U. S. EPA Region 10

Final Focused Feasibility Study

Well 12A Superfund Site
Tacoma, Washington

U.S. Environmental Protection Agency Region X
TASK ORDER NO. 014A

April 2, 2009

Contents

Figures

Tables

Appendices

Section 1
Introduction

This Focused Feasibility Study (FFS) has been prepared by Parametrix/CDM Federal Programs Corporation (CDM) for the South Tacoma Channel/Well 12A Superfund Site (Well 12A site or site), located in Tacoma, Washington. The document has been prepared for the United States Environmental Protection Agency (EPA) Region X under Contract No. 68-S7-03-04 (R-10 AES) Task Order 014A. The FFS was prepared in accordance with the Work Plan Amendment No. 7 Rev. 1 dated January 21, 2009, systematic planning meetings held on March 24, 2008; August 7, 2008; and October 1, 2008 and communications between EPA and CDM.

The purpose of this FFS is to support the selection of a remedial alternative for soil and groundwater that will be documented in a Record of Decision (ROD) Amendment or other administrative vehicle (e.g., Explanation of Significant Difference). A ROD Amendment has been assumed for this FFS for discussion purposes, but the FFS is applicable for any vehicle chosen. In accordance with RODs for Commencement Bay/South Tacoma Channel (EPA 1983) and South Tacoma Channel – Well 12A (EPA 1985), groundwater treatment at Well 12A and groundwater treatment at the Time Oil property using a groundwater extraction and treatment system (GETS) is ongoing. Other completed removal/remedial actions include excavation and disposal of contaminated soil/filter cake and operation of a soil vapor extraction system (SVE). However, contaminant mass still remains in the soil and groundwater. Therefore, EPA has elected to perform this FFS to select a feasible and cost-effective remedial alternative that aggressively destroys contaminant mass and protects public health and the environment from the potential risks posed by soil and groundwater contamination.

1.1 Report Summary

The summary provides a description of the objectives and content of the report.

1.1.1 Purpose

The FFS approach involves evaluating alternatives for soil and groundwater so that a plume management strategy focusing on aggressive source treatment with flexibility in combining technologies to best remove/destroy contaminant mass may be developed. A main goal of the alternatives is the original ROD target goal, which was to treat groundwater at the source and establish a level such that the water from Well 12A would be at the 10^{-6} risk level with no dilution. Another goal, also referred to as a remediation level, is to reduce the contaminant mass flux to a value, which, when achieved, will permit the shutdown of the GETS at the Time Oil property. In addition, land use controls, groundwater monitoring, and documented controls on the management, use, and monitoring of the aquifer by the City of Tacoma are incorporated into the FFS alternatives. Therefore, the components of an effective plume management strategy are adequate use of robust source term removal technologies; timely transition to cost-effective polishing steps; reduce/eliminate the need for pump and treat; and, appropriate reliance on monitoring.

This FFS is for soil and groundwater. However, vapor intrusion is also a concern and is being evaluated by EPA after targeted soil and groundwater contamination is addressed.

Several historical documents and files were accessed for site specific information as referenced in the last section of this report. Also, during the course of the FFS, two field events were conducted to collect data on current groundwater conditions. The data collected during those events are presented in:

- Well 12A Focused Feasibility Study Monitored Natural Attenuation Evaluation Memorandum by CDM dated August 4, 2008

- Final Technical Memorandum Well 12A Superfund Site Groundwater Data and Water Level Summary by Parametrix dated September 29, 2008

The primary objective of this report is to provide the regulatory agencies with sufficient data to select a feasible and cost-effective remedial alternative. The report documents the basis and procedures used in identifying, developing, screening, and evaluating a range of remedial alternatives for site soil and groundwater.

1.1.2 Report Organization

This FFS report is comprised of six sections

Section 1, Introduction, describes the purpose and organization of the report.

Section 2, Site Characterization, provides a summary of site background information including the site description, site history, description of physical characteristics of the site, investigation activities, nature and extent of contamination, and results of a Johnson and Ettinger Screening for vapor intrusion.

Section 3, Identification of Remedial Action Objectives, presents the assessment and selection of treatment zones; develops a list of remedial action objectives (RAOs) by considering the characterization of contaminants, compliance with site-specific applicable or relevant and appropriate requirements (ARARs) and the assumed preliminary remedial goals (PRGs); documents the estimated quantities of contaminated media; and identifies and screens remedial technologies and process options.

Section 4, Development and Detailed Evaluation of Remedial Alternatives, presents the remedial alternatives developed by combining the feasible technologies and process options. This section also describes the detailed analysis of each alternative according to the following seven criteria: overall protection of human health and the environment; compliance with ARARs; long-term effectiveness and permanence; reduction of toxicity, mobility, or volume through treatment; short-term effectiveness; implementability; and cost.

Section 5, Comparative Analysis of Alternatives, provides an overall comparison among the various remedial alternatives in Section 4.0.

Section 6, References, provides a list of references used to prepare the FFS.

Section 2
Site Characterization

This section presents a description of the site history and physical characteristics of the site. It also presents a brief summary of previous investigations, site characterization data, the nature and extent of contamination across the site by location and by media of concern, and the conceptual site model (CSM).

2.1 Site Description and Background

This section presents site history, previous investigations and remedial actions, geology and hydrogeology, and the nature and extent of contamination.

2.1.1 Site Description

The site is located in Township 20 North, Range 3 East, Sections 7 and 18, at approximately 122°28′19″ W longitude and 47°13′52″ N latitude (Tacoma South Quadrangle, USGS 1981). The site includes the area surrounding the City of Tacoma Water Supply Well 12A and the former Time Oil Company property, which is the suspected source of contamination. The site consists primarily of industrial/commercial land, with a small amount of residential land, in southwestern Tacoma, Washington. The site is approximately 4 miles southwest of the southernmost tip of Commencement Bay near the junction of Interstate 5 and State Highway 16 (Figure 2-1). The exact area of the site is not well defined but is generally considered to be about one square mile.

Well 12A is located in the southern and southwest portion of the site, on Pine Street between 38th Avenue and South Tacoma Way. It is the northernmost well in the City of Tacoma south well field. The Time Oil property is located in the northern portion of the site, approximately one-third of a mile north-northeast of Well 12A. The Time Oil Property, located at 3011 South Fife Street, is irregularly shaped and covers an area of about 2.5 acres between the Burlington Northern Railroad tracks to the north and South Tacoma Way to the south. Figure 2-2 shows an area map of well locations at the site and Figure 2-3 shows the location of the building at the Time Oil property and nearby wells.

2.1.2 Site History

In 1923 or 1924, a paint and lacquer thinner manufacturing facility and an oil recycling facility began operating at the site. The paint and lacquer thinner manufacturing process involved the use of many solvents that were stored on the site in barrels, some of which may have leaked. The waste-oil recycling process consisted of collecting waste oil in a large tank, adding chemicals such as sulfuric acid, and pressurizing and heating the contents of the vessel. Absorbents and clay materials were also added to the oil. This process resulted in the formation of a tar-like sludge on the bottom of the tank. The sludge was filtered from the oil, and the resulting filter cake was disposed of or stored in various piles on the site. Some of this sludge was also used for fill around the site.

These operations continued until 1964 when Time Oil Company acquired the majority of the property at 3011 South Fife Street. After purchasing the facility, Time Oil stopped the paint and lacquer thinner manufacturing activities and concentrated on reprocessing waste oil. This continued until 1970 when the oil re-refining operation was terminated. From 1970 to 1972 the facility was used by Time Oil as a warehouse for tires, batteries, and accessories. From 1972 to 1976, the portion of the property that had previously been involved in the oil reprocessing operation was leased to Golden Penn, Inc., who continued the operation. Oil reprocessing ceased in April 1976 following a fire at the facility that destroyed the waste-oil processing apparatus. In 1975 and 1976, Golden Penn was ordered by the State of Washington to clean up the site by removing some of the filter cake and spilled oil from the ground. In 1976, Golden Penn went out of business as a result of the fire.

In 1976, Time Oil resumed operation at the site with its operations limited to the canning of oil. In 1982, the Burlington Northern Railroad spur was extended by Time Oil to its present length so that oil could be delivered by tanker car. During the construction of the spur, some of the filter cake or sludge material stored on the site was used in the roadbed. Time Oil was the sole occupant of the premises and continued to use it as a warehouse and for canning oil until the early 1990s. The area west of the Time Oil Building was vacated in 1991, and storage tanks and associated piping were removed at that time. Recent uses of the Time Oil property include warehousing of heating, ventilating, and air conditioning (HVAC) equipment and small-scale manufacturing of kayaks. In 2003 the property was sold to Western Moving and Storage and has been primarily used for storage. Items continue to be stored at the property today.

2.1.3 Previous Remedial Actions and Investigations

In 1981, chlorinated organic solvents were detected in Well 12A, a municipal water supply well owned and operated by the City of Tacoma Water Department. EPA conducted a site investigation during the summer of 1981, and concentrations of chlorinated organic solvents detected in the well were high enough to remove the well from service. Based on the findings of the investigation, the site was proposed for listing on the National Priorities List (NPL) on September 1, 1981. Well 12A was added to the NPL on September 8, 1983.

An air-stripping treatment system was constructed for Well 12A and began operation in July 1983. The system was operated by the City until early November 1983 when the well was no longer needed for the season. Well 12A and the treatment system continued to be used to meet peak summer demand throughout the 1980s and 1990s; however, due to the cost of operating the treatment system, the use of the well has gradually declined over the years. Well 12A is typically now pumped only during the summer or early fall.

The Burlington Northern Railroad Company right-of-way adjacent to the Time Oil facility was identified by EPA as a source of contamination to Well 12A. As part of the program to clean up the contamination, Burlington Northern agreed to excavate contaminated soil from its railroad spur. In June 1986, Burlington Northern excavated approximately 1,200 cubic yards of contaminated soils along the rail spur north of the Time Oil property. In addition to the excavation in the railroad spur, contaminated soil on a narrow strip of land just west of the current SVE building was excavated (Figure 2-3). At the time, a layer of filter cake was observed in the western sidewall of the excavation at a shallow depth, extending west for an unknown distance (Maurer 2003 as cited in URS 2005).

In November 1988, the GETS began operation to pump and treat contaminated groundwater near the source on the Time Oil property. Groundwater is extracted continuously from the aquifer underlying the Time Oil site and pumped through activated carbon to remove volatile organic compounds (VOCs). The initial system consisted of a single groundwater extraction well, EW-1. In 1995, four additional extraction wells (EW-2 through EW-5) were added to the system. Between 1988 and December 2002, the GETS treated over 550 million gallons of groundwater, removing approximately 16,000 pounds of VOCs. The overall objective of the GETS is to limit migration of the dissolved contaminants in the groundwater. All of the wells of the GETS continue to operate.

In August 1993, an SVE system began operation in the area west of the Time Oil Building where drum storage and disposal operations had previously occurred. During construction of the SVE, approximately 5,000 cubic yards of a waste sludge (filter cake) from the oil recycling operations were excavated. Operation of the SVE was discontinued in 1997. Between 1994 and May 1997 the SVE removed approximately 54,100 pounds of VOCs. Approximately 25 percent of the VOCs were chlorinated and the remainder were light-end hydrocarbons. Although the SVE equipment is still on site, it is in poor condition since it has not been used or maintained since it was shut down in 1997.

In 2004/2005 the EPA installed wells and collected soil samples and groundwater samples as part of a capture zone analysis. Oily product was identified in some soil samples. Groundwater contaminant concentrations and distribution had decreased, in general, compared to previous sampling events, with elevated concentrations of chlorinated VOCs (CVOCs) still found near the Time Oil property. Also, several lines of evidence suggested a capture zone, but the extent of the zone is highly uncertain in some areas. The results of the sampling and capture zone analysis are located in *Draft Final Field Investigation and Capture Zone Analysis Report Commencement Bay/South Tacoma Channel/Well 12A Superfund Site Tacoma, Washington* (URS 2005).

2.1.4 Site Geology and Hydrogeology

The Well 12A site is located within the Puget Sound Lowland, approximately 6 miles south of Commencement Bay and within the Commencement Bay drainage area. The site is underlain by glacial deposits resulting from glacial and glaciofluvial processes of the most recent glaciation. Several distinct channels, one being the South Tacoma Channel where the site is located, were cut into these deposits by high velocity glacial meltwater. The large glacial outwash channels are significant hydrologically in that, where they occur below the water table, wells completed in the coarse sand and gravel filling the channels tend to produce high yields.

The South Tacoma Channel, a steep-sided glacial outwash depression trends west-southwest from Commencement Bay in the direction of the former Time Oil property and Well 12A. Ground surface elevations along the South Tacoma Channel range from sea level at Commencement Bay, to about 250 to 255 feet above mean sea level (msl) at the former Time Oil property, to about 310 feet msl at Well 12A.

The local stratigraphy in the vicinity of the former Time Oil property is complex and characterized by discontinuous local lenses of high and low permeability sediments. As a result, the hydraulic conductivity is highly variable across the site. A semi-confining unit exists at elevations between approximately 120 and 150 feet msl in the vicinity of the Time Oil property and appears to be continuous beneath the property and to a distance of at least 500 ft from the former Time Oil Building, in the direction of Well 12A. The shallow groundwater system above the semi-confining unit is referred to as the upper aquifer and the lower groundwater system below the semi-confining unit is referred to as the lower aquifer.

The majority of the groundwater flow occurs in the upper aquifer (Brown and Caldwell 1985). Beneath the former Time Oil property, the upper aquifer extends from land surface down to approximately 100 ft below ground surface (bgs) and the water table occurs at approximately 33 ft bgs. The underlying semi-confining unit is approximately 30-40 ft thick and the lower aquifer is estimated to be approximately 40 ft thick. Underlying these units is the Kitsap Formation which is a regional confining unit, but can be absent in some offsite areas (Brown and Caldwell 1985).

Regional groundwater flow is generally toward the east and southeast with a relatively flat gradient. With the GETS operating, a capture zone is created. Therefore gradients in the immediate vicinity of the Time Oil property and south to near South Tacoma Way are toward the extraction wells. Several lines of evidence suggest capture zone geometries, but the exact extent of the capture zone has not been clearly delineated (URS 2005). Figure 2-4 shows capture zones that have been estimated for the GETS.

Water level measurements indicate a relatively strong downward vertical gradient both within the upper aquifer and between the upper and lower aquifers. However, limited to no contamination in the lower aquifer suggests that the semi-confining unit prohibits contamination from migrating to depth onsite.

Also, during operation, groundwater extraction at Well 12A depresses the potentiometric surface and changes the normal groundwater flow direction in the vicinity of the site. However, recent operation of Well 12A has been limited to a few days during the summer months when demand is high. Appendix A discusses the impact of Well 12A on the movement of contaminants.

2.1.5 Nature and Extent of Contamination

The Time Oil property had historically been used for various practices including oil recycling as well as paint and lacquer manufacturing. Oil recycling and solvent processing began as early as 1923and continued to 1991 with occasional interruptions due to changes in ownership and a large fire in 1976. The Time Oil Company vacated the premises in 1991, and the space has since been used for storage and small-scale manufacturing.

In addition to a number of possible leaks and spills over the years, some of the filter cake generated during oil recycling was used as fill material in 1982 for constructing the Burlington North Railroad spur to the north of the Time Oil Property. Subsequent investigations have identified this filter cake as a primary source of 1,1,2,2-tetrachloroethane (PCA), tetrachloroethylene (PCE), and other organic solvents discovered in the groundwater at Well 12A.

2.1.5.1 Soil

The most recent soil samples were collected during installation of wells MW-301, MW-302, MW-304, MW-305, MW-306, MW-307, and MW-308 (URS 2005). Soil samples were analyzed in the field by the Environmental Services Assistance Team (ESAT) mobile laboratory for the following contaminants: TCE, PCE, 1,1,2,2-PCA, trans-1,2-DCE, and cis-1,2-DCE.

Soil samples near the source area contained the highest concentrations. Specifically, the most contaminated soil was found at MW-301 about 10 feet below the water table on top of a thin clayey silt layer. Concentrations at MW-301 were generally two to four orders of magnitude higher than contaminant concentrations detected in the soil at the other wells. The next highest concentrations were found at MW-304, where detections of contaminants in soil occurred almost entirely in the unsaturated zone, except for one detection within the semi-confining unit. The highest concentrations in MW-304 were found at the surface in a thin dark layer (less than 1 foot thick) believed to be residual filter cake directly below the concrete pavement.

Farther from the source, at MW-306, contamination was generally located within 10 feet above and below the water table. At MW-307, soil contamination was detected just below the ground surface, then not until just below the water table. Only TCE was found at MW-308, the farthest well from the source, extending from the water table down through the aquifer and into the semi-confining layer. No contaminants were detected in lower aquifer soils in any of the newly drilled monitoring wells.

Figures 2-5 through 2-9 post soil concentrations of PCE, TCE, cis-1,2-DCE, trans-1,2-DCE and 1,1,2,2-PCA, respectively. The soil concentrations were compared against Model Toxics Control Act (MTCA) B modified level soil cleanup standards and soil to groundwater pathway cleanup levels. Method A, B, and B modified level cleanup standards are presented in Table 2-1. The A levels are reported values and, therefore, are not calculated. Development of the B and B modified levels are shown in Tables 2-2 and 2-3. The soil to groundwater pathway Method B cleanup levels are shown in Table 2-4.

