion.
- Groundwater modeling shows that at current conditions, public drinking water receptors will not be impacted above the MCLs.

The final design of the cleanup action will be determined at the time of development of the cleanup action plan and will be based on the conditions present at the time of design.

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Tables

Table 4-1
Summary of Applicable or Relevant Federal and State Laws

Applicable Law	Reference Location	Corresponding Applicable Cleanup Levels (Y/N)
Federal		
The Clean Water Act (CWA)	33 U.S.C §1251 et seq.	Y
Safe Drinking Water Act (SDWA)	42 U.S.C §300f et seq.	N
National Toxics Rule	57 FR 60848; 40 CFR Part 131	Y
Resource Conservation and Recovery Act (RCRA)	42 U.S.C. §6901 et seq.	N
Federal Clean Air Act	42 U.S.C. §7401 et seq.	N
Endangered Species Act of 1973	16 U.S.C. §1531-1544, 87 Stat. 884	N
United States Fish and Wildlife Service (USFWS) Mitigation Policy	46 FR 7644	N
Sole Source Aquifer [Section 1424(3) of SDWA]	42 U.S.C §300f et seq., Public Law 93-523	N
The Fish and Wildlife Coordination Act of 1934	16 U.S.C. 661-667e	N
State		
State Environmental Policy Act (SEPA)	Chapter 43.21C RCW; WAC 197-11	N
Washington Water Pollution Control Act	Chapter 90.48 of RCW; WAC 173-201A	Y
Washington Hydraulic Code	Chapter 77.55 RCW; WAC 220-110	N
Washington State Clean Air Act	Chapter 70.94 RCW	N
Washington Solid Waste Management – Reduction and Recycling Act	Chapter 70.95 RCW; WAC 173-350	N
Washington Hazardous Waste Management Act	Chapter 70.105 RCW; WAC 173-303	N
Underground Injection Control (UIC) Program	Chapter 173-218 WAC	N
Compensatory Mitigation Policy for Aquatic Resources and Aquatic Resources Mitigation Act.	Chapters 75.46 and 90.74 RCW	N
Water Resources Act	Chapter 90.54 RCW	N
State Aquatic Lands Management Laws	Chapters 79.90 through 79.96 RCW; WAC 332-30	N
Healthy Environment for All (HEAL) Act	E2SSB 5141	N
Growth Mangement Act	Chapters 36.70A, 36.70.A.150, and 36.70.A.200 RCW	N

Abbreviations:
1. U.S.C = United States Code.
2. FR = Federal Register.
3. RCW = Revised Code of Washington.
4. WAC = Washington Administrative Code.

Table 5-1
Screening Cleanup Levels for COCs
SMC and Cadet Sites

		Cleanup Level Based on Receptor					
		Shallow Groundwater (µg/L)		Intermediate/Deep Groundwater (µg/L)	Soil (mg/kg)		Air (µg/m3)
Site	COC	Groundwater to Occupational Air [1]	Shallow Groundwater as Drinking Water[2]	Intermediate/Deep Zone GW as Drinking Water[2]	Direct Contact[3]	Leaching to Groundwater[3]	Inhalation of Indoor Air[4]
Cadet	PCE	53.3	**5**	5	480	**0.05**	**9.6**
	TCE	4.76	**4**	4	12	**0.025**	**0.33**
	c-DCE	NA	**16**	16	160	**0.079**	NA
SMC	PCE	53.3	5	5	480	0.05	9.6
	TCE	4.76	4	4	12	0.025	0.33
	c-DCE	NA	16	16	160	0.079	NA

Notes

1. Groundwater Protection of Indoor Air via Vapor Intrusion (Method C Industrial). Cleanup level derived using a Henry's Law Evaluation. Used for comparison check only.
2. Cleanup levels for TCE and cDCE from MTCA Method B published values (Ecology's CLARC database). Method B cleanup level for PCE exceeds the state of Washington MCL; therefore, the MCL is used.
3. Cleanup levels from MTCA Method B published values (Ecology's CLARC database).
4. Cleanup levels from MTCA Method B published values (Ecology's CLARC database).

NA indicates CLARC value is not available and/or applicable.

µg/L = micrograms per liter

mg/kg = milligrams per kilogram

$\mu g/m^3$ = micrograms per cubic meter

Table 5-2
Selected Cleanup Levels for COCs
SMC and Cadet Sites

Cleanup Level Based on Media				
Site	COC	Groundwater (µg/L)[1]	Soil (mg/kg)[2]	Air (µg/m^3)[3]
Cadet/SMC	PCE	5	0.05	9.6
	TCE	4	0.025	0.33
	c-DCE	16	0.079	NA

Notes

1. Cleanup levels for TCE and cDCE from MTCA Method B published values (Ecology's CLARC database). Method B cleanup level for PCE exceeds the state of Washington MCL; therefore, the MCL is used.
2. Cleanup levels from MTCA Method B published values (Ecology's CLARC database). Leaching to groundwater pathway.
3. Cleanup levels from MTCA Method B published values (Ecology's CLARC database).

NA indicates CLARC value is not available and/or applicable.

µg/L = micrograms per liter

mg/kg = milligrams per kilogram

µg/m^3 = micrograms per cubic meter

Table 7-1
Initial Screening and Evaluation of Technologies for Soil
SMC Source Area, Vancouver, WA

General Response Actions	Technology	Description	Screening Criteria: Effectiveness	Screening Criteria: Implementability	Screening Criteria: Cost	Screening Comments
NO ACTION	None	No Action	Not effective in achieving RAOs.	Easy to implement.	No capital or O&M costs incurred.	Does not meet threshold criteria.
INSTITUTIONAL CONTROLS	Deed Restrictions/ Soil Management Plan/Signage	Can prevent disturbance of any required soil cap or other engineering controls, address notification of Site hazards, and ensure proper controls are implemented during future Site activities. Protocols will be established for handling and managing contaminated soils during future Site work to protect workers, public health, and the environment.	Effective at regulating direct contact, but is not effective at preventing migration. Does not address risks associated with migration and does not address contaminant reduction.	Deed restrictions require negotiation and agreement with affected property owners. However, Port owns the property so controls are easily implementable.	Low costs associated with implementing soil management plan.	Institutional controls are useful technologies to address risks during cleanup and to address residuals remaining after primary cleanup.
	Monitoring	Laboratory analysis of soil samples.	Effective for documenting Site conditions to evaluate migration and current Site risks. Does not address contaminant reduction.	Moderately easy to implement. Collection of samples beneath structures more difficult.	Low to moderate costs for monitoring.	Applicable to document Site conditions and effectiveness of any treatment. Must be used in conjunction with other technologies.
ENGINEERING CONTROLS	Access Restrictions	Use of fencing or other controls to limit access to impacted soils.	Effective at preventing direct contact, but is not effective at preventing migration. Does not address contaminant reduction.	Limiting access to area precludes potential future development.	Low costs associated with implementing controls.	Retain for potential use, but likely used in conjunction with other technologies.
	Control of Building HVAC System	Use HVAC system to maintain positive pressure in buildings.	May be effective in preventing migration of volatile contaminants from soil into indoor air as long as a pressure differential is maintained between building and subsurface soil. Does not address migration to other media or contaminant reduction. Generally used in conjunction with other engineering controls.	Can be easy to implement in buildings with existing HVAC systems. No current structures at site.	Low costs associated with implementing these controls. Operational costs include additional heating of outdoor air.	There are no current site structures; thus, not applicable.
	Vapor Barriers	Installation of low-permeability barriers beneath structures to prevent vapor intrusion. Alternatively, can place sealants on floor slabs or paved surfaces.	Effective in preventing migration of volatile contaminants from soil into indoor air. Does not address contaminant reduction.	Easy to implement for new building construction. Products readily available. There are no current structures.	Moderate cost for vapor barriers and surface sealing.	There are no current site structures; thus, not applicable.
	Sub-Slab Depressurization or Sub-Floor Venting	Installation of sub-slab venting systems or suction pits to create negative pressures beneath structures to prevent vapor migration to ambient air. Vapors are collected in the suction pit or venting pipes below the building and vented to the outside of the building, either passively or with fans.	Effective in preventing migration of subsurface volatile contaminants from soil into ambient air. Does not address contaminant reduction.	Easy to implement for new building construction. Existing buildings could be retrofitted. Materials and construction methods are readily available. Generally most suitable for buildings with slab-on-grade floors.	Moderate costs for system installation.	There are no current site structures; thus, not applicable.
CONTAINMENT	Capping	Installation of cap (e.g., soil, asphalt, impermeable liner) over impacted soils.	Effective at preventing direct contact to contaminated soils. May be effective in controlling volatilization to indoor air and outdoor air depending on construction (addressed by vapor barrier technology). Low-permeability caps can reduce rainwater infiltration thereby reducing the potential for contaminants leaching from soil.	Much of impacted soil area currently capped by gravel (preventing direct contact). Easy to implement new caps as needed if redevelopment occurs.	No cost to implement within currently capped areas. Marginal costs to implement capping in new development is low.	Retain this technology for potential use, but must be used in conjunction with other technologies.
REMOVAL/OFF-SITE DISPOSAL	Excavation	Excavate contaminated soils with off-site disposal.	Effective for removing source material from site. Addresses direct exposure pathways, vapor intrusion, and migration by reducing contaminant concentrations and mass. May also improve groundwater conditions as potential for leaching is reduced. Significant excavation was already completed as an initial action.	Implementation involves conventional construction equipment and methods. Difficult to implement in areas with limited access (i.e., under buildings, rail-lines, utility corridors). Soil contamination left in-place at the site is relatively deep and much is below the groundwater table, which would complicate any further excavation.	High costs due to required soil volumes, depth, and groundwater table.	Source area soils are primarily located at and below the water table, thus excavation is extremely difficult to implement.
	Off-site Disposal	Off-site disposal at licensed landfill. Soils would require characterization to determine type of disposal facility (hazardous or non-hazardous).	Effective for containing contaminated soils and reducing risks associated with direct exposure.	Implementation involves transportation of contaminanted soils on public roads for potentially long distances. The nearest permitted hazardous waste landfill is located in Arlington, OR (140 miles away).	Moderate to high costs depending upon soil volumes.	Excavation not retained as technology so disposal is not applicable.

Table 7-1
Initial Screening and Evaluation of Technologies for Soil
SMC Source Area, Vancouver, WA

General Response Actions	Technology	Description	Screening Criteria: Effectiveness	Screening Criteria: Implementability	Screening Criteria: Cost	Screening Comments
IN SITU PHYSICAL/ CHEMICAL/ THERMAL TREATMENT	Soil Vapor Extraction (SVE)	SVE involves extraction of vapors from the vadose zone using system of vertical wells or horizontal vents and vacuum pumps/blowers. Treatment of the discharge may be required; for chlorinated VOCs, treatment is typically achieved using carbon adsorption.	Highly effective at removing volatile organic compounds (VOCs) from unsaturated soils and controlling vapor migration into buildings. Less effective in fine-grained soil.	Applicable for treatment of volatile Site contaminants. Would require installation of new well points and associated infrastructure. Would be most effective when used in conjunction with air sparging technology for groundwater.	Moderate to high capital and O&M costs.	Technology is applicable to Site conditions.
	Electrokinetic Separation	Application of a low-intensity direct current through the soil between electrodes that are divided into a cathode array and an anode array. This mobilizes charged species, causing ions and water to move toward the electrodes.	Effective for removing inorganic ions and polor organics from saturated soil. Most effective in low-permeability soils (particularly clays).	Requires significant power supply and not suitable for use in inhabited areas during implementation. Would require saturation of shallow soils.	High implementation cost.	Not suitable to Site conditions and not compatible with COIs (i.e., non-polar organics).
	Fracturing	Development of cracks in low-permeability or overconsolidated soils to create passageways that increase the effectiveness of other *in situ* processes and extraction technologies.	Effective in conjunction with other technologies (e.g., vapor extraction) in deep, fine-grained or consolidated soils. Not effective with shallow soil.	Specialized equipment and personnel needed to safely implement.	Moderate implementation cost.	Not suitable for shallow sandy/silty soil at site.
	Chemical Oxidation	Chemically converts hazardous contaminants to less toxic compounds. Effective in destroying organic contaminants and oxidizing inorganic contaminants to less toxic/less mobile forms. Can include oxidant chemicals such as peroxides, permanganates, or ozone.	Can be highly effective at destruction of organic contaminants. Can be difficult to achieve full coverage (contact between oxidant and COIs), particularly in unsaturated soils.	Equipment and vendors are readily available. Delivery difficult in unsaturated soils.	High implementation cost.	Technology retained.
	Soil Flushing	Water (or water containing an additive to enhance contaminant solubility) is circulated through the soil to desorb contaminants, recovered, and treated. Single-well implementation can involve injection followed by removal (such as via vacuum truck).	Less effective for organic contaminants and would require groundwater extraction/treatment operation. Can be effective at removing bound separate-phase liquids from vicinity of well (less suited to widespread impacts).	Difficult to maintain control of amended water. Inefficient process for unsaturated soils.	High implementation cost.	Not retained because less suitable to Site contaminants (volatile organics), less effective in shallow unsaturated zone.
	Solidification/ Stabilization/ Vitrification	Contaminants are physically bound or enclosed within a stabilized mass (solidification and vitrification), or chemical reactions are induced between the stabilizing agent and contaminants to reduce their mobility (stabilization).	Most suitable to inorganic contaminants.	Not suitable for use in inhabited areas during implementation. Volatilization of organics would need to be controlled during implementation.	High implementation cost.	Not retained because less suitable to Site contaminants and Site conditions compromise effectiveness. More cost-effective methods of addressing volatile contaminants are available.
	Thermally-Enhanced Removal	High-energy injection (steam/hot air, electrical resistance, electromagnetic, fiber optic, radio frequency) is used to increase the recovery rate of semi-volatile or non-volatile compounds to facilitate extraction (enhanced volatilization or decreased viscosity).	Most suitable to semi-volatile organic contaminants or viscous compounds that are not otherwise extractable with vapor extraction or fluid extraction technologies.	Generally used in conjunction with SVE system or other recovery system (i.e., groundwater extraction). Has high energy requirements.	High implementation cost.	Not retained because less suitable for Site contaminants and high cost.
IN SITU BIOLOGICAL TREATMENT	Bioventing	Bioventing involves inducing air or oxygen flow in the unsaturated zone to promote biodegradation of hydrocarbons and VOCs. Applications include injection of air or oxygen into subsurface, or extraction of air at rates lower than SVE. Due to concerns with uncontrolled migration of VOCs associated with air injections, only air extraction applications will be considered for the site.	Effective in reducing contaminant concentrations in unsaturated soils. As with SVE, effectiveness can be limited by short-circuiting. Less effective for chlorinated solvent hydrocarbons (typically biodegrade anaerobically).	This technology may interfere with anaerobic degradation of chlorinated solvents. Requires air emission testing and modeling to determine if off-gas treatment is required.	Moderate capital and O&M costs.	Would not efficiently promote degradation of chlorinated solvents.

Please refer to note at end of table.

Table 7-1
Initial Screening and Evaluation of Technologies for Soil
SMC Source Area, Vancouver, WA

General Response Actions	Technology	Description	Screening Criteria: Effectiveness	Screening Criteria: Implementability	Screening Criteria: Cost	Screening Comments
IN SITU BIOLOGICAL TREATMENT—CONTINUED	Enhanced Bioremediation (Bioaugmentation, Biostimulation)	Adding nutrients, electron acceptor, or other amendments to enhance bioremediation.	Effective in saturated soils with addition of suitable amendments. Strategic placement of amendments can be effective in conjunction with other technologies. Treatment of vadose zone soils requires means of providing adequate soil moisture.	Temporary injection points would be used;no permanent injection infrastructure exists. The implementability of the technology has been positively demonstrated.	Low to moderate costs depending on number of injection events required.	Not suitable for shallow unsaturated soil. Retained as groundwater technology that would also address saturated soil.
	Land Treatment	Combination of aeration (tilling) and amendments to enhance bioremediation in surface soils.	Effective for organic contaminants in shallow soil that can be degraded aerobically.	Common agricultural equipment can be used to process shallow soil. Less efficient for chlorinated solvent hydrocarbons (degraded anaerobically).	Low to moderate implementation cost.	Not retained because incompatible with Site contamination, structures, or depth to contaminants.
	Monitored Natural Attenuation	Using natural processes to reduce contaminant concentrations to acceptable levels. Process is closely monitored to verify exposures are acceptable prior to concentrations reaching acceptable levels.	May be effective, especially in areas of low concentrations, but is dependant upon Site conditions. Not efficient for source areas; other technologies will likely be required.	Easy to implement. Monitoring of unsaturated soil would require repeated intrusive sampling events. Likely will require significant timeframe to reach cleanup goals.	Moderate costs for monitoring.	May be applicable to address residual low-concentration contamination not efficiently addressed by active remediation.
	Phytoremediation	Phytoremediation is a process that uses plants to remove, transfer, stabilize, and destroy contaminants in soil or sediment.	Can be effective at removing a variety of organic and inorganic compounds from soil through plant uptake in vicinity of roots (rhizosphere).	Requires significant land area suitable for large plants. Contamination must be accessible to plant root zones. Large variety of COIs may not all be addressed by compatible plant species.	Moderate implementation cost.	Not retained because incompatible with Site use. Unlikely to be effective for all COIs.
EX SITU PHYSICAL/ CHEMICAL/ THERMAL TREATMENT	Chemical Extraction	Excavated soil is mixed with an extractant, which dissolves the contaminants. The resultant solution is placed in a separator to remove the contaminant/extractant mixture for treatment.	Most suitable to removal of semi-volatile and inorganic contamination from excavated soil. Less effective in fine-grained soils.	Can be effective in removing most organic contaminants from soil. Difficult to remove all contaminant/extractant mixture from soil—would likely require finish treatment. Requires area for soil treatment or transport to off-site facility. Extractant fluid would need subsequent treatment process or disposal.	Moderate to high implementation cost.	Not retained because excavation technology was not retained.
	Dehalogenation	Reagents are added to soils contaminated with halogenated organics to remove halogen molecules.	Effective at detoxifying halogenated organic compounds in excavated soil. Less effective in fine-grained soils.	Requires area for soil treatment or transport to off-site facility. Risks associated with handling of reagents.	Moderate to high implementation cost.	Not retained because excavation technology was not retained.
	Incineration	High temperatures are used to combust (in the presence of oxygen) organic constituents in hazardous wastes.	Effective at removing organic contaminants from excavated soil.	Requires transport to off-site facility.	High implementation cost.	Not retained because excavation technology was not retained.
	Soil Washing	Contaminants are separated from the excavated soil with wash-water augmented with additives to help remove organics.	Most suitable for semi-volatile organics or inorganic contamination.	Requires area for soil treatment or transport to off-site facility. Resultant fluid would need subsequent treatment process or disposal.	Moderate to high implementation cost.	Not retained because excavation technology was not retained.
	Solar Detoxification	Contaminants are destroyed by photochemical and thermal reactions using ultraviolet energy in sunlight or artificial UV light. Usually involves application of catalyst agent.	Can be effective at treating a variety of organic compounds. Most effective when used with catalyst agent (e.g., titanium dioxide).	Implementation with sunlight limited by availability (not effective during nighttime and limited effectiveness in cloudy/wet seasons). Requires area for treatment or transport to off-site facility.	Low to moderate implementation cost.	Not retained because excavation technology was not retained.
	Thermal Desorption/ Pyrolysis/ Hot Gas Decontamination	Waste soils are heated to either volatilize (desorption and hot gas) or to anaerobically decompose (pyrolysis) organic contaminants. Off-gas is collected and treated.	Effective at removing organic materials from excavated soil (particularly volatile organics). Pyrolysis generally used for semi-volatiles or pesticide wastes.	Requires transport to off-site treatment facility. Treatment of chlorinated hydrocarbons difficult (may generate acid in off-gas). Off-gas treatment required.	Moderate to high implementation cost.	Not retained because excavation technology was not retained.
	Separation	Separation techniques concentrate contaminated solids through physical, magnetic, and/or chemical means. These processes remove solid-phase contaminants from the soil matrix.	Effective only for removal of solids with distinct physical characteristics (size, composition, etc.).	Commercial equipment available for separation by size (sieving) or for removing iron (magnetic removal).	Low to moderate cost.	Not compatible with Site COIs.

Table 7-1
Initial Screening and Evaluation of Technologies for Soil
SMC Source Area, Vancouver, WA

General Response Actions	Technology	Description	Screening Criteria			Screening Comments
			Effectiveness	Implementability	Cost	
EX SITU BIOLOGICAL TREATMENT	Biopiles	Excavated soils are mixed with soil amendments and placed in aboveground enclosures and aerated with blowers or vacuum pumps.	Effective for removal of organic contaminants from excavated soil. Most effective with control of moisture, heat, nutrients, oxygen, and pH to enhance biodegradation.	Requires area for soil treatment or transport to off-site facility. May generate leachate that would need to be collected and managed.	Low to moderate cost.	Not retained because excavation technology was not retained.
	Composting	Excavated soil is mixed with bulking agents and organic amendments to promote microbial activity.	Effective for removal of organic contaminants from excavated soil. Most effective with control of moisture, heat, nutrients, oxygen, and pH to enhance biodegradation.	Requires area for soil treatment or transport to off-site facility. May generate leachate that would need to be collected and managed.	Low to moderate cost.	Not retained because excavation technology was not retained.
	Landfarming	Excavated soil is placed in lined beds and periodically tilled to aerate the soil.	Effective at removing organic contaminants from excavated soil.	Requires area for soil treatment or transport to off-site facility. Common agricultural equipment can be used to process soil in treatment beds.	Low to moderate cost.	Not retained because excavation technology was not retained.
	Slurry Phase Biological Treatment	An aqueous slurry of soil, sediment, or sludge with water and other additives is mixed to keep solids suspended and microorganisms in contact with the soil contaminants. When complete, the slurry is dewatered and the soil is disposed of.	Can be effective at treating a variety of organic compounds.	Requires area for soil treatment or transport to off-site facility. Slurry dewatering generates water that requires treatment or disposal.	Moderate to high implementation cost.	Not retained because excavation technology was not retained.

Note:

1. Shading indicates technology has been eliminated from consideration.

Table 7-2
Initial Screening and Evaluation of Technologies for Groundwater
SMC Source Area, Vancouver, WA

General Response Actions	Technology	Description	Screening Criteria: Effectiveness	Screening Criteria: Implementability	Screening Criteria: Cost	Screening Comments
NO ACTION	None	No Action	Not effective in achieving RAOs.	Easy to implement.	No capital or O&M costs incurred.	Does not meet threshold criteria.
INSTITUTIONAL CONTROLS	Groundwater Use Restrictions	Restricted use of Any Zone groundwater.	Effective at preventing direct contact, but is not effective at preventing migration. Does not address risks associated with vapor intrusion (future building) and does not address contaminant reduction.	May require deed restrictions to prevent off-site and on-site groundwater use. No planned use of on-site groundwater.	Low costs associated with implementing restrictions (off-site deed restrictions could require significant compensation).	Applicable technology used in conjunction with other technologies.
	Monitoring	Laboratory analyses of groundwater samples.	Effective for documenting Site conditions to evaluate migration and current Site risks. Does not address contaminant reduction.	Easy to implement. On-site and off-site monitoring wells already exist.	Low to moderate costs for monitoring.	Applicable to document Site conditions and effectiveness of any treatment.
ENGINEERING CONTROLS	Control of Building HVAC System	Use HVAC system to maintain positive pressure in buildings.	May be effective in preventing migration of volatile contaminants from shallow groundwater into indoor air as long as a pressure differential is maintained between building and subsurface soil. Does not address contaminant reduction. Generally used in conjunction with other engineering controls.	Can be easy to implement in buildings with existing HVAC systems.	Low costs associated with implementing these controls. Operational costs include additional heating of outdoor air.	Potential for future site structures.Technology retained for potential use in conjunction with other technologies.
	Vapor Barriers	Installation of low-permeable barriers beneath buildings to prevent vapor intrusion.	Effective in preventing migration of volatile contaminants from shallow groundwater into indoor air. Does not address contaminant reduction.	Easy to implement for new building construction. Some protection from existing slab-on-grade construction - improvement would require sealing floor from top surface.	Moderate cost for surface application. High cost for sub-floor installation (removal and replacement of slab floor).	Technology retained for potential use in conjunction with other technologies.
	Sub-Slab Depressurization or Sub-Floor Venting	Installation of sub-slab or sub-floor venting systems or suction pits to create negative pressures beneath structures to prevent vapor migration to ambient air. Vapors are collected in the suction pit or venting pipes below the building and vented to the outside of the building, either passively or with fans.	Effective in preventing migration of subsurface volatile contaminants from groundwater into ambient air. Does not address contaminant reduction.	Easy to implement for new building construction. Existing buildings can be retrofitted. Materials and construction methods are readily available. Generally most suitable for buildings with slab-on-grade floors.	Moderate costs for retrofitting existing structures - would require cutting slab floor to install vapor pits.	Applicable technology for addressing vapor migration to indoor air. Retained for use in conjunction with other technologies
	Alternative Water Supply	Develop new water supply in uncontaminated area to provide potable water in the areas of impact.	Effective in preventing use of contaminated groundwater. No contaminant reduction. Does not address risks associated with vapor intrusion (future building).	Conventional construction, requires local and WRD approvals.	High capital costs, low to moderate O&M costs.	Not retained as viable technology. Site groundwater not used. Does not address off-site use of groundwater as drinking water.
	Wellhead Treatment	Treatment at individual impacted water supply wells with use of *Ex-Situ* Physical/Chemical/Thermal treatment technology.	Effective in reducing contaminant concentrations in groundwater prior to use. Does not address risks associated with vapor intrusion (future building). No groundwater pumping is anticipated at the site.	An extraction well is already in use at the site as part of the interim action. Treatment units for large-scale municipal systems would be difficult to implement. Requires ongoing testing and system maintenance to remain effective.	High capital costs and O&M costs for municipal-scale treatment system.	An extraction is already in use at the site as part of the interim action. A potential municipal treatment unit would involve many responsible parties, require significant treatment volumes, and would be cost prohibitive. Technology not retained. .

Table 7-2
Initial Screening and Evaluation of Technologies for Groundwater
SMC Source Area, Vancouver, WA

General Response Actions	Technology	Description	Screening Criteria			Screening Comments
			Effectiveness	Implementability	Cost	
CONTAINMENT	Vertical Barrier	Installation of vertical barriers (e.g., sheet piling, soil-bentonite slurry wall, grout, etc.) to prevent migration of groundwater contamination.	Effective at preventing lateral migration. Requires keying into underlying confining unit. Hydraulic control often necessary as supplemental measure to achieve containment. Cannot prevent downward migration.	Difficult to implement, particularly given depth to groundwater and overall size of groundwater plume. Additionally, groundwater in the Shallow and Intermediate Zones have different flow directions, so multiple barriers would be required to contain all groundwater. Site lacks suitable confining unit at reasonable depth. Some Site contaminants have specific gravity greater than 1 (sinkers). Specialized equipment required for construction.	High capital costs, low to moderate O&M.	Not practical for source area groundwater, no signficant confining unit to prevent lateral migration beneath barrier. Several more cost-effective technologies are available. Technology not retained.
	Pumping / Hydraulic Containment	Extraction well(s) with submersible pumps to lower the water table and create hydraulic gradients that direct contaminant migration into the extraction well. Extracted groundwater would require treatment before discharge (see *Ex-Situ* Physical/Chemical/ Thermal Treatment).	Effective in porous soils for preventing further contaminant migration. May also be used in conjunction with other technologies.	Implementable; pumping rate, depth of extraction well, and design can be tailered to capture zone requirements. Discharge of treated water would need to be permitted.	Moderate to high capital costs. Extraction well and associated infrastructure would be required. Moderate to high O&M costs.	Retained as applicable technology in Pump and Treat (below).
REMOVAL/DISCHARGE	Pumping (Pump & Treat)	Extraction well(s) with submersible pumps to remove contaminated groundwater with goal of plume reduction and aquifer restoration. Treatment of extracted groundwater likely required before discharge (see *Ex-Situ* Physical/Chemical/ Thermal Treatment).	Effective in porous soils for preventing contaminant migration and removing contaminants from extracted groundwater. May also be used in conjunction with other technologies.	Extraction well already in place and operational. Modifcation to target source area may be required. Discharge of treated water currently permitted.	Extraction well already in place and operational. Moderate to high O&M costs.	Applicable technology for Site conditions. Currently is being used as an interim action.
	Subsurface Drains	Trench or horizontal boring filled with porous media—gravity drains to sump/pump. Treatment of extracted groundwater likely required before discharge (see Ex-Situ Physical/Chemical/Thermal Treatment).	Effective for shallow groundwater at preventing contaminant migration. Not effective for impacted deeper groundwater. May also be used in conjunction with other technologies.	Not practical to install at groundwater depths.	Moderate to high capital and O&M costs.	Not retained since groundwater depth greater than appropriate for subsurface drains.
	Discharge to Sewer / Surface Water	Discharge of water (which may require treatment) into surface water, storm sewer, or sanitary sewer.	Effective for disposal of extracted groundwater. Already in use at site. Treatment of water (physical and chemical) is also in existence prior to disposal.	State and federal legislation regulate discharge into river. NPDES permit (already obtained) required to discharge treated water into the Columbia River.	Moderate cost to transport treated water to river. Infrastructure has already been constructed for the Pump and Treat interim action.	Applicable for discharge of extracted groundwater. Currently is being used as part of an interim action.
	Discharge to Reinjection Wells	Discharge of water (which may require treatment) into aquifer by reinjection wells.	Moderate effectiveness, depending upon whether injection wells can be adequately located to prevent plume spreading.	Underground injection control permit required for reinjection.	Moderate to high capital and O&M costs for reinjection wells.	Applicable for discharge of extracted groundwater. UIC permit required for injection wells (treatment needed to meet UIC discharge requirements).
	Reuse	Reuse of treated water for non-potable use such as irrigation or wetland enhancement.	Effective for treated, extracted groundwater.	A suitable use would need to be identified that can accommodate a steady flow rate in all seasons and within reasonable proximity.	Low to high costs depending upon storage and pumping requirements, and length of discharge piping.	No identified potential use suitable for flow rate expected from extraction system.
	Excavation	Excavate contaminated soils with off-site disposal.	Effective for removing source material from site. Addresses direct exposure pathways, vapor intrusion, and migration by reducing contaminant concentrations and mass. May also improve groundwater conditions as potential for leaching is reduced. Significant excavation was already completed as an initial action.	Implementation involves conventional construction equipment and methods. Difficult to implement in areas with limited access (i.e., under buildings, rail-lines, utility corridors). Soil contamination left in-place at the site is relatively deep and much is below the groundwater table, which would complicate any further excavation.	High costs due to required soil volumes, depth, and groundwater table.	Source area soils are primarily located at and below the water table, thus excavation is extremely difficult to implement.

Table 7-2
Initial Screening and Evaluation of Technologies for Groundwater
SMC Source Area, Vancouver, WA

General Response Actions	Technology	Description	Screening Criteria: Effectiveness	Screening Criteria: Implementability	Screening Criteria: Cost	Screening Comments
EX SITU PHYSICAL/ CHEMICAL/ THERMAL TREATMENT	Adsorption	Concentrating solutes on the surface of a sorbent material, such as activated carbon, to remove the solute from the bulk liquid.	Highly effective at removing many organic compounds from extracted water stream.	Applicable for treatment of Site contaminants in extracted water. Treatment equipment is readily available.	Moderate capital and O&M costs.	Applicable for treatment of extracted water.
	Air Stripping	Volatile organics are partitioned from extracted groundwater by increasing surface area exposed to air.	Highly effective at removing many VOCs from extracted water stream. May require treatment of vapor effluent.	Applicable for treatment of Site contaminants in extracted water. Treatment equipment is readily available. Requires air emission testing and modeling to determine if off-gas treatment is required.	Low to moderate capital and O&M costs. Higher costs if off-gas treatment needed.	Applicable for treatment of extracted water. Currently is being used as part of an interim action. Infrastructure is present.
	Separation/ Reverse Osmosis	Extracted groundwater is forced through a selectively permeable membrane under pressure. Water is allowed to pass through the membrane while contaminants are trapped.	Highly effective at removing many contaminants from the extracted water stream.	Applicable for treatment of Site contaminants in extracted water. Treatment equipment is readily available.	High capital and O&M costs.	Not retained since more cost-effective treatment methods exist for removal of Site contaminants from water.
	Ultraviolet (UV) Oxidation	Ultraviolet radiation is used to destroy organic contaminants as water flows through treatment cell.	Effective at removing many organic contaminants from the extracted water stream.	Applicable for treatment of Site contaminants in extracted water. Treatment equipment is readily available.	High capital and O&M costs.	Not retained since more cost-effective treatment methods exist for removal of Site contaminants from water.
	Sprinkler Irrigation	Contaminated water is distributed through a pressurized sprinkler irrigation system (generally onto a highly porous media), allowing transfer of VOCs from aqueous phase to vapor phase.	Effective at removing many organic contaminants from the extracted water stream. Simpler system than more aggressive treatment technologies (such as air stripping).	Applicable for treatment of Site contaminants in extracted water, but requires significant treatment system area.	Low to moderate capital and O&M costs.	Not retained since land use not compatible with Site conditions.
	Ion Exchange	Ion exchange removes ions from the aqueous phase by exchange with counter ions on the exchange medium.	Effective for treatment of inorganic contaminants.	Treatment equipment is readily available.	Moderate to high capital and O&M costs.	Not compatible with Site contaminants.
	Precipitation/ Coagulation/ Flocculation	This process transforms dissolved contaminants into an insoluble solid, facilitating the contaminant's subsequent removal from the liquid phase by sedimentation or filtration.	Effective for treatment of inorganic contaminants.	Treatment equipment is readily available.	Moderate to high capital and O&M costs.	Not compatible with Site contaminants.
EX SITU BIOLOGICAL TREATMENT	Bioreactors / Trickling Filter	Contaminants in extracted groundwater are put into contact with microorganisms in attached or suspended growth biological reactors.	Effective at removing many organic contaminants from the extracted water stream. May be less effective during cold weather. May not reach treatment goals without follow-up polishing treatment.	Difficult to maintain effectiveness with variable operating parameters (i.e., influent concentrations, ambient concentrations). Requires significant area for reactors. Would require significant maintenance.	Moderate capital costs and moderate to high O&M costs	Not retained since more cost-effective treatment methods exist for removal of Site contaminants from water.
	Constructed Wetlands	Utilizes natural geochemical and biological processes inherent in an artificial wetland ecosystem to remove contaminants from extracted groundwater.	Highly effective at removing many organic and inorganic contaminants from the extracted water stream.	Requires large land area to implement. May introduce attractive nuisance hazard for local wildlife.	Moderate to high capital costs. Low O&M costs. Would require signficant land area availability and pumping distances.	Not retained since land use not compatible with Site conditions.
IN SITU BIOLOGICAL TREATMENT	Enhanced Bioremediation (Bioaugmentation, Biostimulation)	Adding nutrients, electron acceptor, or other amendments to enhance bioremediation. Addition of specific microbial cultures can be included if indigenous species not suitable for complete degradation of COIs.	Effective with addition of suitable amendments. Strategic placement of amendments can be effective in conjunction with other technologies. Treating source-area concentrations requires significantly longer time to complete. Has been demonstrated as an effective technology at nearby sites.	Equipment and technology for direct injection are readily available. Amendments for stimulating reductive dechlorination are commercially available.	Low to moderate costs depending on number of injection events required.	Applicable technology for Site contaminants.

Table 7-2
Initial Screening and Evaluation of Technologies for Groundwater
SMC Source Area, Vancouver, WA

General Response Actions	Technology	Description	Screening Criteria			Screening Comments
			Effectiveness	Implementability	Cost	
	Monitored Natural Attenuation	Using natural processes to reduce contaminant concentrations to acceptable levels. Process is closely monitored to verify exposures are acceptable prior to concentrations reaching acceptable levels.	May be effective, especially in areas of low concentrations (near plume boundaries), but not effective for high concentrations, such as at the source area. Other technologies will likely be required.	Easy to implement. Monitoring wells already exist. Likely would require significant timeframe to reach cleanup goals.	Low costs for monitoring.	Not retained since not suitable for source area contamination.
	Phytoremediation	Phytoremediation is a process that uses plants to remove, transfer, stabilize, and destroy contaminants.	Can be effective at removing a variety of organic and inorganic compounds from contaminated groundwater through plant uptake.	Requires significant land area suitable for large plants. Contamination must be accessible to plant root zones.	Moderate implementation cost.	Not retained because incompatible with Site conditions or deep contamination.
IN SITU PHYSICAL/ CHEMICAL/ THERMAL TREATMENT	Aeration / Air Sparging	Increasing the contact between water and air to enhance volatilization. Air sparging involves injecting air into saturated matrices.	Effective for volatile contamination. Use in conjunction with shallow vapor extraction to prevent uncontrolled vapor migration.	Equipment and technology for air sparging are readily available.	Moderate to high capital costs. Low O&M costs.	Applicable technology for source area contaminants.
	Multi-Phase Extraction (MPE)	MPE provides simultaneous extraction of soil vapor, contaminated groundwater, and NAPL using single vacuum pump, multiple in-well pumps, or bioslurping.	Effective for source removal at Site with moderate to low soil permeability. Also effective for treating impacted groundwater in the source area.	Equipment and technology for MPE are readily available. Treatment of recovered soil vapors and groundwater would be required prior to discharge.	Moderate to high capital and O&M costs. Higher costs if vapor treatment needed.	Relatively high cost. Inefficient approach for moderately high hydraulic conductivity at the site.
	Steam Flushing/ Steam Stripping	Steam is injected into the contaminated aquifer to vaporize less volatile organics.	Used in conjunction with vapor recovery. May be effective for increasing usability of SVE for low-volatility compounds.	Equipment and technology are readily available. Treatment of recovered vapors would likely be required.	High capital costs.	Not retained since not beneficial to removal of Site COIs.
	Chemical Oxidation	Chemically converts hazardous contaminants to less toxic compounds. Effective in destroying organic contaminants (including LNAPL) and oxidizing inorganic contaminants to less toxic/less mobile forms. Can include oxidant chemicals such as peroxides, permanganates, or ozone.	Effective in destroying organic contaminants (including free product) and oxidizing inorganic contaminants to less toxic/less mobile forms. Difficult to provide adequate coverage in subsurface. May cause settling in organic soils. Most applicable to source-area concentrations or NAPLs.	Equipment and vendors are readily available. Less efficient at addressing diffuse concentrations of Site COIs.	High implementation costs (potentially requiring multiple applications).	Applicable technology for source area contaminants.
	Passive/Reactive Treatment Walls	Barriers placed across groundwater movement that allows passage of water while facilitating degradation or removal of contaminants.	Can be effective in the remediation of dissolved-phase VOC contamination. May not be suitable for source area remediation. Not cost-effective for very wide or deep plumes. Iron filings have been demonstrated to be effective at removal of HVOCs.	Depth of shallow aquifer would require installation by drilled methods (rather than open excavation). Specialty equipment needed for installation. Barrier materials readily available (iron and sand).	High costs for installation. Moderate costs for performance and compliance monitoring, and periodic maintenance.	Not practical for source area groundwater, no signficant confining unit to prevent lateral migration beneath barrier. Several more cost-effective technologies are available. Technology not retained.