As shown in the figures, B levels are exceeded for PCE, TCE and 1,1,2,2-PCA, with the exceedances focused on the east side of the Time Oil building. Since TCE and 1,1,2,2-PCA concentrations exceed their respective screening level most often, Figures 2-10 and 2-11 were prepared to present the extent of soil contamination for these two compounds, respectively. As can be seen in the figures, soil contamination is greatest near the surface on the east side of the Time Oil building. The contamination extends downward to the water table, which suggests a continuing source to groundwater. The figures also illustrate that limited quantities of soil contamination exist in the vadose zone beneath the Time Oil Building and locations to the west. However, the level of soil contamination increases again in the capillary fringe. These figures were prepared using the data described above from the 300-series wells and also historical data back to 1984. However, soil data that were collected in the SVE treatment area before or during operation of the SVE were not included. Additional data collected during remedial design and construction will be used to verify and update the CSM as appropriate.

2.1.5.2 Groundwater

Groundwater samples have been collected during numerous events over the history of the site, with the samples analyzed most commonly for VOCs. The primary VOC contaminants of concern are PCE, TCE, 1,2-DCE (cis and trans), and vinyl chloride based on risk evaluations. Also, 1,1,2,2-PCA is a primary concern since very elevated concentrations of this compound are found in soil and in groundwater near the source areas. Also, 1,4 dioxane is considered a concern since it has been detected in site groundwater in previous events, can migrate readily in groundwater, and has a low health criterion (6.1 µg/L).

A comprehensive round of groundwater samples was collected in February/March 2008, with the analytical data from this event used to support the FFS evaluation. The results of the analyses are summarized in Table 2-5. Regulatory criteria are posted for the seven compounds of concern. As shown in the table, the CVOC criteria were exceeded at several locations, with the highest concentrations occurring at EW-4, EW-5, CH2M-1 and ICF-2. These wells are located at the south end of the Time Oil property and south of the property. While these data from the February/March 2008 sampling event are the most recent and are generally comparable with other recent data sets, they represent a single point in time and may not adequately account for variability that may result from seasonal fluctuations or variations in pumping scenarios for Well 12A or the GETS. Additional data collected during remedial design and construction will be used to verify and update the CSM as appropriate.

Figures 2-12 through 2-14 present the isoconcentrations maps for TCE, cis-1,2-DCE and 1,1,2,2-PCA in groundwater. These three compounds provide a reasonable depiction of the distribution of site groundwater impacts. As shown in the figures, TCE is the most widespread VOC, with a plume extending east and southwest (towards Well 12A) of the site and the highest concentrations reported south of the Time Oil property. The cis-1,2-DCE plume is much smaller than the TCE plume, with the highest concentrations located on the Time Oil property. Elevated concentrations of 1,1,2,2-PCA were detected in wells on and south of the property.

Figure 2-15 presents the distribution of 1,4 dioxane in groundwater. Except for one well, MW-A, the criterion exceedances for this mobile contaminant are restricted to wells at or near the Time Oil property. However, the concentration from MW-A is 7.2 µg/L, only 1.1 µg/L above the criterion of 6.1 µg/L.

In addition to the standard contaminant sampling in February/March 2008, samples were analyzed for monitored natural attenuation (MNA) parameters in June 2008. The memorandum presenting the MNA results and interpretation is found in Appendix B. As detailed in the memorandum, the groundwater near the Time Oil property is conducive to anaerobic degradation; at distal locations the aquifer is conducive to aerobic biodegradation. However, it appears that the carbon food source near the site has been depleted and anaerobic degradation has subsided. At distal locations, enzyme activity, oxygen concentrations and decreasing TCE concentrations with no daughter products detected, indicate cometabolic aerobic degradation is active. Figure 2-16 presents a summary of the intrinsic bioremediation evaluation and identifies the anaerobic and aerobic conditions.

LNAPL and DNAPL

Despite previous remedial efforts, a number of sources of dissolved phase contamination still remain on or near the Time Oil property. Both light and dense non-aqueous phase liquids (LNAPL and DNAPL) have been identified beneath the property and an additional area of filter cake has been identified to the east of the Time Oil building. The LNAPL exists primarily within a smear zone near the water table where it coats soil particles and partially fills voids in the soil. The presence of DNAPL is evidenced by high soil concentrations of chlorinated solvents (in excess of 29,500 mg/kg of combined 1,1,2,2 PCA and PCE, as stated in Table 3-1 of the 1999 Groundwater Summary Report [ICF Kaiser 1999]) at depths below the historical low groundwater level of 40 feet below ground surface.

During the February/March 2008 sampling event, 1.41 ft of LNAPL was detected at ICF-4, which is located east of the Time Oil building. Also, trace amounts of LNAPL were detected at TOW-6; TOW-7; EW-4; MW-1; and MW-3. All of these wells, except EW-4, and also MW-2, MW-17, TOW-5, and MW-15 have had historical detections of LNAPL. While the LNAPL does not appear to be widespread throughout the source area, it has been observed at several locations and is likely a significant source of VOCs in the source area.

2.2 Conceptual Site Model

The Conceptual Site Model (CSM) presents a description of the contaminant distribution, examines fate and transport issues, and identifies contaminant pathways and the influence on receptors.

2.2.1 Fate and Transport

In order to develop appropriate response actions and remedial alternatives for the site, the fate and transport of contaminants of concern (COC) in the environment is considered.

The fate and transport of contaminants is presented by providing the following:

- COCs
- Summary of potential contaminant transport pathways
- Risk Evaluation

2.2.1.1 Contaminants of Concern

The COCs are PCE; TCE; cis-1,2-DCE; trans-1,2-DCE; VC; and 1,1,2,2-PCA. Based on risk evaluations, PCE, TCE, 1,2-DCE (cis-1,2-DCE and trans 1,2-DCE), and vinyl chloride are concerns and since 1,1,2,2-PCA occurs at elevated concentrations in soil and in groundwater near the source areas, it is also a concern. The ether 1,4-dioxane is not considered a contaminant of concern since it is located at depth in the shallow aquifer and it is not detected at significant concentrations beyond the contaminant source area.

2.2.1.2 Contaminant Transport Pathways and Mass Distribution

The various environmental media onsite present several potential pathways for contaminant migration. The fate and transport of these COCs are determined by their physical and chemical properties in combination with the physical characteristics of the site and source area. In the subsurface, these compounds travel rapidly with water. 1,4-dioxane is the most mobile of the group, and is typically found at the leading edges of plumes.

Although the chemical and physical properties of these compounds play a significant role in the persistence and mobility, the high transmissivity of the aquifer beneath the site is the most important feature that enhances the movement of the contaminants. Very transmissive units of sand and gravel are present in the subsurface and the large open voids in this material allow for easy migration of volatiles and hydrophobic contaminants. Where the sand and gravel is interrupted or interbedded with finer grained units, migration of the contaminant is slowed.

Estimating mass distribution is important in helping to identify and evaluate applicable remedial technologies. Table 2-6 lists contaminant mass in groundwater for select compounds and for total site COCs. As shown in the table, a majority of the COC mass occurs at concentrations above 1,000 µg/L. The table also illustrates that the mass of 1,4 dioxane is negligible compared to that of the chlorinated compounds.

Tables 2-7 and 2-8 provide a measure of the contaminant mass and associated aquifer volume by concentration interval in the groundwater and soil, respectively. Table 2-7 illustrates that the mass of TCE and 1,1,2,2 PCA in soil at concentrations within the >1,000 µg/kg is not appreciably larger than the mass within the 10,000 µg/kg contour, even though the volume of soil within 1,000 ug/kg is four times larger than the volume within 10,000 ug/kg. Also, Table 2-8 demonstrates that TCE, trans-1,2,-DCE and 1,1,2,2 PCA constitute a majority of the mass.

2.2.1.3 Risk Evaluation

Several potential risks have been identified:

- Groundwater – Ingestion, dermal contact, inhalation of vapors
- Vapors – inhalation of vapors migrating from the subsurface and accumulating in buildings
- Shallow Soil/Filter Cake – ingestion and dermal contact

The purpose of this FFS is to address risk from groundwater and shallow soil/filter cake. The potential for vapor intrusion is also a concern to EPA. A recent Johnson-Ettinger (JE) screening performed by EPA indicates a risk to residential human health (Appendix C). The screening evaluated the machine shop building, located immediately south of the Time Oil property, that is at the center of VOC contamination. Following JE protocol, the concentrations at wells within 100 ft of the building were used. The highest TCE concentration within 100 ft of the building is CH2M-1 (1,100 µg/L). Although the highest concentration of TCE (1,300 µg/L) was reported at ICF-2, this value was not used since it lies 200 ft from the machine shop. Vapor intrusion is a concern and will be evaluated by EPA after targeted soil and groundwater contamination is addressed.

2.2.2 Conceptual Site Model Overview

This proposed CSM builds upon the interpretation of the investigations described and summarized in the *LNAPL and Soil Investigation Report* (ICF Kaiser 1999) and in the *Capture Zone Analysis Report* (URS 2005).

The contamination initiated with the release of solvents and petroleum hydrocarbon fluids to the surface soils surrounding the Time Oil building. As discussed in Section 2.1.2, solvents associated with paint thinner manufacturing and petroleum hydrocarbon liquids associated with motor oil reprocessing were released to soils under barrel storage, storage tank, and railroad spur loading areas. In addition, spent filter cake, a fine-grained filtration medium used to filter oil at the Time Oil property, was spread on the ground in areas west, north, and east of the Time Oil building. The soil under the older, southern part of the Time Oil building has not yet been characterized. The industrial activities associated with these releases extend as far back as 1923. Exact dates of the releases are unknown but probably extended over a period of decades. The quantity and precise inventory of the chemicals released to the subsurface are also unknown.

These source areas, contaminant releases, and various groundwater withdrawals (the Tacoma supply wells and GETS wells) have resulted in a complex distribution of subsurface contamination. Between 1994 and May 1997, the SVE system removed approximately 54,100 pounds of VOCs. Because of the successful operation of the SVE from 1993 to 1997, a zone of soil extending from the surface to near the water table (approximately 35 feet bgs) in the areas immediately west and north of the Time Oil building has reduced concentrations of VOCs.

The largest VOC concentrations in the vadose zone appear to be on the east side of the Time Oil building. These concentrations extend from near the surface down to the water table, suggesting a continuing contaminant source to the aquifer. West of the Time Oil building, SVE has decreased soil concentrations and it appears that the degree and extent of contamination is limited in the vadose zone in this area of the site. At the capillary fringe, soil contamination extends from the east side of the Time Oil building to the southwest. Contamination in the capillary fringe away from the source is likely due to contaminated groundwater smearing VOCs into the soil strata.

Well ICF-4, below the heavily contaminated soil on the east side of the building had the thickest layer of LNAPL measured in 2008, which is an indication the area continues to be a primary source area. Trace amounts of LNAPL measured in wells to the north and southwest of the Time Oil building suggest smaller residual sources in these areas.

Contaminated groundwater migrates toward the five GETS extraction wells as shown in Figure 2-17. As shown in the figure, flow gradients at the Time Oil building and areas to the south indicate groundwater is captured by the wells. However, some uncertainty exists regarding the extent of the capture zone as illustrated by the four capture zones in the figure. The modeled capture zone does not extend as far to the northeast of the Time Oil building as groundwater measurements suggest. In this area, contamination may migrate toward the east if it is not captured. However, since negligible groundwater contaminant concentrations have been found to the northeast, it is assumed that the capture zone extends to the northeast as indicated by the groundwater level measurements.

More significantly, to the southeast, numerical modeling data suggest that groundwater at CH2M-1, and possibly ICF-2, is captured by the southern extraction wells. However, as discussed in previous reports, contaminant concentrations continue to increase at ICF-2 (URS 2005). These increasing concentrations indicate capture is lost in this area and the prevailing gradient may be from near CH2M-1 to the southeast toward ICF-2. Conflicting with that prevailing gradient, the mapped potentiometric contours suggest the prevailing gradient is to the east. Therefore, in this area of the plume three data sets suggest three possible prevailing gradients: northeast toward the extraction wells, southeast as indicated by increasing VOC concentrations at ICF-2, and east following measured groundwater gradients. Since the groundwater contaminant plume for TCE and cis-1,2-DCE extends to the east, this direction is believed to be the prevailing gradient in this area. However, no wells are located immediately east of ICF-2 and therefore, the uncertainty of the plume concentrations is high. If additional data (new wells for water levels and groundwater contamination concentrations) are collected, a different interpretation may result.

The complexity of the capture zone geometry is compounded when the operation of Well 12A is considered. When Well 12A is operating, the hydraulic gradient is to the southwest with capture still occurring around the GETS wells. In recent years Well 12A has only operated a few days or weeks during summer months to fulfill demand.

Therefore, its recent impacts are minimal. The interpretation of Well 12A impacts are, in summary, when the well operates for significant periods (e.g., the three summer months), contamination associated with the Time Oil site migrates to the well. However, using available data, estimates of plume distribution with numerical modeling techniques do not acceptably match observed concentrations. The numerical model does not predict contaminant transport to the well; rather, the contamination migrates toward the east over time. The difference suggests that the subsurface characteristics are variable and the material is heterogeneous. Preferred pathways that allow contaminant migration toward sinks (e.g., Well 12A) may exist that have not been identified.

In the source area anaerobic degradation has reduced groundwater TCE concentrations. Although present anoxic conditions are still conducive to anaerobic biodegradation, the carbon food source (aromatic hydrocarbons) has apparently been depleted and the degradation has stalled. This incomplete degradation has caused the greatest concentration of cis-1,2-DCE to remain within the source area and the highest concentrations of TCE in groundwater are present south and southwest of the GETS extraction wells (i.e., at and around the region of South Tacoma Way), where the impact of anaerobic degradation is not as significant as it is nearer the source. South of South Tacoma Way and also to the east of the site, site data (e.g., elevated dissolved oxygen, decreasing TCE concentrations with few/no measurable daughter products, and elevated enzyme activity probe data) suggest cometabolic aerobic degradation is occurring in the low concentration plume.

Section 3
Identification of Remedial Action Objectives

Applicable or Relevant and Appropriate Requirements (ARARs) are defined and Remedial Action Objectives (RAOs) are identified. The RAOs are centered on aggressive source treatment for management of contaminant migration.

3.1 Identification of Potential Applicable or Relevant and Appropriate Requirements

Section 121 of CERCLA specifies that remedial actions for cleanup of hazardous substances must comply with Federal or State environmental regulations and laws that either specifically address, and are therefore directly applicable, to a substance or particular circumstance at a site or, while not directly applicable, address situations that are sufficiently similar (relevant) and are well suited (appropriate) for use at the site. An environmental regulation or law that is not applicable must be both relevant and appropriate to be considered an ARAR.

Inherent in the evaluation of ARARs is the assumption that protection of human health and the environment is ensured, and the primary concern in developing RAOs for a hazardous waste site under CERCLA is defining the degree of protection for each proposed remedy. Section 121 of the Superfund Amendments and Reauthorization Act of 1986 (SARA) mandates that selected remedies achieve or legally waive ARARS. The purpose of this requirement is to make response actions executed under CERCLA comply with pertinent Federal and State environmental requirements.

This section provides a preliminary discussion of the regulations that are applicable or relevant and appropriate to the remediation of the contaminated media, which is soil (includes soil/filter cake) and groundwater. Both Federal and Washington environmental regulations and public health requirements are evaluated. In addition, this section identifies Federal and Washington criteria, advisories, and guidance as TBCs.

3.1.1 Definition and Types of ARARs

EPA defines "Applicable Requirements" as those cleanup standards and requirements promulgated under Federal or State environmental or siting laws that specifically address a hazardous substance or chemical, remedial action, or location at a CERCLA site. Applicable requirements must directly and fully address the situation at the site. For example, if the selected remedy at a site calls for the creation of a new onsite land disposal unit that will receive RCRA hazardous waste, RCRA minimum technology requirements and any State facility siting law would be directly applicable to that action and therefore ARAR.

EPA defines "Relevant and Appropriate Requirements" as those cleanup standards and requirements promulgated under Federal or State environmental or siting laws that, while not directly applicable, are both sufficiently similar and well suited to address a hazardous substance or chemical, remedial action, or location at a CERCLA site. For example, Maximum Contaminant Levels (MCLs) under the Safe Drinking Water Act are often used as cleanup levels for contaminated groundwater. Since MCLs regulate public water suppliers, they are not applicable to groundwater cleanup, however since the MCL is protective of drinking water, the standard is sufficiently similar and well suited as a protectiveness standard in most cases.

State ARARs take precedence over Federal counterparts when they are: 1) a state environmental law of facility siting law; 2) promulgated; 3) more stringent; 4) identified by the State in a timely manner; and 5) consistently applied.

ARARs are not currently available for every chemical, location, medium or action that may be encountered. When ARARs are not available, PRGs may be based upon other Federal or State criteria, guidance, or local ordinances. This information is known as "To Be Considered" or TBC. TBCs may be used to determine the necessary level of protection for certain remedial alternatives, and are generally used when ARARs do not exist or are not protective.

ARARs and TBCs are both used during the FS process to evaluate the remedial alternatives. ARARs and TBCs are evaluated and, as appropriate, may be used to derive PRGs that can be utilized throughout the FS process. These cleanup goals are developed such that they meet the intent of the ARAR or TBC to be protective of human health and the environment.

ARARs and TBCs fall into three broad categories, based on the manner in which they are applied at a site. These categories are as follows:

Chemical-specific: These ARARs and TBCs usually are numerical values that are health- or risk-based values or methodologies. They establish acceptable amounts or concentration of chemicals that may be found in, or discharged to, the ambient environment. The also may define acceptable exposure levels for a specific contaminant in an environmental medium. They may be actual concentration-based cleanup levels, or they may provide the basis for calculating such levels. Examples of chemical-specific ARARs are the A, B and B-modified level criteria for soil under Washington State Department of Ecology's MTCA.

Location-specific: These ARARs and TBCs set restrictions on remedial activities at a site due to its proximity or location in specific natural or man-made features. Examples of natural site features include floodplains or wetlands. Examples of man-made features are local historic buildings and structures.