Note:

1. Shading indicates technology has been eliminated from consideration.

Table 7-3
Comparative Analysis of Remedial Alternatives for the SMC Source Area

Alternative		Selection Criteria**							Sum	Cost Effectiveness*
		Protectiveness	Permanence	Long-term Effectiveness	Implementability	Short-Term Risk	Reduce Disparate Impacts	Public Concerns		
Alternative A:	Institutional Controls, Engineering Controls, and MNA	Protects all exposure scenarios via institutional or engineering controls. Does not attain cleanup standards or RAOs quickly. Source area has been been reduced to SMC only, which can be controlled.	Controls future land use and restricts groundwater use; prevents all exposure pathways. Easy to maintain controls.	Effective at eliminating exposure and institional controls can remain in-place indefinantly; does not achieve cleanup levels qucikly.	Can be implemented in short order. Restrictive covenant can be recorded on Port-owned property. Engineering controls (future) are well known and easy to implement during new building construction.	Must meet Agency acceptance; does not remove contaminants, only isolates them from exposure.	Provides isolation of contaminants from the community. Long-term timeframe for cleanup is higher than for active alternatives.	The neighborhood has witnessed several interim actions since discovery, and there has been some concern regarding the contamination. Alternative does not remove contaminants, which could be public perception issue.		$120,000
	Score	**7**	**9**	**7**	**10**	**8**	**7**	**6**	**54**	**5**
Alternative B:	Remedial Excavation of Source Area	Meets effectiveness criteria by preventing potential exposure to contaminants. Direct removal at one time. Places soil in a permitted landfill.	High reliability due to excavation and off-site disposal of the impacted soil. Soil is placed at a permitted landfill.	Effectively removes the impacted soil and disposes off-site. However, this is direct removal at one time, with no long-term monitoring.	Excavation is a common method and disposal options exist. However, groundwater will be encountered. Dewatering and shoring will be required, and extracted water needs to be treated before discharging. Site access is limited. Clean overburden needs to be stockpiled, and space is limited.	High incremental implementation risk. There is increased risk to excavation workers to implement this alternative. There is potential that de-watering can not occur. The exact volume to excavate is not known. Potential impacts from soil contaminants to the surrounding community and environment can be minimized through implementation of BMPs specified in a CMMP. Confirmation sampling will need to be conducted to confirm that remedial excation achives site RAOs.	Provides removal of source area contaminants and places them off-site in landfill; thus, reducing future potential impacts from these contaminants. However, implementation of large-scale excavation could impact nearby community through vehicle traffic, dust emmissions, potential spills, and noise.	This alternative addresses public concern by actively removing the source and disposing the contamination off-site. May be some concern of a large-scale excavation project near the FVN.		$900,000
	Score	**8**	**8**	**8**	**3**	**4**	**5**	**7**	**43**	**1**
Alternative C:	Air Sparging and Soil Vapor Extraction	This is a very effective technique for removing volatile organic compounds from groundwater. However, soil at the site has very low permeability, and the radius of influence (ROI) for each well would be small.	AS/SVE systems have proven reliable in extracting volatile organic compounds from groundwater. The Port would have to maintain the AS/SVE system until the site can be closed, and Ecology determines an NFA. This technique includes some risk of rebound.	Proven to be a very effective technique. However, long-term maintanence is necessary, and there is some risk of rebound after the system is shut off.	Requires design, engineering, and more consultation with regulatory agencies. Easy to implement on currently mostly vacant site. However, the source area is a thin layer, with low permeability, and groundwater will be encountered. Exact placement of wells is necessary for success. Requires long-term system operation and maintenance.	Minimum risk to construction workers. Potential impacts from soil contaminants to the surrounding community and environment can be minimized through implementation of BMPs specified in a CMMP.There is a risk of placing the AS wells in the wrong location due to several factors: depth and elevation of the fine grain sand layer (source area) is not precisely known; the source area layer is thin; and, this layer has low permeability, making the radius of influence small.	Provides removal of source area contaminants through in-situ remediation; thus, reducing future potential impacts from these contaminants. However, implementation of AS/SVE could impact nearby community through on-site equipment, short-term vehicle traffic and construction, emmissions of contaminants through SVE exhaust.	This technique addresses public concern. It is an effective remedial action that the public has witnessed at the Cadet site.		$280,000
		8	**7**	**8**	**6**	**5**	**7**	**8**	**49**	**3**
Alternative D:	In-Situ Substrate Injection	Meets effectiveness criteria by reducing contaminants in place. However this alternative needs to be designed with site conditions in mind, to maintain its effectiveness.	Capable of achieving high treatment efficiencies (>90%) for VOC compounds such as TCE. Other organics are amenable to partial degradation as an aid to subsequent bioremediation. This technique includes some risk of rebound. May be difficult to implement effectively within the thin fine-grained sand layer.	This techinque requires design and engineering specific to the site conditions. If the agent can be injected into the fine-grain sand layer, and dispersed horizontally, this alternative can be effective long term. However, there are some risks.	Requires design, engineering, and more consultation with regulatory agencies. Easy to implement on currently mostly vacant site, however the key to successful implementation will be to inject the agent into the fine-grain sand layer, and to get it dispersed horizontally. Requires subsequent injections.	Minimal risk to construction workers. Potential impacts from soil contaminants to the surrounding community and environment can be minimized through implementation of BMPs specified in a CMMP. There is a risk of placing the injection wells in the wrong location due to several factors: depth and elevation of the fine grain sand layer (source area) is not precisely known; the source area layer is thin; and, this layer has low permeability, making the radius of influence small.	Provides removal of source area contaminants through in-situ remediation; thus, reducing future potential impacts from these contaminants. However, implementation of injection could impact nearby community through on-site equipment, short-term vehicle traffic and construction, use of chemcial compounds and potential aboveground storage and spills, and contaminant off-gassing.	This technique addresses public concern by actively treating the contamination, over the long-term.		$400,000
		6	**6**	**6**	**3**	**5**	**7**	**8**	**41**	**2**

Criteria

Protectiveness
The overall protectiveness of human health and the environment, including the degree to which existing risks are reduced, time required to reduce risk at the facility and attain cleanup standards, on-site and off-site risks resulting from implementing the alternative, and improvement of the overall environmental quality.

Permanence
The degree to which the alternative permanently reduces the toxicity, mobility or volume of hazardous substances, including the adequacy of the alternative in destroying the hazardous substances, the reduction or elimination of hazardous substance releases and sources of releases, the degree of irreversibility of waste treatment process, and the characteristics and quantity of treatment residuals generated.

Cost
The cost to implement the alternative, including the cost of construction, the net present value of any long-term costs, and agency oversight costs that are cost recoverable. Long-term costs include operation and maintenance costs, monitoring costs, equipment replacement costs, and the cost of maintaining institutional controls. Cost estimates for treatment technologies shall describe pretreatment, analytical, labor, and waste management costs. The design life of the cleanup action shall be estimated and the cost of replacement or repair of major elements shall be included in the cost estimate.

Long-Term Effectiveness
This includes the degree of certainty that the alternative will be successful, the reliability of the alternative during the period of time hazardous substances are expected to remain on-site at concentrations that exceed cleanup levels, the magnitude of residual risk with the alternative in place, and the effectiveness of controls required to manage treatment residues or remaining wastes. The following types of cleanup action components may be used as a guide, in descending order, when assessing the relative degree of long-term effectiveness: Reuse or recycling; destruction or detoxification; immobilization or solidification; on-site or offsite disposal in and engineered, lined and monitored facility; on-site isolation or containment with attendant engineering controls; and institutional controls and monitoring.

Short-term Risks
The risk to human health and the environment associated with the alternative during construction and implementation, and the effectiveness of measures that will be taken to manage such risks.

Implementability
Ability to be implemented including consideration of whether the alternative is technically possible, availability of necessary offsite facilities, services and materials, administrative and regulatory requirements, scheduling, size, complexity, monitoring requirements, access for construction operations and monitoring, and integration with existing facility operations and other current of potential remedial actions.

Consideration of Public Concerns
Whether the community has concerns regarding the alternative and, if so, the extent to which the alternative addresses those concerns. This process includes concerns from individuals, community groups, local governments, tribes, federal and state agencies, or any other organization that may have an interest in or knowledge of the site.

Reduce Disparate Impacts
The relative ability for the remedial alternative to reduce potential disproportionate impacts or outcomes (health, community quality, etc.) during both implementation of the remedy and continued operation on the highly impacted community. Ecology defines a highly impacted community as likely to bear a disproportionate burden of public health risks from environmental pollution, such as minority, low-income, tribal or indigenous populations.

Criteria Scoring

1 - Does not satisfy the criterion
3 - Marginally satisfies the criterion
5 - Partially satisfies the criterion
7 - Mostly satisfies the criterion
10 - Completely satisfies the criterion

* Costs excludes those items common to the alternatives, including long-term monitoring.

Table 8-1
Initial Screening and Evaluation of Technologies for Groundwater Cleanup
SMC and Cadet Site, Vancouver, WA

General Response Actions	Technology	Description	Screening Criteria: Effectiveness	Screening Criteria: Implementability	Screening Criteria: Cost	Screening Comments
NO ACTION	None	No Action	Not effective in achieving RAOs.	Easy to implement.	No capital or O&M costs incurred.	Does not meet threshold criteria.
INSTITUTIONAL CONTROLS	Groundwater Use Restrictions	Restricted use of Shallow Zone and Intermediate Zone groundwater.	Effective at preventing direct contact, but is not effective at preventing migration. Does not address contaminant reduction.	May require deed restrictions to prevent off-site and on-site groundwater use.	Low to moderate costs associated with implementing restrictions (off-site deed restrictions could require significant compensation).	Applicable technology used in conjunction with other technologies.
	Monitoring	Laboratory analyses of groundwater samples.	Effective for documenting plume conditions to evaluate migration and current risks. Does not address contaminant reduction.	Easy to implement. Monitoring well network already exists.	Low to moderate costs for monitoring.	Applicable to document plume conditions and effectiveness of any treatment.
ENGINEERING CONTROLS	Control of Building HVAC System	Use HVAC system to maintain positive pressure in buildings.	May be effective in preventing migration of volatile contaminants from shallow groundwater into indoor air as long as a pressure differential is maintained between building and subsurface soil. Does not address contaminant reduction. Generally used in conjunction with other engineering controls.	Can be easy to implement in buildings with existing HVAC systems.	Low costs associated with implementing these controls in individual buildings; however, to install in numerous buildings would incur high costs.	Not applicable to dissolved-phase plume. Does not address contaminant reduction. Not retained as viable technology.
	Vapor Barriers	Installation of low-permeable barriers beneath buildings to prevent vapor intrusion.	Effective in preventing migration of volatile contaminants from shallow groundwater into indoor air. Does not address contaminant reduction.	Easy to implement for new building construction. Some protection from existing slab-on-grade construction - improvement would require sealing floor from top surface (including removal/replacement of finish floor surface), which is not feasible for the all building overlying dissolved-phase plume.	Moderate cost for individual building surface application. High cost for sub-floor installation (removal and replacement of slab floor). High costs for area overlying dissolved-phase plume.	Not applicable to dissolved-phase plume. Does not address contaminant reduction. Not retained as viable technology.
	Sub-Slab Depressurization or Sub-Floor Venting	Installation of sub-slab or sub-floor venting systems or suction pits to create negative pressures beneath structures to prevent vapor migration to ambient air. Vapors are collected in the suction pit or venting pipes below the building and vented to the outside of the building, either passively or with fans.	Effective in preventing migration of subsurface volatile contaminants from groundwater into ambient air. Does not address contaminant reduction.	Easy to implement for new building construction. Existing buildings could be retrofitted. Materials and construction methods are readily available. Generally most suitable for buildings with slab-on-grade floors. Not feasible for area overlying dissolved-phase plume.	Moderate costs for retrofitting individual existing structures - would require cutting slab floor to install vapor pits. High costs for retrofitting structures overlying dissolved-phase plume.	Not applicable to dissolved-phase plume. Does not address contaminant reduction. Not retained as viable technology.
	Alternative Water Supply	Develop new water supply in uncontaminated area to provide potable water in the areas of impact.	Effective in preventing use of contaminated groundwater. No contaminant reduction.	Conventional construction, requires local and WRD approvals.	High capital costs, low to moderate O&M costs.	Not retained as viable technology. No contaminant reduction and very high costs.
	Wellhead Treatment	Treatment at individual impacted water supply wells with use of *Ex-Situ* Physical/Chemical/Thermal treatment technology.	Effective in reducing contaminant concentrations in groundwater prior to use. Currently in use at Great Western Malting as part of initial actions.	Treatment units for large-scale municipal systems would be difficult to implement. Requires ongoing testing and system maintenance to remain effective.	High capital costs and O&M costs for municipal-scale treatment system.	An extraction ssytem is already in use at the site as part of the interim action. A potential municipal treatment unit would involve many responsible parties, require significant treatment volumes, and would be cost prohibitive. Technology not retained. .

Table 8-1
Initial Screening and Evaluation of Technologies for Groundwater Cleanup
SMC and Cadet Site, Vancouver, WA

General Response Actions	Technology	Description	Screening Criteria: Effectiveness	Screening Criteria: Implementability	Screening Criteria: Cost	Screening Comments
CONTAINMENT	Vertical Barrier	Installation of vertical barriers (e.g., sheet piling, soil-bentonite slurry wall, grout, etc.) to prevent migration of groundwater contamination.	Effective at preventing lateral migration. Requires keying into underlying confining unit. Hydraulic control often necessary as supplemental measure to achieve containment. Cannot prevent downward migration.	Difficult to implement, particularly given depth to groundwater and overall size of groundwater plume. Additionally, groundwater in the Shallow and Intermediate Zones have different flow directions, so multiple barriers would be required to contain all groundwater. Site lacks suitable confining unit at reasonable depth. Some Site contaminants have specific gravity greater than 1 (sinkers). Specialized equipment required for construction. Not feasible for the entireity of the site.	High capital costs, low to moderate O&M.	Not practical for dissolved-phase plume area. Several more cost-effective technologies are available. Technology not retained.
	Pumping / Hydraulic Containment	Extraction well(s) with submersible pumps to lower the water table and create hydraulic gradients that direct contaminant migration into the extraction well. Extracted groundwater would require treatment before discharge (see *Ex-Situ* Physical/Chemical/ Thermal Treatment).	Effective in porous soils for preventing further contaminant migration. May also be used in conjunction with other technologies. Not efficient for removal of contaminant mass.	Extraction well already in place at the SMC source area, and is currently operational. Achieves containment of dissolved-phase plume. Discharge of treated water currently permitted.	Extraction well already in place at SMC source area, and operational. Additional extraction wells may be considered. Moderate to high O&M costs.	Applicable technology for dissolved-phase plume. Currently is being used as an interim action at SMC source area and achives containment of dissolved-phase plume.
REMOVAL/DISCHARGE	Pumping (Pump & Treat)	Extraction well(s) with submersible pumps to remove contaminated groundwater with goal of plume reduction and aquifer restoration. Treatment of extracted groundwater likely required before discharge (see *Ex-Situ* Physical/Chemical/ Thermal Treatment).	Effective in porous soils for preventing contaminant migration and removing contaminants from extracted groundwater. Less effective for achievement of cleanup of source areas. May also be used in conjunction with other technologies.	Extraction well already in place at the SMC source area, and is currently operational. Achieves containment of dissolved-phase plume. Discharge of treated water currently permitted.	Extraction well already in place at SMC source area, and operational. Moderate to high O&M costs.	Applicable technology for dissolved-phase plume. Currently is being used as an interim action at SMC source area and achives containment of dissolved-phase plume.
	Subsurface Drains	Trench or horizontal boring filled with porous media—gravity drains to sump/pump. Treatment of extracted groundwater likely required before discharge (see Ex-Situ Physical/Chemical/Thermal Treatment).	Effective for shallow groundwater at preventing contaminant migration. Not effective for impacted deeper groundwater. May also be used in conjunction with other technologies.	Not practical to install at groundwater depths or for the entire area of the dissolved-phase plume.	Moderate to high capital and O&M costs.	Not retained due to area of dissolved-phase plume. Additionally, groundwater depth is greater than appropriate for subsurface drains.
	Discharge to Sewer / Surface Water	Discharge of water (which may require treatment) into surface water, storm sewer, or sanitary sewer.	Effective for disposal of extracted groundwater. Already in use at site for discharge of treated water to the Columbia River. Treatment of water (physical or chemical) required prior to discharge.	State and federal legislation regulate discharge into river. NPDES permit (already obtained) required to discharge treated water into the Columbia River.	Moderate cost to transport treated water to river. Infrastructure has already been constructed for the SMC extraction well interim action.	Applicable for discharge of extracted groundwater. Currently is being used as part of an interim action.
	Discharge to Reinjection Wells	Discharge of water (which may require treatment) into aquifer by reinjection wells.	Moderate effectiveness, depending upon whether injection wells can be adequately located to prevent plume spreading.	Underground injection control permit required for reinjection.	Moderate to high capital and O&M costs for reinjection wells.	Applicable for discharge of extracted groundwater. UIC permit required for injection wells (treatment needed to meet UIC discharge requirements).
	Reuse	Reuse of treated water for non-potable use such as irrigation or wetland enhancement.	Effective for treated, extracted groundwater.	A suitable use would need to be identified that can accommodate a steady flow rate in all seasons and within reasonable proximity.	Low to high costs depending upon storage and pumping requirements, and length of discharge piping.	No identified potential use suitable for flow rate expected from extraction system.
EX SITU PHYSICAL/ CHEMICAL/ THERMAL TREATMENT	Adsorption	Concentrating solutes on the surface of a sorbent material, such as activated carbon, to remove the solute from the bulk liquid.	Highly effective at removing many organic compounds from extracted water stream. However, may not be capable of processing the flow rate/volume from the extraction well(s)	Applicable for treatment of dissolved-phase contaminants in extracted water. Treatment equipment is readily available.	Moderate capital and O&M costs.	Not suitable for flow rate/volume expected from extraction system.
	Air Stripping	Volatile organics are partitioned from extracted groundwater by increasing surface area exposed to air.	Highly effective at removing many VOCs from extracted water stream. May require treatment of vapor effluent.	Applicable for treatment of dissolved-phase contaminants in extracted water. Treatment equipment is readily available. Requires air emission testing and modeling to determine if off-gas treatment is required.	Low to moderate capital and O&M costs. Higher costs if off-gas treatment needed.	Applicable for treatment of extracted water. Currently is being used as part of an interim action at SMC source area.

Table 8-1
Initial Screening and Evaluation of Technologies for Groundwater Cleanup
SMC and Cadet Site, Vancouver, WA

General Response Actions	Technology	Description	Screening Criteria: Effectiveness	Screening Criteria: Implementability	Screening Criteria: Cost	Screening Comments
	Separation/ Reverse Osmosis	Extracted groundwater is forced through a selectively permeable membrane under pressure. Water is allowed to pass through the membrane while contaminants are trapped.	Highly effective at removing many contaminants from the extracted water stream.	Applicable for treatment of dissolved-phase contaminants in extracted water. Treatment equipment is readily available.	High capital and O&M costs.	Not retained since more cost-effective treatment methods exist for removal of contaminants from dissolved-phase plume.
	Ultraviolet (UV) Oxidation	Ultraviolet radiation is used to destroy organic contaminants as water flows through treatment cell.	Effective at removing many organic contaminants from the extracted water stream.	Applicable for treatment of dissolved-phase contaminants in extracted water. Treatment equipment is readily available.	High capital and O&M costs.	Not retained since more cost-effective treatment methods exist for removal of contaminants from dissolved-phase plume.
	Sprinkler Irrigation	Contaminated water is distributed through a pressurized sprinkler irrigation system (generally onto a highly porous media), allowing transfer of VOCs from aqueous phase to vapor phase.	Effective at removing many organic contaminants from the extracted water stream. Simpler system than more aggressive treatment technologies (such as air stripping).	Applicable for treatment of site contaminants in extracted water, but requires significant treatment system area.	Low to moderate capital and O&M costs.	Not retained since land use not compatible with site conditions.
	Ion Exchange	Ion exchange removes ions from the aqueous phase by exchange with counter ions on the exchange medium.	Effective for treatment of inorganic contaminants.	Treatment equipment is readily available.	Moderate to high capital and O&M costs.	Not compatible with dissolved-phase plume contaminants.
	Precipitation/ Coagulation/ Flocculation	This process transforms dissolved contaminants into an insoluble solid, facilitating the contaminant's subsequent removal from the liquid phase by sedimentation or filtration.	Effective for treatment of inorganic contaminants.	Treatment equipment is readily available.	Moderate to high capital and O&M costs.	Not compatible with dissolved-phase plume contaminants.
EX SITU BIOLOGICAL TREATMENT	Bioreactors / Trickling Filter	Contaminants in extracted groundwater are put into contact with microorganisms in attached or suspended growth biological reactors.	Effective at removing many organic contaminants from the extracted water stream. May be less effective during cold weather. May not reach treatment goals without follow-up polishing treatment.	Difficult to maintain effectiveness with variable operating parameters (i.e., influent concentrations, ambient concentrations). Requires significant area for reactors. Would require significant maintenance.	Moderate capital costs and moderate to high O&M costs	Not retained since may require further treatment, and may not be effective during cold weather.
	Constructed Wetlands	Utilizes natural geochemical and biological processes inherent in an artificial wetland ecosystem to remove contaminants from extracted groundwater.	Highly effective at removing many organic and inorganic contaminants from the extracted water stream.	Requires large land area to implement. May introduce attractive nuisance hazard for local wildlife.	Moderate to high capital costs. Low O&M costs.	Applicable technology for dissolved-phase plume contaminants. Sufficient space may be available, but located significantly away from existing infrastructure.
IN SITU BIOLOGICAL TREATMENT	Enhanced Bioremediation (Bioaugmentation, Biostimulation)	Adding nutrients, electron acceptor, or other amendments to enhance bioremediation. Addition of specific microbial cultures can be included if indigenous species not suitable for complete degradation of COIs.	Effective with addition of suitable amendments. Strategic placement of amendments can be effective in conjunction with other technologies. Treating source-area concentrations requires significantly longer time to complete. Has been demonstrated as an affective technology at nearby sites.	Equipment and technology for direct injection are readily available. Amendments for stimulating reductive dechlorination are commercially available.	Low to high costs depending on number of injection events required. Area of dissolved-phase plume would incur very high costs.	Not practical for dissolved-phase plume area. Several more cost-effective technologies are available. Technology not retained.
	Monitored Natural Attenuation	Using natural processes to reduce contaminant concentrations to acceptable levels. Process is closely monitored to verify exposures are acceptable prior to concentrations reaching acceptable levels.	May be effective, especially in areas of low concentrations (near plume boundaries), but not effective for high concentrations, such as at the source areas. Other technologies will likely be required.	Easy to implement. Monitoring well system already exists. Likely would require significant timeframe to reach cleanup goals.	Low costs for monitoring.	Retained as an applicable technology. May be most effective in conjunction with other technologies to reduce concentrations.
	Phytoremediation	Phytoremediation is a process that uses plants to remove, transfer, stabilize, and destroy contaminants.	Can be effective at removing a variety of organic and inorganic compounds from contaminated groundwater through plant uptake.	Requires significant land area suitable for large plants. Contamination must be accessible to plant root zones.	Moderate implementation cost.	Not retained because incompatible with site conditions or deep contamination.

Table 8-1
Initial Screening and Evaluation of Technologies for Groundwater Cleanup
SMC and Cadet Site, Vancouver, WA

General Response Actions	Technology	Description	Screening Criteria			Screening Comments
			Effectiveness	Implementability	Cost	
IN SITU PHYSICAL/ CHEMICAL/ THERMAL TREATMENT	Aeration / Air Sparging	Increasing the contact between water and air to enhance volatilization. Air sparging involves injecting air into saturated matrices.	Effective for volatile contamination. Use in conjunction with shallow vapor extraction to prevent uncontrolled vapor migration. Has been demonstrated as an affective technology at nearby Cadet source area.	Equipment and technology for air sparging are readilly available.	Typically, moderate to high capital costs. Low O&M costs. High costs for the total area overlying the dissolved-phase plume.	Not practical for dissolved-phase plume area. Several more cost-effective technologies are available. Technology not retained.
	Multi-Phase Extraction (MPE)	MPE provides simultaneous extraction of soil vapor, contaminated groundwater, and NAPL using single vacuum pump, multiple in-well pumps, or bioslurping.	Effective for source removal at sites with moderate to low soil permeability. Also effective for treating impacted groundwater in the source area. Not efficient for removal of plume.	Equipment and technology for MPE are readily available. Treatment of recovered soil vapors and groundwater would be required prior to discharge.	Moderate to high capital and O&M costs. Higher costs if vapor treatment needed.	Not practical for dissolved-phase plume area. Several more cost-effective technologies are available. Technology not retained.
	Steam Flushing/ Steam Stripping	Steam is injected into the contaminated aquifer to vaporize less volatile organics.	Used in conjunction with vapor recovery. May be effective for increasing usability of SVE for low-volatility compounds.	Equipment and technology are readily available. Treatment of recovered vapors would likely be required.	High capital costs.	Not practical for dissolved-phase plume area. Several more cost-effective technologies are available. Technology not retained.
	Chemical Oxidation	Chemically converts hazardous contaminants to less toxic compounds. Effective in destroying organic contaminants (including LNAPL) and oxidizing inorganic contaminants to less toxic/less mobile forms. Can include oxidant chemicals such as peroxides, permanganates, or ozone.	Effective in destroying organic contaminants (including free product) and oxidizing inorganic contaminants to less toxic/less mobile forms. Difficult to provide adequate coverage in subsurface. May cause settling in organic soils. Most applicable to source-area concentrations or NAPLs.	Equipment and vendors are readily available. Less efficient at addressing diffuse concentrations of Site COIs.	High implementation costs (potentially requiring multiple applications).	Not practical for dissolved-phase plume area. Several more cost-effective technologies are available. Technology not retained.
	Passive/Reactive Treatment Walls	Barriers placed across groundwater movement that allows passage of water while facilitating degradation or removal of contaminants.	Can be effective in the remediation of dissolved-phase VOC contamination. May not be suitable for source area remediation. Not cost-effective for very wide or deep plumes. Iron filings have been demonstrated to be effective at removal of HVOCs.	Depth of shallow aquifer would require installation by drilled methods (rather than open excavation). Specialty equipment needed for installation. Barrier materials readily available (iron and sand).	High costs for installation. Moderate costs for performance and compliance monitoring, and periodic maintenance.	Not practical for the area overlying the dissolved-phase plume. Would need to extend below deepest potential impact to prevent lateral migration beneath barrier. Several more cost-effective technologies are available. Technology not retained.

Note:
1. Shading indicates technology has been eliminated from consideration.

Table 8-2
Comparative Analysis of Remedial Alternatives for the Dispersed Residual Groundwater Contamination

Alternative		Selection Criteria**							Sum	Cost Effectiveness
		Protectiveness	Permanence	Long-term Effectiveness	Implementability	Short-Term Risk	Public Concerns	Reduce Disparate Impacts		
Alternative A:	MNA	Meets protectiveness criteria by isolating source area contaminants. Current receptors (drinking water wells) are protected through MNA monitoring to cleanup levels at all POCs. Modeling indicates contaminants do not reach regional source wells at unacceptable levels.	High reliability due to source area control. MNA monitoring program implemented on a site-wide basis to ensure permanance. P&T can remain as backup contingency under this alternative.	Effectively isolates the most impacted groundwater (source area). MNA monitoring program implemented on a site-wide basis to ensure long-term effectiveness remains intact. P&T can remain as backup contingency under this alternative.	Existing source area remedial actions are implementable. MNA can be easily implemented and incorporated into the sampling program. P&T maintained as contingency.	Moderate risk due to some uncertainty of source area contaminants migrating to intermediate zone. Robust sampling required to confirm that remedial actions achieve RAOs and MNA is implemented.	Little percieved public concerns. This alternative addresses public concern by removing any potential risk in the source area and implmentating a long-term MNA plan.	Shut-down of the P&T has shown to reduce GHG emmissions by 0.1 tons per year.		$1M - $1.5M
	Score	**8**	**8**	**8**	**10**	**7**	**9**	**9**	**59**	**5**
Alternative B:	Continued Pump and Treat	Meets protectiveness criteria by isolating source area contaminants, with some containment due to P&T system operation. Current receptors (drinking water wells) are protected through continued operation of the P&T to achieve cleanup levels.	High reliability due to source area control. P&T will be operational until cleanup levels met and includes containment of all contaminants. After 5-year operation, MNA implemented to ensure permanance.	P&T proven to be a very effective technique. System will continue to be operational until cleanup levels met. Long-term maintanence is necessary.	Existing source area remedial actions are implementable. P&T currently exists and is operational. P&T has some potential maintenance issues and costs associated with continued operation.	Moderate risk due to uncertainty of source area contamination; P&T has little impact on source area contaminants but does capture migrating contaminants to the intermediate zone. P&T is currently operational, so little risk of typical construction issues. Robust sampling required to confirm that remedial actions achieve RAOs.	Little percieved public concern. Public has been receptive of P&T and its operating success. Discharge of VOCs through the P&T system stack may be of some public concern. Climate change analysis indicated GHG emmissions related to high electricity for operation of the system may have some public concern.	Emissions from the pump and treat system will be continued and has some potential to impact the nearby community.		$2M-$2.5M
	Score	**9**	**8**	**8**	**8**	**9**	**8**	**6**	**56**	**3**

Criteria

Protectiveness The overall protectiveness of human health and the environment, including the degree to which existing risks are reduced, time required to reduce risk at the facility and attain cleanup standards, on-site and off-site risks resulting from implementing the alternative, and improvement of the overall environmental quality.

Permanence The degree to which the alternative permanently reduces the toxicity, mobility or volume of hazardous substances, including the adequacy of the alternative in destroying the hazardous substances, the reduction or elimination of hazardous substance releases and sources of releases, the degree of irreversibility of waste treatment process, and the characteristics and quantity of treatment residuals generated.

Cost The cost to implement the alternative, including the cost of construction, the net present value of any long-term costs, and agency oversight costs that are cost recoverable. Long-term costs include operation and maintenance costs, monitoring costs, equipment replacement costs, and the cost of maintaining institutional controls. Cost estimates for treatment technologies shall describe pretreatment, analytical, labor, and waste management costs. The design life of the cleanup action shall be estimated and the cost of replacement or repair of major elements shall be included in the cost estimate.

Long-Term Effectiveness This includes the degree of certainty that the alternative will be successful, the reliability of the alternative during the period of time hazardous substances are expected to remain on-site at concentrations that exceed cleanup levels, the magnitude of residual risk with the alternative in place, and the effectiveness of controls required to manage treatment residues or remaining wastes. The following types of cleanup action components may be used as a guide, in descending order, when assessing the relative degree of long-term effectiveness: Reuse or recycling; destruction or detoxification; immobilization or solidification; on-site or offsite disposal in and engineered, lined and monitored facility; on-site isolation or containment with attendant engineering controls; and institutional controls and monitoring.

Short-term Risks The risk to human health and the environment associated with the alternative during construction and implementation, and the effectiveness of measures that will be taken to manage such risks.

Implementability Ability to be implemented including consideration of whether the alternative is technically possible, availability of necessary offsite facilities, services and materials, administrative and regulatory requirements, scheduling, size, complexity, monitoring requirements, access for construction operations and monitoring, and integration with existing facility operations and other current of potential remedial actions.

Consideration of Public Concerns Whether the community has concerns regarding the alternative and, if so, the extent to which the alternative addresses those concerns. This process includes concerns from individuals, community groups, local governments, tribes, federal and state agencies, or any other organization that may have an interest in or knowledge of the site.

Reduce Disparate Impacts The relative ability for the remedial alternative to reduce potential disproportionate impacts or outcomes (health, community quality, etc.) during both implementation of the remedy and continued operation on the highly impacted community. Ecology defines a highly impacted community as likely to bear a disproportionate burden of public health risks from environmental pollution, such as minority, low-income, tribal or indigenous populations.

Criteria Scoring

1 - Does not satisfy the criterion
3 - Marginally satisfies the criterion
5 - Partially satisfies the criterion
7 - Mostly satisfies the criterion
10 - Completely satisfies the criterion

Table 8-3 Estimated Restoration Timeframe Starting in 2022

Well ID	Most Recent TCE Concentration Result	Date of Most Recent TCE Result	Approach 15-Year Half-Life [1]	 Average Annual % Decrease [2]	 Projected Linear Trendline [3]
			Years	Years	Years
CM-MW-01d-161	4.19	3/26/2022	2	3	0
CM-MW-01d-194	6.62	3/26/2022	12	24	0
CM-MW-01d-224	13.1	3/26/2022	27	56	41
CM-MW-02d	8.32	3/11/2020	16	34	19
CM-MW-03d-141	6.25	3/26/2022	10	21	6
CM-MW-03d-181	7.19	3/26/2022	13	28	9
CM-MW-03d-227	12.5	3/26/2022	26	53	58
CM-MW-05d	25.9	3/28/2022	42	87	70
CM-MW-18d	2.63	3/24/2022	0	0	0
CM-MW-19d	11.6	3/24/2022	24	50	47
CM-MW-28USA-180	7.45	3/24/2022	14	29	-
MW-01d	17.3	3/11/2020	32	69	4
MW-05dR	12.0	3/4/2020	25	51	0
MW-12d	9.00	3/31/2020	18	38	1
MW-14d	2.97	3/22/2022	0	0	0

Notes:

Cleanup level (CL) for TCE is 4.00 ug/L.

Years to restoration = when TCE concentration at or below 4.0 ug/L.

[1] 15-Year Half-Life: Calculates restoration timeframe (years from 2020) assuming biodegradation only with a conservative (slow) 15-year half-life.

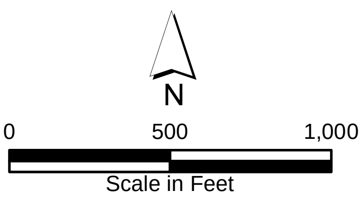
[2] Average Annual % Decrease: Calculates restoration timeframe (years from 2020) assuming TCE concentration decreases 2.13% annually (based on average 2.13% annual decrease in TCE concentrations measured in all deep wells between 2010 and 2022).

[3] Projected Linear Trendline: Based on a linear trendline projection of TCE results since January 2010.

Figures

Parametrix Date: 5/25/2021 File: U:\Port\Projects\Clients\1940-Port of Vancouver\275-1940-006-POV TCE\99Svcs\GIS\POV\MXD_PDF\SMC_Cadet_FeasibilityStudy_2021\Fig_1-1_ProjectArea.mxd

Figure 1-1
Project Area



SMC and Cadet Feasibility Study
Vancouver, Washington

Date: 5/3/2021 Author: ZieglCor Path: U:\PortProjects\Clients\1940-Port of Vancouver\275-1940-006-POV TCE\99Svcs\GIS\POV\MXD_PDF\SMC_Cadet_FeasibilityStudy_2021\Fig_1-2_SiteLocationMap.mxd

Parametrix

Source: © Mapbox, © OpenStreetMap, Port of Vancouver

N

0 250 500 1,000 Feet

- Site - Historical Maximum Extent of HVOC Contamination
- SMC Site
- Cadet Facility
- Kinder Morgan Facility
- NuStar Facility

Figure 1-2
Site Location Map

SMC and Cadet Feasibility Study
Vancouver, Washington

Date: 5/3/2021 Author: ZieglCor Path: U:\Port\Projects\Clients\1940-Port of Vancouver\275-1940-006-POV TCE\99Svcs\GIS\POV\MXD PDF\SMC Cadet Feasibility Study 2021\Fig 1-3 SwanAndCadetSitePortionMap.mxd

Parametrix

Source: © Mapbox, © OpenStreetMap, Port of Vancouver

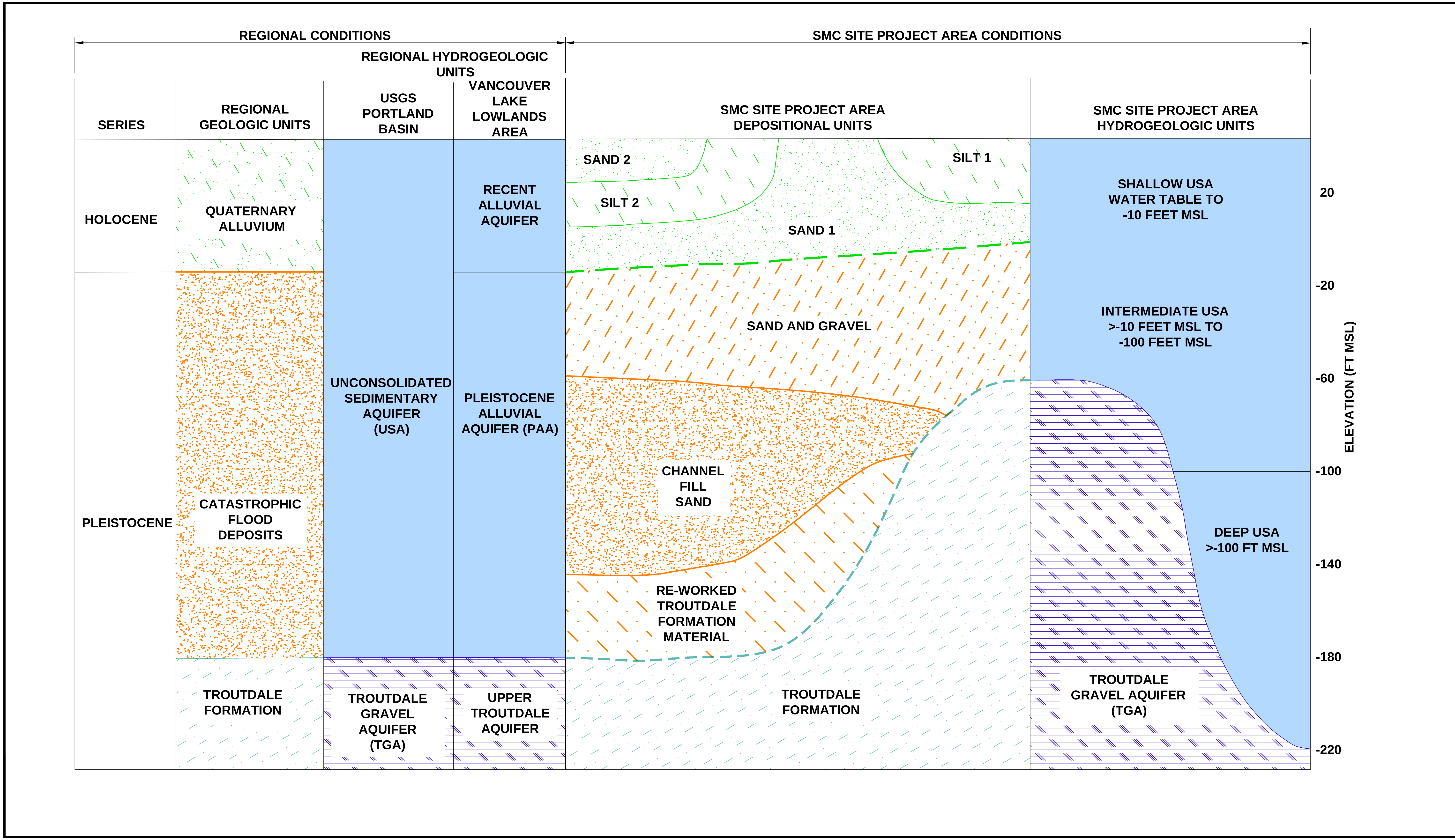
N

0 250 500 1,000 Feet

- Site - Historical Maximum Extent of HVOC Contamination
- Area of Site Included in Agreed Order 18152
- SMC Site
- Cadet Facility
- Kinder Morgan Facility
- NuStar Facility

Figure 1-3
Swan and Cadet Site Portion

SMC and Cadet Feasibility Study
Vancouver, Washington



Parametrix DATE: Jan 20, 2021

Figure 2-1
Regional and SMC Site Project Area Geologic and Hydrologic Units

SMC AND CADET FEASIBILITY STUDY
VANCOUVER, WASHINGTON

Parametrix Date: 2/24/2022 Path: U:\Port\Projects\Clients\1940-Port of Vancouver\275-1940-006-POV TCE\99Svcs\GIS\POV\MXD_PDF\SMC_Cadet_FeasibilityStudy_2021\Fig_2-2_CrossSectionOrientation.mxd