Action-specific: These ARARs and TBCs set controls or restrictions for particular remedial activities related to the management of hazardous substances, but do not in themselves determine what the remedial alternative should be. Selection of a particular remedial action at a site will invoke the appropriate action-specific ARARs which specify performance standards or technologies, as well as specific environmental levels for discharged or residual chemicals. Examples of action-specific ARARs are hazardous waste listing and disposal requirements.

ARARs apply to those Federal and State regulations that are designed to protect public health and the environment and do not apply to occupational safety regulations. EPA requires compliance with the OSHA standards in 40 CFR 300.150 of the National Contingency Plan (NCP), but not through the ARARs process. Therefore, the regulations promulgated by OSHA are not addressed as ARARs.

Chemical, location, and action-specific ARARs for the site are presented in Tables 3-1, 3-2, and 3-3, respectively.

3.2 Identification of Potential Treatment Zones and Remediation Boundaries

The CSM (which includes the nature and extent of contamination, the location of contaminant mass, the transport of contaminants and zones of biodegradation), in conjunction with ARARs, is used to identify treatment zones and remediation boundaries.

3.2.1 Filter Cake and Shallow Impacted Soil

Figure 3-1 shows the proposed treatment zone for filter cake and shallow impacted soil. The COC 1, 1, 2, 2-PCA is shown in the figure since it is the most widespread contaminant in the soil medium. This zone has been proposed since it is at the surface and it appears to be contributing to contamination at depth at the north side. The continued migration of contamination at depth is indicted by the elevated concentrations that are in the vadose zone above the capillary fringe.

The area of the treatment zone is generally rectangular in shape and measures approximately 80 ft wide by 130 ft long. The area of the treatment zone is not a perfect rectangle; as EVS algorithms estimate the area to be approximately 11,340 square feet (SF). The depth of the filter cake and shallow impacted soils treatment zone is estimated to be approximately 10 ft, since at about 10 ft bgs in the south half of the zone the elevated concentrations of 1,1,2,2-PCA appear to terminate. In the north end, elevated concentrations extend down into the soil column as previously noted. Results from samples collected during future events (e.g., a design investigation) can be used to refine the zone area and depths. Therefore, the volume estimated to be excavated is 11,340 SF x 10 ft = 113,400 cubic feet or 4,200 cubic yards.

EVS modeling based on recent and historical soil data (see Figure 3-1) was used to estimate the excavation volume. The approximate aerial extent was calculated taking into account limitations associated with current site development and land use (e.g., buildings and railroad tracks) and the average depth of the excavation was estimated to be 10 feet based on available soil data and feasibility considerations (e.g,, proximity to buildings). More or less excavation may be required based on observations and field screening data to be collected during the remedial action. Soil cleanup targets for excavation will be developed and defined during remedial design. The 10-ft excavation depth also assumes that ERH will be implemented for impacted soils greater than 10 feet bgs. A cost-benefit analysis will be performed during the remedial design to evaluate the most cost-effective depth to transition from excavation to ERH.

3.2.2 Deep Vadose Zone Soil and Upper Saturated Zone East of Time Oil Building

Figure 3-1 also shows the proposed treatment zone east of the Time Oil building for the highly contaminated soil in the vadose zone at depth and in the groundwater. The part of the zone below the water table is defined by the high concentrations of CVOCs identified on soil samples found in the saturated zone. In effect, remediation that is performed below the water table will be focused on reducing contaminant concentrations in groundwater. However, since technologies applied in the deep vadose zone would likely be applicable to the upper saturated zone, the two media are combined in this one treatment zone. The extension of vadose zone contamination into the water table suggests that it is a continuing source of contamination. If left untreated, these high concentrations of contamination would continue to impact groundwater.

The area of the treatment zone is generally rectangular in shape and measures approximately 90 ft wide by 140 ft long. The treatment zone extends from a depth of 10 ft bgs to 55 ft bgs. The water table occurs at approximately 34 ft bgs in the zone. Therefore, the upper 21 ft of the saturated zone is included. Results from samples collected during future events (e.g., a design investigation) can be used to refine the zone area and depths.

3.2.3 High Concentration Groundwater

Figure 3-2 presents the proposed treatment zone for the high concentration groundwater. This area is defined by TCE and cis-1, 2, DCE in groundwater at concentrations above 300 µg/L. The 300 µg/L concentration was chosen since beyond this concentration negligible additional contaminant mass is gained. Also, at this contour line, the aquifer begins to transition from anaerobic conditions to aerobic conditions. Two other relatively small areas are included in the proposed treatment zone that are outside of the 300 µg/L isoconcentration contour. The area east of the Time Oil building with elevated concentrations of 1,1,2,2-PCA was included (and is discussed in the section above). Also, the area southwest of the Time Oil building that lies underneath a large drive area for loading docks was included. The area was included because it currently is within the capture zone of the site extraction wells and limited data are available in the area (i.e., possible contamination is present but not detected).

3.2.4 Low Concentration Groundwater

Figure 3-2 also presents the proposed treatment area for the dissolved phase plume. The treatment zone is the area beyond the 300 µg/L isoconcentration for TCE/cis-1, 2-DCE and extends to the distal monitoring points to the southwest (e.g., Well 12A) to the southeast (CH2M-2) and to the east (CH2M-3). While it was observed to be continuous beneath the Time Oil property, the semi-confining unit separating the upper and lower aquifers does not appear to extend all the way southwest to Well 12A. As a result, southwest of the site (e.g., at MW-308), the low concentration groundwater treatment zone includes both the upper aquifer and the upper portion of the lower aquifer. Groundwater data from wells located in this treatment zone generally indicate that conditions conducive to aerobic cometabolism dominate and the degradation of CVOCs is likely occurring.

3.3 Remedial Action Objectives

Remedial Action Objectives (RAOs) have been developed in conjunction with four defined treatment zones. A compilation of the treatment zones plus a description of the RAOs is presented in Figure 3-3. These RAOs will result in an effective plume management strategy to reduce contaminant mass, decrease the size of the contaminated area and prevent contamination from impacting human health and the environment.

Aggressive source treatment was evaluated for three defined treatment zones, which include Filter Cake/Shallow Soil, Deep Vadose Zone Soil and Upper Saturated Zone East of Time Oil Building, and High Concentration Groundwater. Aggressive treatment in these zones is the primary first tier goal of the RAOs. A containment remedy is not the main focus of the RAOs.

Filter Cake/Shallow Soil

- Eliminate the risk of direct contact with filter cake at and near the surface. Eliminating the direct contact risk will also reduce possible vapor intrusion issues. EPA will address vapor intrusion under a separate activity when targeted soil and groundwater contamination is addressed.

- Prevent or minimize the migration of contamination from highly contaminated shallow source areas into the deeper vadose zone to prevent further degradation of deep soil and groundwater.

Deep Vadose Zone Soil and Upper Saturated Zone East of Time Oil Building

- Eliminate/minimize the mass of contaminants to reduce the mass flux from this highly contaminated area to downgradient groundwater.

High Concentration Groundwater

- Reduce contaminant mass flux by ninety percent from the source area through a specific plane into the low concentration groundwater treatment zone. The proposed plane is defined by the current location of the 300 µg/L TCE/cis-DCE isoconcentration. This flux reduction goal is a groundwater remediation level to be met in order to document that active source treatment is complete.

Low Concentration Groundwater

- The interim groundwater ROD Amendment remediation level (i.e., to assure a protective remedy along with well head treatment at 12A as needed) is to meet MCLs at compliance wells 12A, new well CW1, and new well CW2.

- The conditional point of compliance wells are identified as CH2M2, new well IM1, and new well IM2. The action will be considered an interim action until the cleanup level is attained at these wells.

Figure 3-4 shows the locations of the proposed compliance wells and conditional points of compliance wells.

3.3.1 Mass Flux Measurement

One of the performance goals of the active source treatment is reducing contaminant mass flux by ninety percent from the source area to the low concentration groundwater treatment zone at the 300 µg/L TCE/cis-DCE isoconcentration. Based on preliminary modeling, this is likely sufficient to achieve MCLs at the proposed compliance wells (Appendix D). Measuring this parameter is critical since it provides a metric for the amount of contamination that is migrating away from an active treatment zone and into a passive treatment zone. However, it will not be the only performance standard for the strategy. For example, mass reduction in the active treatment zone and decreases in dissolved phase concentrations in the passive treatment zone are also expected to be performance criteria.

Mass flux will be measured using the passive flux meter technology, developed by the University of Florida, which evaluates both contaminant mass flux and groundwater Darcy velocity. The passive flux meter is a sock that is filled with absorbent material and a tracer. The sock is deployed down the well within the screened interval and allowed to be passively exposed to groundwater for some defined time interval. Groundwater velocity is calculated based on the rate in which the tracer desorbs from the sorbent. In addition, the rate at which contaminants (organics) sorbs to the sorbent is used to estimate mass flux. This method was chosen because both groundwater velocity (which is generally the term that has the greatest uncertainty in a mass flux calculation using standard groundwater analyses) and mass flux are directly measured.

Multiple samples will be collected at discrete vertical points along the flux meter to measure groundwater velocity and contaminant mass flux. These data will be used to generate vertically discrete mass flux estimates (units of mass/area/time) that can then be used to estimate total flux at the flux well point. In addition, multiple wells transecting the groundwater plume can be integrated to assess total contaminant mass flux (mass/area/time) and contaminant discharge (units of mass/time) through a flux well plane.

Overall, the data will be interpreted in two ways; changes in mass flux at discrete points will be evaluated to determine impacts of upgradient treatment on mass flux at those locations. For instance, flux wells that are closer to the active treatment areas may observe changes in mass flux before locations that are further away from the active treatment areas. This may also be used during active treatment optimization to focus treatment to areas that are contributing relatively high contaminant mass flux. In addition, a total mass discharge will be evaluated for the flux well planes. It is the total mass discharge value that will be used to determine if the 90% reduction goal has been achieved. The discharge values may be evaluated both in terms of mass flux discharge along one of the flux well planes and total mass discharge across the flux-plane boundary.

It is also important to note that groundwater samples will be collected in wells that correspond to the mass flux analysis and analyzed for COCs using acceptable analytical procedures at a much greater frequency that the mass flux analysis. These data will be used to compare standard analytical contaminant concentration changes as another line of evidence for mass flux changes that are observed with the passive flux meters. In addition, groundwater analytical results will be used to determine when to conduct a mass flux assessment. For instance, if a 90% reduction in contaminant concentrations is observed at a flux-well pair of interest, mass flux evaluation may be conducted to verify a corresponding reduction in mass flux.

Currently, the remedial action includes operation of the GETS system within the source area to hydraulically capture contaminant mass before it migrates to downgradient locations. There is substantial evidence, however, that the GETS system does not provide sufficient hydraulic containment to prevent all contaminant mass from migrating downgradient, as indicated by a persistent groundwater contaminant plume outside the estimated capture zone of the GETS (Figure 3-4). Therefore, the baseline mass flux measurement will be conducted with the GETS system operating, but before any additional source area remedial actions are conducted.

Figure 3-4 shows the proposed flux measurement plane and the wells that will be used to measure flux relative to the estimated capture zone(s) of the GETS and the TCE contaminant plume isopleths. A flux estimate at the proposed plane will provide a measure on the impacts of remedial actions in the source areas and high TCE concentration groundwater. The location of the plane has been chosen since the plane lies

- at or near the downgradient edge of the high concentration groundwater treatment zone,
- in the shallow aquifer where groundwater contamination is located,
- along four existing wells (WCC-3, CBW-10, WCC-6 and WCC-2); thus, taking advantage of these existing measuring locations and the historical data available from these locations.

The high concentration groundwater treatment zone is defined as the location where the concentration of TCE or cis-1,2 DCE is at or above 300 µg/L, which is shown on Figure 3-4. Figure 3-5 compares the location of the flux plane to the TCE and cis-1,2-DCE concentrations and bioremediation parameters. Downgradient of the proposed flux plane (i.e., downgradient of the high concentration groundwater treatment zone) the figure illustrates that aerobic conditions dominate.

Based on current modeling using compliance point well 12A and conditional point compliance well CH2M-2, the ninety percent flux reduction goal is sufficient to allow for intrinsic bioremediation to eventually achieve the MCL goals at these wells (Appendix D). The ninety percent reduction is based on estimated mass flux across the flux plane boundary. The analysis uses the most current known data and standard practices to make the estimates. Additional data, such as from the passive flux meters, may be input into the current model to revise or enhance the mass flux estimates, or may be analyzed using other related methods (i.e., numerical modeling). For instance, one of the greatest uncertainties in the mass flux calculation is the actual groundwater Darcy velocity and direction at the various points along the flux plane boundary. Therefore, passive flux meters will be used to directly measure both Darcy velocity and mass flux at the flux plane locations. Verification of the current mass flux discharge and validation of the ninety percent flux reduction goal will be conducted following the baseline flux measurement using the actual groundwater Darcy velocities measured and impacts recalculated per procedures described in Appendix D. A discussion of methods, assumptions and uncertainties in the current hydrological analysis used to determine the ninety percent flux reduction RAO are discussed below.

Groundwater velocities used to estimate current and reduced mass flux is based on Darcy velocities of 0.14 ft/day to the east of the Time Oil source area and 1.48 ft/day to the south of the source area. These are estimates based on the GETS system not operating and Well 12A operating 3 months/year. As discussed in Appendix A and D, there is significant uncertainty in the modeling inputs (i.e. hydraulic conductivity, dispersivity, and gradient) for various portions of the contaminated subsurface aquifer. In addition, there is likely substantive heterogeneity in the physical and hydraulic properties of various vertical and lateral portions of the aquifer. A combination of these uncertainties is likely the reason that there was substantial difficulty fitting the modeling outputs to the actual dimensions of the contaminant plume and matching predicted and actual contaminant arrival times at particular locations.

The groundwater velocities reported in Appendix D were used to estimate when impacts from remedial actions may be seen at the flux monitoring wells and at the points of compliance. The distance from the south edge of South Tacoma Way (a proposed location to receive enhanced bioremediation amendment) to proposed flux measurement wells MW-311 and 312 is 220 feet. With a contaminant velocity of 0.42 ft/day, reduced concentrations are estimated to be measured after approximately 524 days (220 ft/0.42 ft/day) or about eighteen months. A similar estimate can be prepared for the distal conditional point of compliance wells. The distance from the south edge of South Tacoma Way to Well 12A is approximately 1,400 ft. Therefore, impacts on Well 12A from active remediation are estimated to be measured after approximately 3,333 days (1,400 ft/0.42 ft/d) or about nine years. These values are general estimates on when impacts may be seen using current data and standard analytical methods. However, due to the complexity of the subsurface (e.g., highly heterogeneous) and groundwater gradients (e.g., Well 12A pumping on and off) the actual travel times and times when the impacts of remediation is measureable may differ.

As noted, groundwater velocities are variable and the uncertainty of groundwater velocity is substantial. If groundwater velocities measured in the field differ from what is estimated in this FFS, then adjustments to the remedy and performance monitoring may need to be made. Therefore, the in-field measurement of Darcy velocity during GETS pumping and after GETS pumping has stopped is an integral component of the remedy. For example, flux measurements will be collected (based on the measured Darcy velocity and not the estimated FFS velocity) when the front of the treated groundwater is estimated to reach the flux plane.

Also, variable groundwater velocities may impact the costs of the remedy. For example, if groundwater velocities greater than estimated are experienced at the in-situ thermal treatment zone, then additional engineering, equipment and operations may need to be employed so that the water is sufficiently heated for the treatment to be successful, which would increase the costs. Conversely, if velocities are lower than estimated, then costs to treat the zone would likely be less.

In addition to the hydrogeological analysis, the flux reduction goal is also based on an estimation of biodegradation rates in the low concentration plume zone (Appendix D). As there is inherent uncertainty in both of these values, the goal to reduce flux by ninety percent is conservative. The analysis estimates that concentrations need to be reduced by approximately 80 percent (reduce 300 µg/L TCE down to 70 µg/L) on the east side of the plume using a TCE half-life of 8.25 years and approximately 50 percent (reduce 300 µg/L TCE down to 160 µg/L) on the southwest side of the plume using a TCE half life of 1.5 years to achieve MCLs at downgradient wells CH2M-2 and CBW-11. During the February/March 2008 sampling event, the TCE concentrations at wells CH2M-2 and CBW-11 were 21 µg/L and 8.5 µg/L, respectively. These two wells were included in the analysis since the February/March 2008 TCE concentrations are above the MCL. Compliance Well 12A was not included since the detected concentration was below the MCL. This assumes that all other parameters (e.g., groundwater velocity) are constant and result in reductions in mass flux that are proportional to decreases in contaminant concentration(s). The expected concentration reductions are attributed to the natural attenuation capacity of the aquifer in the location of the low concentration plume.

The biodegradation rates identified in the hydrogeological analysis provide, to a certain degree, a measure of the natural attenuation capacity of the aquifer in the area of the low concentration plume. Based on the analysis, the biodegradation rate (in half-lives) varies from approximately 1.5 years (southwest part of the plume) to 8 years (east part of the plume). These rates are within the range of typical degradation rates under aerobic conditions (Starr et al., 2005). Additionally, site data (e.g., elevated dissolved oxygen, decreasing TCE concentrations with few/no measurable daughter products, and elevated enzyme activity probe data) suggest cometabolic aerobic degradation is occurring in the low concentration plume.

Aerobic biodegradation of TCE relies on various microbial oxygenases that are capable of cometabolic TCE degradation. Cometabolism occurs when an aerobic microorganisms uses growth substrates (what the microorganism grows and feeds on) and generate enzymes that react with contaminants with structural similarity to their growth substrates. The cometabolic degradation of contaminants (i.e. TCE) does not benefit the microorganisms directly, but is a fortuitous reaction as a result of the presence of the enzymes. Examples of non-specific enzymes that cometabolize TCE are methane monooxygenase, toluene monooxygenase, and propane monooxygenase. Since the bacterium producing the enzyme derives no carbon or energy from the process, and because the cometabolic substrate actually competes for the enzyme active site with the growth substrate, intrinsic biodegradation occurring in aquifer systems is relatively slow compared to other mechanisms (such as anaerobic reductive dechlorination during EAB). Field evaluation at Well 12A has demonstrated that aerobic enzymes capable of cometabolism of TCE are present within the aerobic groundwater plume at Well 12A.