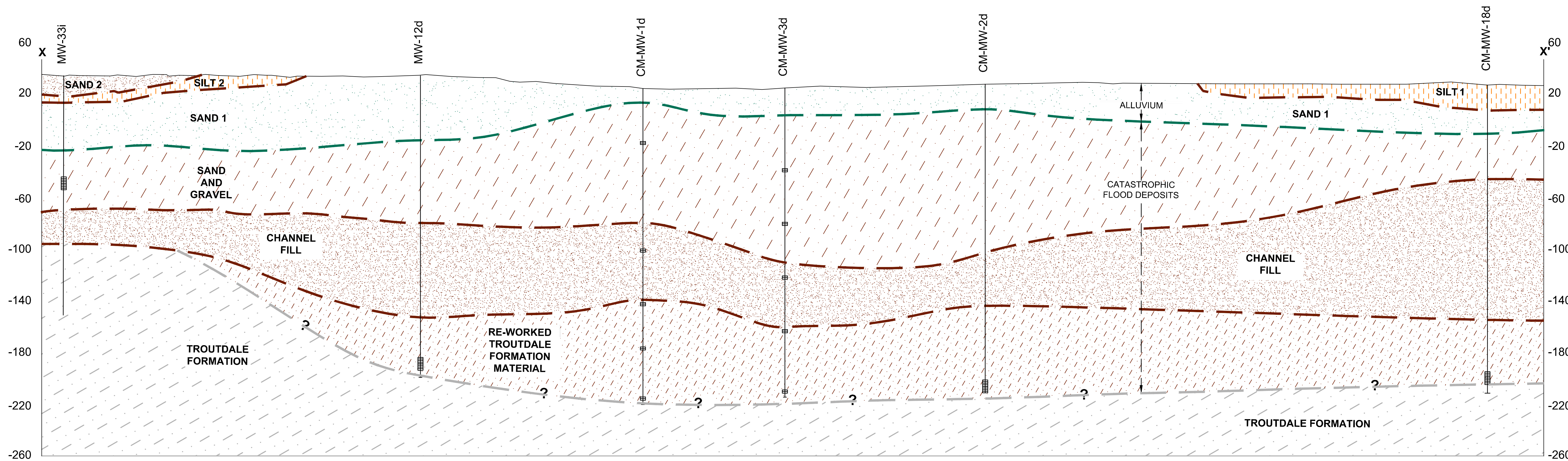
N

0 250 500
Scale in Feet

- SMC Site Well
- Cadet Manufacturing Well
- NuStar Well
- Recirculating Well
- Carborundum Well
- Cross Section Location

Figure 2-2
Cross Section Orientations

SMC and Cadet Feasibility Study
Vancouver, Washington



Parametrix DATE: Jan 20, 2021

LEGEND

WELL

WELL SCREEN INTERVAL

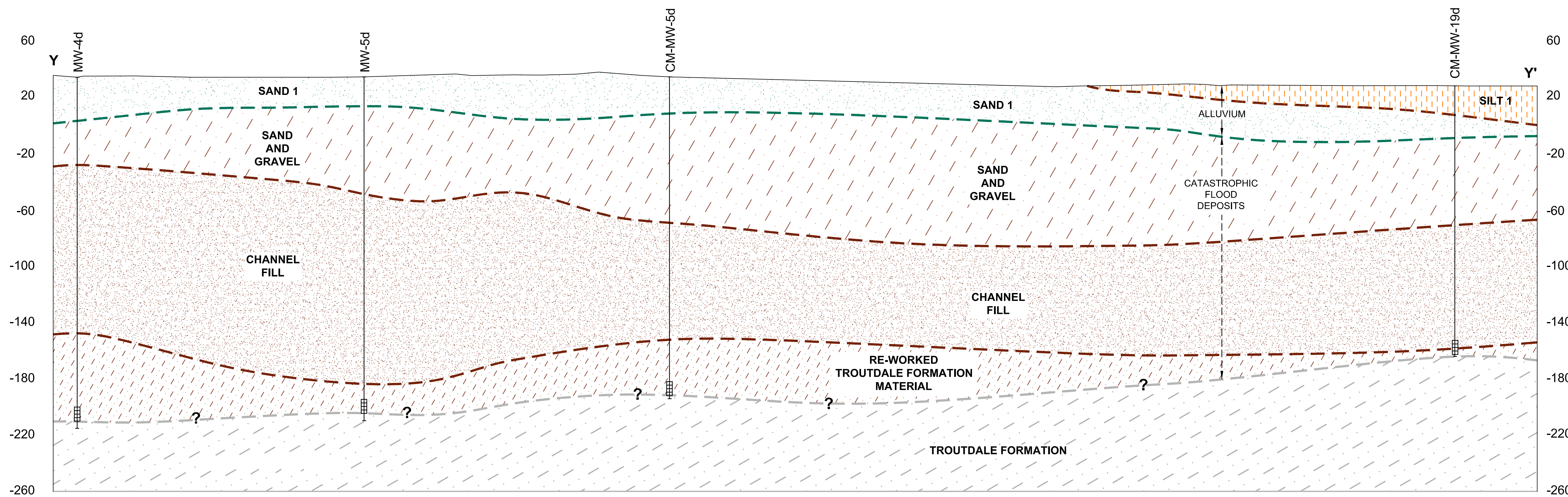
GEOLOGIC CONTACT

BOTTOM OF BORING

APPROXIMATE SCALE: HORIZONTAL 1"=200'
VERTICAL 1"=80'

Figure 2-3
Cross Section X-X'

SMC AND CADET FEASIBILITY STUDY
VANCOUVER, WASHINGTON



Parametrix

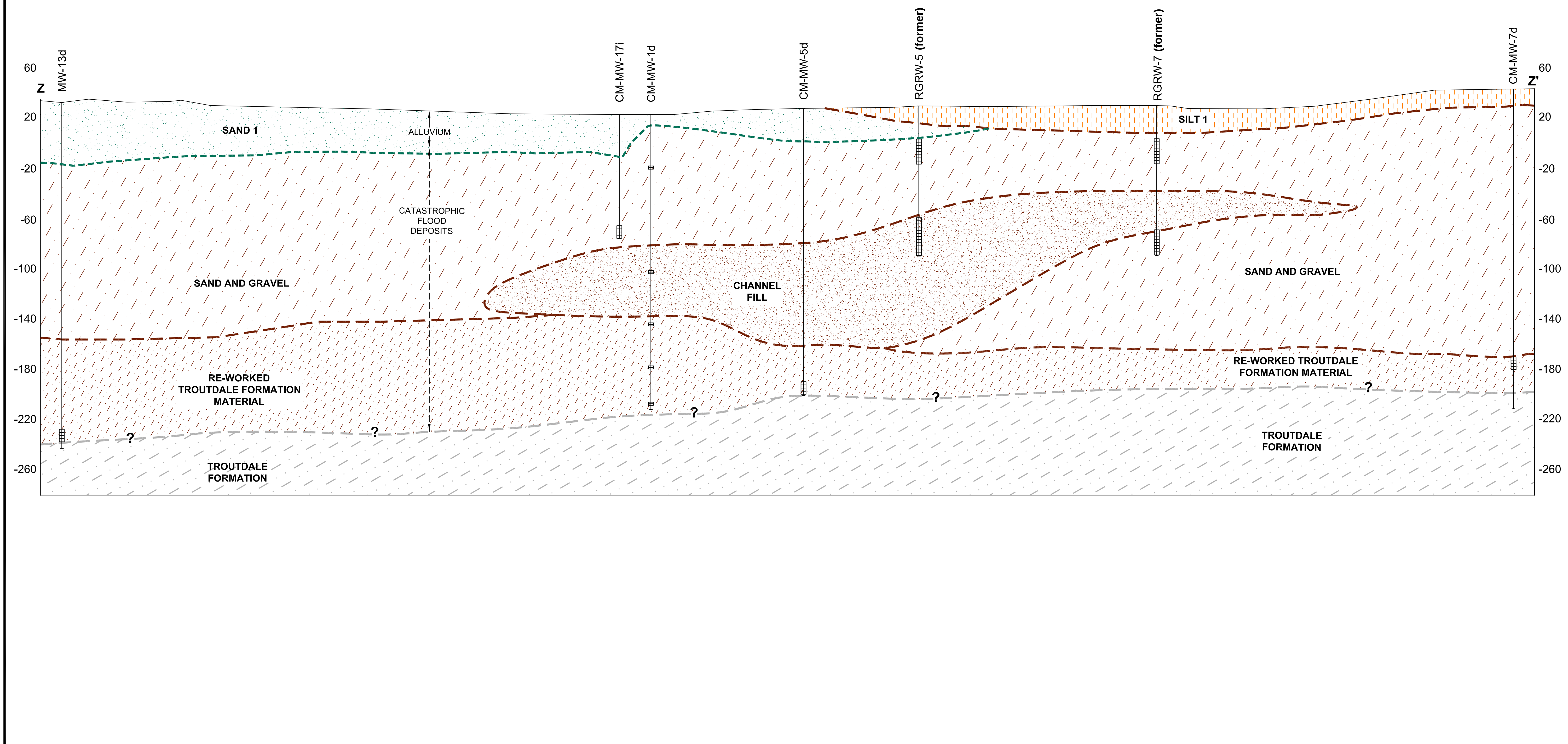
APPROXIMATE SCALE: HORIZONTAL 1"=200'
VERTICAL 1"=80'

LEGEND

- WELL
- WELL SCREEN INTERVAL
- GEOLOGIC CONTACT
- BOTTOM OF BORING

Figure 2-4
Cross Section Y-Y'

SMC AND CADET FEASIBILITY STUDY
VANCOUVER, WASHINGTON



Parametrix

APPROXIMATE SCALE: HORIZONTAL 1"=200'
VERTICAL 1"=80'

LEGEND

- WELL
- WELL SCREEN INTERVAL
- GEOLOGIC CONTACT
- BOTTOM OF BORING

Figure 2-5
Cross Section Z-Z'

SMC AND CADET FEASIBILITY STUDY
VANCOUVER, WASHINGTON

Parametrix Date: 5/3/2021 Path: U:\Port\Projects\Clients\1940-Port of Vancouver\275-1940-006-POV TCE\99Svcs\GIS\POV\MXD_PDF\SMC_Cadet_FeasibilityStudy_2021\Fig_2-6_TCE_Shallow_2020.mxd

N

0 250 500 750

Scale in Feet

MW-10 — Well Location Name
23 — March 2020 Sample Result (µg/L)
15 — Jan 2020 Sample Result (µg/L)
19 — March 31, 2020 Sample Result (µg/L)
27 — August 2020 Sample Result (µg/L)

ND = Non-Detect
NS = Not sampled
IA = Inactive Sampling Location

> 4 µg/L
> 25 µg/L
> 50 µg/L
> 100 µg/L
> 500 µg/L
> 1000 µg/L

Note: Wells shown in italics have been decommissioned.

*Isoconcentrations are based on March 2020 Results.

Figure 2-6
2020 TCE Isoconcentrations in Shallow USA Zone Groundwater

SMC and Cadet Feasibility Study
Vancouver, Washington

Parametrix Date: 5/3/2021 Path: U:\Port\Projects\Clients\1940-Port of Vancouver\275-1940-006-POV TCE\99Svcs\GIS\POV\MXD_PDF\SMC_Cadet_FeasibilityStudy_2021\Fig_2-7_PCE_Shallow_2020.mxd

N

0 250 500 750

Scale in Feet

MW-10 — Well Location Name
23 — March 2020 Sample Result (µg/L)
15 — Jan 2020 Sample Result (µg/L)
19 — March 31, 2020 Sample Result (µg/L)
27 — August 2020 Sample Result (µg/L)
ND = Non-Detect
NS = Not sampled
IA = Inactive Sampling Location

Note: Wells shown in italics have been decommissioned.

*Isoconcentrations are based on March 2020 Results.

> 5 µg/L
> 25 µg/L
> 50 µg/L
> 100 µg/L
> 500 µg/L
> 1000 µg/L

Figure 2-7
2020 PCE Isoconcentrations in Shallow USA Zone Groundwater

SMC and Cadet Feasibility Study
Vancouver, Washington

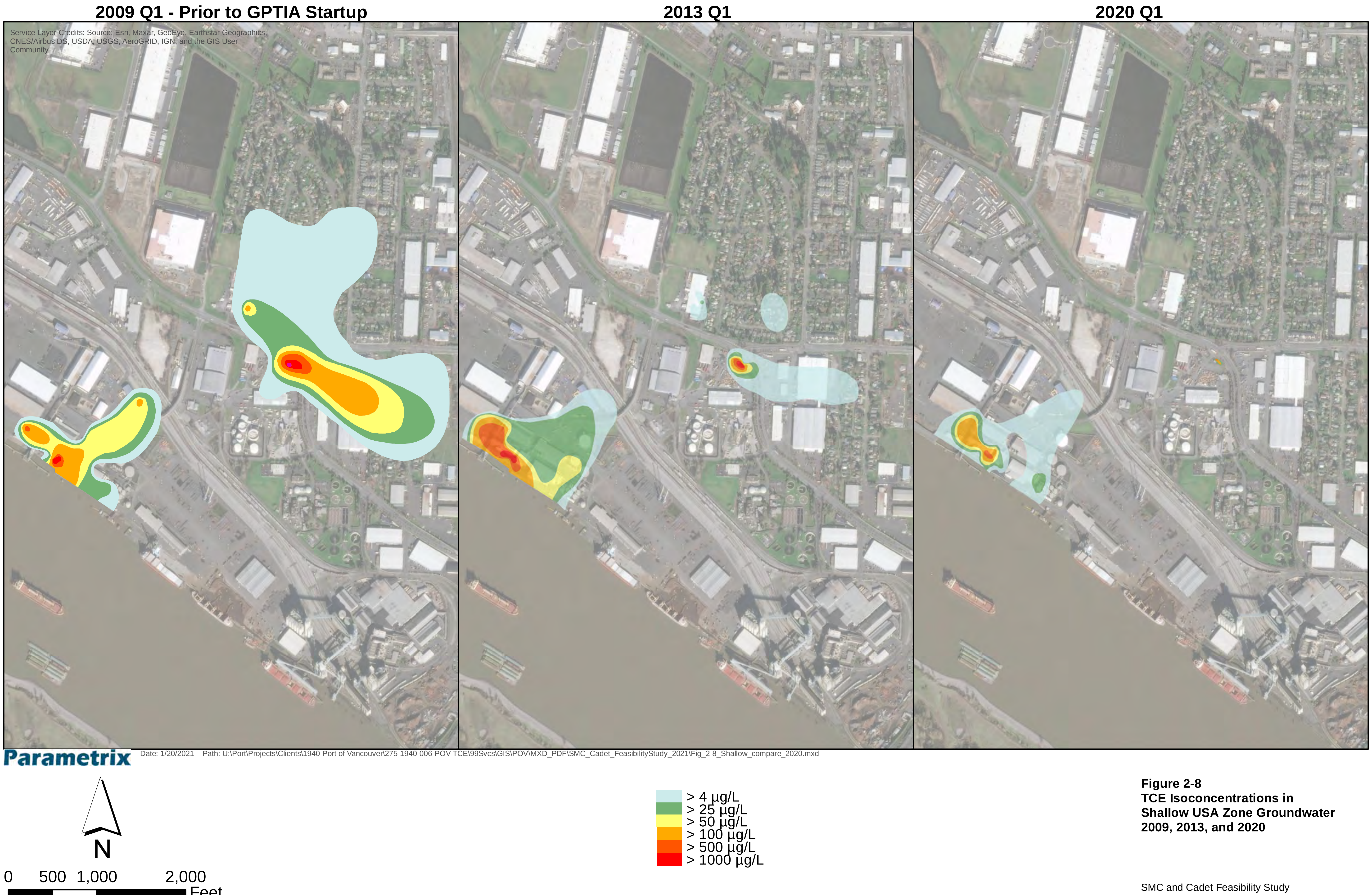


Figure 2-8
TCE Isoconcentrations in Shallow USA Zone Groundwater 2009, 2013, and 2020

SMC and Cadet Feasibility Study
Vancouver, Washington

Note: Not all groundwater concentrations in the intermediate USA in the vicinity of the NuStar site were used for contouring in order to simplify and present a general picture of the nature and extent of groundwater contamination at a project area level.

Parametrix Date: 5/3/2021 Path: U:\Port\Projects\Clients\1940-Port of Vancouver\275-1940-006-POV TCE\99Svcs\GIS\POV\MXD_PDF\SMC_Cadet_FeasibilityStudy_2021\Fig_2-9_TCE_Intermediate_2020.mxd

N

0 250 500 750

Scale in Feet

MW-10 — Well Location Name
23 — March 2020 Sample Result (µg/L)
15 — Jan 2020 Sample Result (µg/L)
27 — August 2020 Sample Result (µg/L)
12 — December 1, 2020 Sample Result (µg/L)

> 4 µg/L
> 25 µg/L

ND = Non-Detect
NS = Not sampled
IA = Inactive Sampling Location

Note: Wells shown in italics have been decommissioned.
*Isoconcentrations are based on March 2020 Results.

Figure 2-9
2020 TCE Isoconcentrations in Intermediate USA Zone Groundwater

SMC and Cadet Feasibility Study
Vancouver, Washington

Parametrix Date: 5/3/2021 Path: U:\Port\Projects\Clients\1940-Port of Vancouver\275-1940-006-POV TCE\99Svcs\GIS\POV\MXD_PDF\SMC_Cadet_FeasibilityStudy_2021\Fig_2-10_PCE_Intermediate_2020.mxd

N

0 250 500 750

Scale in Feet

MW-10 Well Location Name
23 March 2020 Sample Result (µg/L)
15 Jan 2020 Sample Result (µg/L)
27 August 2020 Sample Result (µg/L)
12 December 1, 2020 Sample Result (µg/L)

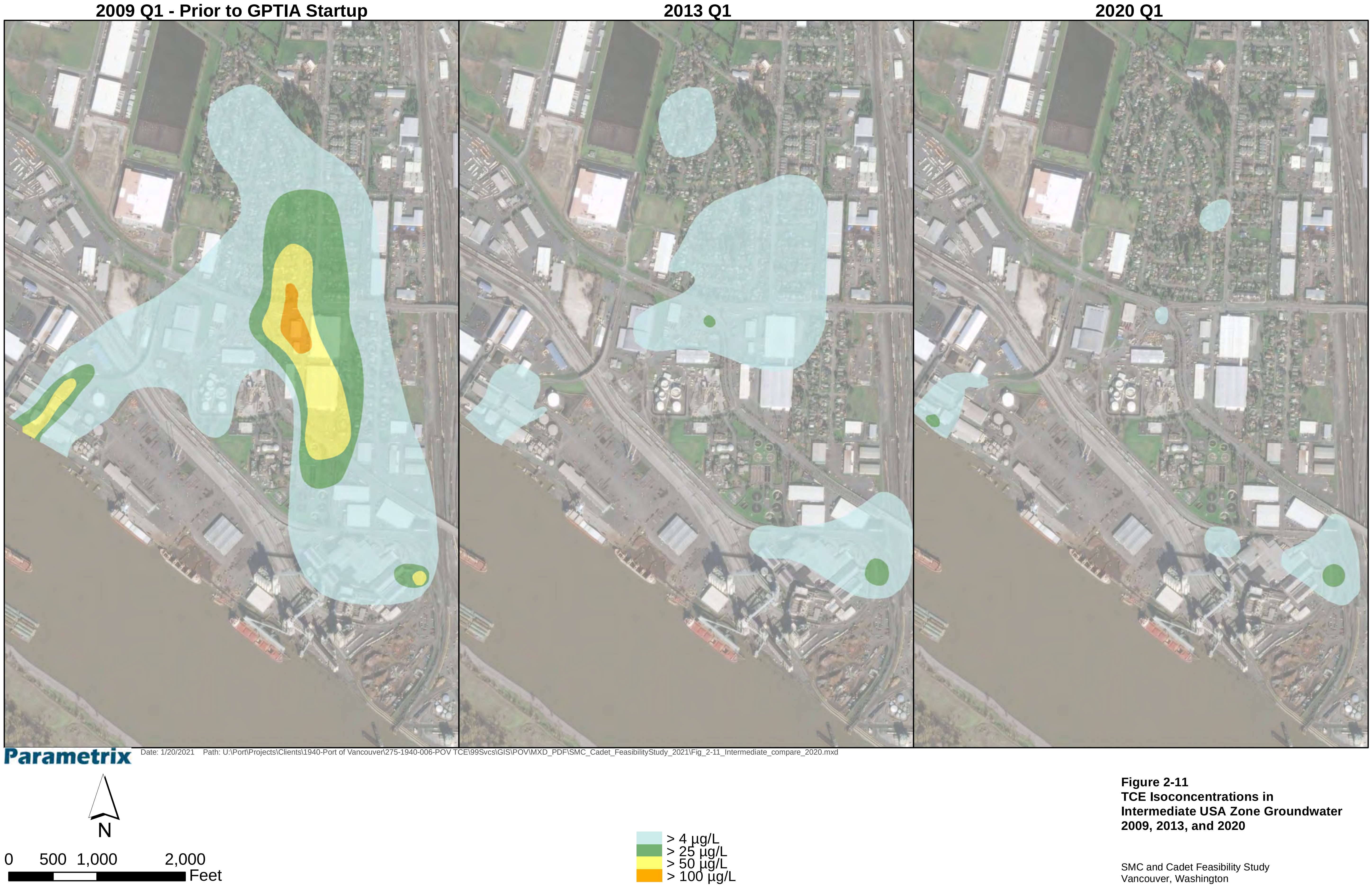
> 5 µg/L
> 25 µg/L

ND = Non-Detect
NS = Not sampled
IA = Inactive Sampling Location

Note: Wells shown in italics have been decommissioned.
*Isoconcentrations are based on March 2020 Results.

Figure 2-10
2020 PCE Isoconcentrations in Intermediate USA Zone Groundwater

SMC and Cadet Feasibility Study
Vancouver, Washington



Parametrix

Date: 1/20/2021 Path: U:\Port\Projects\Clients\1940-Port of Vancouver\275-1940-006-POV TCE\99Svcs\GIS\POV\MXD_PDF\SMC_Cadet_FeasibilityStudy_2021\Fig_2-11_Intermediate_compare_2020.mxd

Figure 2-11
TCE Isoconcentrations in Intermediate USA Zone Groundwater 2009, 2013, and 2020

SMC and Cadet Feasibility Study
Vancouver, Washington

Parametrix Date: 5/3/2021 Path: U:\Port\Projects\Clients\1940-Port of Vancouver\275-1940-006-POV TCE\99Svcs\GIS\POV\MXD_PDF\SMC_Cadet_FeasibilityStudy_2021\Fig_2-12_TCE_Deep_2020.mxd

N

0 250 500 750

Scale in Feet

MW-10 — Well Location Name

23 — March 2020 Sample Result (µg/L)

ND = Non-Detect
NS = Not sampled
IA = Inactive Sampling Location

> 4 µg/L
> 25 µg/L

Note: Wells shown in italics have been decommissioned.

Figure 2-12
2020 TCE Isoconcentrations in Deep USA Zone Groundwater

SMC and Cadet Feasibility Study
Vancouver, Washington

Parametrix Date: 5/3/2021 Path: U:\Port\Projects\Clients\1940-Port of Vancouver\275-1940-006-POV TCE\99Svcs\GIS\POV\MXD_PDF\SMC_Cadet_FeasibilityStudy_2021\Fig_2-13_PCE_Deep_2020.mxd

N

0 250 500 750

Scale in Feet

MW-10 — Well Location Name

23 — Concentration Value (µg/l)

ND = Non-Detect

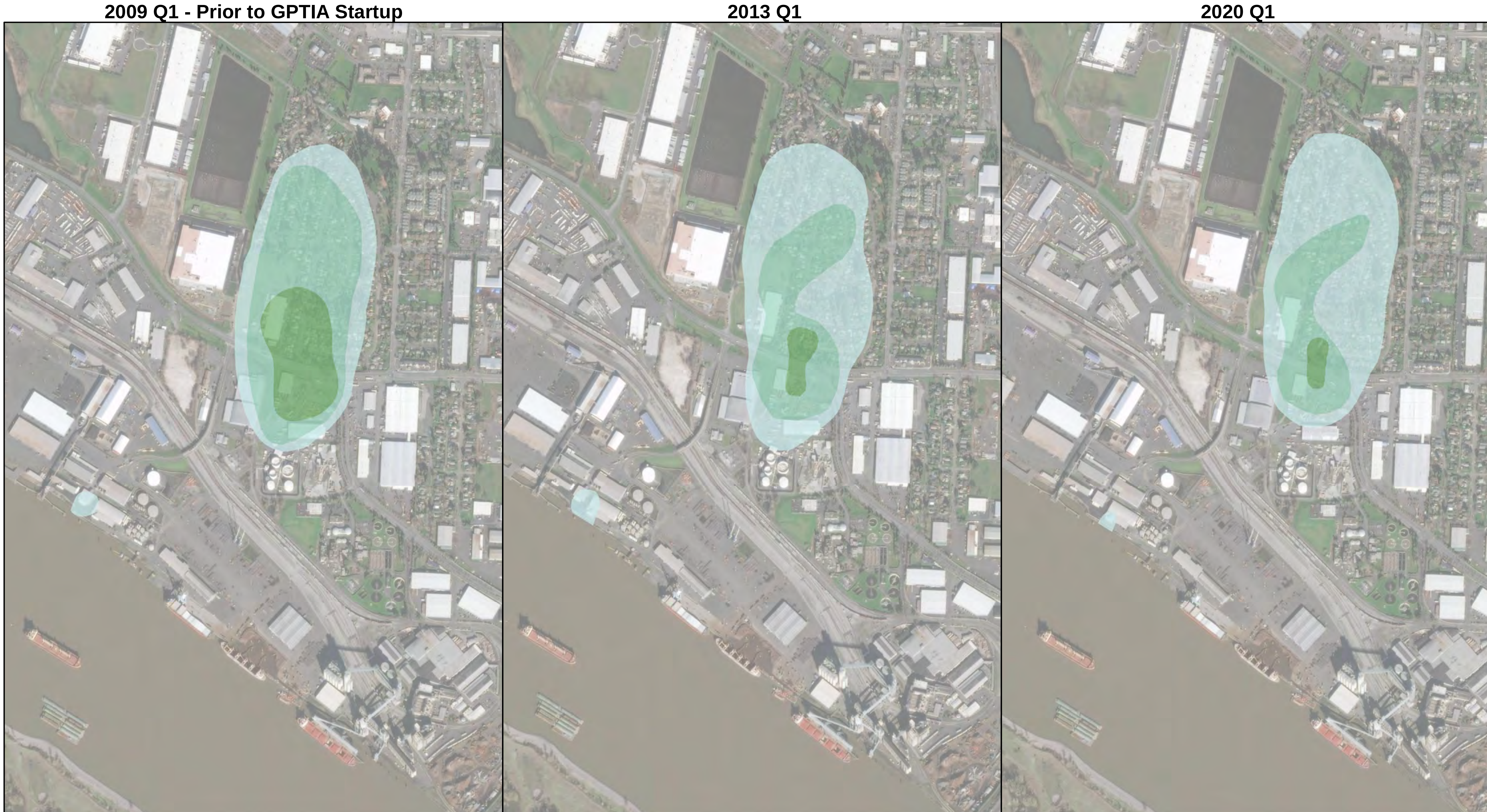
NS = Not sampled

IA = Inactive Sampling Location

> 5 µg/L

Figure 2-13
2020 PCE Isoconcentrations in Deep USA Zone Groundwater

SMC and Cadet Feasibility Study
Vancouver, Washington



Parametrix

Date: 1/20/2021 Path: U:\Port\Projects\Clients\1940-Port of Vancouver\275-1940-006-POV TCE\99Svcs\GIS\POV\MXD_PDF\SMC_Cadet_FeasibilityStudy_2021\Fig_2-14_Deep_compare_2020.mxd

N

0 500 1,000 2,000 Feet

> 4 µg/L
>10 µg/L
> 25 µg/L

Figure 2-14
TCE Isoconcentrations in Deep USA Zone Groundwater 2009, 2013, and 2020

SMC and Cadet Feasibility Study
Vancouver, Washington

N

0 125 250 500 Feet

- Shallow USA Groundwater Monitoring Well
- Intermediate USA Groundwater Monitoring Well
- Deep USA Groundwater Monitoring Well
- TGA Monitoring Well

Note: Wells shown in italics have been decommissioned.

Figure 2-15
TGA Monitoring Well Locations

2021 Feasibility Study
SMC and Cadet Sites
Port of Vancouver, WA

Parametrix Date: 2/24/2022 Path: U:\Port\Projects\Clients\1940-Port of Vancouver\275-1940-006-POV TCE\99Svcs\GIS\POV\MXD_PDF\SMC_Cadet_FeasibilityStudy_2021\Fig_7-1_ResidualSourceArea.mxd

N

0 50 100
Feet

Extent of Former Excavation
Potential Extent of Residual Source Area
Elevated Source Area*

Based on historical soil conc. exceeding 10,000 µg/kg and groundwater exceeding 10,000 µg/L.

Extraction Well
Shallow Source Area Monitoring Well

Figure 7-1
Residual Source Area - SMC

SMC and Cadet Feasibility Study
Vancouver, Washington

Figure 7-2
Former SMC Site Area
TCE Concentrations in Groundwater
1st Quarter 2020

SMC and Cadet Feasibility Study
Vancouver, Washington

Parametrix Date: 2/21/2022 Path: U:\Port\Projects\Clients\1940-Port of Vancouver\275-1940-006-POV TCE\99Svcs\GIS\POV\MXD_PDF\SMC_Cadet_FeasibilityStudy_2021\Fig_7-3_FormerSMCSiteArea_PCE_Q1_2020.mxd

Source: Clark County

N

0 80 160 Feet

MW-10 — Well Location Name
23 — March 2020 Result (µg/L)
15 — January 2020 Result (µg/L)
19 — March 31, 2020 Result (µg/L)
27 — August 2020 Result (µg/L)
Indicates shallow zone result
ND = Non-Detect
NS = Not sampled
IA = Inactive Sampling Location

> 5 µg/L
> 25 µg/L

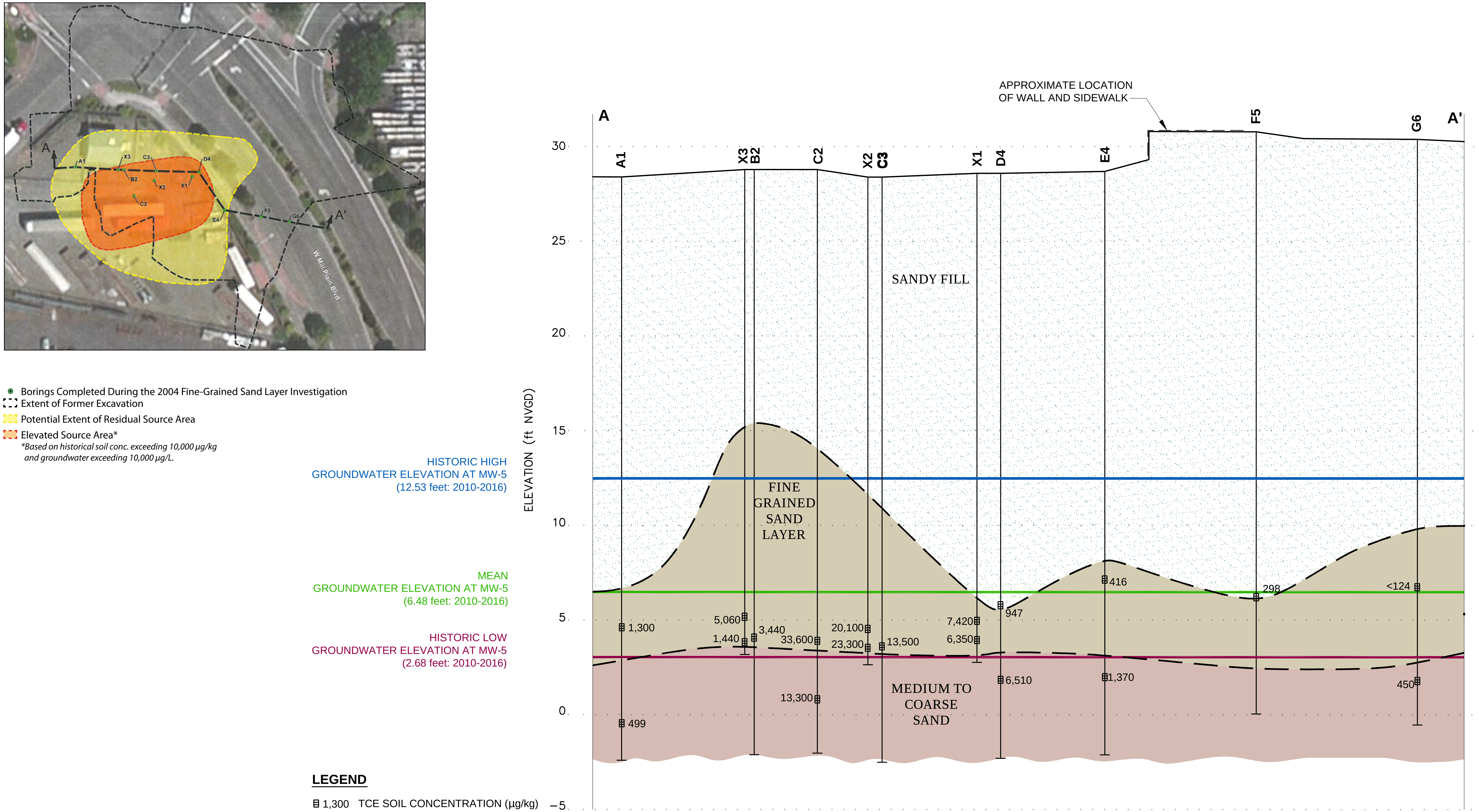
SMC Site Property Boundary
Ownership
City of Vancouver ROW (No Fill)
Port of Vancouver
Private

Shallow USA Groundwater Monitoring Well
Intermediate USA Groundwater Monitoring Well
Deep USA Groundwater Monitoring Well
TGA Monitoring Well
GPTIA Extraction Well

Note: Isoconcentrations are based on shallow zone well results

Figure 7-3
Former SMC Site Area
PCE Concentrations in Groundwater
1st Quarter 2020

SMC and Cadet Feasibility Study
Vancouver, Washington



Parametrix DATE: 01/20/2021

HORIZONTAL SCALE: 1"=20'
VERTICAL SCALE : 1"=5'

Figure 7-4
SMC Source Area
Fine Grained Sand Layer

CADET AND SMC FEASIBILITY STUDY
VANCOUVER, WASHINGTON

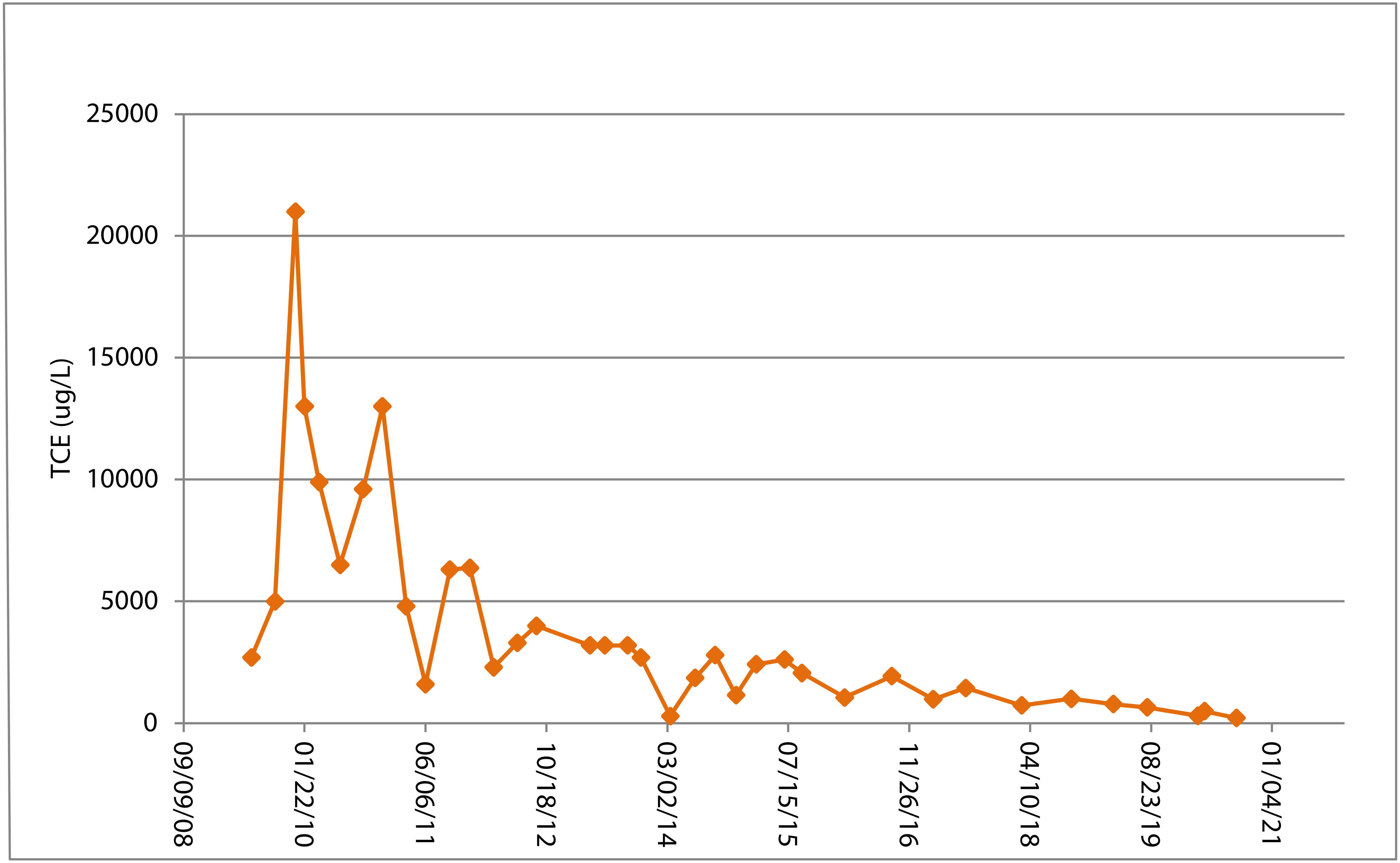
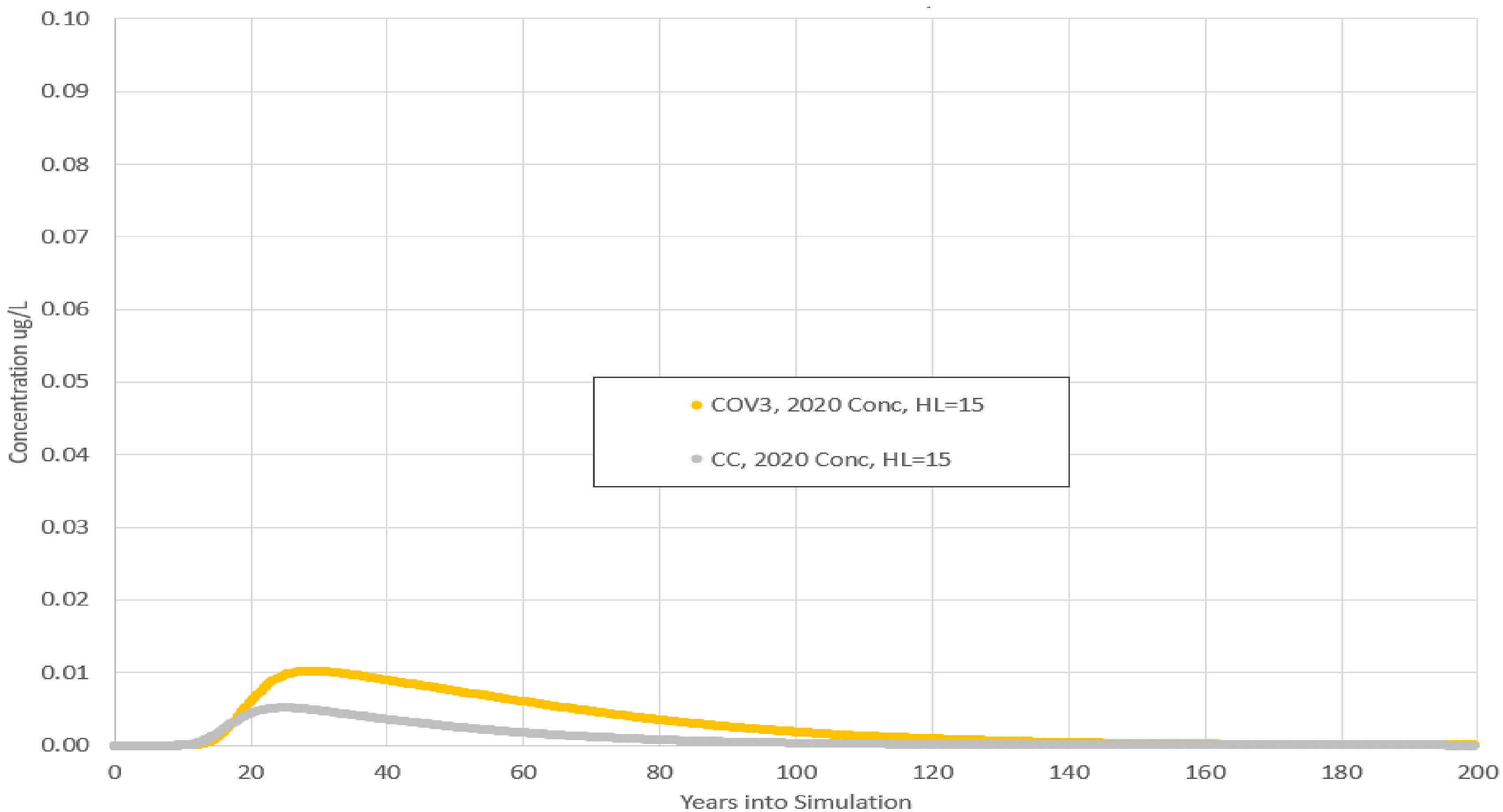