In light of the age of the plume, it is assumed that the current range of degradation rates reflects an equilibrium condition that accounts for the dissolved oxygen flux, the TCE flux, and the flux of compound(s) inducing the oxygenase enzyme(s) responsible for cometabolic degradation. Compounds that might be inducing the enzyme(s) include recalcitrant organics such as lignins; methane from a deep, subsurface source; or possibly even TCE itself. Research on measuring some of these substrates and relating concentrations to degradation rates and natural attenuation capacity is ongoing. In any case, the site data and analysis provide convincing support that aerobic cometabolic degradation is sufficient in the context of the established flux goals and RAOs proposed for the site.

Degradation and interim degradation by-products vary for environments that are anaerobic and aerobic. In general, by-products for TCE degradation under anaerobic conditions are cis-DCE, vinyl chloride and ethene. Under aerobic conditions, carbon dioxide, water and chloride are the end-products. The transition zone between an anaerobic (i.e. EAB treatment zone) and aerobic plume can also facilitate alternate degradation pathways for contaminants and degradation by-products. For instance, vinyl chloride can be directly oxidized to carbon dioxide and water if it is transported to an aerobic environment. The actual degradation pathways will likely be complex and the by-products detected during performance monitoring may vary.

In addition to the contaminant concentration estimates, the hydrogeological analysis also recognizes a difference between biodegradation rates applied on the east side of the plume and the rates on the southwest side. Different or variable characteristics other than biodegradation rates have also been recognized previously. For example, using currently available data, estimates of plume distribution using numerical modeling techniques do not acceptably match observed concentrations. These observations suggest that the subsurface characteristics are variable and the material is heterogeneous. Preferred pathways that allow contaminant migration toward sinks (e.g., Well 12A) may exist that have not been identified. As a result, it is proposed to continue to evaluate contaminant attenuation within the low-concentration dissolved phase plume before, during and after any remediation conducted at the Well12A site. This evaluation will help to verify estimated degradation rates and determine impacts of remedial actions on contaminant concentrations and attenuation rates in this area of the contaminant plume.

3.4 Identification and Screening of Remedial Technologies and Process Options

A list of remedial technologies and process options applicable to the filter cake, soil and groundwater were developed through a review of EPA guidance documents related to remediation of similarly contaminated material, review of regional Record of Decision (ROD) summaries, vendor sources, and professional experience. Also, the following EPA guidance documents were used to identify remedial technologies applicable to the Well 12A site:

- Presumptive Response Strategy and Ex-Situ Treatment Technologies for Contaminated Ground Water at CERCLA Sites (EPA 1996)

- Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA" (USEPA, 1988)

Based on the review of remedial technologies applicable to the site, results were developed to provide a listing of remedial technologies and process options for soil and groundwater. The results of the technology screening evaluations are documented in the Draft Remedial Alternatives Screening Memorandum (CDM 2008) and summarized in the two tables presented in Appendix E with some modifications.

These tables document the preliminary screening step based on effectiveness, implementability, and cost. Technologies and process options that were retained for one or more treatment zones are marked with a "Y" in the "Retained? (Y/N)" column. Technologies retained through the screening process were used to develop the remedial alternatives for each treatment zone (see Section 4).

Section 4
Development and Detailed Evaluation of Remedial Alternatives

In this section, remedial alternatives for the Well 12A site are assembled by combining the remedial technologies and process options which were retained following the screening step performed in Section 3.4. Under typical FS procedures, the list of alternatives is then screened using the effectiveness, implementability, and cost criteria. However, because only nine alternatives (with two being existing actions) are developed in this section, the alternative screening step has been omitted from the evaluation process. Rather, all nine of the alternatives are thoroughly evaluated in this section against seven of EPA's nine evaluation criteria: overall protection of human health and the environment; compliance with ARARs; long-term effectiveness and permanence; reduction of toxicity, mobility, or volume through treatment; short-term effectiveness; implementability; and cost. The remaining two EPA evaluation criteria, support agency and community acceptance, will be addressed in future actions by the EPA (e.g., ROD Amendment).

4.1 Remedial Alternative Development

Filter cake/soil was excavated from the site in 1986, a soil vapor extraction system operated west of the Time Oil building from 1993 to 1997, and the GETS has operated since 1988 (with an expansion in 1995). Also, Well 12A continues to operate with an air stripping unit, which was installed in 1983. In spite of these site removal/remedial activities soil and groundwater contamination still persists and EPA has elected to aggressively treat or destroy source area contamination.

The largest concentrations of soil contamination have been identified east of the Time Oil Building in the former East Tank Farm. Filter cake is also believed to be near the surface in this area. Based on data visualizations, this area is believed to be a continuing source of groundwater contamination. Elevated concentrations of contaminants in groundwater extend from at/near the Time Oil Building to the south and southwest. A portion of the groundwater contaminant plume is within the capture zone of the GETS wells. However, some data suggest that elevated concentrations of groundwater contaminants may have escaped or are continuing to escape the capture zone in the south and southwest part of the plume. Moderate to high uncertainty is associated with the capture zone and plume extent in this area (i.e., at and south of South Tacoma Way). Additionally, the operation of Well 12A impacts the geometry of the capture zone; contaminants in the southern end of the plume are likely accelerated toward Well 12A when it is in operation. Also, unidentified pathways (e.g., high hydraulic conductivity zones) may exist that lend to a complex and chaotic distribution of contamination.

A natural attenuation evaluation indicates that conditions are conducive to anaerobic degradation in the high concentration plume (i.e., TCE and cis-1,2-DCE concentrations > 300 µg/L) and cometabolic aerobic degradation conditions persist in the low concentration plume (i.e., TCE and cis-1,2-DCE concentrations < 300 µg/L).

Given the complexity of the site, no single remedial alternative would be appropriate as a site-wide remedy. Thus, for the purpose of developing and evaluating appropriate remedial alternatives, the site was divided up into four treatment zones:

- Filter Cake and Shallow Impacted Soils (FC)
- Deep Vadose Zone Soil and Upper Saturated Zone East of Time Oil Building (SG)
- High Concentration Groundwater Plume (HG)
- Low Concentration Groundwater Plume (LG)

The following subsections provide a description of each treatment zone and the alternatives for that zone that will be evaluated.

4.2 Detailed Description of Alternatives

This section provides detailed descriptions of the proposed alternatives that have been discussed with EPA. Descriptions of these alternatives provide sufficient information to carry out a detailed analysis. Preliminary design assumptions have been made so that cost estimates could be prepared for each alternative. The final configuration of the remedial alternative selected by EPA for implementation will be determined during the remedial design phase, and will include detailed plans, specifications, and treatment processes. Each alternative description includes a summary of the alternative with descriptions of individual components of the alternative. These descriptions address the site conditions that are expected to exist during remedial activities.

4.2.1 Filter Cake and Shallow Impacted Soil

Figure 4-1 identifies the location of this treatment zone.

4.2.1.1 Alternative FC1 - No Action

Under this alternative, no action would be taken to remedy the filter cake and shallow contaminated soils. The no action alternative is considered in accordance with NCP requirements and provides a baseline for comparison with the other alternatives. No further action would be conducted and the status of the filter cake and shallow impacted soil would remain unchanged. This alternative does not include the implementation of any institutional controls such as deed restrictions or future groundwater monitoring. CERCLA (Section 121(c)), as amended by SARA (1986), would require that the site be reviewed at least every 5 years since contamination would remain on site.

4.2.1.2 Alternative FC2—Institutional Controls

For this alternative, institutional controls (ICs) would be employed at the site to protect human health. The ICs would be used to limit access to and future development, improvement, and use of affected properties. Specifically, ICs would include activity and use restrictions enacted through proprietary (e.g. easements, covenants) and/or governmental (e.g. zoning requirements) controls to prevent use of the property that would pose an unacceptable risk to receptors (i.e. for residential use). Informational device ICs (warning signs, advisories, additional public education) also would be employed to limit access to contaminated soils.

In accordance with CERCLA, this alternative would be evaluated at least every five years because contaminants would remain on site with this alternative.

4.2.1.3 Alternative FC3—Capping Contaminated Soils In Place

This alternative consists of capping filter cake and contaminated soils in place. The cap would be a bituminous asphalt cap which would prevent infiltration of precipitation into underlying groundwater. Institutional controls would be implemented to restrict future development/use and a long-term O&M program. Long-term groundwater monitoring would also be implemented to monitor changes in site conditions. A bituminous asphalt cap would not be necessary where a building structure or concrete (such as sidewalks or curbing) currently exist on site.

In accordance with CERCLA, this alternative would be evaluated at least every five years because contaminants would remain on site with this alternative.

4.2.1.4 Alternative FC4—Excavation of Soils, Transportation to and Disposal in RCRA Subtitle C or D Landfill

This alternative consists of excavating filter cake and contaminated soils and transporting them off site to a RCRA-permitted Subtitle C or D landfill based on results of TCLP testing. For the purpose of this FFS, an average excavation depth of 10 feet has been assumed; however, more or less excavation may be required based on observations and field screening data to be collected during the remedial action. Soils near building foundations may need to remain in place to ensure structural integrity of the building. Assuming an average excavation depth of 10 feet, approximately 4,200 cy of contaminated soils would require excavation and disposal.

After removal of contaminated soils, the excavations would be backfilled with clean soil and gravel cover would be placed across the Site surface. For areas where contaminated soils remain, either further in situ treatment would be performed or institutional controls such as deed restrictions and information devices would be used to further reduce the potential for exposure.

Water would be used to minimize fugitive dust emissions during soil excavation, transport, and handling. Any stockpiles of material during interim storage would be covered by tarps or plastic sheeting to minimize fugitive dust emissions and runoff releases. Surface water runoff, fugitive emissions and treated soils would be monitored to ensure that the RAOs were being met.

In accordance with CERCLA, this alternative would be evaluated at least every five years if contaminants remain onsite that are not addressed with an in situ remedy (e.g., in situ thermal remediation).

4.2.2 Deep Vadose Zone Soil and Upper Saturated Zone East of Time Oil Building

Figure 4-1 identifies the location of this treatment zone.

4.2.2.1 Alternative SG1 - No Action

The no action alternative is considered in accordance with NCP requirements and provides a baseline for comparison with the other alternatives. No further action would be conducted and the status of the deep vadose soil and shallow groundwater would remain unchanged. This alternative does not include the implementation of any institutional controls such as deed restrictions or future groundwater monitoring. CERCLA (Section 121(c)), as amended by SARA (1986), would require that the site be reviewed every 5 years, because contamination would remain on site.

4.2.2.2 Alternative SG2 - Institutional Controls

For this alternative, ICs would be employed to protect human health. The ICs would be used to limit access to and future development, improvement, and use of affected properties. Specifically, ICs would include activity and use restrictions enacted through proprietary (e.g. easements, covenants) and/or governmental (e.g. zoning requirements) controls to prevent use of the property that would pose an unacceptable risk to receptors (i.e. for residential use). Tacoma-Pierce County Board of Health Resolution No. 2002-3411, Land Use Regulations and applicable sections of Washington Administrative Code Titles 173 and 246 are current guidelines that would be considered, or possibly amended, for the location and installation of supply wells. Additional details regarding potential institutional controls associated with Tacoma Water's use of groundwater from the South Tacoma well field are presented in Section 4.2.4.2. Informational device ICs (warning signs, advisories, additional public education) also would be employed to limit access to contaminated soils and groundwater. An additional component of this alternative involves the continued monitoring of groundwater at the site. For the purpose of cost estimating, ten wells at and near the treatment zone would be monitored for VOCs for a period of 30 years.

In accordance with CERCLA, this alternative would be evaluated at least every five years because contaminants would remain on site with this alternative.

4.2.2.3 Alternative SG3 – In-situ Thermal Remediation

Electrical resistance heating (ERH) is believed to be the most applicable in situ thermal remediation (ITR) technology for the site. Prior to installing the ERH electrodes and vapor recovery wells for the ERH system, approximately 10 soil borings will be advanced in the treatment area to refine the selected locations of the treatment zone and grid. The treatment zone boundaries may be adjusted based on results of the initial soil sampling. After the soil and shallow groundwater concentrations are delineated, a grid of electrodes and vapor recovery wells will be installed. For the purpose of this estimate, a grid of 52 electrodes separated, on average, by 20 ft and installed to a depth of 57 ft is assumed. A grid of 52 co-located vapor recovery wells will also be installed. For this estimate, approximately half of the piping and conduit will be installed below ground surface in this relatively open lot. However, if the shallow impacted soil is excavated, then the piping may be placed below grade prior to returning the excavated area to grade. The vapor will be treated using granular activated carbon (GAC). During operation, temperature, groundwater quality, vapor emissions and condensate/discharge will be monitored.

During heating, the following monitoring is proposed

- Temperature - temperature monitoring sensors (TMS) may be proposed for vapor extraction wells, groundwater extraction wells, electrodes, and temperature monitoring points completed in soils within the treatment volume
- Groundwater - collect samples in treatment zone monthly during treatment operations
- Air/Vapor - collect weekly to evaluate when the remedy is nearing a point of diminishing return in terms of NAPL, aqueous phase COCs, and vapor extraction and treatment
- Vapor Control (Pneumatic Vacuum Pressure) – monitor with vapor pressure gauges to check on controlling and capturing vapors, steam, and air in the subsurface soil in order to prevent migration of vapors, steam, and air from the treatment area

The primary purpose of this technology is to aggressively remove mass from what is believed to be a main source area. This conceptual design provides for a 92% reduction in mass in the treatment zone and a heating period of approximately six months. For cost estimating purposes, annual monitoring for VOCs at ten wells in and near this treatment zone will continue for 30 years after the heating period is ended.

This alternative should be combined with an alternative for shallow soil and filter cake or the ERH treatment zone should be extended vertically to include the shallow soil and filter cake. If it is not, then contamination from the shallow zone will recontaminate the treated soils. Also, if the alternative is combined with an aggressive treatment option for high concentration groundwater (generally areas to the south and southwest) the mass removed from the groundwater system and the contaminant flux reduction will be substantial. Contaminant flux measurements are discussed in Section 4.2.3.

Increasing the biodegradation rates in groundwater that is warmed outside of the treatment zone has been shown to be a secondary benefit of ERH. Therefore, biodegradation rates may increase in downgradient areas (e.g., underneath the Time

Oil Building). However, due to limited research in this area, this secondary benefit was not evaluated.

ERH is the ITR technology proposed for the site in this FFS. Other methods (conduction and steam injection) are also available, but their application does not seem to meet site requirements. Conduction is generally more appropriate for shallower and smaller contaminant volumes and the cost of the steam technology is typically considered higher than ERH. However, if groundwater fluxes are elevated, steam may have some advantages over ERH. During this FFS an ERH contractor was provided the site information and that contractor believes ERH is applicable. However, if conditions are found to be different (e.g., higher groundwater flux) than estimated in this FFS, then a different ITR technology (e.g., steam) may be considered.

4.2.3 High Concentration Groundwater

High concentration groundwater is identified as TCE or cis-1,2-DCE concentrations greater than 300 μg/L.

4.2.3.1 Alternative HG1 – No Action

The no action alternative is considered in accordance with NCP requirements and provides a baseline for comparison with the other alternatives. No further action would be conducted and the status of the site groundwater would remain unchanged. The GETS would be shut down. This alternative does not include the implementation of any institutional controls such as deed restrictions or future groundwater monitoring. CERCLA (Section 121(c)), as amended by SARA (1986), would require that the site be reviewed every 5 years, because contamination would remain on site.

4.2.3.2 Alternative HG2 – Institutional Controls

ICs would be employed to protect human health. The ICs would be used in limiting access to future development, improvement, and use of affected properties. Specifically, ICs would include activity and use restrictions enacted through proprietary (e.g. easements, covenants) and/or governmental (e.g. zoning requirements) controls to prevent use of the property that would pose an unacceptable risk to receptors (i.e. for residential use). Tacoma-Pierce County Board of Health Resolution No. 2002-3411, Land Use Regulations and applicable sections of Washington Administrative Code Titles 173 and 246 are current guidelines that would be considered, or possibly amended, for the location and installation of supply wells. Additional details regarding potential institutional controls associated with Tacoma Water's use of groundwater from the South Tacoma well field are presented in Section 4.2.4.2. Informational device ICs (warning signs, advisories, additional public education) also would be employed to limit access to contaminated groundwater. The GETS would be shut down. An additional component of this alternative involves the continued monitoring of groundwater at the site. For cost estimating purposes, it was assumed that 20 wells will be monitored for VOCs for a period of 30 years.

In accordance with CERCLA, this alternative would be evaluated at least every five years because contaminants would remain on site with this alternative.

4.2.3.3 Alternative HG3 – Extraction and Treatment with GETS

This alternative is for the operation and maintenance of the existing GETS. It does not include system replacement if the life cycle of the treatment plant is reached. The extraction system originally consisted of a single extraction well (EW-1) designed to extract water at 500 gpm. While a maximum sustained pumping rate of approximately 300 gpm was achieved in this well during 1988, the maximum sustained pumping rate decreased steadily to approximately 50 gpm in 1999. To augment EW-1, four additional extraction wells were installed in 1995. While the design yield of each of these wells was 50 gpm, each well only produces approximately 10 gpm; the total extraction rate of the five wells is approximately 100 gpm. The treatment system is located outside on a concrete pad surrounded by a chain-link fence. The system consists of two bag filters arranged in parallel that precede two 20,000-pound GAC units arranged in series. Effluent from the second carbon unit is discharged to the Thea Foss Waterway via storm drains.

Although the system has been operating for 20 years, substantial contaminant mass still remains in the soil and groundwater. However, a capture zone analysis indicates that the GETS provides hydraulic control although the capture zone extent is uncertain in some areas. Continuing to operate the GETS will limit the migration of contaminants away from the site.

The GETS will be used to maintain hydraulic control and treat contaminated groundwater. If no other aggressive actions are taken to reduce contaminant mass, the GETS may need to continue to operate ad infinitum to maintain hydraulic control. Therefore, the duration of this alternative was assumed to be 30 years.

4.2.3.4 Alternative HG4 – Enhanced Anaerobic Bioremediation

This alternative consists of in situ treatment of contaminated groundwater through enhanced anaerobic biological treatment. TCE and cis-1,2-DCE could be effectively biodegraded through reductive dechlorination under anaerobic conditions. The MNA results indicate that the groundwater in the high concentration zone is anaerobic, but a carbon food source for cometabolic degradation has been depleted. Therefore, the delivery of an amendment will jump start the anaerobic degradation process. Case histories suggest that contaminant concentration reductions of more than 80% may be experienced. A mass balance calculation could be performed; however, the estimate would have significant uncertainty since the subsurface chemistry is very complex. Therefore, the calculation would not have much meaning and was not performed.

Figure 4-2 presents the selected distribution of wells to be installed to deliver the amendment. The wells are aligned such that amendment will be delivered into the subsurface and travel through the treatment zone following the hydraulic gradient. Five rows of wells are proposed so that amendment is distributed with the varying hydraulic gradient directions. This technique establishes proper conditions for microbial degradation while taking advantage of the groundwater flow velocities and gradients.

Commercially available electron donors come in both solid and liquid forms and vary considerably with respect to longevity. Available placement techniques include direct-push, trenching, injection wells, and fracturing. Based on the size and depth of the plume at this site, directly injecting an emulsified soybean oil-based substrate, EOS™, was selected for this FFS. Various options would be evaluated based on results from the pre-design investigation and a phased approach would be implemented during the remedial action.

The optimal well spacing within each row depends on a variety of factors including formation, drilling costs, amendment costs, desired injection period, and the vertical treatment zone thickness. Based on 35-foot injection well spacing, 34 injection wells are needed. A 35 foot spacing (ROI of approximately 18 ft) is expected to be achieved in the hydrogeologic conditions. A short term pilot injection test should be conducted prior to full scale implementation to confirm the optimal ROI.

The injection wells, with a depth of approximately 100 ft, would be constructed with 2-inch diameter schedule 40 PVC, and screened in the lower 60 feet (approximate aquifer thickness) of the installation. It is assumed that they would be installed via hollow stem auger (HSA) rig without sampling other than bulk soil cuttings to confirm disposal options. The wellheads would be modified for hose fittings and finished with a simple flush mounted casing.

Amendment Injection

Once the injection wells have been installed, the initial injection event would occur one row at a time. The viscosity of EOS™ solution is temperature sensitive, therefore injections should occur during warm weather. Also, EOS™ is expected to adhere to soil particles; therefore, allowing some diffusion to occur into low velocity environments. Temporary aboveground piping and hoses would be used to distribute the amendment to the injection wells. For the cost estimate of this FFS, it is assumed that a trailer mounted distribution system would be constructed for injection to all the wells in a given row simultaneously, and two water trucks would be used to transport potable water from a metered hydrant.

Once injection to all rows of wells has been completed, the temporary injection equipment would be removed and no activity would be required other than periodic groundwater monitoring for one year. It is assumed that an additional full-scale injection event would take place approximately 18 months after the first injection.

Enhanced Anaerobic Bioremediation Performance Monitoring

Eight new monitoring wells plus 10 existing wells will be monitored to track the progress of the remedy. Six of the new wells will be installed along the proposed flux measurement line and two wells (in the shallow aquifer in upper and lower depths) will be installed in the VOC plume south and east of South Tacoma Way. Well locations would be selected to allow for monitoring conditions both inside the plume and along the edges, which would address concerns for lateral movement of the amendment.

The required analyte list would include: CVOCs, ethene, ethane, methane, sulfate, iron, alkalinity, total organic carbon, and water quality parameters (DO, conductivity, temperature, oxidation reduction potential (ORP), and pH). While it is assumed that the EOS™ product will maintain desired carbon levels for at least 3 years (i.e., about two times longer than the currently estimated injection interval of 18 months), the results from the monitoring program would be the basis for determining if and when a second injection is necessary. Quarterly sampling is assumed for the first year, with the frequency reduced to twice a year thereafter. Monitoring will continue at 18 wells for 30 years.

<u>Flux Measurement</u>
In addition to the performance monitoring described above, passive flux meters will be used to measure contaminant flux. Figure 4-2 shows the wells to be used to measure flux. A passive flux meter is a self-contained permeable unit that is inserted into a well and provides depth discrete measurement of contaminant flux. The meter intercepts groundwater flow but does not retard it. The interior composition of the flux meter is a matrix of hydrophobic and hydrophilic permeable sorbents that retain dissolved organic and/or inorganic contaminants present in fluid intercepted by the unit. The sorbent matrix is also impregnated with known amounts of one or more fluid soluble 'resident tracers.' These tracers are leached from the sorbent at rates proportional to fluid flow, which allows contaminant flux to be estimated.

The passive flux meter test involves collecting and analyzing data in a series of wells to estimate the mass flux at the well line. The technique is passive and requires no purging or pumping at the well and, therefore, produces a relatively small amount of sampling derived waste. Because passive flux meters can be deployed at multiple vertical locations in each well, the vertical distribution of contaminant concentrations and groundwater flow rate at the wells can be measured. The Darcy flux at each well is also estimated as part of the testing method concurrent with estimating the contaminant mass flux.

Baseline flux measurement will be collected prior to implementing any remedial action. The baseline measurements will be collected

- while the GETS is operating
- while the GETS is not operating (ambient conditions)

Estimating flux under these two conditions is recommended so that the impact of the groundwater extraction operations on flux can be assessed. Converging lines of evidence suggest the capture zone developed by the GETS is near the east (between WCC-6 and WCC-2) and southwest (between WCC-3 and proposed cluster MW-309/310) sections of the flux measurement plane. Understanding the flux estimates under the two scenarios will provide a measure of groundwater extraction impacts on flux and will assist in delineating the extent of the capture zone, which is especially important near the east and southwest ends of the flux plane. Lastly, when flux is being measured in both scenarios, a synoptic round of groundwater levels will be collected from all site wells. The water levels will be used to estimate the direction of groundwater flow at the flux plane and across the site.

Presently, the first flux measurement event (after the baseline measurement event) is estimated to occur approximately 18 months after the first remedial activity is completed. The flux measurements are proposed to be measured while the GETS is operating. An 18 month period is proposed since the longest travel time from a proposed treatment location to a proposed flux measurement well is approximately 18 months. This estimate is based on the travel time from the south edge of South Tacoma Way (a proposed location to receive enhanced bioremediation amendment) to proposed flux measurement wells MW-311 and 312 (220 feet) using a retarded TCE velocity of 0.42 ft/day

220 ft/(0.42 ft/day) = 524 days (approximately 18 months)

This value may be revised based on observations or changes (e.g., the repositioning of amendment injection locations due to access issues) made during design. These measurement intervals may be revised based on contaminant concentration trends in the treatment zones using results from monitoring well sampling activities conducted concurrently with the flux measurements. For example, if concentrations are considerably reduced such that the flux goal will be clearly met, then the frequency of flux measurements may be reduced. Conversely, if concentrations are persistent, then the frequency of flux measurements may be increased. For the purpose of cost estimating, five flux measurements at twelve wells will be made over a six year period. The cost includes the installation of the six new flux measurement wells. Two wells will be completed to a depth of 50 ft and four wells will be installed to a depth of 100 ft.

<u>GETS Operation</u>
This alternative includes the operation of the GETS to maintain hydraulic control while mass is reduced via EAB. Operation of the GETS will be terminated when it is shown that site COC concentrations have been reduced and the mass flux of COCs through the proposed plane meets the RAO. The GETS will operate during the EAB injection (assume three year period) and an estimated two years after the second injection is made. Therefore, the GETS is assumed to need to be operated and maintained for five years.

4.2.3.5 Alternative HG5 – Air Sparging and Soil Vapor Extraction
This alternative uses in situ air sparging (AS) coupled with SVE to remove volatile organics from the groundwater. The location of the AS/SVE wells are proposed for the area west of the Time Oil Building. From 1993 to 1997 an SVE system was successfully operated in this area; VOC soil concentrations have decreased but VOC groundwater concentrations remain elevated. The AS/SVE well locations are shown on Figure 4-3.

This alternative has been retained since the SVE system operated in the 1990s was very successful at removing VOCs. However, significant data have been collected to demonstrate that anaerobic reductive dechlorination is a significant degradation pathway. Therefore, the operation of an AS/SVE system would introduce oxygen into the subsurface, which would counteract the benefits of the existing anaerobic conditions. The AS/SVE alternative is proposed in a small portion of the high concentration plume west of the former Time Oil building, but EAB is proposed for most of the rest of the plume. Existing SVE equipment and wells are at the site. However, since the equipment has not been used in more than ten years and a cursory inspection of the equipment revealed that it is in poor condition, the equipment was assumed to be unusable for this estimate. However, if the alternative is selected, a detailed inspection and evaluation can be performed in the design to determine if any of the equipment (including wells) is usable.

AS is a groundwater remediation technology that involves the injection of air under pressure into a well installed within the groundwater plume. Air sparging technology extends the applicability of SVE to saturated soils and groundwater through physical removal of volatilized groundwater contaminants. Generally, AS is more effective for contaminants with greater volatility and lower solubility and for soils with higher permeability. Therefore, it is well suited for the treatment of the main CVOCs found at the site. The rate at which the contaminant mass is removed decreases as AS operations proceed and concentrations of dissolved contaminants are reduced.

Air injected below the water table volatilizes aqueous phase contaminants in groundwater. The volatilized contaminants migrate upward to the vadose zone, where they are removed using SVE. With SVE, a vacuum is applied to the contaminated soil matrix through extraction wells. This creates a negative pressure gradient in the unsaturated zone that causes movement of vapors toward these wells. The extracted vapors are then treated, as necessary, and discharged to the atmosphere.

Air sparging systems can be designed with air flow rates and pressures to provide adequate coverage of the area of contamination, but need to minimize the potential for uncontrolled releases of contaminated vapors to the atmosphere, into houses or industrial buildings. Other air sparging systems can be utilized in a barrier type of alignment, referred to as a sparge curtain. Off-gas treatment is expected to be required given the high VOC concentrations and proximity of homes and industrial buildings.

Field pilot studies will be necessary to adequately design and evaluate the system. The most important design parameter to be considered for the air sparging system is the radius of influence. This radius is the greatest distance from a sparging well at which sufficient sparge airflow can be induced to enhance the mass transfer of contaminants from the aqueous phase to the vapor phase. The radius of influence will determine the number and spacing of the sparging wells that are required, with an overlap in their radii of influence so that the contamination area is covered. The sparging air flow rate required to provide sufficient air flow to enhance mass transfer is site-specific and will be determined during the pilot test phase. These studies will also help to determine if hydraulic controls may be necessary to control possible plume migration or enhance flows through sparge curtains.

At the Well 12A site, it is envisioned that the sparging wells will be placed on 50-foot centers across the high concentration groundwater plume west of the Time Oil Building. This will require a total of five sparging wells. The air sparging wells will be placed at 100 feet bgs, which is at the top of the semi confining unit, approximately 65 ft below the water table. In the same area as the sparging wells, ten SVE wells will be placed above the shallow aquifer (approximately 30 feet bgs) to capture any volatilized compounds that are forced out of the vadose zone by the sparging process. One sparge well and two vapor extraction wells are proposed to be installed at an angle to reach underneath the Time Oil building. It is estimated that the AS/SVE system will operate for a period of five years. Thereafter, monitoring in the treatment zone would occur for a two year period.

<u>GETS Operation</u>
This alternative includes the operation of the GETS to maintain hydraulic control while mass is reduced via AS/SVE and EAB. Operation of the GETS will be terminated when it is shown that site COC concentrations have been reduced and the mass flux of COCs through the proposed plane meets the RAO. The GETS will operate during the EAB injection (assume three year period) and an estimated two years after the second injection is completed. Therefore, it is assumed that the GETS will need to be operated and maintained for eight years.

4.2.4 Low Concentration Groundwater

This zone extends from the high concentration zone to the three conditional points of compliance wells: Well 12A, and proposed compliance wells 1 and 2.

4.2.4.1 Alternative LG1 - No Action

The no action alternative is considered in accordance with NCP requirements and provides a baseline for comparison with the other alternatives. No further action would be conducted and the status of the site groundwater would remain unchanged. The air stripping towers at Well 12A would not be operated. This alternative does not include the implementation of any institutional controls such as deed restrictions or future groundwater monitoring. CERCLA (Section 121(c)), as amended by SARA (1986), would require that the site be reviewed every 5 years, because contamination would remain on site.

4.2.4.2 Alternative LG2 – Wellhead Treatment at Well 12A

In 1983 five air stripping towers were installed to treat the discharge water at Well 12A. Tacoma Water has operated and maintained the towers since their installation. This alternative includes the continued O&M of the five air stripping units and monitoring groundwater for VOCs at Well 12A. For cost estimating purposes, it was assumed that the O&M would continue for a period of 30 years.

As part of the wellhead treatment alternative, an IC plan would be developed and ICs would be employed to protect human health. The ICs would be used to limit access to and future development, improvement, and use of affected properties. Specifically, ICs would include activity and use restrictions enacted through proprietary (e.g. easements, covenants) and/or governmental (e.g. zoning requirements) controls to prevent use of the property that would pose an unacceptable risk to receptors (i.e. for residential use). Tacoma-Pierce County Board of Health Resolution No. 2002-3411, Land Use Regulations and applicable sections of Washington Administrative Code Titles 173 and 246 are current guidelines that would be considered, or possibly amended, for the location and installation of supply wells.

Additional ICs may include temporary operational guidelines and/or restrictions on Tacoma Water's use of the South Tacoma Well Field; however, the plan would also set forth communication and evaluation procedures for any required or proposed deviations from the plan. These guidelines and/or restrictions are expected to be similar to the informal pumping strategy currently used by Tacoma Water, but the procedures would be formalized in the IC plan. The plan would be developed during the remedial design and would set forth operational guidelines, restrictions, and procedures to ensure protection of human health for the duration of the remedy. Informational device ICs (warning signs, advisories, additional public education) also would be employed to limit access to contaminated groundwater. A health and safety plan would be developed and implemented to protect workers from contact to groundwater contaminants.

This alternative makes use of new and existing monitoring wells to perform long-term monitoring of groundwater contamination. Wells installed in the upper and lower aquifers will be monitored for VOCs. Also, half of the wells will be monitored for ethene, ethane, methane, sulfate, iron, alkalinity, total organic carbon, and water quality parameters (DO, conductivity, temperature, oxidation reduction potential (ORP), and pH). Two new wells will be installed in the shallow aquifer southeast of South Tacoma Way in the area where the extent of TCE contamination is uncertain. For evaluation purposes, it is estimated that 20 monitoring wells would be included in the sampling program for a long-term monitoring period of 30 years.

In accordance with CERCLA, this alternative would be evaluated at least every five years because contaminants would remain on site.

Presently, VOC concentrations at interim monitoring points (in this example CH2M-2) are expected to decrease to below the MCLs after the second EAB injection is made in the high concentration groundwater treatment zone. The second injection event will occur approximately 18 months after implementing the action. The time for the treated groundwater to be detected at CH2M-2 after the second treatment is estimated to be three years plus the travel time from the injection point line to the well (a distance of approximately 600 ft):

- 3 years + 600 ft/(0.42 ft/day x 1 yr/365 days) = 7 years

This estimate is based on current hydraulic conditions. If additional data are collected (e.g., higher hydraulic conductivity that provides a more direct pathway to the well) the estimate may change. Also, if pumping conditions change (e.g., Well 12A increase production) the estimate may change. Increases in withdrawal at Well 12A may decrease the travel time to CH2M-2, since more flow would be occurring from the Time Oil property to the production well (i.e., away from CH2M-2). If withdrawal is for six months rather than the estimated three months, the velocity may be reduced by one-half 0.42 ft/day to 0.21 ft/day. Therefore, impacts may be seen in 14 years (twice seven years). These estimates provide a general concept of travel times. However, the aquifer and withdrawal scenarios are very complex and travel times will vary. Therefore, measuring Darcy velocity with the GETS on and off, which is proposed, will be an important component of the remedy.

4.3 Evaluation Criteria

EPA has outlined nine evaluation criteria to be used in assessing remedial alternatives in the NCP which take into consideration the statutory requirements specified in Section 121 of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 as amended by the Superfund Amendments and Reauthorization Act of 1986. In addition, EPA has issued additional guidance on the evaluation criteria in "Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA" (EPA, 1998). The criteria are classified into the following three groups.

Threshold Criteria. The threshold criteria are requirements that each alternative must meet in order to be eligible for selection.

- Overall Protection of Human Health and the Environment
- Compliance with ARARs (unless waived)

Primary Balancing Criteria. These criteria are used to distinguish the relative effectiveness of each alternative so that decision makers can evaluate the strengths and weaknesses of each alternative.

- Long-term Effectiveness and Permanence
- Reduction of Toxicity, Mobility, or Volume Through Treatment
- Short-term Effectiveness
- Implementability
- Cost

Modifying Criteria. These factors are typically considered following review of this document and the Proposed Plan by the regulatory agencies and the public, and are formally documented as part of the ROD Amendment. These criteria are not evaluated in this FFS.