Figure 7-5
Monitoring Well MW-05 TCE Trend

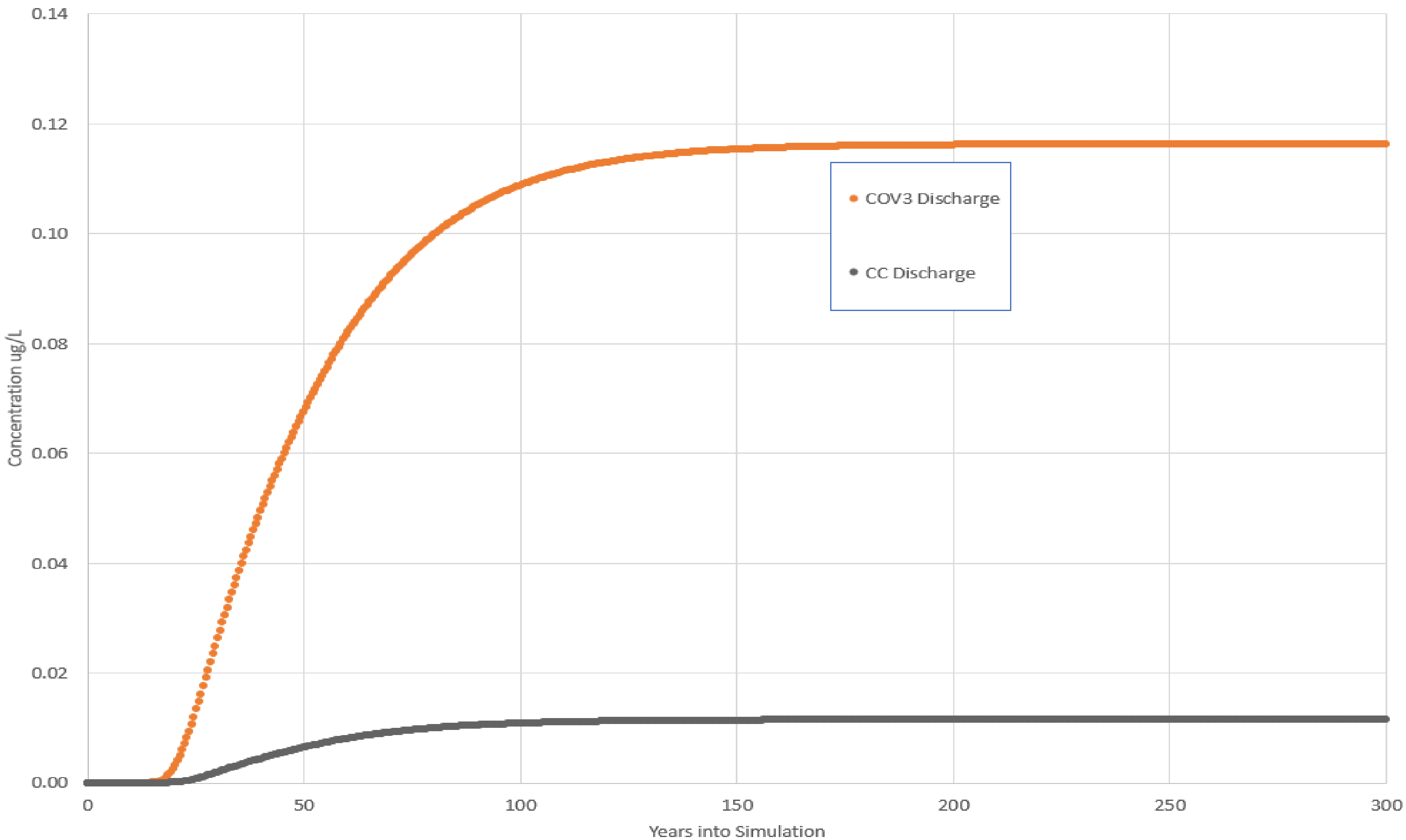
SMC and Cadet Feasibility Study
Vancouver, Washington



NOTES:
COV3 = City of Vancouver Water Station #3
CC = Carol Curtis Wellfield
HL = half-life (years)

Figure 8-1
Groundwater Model Simulation: Finite Mass
Predicted TCE Concentrations in Production Wells

SMC and Cadet Feasibility Study
Vancouver, Washington



NOTES:
COV3 = City of Vancouver Water Station #3
CC = Carol Curtis Wellfield

Figure 8-2
Groundwater Model Simulation: Infinite Mass
Predicted TCE Concentrations in Production Wells

SMC and Cadet Feasibility Study
Vancouver, Washington

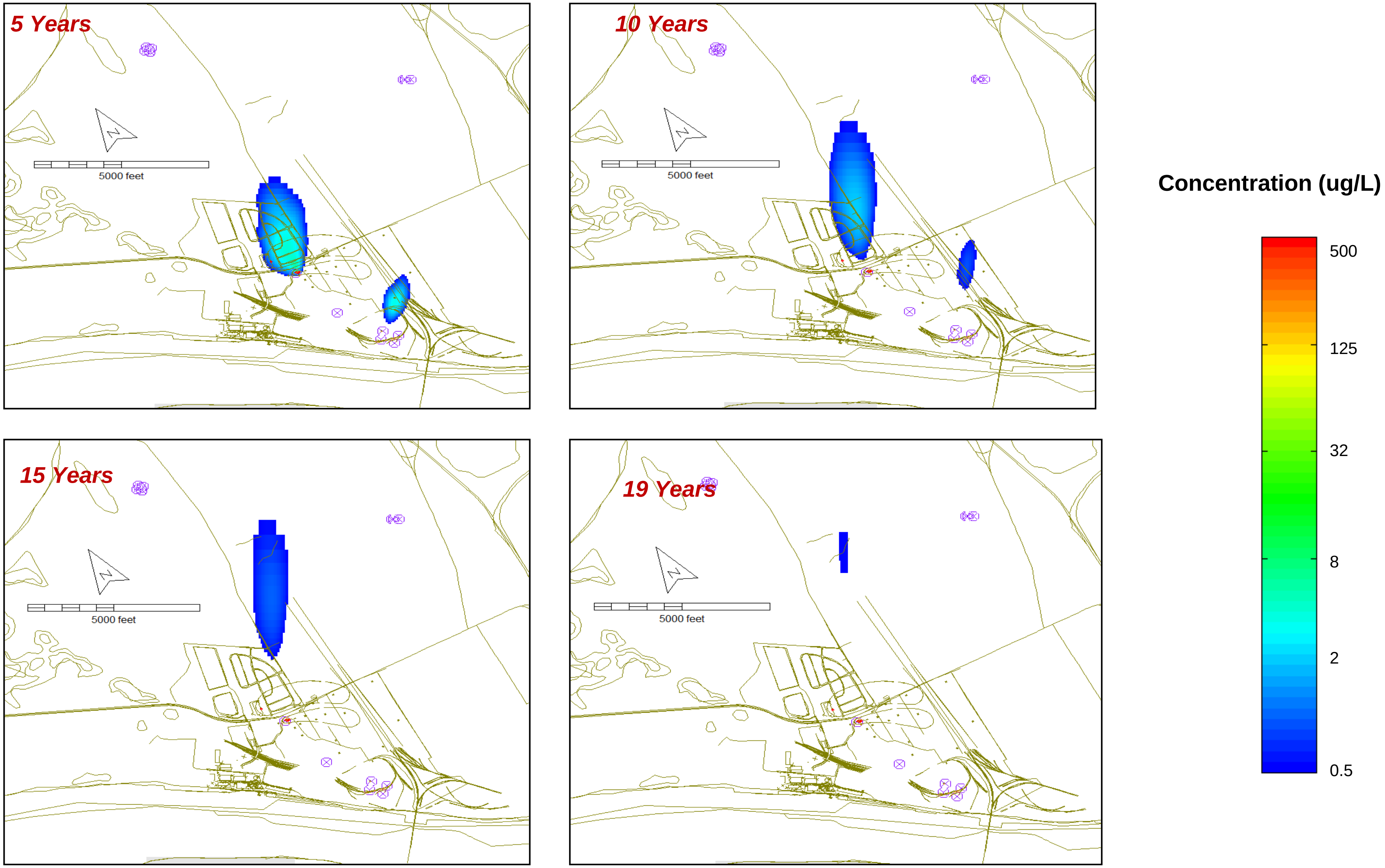


Figure 8-3
Predicted TCE Concentration in Intermediate Zone
Finite Mass Simulation

SMC and Cadet Feasibility Study
Vancouver, Washington

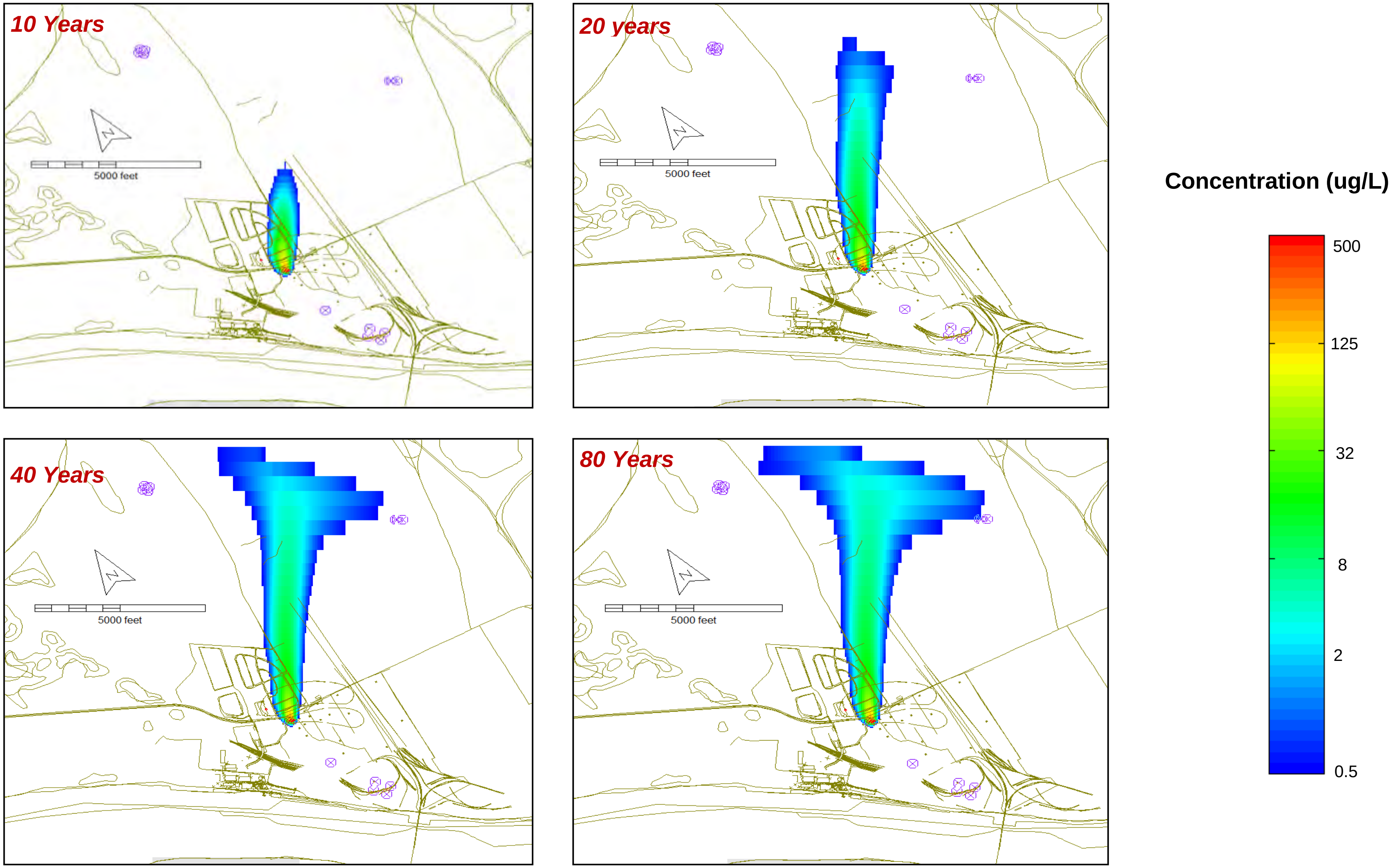
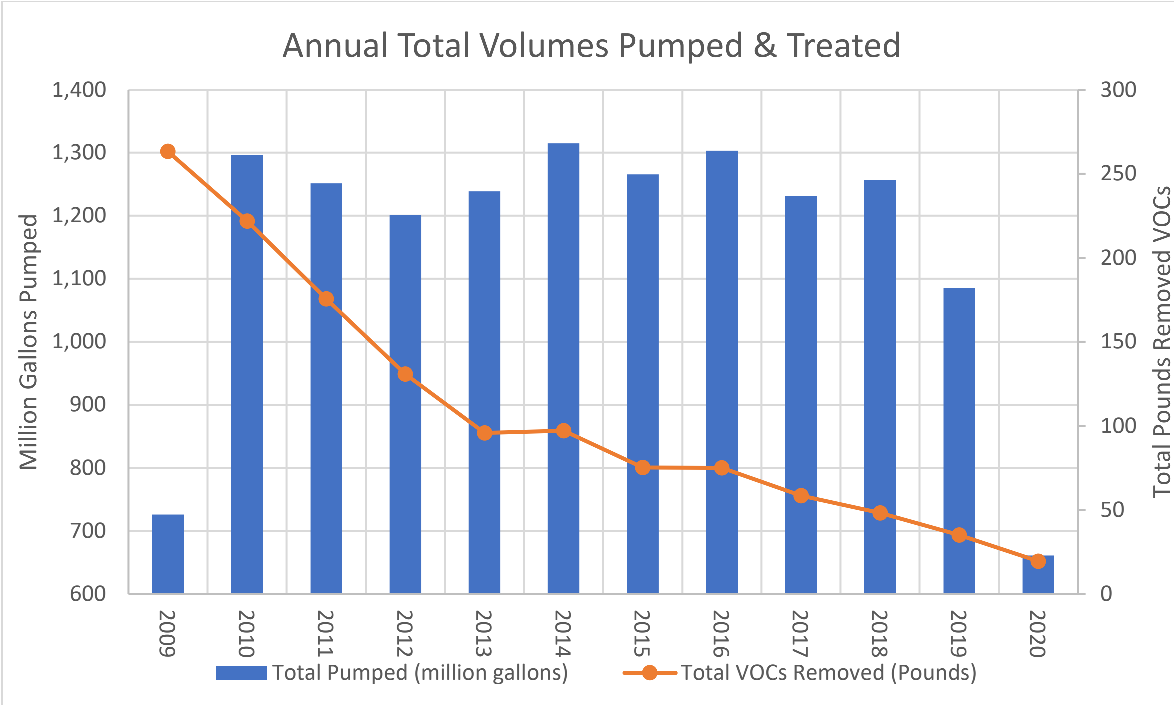


Figure 8-4
Predicted TCE Concentration in Intermediate Zone
Infinite Mass Simulation

SMC and Cadet Feasibility Study
Vancouver, Washington



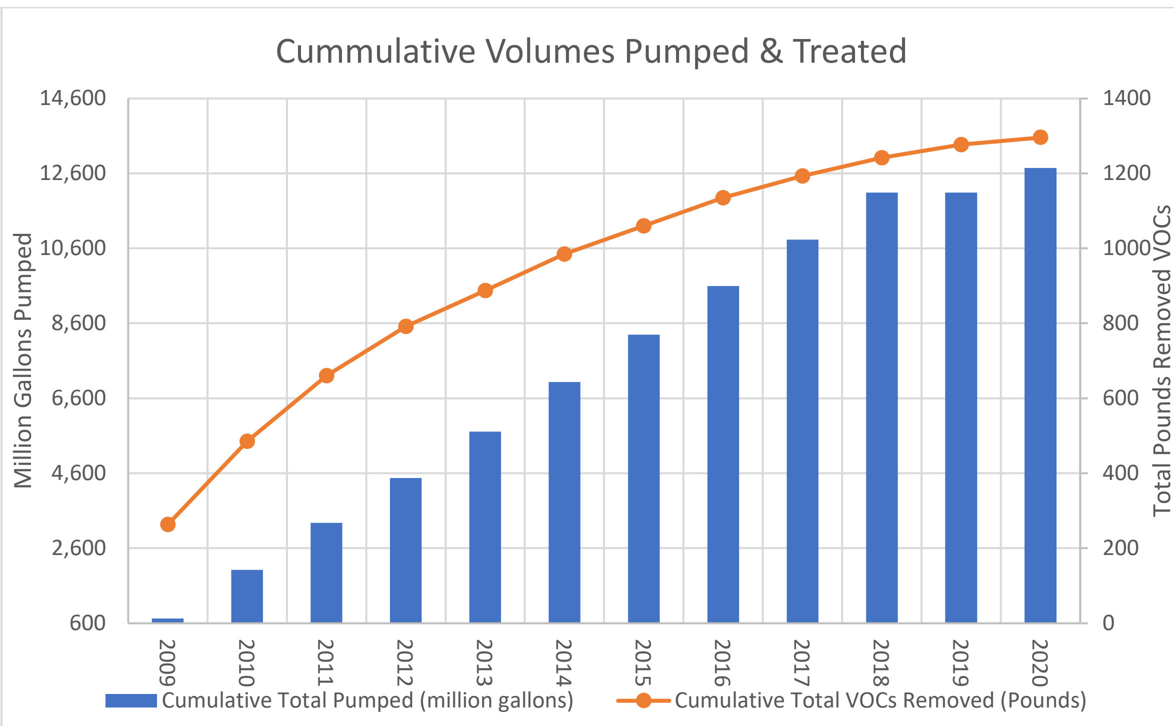
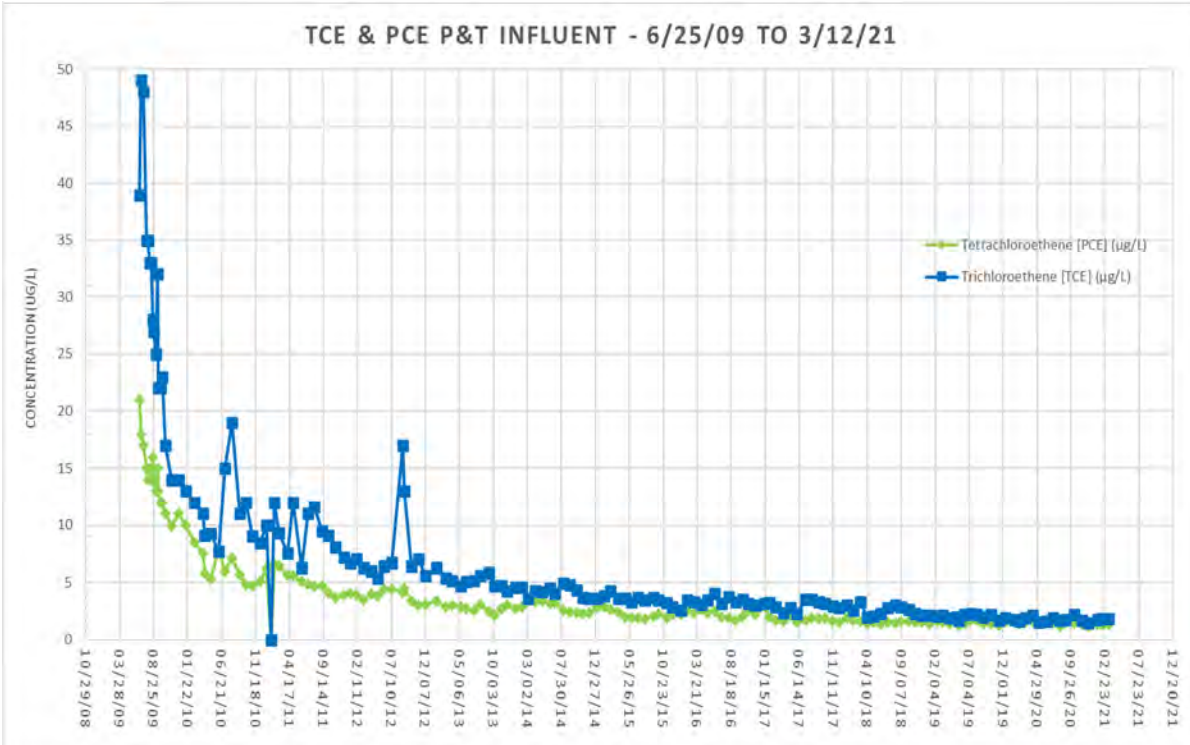


Figure 8-5
Groundwater Pump and Treatment System
Water Volume Extracted and VOCs Removed

SMC and Cadet Feasibility Study
Vancouver, Washington



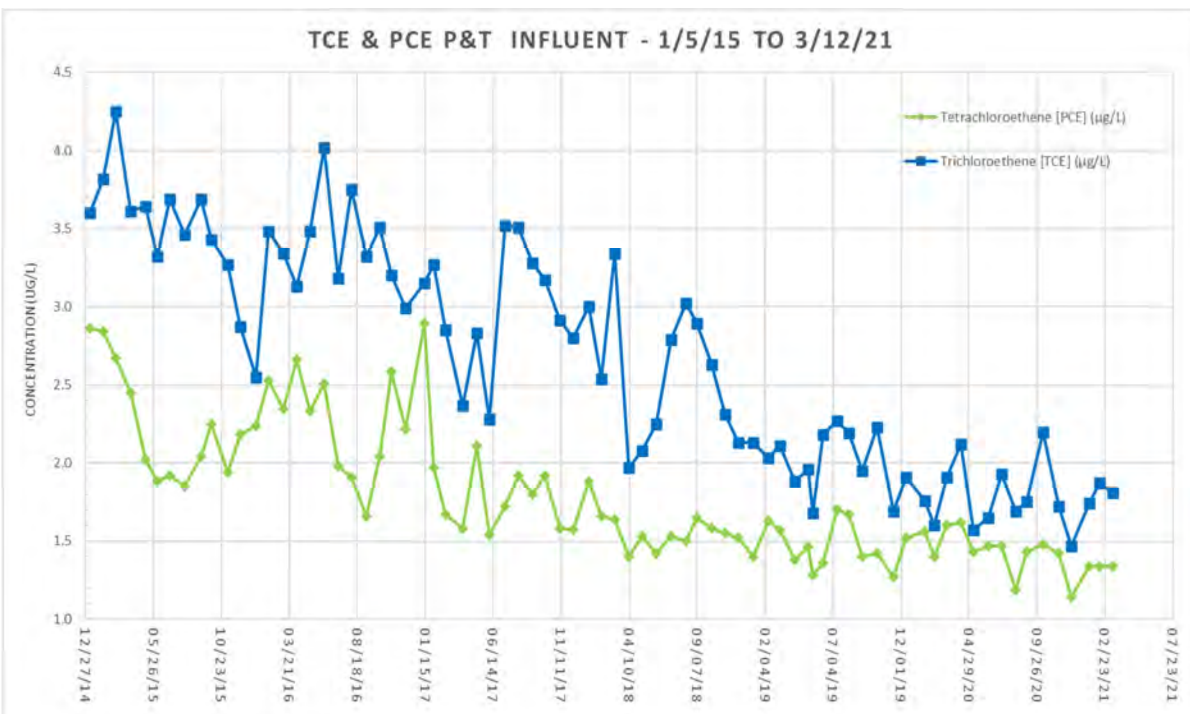


Figure 8-6
Groundwater Pump and Treatment System
TCE and PCE Influent Concentrations

SMC and Cadet Feasibility Study
Vancouver, Washington

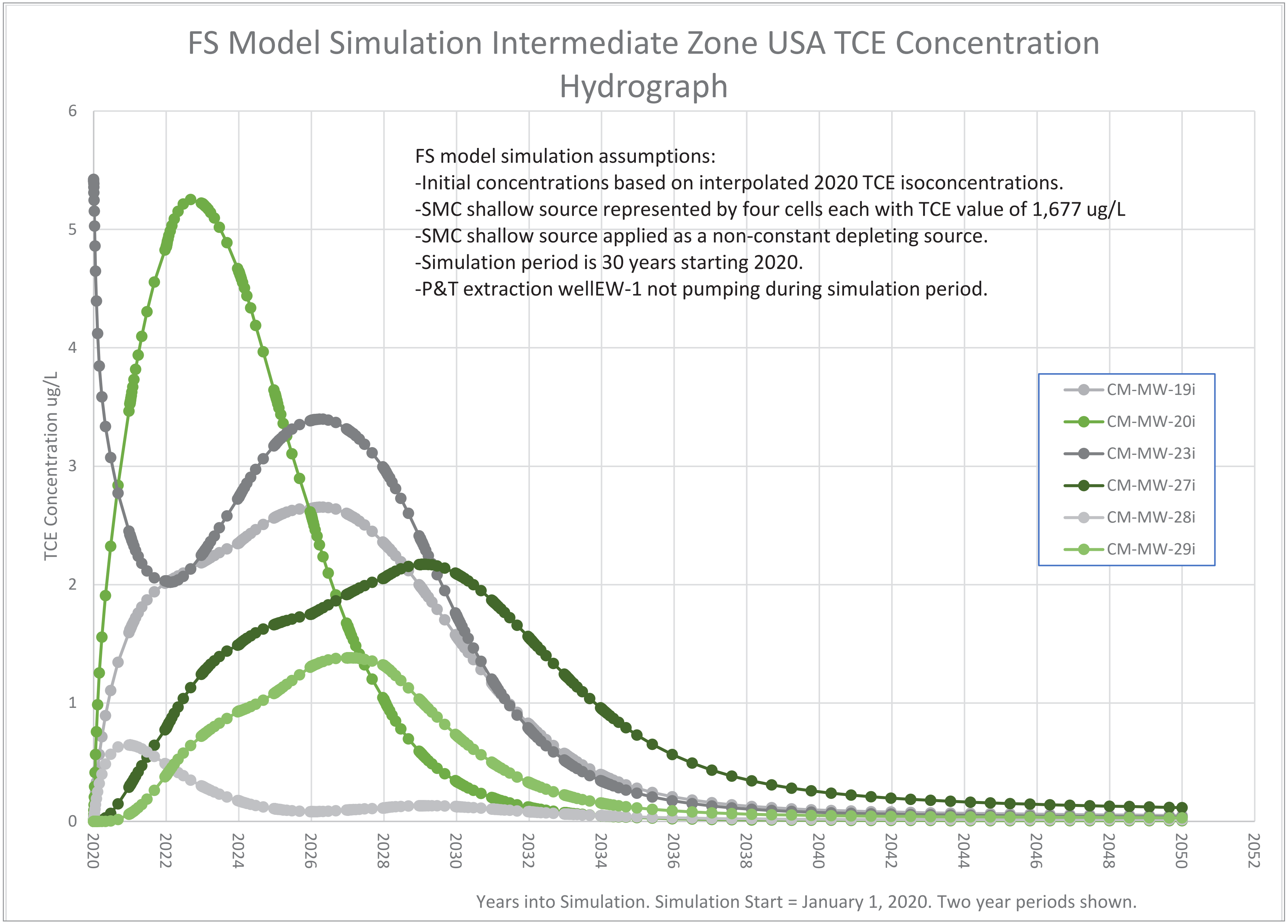


Figure 8-7
Intermediate Zone Cleanup Timeframe Modelling

SMC and Cadet Feasibility Study
Vancouver, Washington

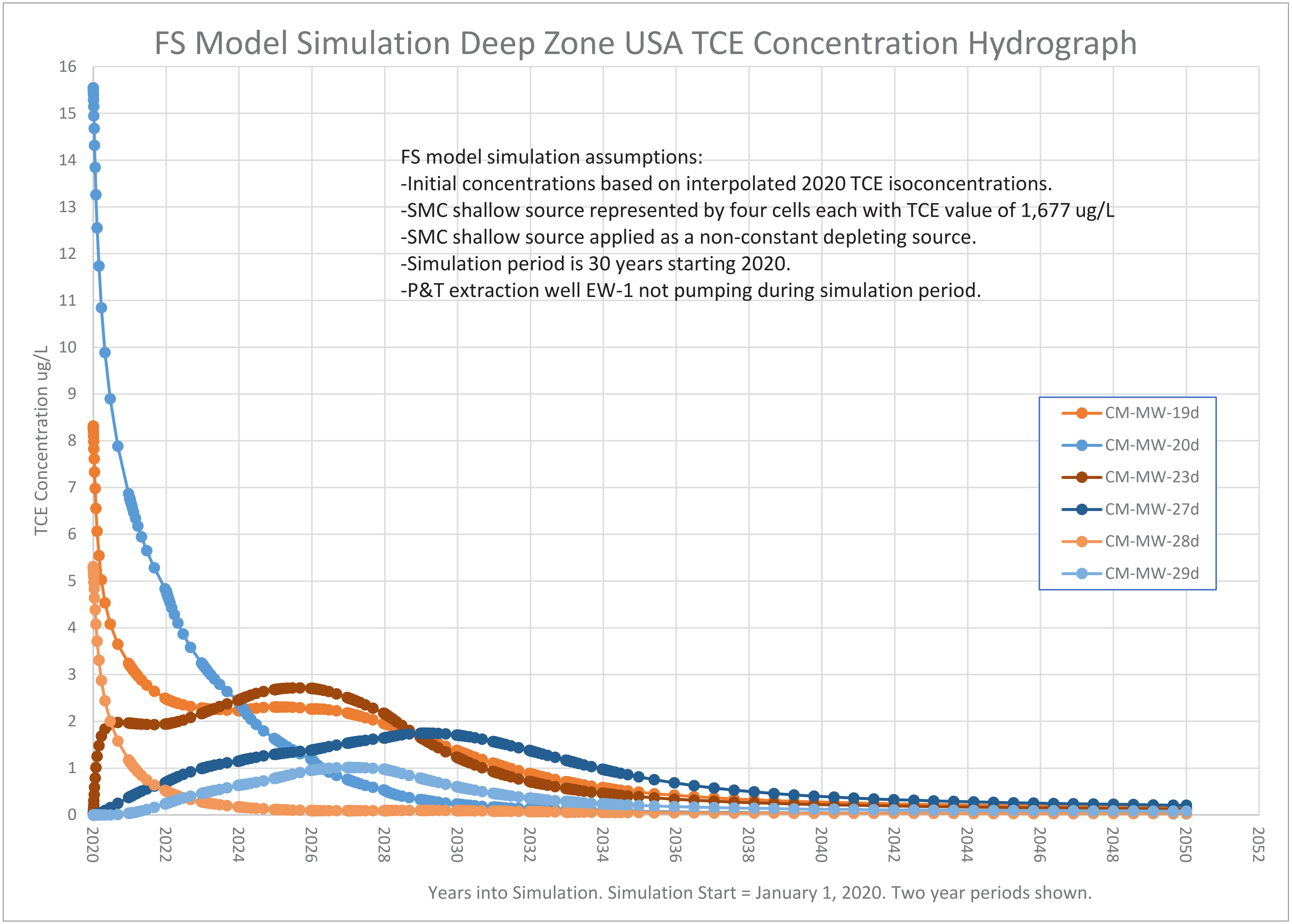


Figure 8-8
Deep Zone Cleanup Timeframe Modelling

SMC and Cadet Feasibility Study
Vancouver, Washington

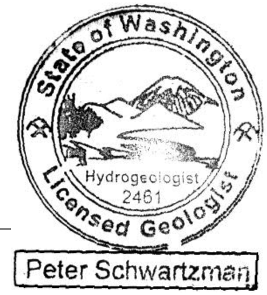
Appendix A

Groundwater Model Technical Memo

PACIFIC groundwater GROUP

A Mott MacDonald Company

Technical Memorandum



To: Richard Roche & Rick Malin, Parametrix

From: Peter Schwartzman, Pacific Groundwater Group

Re: Vancouver Lake Lowland Long-Term Contaminant Transport Analysis

Date: October 5, 2021

The Port of Vancouver (Port) is in the process of completing a Feasibility Study (FS) to present proposed final remedy(s) to address residual dissolved trichloroethylene (TCE), tetrachloroethylene (PCE), and associated compounds from the Cadet and Swan Manufacturing Company (SMC) sites. As part of the Cadet and SMC Remedial Investigations, the Port and Clark Public Utilities (CPU) developed a numeric groundwater model in 2008 (“VLL Model”) to simulate groundwater movement in the Vancouver Lake Lowlands area and evaluate the effectiveness of cleanup action alternatives. In order to support preparation of the FS, Pacific Groundwater Group (PGG) used the VLL Model to:

- Assess future contaminant (TCE) concentrations in groundwater once the pump-and-treat system is turned off and identify potential receptors, and
- Perform sensitivity analysis to estimate source concentrations that would result in detectible concentrations at identified receptors.

This technical memorandum presents the results of fate and transport analyses performed by PGG. It includes a summary of findings and recommendations, a description of the VLL Model, descriptions of the simulations performed, model predictive results, and a discussion of factors influencing model results.

PGG’s work was performed and this memorandum was prepared in accordance with generally accepted hydrogeologic practices at this time and in this area for the exclusive use of Parametrix and their client (Port of Vancouver). Use of this report and any information or analyses contained herein for any purpose beyond that of predicting long-term contaminant transport from the SMC/Cadet sites using the existing Vancouver Lake Lowland groundwater model is at the sole risk of the person, persons, or organization using the information or analyses. Pacific Groundwater Group is not responsible for, and makes no warranty for, any other use of the information and analyses presented herein. No other warranty, expressed or implied, is made.

P 206.329.0141 F 206.329.6968 | 2377 Eastlake Avenue East | Seattle, Washington 98102 | www.pgwg.com

Water Resource & Environmental Consulting

1.0 SUMMARY OF FINDINGS AND RECOMMENDATIONS

The following bullets summarize the findings and recommendations of PGG's modeling analysis:

1. PGG used the VLL model to simulate how current TCE concentrations at the SMC/Cadet source area would affect groundwater receptors once the existing pump-and-treat system is turned off. PGG performed two "base-case" simulations: a "finite mass" simulation in which current concentrations were used to define a limited mass of residual TCE at the source area, and an "infinite mass" simulation in which current source concentrations were assumed to remain constant over time (e.g., steady state source area concentrations. The infinite mass assumption of constant concentrations is considered to be highly conservative.
2. The model predicted that contaminant receptors would include the City of Vancouver's Water Station 3 (COV3) and Clark Public Utility's (CPU's) Carol Curtis Wellfield (CPU-CC). It predicted that COV3 concentrations would exceed CPU-CC concentrations.
3. PGG also performed model sensitivity analyses to estimate how much higher source concentrations would need to be in order to cause TCE concentrations at COV3 and/or CPU-CC to exceed the laboratory detection limit of 0.5 ug/L. Sensitivity analyses were performed by "scaling up" (increasing) the source concentrations until predicted receptor concentrations exceeded the detection limit.
4. Base-case finite mass and infinite mass simulations predicted that current concentrations at the SMC/Cadet source area concentrations will not cause detectable TCE concentrations (0.5 ug/L) in receptor wellfields (COV3 and CPU-CC). Model simulations predict TCE arrival at the COV3 & CPU-CC wellfields around 20 years after the pump and treat system is turned off.
5. When existing TCE source concentrations are modeled as a finite mass within the subsurface, model sensitivity analysis suggests that existing source concentrations would need to increase by 49 times compared to current concentrations to cause TCE detections at COV3 or CPU-CC. Sensitivity analysis for the infinite mass representation suggests that existing source-area concentrations would need to increase by 4.3 times to cause TCE detections.
6. All groundwater flow and transport models include sources of uncertainty, and dominant sources of uncertainty associated with the VLL Model and the simulations described above include simulated aquifer properties (hydraulic conductivity) and potential over-prediction of the geographic extent of the contaminant plume due to numerical dispersion., However, TCE concentrations in identified wellfield receptors are expected to be low and near or below standard detection limits even when these sources of uncertainty are considered.
7. PGG recommends that the model results be used to identify future groundwater quality monitoring after the pump and treat system is turned off. The model can be used to identify "sentry wells" and "trigger concentrations" to validate model

assumptions and assess whether additional model refinement and/or or other remedial actions are required.

2.0 MODEL DESCRIPTION

PGG performed predictive simulations using the Vancouver Lake Lowland Groundwater Model ("VLL Model"). The VLL Model is a numerical groundwater flow model developed in MODFLOW. A detailed description of the groundwater flow model is provided in the Groundwater Model Summary Report (Parametrix, 2008). Further validation of the model was completed using weekly averages of river stage and pumping rates as described in the Interim Action Summary Report (Parametrix 2011). Contaminant transport simulation functionality was added to the flow model as part of a feasibility study (FS) to evaluate remediation scenarios (Parametrix, 2015).

PGG used the version of the model previously submitted to (and approved) by Ecology. The version was provided by PMX to PGG in a compressed file titled "Base-Case_GWV_07_12_05.zip". PGG reviewed the model files and confirmed their consistency with published documentation of specified flow and transport parameters. PGG ran the VLL model in Groundwater Vistas graphical user's interface (ESI, 2015). Consistent with the original VLL model, groundwater flow was simulated with the 1988/1996 version of MODFLOW (Harbaugh & McDonald, 1996). Transport was run using the "MT3DMS" version of the MT3D contaminant fate and transport code (Zheng & Wang, 1999).

2.1 SIMULATION PERIOD

The model was initially run over a 15-year time period (2020-2035) using the schedule of pumping rates discussed in Section 2.2. However, in order to illustrate hypothetical scenarios in which the contaminant is represented as continuously replenished ("infinite mass simulations", described in Section 3), PGG extended the simulation period to 300 years, where the pumping rates in year 15 were maintained through years 16 to 300 in order to illustrate hypothetical scenarios in which the contaminant is represented as continuously replenished ("infinite mass simulations", described in Section 3). Although the flow model was run in transient mode, each annual distribution of pumping rates was simulated as a steady-state stress period for the associated period of time.

2.2 PUMPING ASSUMPTIONS

Pumping was simulated from major groundwater users in the Vancouver Lake Lowland, including: the City of Vancouver (COV), Clark Public Utilities (CPU), Great Western Malting (GWM) and the Port of Vancouver (POV). COV pumping included withdrawals from three local water stations (COV1, COV3 and COV4) and from their Westside Wastewater Treatment Facility (WWTF). CPU pumping included withdrawals from their cogeneration plant (currently in operation) and from shallow (Pleistocene Alluvial Aquifer, or "PAA") wells at their Carol Curtis Wellfield (simulated to begin operation in 2021).

The model assumed discontinuation of POV's pump-and-treat system that has been capturing groundwater contamination from the SMC and Cadet plumes by simulating zero pumping from extraction well EW-1.

Pumping was simulated at average annual rates of withdrawal, as shown on **Figure 1**. Projected growth in pumping for COV facilities was provided to PGG by PMX, and assumed the following:

- Pumping from all three water stations in 2020 was set at COV-reported withdrawals, and assumed a subsequent 32, 8, and 15-percent annual growth rate at Water Station 1, 3, and 4, respectively.
- Pumping from the WWTF in 2020 was set at COV-reported withdrawals and assumed a subsequent 2-percent annual growth rate.

PMX assumed that 2020 pumping from POV Wells #1 and #2 is evenly split and will increase at an annual growth rate of 0.5 percent. PMX further assumed that pumping from the two GWM production wells is evenly split and will remain constant at 2020 withdrawals.

PGG conferred with CPU to obtain future pumping projections for its cogeneration plant ("COGEN") and from Carol Curtis Wellfield PAA wells ("CPU-CC"). CPU estimated that pumping from the Cogeneration Plant has remained fairly constant and will not change into the future; therefore, PGG specified the same annual (2006) rate of withdrawal as used in the VLL Model (Parametrix, 2008). Projected withdrawals for the Carol Curtis Wellfield were estimated based on expected capacities of future production wells and the assumption that CPU would shift other withdrawals to the wellfield as production capacity became available. The entire 20,000 acre-feet/year water right allocated to the PAA wells was assumed to be utilized at 20 percent during the first year of wellfield operation, increasing by another 20 percent every two years until the full water right could be employed after 9 years. It should be noted that model representation of Carol Curtis pumping assumed that the first PAA well would be online in 2021, whereas it is more likely to begin production in 2022.

Pumping was assumed to be evenly distributed between wells for wellfields that include multiple production wells. Specifically, COV1 was modeled with four production wells[1], COV 3 with three production wells, and the Carol Curtis Wellfield with five (future) PAA production wells. In addition, production wells were represented as withdrawing water from multiple layers within the Unconsolidated Sedimentary Aquifer (USA). The USA is represented by model layers 1 through 9 and includes that PAA. The following table summarizes the pumped layers specified for each pumping center. Groundwater Vistas distributes total specified withdrawals between model layers proportional to the transmissivity of each layer:

[1] COV WS1 has 12 active groundwater wells all located at Waterworks Park. The VVL model simulated pumping at WS1 utilizing 4 wells.

Pumping Center	Top Layer	Bottom Layer		Pumping Center	Top Layer	Bottom Layer
COV1	4	9		CPU-CC	4	9
COV3	6	9		COGEN	4	4
COV4	7	9		POV	4	7
WWTF	2	3		GWM	5	6

Comparison of wellfield production curves shows that the combined simulated pumping from the POV/ GWM / COV WWTF wells is small compared to all other withdrawals (Figure 1). At the beginning of the model simulation in 2020, the highest withdrawal occurs at COV1 with increasing pumping rates at Carol Curtis having the highest withdrawal by 2025.

2.3 FATE & TRANSPORT PARAMETERS

Mass transport was simulated using MT3DMS (Zheng & Wang, 1999). MT3DMS simulates mass transport within the model area by utilizing the flow distribution generated by MODFLOW to calculate a velocity distribution for the model area. The partial differential transport equation is then solved by MT3DMS. For the groundwater model, the transport equation was solved using the Modified Choleski method, and advection was simulated using the finite difference solution scheme and upstream weighting.

PGG initially ran model simulations for both TCE and PCE. However, given lower initial concentrations for PCE and lower predicted PCE concentrations at predicted contaminant receptors, all reported project simulations were limited to just TCE.

Parameters considered in prior mass transport modeling included: boundary conditions, porosity, dispersion, and retardation. These parameters were previously evaluated in the Groundwater Model Summary Report (Parametrix 2004). PGG added consideration of biodegradation (first order decay) along the approximately 2.5-mile flowpath between the contaminant source area and receptors at the dominant pumping centers. These fate and transport parameters are described below.

Boundary Conditions

Simulation of contaminant fate and transport assumes that TCE does not enter the project area from precipitation recharge, from seepage losses derived from modeled surface-water features (e.g. Columbia River, Burnt Bridge Creek, Vancouver Lake, Lake River) or from other sources outside the model area. PGG maintained prior differentiation of the flow model domain between a region that actively simulates contaminant fate and transport (“transport model area”) and a region specified within MT3DMS as inactive for simulating transport. The transport model area is a 7.3- by 3.1-mile rectangle that extends far beyond those regions where significant concentrations are predicted under the prior simulations and the simulations discussed below.

TCE in SMC/Cadet source areas and associated residual plume areas was simulated using “initial concentrations” specified for associated model cells and/or “constant concentrations" specified for the model cells coincident with the source areas, as discussed in Section 3.1.

Porosity

PGG retained prior specification of porosity (η), discussed in Appendix B of the feasibility study report for NuStar, Cadet and SMC sites (Parametrix, 2015), and reproduced below:

> "Effective porosity controls the seepage velocity; total porosity determines the volume of water available for solute storage in a model cell. Effective porosity is that portion of total porosity that conveys flow. Therefore, dead zones and blocked pore spaces do not contribute to effective porosity. For a very coarse grain matrix, such as the USA, the large pore spaces are not easily blocked, and dead zones are unlikely. Therefore, for this model, no distinction was made between effective porosity and total porosity. A value of 0.30 was used for porosity in all model layers throughout the model area. This value may be slightly high for the fine-grain alluvium, but this just has the effect of slightly reducing the contaminant transport velocity."

Dispersion

PGG retained prior specification of dispersion, discussed in Appendix B of the feasibility study report for NuStar, Cadet and SMC sites (Parametrix, 2015), and reproduced below:

> "Dispersion refers to the reduction in concentration along a flowpath, which is primarily due to non-uniform velocity distributions in the porous media. A value of three feet was used for longitudinal dispersivity in all model layers throughout the model area (Zheng and Bennett 2002). Transverse and vertical dispersivities were taken as 0.3 and 0.03 feet, respectively, based on literature values (Zheng and Bennett 2002) of the ratio among longitudinal, transverse, and vertical dispersivities."

Retardation

PGG retained prior specification of retardation, discussed in Appendix B of the feasibility study report for NuStar, Cadet and SMC sites (Parametrix, 2015), and reproduced below:

> "Retardation refers to the tendency of many contaminants to travel slower than the groundwater flow rate. This is largely due to the interaction between contaminants and the aquifer matrix. Retardation factors of 1 (no retardation), 2, 3, 4, and 6 were tested during the 2004 modeling effort (Parametrix 2004). Higher retardation factors indicate that the contaminant interacts more strongly with the aquifer matrix and therefore has a slower velocity with respect to the groundwater velocity. The 2004 modeling effort found that at higher retardation rates, the predicted concentration at the GWM wells was reduced due to the slower mass transport of contaminants into the total volume of water pumped at the GWM wells. The 2004 modeling effort found that predicted concentrations were closest to the observed concentrations at GWM production well 5 (the GWM well with the highest observed and predicted concentration of TCE) when a retardation factor of 1 (no retardation) was used. This was not considered realistic because some retardation is expected. Assuming no retardation is also not conservative with respect to cleanup time frame because it would predict a shorter cleanup time. To be more realistic and

> more conservative, a retardation factor (R) of 2 was used. This retardation rate is similar to the retardation rate derived from MTCA default parameters, which would be 1.5 using an estimated bulk density (P_d) of 1.5 kg/L and a porosity (η) of 0.3. Given the uncertainty in bulk density and porosity, retardation factors of 1.5 or 2 are equally defensible."

Biodegradation

Biodegradation of TCE during groundwater transport is included in the model with slow decay based on observation of degradation compounds and the long model-estimated transport times (greater than 17 years to potential well receptors). MT3DMS simulates biodegradation using half-life (first-order) decay, consistent with standard practice for estimation of chlorinated solvent fate and transport analysis (Newell 2002). Degradation rates are influenced by subsurface geochemical conditions including availability of electron donors (typically carbon sources), oxidation-reduction potential (with negative values associated with more rapid degradation), and presence of microbial populations that degrade TCE. Abiotic degradation may also occur. The presence of degradation daughter compounds cis-1,2 DCE and vinyl chloride within the plume indicate that degradation is occurring. However, the aquifer is generally not strongly chemically-reducing, and prevalence of TCE relative to degradation products indicates that biodegradation is less rapid than observed in other more chemically-reducing environments. Published biodegradation rate half-life values for TCE are typically reported for anaerobic aquifer systems with half lives of 4 years or less (Aronson, 1997; Schaerlaekens, 1999). Site-specific TCE degradation rates were not estimated because monitoring data is influenced by the active remediation at the site and empirical methods would result in spurious results. Instead, a conservative (slow) 15-year half-life was assumed in this modeling effort. Application of a slow rate will result in over-estimation of receptor steady state concentrations compared to a shorter half-life (similar to those more commonly reported in the literature).

3.0 SIMULATIONS PERFORMED

The model was used to perform two "base-case" simulations and two "sensitivity analysis" simulations (four simulations total). The base-case simulations were performed to assess how *current* TCE occurrence might affect concentrations in key receptors (production wells) downgradient of the contaminant source area. The sensitivity analysis simulations were performed to assess how much larger current concentrations would need to be to result in TCE detections in production wells at the current standard laboratory detection limit of 0.5 ug/L. Note that this detection limit is almost an order of magnitude smaller than the TCE maximum contaminant level (MCL) of 4 ug/L.

3.1 BASE-CASE SIMULATIONS

The base-case analysis included a "finite mass" simulation and an "infinite mass" simulation. The finite mass simulation assumed that TCE concentrations measured in the first quarter of 2020 (2020-Q1) groundwater sampling event represent contaminant occurrence in the subsurface. Measured concentrations (where present) are represented as "initial concentrations" specified for associated model cells in the base-case simulations. MT3DMS uses groundwater concentrations to assign adsorbed concentrations on aquifer materials based on the partitioning coefficient (K_d), which is derived from the following equation and employs the parameter values referenced in Section 2.3:

$$K_d = (R-1)*\eta/P_d$$

For the finite mass simulation, the 2020-Q1 distribution of TCE was used to assign initial concentrations to model cells using the following algorithm:

1. Mapped 2020-Q1 concentration contours for the shallow, intermediate and deep zones in the USA (**Figure 2**), along with one-or-more point values for the maximum measured concentration measured within the highest-value contour, were used to interpolate initial TCE values per model cell[2].
2. Interpolated model-cell values per zone were assigned to model layers: the shallow zone was assigned to layer 1, the intermediate zone was assigned to layer 4, and the deep zone was assigned to layer 9. Initial concentration values for model cells in intervening layers were assigned by linearly interpolating between upper and lower layers[3].
3. The model assumed zero TCE below the USA (model layers 10 through 16).

The infinite mass simulation assumed that the current maximum TCE concentrations in the source areas will not reduce over time. This assumption is considered highly conservative and provides an upper limit on predicted downgradient transport concentrations associated with currently observed source concentrations. Source areas were assumed to occur close to the land surface in the shallow zone (layer 1) and were therefore limited to the "Shallow Zone" TCE distribution shown on **Figure 2**. Rather than interpolating values per model cell based on mapped TCE contours, PGG assigned the *maximum* 2020-Q1 Shallow Zone concentration measured in each model cell (in which a 2020-Q1 detection occurred) as a "constant concentration" boundary condition in MT3DMS. Four shallow-zone model cells were identified with 2021Q1 TCE detections; however, PGG simulated only three cells because the fourth cell was located immediately downgradient of a higher-concentration cell and would therefore replace the higher concentration with a lower concentration. From northwest to southeast, the three "constant concentration" cells had values ranging from 490 to 560 to 19 ug/L.

3.2 SENSITIVITY ANALYSIS

PGG's performed a sensitivity analysis on both base-case simulations (finite mass and infinite mass) to assess how much higher source concentrations would need to be to cause

[2] PGG used the ESRI application "Topo to Raster" to resolve the contoured TCE surface (and additional points) to a 10-foot grid within ARC-GIS, and then assigned the value of the ARC-GIS grid point closest to the model cell centroid as the model cell value.

[3] Linear interpolation was indexed on model layer (one unit per layer) rather than on depth from land surface.

TCE detection in downgradient receptors (production wells). Conceivably, once the pump-and-treat system is turned off, TCE concentrations could exhibit some degree of "rebound" under which currently observed concentrations increase somewhat. The sensitivity analyses were performed by simply scaling the initial concentrations (finite mass simulation) and constant concentrations (infinite mass simulation) upwards until the detection limit of 0.5 ug/L was predicted in the dominant receptor[4]. The sensitivity analysis simulations employed the exact same assumptions as the base-case simulations, with the exception initial and constant concentrations simulated for the source areas.

4.0 MODEL PREDICTIONS

This section provides the results of the base-case and sensitivity analysis simulations along with general observations about the elements of the model that affect predictions, sources of model uncertainty and associated implications.

4.1 GENERAL OBSERVATIONS

Several characteristics of the model influence predictions of contaminant fate and transport in the model domain. This subsection describes how modeled groundwater flow directions, model representation of dispersion along contaminant flowpaths, and modeled aquifer properties between the contaminant source area and the COV and CPU wellfields influence predictive results.

Modeled groundwater flow directions have the strongest influence on contaminant transport pathways. **Figure 3** presents modeled groundwater elevation contours in the PAA under recent (2020) and maximum simulated pumping (2035) conditions. Under 2020 pumping conditions, the model predicts groundwater flow from the Columbia River towards COV's water stations COV3 and COV1. Predicted groundwater elevations are most depressed around COV1 due to its higher pumping rate, and COV1 is predicted to capture more Columbia River water than COV3. Based on the 2020 modeled water-level contours, groundwater from the SMC/Cadet source areas appears to flow towards both water stations. Under 2035 pumping conditions, groundwater flow from the source area is predicted to shift away from COV1 and towards both COV3 and CPU's Carol Curtis Wellfield (CC). Although 2035 CC groundwater withdrawals are the highest on the Vancouver Lake Lowland, the associated cone of depression is relatively shallow because drawdown from the wellfield is stabilized by modeled leakage through the bottom of Vancouver Lake.

Figure 4 presents mapped comparisons of TCE "plumes" predicted by advective flow alone and based on the fate/transport parameters defined in Section 2.3) at transport times of 10, 20, 40 and 80 years into the model simulation. The simulations all use the same source areas (three model cells associated with the "infinite mass" simulation, as discussed in Section 3.1. The mapped comparisons show the advective plume as particle traces

[4] Modeled TCE concentrations for multi-well wellfields were calculated by averaging the concentrations predicted for all wellfield wells.

generated using MODPATH and fate/transport plume delineations using a color flood of TCE concentrations predicted by MT3DMS[5]. Figure 4 shows that:

- The fate/transport plume has a notably wider footprint than the advective plume.
- Within the first 10 years, the fate/transport plume extends farther downgradient than the advective plume. However, by 20 years the advective plume has overtaken the fate/transport plume and progressed farther downgradient.
- Both the advective and fate/transport plumes continue to expand through 40 years of transport simulation, however expansion between 40 and 80 years is minor.

The wider footprint (and initial greater extent) of the fate/transport plume reflects the degree of dispersion simulated by MT3DMS. Comparison to analytic predictions of plume width suggest that the bulk of modeled dispersion arises from numerical dispersion rather than the range of dispersivity values used in the VLL Model (0.03 to 3 feet, as documented in Section 2.3). Although numerical dispersion expands the fate/transport plume beyond that expected from the specified dispersivity values, it should be noted that hydrogeologic conditions in the VLL are likely to cause more dispersion than would occur in a simple uniform flow field. Groundwater flow in the VLL is not expected to be uniform or steady because the shallow aquifer (PAA) is highly transmissive and highly responsive to Columbia River tidal and seasonal river-level variations. The river-level variations propagate into the aquifer system, causing variations in groundwater flow directions at similar timescales. These variations have been described as causing a “sloshing” effect, which is expected to accentuate dispersion beyond that expected from uniform/steady flow. Model simulations could be performed to assess the extent to which numerical dispersion represents dispersion expected from Columbia River variations; however, this would require significant modifications to the VLL Model and is beyond the scope of this investigation.

Differences between transport distances predicted for advective vs. fate/transport contaminant migration is caused by both modeled aquifer properties and the effects of fate/transport parameters. During the first 10 years, the fate/transport plume extends beyond the advection plume (**Figure 4**) because advection is slowed by the relatively low hydraulic conductivity (K) of the shallow sediments in the contaminant source area. **Figure 5** shows the zonation of hydraulic conductivity near the source area in model layer 1. KZone 1 occurs along the contaminant flowpath and represents fine-grained Quaternary alluvium (Qal) with relatively low hydraulic conductivity (1 ft/d). In layers 2 and 3, KZone 1 is largely replaced by Qal KZone 2, which also has a relatively low hydraulic conductivity compared to PAA sediments (59 ft/d versus >2,000 ft/d)[6]. Near the source area, contaminant transport is predicted to occur within the shallow Qal sediments. The degree to which the fate/transport plume extends beyond the advection plume is interpreted to reflect the influence of actual and numerical dispersion. However, once advective particles have migrated beyond the low hydraulic conductivity Qal zones, advective plume migration is predicted to occur at a faster rate than fate/transport plume migration with dispersion,

[5] The color flood of modeled concentrations is based on the sensitivity analysis simulation in which maximum observed TCE concentrations are increased by a factor of 4.3x. See discussion in Section 4.3.

[6] Zonation of hydrogeologic units and associated hydraulic conductivity values are based on site characterization with multiple monitoring wells and prior model calibration (Malin, 2021).

retardation and biodegradation. Within the PAA, the model predicts that the effects of retardation and biodegradation tend to significantly slow contaminant transport relative to purely advective transport.

4.2 BASE-CASE PREDICTIONS

The model predicts that residual TCE will migrate towards COV3 and CC, and very low concentrations (below the standard detection limit of 0.5 ug/L) will occur in production wells at both wellfields. **Figures 6** and **7** show the predicted concentration hydrographs for the finite mass and infinite mass simulations (respectively). The finite mass simulation predicts that trace concentrations of TCE will arrive at the two wellfields about 15 years after the pump-and-treat system is shut down. Concentrations in COV3 production wells are predicted to increase to a maximum concentration of 0.01 ug/L after around 26 years, and then slowly decline as the fixed mass of TCE is depleted. A similar response is predicted for TCE concentrations in the CC production wells, with a maximum predicted concentration of 0.005 ug/L occurring at around 23 years. The concentrations predicted at the wellfields are much lower than the source concentrations shown on **Figure 2** due to dilution and biodegradation. Both of the maximum predicted concentrations are well below standard laboratory reporting limits for TCE analyzed by EPA Method 8260 (0.2 to 0.5 ug/L depending on instrument and sample purge volume) and would likely not be detected in routine sampling.

The infinite mass simulation predicts that trace concentrations of TCE will arrive at the two wellfields in a similar timeframe as the finite mass simulation. Concentrations in COV3 production wells are predicted to increase over the next 100 years a maximum concentration of 0.11 ug/L and remain below 0.12 ug/L as the infinite mass TCE source forms a steady-state contaminant distribution within the groundwater system. A similar response is predicted for TCE concentrations in the CC production wells, with a maximum predicted TCE value of 0.01 ug/L. As above, the concentrations are below standard reporting limits for TCE.

4.3 SENSITIVITY ANALYSIS SIMULATIONS

As noted in Section 3.2, sensitivity analysis simulations were performed to evaluate how much higher specified source area TCE concentrations would need to be to result in production well concentrations at the current laboratory detection limit of 0.5 ug/L. The sensitivity analyses were performed by simply scaling up the specified source area TCE concentrations until predicted concentrations in COV3 or CC production wells reached 0.5 ug/L. This was accomplished using a scaling factor of 49x for the finite mass base-case simulation and 4.3x for the infinite mass base-case simulation. **Figures 8** and **9** show the predicted time-concentration curves at both wellfields for the finite mass and infinite mass sensitivity simulations (respectively). The 4.3x and 49x concentration multipliers are greater than expected source area concentration rebound that may occur for TCE following pumping shutoff; rebound potential was therefore not separately considered or modeled.

4.4 FACTORS AFFECTING PREDICTIVE RESULTS

PGG reviewed the factors affecting model predictions to identify related degrees of uncertainty. The following hydraulic and fate/transport factors were identified:

1. Hydraulic Conductivity
2. Surface-Water/Groundwater Connections
3. Total Pumping and Distribution Among Wellfield Wells
4. Retardation & Effective Porosity
5. Dispersion
6. Biodegradation (decay)

Aquifer hydraulic conductivity estimates are based on a number of factors, including referenced aquifer tests, sedimentary textures observed during drilling and prior model calibration. While prior calibration has provided reasonably good confidence in hydraulic conductivity estimates, it should be noted that groundwater velocities and fluxes are directly proportional to hydraulic conductivity and therefore affect model predictions. Groundwater velocities affect the residence time of a "particle" of contaminated water in the subsurface, which controls concentration reduction via biodegradation. For the infinite mass scenarios, groundwater flux through the source area controls the rate of TCE introduced by the model at the source area. Shallow, relatively low permeability Qal sediments surrounding the source area (described in Section 4.1) control associated groundwater fluxes and therefore control simulated rates of TCE introduction to the groundwater flow system. Model predictions suggest that even if Qal hydraulic conductivities were underestimated by a factor of four, TCE concentrations would still be undetectable at the COV3 and CPU-CC wellfields.

The model simulates hydraulic connection between groundwater and surface water features such as the Columbia River, Vancouver Lake, Burnt Bridge Creek and Lake River. The magnitude of these interactions is controlled by the modeled hydraulic conductivities of lakebed/streambed sediments and adjacent aquifer materials. Model calibration required consideration of these hydraulic connections to properly simulate observed groundwater levels.

Simulated rates of groundwater pumping have relatively low uncertainty. It should be noted that predicted TCE concentrations at multi-well receptors (COV3 and CPU-CC wellfields) were reported as *averaged* values between the multiple production wells. Review of *per-well* model predictions showed that the production well with the highest simulated concentration was that positioned closest to the mapped plume, with its concentration within 2x of the wellfield average. At 2x the wellfield average, the maximum predicted concentrations are still near or below standard reporting limits for TCE.

As described in Section 2.3, assumed values of retardation and effective porosity are reasonable and within typical published values used for contaminant transport analysis. While modeled dispersion coefficients are relatively low for contaminant transport over the distance between the source area and the pumping receptors, *effective* dispersion is considerably higher due to numerical dispersion associated with the model grid dimensions and the MT3DMS solver. Numerical dispersion may exaggerate actual dispersion; however, the extent to which this may be true is difficult to discern due daily and seasonal variations in the groundwater flow field associated with variations in Columbia River stage. Overestimation of actual dispersion would lead to longer contaminant flowpaths and later TCE arrival times at the receptor wellfields, but would not dilute predicted steady-state TCE concentrations under the (more conservative) infinite mass base-case simulation. Maximum TCE concentrations associated with the finite mass base-case simulation would be underestimated due to dispersion of the plume; however, predicted concentrations for the finite mass simulation are exceedingly low (Section 4.2).

Modeling of biodegradation employs a reasonable and defensible half-life value for first-order decay (Section 2.3). However, to the extent that transport times may be overestimated due to numerical dispersion, reductions of TCE concentrations due to biodegradation may also be overestimated. For every 15 additional years a contaminant "particle" remains within its groundwater flowpath from source to receptor, its concentration is reduced by half. Because it is difficult to estimate the additional travel time associated with possible overprediction of dispersion, it is difficult to use time-based calculations to estimate possible underprediction of TCE concentrations at predicted receptors. However, supplemental calculations derived from infinite mass base-case model results, PGG found that the combined effect of dispersion and decay does not significantly reduce predicted receptor concentrations relative to the TCE detection limit. A conservative mass balance calculation used as a check on the model results is described in the bullets below:

- The TCE constant-concentration source is simulated by three cells in the top model layer with a maximum concentration of 560 ug/L and an average concentration of 356 ug/L
- The model predicts that groundwater flux through these three cells at maximum (year 2035) pumping rates is 201 cubic feet per day (3.95 liters per minute (lpm)).
- Applying 356 ug/L to 3.95 lpm imparts 1,408 ug/min of TCE to the groundwater flow system.
- The bulk of the TCE is predicted to migrate to COV3, which has a 2035 average pumping rate of 1,900 gpm (7,200 lpm). Assuming that all of the imparted TCE migrates to COV3 would result in an average wellfield concentration of 0.20 ug/L.

The model prediction of 0.115 ug/L at COV3 suggests that simulation of combined dispersion/decay reduces the maximum expected TCE concentration at the wellfield by around 43%. Even if combined simulation of dispersion/decay reduced TCE concentrations by 75%, corrected infinite mass base-case model predictions still would not exceed the detection limit of 0.5 ug/L.

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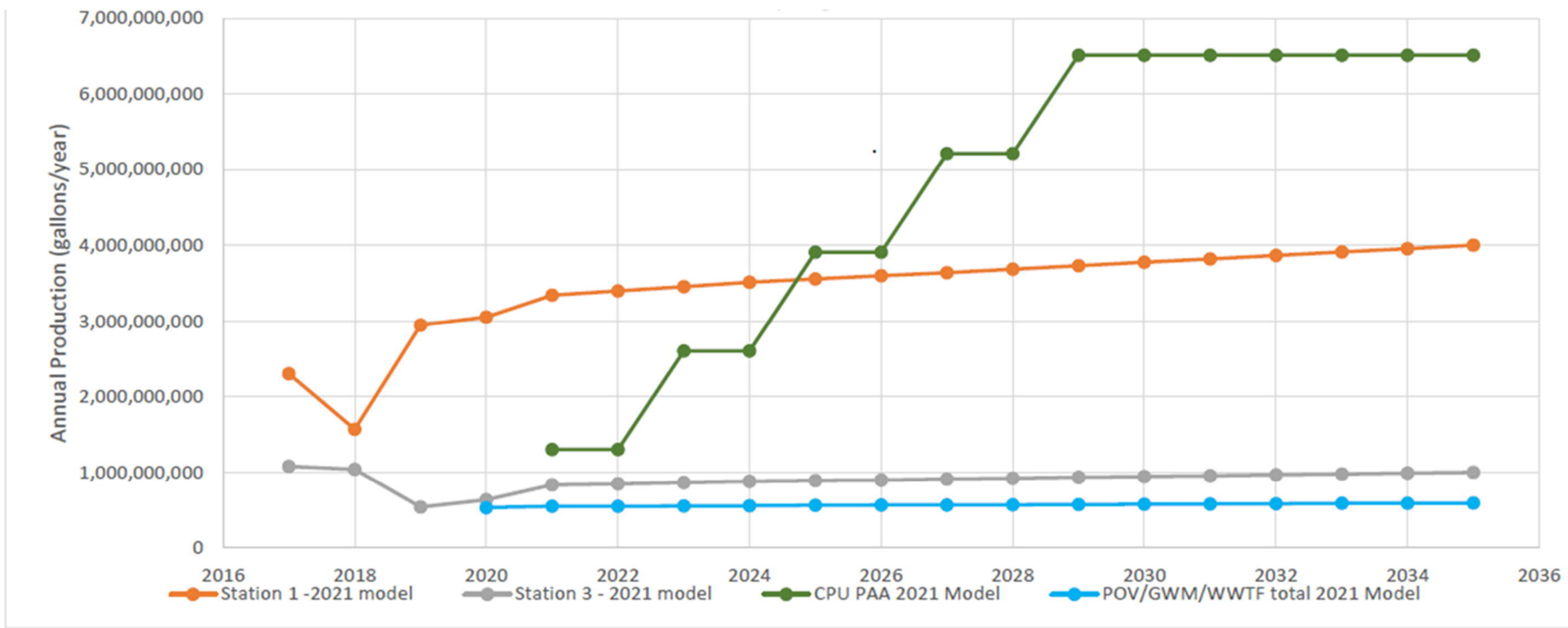
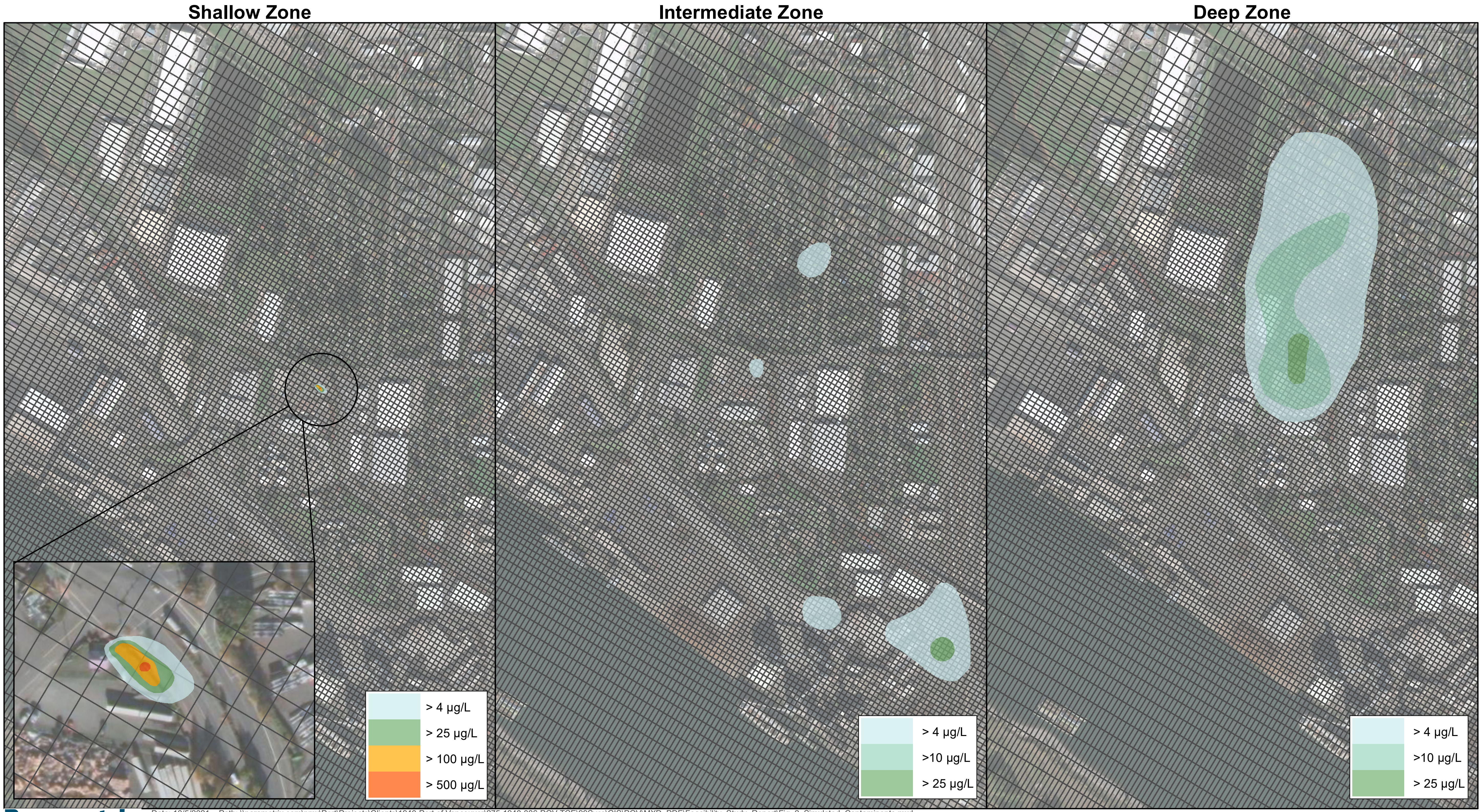


FIGURE 1
GROUNDWATER PUMPING SPECIFIED IN VLL MODEL

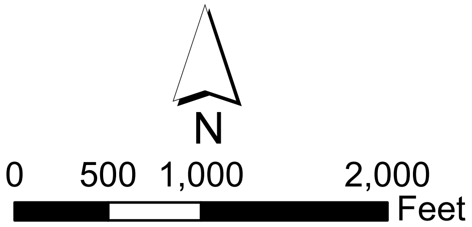
Port of Vancouver
VLL Long-Term Transport Analysis

PGG



Parametrix

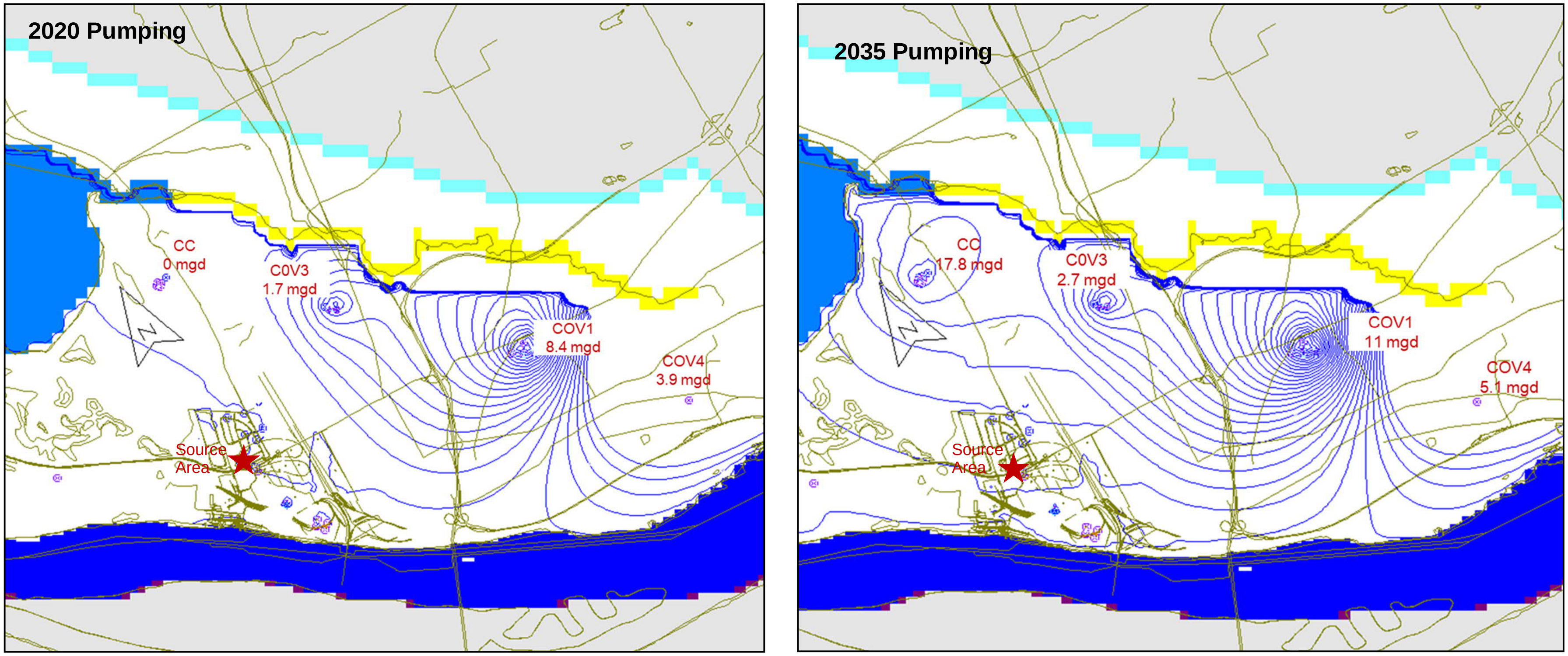
Date: 10/5/2021 Path: \\parametrix.com\pmx\Port\Projects\Clients\1940-Port of Vancouver\275-1940-006-POV TCE\99Svcs\GIS\POV\MXD_PDF\Feasibility_Study_Report\Fig_2_Simulated_Contaminants.mxd



TCE ISOCONCENTRATIONS IN USA ZONE
GROUNDWATER MARCH 2020

Figure 2
Simulated Contaminant Concentrations

VLL LONG-TERM TRANSFERS ANALYSIS
PORT OF VANCOUVER, WASHINGTON



Notes:
Contour interval = 0.2 feet
Columbia River elevation on map ranges from 3.97 to 3.90 feet DATUM
Groundwater flow directions are typically perpendicular to contours.