- Support Agency (Washington Department of Ecology for this site) Acceptance

- Community Acceptance

Brief discussions for each of the above criteria are provided below.

- **Overall Protection of Human Health and the Environment** - This criterion assesses each alternative's ability to provide adequate protection of human health and the environment, and describes how site risks associated with each exposure pathway are eliminated, reduced, or controlled, through treatment, engineering, and/or institutional controls.

- **Compliance with ARARs** - Alternatives are assessed as to whether they attain legally applicable or relevant and appropriate requirements of Federal and State requirements, standards, criteria, and limitations which are collectively referred to as "ARARs," unless such ARARs are waived under CERCLA section 121(d)(4).

- **Long-term Effectiveness and Permanence** - This criterion considers the ability of an alternative to maintain reliable protection of human health and the environment over time. The evaluation takes into account the residual risk remaining on site at the conclusion of remedial activities, as well as the adequacy and reliability of containment systems and institutional controls.

- **Reduction of Toxicity, Mobility, or Volume Through Treatment** - This criterion addresses the statutory preference for selecting remedial actions that employ treatment technologies that permanently and significantly reduce the toxicity, mobility, or volume (T/M/V) of the hazardous substances as their principal element. This criterion evaluates the anticipated performance of the treatment technologies that may be included as part of a remedy.

- **Short-term Effectiveness** - Short-term effectiveness addresses the period of time needed to implement the remedy and any adverse impacts that may be posed to workers, the community, and the environment during construction and operation of the remedy until cleanup levels are achieved.

- **Implementability** - This criterion addresses the technical and administrative feasibility of implementing a remedy from design through construction and operation. Factors such as the availability of services and materials and coordination with other governmental entities are considered.

- **Cost** - An estimate of the cost for each alternative is determined so that the cost can be compared to the level of protectiveness that each alternative provides. The typical cost estimate made during the FFS is intended to provide an accuracy of +50 percent to -30 percent, as discussed in the EPA RI/FS guidance document. The types of costs that are assessed include the capital costs, operation and maintenance (O&M) costs, and present worth.

- Capital Costs - The capital costs include both the direct and indirect capital costs required to implement the remedial action. Direct costs are comprised of construction costs for equipment, labor, materials, transportation, and disposal. Indirect costs include those associated with permitting and legal, engineering, services during construction, and contingencies.

- O&M Costs - These costs include labor and materials associated with operation and maintenance following the remedial action, such as operating a pump-and-treat system, long-term monitoring costs, or 5-year site reviews. The EPA RI/FS guidance document recommends that O&M costs not be determined for longer than 30 years.

- Present Worth - The present worth of the capital and O&M costs is determined to evaluate expenditures that occur over different time periods so that the costs for remedial alternatives can be compared on the basis of a single figure. The present worth has been calculated based on Federal policy which recommends assuming a 7% discount rate.

- **Support Agency (State) Acceptance** - Support agency acceptance is typically considered following review of this document and the Proposed Plan by the regulatory agencies, and is formally documented as part of the ROD Amendment.

- **Community Acceptance** - The preferred remedy will be presented to the public in the Proposed Plan. Issues raised by the community will be discussed in the Responsiveness Summary of the ROD Amendment, which will respond to public questions and concerns on the FFS and Proposed Plan.

4.4 Individual Analysis of Alternatives

In this section, the alternatives are assessed on the basis of the evaluation criteria described in Section 4.3. Descriptions of each alternative are provided in Section 4.2.

4.4.1 Filter Cake and Shallow Impacted Soil

This zone is located east of the Time Oil Building and extends to a depth of 10 ft bgs.

4.4.1.1 Alternative FC1 - No Action

Overall Protection of Human Health and the Environment

No action would not be protective of human health and the environment. Filter cake and shallow soil that is contaminated with COCs at concentrations exceeding MTCA B-modified levels will remain at the site. Direct contact with these materials by tenants or trespassers and excavation or trenching activities would pose a risk. In addition, the contamination would continue to provide a source to groundwater.

The No Action Alternative fails to meet this threshold criterion of protectiveness and, therefore, will not be evaluated further.

4.4.1.2 Alternative FC2 - Institutional Controls

Overall Protection of Human Health and the Environment

This alternative would provide protection of human health through access restrictions. Long-term soil monitoring would be performed to track contaminant levels over time.

Compliance with ARARs

This alternative would not achieve chemical-specific ARARs (soil MTCA levels) established for the contaminated soils. Action-specific ARARs would not apply to this alternative since further remedial actions would not be conducted.

Long-Term Effectiveness and Permanence

This alternative would not provide long-term effectiveness and permanence. The long-term monitoring program would be used to track contaminant persistence and potential migration. The potential for future human exposure would be minimized through the implementation of restrictions forbidding or limiting areas where digging would be allowed. The continued exposure of onsite receptors to surface soil would be a potential long-term impact of this alternative and remediation goals derived for protection of human health would not be met. Because contaminated material would remain on site under this alternative, a review/reassessment of the conditions at the site would be performed at 5-year intervals to ensure that the remedy would not become a greater risk to human health and the environment.

Reduction of T/M/V Through Treatment

No reductions in contaminant T/M/V would be realized under this alternative.

Short-Term Effectiveness

No construction activities would be associated with this alternative so no risks to construction workers would occur from implementation. There would be minimal exposure risk to personnel during sampling activities associated with the long-term monitoring program, which would continue for 30 years. Every five years, an evaluation would be performed to determine whether the remedy would be protective and whether long-term monitoring should be continued or whether additional remedial action would be necessary. However, there are no impacts because no action is taken and protection is not achieved.

Implementability

This alternative would be easily implemented. Minimal administrative tasks would be involved with the long-term monitoring program and minimal services and materials would be required. This alternative would require the state or local government to secure restrictions on digging at all affected areas as well as the implementation of proprietary controls.

Cost

The capital cost, annual O&M costs, and present worth for this alternative are listed below. Details of the cost estimates are presented in Appendix F.

- Capital Cost: $30,600
- Annual O&M Cost: $39,000
- Present Worth: $114,800

4.4.1.3 Alternative FC3 – Capping Contaminated Soils In Place

Overall Protection of Human Health and the Environment

Capping contaminated soils in place would eliminate exposure pathways and significantly reduce the level of risk at the Well 12A Site. The implementation of ICs such as deed restrictions and asphalt cap maintenance requirements would limit exposure to contaminated soils remaining on site.

Compliance with ARARs

Because contamination will remain in place, ICs would be required to comply with MTCA's 15 ft point of compliance for the direct contact human exposure pathway.

Long-Term Effectiveness and Permanence

This alternative would provide long-term effectiveness and permanence by capping contaminated soils and minimizing the potential for future human exposure through the implementation of ICs restricting future digging in the area and maintenance of the cap. Because contaminated material would remain on site under this alternative, a review/ reassessment of the conditions at the site would be performed at 5-year intervals to ensure that the remedy would not become a greater risk to human health and the environment.

Reduction of T/M/V Through Treatment

Capping the contaminated soil at the site would reduce the mobility since the cap will prevent (or significantly minimize) infiltration of precipitation. Toxicity and volume of the contaminants that remain under the cap will not be reduced.

Short-Term Effectiveness

During placement of the cap, Level D personnel protective equipment would be required. Grading may result in release of nuisance or contaminated dust. Use of heavy equipment may cause a noise nuisance. Engineering controls would be utilized for controlling the dust. Higher levels of personnel protection may become necessary for onsite workers during activities if engineering controls do not reduce dust or noise.

Implementability
This alternative would have minimal technical considerations as long as asphalt remains readily available. This alternative would require implementation of ICs to ensure the cap is maintained and that digging below the cap is restricted.

Cost
The capital cost, annual O&M costs, and present worth for this alternative are listed below. Details of the cost estimates are presented in Appendix F.

- Capital Cost: $798,100
- Annual O&M Cost: $75,400
- Present Worth: $1,267,300

4.4.1.4 Alternative FC4—Excavation of Soils, Transportation to and Disposal in RCRA Subtitle C or D Landfill

Overall Protection of Human Health and the Environment
Excavating contaminated soil and transporting it to an offsite RCRA-permitted landfill for disposal would eliminate exposure pathways and significantly reduce the level of risk at the Well 12A Site. The implementation of ICs such as deed restrictions and limits on digging would reduce exposure to contaminated soils remaining on site.

Compliance with ARARs
Transportation of contaminated soil would be in accordance with applicable Department of Transportation hazardous material regulations. Disposal at a RCRA permitted landfill would be in compliance with ARARs. For areas where contaminated soils remain, either additional in situ treatment would be performed or ICs would be used to further reduce the potential for exposure and achieve compliance with MTCA's 15 ft point of compliance for the direct contact human exposure pathway.

Long-Term Effectiveness and Permanence
This alternative would provide long-term effectiveness and permanence by removing contaminated soils. Where contaminated soils remain, the potential for future human exposure would be minimized through the implementation of engineering controls and restrictions forbidding or limiting areas where future digging would be allowed. Because contaminated material would remain on site under this alternative, a review/ reassessment of the conditions at the properties where contamination would still be present would be performed at 5-year intervals to ensure that the remedy would not become a greater risk to human health and the environment.

Reduction of T/M/V Through Treatment
Removal of the contaminated soil would reduce the mobility and volume of the waste at the site because the material would be excavated and transferred to the disposal location. The toxicity would be removed from the site, with the final toxicity

contingent upon the disposal methods. Disposal in a landfill would not reduce toxicity.

Short-Term Effectiveness

During onsite removal actions Level D personnel protective equipment would be required. The potential exists for a higher level of protection to be used during excavation or loading of trucks. Excavation and grading may result in release of nuisance or contaminated dust. Use of heavy equipment may cause a noise nuisance. Engineering controls would be utilized for controlling the dust. Higher levels of personnel protection may become necessary for onsite workers during activities if engineering controls do not reduce dust, or noise.

Implementability

This alternative has minimal technical considerations except for the need to ensure structural stability while digging near building foundations. Representative soil samples would be collected and presented to the receiving landfill(s) for their acceptance evaluation, and providing requirements specified in 40 CFR 268.30 are met. Historical knowledge and current information about soil chemical and physical characteristics would be provided to the landfill(s). The available data suggest that the excavated soils could be disposed in a Subtitle D landfill.

Cost

The capital cost, annual O&M costs, and present worth for this alternative are listed below. Details of the cost estimates are presented in Appendix F.

- Capital Cost: $2,346,500
- Annual O&M Cost: $68,900
- Present Worth: $2,801,700

4.4.2 Deep Vadose Zone Soil and Upper Saturated Zone East of Time Oil Building

This zone lies east of the Time Oil Building and extends to a depth of 55 ft bgs.

4.4.2.1 Alternative SG1 - No Action

Overall Protection of Human Health and the Environment

No action would not be protective of human health and the environment. Soil that is contaminated with COCs at concentrations exceeding MTCA B-modified levels will remain at the site. Direct contact with these materials by tenants or trespassers and excavation or trenching activities would pose a risk. In addition, the contamination would continue to provide a source to groundwater. The status of the upper saturated zone groundwater would remain unchanged. This alternative does not include the implementation of any institutional controls such as deed restrictions or future groundwater monitoring. CERCLA (Section 121(c)), as amended by SARA (1986), would require that the site be reviewed every 5 years, because contamination would remain on site.

The No Action Alternative fails to meet this threshold criterion of protectiveness and, therefore, will not be evaluated further.

4.4.2.2 Alternative SG2 - Institutional Controls

Overall Protection of Human Health and the Environment
This alternative would provide protection of human health by restricting site access and the installation of new wells. Long-term soil and groundwater monitoring would be performed to track contaminant levels over time.

Compliance with ARARs
This alternative would not achieve chemical-specific ARARs (e.g., soil MTCA levels) or RAOs (mass reduction) established for the contaminated soils. Action-specific ARARs would not apply to this alternative since further remedial actions would not be conducted.

Long-Term Effectiveness and Permanence
This alternative would not provide long-term effectiveness and permanence. The long-term monitoring program would be used to track contaminant persistence and potential migration. The potential for future human exposure would be minimized through the implementation of restrictions forbidding or limiting areas where digging would be allowed and wells installed. The continued exposure of onsite receptors to soil would be a potential long-term impact of this alternative and remediation goals derived for protection of human health would not be met. Because contaminated material would remain on site under this alternative, a review/reassessment of the conditions at the site would be performed at 5-year intervals to ensure that the remedy would not become a greater risk to human health and the environment.

Reduction of T/M/V Through Treatment
No reductions in contaminant T/M/V would be realized under this alternative.

Short-Term Effectiveness
No construction activities would be associated with this alternative so no risks to construction workers would occur from implementation. There would be minimal exposure risk to personnel during sampling activities associated with the long-term monitoring program, which would continue for 30 years. Every five years, an evaluation would be performed to determine whether the remedy would be protective and whether long-term monitoring should be continued or whether additional remedial action would be necessary. However, there are no impacts because no action is taken and protection is not achieved.

Implementability
This alternative would be easily implemented. Minimal administrative tasks would be involved with the long-term monitoring program and minimal services and materials would be required. This alternative would require the state or local

government to secure restrictions on digging at all affected areas as well as the implementation of proprietary controls.

Cost

The capital cost, annual O&M costs, and present worth for this alternative are listed below. Details of the cost estimates are presented in Appendix F.

- Capital Cost: $30,600
- Annual O&M Cost: $39,000
- Present Worth: $114,800

4.4.2.3 Alternative SG3 – In situ Thermal Remediation

Overall Protection of Human Health and the Environment

This alternative would provide protection of human health and the environment by reducing the mass of VOC contamination in this zone. A goal of 90% mass reduction has been assigned. Reducing the mass would, in effect, remove the source area so that downgradient concentrations would decrease at a more rapid rate. Therefore, the alternative is protective of human health and the environment due to the reduction in mass.

Compliance with ARARs

The first tier goal is to aggressively destroy contaminant mass. One benefit of mass destruction is that it results in reduced concentrations in soil and in groundwater in the treatment zone. Theoretically, the soil and groundwater concentrations could decrease to below MTCA and MCL levels, respectively, in some areas. However, the primary goal is to achieve a mass reduction of at least 90%; reductions to below health-based standards would be a secondary benefit. Therefore, the alternative complies with the RAOs, but it may not achieve compliance with chemical-specific ARARs within the treatment zone boundary. Compliance with chemical-specific ARARs will be measured at the proposed compliance well locations. The MTCA soil levels and groundwater MCLs may not be achieved within the 30-year evaluation period; however, this remains a long-term goal. Residual impacts exceeding MTCA cleanup levels and MCLs will be addressed via ICs and ongoing wellhead treatment at Well 12A.The heat treatment time is approximately six months. Decreases in mass will be seen soon after the heating process is initiated. This alternative would be designed to comply with location and action-specific ARARs/RAOs. Permit equivalencies would be addressed including air limits.

Long-Term Effectiveness and Permanence

This alternative would provide long-term effectiveness and permanence. Thermal remediation would reduce contaminant concentrations in the soil and groundwater plume over time. This decrease would enhance existing natural processes and institutional controls. Reductions in plume concentration and size would be tracked by the long-term groundwater monitoring program. The potential for future exposure of contaminated groundwater to receptors would be minimized through the implementation of well drilling and groundwater use restrictions in the plume area.

Reduction of T/M/V Through Treatment
ITR would reduce the toxicity and volume of contaminated soil and groundwater. Heated VOCs would be extracted with SVE wells and the vapor treated via a GAC system prior to discharge. The VOCs would be transferred to the carbon media, which would be regenerated thereby permanently destroying the VOC contaminants through thermal treatment processes. Mobility is reduced since the source is being removed.

Short-Term Effectiveness
It is estimated that construction of the ITR treatment system could be completed within six months of site mobilization and the ITR heating phase would last approximately six months. Therefore, the estimated time for the mass in this source area to be reduced by at least 90% is one year. The estimate may differ based on the collection of additional data (e.g., if more mass is identified). Groundwater monitoring in the zone would continue for 30 years. Every five years, an evaluation would be performed to determine whether remedial action goals have been achieved or whether another treatment action should occur.

Implementability
This alternative is technically and administratively implementable. Construction of the ITR treatment system could be completed using conventional construction equipment and services, with contractors that specialize in this innovative technology. For cost estimating purposes, this FFS has assumed the ITR technology will be ERH. However, if data are collected that suggest a different technology is required (e.g., steam), then that technology shall be used.

The implementation is suggested to be performed as a phased approach. Treatment of VOCs in the air discharge using carbon adsorption is a proven technology and is readily implementable.

The regulatory and permitting requirements associated with installation of electrode and SVE wells, laying piping, constructing the treatment system, and securing approval for air emissions are considered to be moderately administratively intensive.

Cost
The capital cost, annual O&M costs, and present worth for this alternative are listed below. Details of the cost estimates are presented in Appendix F.

- Capital Cost: $4,106,200
- Annual O&M Cost: $110,500
- Present Worth: $4,662,000

4.4.3 High Concentration Groundwater

High concentration groundwater is identified as the plume where TCE or cis-1,2-DCE concentrations are greater than 300 µg/L.

4.4.3.1 Alternative HG1 – No Action

Overall Protection of Human Health and the Environment

The no action alternative is considered in accordance with NCP requirements and provides a baseline for comparison with the other alternatives. No further action would be conducted and the status of the site groundwater would remain unchanged. This alternative does not include the implementation of any institutional controls such as deed restrictions or future groundwater monitoring. CERCLA (Section 121(c)), as amended by SARA (1986), would require that the site be reviewed every 5 years, because contamination would remain on site.

The No Action Alternative fails to meet this threshold criterion of protectiveness and, therefore, will not be evaluated further.

4.4.3.2 Alternative HG2 – Institutional Controls

Overall Protection of Human Health and the Environment

This alternative would provide protection of human health by restricting site access and the installation of new wells. Long-term groundwater monitoring would be performed to track contaminant levels over time.