FIGURE 3
MODEL PREDICTED PAA GROUNDWATER ELEVATION CONTOURS

Port of Vancouver
VLL Long-Term Transport Analysis

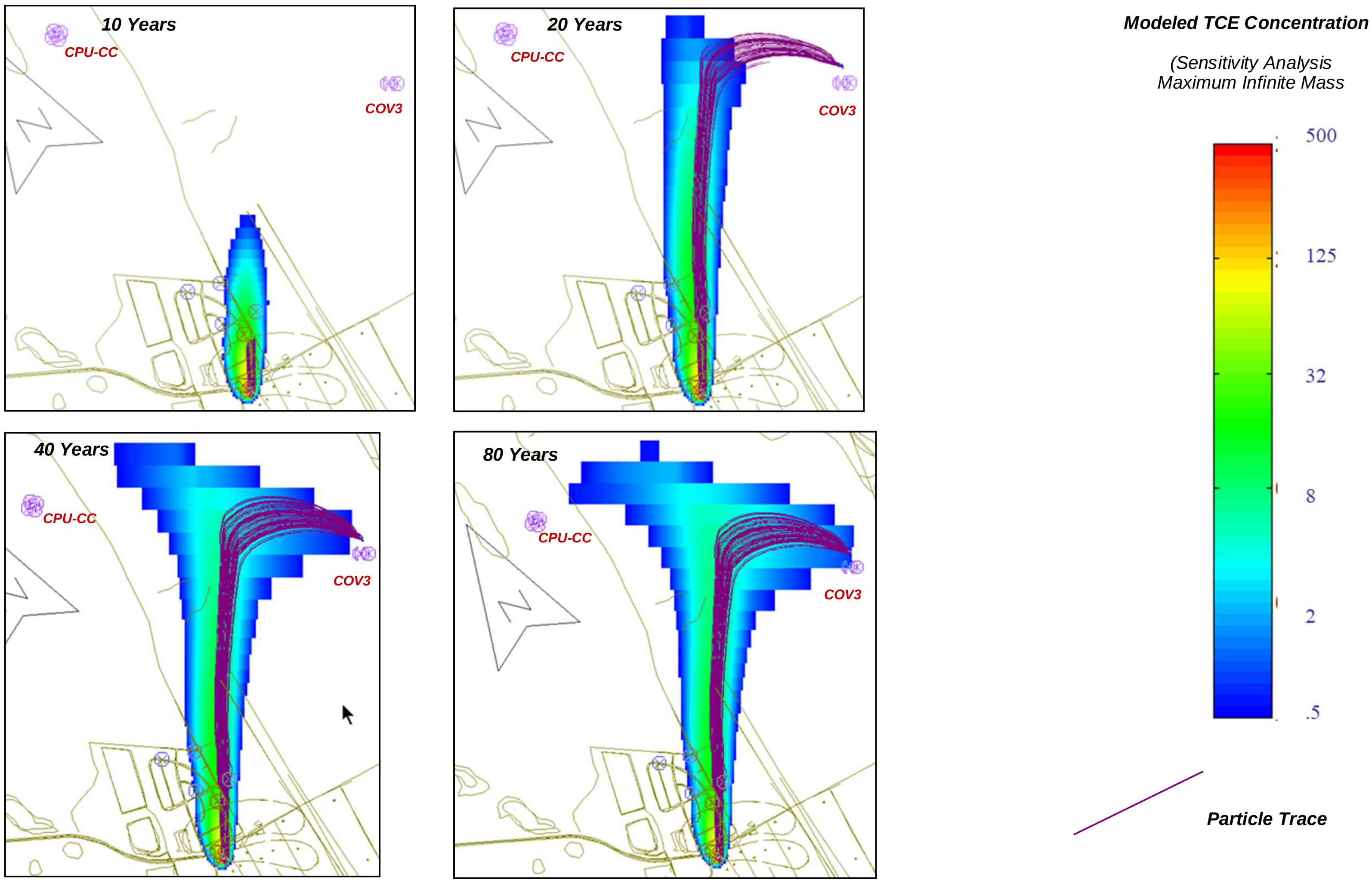
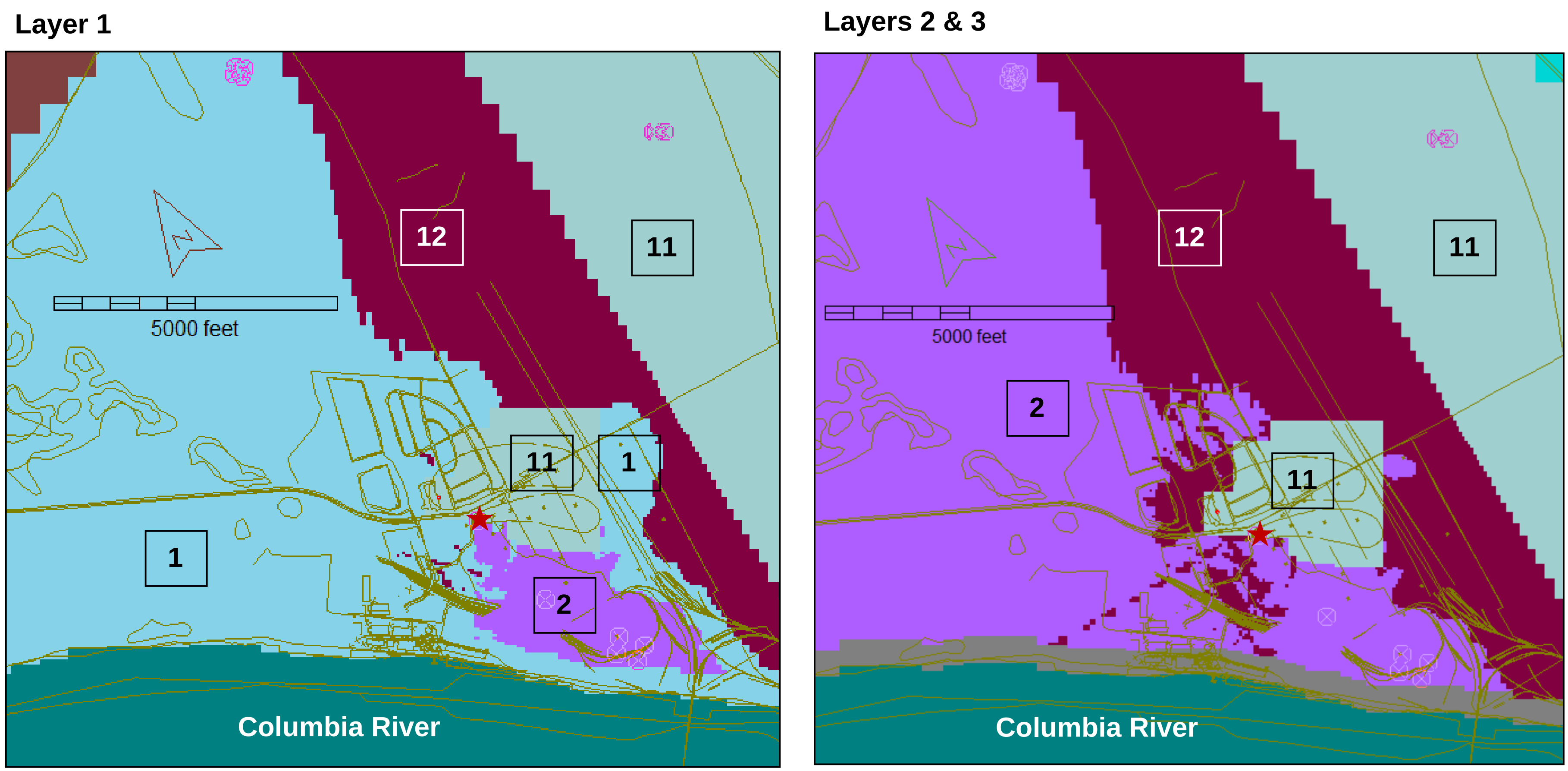


FIGURE 4
MODELED ADVECTION & DISPERSION

Port of Vancouver
VLL Long-Term Transport Analysis



★ Infinite Mass TCE Source Area

Hydraulic Conductivity Zones: KZone 1 = 1 ft/d, KZone 2 = 59 ft/d, KZone 11 = 2,119 ft/d, KZone 12 = 12,409 ft/d

FIGURE 5
SHALLOW LAYER HYDRAULIC CONDUCTIVITY ZONES

Port of Vancouver
VLL Long-Term Transport Analysis

PgG

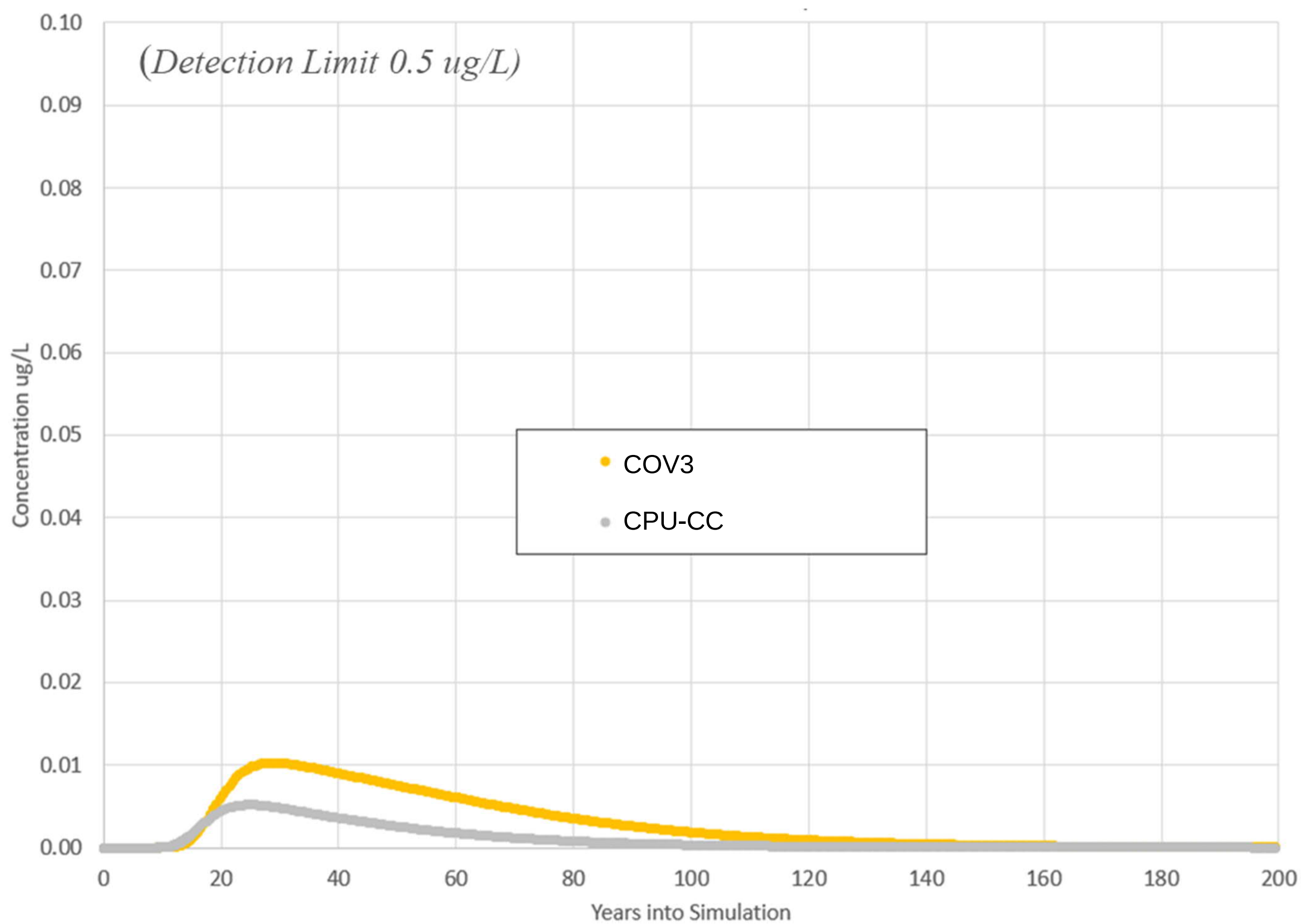


FIGURE 6
MODEL PREDICTED TCE CONCENTRATIONS FROM THE BASE-CASE FINITE MASS SIMULATION

Port of Vancouver
VLL Long-Term Transport Analysis

PgG

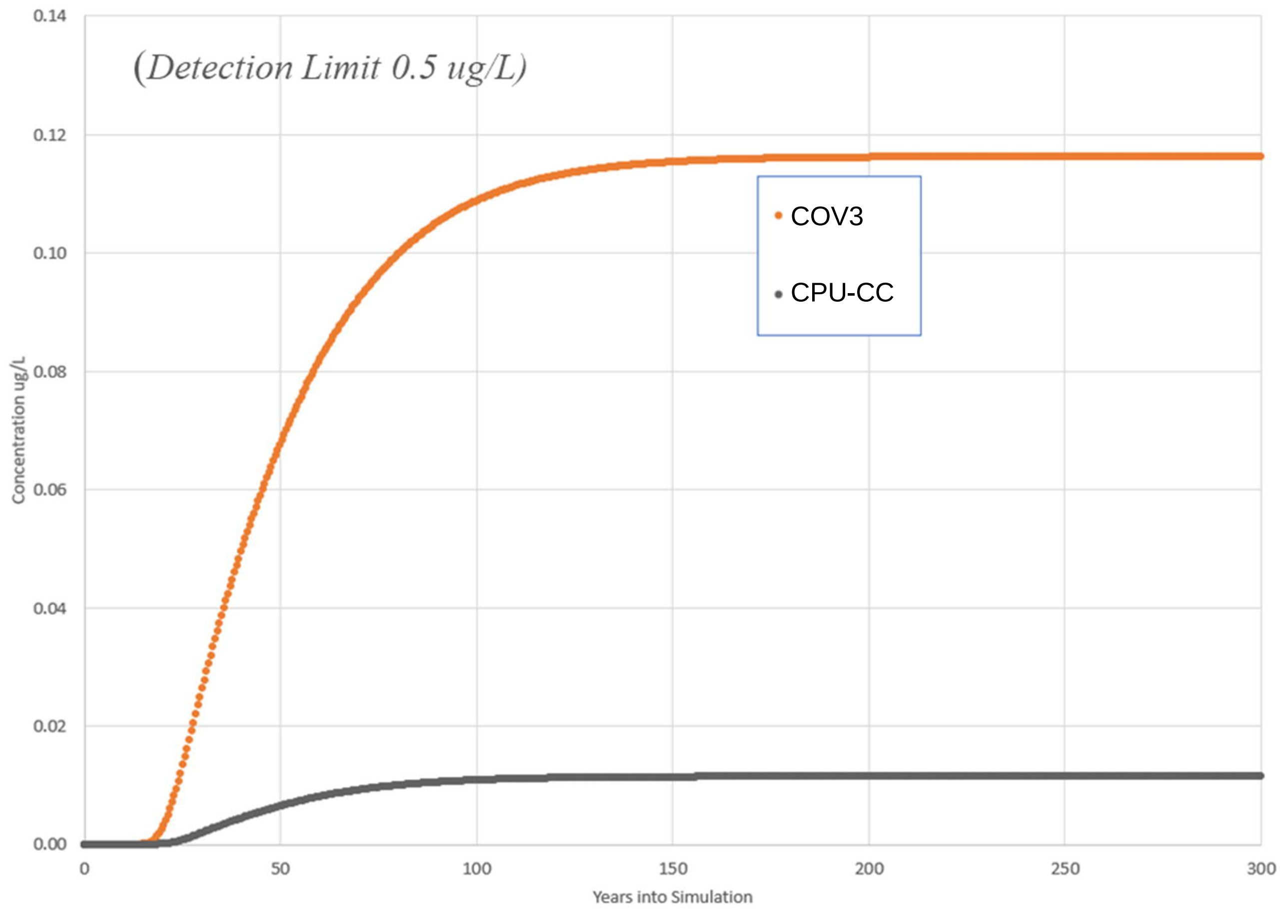


FIGURE 7
MODEL PREDICTED TCE CONCENTRATIONS FROM THE BASE-CASE INFINITE MASS SIMULATION

Port of Vancouver
VLL Long-Term Transport Analysis

PgG

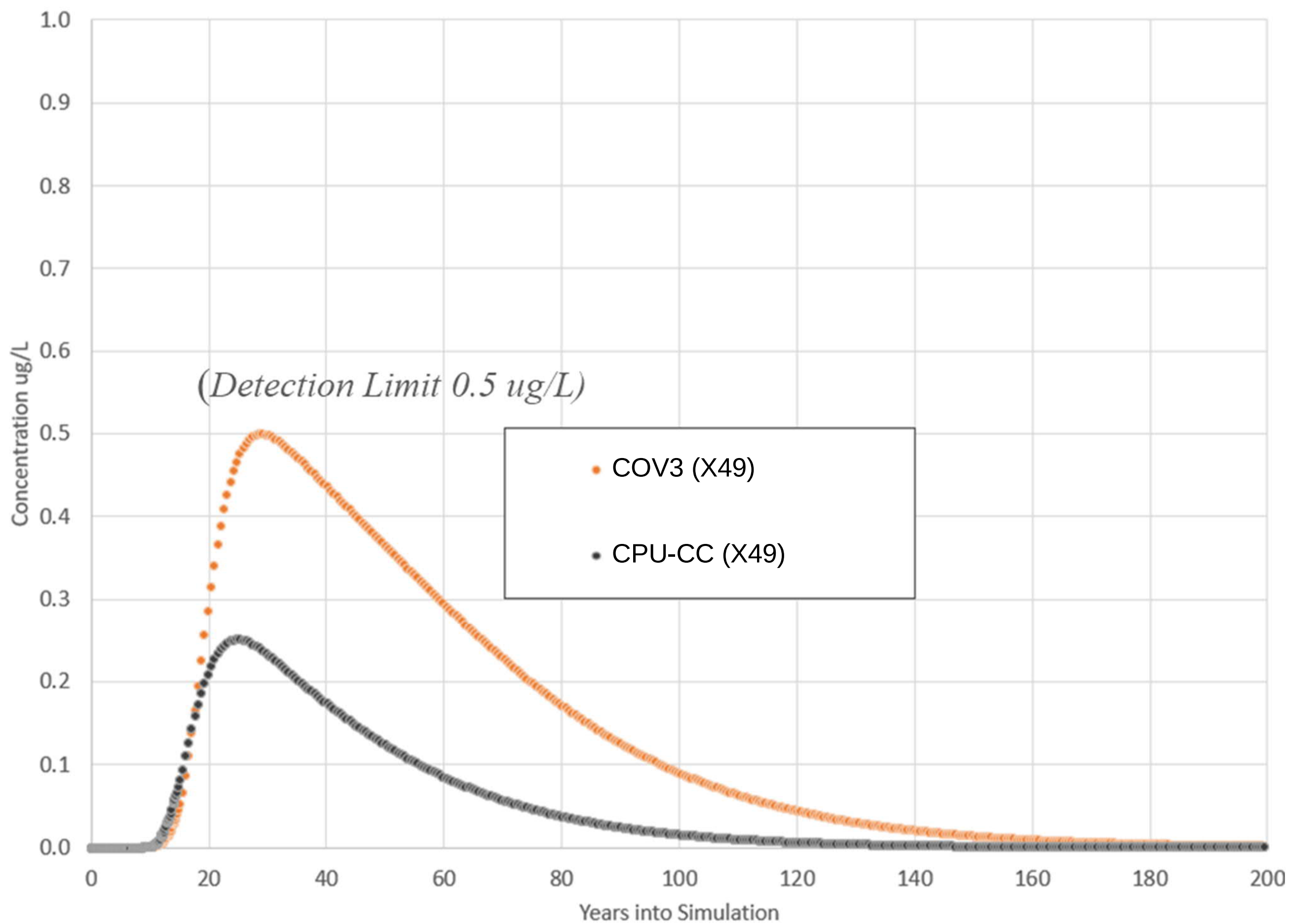


FIGURE 8
MODEL PREDICTED TCE CONCENTRATIONS FROM THE SENSITIVITY ANALYSIS FINITE MASS SIMULATION

Port of Vancouver
VLL Long-Term Transport Analysis

PgG

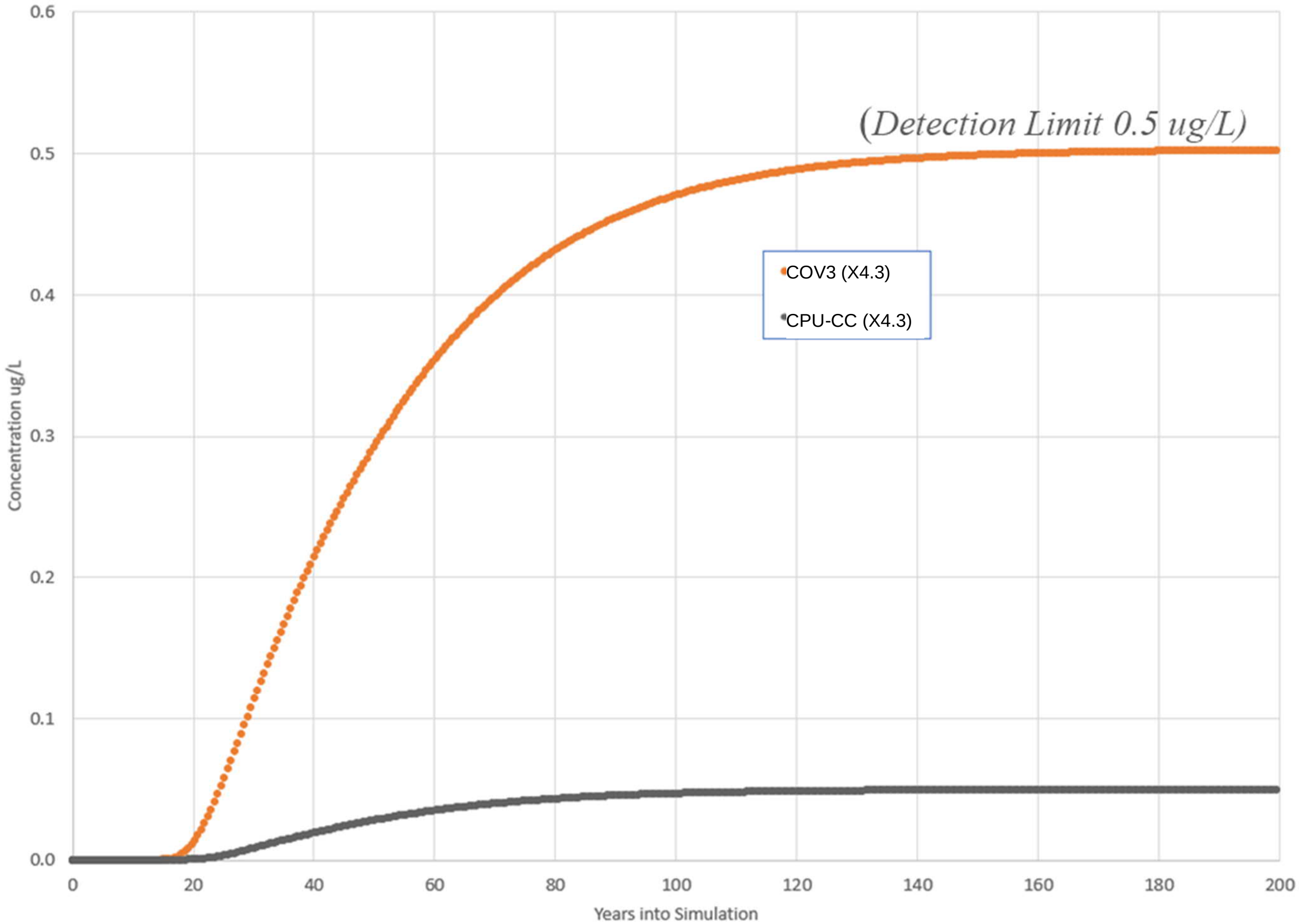


FIGURE 9
MODEL PREDICTED TCE CONCENTRATIONS FROM THE SENSITIVITY ANALYSIS INFINITE MASS SIMULATION

Port of Vancouver
VLL Long-Term Transport Analysis

PgG

Appendix B

Applicable or Relevant and Appropriate Requirements

B.1 Federal Requirements

The Clean Water Act. The Clean Water Act (CWA) was established to protect the quality of surface water in the United States (33 United States Code (U.S.C.) Section 1251 et seq). The statute utilizes a variety of regulatory and non-regulatory tools to reduce direct pollutant discharges into waterways, finance municipal wastewater treatment facilities, and manage polluted runoff. Section 304 of the CWA requires the U.S. Environmental Protection Agency (EPA) to publish water quality criteria, which are developed for the protection of human health and aquatic species. Federal water quality standards are published in *Quality Criteria for Water, EPA 440/5-86-001*, dated May 1, 1986. Updates to water quality standards are included in the Federal Register (51 FR 43665) as they are developed. The State of Washington uses federal water quality standards to set water quality standards for the protection of state surface water.

The discharge of pollutants into navigable waters is regulated under Sections 401 and 404 of the CWA. These requirements include regulations for the excavation of shoreline materials and the placement of fill material below the ordinary high water elevation of U.S. waters. These regulations are implemented by the U.S. Army Corps of Engineers (USACE) and EPA. The guidelines also provide that no discharge will be authorized which contributes to significant degradation of U.S waters. Sections 401—404 of the CWA may be applicable to environmental remediation projects that address potential groundwater discharges to surface water, or shoreline cleanup projects if sediment removal or capping technologies are implemented.

Safe Drinking Water Act (42 USC Section 300f). The Safe Drinking Water Act (SDWA) sets a framework for the Underground Injection Control (UIC) Program to control the injection of wastes into groundwater. EPA and individual states implement the UIC program, which sets standards for safe waste injection practices and bans certain types of injection altogether.

Resource Conservation and Recovery Act. The Resource Conservation and Recovery Act (RCRA) is the principal federal law in the United States governing the disposal of solid waste and hazardous waste. RCRA handles many regulatory functions of hazardous and non-hazardous waste. The Subtitle C program tracks the progress of hazardous wastes from their point of generation through their transport, and their treatment and/or disposal. The overall process has become known as the "cradle to grave" system. In the State of Washington, RCRA is implemented by the Department of Ecology (Ecology) under the Dangerous Waste Regulations (Washington Administrative Code [WAC] 173-303).

Federal Clean Air Act. The Federal Clean Air Act (FCAA) regulates the emissions of hazardous pollutants into air. Specific controls for this program are regulated under federal, state, and local programs. In the State of Washington, the FCAA is implemented through the Washington Clean Air Act (Revised Code of Washington [RCW] 70.94). Remedial actions that result in the release of hazardous substances to air are regulated under the Washington Clean Air Act.

Endangered Species Act. The Endangered Species Act of 1973 (16 U.S.C. 1531-1544, 87 Statute 884) was established to protect ecosystems upon which threatened and endangered species of fish, wildlife, and plants depend.

United States Fish and Wildlife Service Mitigation Policy (46 FR 7644). The policy provides guidance for United States Fish and Wildlife Service personnel responsible for making recommendations to protect or conserve fish and wildlife resources.

The Fish and Wildlife Coordination Act (16 U.S.C. 661-667e). The act of March 10, 1934 authorizes the Secretaries of Agriculture and Commerce to provide assistance to and cooperate with federal and state agencies to protect, rear, stock, and increase the supply of game and fur-bearing animals, as well as to study the effects of domestic sewage, trade wastes, and other polluting substances on wildlife.

B.2 Washington State and Local Requirements

Cleanup standards are adopted under the Model Toxics Control Act (MTCA) for remedial actions at sites where hazardous substances are present. The specific processes for identifying, investigating, and remediating those sites are defined and cleanup standards are developed for soil, groundwater, surface water, and air (WAC 173-340). The development of cleanup levels for sediments is described in MTCA (WAC 173-340-760) through reference to WAC 173-294. In addition to MTCA, other state requirements may apply to this remedial action, and are summarized below.

State Environmental Policy Act (43.21C RCW; WAC 197-11). The State Environmental Policy Act (SEPA) was created to ensure that state and local government officials consider potential environmental impacts when making decisions. These decisions may be related to issuing permits for private projects, constructing public facilities, or adopting regulations, policies, or plans. The SEPA process begins when an application for a permit is submitted to a state or local government agency, or when an agency proposes to take an action such as the implementation of a remedial action. One agency is identified as the "lead agency" under the SEPA Rules (WAC 197-11-924—938), and is responsible for conducting the environmental review for a proposal and documenting that review in the appropriate SEPA documents.

Washington Water Pollution Control Act (Chapter 90.48 of RCW; WAC 173-201A). This act provides for the protection of surface water and groundwater quality. Under this act, groundwater quality standards are established for surface waters of the state (WAC 173-201A). In accordance with RCW Chapter 90.48, Ecology will issue a water quality certification, including cleanup actions under MTCA, which may result in discharging to state waters. According to RCW 90.48.039, the procedural requirements of the aforementioned chapter do not apply to any person conducting a remedial action at a facility pursuant to a consent decree, order, or agreed order issued pursuant to chapter 70.105D RCW.

Washington Hydraulic Code (Chapter 77.55 of RCW; WAC 220 110). Under this code, any organization or agency wishing to conduct any construction activity that will use, divert, obstruct, or change the natural flow or bed of state waters must do so under the terms of a permit (called the Hydraulic Project Approval [HPA]) issued by the Washington Department of Fish and Wildlife.

Washington State Clean Air Act (RCW 70.94). As discussed in above, the FCAA is implemented in Washington through the Washington Clean Air Act (RCW 70.94). Ecology, the Energy Facility Site Evaluation Council (EFSEC), and any of seven local air quality agencies have received EPA approval to administer Washington's air operating permit program.

Washington Solid Waste Management – Reduction and Recycling Act (Chapter 70.95 RCW; Chapter 173-350 WAC). This act establishes a state-wide program for solid waste handling, recovery, and/or recycling to prevent land, air, and water pollution and conserve the natural and economic resources of the state.

Washington Hazardous Waste Management Act (Chapter 70.105 RCW; Chapter 173-303 WAC). Under this act, hazardous waste materials must be monitored until they are properly disposed of or are converted to non-hazardous waste. Any hazardous materials transported from the Site must be sampled, tracked, and monitored under the appropriate regulations. This act also establishes regulations for hazardous waste treatment, storage, transfer, and disposal facilities.

Underground Injection Control Program (Chapter 173-218 WAC). The program was designed to protect groundwater quality by preventing groundwater contamination by regulating the discharge of fluids into UIC wells. The program satisfies the intent and requirements of Washington State Water Pollution Control Act (Chapter 90.48 RCW) as well as Part C of the SDWA.

Compensatory Mitigation Policy for Aquatic Resources and Aquatic Resources Mitigation Act. (Chapters 75.46 and 90.74 RCW). RCW 75.46 states that the guidance shall develop procedures that provide for alternative mitigation that have a low risk to the environment and have a high net environmental, social, and economic benefit when compared to "status quo" operations. In 1996, the Washington State Legislature passed the Aquatic Resources Mitigation Act (RCW 90.74), stipulating that it is the policy of the state to authorize mitigation measures by requiring state regulatory agencies to consider mitigation proposals for infrastructure projects that are "timed, designed, and located in a manner to provide equal (or better) biological values and function, compared to traditional on-site mitigation proposals." When making regulatory decisions regarding mitigation plans, the agencies must consider factors identified in the Hydraulic Code, the State Water Pollution Control Act, and the Aquatic Resources Mitigation Act.

Water Resources Act (Chapter 90.54 RCW). This act establishes fundamental policies for the utilization and management of the waters of the State of Washington.

State Aquatic Lands Management Laws (Chapters 79.90—79.96 RCW; WAC 332-30, particularly WAC 332-30-11). Section 332-30-11 of WAC authorizes a port district to manage some or all of those aquatic lands within the port district, provided that the port district adheres to the aquatic land management laws and policies of the state.

Growth Management Act (Chapters 36.70A, 36.70.A.150, and 36.70.A.200 RCW). The Growth Management Act (GMA) was adopted because the Washington State Legislature found that uncoordinated and unplanned growth posed a threat to the environment, sustainable economic development, and the quality of life in Washington. This act requires counties and cites to classify and designate natural resource lands and critical areas (including "waters of the state"). Additionally, select cities and counties (typically those experiencing the fastest growth) must adopt comprehensive and development regulations regarding land use within their jurisdiction. The state sets goals and manages deadlines for compliance, while comprehensive plans and regulations are often developed and implemented at the local level.

Appendix C

SMC Source Area Remedial Alternatives Support

Feasibility Study Conceptual Design/Costs
SMC Source Area

Alternative A
Institutional Controls, Engineering Controls (Future), and Site-Wide Monitored Natural Attenuation

This alternative is primarily made up of controls to limit or eliminate potential exposure pathways. There are no current complete exposure pathways from the source area contaminants. However, the potential or reasonably likely future exposure pathways for the source area are:

- Site worker exposure to groundwater via drinking water (from a local SMC well)
- Construction worker exposure to soil and vapors via construction or excavation
- Site worker exposure to indoor air via vapor intrusion to an overlying building

All of these potential exposure pathways can be limited by the use of institutional or engineering controls.

Institutional controls will be placed on the site in the form of restrictive covenants to prevent potential exposure. Potential site worker exposure to groundwater via drinking water will be managed by implementing a restrictive covenant for drinking water wells on the SMC site. Since operation of the GPTIA began in 2009, the footprint of the shallow groundwater zone contamination exceeding MTCA cleanup levels has been significantly reduced and is now confined within the SMC site. The current impacted groundwater zone is located in the northeast corner of the property and encompasses an area of approximately 75 x 100 feet. A small exceedance of the MTCA cleanup level is present slightly offsite the SMC property beneath W. Mill Plain Blvd. The placement of a restrictive covenant for drinking water on the SMC site eliminates that potential pathway. In addition, drinking water wells could not be placed within the Mill Plain Blvd. right-of-way. A restrictive covenant would not be placed on any of the adjacent private property. However, all drinking water within the area is supplied by the City of Vancouver from wells away from the SMC site and the potential for drinking water wells to be placed within the FVN or other areas near the site *and* targeting shallow groundwater is low or negligible. Based on these considerations, the placement of a restrictive covenant on the Port-owned SMC property effectively eliminates the drinking water exposure route as a complete pathway.

Based on the elevated groundwater concentrations of VOCs (TCE and PCE) remaining in the source area, vapor intrusion to indoor air of an overlying building is a potential future complete exposure pathway (no current occupied building exists). A restrictive covenant for future use of the site will be established. The site is currently zoned and utilized for industrial purposes. This land use will be maintained; no residential development will be allowed. However, future development of the site could include office space or other occupied building use. Potential site worker exposure to indoor air via vapor intrusion will be managed by requiring engineering controls for all occupied buildings on the property to prevent vapor intrusion. This can be in the form of a vapor barrier, passive venting systems beneath the building foundation, or building HVAC controls such as maintaining internal positive pressure or other similar technologies. The requirement for assessment of engineering controls on a future building will be included as part of the restrictive covenant. Based on these considerations, the placement of a restrictive covenant on the Port-owned SMC property and requirement of engineering controls will effectively limit the vapor intrusion exposure route as a complete pathway.

Residual soil and groundwater contamination in the source area is present at elevated levels. There is no current exposure route to site workers. However, in the event of construction or utility work with deep excavations there is some potential for construction worker exposure to subsurface contaminated media and vapors. This potentially complete exposure pathway can be managed through the preparation of pre-construction documents and health and safety plans. A contaminated media management plan (CMMP) will be prepared for the site to guide future construction activities, if any. The CMMP will include health and safety protocols, and measures and requirements for soil, vapors, and/or groundwater encountered during construction. The requirement for health and safety measures during construction with effectively limit the construction worker exposure route as a complete pathway.

MNA involves utilizing natural processes to reduce COC levels to acceptable concentrations. These processes include natural biodegradation, dispersion, dilution, sorption, volatilization, and chemical and biological stabilization, transformation, or destruction of hazardous substances. Monitoring is used to verify that these processes are actively reducing hazardous substance concentrations. This alternative utilizes the site-wide MNA approach to reduce the residual groundwater concentrations throughout the Site, including the SMC source area. Focused monitoring of the SMC source area will be incorporated into the overall Site compliance monitoring plan to ensure that the compliance objectives are being met and contingency measures can be employed, as needed.

Costs associated with Alternative A include the preparation of restrictive covenants, CMMP, engineering control plans and design documents (future, if needed), and ongoing compliance monitoring. Compliance monitoring for the SMC source area includes monitoring for up to 20 years.

Attachments

Estimated Costs for Implementation of Alternative A

Alternative A Cost Estimate: Institional Controls and Source Area Monitored Natural Attenuation
Port of Vancouver
Vancouver, Washington

Activity	Unit Costs	Unit	Extended Cost
Restrictive Covenant	**$10,000**	**1**	**$10,000**
CMMP	**$5,000**	**1**	**$5,000**
Groundwater Monitoring			
2022	$4,000	per year	$4,000
2023	$4,120	per year	$4,120
2024	$4,244	per year	$4,244
2025	$4,371	per year	$4,371
2026	$4,502	per year	$4,502
2027	$4,637	per year	$4,637
2028	$4,776	per year	$4,776
2029	$4,919	per year	$4,919
2030	$5,067	per year	$5,067
2031	$5,219	per year	$5,219
2032	$5,376	per year	$5,376
2033	$5,537	per year	$5,537
2034	$5,703	per year	$5,703
2035	$5,874	per year	$5,874
2036	$6,050	per year	$6,050
2037	$6,232	per year	$6,232
2038	$6,419	per year	$6,419
2039	$6,611	per year	$6,611
2040	$6,810	per year	$6,810
2041	$7,014	per year	$7,014
Estimated Total Cost			**$122,481**

<u>Notes:</u>

This alternative includes semi-annual monitoring of up to 4 source area wells only.
Source wells include current highest concentrations (MW-05, VMW-08, VMW-09, and VMW-10)
This alternative assumes 20 years of monitoring required for MNA.
Monitoring costs include labor and lab costs and a 3% yearly increase.
Site-wide costs to achieve closure is included in the Site alternatives.
CMMP = Contaminated Media Management Plan

Feasibility Study Conceptual Design/Costs
SMC Source Area

Alternative B
Excavation of Source Area Material

This alternative primarily includes excavation and off-site disposal of impacted source area material. As discussed in the RI Report, it appears that the presence of a fine-grained sand layer within the source area has confined some contaminants to that layer and continues to slowly migrate to shallow groundwater. The majority of the fine-grained sand layer is saturated most of the year. It is expected that much of the contaminants reside in the pore space of the soil particles and are slowly leaching to shallow groundwater.

While excavation is primarily a vadose zone soil remedial action, the relatively shallow depth and the unique complexity of this site lends itself to consider a removal action for saturated material. Based on an evaluation of site data, the removal action area is approximately 70 feet by 100 feet and would extend to a depth of 27 feet below ground surface (bgs). This yields an approximate excavation volume of 7,000 cubic yards.

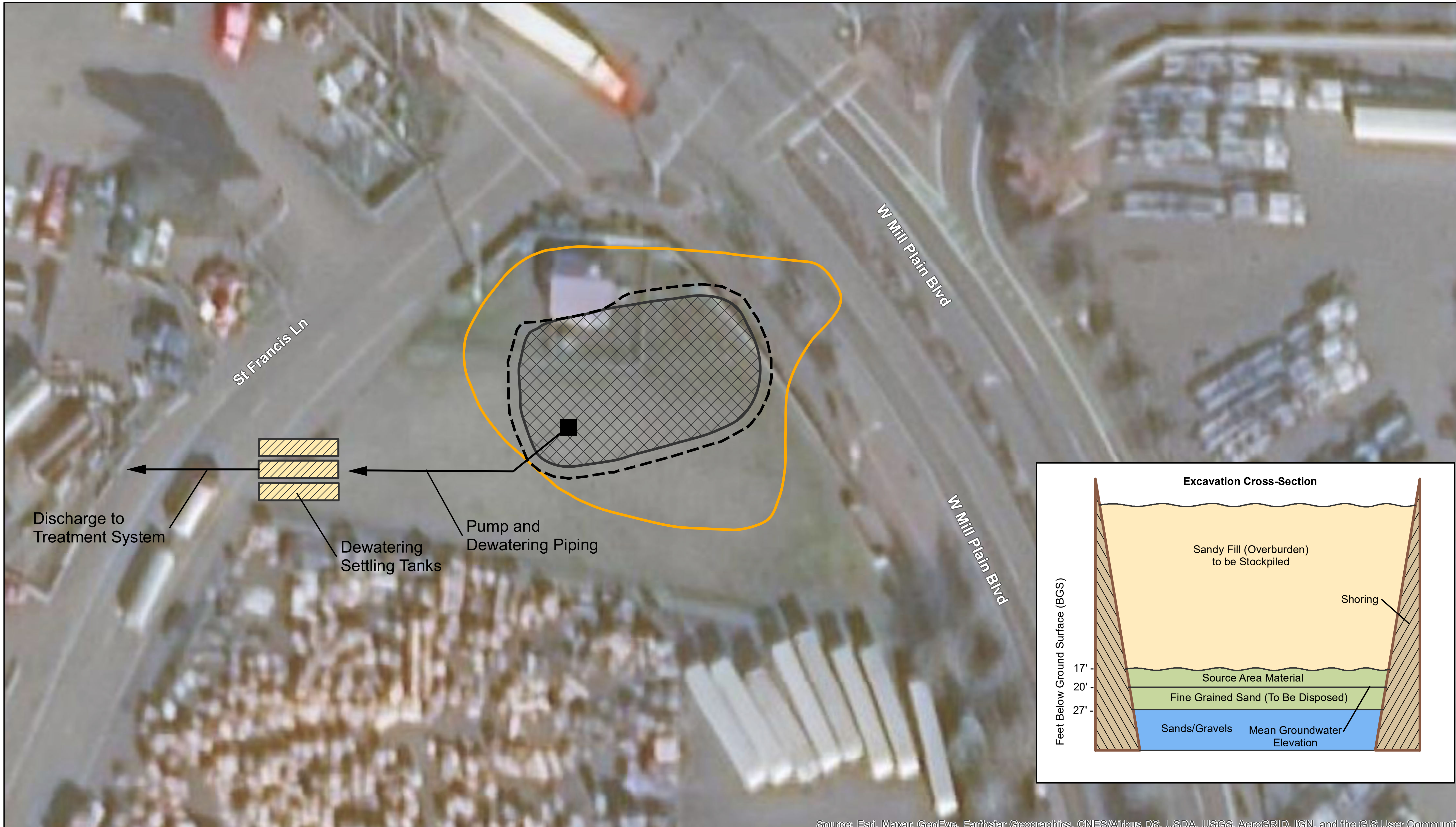
The top 17 feet is considered overburden material and is expected to be free of any contamination. Much of the overburden is clean fill (about 4,500 cubic yards) that was placed during the remedial excavation in 1998. The former excavation was stopped at approximately 17 feet bgs due to the presence of groundwater. This proposed alternative would primarily target the underlying 10 feet of material from the previous excavation depth, which includes the fine-grained sand layer. Due to the expected presence of groundwater at less than 20 feet bgs, this alternative will require significant shoring and dewatering. Extracted groundwater from the dewatering will be required to be treated prior to discharge to a sanitary sewer or other method of disposal (potentially using the existing pump and treatment system).

Based on the conceptual design, approximately 2,500 cubic yards of excavated contaminated soil (saturated) would be placed into lined trucks and transported to a permitted municipal landfill (Subtitle D) for disposal under an approved permit. Confirmation sampling would be conducted in accordance with an Ecology-approved sampling and analysis plan (SAP) and quality assurance project plan (QAPP). The excavation would be backfilled with a combination of imported clean fill and the stockpiled clean overburden material.