Compliance with ARARs

This alternative would not achieve chemical-specific ARARs/RAOs (e.g., 90% flux reduction). Action-specific ARARs would not apply to this alternative since further remedial actions would not be conducted.

Long-Term Effectiveness and Permanence

This alternative would not provide long-term effectiveness and permanence. The long-term monitoring program would be used to track contaminant persistence and potential migration. The potential for future human exposure would be minimized through the implementation of restrictions forbidding or limiting areas where digging would be allowed and wells installed. The continued exposure of receptors to contaminated groundwater would be a potential long-term impact of this alternative and remediation goals derived for protection of human health would not be met. Because contaminated material would remain on site under this alternative, a review/reassessment of the conditions at the site would be performed at 5-year intervals to ensure that the remedy would not become a greater risk to human health and the environment.

Reduction of T/M/V Through Treatment

No reductions in contaminant T/M/V would be realized under this alternative.

Short-Term Effectiveness
No construction activities would be associated with this alternative so no risks to construction workers would occur from implementation. There would be minimal exposure risk to personnel during sampling activities associated with the long-term monitoring program, which would continue for 30 years. Every five years, an evaluation would be performed to determine whether the remedy would be protective and whether long-term monitoring should be continued, or whether additional remedial action would be necessary. However, there are no impacts because no action is taken and protection is not achieved.

Implementability
This alternative would be easily implemented. Minimal administrative tasks would be involved with the long-term monitoring program and minimal services and materials would be required. Existing wells would be used. This alternative would require the state or local government to secure restrictions on digging at all affected areas as well as the implementation of proprietary controls.

Cost
The capital cost, annual O&M costs, and present worth for this alternative are listed below. Details of the cost estimates are presented in Appendix F.

- Capital Cost: $61,300
- Annual O&M Cost: $52,000
- Present Worth: $173,500

4.4.3.3 Alternative HG3 – Extraction and Treatment with GETS

Overall Protection of Human Health and the Environment
This alternative would provide protection of human health and the environment by actively pumping and treating the contaminated groundwater and maintaining hydraulic control of part of the groundwater plume. It is expected that pumping would reduce the plume size and contaminant concentrations over time. However the system has been operating for 20 years and substantial contaminant mass still remains in the subsurface.

Compliance with ARARs
The alternative would include groundwater extraction and treatment to meet chemical-specific Federal and State ARARs over time. The time required to achieve groundwater MCLs would vary depending on whether source control measures are implemented. Since this alternative has been operating for 20 years and substantial mass remains in the subsurface, it is not an alternative that aggressively destroys or removes contaminant mass, which is a primary RAO. This alternative is operated in compliance with location and action-specific ARARs.

Long-Term Effectiveness and Permanence
This alternative does not provide long-term effectiveness and permanence. The system has been operating for 20 years and substantial contaminant mass remains in the subsurface. LNAPL has been observed (more than one foot of NAPL in one well and trace amounts in several others) in wells northeast of the EWs and concentrations of TCE between 1,000 and 2,000 μg/L measured in wells southwest of the EWs.

Reduction of T/M/V Through Treatment
Groundwater extraction and treatment provide minimal reduction in volume of contaminated groundwater. Toxicity is reduced; the VOCs are transferred to the carbon media, which would be periodically regenerated thereby permanently destroying the VOC contaminants through thermal treatment processes. The system reduces mobility by providing capture of parts of the high concentration plume. However, some data suggest that part of the plume has been or is being released. Therefore, the flux reduction RAO may not be achieved.

Short-Term Effectiveness
The system is already installed so there would be no short term effectiveness issues.

Implementability
This alternative is technically and administratively implementable. The GETS is constructed and is being operated and maintained.

Cost
The capital cost, annual O&M costs, and present worth for this alternative are listed below. Details of the cost estimates are presented in Appendix F.

- Capital Cost: $30,600
- Annual O&M Cost: $339,300
- Present Worth: $3,708,000

4.4.3.4 Alternative HG4 – Enhanced Anaerobic Bioremediation

Overall Protection of Human Health and the Environment
This alternative would provide protection of human health and the environment. It would meet the RAOs. Contamination within the 300 μg/L TCE and cis-1,2-DCE contour line would be treated in situ through enhanced anaerobic bioremediation. The remaining contaminant concentration areas (low concentration zone) could be readily reduced through natural processes (data indicate cometabolic aerobic degradation) in the subsurface.

The implementation of EAB includes the delivery of a considerable amount of food-grade amendment into the groundwater. This amendment may remain in the subsurface for years after the RAOs are achieved.

Compliance with ARARs

This alternative would meet the mass flux reduction RAO. Source removal/reduction would need to be implemented east of the Time Oil Building so that the EAB reduction would occur. Implementation of EAB would reduce contaminant concentrations in the treatment area; however, compliance with chemical-specific ARARs (reduction of CVOCs to MCLs) may not be achieved within the 30-year evaluation period. This alternative would be designed to meet the RAO of reducing mass flux by 90%. This mass flux reduction is necessary for management of plume migration and is a critical step towards achieving compliance with the chemical-specific ARARs at the proposed compliance well locations.

Long-term Effectiveness and Permanence

This action would have long-term effectiveness and permanence. Enhanced anaerobic biodegradation, once established, would destroy the chlorinated VOC contaminants in the subsurface, therefore reducing the risk posed by the contaminants. The treatment would focus on the area within the 300 μg/L TCE and cis-1,2-DCE contour line.

The existence of relatively low permeability silt zones and clay seams would not reduce the effectiveness of EAB, since the dechlorination conditions and bacteria would stay in the subsurface for some time. Therefore, any contaminants diffused out of the low permeable zones would also be treated. In addition, the concentration reductions of contaminants in the groundwater could increase the rates of mass transfer for contaminants out of the low permeable zones.

Reduction of T/M/V through Treatment

In situ bioremediation would reduce the toxicity and volume of contamination. Chlorinated VOCs would be biotransformed to ethene, ethane and methane. The intermediate product, VC, is more toxic than PCE and TCE, but accumulation of VC is unlikely because of its ability to degrade under aerobic conditions. Downgradient and outside of this treatment zone, aerobic conditions prevail. Intermediates, such as DCEs and VC, would be closely monitored.

Short-term Effectiveness

Although a fairly significant amount of site work would be required for this alternative, this type of construction is routine, as installation of bioremediation amendment injection systems are relatively common. Because of this, the work would be performed without significant risk to the community. Site workers would wear appropriate PPE to minimize exposure to contamination and as protection from physical hazards.

This alternative would have short-term impacts to the community during construction due to the large number of injection wells that would be installed. Access to private properties would be required for well drilling and nutrient injections. Some traffic control would be required. There would be noise during drilling and nutrient injections. Injection requires a large amount of water that would need to be taken from a hydrant.

Initially, installation of injection wells and the amendment injection system would be completed in six months. One site-wide amendment injection would be performed within 3 months and after approximately 18 months.

Implementablility
This alternative is technically implementable. This alternative would be constructed and implemented using conventional construction methods and equipment. The processes that govern degradation reactions are well understood, and technical feasibility of enhanced bioremediation has been established at numerous sites. Despite this, bioremediation is still considered an innovative technology. As such, it would require bench and pilot scale testing prior to implementation. In general, no significant technical difficulties are anticipated. No difficulty in obtaining a permit for the injection of bioremediation amendments into groundwater is anticipated.

Services and materials for implementation of this alternative are readily available. Competitive bids can be obtained from a number of equipment vendors and remediation contractors. No problems are anticipated for the implementation and enforcement of the institutional controls.

Currently, the treatment zone is underneath private properties and some roadways. Obtaining permission for access to private properties to install the injection wells and amendment system and perform frequent visits to the system may be a challenge. Therefore, the administrative implementation of this alternative will be more difficult due to it being implemented in a city area. As a result, the remedial designers will need to consult with the city engineer and private residents for the proper placement of the injection wells in order to take into account utilities, roads and private properties.

Cost
The capital cost, annual O&M costs, and present worth for this alternative are listed below. Details of the cost estimates are presented in Appendix F.

- Capital Cost: $2,423,900
- Annual O&M Cost: $408,200
- Present Worth: $4,217,700

4.4.3.5 Alternative HG5 – Air Sparging and Soil Vapor Extraction
This alternative is for AS/SVE west of the Time Oil Building and EAB. AS/SVE replaces the line of EAB wells proposed west and north of the Time Oil Building in Alternative HG4. Discussion in the subsection focuses on the AS/SVE part of the alternative.

Overall Protection of Human Health and the Environment
This alternative is protective of human health and the environment by treating contaminants in the groundwater. By reducing VOC contamination in groundwater

(and soil), it will reduce possible soil gas vapors at and near the Time Oil Building, providing a secondary benefit to human health and the environment.

Compliance with ARARs

This alternative meets chemical-specific Federal and State ARARs through active treatment of groundwater; however, compliance with chemical-specific ARARs (reduction of CVOCs to MCLs) may not be achieved within the 30-year evaluation period. It will be designed to reduce the mass in the area west of the Time Oil Building by an estimated ninety percent. This mass reduction is necessary for management of plume migration and is a critical step towards achieving compliance with the chemical-specific ARARs at the proposed compliance well locations. Action- and location-specific ARARs will apply and will be met by this alternative. Air monitoring will need to be completed to ensure that air emissions are below regulatory levels.

Long-Term Effectiveness and Permanence

The use of AS/SVE for groundwater will reduce the concentration of contaminants in the plume by treating water inside the contaminated plume. Contamination that is upgradient of this proposed AS/SVE treatment area must be destroyed so that it does not provide a continuing source. During operation of the GETS, the area east of the Time Oil Building is upgradient of the AS/SVE area.

Reduction of T/M/V Through Treatment

This alternative consists of the active removal and treatment of chlorinated organic compounds from groundwater. The toxicity of the contaminants will be reduced through removal from the groundwater and treatment at the surface by vapor treatment. The process will reduce the mobility of contaminants as a result of the hydrologic effects of the sparging process. The volume of contaminants in the aquifer will be reduced by the AS/SVE due to the volatilization and removal of organics.

Short-Term Effectiveness

This alternative has the potential to have adverse short-term impacts on site workers conducting the remediation activities since trenching will be performed in areas of probable high contaminant concentrations. As a result, construction activities will impose short-term worker health and safety risks. Controls will be put in place to limit exposure to site workers and nearby residences.

Implementability

This alternative employs common technologies and practices that have been in use for many years. Equipment is readily available and installation is relatively easy. The operation of the treatment system will require more specialized training, since there are air injection and vapor extraction mechanisms that will need to be monitored and maintained, but it is not considered to be difficult. In some aquifer conditions, the presence of high iron or manganese in the groundwater can cause excessive buildup of scaling on the air sparging screens, or biofouling through bacterial activity. This can require periodic treatment of the air injection wells by chlorination to reduce bacterial growth.

Implementation of this alternative will be more difficult due to it being implemented in a city area. As a result, the remedial designers will need to consult with the city engineer for the proper placement of the AS wells, the SVE wells, and the treatment plant in order to take into account city utilities and existing roads. Time of installation is relatively short, and expected to be completed in approximately six months.

Cost
The capital cost, annual O&M costs, and present worth for this alternative are listed below. Details of the cost estimates are presented in Appendix F.

- Capital Cost: $3,344,800
- Annual O&M Cost: $545,100
- Present Worth: $5,275,500

4.4.4 Low Concentration Groundwater

This zone extends from the high concentration zone to the points of compliance wells: Well 12A and proposed compliance wells 1 and 2.

4.4.4.1 Alternative LG1 - No Action

Overall Protection of Human Health and the Environment
The no action alternative is considered in accordance with NCP requirements and provides a baseline for comparison with the other alternatives. No further action would be conducted and the status of the site groundwater would remain unchanged. This alternative does not include the implementation of any institutional controls such as deed restrictions or future groundwater monitoring. CERCLA (Section 121(c)), as amended by SARA (1986), would require that the site be reviewed every 5 years, because contamination would remain on site.

The No Action Alternative fails to meet this threshold criterion of protectiveness and, therefore, will not be evaluated further.

4.4.4.2 Alternative LG2 – Wellhead Treatment at Well 12A

Overall Protection of Human Health and the Environment
This alternative provides protection of human health and the environment by actively pumping and treating the contaminated groundwater prior to discharge to the Tacoma distribution system. Treating water to meet health criteria is the primary goal; the decrease of contaminant concentrations in the aquifer due to the pumping impacts is a secondary goal. Additionally, increased pumping of the well may temporarily increase the concentration of COCs in the groundwater plume by increasing the gradient from the source area towards Well 12A. This alternative would also provide protection by eliminating human exposure pathways through

prohibitions on groundwater well installation and groundwater use restrictions within the plume area.

Compliance with ARARs
The purpose of the Well 12A treatment system is to meet chemical-specific Federal and State ARARs for the public water supply.

Long-Term Effectiveness and Permanence
This alternative provides long-term effectiveness and permanence by treating contaminated groundwater prior to discharge to the public water supply. Groundwater extraction and treatment would also reduce contaminant concentrations in the groundwater plume over time. However, it is recognized that the subsurface is complex and more than one source exists in the area. Therefore, increased pumping of the well may temporarily increase the concentration of COCs in the groundwater plume by increasing the gradient from the source area towards Well 12A. Effectiveness would be verified though a long-term groundwater monitoring program and the potential for future exposure would be minimized through the implementation of well installation and groundwater use restrictions within the plume area.

Reduction of T/M/V Through Treatment
The stripping towers remove volatiles from the groundwater and they are emitted to the atmosphere. When the well operates, some control is maintained for contaminants that are in the vicinity of the well. However, data suggest that the pumping action mobilizes contamination near the Time Oil property and contaminants migrate further along the prevailing gradient. Therefore, operation of the well is considered to not reduce T/M/V.

Short-Term Effectiveness
The system is already installed so there would be no short term effectiveness issues.

Implementability
This alternative is technically and administratively implementable. This alternative has been constructed and operated since 1983. Minimal administrative tasks are involved with the long-term groundwater monitoring program and minimal services and materials are required. This alternative would require coordination with the Tacoma-Pierce County Board of Health and Tacoma Water to implement ICs.

Cost
The capital cost, annual O&M costs, and present worth for this alternative are listed below. Details of the cost estimates are presented in Appendix F.

- Capital Cost: $341,500
- Annual O&M Cost: $263,900
- Present Worth: $2,094,200

Section 5
Comparative Analysis of Alternatives

This section presents an overall comparison of the remedial alternatives which were evaluated in Section 4. The alternatives are compared to each other for each treatment zone based on the EPA evaluation criteria. A summary of the comparative analyses for the alternatives is provided in Table 5-1.

5.1 Filter Cake and Shallow Impacted Soils

This treatment zone is located east of the Time Oil Building and extends from land surface to a depth of ten feet. The alternatives for this treatment zone are

- Alternative FC1 No Action
- Alternative FC2 Institutional Controls
- Alternative FC3 Capping
- Alternative FC4 Excavation

5.1.1 Overall Protection of Human Health and the Environment

A threshold criterion set forth in the NCP is that the selected remedial action must be protective of human health and the environment. This criterion assesses each alternative's ability to provide adequate protection of human health and the environment, and describes how site risks associated with each exposure pathway are eliminated, reduced, or controlled, through treatment, engineering, and/or institutional controls.

Alternative FC1 would provide no protection against exposure to filter cake or contaminated soil, nor would it provide protection of groundwater from migration of contaminants in waste and soil. The potential for exposure to this material is high since it is near the surface and data visualizations suggest the waste continues to serve as a source of contamination to groundwater.

Alternatives FC2 and FC3 would provide moderate protection. The institutional controls would prohibit the use of groundwater and limit excavation/trenching, which would limit exposure to contaminants. With the source material remaining in place, contaminants will still be present to migrate to groundwater and travel away from the controlled area. Capping would provide an additional level of protection, since the direct contact pathway would be eliminated and the potential for contaminants leaching further into the subsurface via infiltration or possibly traveling away from the zone via runoff would be eliminated.

Alternative FC4 provides a high degree of protection of human health and the environment through removal of contaminants from the site. Alternative FC4 would be protective by removing the filter cake and shallow impacted soil from depths down to an estimated ten ft bgs. The direct contact pathway would be removed and the shallow contaminants would not be present to allow leaching to occur to depth or runoff to carry contaminants off of the property.

5.1.2 Compliance with ARARs

This threshold criterion addresses whether a remedy would attain legally applicable or relevant and appropriate requirements of Federal and State requirements, standards, criteria, and limitations which are collectively referred to as "ARARs," or provides grounds for invoking a waiver under CERCLA section 121(d)(4).

Chemical specific ARARs for soil are the MTCA B-modified levels. Several CVOCs have been shown to exceed these levels. The compounds are in filter cake and shallow soil and the elevated concentrations have remained in the materials for more than 20 years. These compounds would be expected to remain in the soil above MTCA levels for the 30-year evaluation period. Therefore, Alternatives FC1, FC2 and FC3 do not comply with ARARs. Alternative FC4 does comply with ARARs since it removes the majority of filter cake and shallow soil with concentrations above the MTCA B-modified level. Where contaminated soils remain in place, either further in situ treatment would be performed or ICs would be used to reduce the potential for exposure and comply with MTCA's 15-ft point of compliance for the direct contact human exposure pathway. Offsite waste transportation and disposal of Alternative FC4 would be performed in accordance with applicable RCRA, DOT, and Ecology requirements; and only RCRA-permitted disposal facilities approved by EPA and Ecology would be used. Additionally, Alternative FC4 (as does FC3) meets the RAO of preventing the migration of contamination to depth.