<u>**Attachments**</u>

Figure C-1 : Conceptual Design of Remedial Excavation

Estimated Costs for Implementation of Alternative B



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Feet

Potential Extent of Residual Source Area
Focused Treatment Area
Conceptual Excavation Area

Figure C-1
Conceptual Excavation Area

Feasibility Study
Port of Vancouver
Vancouver, Washington

Alternative B Cost Estimate: Source Area Remedial Excavation
Port of Vancouver
Vancouver, Washington

Activity	Quantity	Unit	Unit Costs	Extended Cost	Notes
Preparatory Activities					
Environmental Engineering Assistance (Design and Specs)	1	lump sum	$15,000	$15,000	Parametrix estimate. Professional judgement.
Contaminated Media Management Plan	1	lump sum	$5,000	$5,000	Parametrix estimate. Professional judgement.
Contractor Solicitation and Procurement	1	lump sum	$3,000	$3,000	Parametrix estimate. Professional judgement.
Project Management and Meetings	1	lump sum	$5,000	$5,000	Parametrix estimate. Professional judgement.
Construction Activities (Excavation)					
Contractor Health and Safety and Worker Protection	1	lump sum	$2,000	$2,000	Parametrix estimate. Professional judgement.
Excavation Oversight, including Supplies and Equipment	24	days	$1,000	$24,000	Parametrix estimate. Professional judgement.
Equipment Mobilization	1	lump sum	$4,000	$4,000	Contractor estimate.
Contractor Equipment Rate	24	days	$3,000	$72,000	Estimate for contractor daily rate for personnel, trackhoe, support trucks, and misc. equipment and supplies
Source Area Clean Overburden Excavation	4,500	yards	$6	$26,550	70'x100' = 7000 sqft x 17' = 119,000 cuft = 4400 cuyds. Use 4,500 yards. Based on similar project.
Overburden Stockpiling onsite - visqueen and cover	1	lump sum	$1,000	$1,000	Parametrix estimate. Professional judgement.
Backfill Overburden, Additional Fill Material, Compaction	7,000	cubic yards	$6	$42,000	Place back 4,500 yards stockpiled overburden + 2500 yards fill material. Only need fill for removed material, overburden placed back in excavation.
Source Area Contaminated Soil Excavation	2,500	yards	$6	$15,000	70'x100' = 7000 sqft x 10' = 70,000 cuft = 2592 cuyds. Assuming depth of fine-grain sand layer varies from 5-10'. Use 2,500 yards.
Haul and Landfill Disposal of Contaminated Soil	3750	tons	$70	$262,500	Transportation and landfill disposal of $70/ton. Based on recent projects. Assume Subtitle D (Hillsboro) disposal.
Soil Sampling and Analysis	1	lump sum	$5,000	$5,000	Sample analyses primarily for VOCs; includes profiling and confirmation samples.
Shoring (Sheet Pile) and Dewatering/Disposal	1	lump sum	$400,000	$400,000	Groundwater 20-25 feet bgs. Would pump water out, and flocculate, then have the bulk settle into a weir tank. Dispose of solids and pump water through GPTIA. Based on recent project and professional judgement.
Closure Activities					
Closure Report	1	lump sum	$15,000	$15,000	Parametrix estimate. Professional judgement.
Project Management and Meetings	1	lump sum	$3,000	$3,000	Parametrix estimate. Professional judgement.
Estimated Total Cost				**$900,050**	

NOTES:

Estimate does not include operation of the existing pump and treatment system. Costs above considered supplemental to the P&T.

Costs above do not include the site-wide monitoring that will be required to achieve Site closure.

Monitoring costs above is only for source area; remaining costs for monitoring is included in the Site alternatives.

P&T = Pump and treatment system.

Feasibility Study Conceptual Design/Costs
SMC Source Area

Alternative C
AS/SVE in the Source Area

This alternative includes the construction of an air sparging and soil vapor extraction (AS/SVE) system in the source area and primarily targets the fine-grained sand layer. The AS/SVE system works on the injection of air into the groundwater to volatilize contaminants. The volatile contaminants in the air phase rise into the vadose zone, where they are captured by the SVE wells under a vacuum influence. The volatilized contaminants are then adsorbed via a granulated activated carbon (GAC) canister prior to ventilation to the atmosphere. Given ideal conditions, a typical timeframe for remediation of groundwater contaminants to beneath levels of concern is 2 to 4 years.

Based on the extent and depth of source area contamination (target area), the preliminary conceptual design suggests that a total of approximately 8 air sparging wells would be adequate to treat the SMC source area. The AS wells would be installed to the bottom of the fine-grained sand layer (approximately 25 feet below ground surface [bgs]), with a 0.5 foot well screen at the bottom (groundwater is approximately 20 feet bgs). Seven to ten soil vapor extraction wells would be installed around the AS wells to capture soil vapors in the vadose zone. The SVE wells would be drilled to approximately 15 to 20 feet bgs, with a 10 foot well screen.

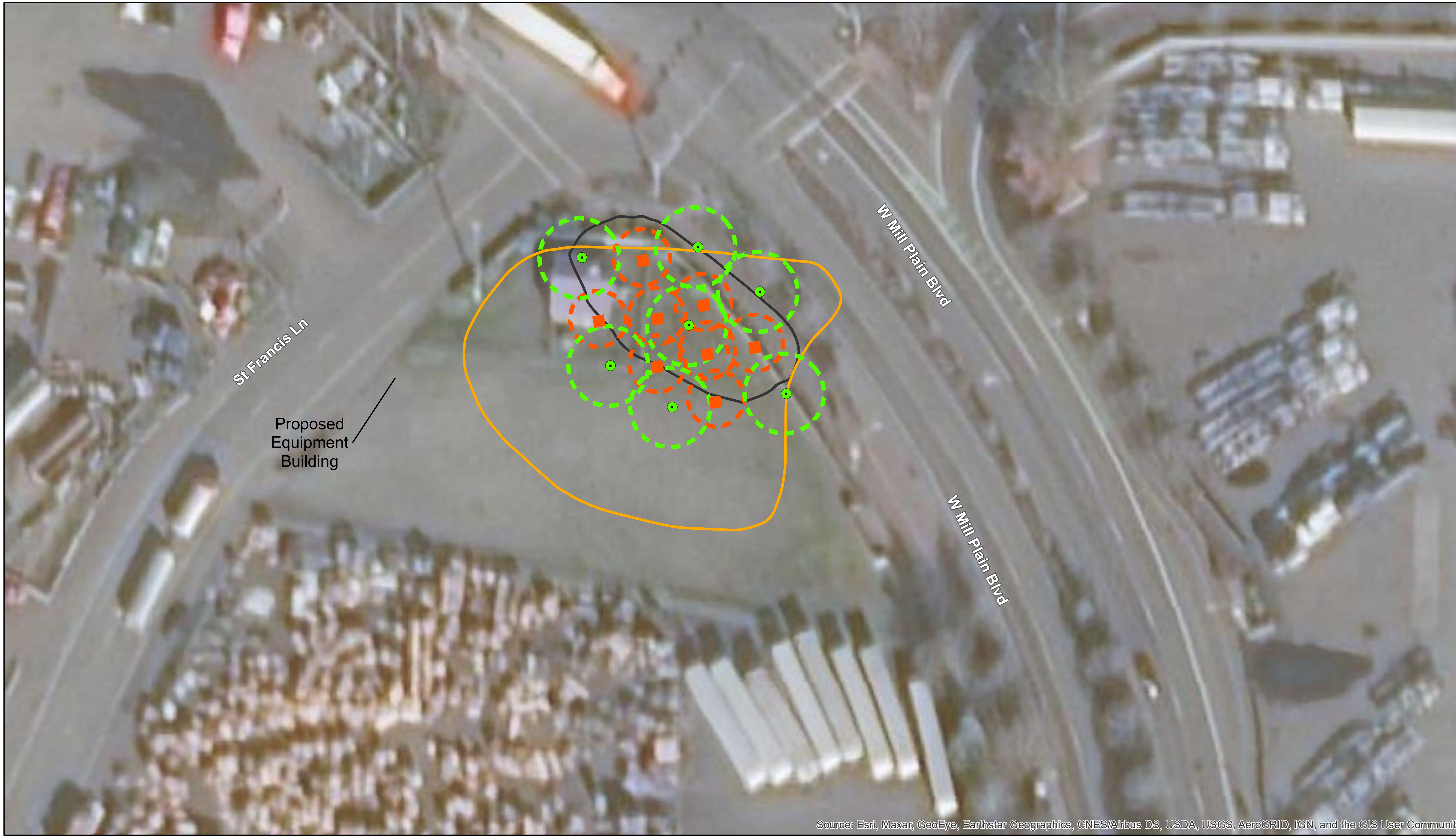
The AS wells would be connected via a hose or piping to an air blower and the SVE wells connected via 2-inch PVC piping to a vacuum unit. A small equipment shed would likely be required to house the blower, vacuum, electrical unit, sound insulation, and other equipment. The air collected by the vacuum would be discharged through a GAC canister for treatment, prior to ventilation to the atmosphere.

Due to the complexity of the source area, installation of an AS/SVE system would be difficult and potentially problematic. A design study would be required to evaluate the precise geology of the fine-grained sand layer and placement of AS wells. The relatively thin nature of the fine-grained sand layer may be difficult in terms of placement of the AS wells. In addition, based on past evaluation, the fine-grained sand layer is not always fully saturated, thus limiting the effectiveness of air sparging in that layer. Completion of AS wells below the fine-grained sand layer would not be effective due to the tight formation of the sand which would promote lateral movement of air at the fine-grained sand layer interface, rather than vertical movement through the contaminated zone.

<u>**Attachments**</u>

Figure C-2: Conceptual Design of AS/SVE

Estimated Costs for Implementation of Alternative C



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Feet

- Horizontal AS Well
- SVE Well
- Potential Extent of Residual Source Area
- Focused Treatment Area
- Estimated Air Sparging Radius of Influence
- Estimated Soil Vapor Extraction Radius of Influence
- AS Piping
- SVE Piping

Figure C-2
Conceptual AS/SVE System Layout (Horizontal AS Wells)

Feasibility Study
Port of Vancouver
Vancouver, Washington

Alternative C Cost Estimate: Source Area Air Sparge/Soil Vapor Extraction System
Port of Vancouver
Vancouver, Washington

Activity	Quantity	Unit	Unit Costs	Extended Cost	Notes
Preparatory Activities					
Environmental Engineering Assistance (Design and Specs)	1	lump sum	$15,000	$15,000	Parametrix estimate. Professional judgement.
Contractor Solicitation and Procurement	1	lump sum	$4,000	$4,000	Parametrix estimate. Professional judgement.
Project Management and Meetings	1	lump sum	$3,000	$3,000	Parametrix estimate. Professional judgement.
Air Sparge/Soil Vapor Extraction System					
Air Sparging Wells/ Soil Vapor Wells	1	lump sum	$40,000	$40,000	Assume 8 sparge wells (25') and 7 SVE wells (20'). Includes drilling and completion of wells. Cascade Drilling bid Aug 2013.
Construction of System; Contractor Labor	1	lump sum	$25,000	$25,000	Environmental contractor costs; 7 days of construction after wells installed.
Equipment					
8x10' TuffShed	1	shed	$5,000	$5,000	8 x 10 foot shed.
Regenerative Blower (SVE) - Rotron, Model 808	1	blower	$8,000	$8,000	Typcial costs. Professional judgement.
Rotary scroll Compressor (AS) - Powerex, Model SED 1007	1	compressor	$15,000	$15,000	Typcial costs. Professional judgement.
Vent-Scrub Carbon Adsorber (Siemens GAC Air treatment unit (55 gal))	1	lump sum	$1,000	$1,000	Typcial costs. Professional judgement.
Muffler (Sound Reduction)	1	lump sum	$500	$500	Typcial costs. Professional judgement.
SVE moisture separator tank	1	lump sum	$300	$300	Typcial costs. Professional judgement.
Misc. Piping, Valves, etc.	1	lump sum	$2,500	$2,500	Typcial costs. Professional judgement.
Pressure regulator/gauges	1	lump sum	$300	$300	Typcial costs. Professional judgement.
Flow meter	1	lump sum	$300	$300	Typcial costs. Professional judgement.
System control panel	1	lump sum	$5,000	$5,000	Typcial costs. Professional judgement.
Visqueen	4	20' x 100'	$100	$400	
3" gravel cap	50	cubic yards	$40	$2,000	75 x 100 x 0.25 = 1175 cubic feet = 43 cubic yards
Operation and Maintenance, Monitoring	16	per year for 4 years	$4,000	$64,000	4 monitoring events per year; assume 4 years
Laboratory	16	per year for 4 years	$600	$9,600	Quarterly effluent monitoring (air)
Other Maintenance	4	lump sum	$7,500	$30,000	Parametrix estimate. Professional judgement.
Closure Activities					
Groundwater Monitoring (source area only)	5	years	$5,000	$25,000	Parametrix estimate. Professional judgement.
Closure Report	1	lump sum	$20,000	$20,000	Parametrix estimate. Professional judgement.
Project Management and Meetings	1	lump sum	$4,000	$4,000	
Estimated Total Cost				**$279,900**	

NOTES:

Estimate does not include operation of the existing pump and treatment system. Costs above considered supplemental to the P&T.

Costs above do not include the site-wide monitoring that will be required to achieve Site closure.

Monitoring costs above is only for source area; remaining costs for monitoring is included in the Site alternatives.

P&T = Pump and treatment system

Feasibility Study Conceptual Design/Costs
SMC Source Area

Alternative D
Injection of Chemical Oxidant in the Source Area

This alternative consists of injecting a chemical oxidant (likely Fenton's Reagent) below the water table using a combination of injection wells and temporary direct-push injection points.

As is typical of in-situ oxidizing treatments, the injection of Fenton's Reagent disrupts aquifer equilibrium conditions in two ways: 1) physical agitation of the aquifer, and 2) liberation of bound TCE from the soil matrix. Both of these actions can result in dissolved TCE concentrations that are initially higher after treatment than those observed prior to treatment. After mobilizing the bound TCE, subsequent treatments are aimed at destroying the resulting dissolved TCE. After the final treatment, equilibrium conditions would be re-established naturally and TCE concentrations decreased. Given ideal conditions, it is estimated that two to three treatment events would occur, followed by monthly monitoring of the wells for 1 to 3 years. Cleanup would be achieved with 4 years.

Chemical oxidation via injection points was the chosen method for the interim action during source remediation and proved to be an effective method of destroying residual TCE. This alternative includes additional injection points and direct delivery to the fine-grain sand layer, approximately 20 to 25 feet below ground surface (bgs).

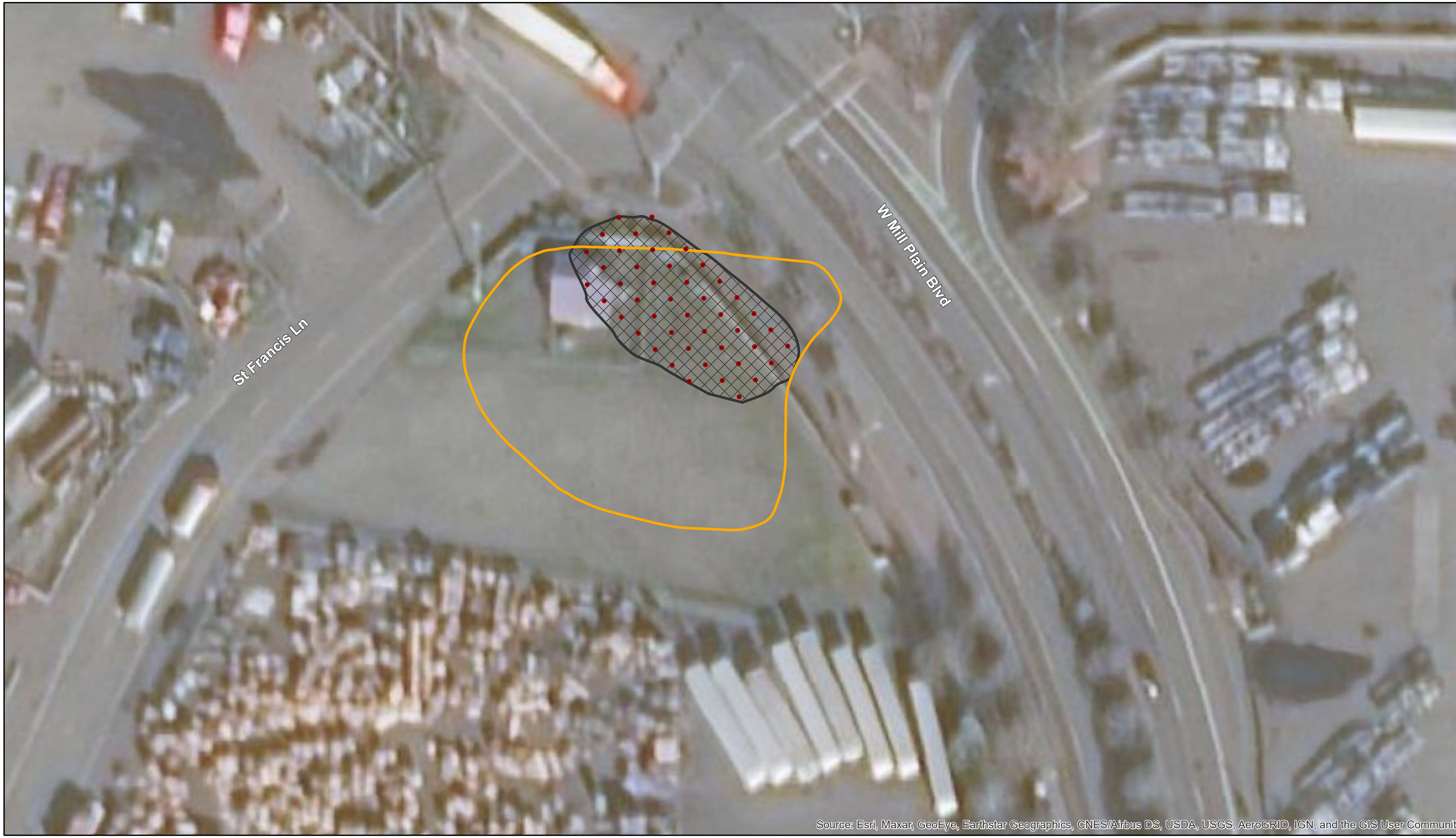
Approximately 50 to 60 injection borings would be completed up to 30 feet bgs throughout the 70' x 100' source area. The size and distribution of source area would make implementing an effective delivery system manageable. Because of the rapid decomposition of oxidizing agents, injection points would have to be located throughout the source area in order to achieve the cleanup goals.

Due to the complexity of the source area, effectiveness of chemical oxidation via injection could be difficult and potentially problematic, similar to those described for the AS/SVE option. A design study would be required to evaluate the precise geology of the fine-grained sand layer and placement of injection points. The relatively thin nature of the fine-grained sand layer may be difficult in terms of placement of the chemical oxidant. Distribution of chemical oxidants may also be difficult in the tight formation of the fine-grained sand layer. Past experience during the source area interim action indicated that the radius of influence from injection points may be limited; thus, requiring a high concentration of injection points within the target area.

<u>Attachments</u>

Figure C-3: Conceptual Design of Chemical Injection

Estimated Costs for Implementation of Alternative D



Parametrix Date: 5/5/2021 Path: \\parametrix.com\pmx\Port\Projects\Clients\1940-Port of Vancouver\275-1940-006-POV TCE\99Svcs\GIS\POV\MXD_PDF\PumpStation\2021\Fig_C-3_InjectionPoints.mxd

N

0 50 100
Feet

Potential Extent of Residual Source Area
Focused Treatment Area
Temporary Injection Point

Figure C-3
Conceptual Substrate Injection Points

Feasibility Study
Port of Vancouver
Vancouver, Washington

Alternative D Cost Estimate: Source Area Injection of Substrate (Fenton's Reagent or Other Oxidant)
Port of Vancouver
Vancouver, Washington

Activity	Quantity	Unit	Unit Costs	Extended Cost	Notes
Preparatory Activities					
Environmental Engineering Assistance (Design and Specs)	1	lump sum	$20,000	$20,000	Parametrix estimate. Professional judgement.
Contractor Solicitation and Procurement	1	lump sum	$5,000	$5,000	Parametrix estimate. Professional judgement.
Project Management and Meetings	1	lump sum	$5,000	$5,000	Parametrix estimate. Professional judgement.
Injection Events					
Equipment Mobilization	1	lump sum	$10,000	$10,000	Parametrix estimate. Professional judgement.
Temporary probe boring wells (average 50 holes) (contractor and equipment)	1	lump sum	$90,000	$90,000	Assume average of 50 temporary probe borings. Includes drilling and completion of wells. Cascade Drilling bid based on conceptual design.
Second event (assume same scenario as first event)	1	lump sum	$45,000	$45,000	Assume average of 50 temporary probe borings. Includes drilling and completion of wells. Cascade Drilling bid based on conceptual design.
Third Event (assume half of first event)	1	lump sum	$25,000	$25,000	Assume average of 25 temporary probe borings. Includes drilling and completion of wells. Cascade Drilling bid based on conceptual design.
Equipment/Miscellaneous					
Fenton's Reagent or emulsified oil (average 250 gallons/hole)	1	lump sum	$125,000	$125,000	Cascade Drilling estimate. Professional judgement.
Operation and Maintenance, Monitoring	1	lump sum	$15,000	$15,000	Environmental contractor; equipment maintenance, monitoring.
Laboratory	4	events	$5,000	$20,000	Sample analyses primarily for VOCs; includes profiling and confirmation samples in VMW wells, MW-5, etc.
Other Maintenance	1	lump sum	$10,000	$10,000	Parametrix estimate. Professional judgement.
Closure Activities					
Closure Report	1	lump sum	$25,000	$25,000	Parametrix estimate. Professional judgement.
Project Management and Meetings	1	lump sum	$5,000	$5,000	Parametrix estiamte. Professional judgement.
Estimated Total Cost				**$400,000**	

<u>NOTES:</u>

Estimate does not include operation of the existing pump and treatment system. Costs above considered supplemental to the P&T.

Costs above do not include the site-wide monitoring that will be required to achieve Site closure.

Monitoring costs above is only for source area; remaining costs for monitoring is included in the Site alternatives.

P&T = Pump and treatment system.

Appendix D

Residual Groundwater Plume Alternatives Support

Alternative A Cost Estimate: Monitored Natural Attenuation
SMC and Cadet Sites
Vancouver, Washington

Activity	Unit Costs	Unit	Extended Cost	Extended Cost
Groundwater Monitoring				
2022	$60,000	per year	$60,000	$60,000
2023	$61,800	per year	$61,800	$61,800
2024	$63,654	per year	$63,654	$63,654
2025	$65,564	per year	$65,564	$65,564
2026	$67,531	per year	$67,531	$67,531
2027	$69,556	per year	$69,556	$69,556
2028	$71,643	per year	$71,643	$71,643
2029	$73,792	per year	$73,792	$73,792
2030	$76,006	per year	$76,006	$76,006
2031	$78,286	per year	$78,286	$78,286
2032	$80,635	per year		$80,635
2033	$100,000	per year		$100,000
2034	$103,000	per year		$103,000
2035	$106,090	per year		$106,090
2036	$109,273	per year		$109,273
Total 10 years			**$687,833**	
Total 15 years				**$1,186,830**
Planning and Regulatory Documents			**$350,000**	**$350,000**
Prior to Implementation		Lump Sum Estimate	$100,000	$100,000
Annual MNA Reporting			$150,000	$150,000
Closure Documents			$100,000	$100,000
Estimated Total Cost (Low to High)			**$1,037,833**	**$1,536,830**

Notes:
This alternative assumes 10 - 15 years of MNA will be required to meet CULs.
Monitoring costs include labor (field and reporting) and lab costs and a 3% yearly increase.
Costs are based on current project area well network and expected POCs and monitoring requirements.

Alternative B Cost Estimate: Pump and Treat and Site Monitoring
SMC and Cadet Sites
Vancouver, Washington

Activity	Unit Costs	Unit	Extended Cost	Extended Cost
Operation and Maintenance				
2022	$150,000	per year	$150,000	$150,000
2023	$154,500	per year	$154,500	$154,500
2024	$159,135	per year	$159,135	$159,135
2025	$163,909	per year	$163,909	$163,909
2026	$168,826	per year	$168,826	$168,826
Total 5 years			**$796,370**	**$796,370**
Groundwater Monitoring				
2022	$60,000	per year	$60,000	$60,000
2023	$61,800	per year	$61,800	$61,800
2024	$63,654	per year	$63,654	$63,654
2025	$65,564	per year	$65,564	$65,564
2026	$67,531	per year	$67,531	$67,531
2027	$69,556	per year	$69,556	$69,556
2028	$71,643	per year	$71,643	$71,643
2029	$73,792	per year	$73,792	$73,792
2030	$76,006	per year	$76,006	$76,006
2031	$78,286	per year	$78,286	$78,286
2032	$80,635	per year		$80,635
2033	$100,000	per year		$100,000
2034	$103,000	per year		$103,000
2035	$106,090	per year		$106,090
2036	$109,273	per year		$109,273
Total 10 years			**$687,833**	
Total 15 years				**$1,186,830**
Equipment/Maintenance Expenditures		Lump Sum Estimate	**$200,000**	**$200,000**
Planning and Regulatory Documents			**$350,000**	**$350,000**
Prior to Implementation		Lump Sum Estimate	$100,000	$100,000
Annual MNA Reporting			$150,000	$150,000
Closure Documents			$100,000	$100,000
Estimated Total Cost (Low to High)			**$2,034,203**	**$2,533,201**

Notes:
This alternative assumes 5 years of O&M and 10-15 years of monitoring of the project area well network.
O&M costs only include O&M going forward. Capital costs have been incurred, but are not reflected in the cost for this alternative.
Monitoring costs include labor (field and reporting) and lab costs and a 3% yearly increase.

Appendix E

Environmental Justice Summary Report

1. Introduction and Background

The Port of Vancouver ("the port") recognizes that environmental justice and disparate community impacts are an emerging and important issue and will need to be considered in a number of new state policies. The Washington State Department of Ecology ("Ecology") is updating the Model Toxics Control Act ("MTCA") Cleanup Rule and proposing the incorporation of environmental justice ("EJ") into remedy selection as part of the feasibility study ("FS") process. The updates to the rule will be completed in three rulemakings over several years and is not expected to be formalized for some time. In addition, the State of Washington enacted the Healthy Environment for All (HEAL) Act, E2SSB 5141, imposing obligations on state agencies, including Ecology, to incorporate environmental justice in the administration of environmental programs. RCW 70A.02.005. Based on this information, the port determined that it would consider EJ in the remedy selection process for this current FS, before the implementation date for the HEAL Act and prior to the completion of Ecology's MTCA rulemaking and updated guidance.

During early 2021, the port engaged with Ecology personnel[1] in a series of meetings to discuss its interest in incorporating EJ in its remedy selection, explore the methodology for doing so, outline a plan, and develop language for community outreach. Ecology was supportive of the port's efforts and suggested that the port carry out its efforts as a pilot project that could inform Ecology's rulemaking.

The port is located in the Fruit Valley Neighborhood, is a member of the neighborhood association and attends monthly neighborhood association meetings to share port news and activities. The Fruit Valley Neighborhood is known to house low-income and minority populations.

In summer 2021, the Port of Vancouver conducted outreach to the Fruit Valley Neighborhood. Neighborhood as part of the FS to evaluate final groundwater cleanup options for contamination associated with the Cadet Manufacturing and former Swan Manufacturing areas of the Vancouver Port of NuStar Cadet Swan Site. These areas are located near the Fruit Valley Neighborhood.,

The port has been conducting outreach specific to the cleanup effort to the Fruit Valley Neighborhood since the discovery of contamination at the Swan and Cadet sites. Although not required to implement Ecology Draft EJ rules at the time of this writing, the port conducted analysis of and additional outreach to the Fruit Valley Neighborhood populations and shared information about the cleanup and to gather community feedback to inform the Feasibility Study and future Cleanup Action Plan (CAP).

The following sections briefly summarize the background, process, and findings resulting from this pilot effort by the port.

[1] Ecology personnel included Clint Stanovsky, the Ecology Rulemaking Lead for the MTCA Cleanup Rule update; Richelle Perez, Acting Unit Supervisor Toxics Cleanup Program SWRO; Rebecca Lawson, the then-Acting Program Manager, Toxics Cleanup Program; Scott O'Dowd, the then-Environmental Justice Policy Lead, Toxics Cleanup Program; and Ivy Anderson, manager of the Cleanup Section of the Ecology Division of the Attorney General's Office.

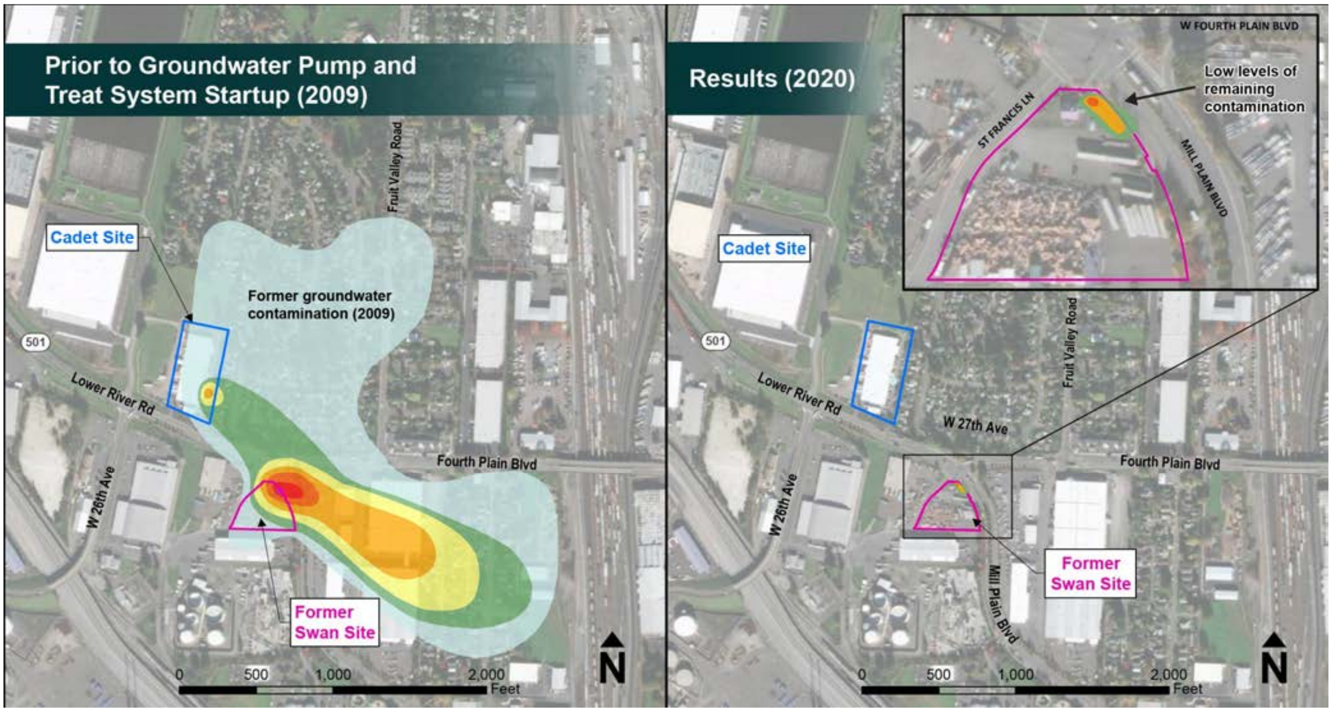
Background

Although contamination occurred many years before the port owned the properties, cleanup of the Cadet and former Swan areas is a top priority for the port. The contamination is related to the use of solvent-based cleaning products at the sites by previous operators. Cleanup has been ongoing with oversight from Ecology since 1998, and these efforts have been very successful. Prior cleanup actions have included:

- Soil Cleanup
- Groundwater Cleanup
- Residential Indoor Air Cleanup

The 2020 data indicate that interim remedial actions conducted by the port have addressed soil contamination at the Cadet and former Swan areas and shallow groundwater contamination under and indoor air quality in the Fruit Valley Neighborhood. Shallow groundwater contamination is now confined to a small area under the former Swan property (see Figure 1 below).

Figure 1. Groundwater Pump and Treat System Results (2009 - 2020)



This map was used to illustrate cleanup progress from the initial pump and treat system construction and operation in 2009 to the most recent available data in 2020.

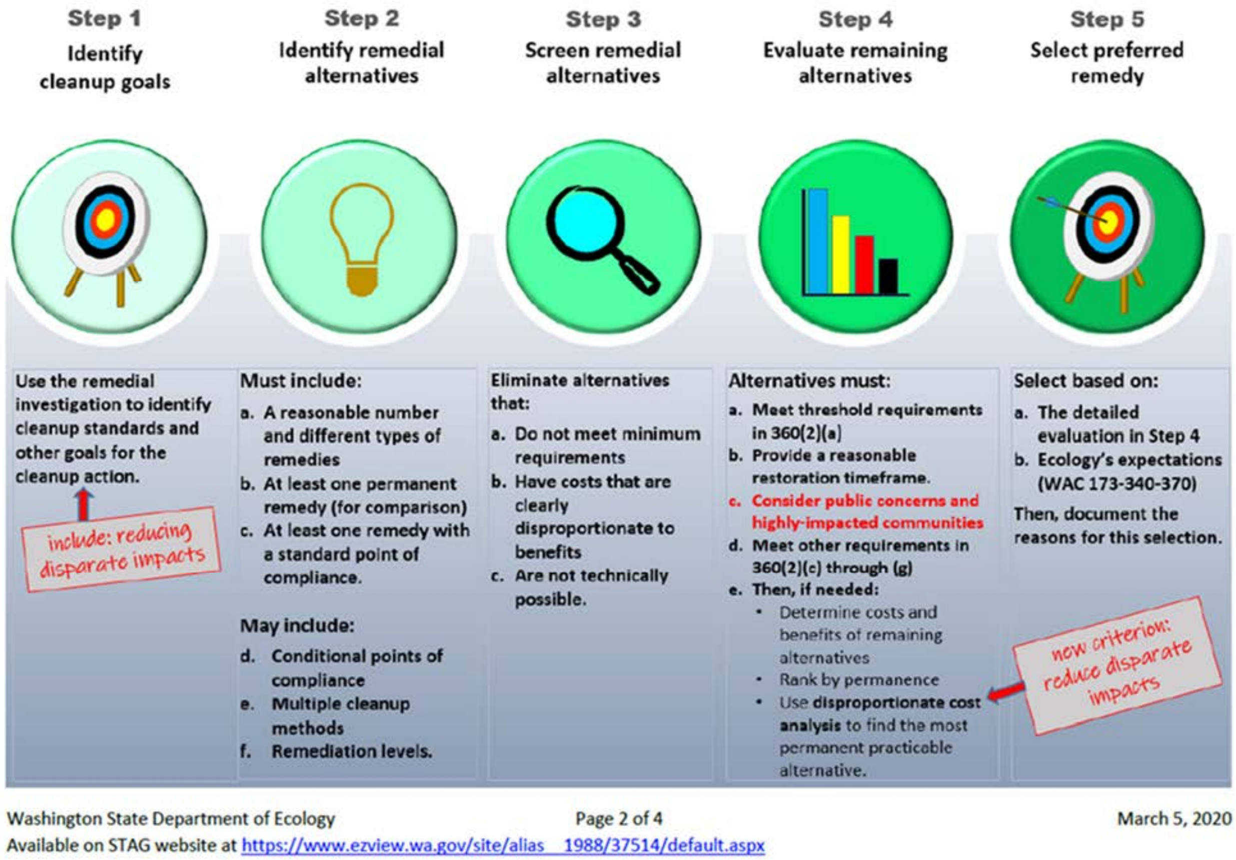
Ecology Draft EJ Rules

The draft rules define "highly impacted communities" as those that "Ecology has determined is likely to bear a disproportionate burden of public health risks from environmental pollution, such as minority, low-income, tribal or indigenous populations." Ecology currently identifies a highly impacted community as one where the population of the census tract exceeds the 75th percentile for one or more of the following five criteria:

- Low income
- Less than a high school education
- Minority
- Under 5 years of age
- Over 65 years of age
- Also consider linguistic isolation

Ecology also provided draft guidance on how consideration of highly impacted communities and EJ populations would be incorporated into the remedy selection process, summarized in Figure 2 below. The draft guidance specifies that cleanup goals at the start of the remedy selection process include reduction of disparate impacts to highly impacted communities. During the evaluation of alternatives, the rules also specify that public concerns of highly impacted communities are considered and that reducing disparate impacts is included as a criterion in the alternatives evaluation process and disproportionate cost analysis.

Figure 2. Remedy selection process under Ecology Draft EJ Rules



Related EJ Laws, Regulations, and Guidance

The port considered existing laws and regulations in formulating a pilot approach for evaluating environmental justice concerns for Fruit Valley neighbors regarding final cleanup actions for the Cadet/Swan cleanup sites. The port also considered the HEAL Act and recent legislation passed by the Biden Administration: *Executive Order 13985 on Racial Equity and Underserved Communities* and *Executive Order 13990 on Tackling Climate Crisis at Home and Abroad:*

- Executive Order 12898 on Environmental Justice defines EJ populations as minority and low-income populations and directs public agencies to improve analysis methods for identifying low-income and minority populations and to expand outreach to these groups.
- Executive Order 13985 directs the Director of the Office of Management and Budget to form a federal working group to identify analysis methods and implementation guidance for addressing racial equity and addressing the needs of underserved communities in federal processes. Methods and guidance still pending, this EO was considered due to alignment between Ecology-defined "highly impacted communities" and community groups addressed in the EO.
- Executive 13990 directs federal agencies to consider human health, environmental, climate-related, and other cumulative impacts on disadvantaged communities, and the economic challenges of such impacts, in all decision-making activities. This EO also directs the creation of

geospatial Climate and Economic Justice Screening Tool and annual publishing of interactive maps highlighting disadvantaged communities.

- Washington State Environmental Justice Task Force Final Report (2020) – Provides recommendations for prioritizing EJ in Washington State government, including specific guidance for agencies such as the Department of Ecology. The HEAL Act adopted the recommendations of the Task Force.
- EPA is directed to strengthen enforcement of environmental violations with disproportionate impact on underserved communities through the Office of Enforcement and Compliance Assurance, and create a community notification program to monitor and provide real-time data to the public on current environmental pollution, including emissions, criteria pollutants, and toxins, in frontline and "fenceline" communities.

2. Environmental Justice Analysis

The Environmental Justice Screening and Mapping tool (EJSCREEN) published by the U.S. Environmental Protection Agency (EPA) was used to assess the presence of EJ communities in the Fruit Valley Neighborhood. This tool was used to measure the presence of EJ populations and environmental exposures within the Fruit Valley Neighborhood compared to the city of Vancouver as well as to state, EPA Region 10[2], and national percentiles. The purpose of this comparison was to assess the concentration of EJ populations within the Fruit Valley Neighborhood and their relative exposure to environmental hazards compared to EJ populations and exposures throughout the city. For the purposes of this study, the entirety of the Census Tract (53011041005) containing the Fruit Valley Neighborhood was used as the local study geography (See Attachment B).

EJSCREEN allows users to retrieve demographic and environmental information for a chosen geographic area using a nationally consistent dataset and approach for combining environmental and demographic indicators into an "EJ Index." The EJ Index is a multi-criteria assessment based on a combination of eleven (11) environmental and six (6) demographic indicators. Environmental indicators include exposure to wastewater discharge, hazardous waste proximity, and PM 2.5[3]. Demographic indicators assess characteristics that define EJ populations: concentrations of people of color, low-income households, and linguistically-isolated populations. The EJ Index combines demographic indicators with a single environmental indicator, resulting in eleven (11) EJ Indexes. The EJ Indexes provide a measure of the relative level of exposure to environmental indicators facing the low-income, minority, and linguistically-isolated population in a given area. The specific environmental indicators used are as follows:

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[2] For regional comparisons, EJSCREEN utilizes data from EPA Regions. For the purposes of this analysis, demographic and environmental indicators were compared to EPA Region 10 (Pacific Northwest), serving Alaska, Idaho, Oregon, Washington, and 271 Tribal Nations. More information on EPA Region 10 can be found at: https://www.epa.gov/aboutepa/epa-region-10-pacific-northwest

[3] PM stands for particulate matter (also called particle pollution): the term for a mixture of inhalable solid particles and liquid droplets found in the air. Particle pollution is measured in micrometers and is generally organized into two categories – PM 10 and PM 2.5. PM 10 refers to inhalable particles with diameters that are generally 10 micrometers and smaller. PM 2.5 refers to fine inhalable particles with diameters that are generally 2.5 micrometers and smaller. Generally, particles less than 2.5 micrometers in diameters, also known as fine particles or PM 2.5, pose the greatest risk to health and are often used as proxy measures for evaluating air quality and environmental pollution.

1. National Scale Air Toxics Assessment (NATA) Air Toxics Cancer Risk
2. NATA Respiratory Hazard Index (HI)
3. NATA Diesel PM (DPM)
4. Particulate Matter (PM 2.5)
5. Ozone
6. Lead Paint Indicator
7. Traffic Proximity and Volume
8. Proximity to Risk Management Plan (RMP) Sites
9. Hazardous Waste Proximity to Treatment Storage and Disposal Facilities
10. Superfund Proximity to National Priorities List Sites
11. Wastewater Discharge Indicator

These measures are combined into a single EJ Index to support analysis of the presence of environmental justice populations in a given community and their exposure to environmental risks and hazards.
The EJSCREEN tool reports EJ Indexes using statistical **percentiles**[4] compared to all people in the state, reference EPA region, and U.S. Therefore, the tool provides a relative measure of the:

- **Proportion of EJ populations that are subject to environmental exposures** in a given location compared to the statistical distribution of all people in the state, reference EPA region, and U.S.
- **Level of environmental exposure that EJ populations are subject to** in a given location compared to the statistical distribution of all people in the state, reference EPA region, and U.S.

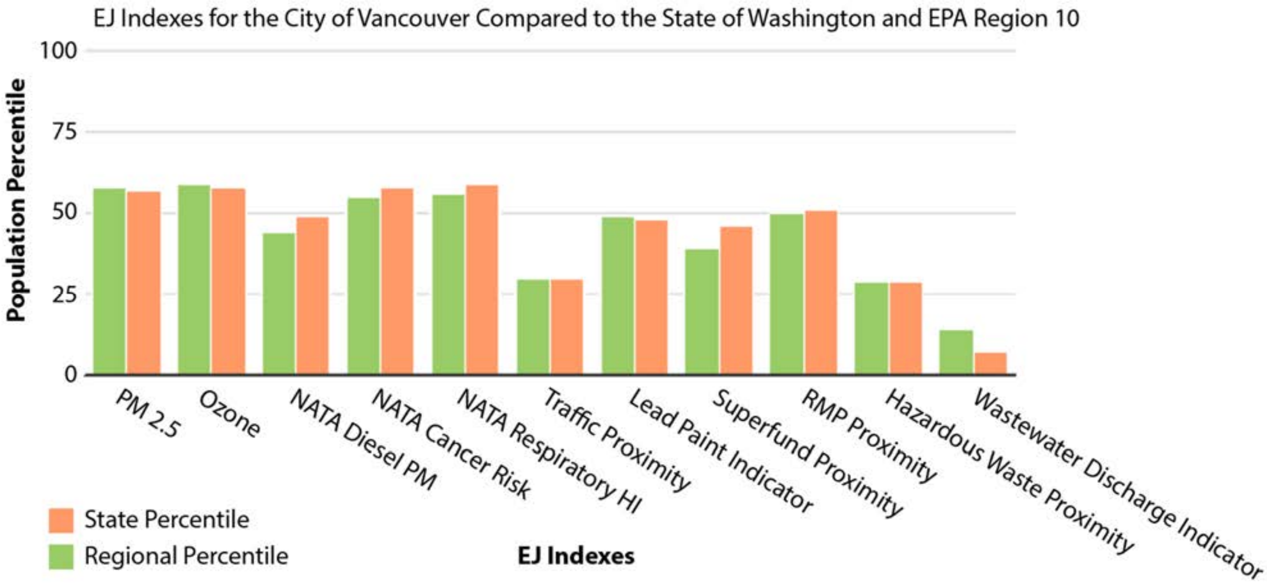
The EJ analysis sought to compare EJ Indexes between the Fruit Valley Neighborhood and the city as a whole, which are both considered local geographies by EJSCREEN. However, EJSCREEN does not allow for comparisons between local geographies. Therefore, two separate EJSCREEN reports were created – one for the Fruit Valley Neighborhood and one for the city of Vancouver. Figure 3 below displays EJSCREEN results for the city of Vancouver compared to the State of Washington and EPA Region 10.

For comparison, population statistics for each reference geography are summarized below based on 2020 EJSCREEN Standard Reports (See Attachments A and B) and American Community Survey 5-Year Estimates published by the U.S. Census Bureau.

- EPA Region 10 – 14.4 Million
- State of Washington – 7.6 Million
- City of Vancouver – 172,501
- Fruit Valley Neighborhood – 2,471

[4] In statistics, a percentile refers to the value *at or below which* a given percentage of observations in a group of observations fall. For example, the 50th percentile is also the median, and is the value at or below which 50% of the scores in the distribution may be found.

Figure 3. EPA EJSCREEN Results - City of Vancouver Compared the State and EPA Region 10



To interpret these results, consider that the tool compares the city's EJ Indexes (X axis) compared to State of Washington and EPA Region 10 percentiles (Y axis). Regional percentile refers to EPA Region 10. For example, the city's EJ Index for hazardous waste proximity is approximately at the 25th percentile for to both the state (orange bar) and EPA Region 10 (green bar). This means that approximately 75 percent of the state and EPA Region 10 population have a higher EJ Index for hazardous waste proximity than the city of Vancouver. As described above, also consider that the EJ Index refers to a combination demographic and environmental factors: hazardous waste proximity, population size, low-income populations, and minority populations. In summary, the results suggest that the city has a relatively low number of low-income, minority, and linguistically-isolated populations with high proximity to hazardous waste compared to the rest of the state and EPA Region 10.

EJSCREEN indexes for PM 2.5, ozone, and diesel particulate matter refer to estimates of ambient levels of air pollutants. For example, the city's EJ Index for PM 2.5 is approximately at the 50th percentile compared to both the state (orange bar) and EPA Region 10 (green bar). This means that approximately 50 percent of the state and EPA Region 10 population have a higher EJ Index for PM 2.5 than the city of Vancouver. These results suggest that the relative proportion of EJ populations with exposure to PM 2.5 is slightly above average compared to the rest of the state and EPA Region 10.[5]

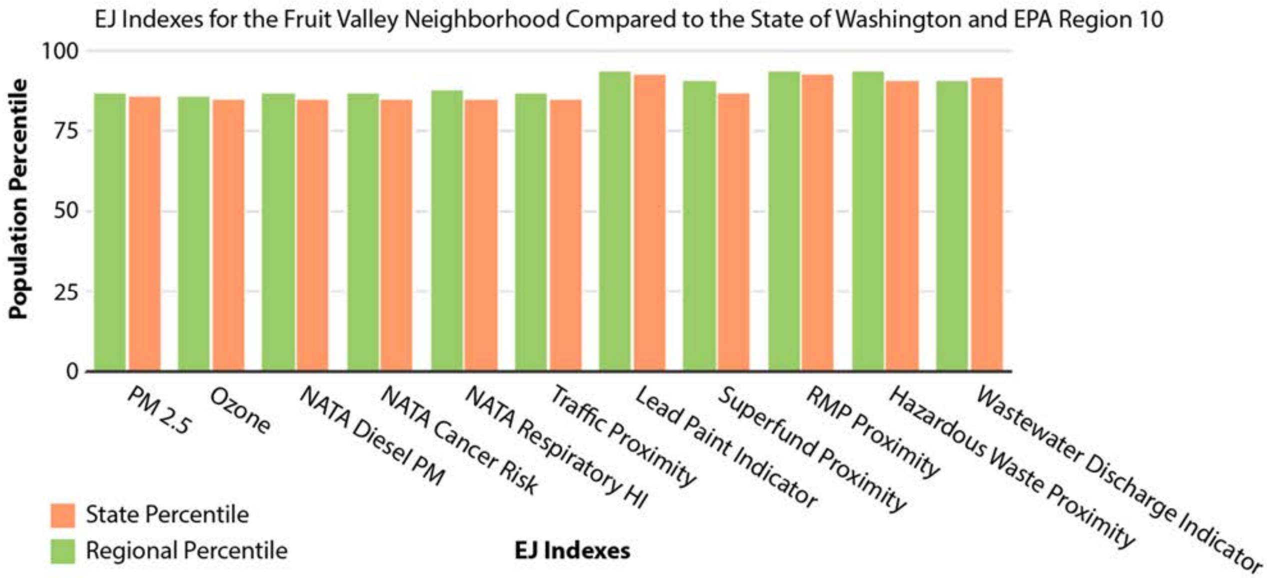
Overall, EJ populations within the city of Vancouver had environmental exposure levels ranging from relatively low (near the 25th percentile) to average (near the 50th percentile) compared to the state and EPA Region 10. For example, EJ Indexes for traffic and hazardous waste proximity were near the 25th percentile, while the EJ Index for wastewater discharge was well below the 25th percentile. All other EJ

[5] Note: the EJSCREEN ozone EJ index measures ozone by considering the summer seasonal average of daily maximum 8-hour ozone concentration in air in parts per billion.

Indexes approximated the 50th percentile, which can be considered average compared to the state and EPA Region 10.

The next step in the analysis was to compare citywide EJ Indexes to EJ Indexes for the Fruit Valley Neighborhood. Figure 4 below displays EJSCREEN results for the census tract containing the Fruit Valley Neighborhood (the smallest available geographic unit of analysis in the tool) compared to the State of Washington and EPA Region 10.

Figure 4. EPA EJSCREEN Results – Fruit Valley Neighborhood Compared the State and EPA Region 10



As seen in Figure 4 above, all EJ Indexes for the Fruit Valley Neighborhood exceeded the 75th percentile compared to the state and EPA Region 10. This means that less than 25 percent of the statewide and regional population has EJ Index scores higher than the Fruit Valley Neighborhood. These findings suggest that the Fruit Valley Neighborhood has some of the highest concentrations of EJ populations with environmental exposures in the state and EPA Region 10. These findings confirm a significant presence of EJ populations in the Fruit Valley Neighborhood, as well as significant levels of environmental exposure compared to the state and EPA Region 10 as a whole. This information was considered in how to incorporate EJ into the Feasibility Study and in the development of the public engagement process (Section 3 below).

It is important to note that the environmental indicators reported by EJSCREEN **do not describe direct impacts from the Swan/Cadet manufacturing sites.** Rather, the environmental indicator data reported by EJSCREEN reflects the latest available data submitted to EPA.

Complete EJSCREEN Reports for the city of Vancouver are included as attachments at the end of this appendix report.

3. Public Engagement Process

Based on the EJSCREEN findings and consistent with the port's ongoing outreach to the Fruit Valley Neighborhood, the port conducted additional outreach to Fruit Valley neighbors about cleanup progress to date, the Feasibility Study, and work to determine a final remedy option for the Cadet/Swan groundwater contamination sites.

The port's outreach was impacted by COVID, which limited its ability to use its ordinary methods of community engagement with the Fruit Valley Neighborhood. For example, in a normal year the port would have held an event in the park, invited neighborhood residents to an open house in the Fruit Valley Community Center, or reached out through the Fruit Valley Elementary School at the heart of the Neighborhood. Given the ongoing pandemic, outreach to Fruit Valley neighbors was limited to online methods. In designing its outreach, the port considered issues that included access to technology and language barriers. The port conducted outreach to the Fruit Valley Neighborhood using the following methods:

- **Web page updates:** On June 21, 2021, the port completed content and URL updates to the public "Cleanups" webpage: https://www.portvanusa.com/environmental-services/cleanups/ . This update shared key information with community members to set the stage for outreach to Fruit Valley neighbors, including details about past cleanup actions and progress to date, including the extraction and treatment of 12.8 billion gallons of groundwater and removal of approximately 1,300 pounds of contaminants. The web page also provides a link to the online survey and a link to additional information about the cleanup on Ecology's webpage: https://apps.ecology.wa.gov/gsp/Sitepage.aspx?csid=3450
- **News release:** The port issued a news release containing the same information as the web page updates. https://www.portvanusa.com/assets/Active-Cleanups.pdf
- **Online survey:** An online survey was created and published using the online platform Survey123 to collect feedback from the Fruit Valley community and to inform the Feasibility Study. The survey was open from July 2 to August 6, 2021.
- **Spanish translations:** A review of the most recent American Communities Survey 5-Year Estimates (2009 – 2019) published by the US Census Bureau identified Spanish as the most frequently spoken language in the Fruit Valley Neighborhood after English. The postcard, web page, and survey were all translated to Spanish to reach Spanish-speakers in the area.
- **Mailed postcard:** A graphical postcard was mailed to 746 Fruit Valley neighbors on July 2, 2021 (Figure 4 below). The postcard invited residents to participate in the online survey via direct link and QR scan code. As noted above, the postcard also included Spanish translation.

Figure 5. Mailed Postcard - Fruit Valley Survey Invitation

Mailed postcard FRONT - English

Mailed postcard BACK - Spanish

Port of Vancouver USA
3103 NW Lower River Road
Vancouver, WA 98660 USA

PRSRT STD
U.S. POSTAGE
PAID
RIDGEFIELD, WA
PERMIT NO. 94

LIMPIEZA DE SWAN / CADET

¡Comparta sus comentarios con el puerto!

La encuesta en línea cierra el 6 de agosto de 2021: tinyurl.com/fruitvalleycleanup

El Puerto de Vancouver ahora está evaluando las opciones de limpieza final para la contaminación previamente identificada en los sitios de fabricación industrial de Cadet y la antigua Swan Manufacturing Company, ubicados cerca del vecindario de Fruit Valley.

Como participar

Tómese unos minutos para compartir sus comentarios sobre este proceso visitando **tinyurl.com/fruitvalleycleanup** o escaneando el código QR con su celular:

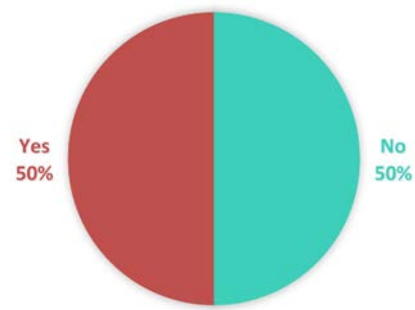
Preguntas: correo electrónico:
CleanUp@portvanusa.com

Survey Response Summary

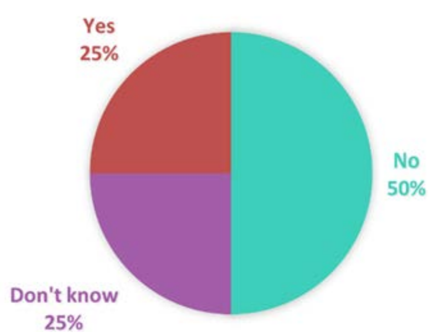
A total of four (4) residents responded to the survey. The following section summarizes survey responses collected from Fruit Valley neighbors between July 2 and August 6, 2021.

Question #1: Do you have any concerns regarding the overall cleanup?

Two (2) respondents said they had concerns regarding the overall cleanup. One respondent did not have much information on how the contamination first occurred and would like to see the next steps on how to prevent future contamination. Another respondent expressed interest in learning more about long-term health impacts on the residents from the contamination.



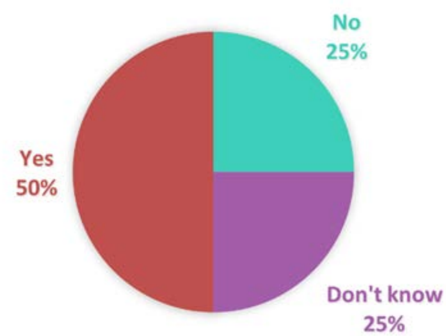
Question #2: Has the Cadet/Swan project and associated cleanup effort affected you and your community?



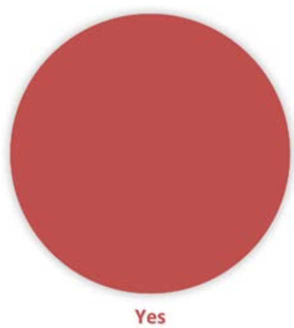
Half the respondents said that the Cadet/Swan cleanup has not affected their neighborhood. The remaining two (2) responses were split "Yes" (25%) and "Don't know" (25%). One respondent mentioned intense odors emanating from the city of Vancouver water treatment plant during the summer months, although this is unrelated to port property or the Cadet/Swan project.

Question #3: Do you feel like you've been adequately informed or engaged throughout the cleanup process?

Two (2) respondents (50%) said they felt adequately informed or engaged throughout the cleanup process. One (1) respondent answered "don't know" to this question (25%), potentially because cleanup efforts have been ongoing for over two decades and present cleanup actions that could go unnoticed by those who moved to the community after the contamination had occurred. One (1) respondent answered "No" (25%).



Question #4: Would you like to stay up to date as this process moves forward?



100% of respondents would like to be kept up to date as this process moves forward, consistent with findings from Question #1. Neighbors want to be kept informed on current and future actions, and how it affects their daily lives.

Question #5: What is your zip code? This question helps the ort understand the effectiveness of our outreach.

100% of respondents indicated that they live within the 98660 zip code area, which encompasses the Fruit Valley Neighborhood and nearby areas. This indicates the Port of Vancouver was successful in targeting the right population with mail outreach.

Question #6: Anything else?

The final question asked respondents to share anything else on their minds. One respondent asked to be informed on future decision-making around final cleanup actions and asked who will be accountable for cleanup impacts moving forward. One respondent also shared general concerns about current and future impacts of groundwater contamination on people and wildlife.

4. Findings and Key Themes

Community Responses

Overall, concerns around the Cadet/Swan final cleanup effort were low. The main concerns participants did have were:

- 1) being kept informed and up-to-date on cleanup actions
- 2) long-term health impacts on residents
- 3) potential future impacts on people and wildlife

Respondents have a major interest in being kept informed and engaged on the cleanup process, including information on project history and the process moving forward.

Future Outreach

A total of four (4) surveys were submitted back to the port. The total population of the Census Tract encompassing the Fruit Valley Neighborhood is approximately 2,400 according to the most recent American Communities Survey 5-Year Estimates (2009 – 2019). Future efforts by the port to engage this population could consist of strategies such as advertisements and notifications on the project website and social media to share progress on the overall cleanup process, Feasibility Study, and future Cleanup Action Plan. In addition, post-Covid 19 outreach efforts could include in-person gatherings such as neighborhood events or presentations at the neighborhood association meetings.

EJ Analysis Methods

Future cleanup/remediation activities could utilize more robust analysis methods for identifying EJ populations. In addition to tools like EJSCREEN, future efforts could locate and quantify disadvantaged communities identified in the Ecology Draft EJ procedures and overlay community information and technical data to identify potential gaps.

Incorporation of EJ in Future Cleanup/Remediation Activities

Ecology will continue to refine draft EJ rules for cleanup actions and remedies. The exact process for how EJ considerations will be incorporated into future cleanups, feasibility studies, and cleanup action plans will continue to evolve according to ongoing coordination and discussion between agency partners and findings from pilot efforts such as this one.

Consideration of EJ factors in future cleanup and remediation efforts will also be informed by recent legislative orders such as Executive Order 13985 on Racial Equity and Underserved Communities and Executive Order 13990 on Tackling Climate Crisis at Home and Abroad; specific implementation guidance for each of these EOs is yet to be determined, but will likely impact future analysis of and outreach to EJ populations.

Attachment A – City of Vancouver –EJSCREEN Standard Report

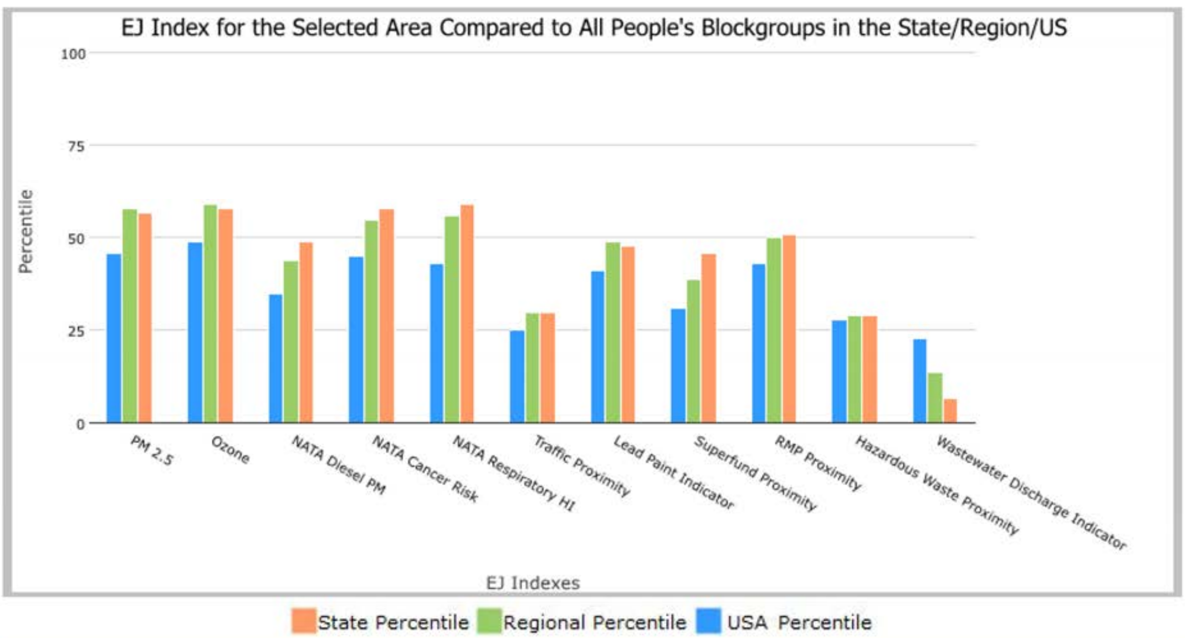
EJSCREEN Report (Version 2020)

City: Vancouver, WASHINGTON, EPA Region 10

Approximate Population: 172,501

Input Area (sq. miles): 50.44

Selected Variables	State Percentile	EPA Region Percentile	USA Percentile
EJ Indexes			
EJ Index for PM2.5	57	58	46
EJ Index for Ozone	58	59	49
EJ Index for NATA* Diesel PM	49	44	35
EJ Index for NATA* Air Toxics Cancer Risk	58	55	45
EJ Index for NATA* Respiratory Hazard Index	59	56	43
EJ Index for Traffic Proximity and Volume	30	30	25
EJ Index for Lead Paint Indicator	48	49	41
EJ Index for Superfund Proximity	46	39	31
EJ Index for RMP Proximity	51	50	43
EJ Index for Hazardous Waste Proximity	29	29	28
EJ Index for Wastewater Discharge Indicator	7	14	23

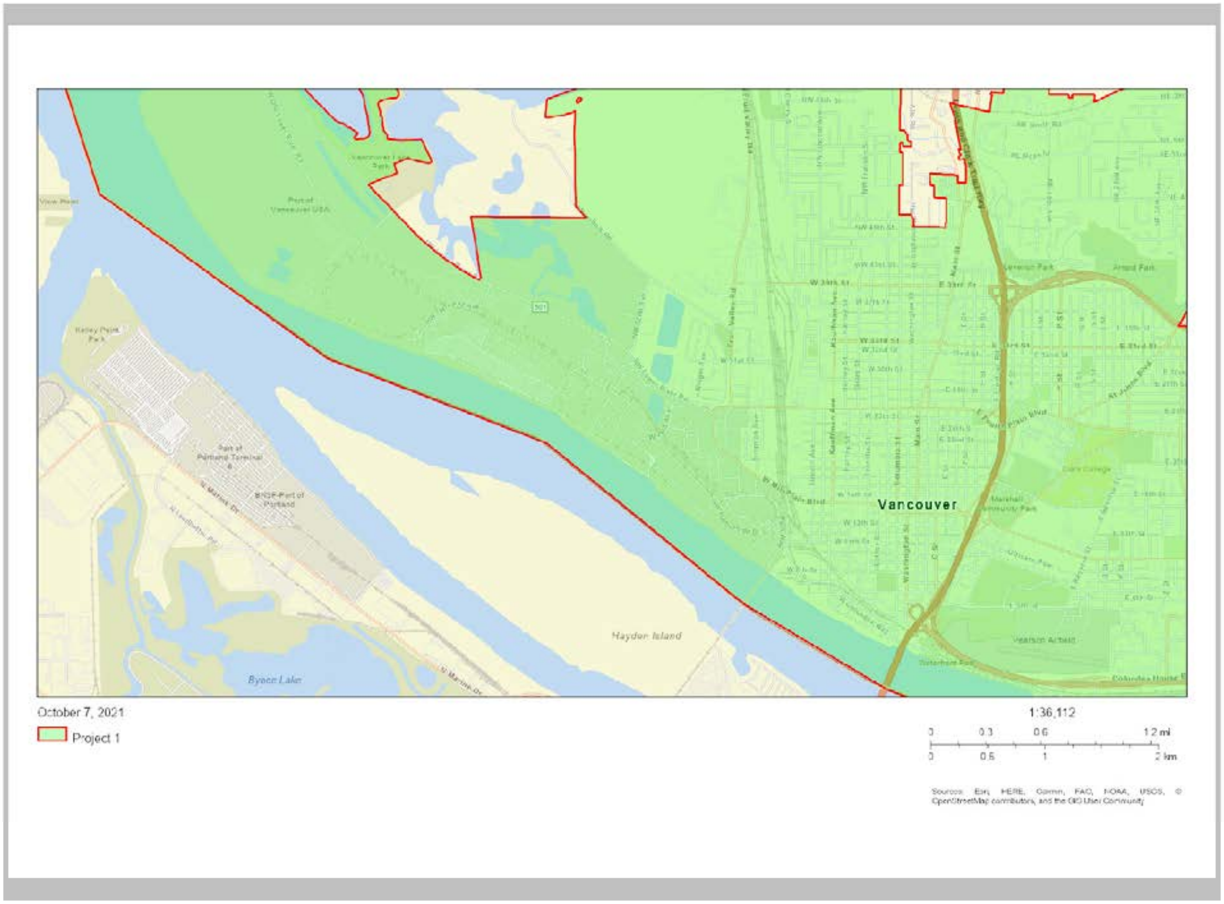


This report shows the values for environmental and demographic indicators and EJSCREEN indexes. It shows environmental and demographic raw data (e.g., the estimated concentration of ozone in the air), and also shows what percentile each raw data value represents. These percentiles provide perspective on how the selected block group or buffer area compares to the entire state, EPA region, or nation. For example, if a given location is at the 95th percentile nationwide, this means that only 5 percent of the US population has a higher block group value than the average person in the location being analyzed. The years for which the data are available, and the methods used, vary across these indicators. Important caveats and uncertainties apply to this screening-level information, so it is essential to understand the limitations on appropriate interpretations and applications of these indicators. Please see EJSCREEN documentation for discussion of these issues before using reports.

EJSCREEN Report (Version 2020)

City: Vancouver, WASHINGTON, EPA Region 10

Approximate Population: 172,501
Input Area (sq. miles): 50.44



Sites reporting to EPA	
Superfund NPL	0
Hazardous Waste Treatment, Storage, and Disposal Facilities (TSDF)	12

EJSCREEN Report (Version 2020)

City: Vancouver, WASHINGTON, EPA Region 10

Approximate Population: 172,501

Input Area (sq. miles): 50.44

Selected Variables	Value	State Avg.	%ile in State	EPA Region Avg.	%ile in EPA Region	USA Avg.	%ile in USA
Environmental Indicators							
Particulate Matter (PM 2.5 in µg/m^3)	8.85	8.21	78	8.52	60	8.55	59
Ozone (ppb)	37.4	37.3	62	39.1	47	42.9	18
NATA* Diesel PM (µg/m^3)	0.628	0.585	60	0.481	70-80th	0.478	70-80th
NATA* Cancer Risk (lifetime risk per million)	34	34	47	31	50-60th	32	60-70th
NATA* Respiratory Hazard Index	0.5	0.5	46	0.46	50-60th	0.44	60-70th
Traffic Proximity and Volume (daily traffic count/distance to road)	790	610	79	510	83	750	77
Lead Paint Indicator (% Pre-1960 Housing)	0.16	0.23	56	0.22	56	0.28	48
Superfund Proximity (site count/km distance)	0.16	0.19	67	0.13	78	0.13	80
RMP Proximity (facility count/km distance)	0.73	0.63	73	0.65	72	0.74	69
Hazardous Waste Proximity (facility count/km distance)	1.9	1.9	72	1.5	77	5	65
Wastewater Discharge Indicator (toxicity-weighted concentration/m distance)	0.00012	0.0091	81	3.1	72	9.4	54
Demographic Indicators							
Demographic Index	30%	29%	61	29%	61	36%	50
People of Color Population	28%	31%	53	28%	60	39%	47
Low Income Population	32%	27%	65	30%	59	33%	55
Linguistically Isolated Population	4%	4%	70	3%	75	4%	69
Population With Less Than High School Education	9%	9%	63	9%	61	13%	49
Population Under 5 years of age	6%	6%	57	6%	56	6%	57
Population over 64 years of age	15%	15%	59	15%	56	15%	55

* The National-Scale Air Toxics Assessment (NATA) is EPA's ongoing, comprehensive evaluation of air toxics in the United States. EPA developed the NATA to prioritize air toxics, emission sources, and locations of interest for further study. It is important to remember that NATA provides broad estimates of health risks over geographic areas of the country, not definitive risks to specific individuals or locations. More information on the NATA analysis can be found at: https://www.epa.gov/national-air-toxics-assessment.

For additional information, see: www.epa.gov/environmentaljustice

EJSCREEN is a screening tool for pre-decisional use only. It can help identify areas that may warrant additional consideration, analysis, or outreach. It does not provide a basis for decision-making, but it may help identify potential areas of EJ concern. Users should keep in mind that screening tools are subject to substantial uncertainty in their demographic and environmental data, particularly when looking at small geographic areas. Important caveats and uncertainties apply to this screening-level information, so it is essential to understand the limitations on appropriate interpretations and applications of these indicators. Please see EJSCREEN documentation for discussion of these issues before using reports. This screening tool does not provide data on every environmental impact and demographic factor that may be relevant to a particular location. EJSCREEN outputs should be supplemented with additional information and local knowledge before taking any action to address potential EJ concerns.

Attachment B – Fruit Valley Neighborhood – EJSCREEN Standard Report

EPA United States Environmental Protection Agency

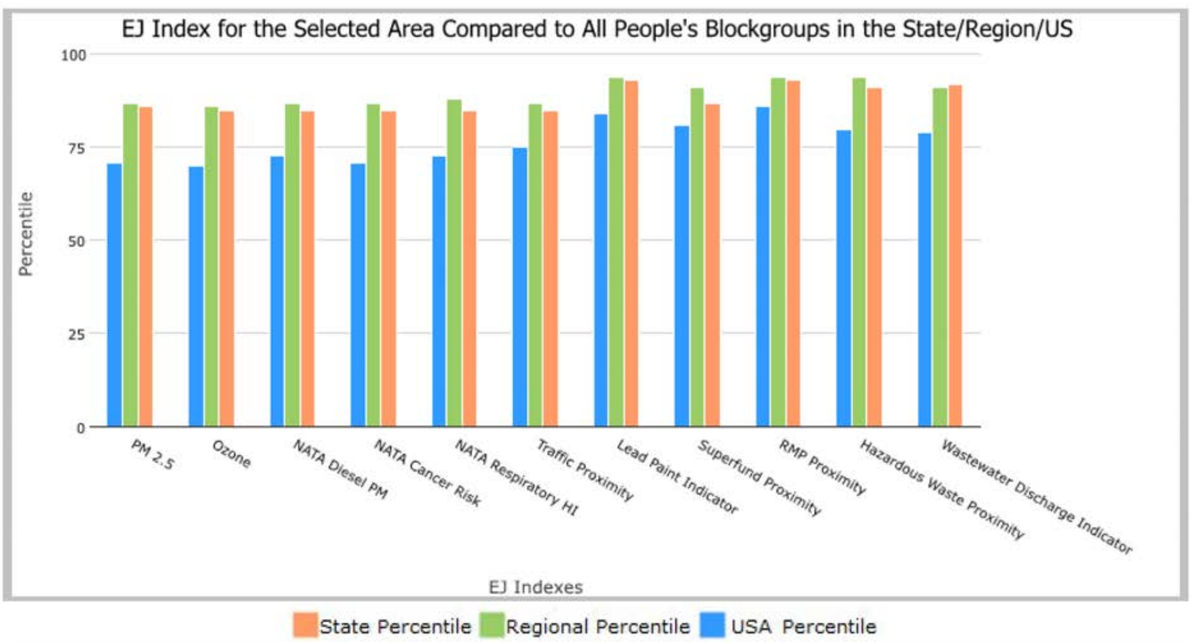
EJSCREEN Report (Version 2020)

Tract: 53011041005, WASHINGTON, EPA Region 10

Approximate Population: 2,471

Input Area (sq. miles): 22.62

Selected Variables	State Percentile	EPA Region Percentile	USA Percentile
EJ Indexes			
EJ Index for PM2.5	86	87	71
EJ Index for Ozone	85	86	70
EJ Index for NATA* Diesel PM	85	87	73
EJ Index for NATA* Air Toxics Cancer Risk	85	87	71
EJ Index for NATA* Respiratory Hazard Index	85	88	73
EJ Index for Traffic Proximity and Volume	85	87	75
EJ Index for Lead Paint Indicator	93	94	84
EJ Index for Superfund Proximity	87	91	81
EJ Index for RMP Proximity	93	94	86
EJ Index for Hazardous Waste Proximity	91	94	80
EJ Index for Wastewater Discharge Indicator	92	91	79



This report shows the values for environmental and demographic indicators and EJSCREEN indexes. It shows environmental and demographic raw data (e.g., the estimated concentration of ozone in the air), and also shows what percentile each raw data value represents. These percentiles provide perspective on how the selected block group or buffer area compares to the entire state, EPA region, or nation. For example, if a given location is at the 95th percentile nationwide, this means that only 5 percent of the US population has a higher block group value than the average person in the location being analyzed. The years for which the data are available, and the methods used, vary across these indicators. Important caveats and uncertainties apply to this screening-level information, so it is essential to understand the limitations on appropriate interpretations and applications of these indicators. Please see EJSCREEN documentation for discussion of these issues before using reports.

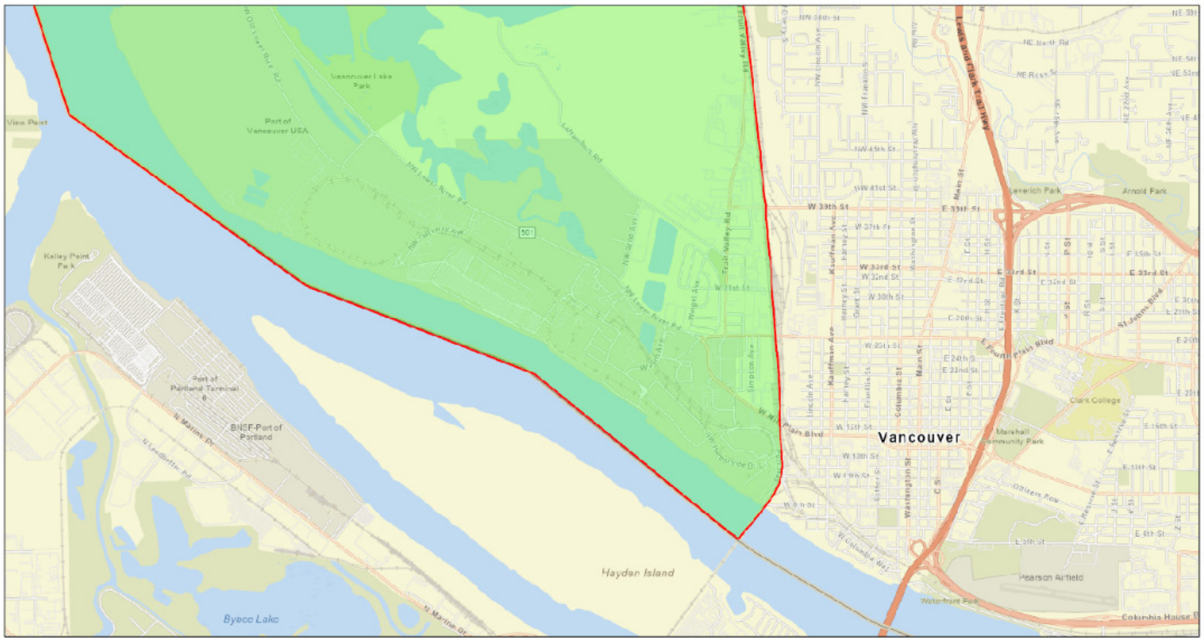
United States Environmental Protection Agency

EJSCREEN Report (Version 2020)

Tract: 53011041005, WASHINGTON, EPA Region 10

Approximate Population: 2,471

Input Area (sq. miles): 22.62



October 7, 2021

Project 1

1:36,112

0 0.3 0.6 1.2 mi

0 0.5 1 2 km

Sources: Esri, HERE, Garmin, FAO, NOAA, USGS, © OpenStreetMap contributors, and the GIS User Community

Sites reporting to EPA	
Superfund NPL	0
Hazardous Waste Treatment, Storage, and Disposal Facilities (TSDF)	3

EJSCREEN Report (Version 2020)

Tract: 53011041005, WASHINGTON, EPA Region 10

Approximate Population: 2,471

Input Area (sq. miles): 22.62

Selected Variables	Value	State Avg.	%ile in State	EPA Region Avg.	%ile in EPA Region	USA Avg.	%ile in USA
Environmental Indicators							
Particulate Matter (PM 2.5 in μg/m^3)	8.62	8.21	76	8.52	57	8.55	52
Ozone (ppb)	36.1	37.3	49	39.1	33	42.9	14
NATA* Diesel PM (μg/m^3)	0.469	0.585	46	0.481	50-60th	0.478	60-70th
NATA* Cancer Risk (lifetime risk per million)	32	34	40	31	50-60th	32	50-60th
NATA* Respiratory Hazard Index	0.5	0.5	48	0.46	50-60th	0.44	60-70th
Traffic Proximity and Volume (daily traffic count/distance to road)	340	610	60	510	63	750	60
Lead Paint Indicator (% Pre-1960 Housing)	0.47	0.23	82	0.22	84	0.28	75
Superfund Proximity (site count/km distance)	0.15	0.19	65	0.13	77	0.13	79
RMP Proximity (facility count/km distance)	2	0.63	92	0.65	91	0.74	90
Hazardous Waste Proximity (facility count/km distance)	3.3	1.9	82	1.5	86	5	77
Wastewater Discharge Indicator (toxicity-weighted concentration/m distance)	6.4E-05	0.0091	80	3.1	71	9.4	51
Demographic Indicators							
Demographic Index	50%	29%	88	29%	89	36%	74
People of Color Population	43%	31%	75	28%	80	39%	61
Low Income Population	58%	27%	92	30%	91	33%	86
Linguistically Isolated Population	7%	4%	80	3%	84	4%	78
Population With Less Than High School Education	16%	9%	84	9%	83	13%	72
Population Under 5 years of age	8%	6%	75	6%	75	6%	75
Population over 64 years of age	8%	15%	22	15%	21	15%	21

* The National-Scale Air Toxics Assessment (NATA) is EPA's ongoing, comprehensive evaluation of air toxics in the United States. EPA developed the NATA to prioritize air toxics, emission sources, and locations of interest for further study. It is important to remember that NATA provides broad estimates of health risks over geographic areas of the country, not definitive risks to specific individuals or locations. More information on the NATA analysis can be found at: https://www.epa.gov/national-air-toxics-assessment.

For additional information, see: www.epa.gov/environmentaljustice