5.1.3 Long-Term Effectiveness and Permanence

Long-term effectiveness and permanence refers to expected residual risk and the ability of a remedy to maintain reliable protection of human health and the environment over time. This criterion includes the consideration of residual risk that will remain on site following remediation and the adequacy and reliability of controls.

Alternative FC1 would not provide long-term effectiveness or permanence. Contaminants would persist and continue to migrate into the environment. No controls would be implemented to prevent future exposure.

Alternatives FC2 and FC3 would provide a moderate level of long-term effectiveness and permanence by minimizing future exposure through the use of institutional controls and placing a barrier at the surface, respectively. Alternative FC3 would be more effective given that the mobility of the contaminants present in the soil/filter cake would be reduced by eliminating infiltrating water and runoff. Both alternatives would require long-term maintenance because contaminants would remain on site; however, Alternative FC2 would require less O&M to maintain the controls (e.g. signage for institutional controls versus resurfacing cap).

Alternative FC4 would provide the highest degree of long-term effectiveness and permanence by removing the filter cake and contaminated soil and disposing of this material off site. Little to no residual risk would remain in the areas where the filter cake and contaminated soil was excavated. However, institutional controls and some O&M measures would be required since some residual contamination may be left in areas that cannot be excavated (e.g., near or underneath the Time Oil building).

5.1.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

This criterion addresses the statutory preference for selecting remedial actions that employ treatment technologies that permanently and significantly reduce the toxicity, mobility, or volume of the hazardous substances. This criterion evaluates the anticipated performance of the treatment technologies that may be included as part of a remedy.

Alternative FC1 would not achieve any reduction in toxicity, mobility, or volume through treatment, since no action would be taken for the filter cake and contaminated soil.

Under Alternatives FC2 and FC3, treatment is not a component of the remedy. Therefore, no reduction in toxicity or volume would be achieved through treatment. However, contaminant mobility would be reduced through capping by removing the impacts of precipitation (infiltration leaching contaminants to depth and runoff carrying contaminants along the surface).

For Alternative FC4, the mobility and volume of the waste are also reduced at the site because the material is excavated and transferred to the disposal location. The toxicity is removed from the site, with the final toxicity contingent upon the disposal methods. Disposal in a landfill will not reduce toxicity.

5.1.5 Short-Term Effectiveness

Short-term effectiveness addresses the period of time needed to implement the remedy and any adverse impacts that may be posed to workers, the community, and the environment during construction and operation of the remedy.

Under Alternatives FC1 no construction activities would be performed so no risks to remediation workers or the community would occur. Little risk would also be incurred for the implementation of institutional controls, Alternative FC2, since little to no contact would be made with the contaminants.

For Alternative FC3 the risk would be low. Some contact may be made with the contaminants while placing the cap. However, since no excavation is required, the contact should be minimal. Remediation workers would not be subject to significant risks associated with direct contact with contaminated materials. Air monitoring would be required to reduce risks to workers and the community from potential fugitive emissions during construction. Conventional engineering controls would be used to prevent contaminated materials from migrating with run off water or becoming airborne during construction. It is estimated that construction for Alternative FC3 could be completed within one month of site mobilization.

Alternative FC4 would have moderately high risks to workers performing the excavation due to volatilization of contaminants. The open excavation will also pose a physical risk. Additionally, the volatiles may impact nearby residents and workers at adjacent properties. Controls such as performing the work in cooler weather and only maintaining a small portion of the excavation open at one time will limit volatilization to the community. There would also be additional short term impacts due to transport and offsite disposal of significant quantities of waste and contaminated soil. Conventional traffic controls for waste transport, such as defining specific travel routes to/from the site for waste transportation vehicles and coordinating waste shipments to avoid peak traffic hours, would be used to minimize the potential for accidents. It is estimated that construction for Alternative FC4 can be completed within two months of site mobilization.

5.1.6 Implementability

This criterion addresses the technical and administrative feasibility of implementing a remedy from design through construction and operation. Factors such as the availability of services and materials and coordination with other governmental entities are considered.

Alternative FC1 would be the easiest to implement due to the lack of any active construction or treatment activities. Alternative FC2 is only slightly more difficult to implement since limited site activities are required. Some coordination will be needed with regulators to implement administrative requirements.

Alternatives FC3 and FC4 are technically and administratively implementable. None of these alternatives would require specialized equipment. Services required to place asphalt caps and excavate waste and contaminated soil would be easily obtainable. Access agreements and coordination with property owners will be required to accommodate the construction activities for these two alternatives. Alternative FC4 would require imported clean fill to backfill the excavation, which is expected to be readily available in the general vicinity of the site. The regulatory and permitting requirements associated with offsite treatment/disposal under Alternative FC4 are not considered to be administratively intensive. Several RCRA Subtitle D Landfills are located in the general vicinity of the site.

5.1.7 Cost

This criterion considers the construction, O&M, and present worth costs associated with each alternative. The present worth has been calculated based on Federal policy which recommends assuming a 7 percent discount rate over a 30-year evaluation period.

Alternative FC1, the no action alternative, has no costs associated with it since no remedial activities would be performed. Alternative FC2, institutional controls, has a present worth of $114,800. Alternative FC3, capping, has a present worth of $1,267,300 with the capital cost ($798,100) being a little more than half of the estimate. Alternative FC4 is the most expensive with a present worth of $2,801,700 and a capital cost of $2,346,500.

5.2 Deep Vadose Zone Soil and Upper Saturated Zone East of the Time Oil Building

This treatment zone is located at depths from 10 ft to 55 ft bgs. The water table lies at approximately 34 ft bgs. The alternatives for this treatment zone are

- Alternative SG1 No Action
- Alternative SG2 Institutional Controls
- Alternative SG3 In Situ Thermal Remediation

5.2.1 Overall Protection of Human Health and the Environment

Alternative SG1, the no action alternative, provides no protection against possible exposure to soil and contaminated groundwater, and will continue to be a source for migration of contaminants via groundwater. Alternative SG2, institutional controls, is protective of human health but does not address any environmental concerns since there is no action taking place to mitigate the contaminants in the soil and groundwater. Alternative SG3 provides a high degree of protection since it will be designed to remove more than 90% of the contaminant mass in this source treatment zone.

5.2.2 Compliance with ARARs

This threshold criterion addresses whether a remedy would attain legally applicable or relevant and appropriate requirements of Federal and State requirements, standards, criteria, and limitations which are collectively referred to as "ARARs," or provides grounds for invoking a waiver under CERCLA section 121(d)(4).

Chemical specific ARARs for soil are the MTCA B-modified levels. Chemical specific ARARs for the groundwater are MCLs. Concentrations of site COCs in soil and groundwater in this treatment zone exceed these values. The values are significantly elevated and more than one foot of LNAPL has been measured in a well in this zone. These compounds would be expected to remain in the soil and groundwater above MTCA levels and MCLs, respectively, for more than the 30-year evaluation period. Therefore, Alternatives SG1 and SG2 do not comply with ARARs.

The goal of Alternative SG3 is to eliminate/minimize the mass of contaminants in this treatment zone to reduce the mass flux from deep soils into groundwater. The remedy will be designed to remove more than 90% of the mass in the zone. Therefore, the alternative complies with the RAO, but it may not achieve compliance with chemical-specific ARARs within the treatment zone boundary. Compliance with chemical-specific ARARs will be measured at the proposed compliance well locations. The MTCA soil levels and groundwater MCLs may not be achieved within the 30-

year evaluation period; however, this remains a long-term goal. Residual impacts exceeding MTCA cleanup levels and MCLs will be addressed via ICs and ongoing wellhead treatment at Well 12A.

5.2.3 Long-Term Effectiveness and Permanence

Long-term effectiveness and permanence refers to expected residual risk and the ability of a remedy to maintain reliable protection of human health and the environment over time. This criterion includes the consideration of residual risk that will remain on site following remediation and the adequacy and reliability of controls.

Alternative SG1 would not provide long-term effectiveness or permanence. Contaminants would persist at the site and continue to migrate into the environment. No controls would be implemented to prevent future exposure. Alternative SG2 would provide minimal long-term effectiveness or permanence since controls would be in place to limit contact; however, the contamination would remain at the site and continue to be a source to the aquifer.

Alternative SG3 is effective in treating contaminants over the long-term. The alternative will reduce contaminant concentrations in this source area. Thus, the contribution of contamination to the groundwater will be reduced and concentrations in the groundwater at downgradient locations will also decrease.

5.2.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

This criterion addresses the statutory preference for selecting remedial actions that employ treatment technologies that permanently and significantly reduce the toxicity, mobility, or volume of the hazardous substances. This criterion evaluates the anticipated performance of the treatment technologies that may be included as part of a remedy.

Alternatives SG1 and SG2 would not achieve any reduction in toxicity, mobility, or volume through treatment, since no action would be taken for the contamination in the soil and upper groundwater.

Reduction in volume would be achieved with Alternative SG3. The main goal of SG3 is to destroy contaminant mass, which, in effect, decreases hazardous substance volume. Volatiles are transferred to GAC and ultimately destroyed by regeneration. Alternative SG3 would also decrease toxicity by lowering soil and groundwater concentrations and would reduce contaminant mobility due to reduced concentration gradients.

5.2.5 Short-Term Effectiveness

Short-term effectiveness addresses the period of time needed to implement the remedy and any adverse impacts that may be posed to workers, the community, and the environment during construction and operation of the remedy.

Under Alternatives SG1 no construction activities would be performed so no risks to remediation workers or the community would occur. Low risks would also be incurred during the implementation of institutional controls, Alternative SG2, since little to no contact would be made with the contaminants.

For Alternative SG3 the risk would be moderate. Some contact may be made with the contaminants while installing wells and piping. However, if the remedy is constructed after the shallow soils are excavated (Alternative FC4), the risk would be reduced. Remediation workers would not be subject to significant risks associated with direct contact with contaminated materials. Air monitoring would be required to reduce risks to workers and the community from fugitive emissions during construction. Conventional engineering controls would be used to prevent contaminated materials from migrating with run off water or becoming airborne during construction. It is estimated that construction and completion of the heating process would performed in 12 to 18 months after site mobilization.

5.2.6 Implementability

This criterion addresses the technical and administrative feasibility of implementing a remedy from design through construction and operation. Factors such as the availability of services and materials and coordination with other governmental entities are considered.

Alternative SG1 would be the easiest to implement due to the lack of any active construction or treatment activities. Alternative SG2 is only slightly more difficult to implement since limited site activities are required. Some coordination will be needed with regulators to implement administrative requirements.

Alternative SG3 is technically and administratively implementable. This alternative is innovative, but experienced contractors are available to implement the action. Permits will need to be obtained for air emissions and the installation of wells, piping and related remediation system equipment. Access agreements will be required to accommodate the construction activities for this alternative. Coordination with property owners would be required for the installation and operation of the remediation system.

5.2.7 Cost

This criterion considers the construction, O&M, and present worth costs associated with each alternative. The present worth has been calculated based on Federal policy which recommends assuming a 7% discount rate over a 30-year evaluation period. Alternative SG1, the no action alternative, has no costs associated with it since no remedial activities would be performed. Alternative SG2, institutional controls, has a present worth of $114,800. Alternative SG3, Insitu Thermal Remediation, has a present worth of $4,662,000 and a capital cost of $4,106,200. The bulk of the capital cost is for the in situ treatment remediation action.

5.3 High Concentration Groundwater

This treatment zone is the groundwater plume of TCE and cis-1,2-DCE at concentrations greater than 300 ug/l. The alternatives for this treatment zone are

- Alternative HG1 No Action
- Alternative HG2 Institutional Controls
- Alternative HG3 Groundwater Extraction and Treatment
- Alternative HG4 Enhanced Anaerobic Biodegradation
- Alternative HG5 Enhanced Anaerobic Biodegradation plus Air Sparging/Soil Vapor Extraction

5.3.1 Overall Protection of Human Health and the Environment

A threshold criterion set forth in the NCP is that the selected remedial action must be protective of human health and the environment. This criterion addresses whether each alternative provides adequate protection of human health and the environment, and describes how site risks associated with each exposure pathway are eliminated, reduced, or controlled, through treatment, engineering, and/or institutional controls.

Alternative HG1, the no action alternative, would provide no protection against exposure to contaminated groundwater.

Alternative HG2 provides protection of human health and the environment through the implementation of institutional controls to prevent installation of groundwater wells and use of contaminated groundwater. However, without reduction or control of the contaminated groundwater in this zone, it will continue to decrease the quality of downgradient groundwater.

Alternative HG3, operation of the GETS, provides an additional degree of protectiveness by actively removing contaminants from the aquifer and maintaining some degree of hydraulic control. However, VOC concentrations in groundwater remain elevated even though the GETS has operated for over 20 years. The concentrations are estimated to remain elevated for more than the 30 year evaluation period. Also, some data suggest that the GETS has a limited capture zone in the southwest part of the high concentration plume.

Alternatives HG4 and HG5 provide a high degree of protection. Enhanced anaerobic biodegradation and AS/SVE will reduce the contaminant concentrations in the high concentration groundwater zone. The amendment used for the biodegradation will be food grade so impact to drinking water wells and the environment are not a concern.

5.3.2 Compliance with ARARs

This threshold criterion addresses whether a remedy would attain legally applicable or relevant and appropriate requirements of Federal and State requirements, standards, criteria, and limitations which are collectively referred to as "ARARs," or provide grounds for invoking a waiver under CERCLA section 121(d)(4). Any remedial alternative selected by EPA must comply with all ARARs or, under certain circumstances, waive one or more ARARs.

Alternatives HG1 and HG2 would not comply with chemical-specific ARARs. No location-specific ARARs would apply to either alternative. Also, action-specific ARARs would not apply because there would be no active remedial action associated with these alternatives.

Alternative HG3, the groundwater extraction and treatment alternative, is not expected to comply with chemical specific ARARs. The system has operated for 20 years and groundwater concentrations continue to exceed MCLs. The system presently complies with surface water discharge limits and air emission standards. Lastly, this alternative does not meet the RAO of reducing mass flux out of this zone by 90%.

Alternatives HG4 and HG5 are not expected to comply with chemical specific ARARs within the treatment zone boundary, as MCLs are not anticipated to be achieved within the 30-year evaluation period. However, these alternatives would be designed and operated to meet the RAO of reducing mass flux by 90%. This mass flux reduction is necessary for management of plume migration and is a critical step towards achieving compliance with the chemical-specific ARARs at the proposed compliance well locations.

5.3.3 Long-Term Effectiveness and Permanence

Long-term effectiveness and permanence refers to expected residual risk and the ability of a remedy to maintain reliable protection of human health and the environment over time, once clean-up levels have been met. This criterion includes the consideration of residual risk that will remain on site following remediation and the adequacy and reliability of controls.

Alternatives HG1 and HG2 would not provide long-term effectiveness or permanence. The potential for future exposure of contaminated groundwater to receptors would not be eliminated given that no restrictions on well drilling or groundwater use would be instituted for Alternative HG1. With Alternative HG2, future exposure would be minimized through the implementation of well drilling and groundwater use restrictions in the plume area. However, the high concentrations in the groundwater would continue to impact downgradient locations.

Alternative HG3 would provide a moderate degree of long-term effectiveness and permanence. Groundwater extraction and treatment would reduce contaminant concentrations in the groundwater plume over time. However, based on the poor response to pumping in the last 20 years, it is expected that contaminant reductions will continue to be limited.

Alternatives HG4 and HG5 would provide the highest degree of long-term effectiveness and permanence. These alternatives will be designed to aggressively reduce VOC concentrations in the treatment zone and the EAB processes, once stimulated, will remain effective over the long term through ongoing in situ degradation of VOCs by natural bacteria. With alternative HG5, the application of AS/SVE will likely limit the performance of the EAB in other sectors of the treatment zone because the aerobic conditions that will be created by the AS/SVE system are toxic to anaerobic bacteria.

5.3.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

This criterion addresses the statutory preference for selecting remedial actions that employ treatment technologies that permanently and significantly reduce the toxicity, mobility, or volume of the hazardous substances. This criterion evaluates the anticipated performance of the treatment technologies that may be included as part of a remedy.

Alternatives HG1 and HG2 would not achieve any reduction in toxicity, mobility, or volume through active treatment, since no action would be taken.

Alternative HG3 would reduce the toxicity and volume of contaminated groundwater through carbon adsorption. Contaminants transferred from the groundwater to the carbon media would be destroyed by the regeneration process.

Alternatives HG4 and HG5 would provide significant and permanent reduction in toxicity, mobility and volume. The EAB technology will destroy contaminant mass, which, in effect, decreases hazardous substance volume. EAB will significantly reduce toxicity by degrading the ethenes into innocuous gasses and associated reductions in concentration gradients will also decrease contaminant mobility. The AS/SVE will transfer the contamination from groundwater to vapor, which will be treated using carbon and destroyed by the regeneration process.

Alternative SG3 would also decrease toxicity by lowering soil and groundwater concentrations and would reduce contaminant mobility due to reduced concentration gradients.

5.3.5 Short-Term Effectiveness

Short-term effectiveness addresses the period of time needed to implement the remedy and any adverse impacts that may be posed to workers, the community, and the environment during construction and operation of the remedy.

Under Alternative HG1 no construction activities would be performed so no risks to remediation workers or the community would occur. Low risks would be incurred for the implementation of Alternative HG2, institutional controls, since little to no contact would be made with the contaminants.

Alternative HG3, the extraction and treatment alternative, would have minimal impact to remediation workers. The GETS is already constructed and the only possible worker contact with contaminants would be during O&M of the system.

Alternatives HG4 and HG5 would have the greatest potential impact to remediation workers and the community during construction of the systems. The installation of both of the alternatives can be completed within six months of site mobilization. Amendment injection is anticipated to occur in two rounds, so the same risks (vapors at wells, onsite physical hazards and traffic) will be incurred twice.

5.3.6 Implementability

This criterion addresses the technical and administrative feasibility of implementing a remedy from design through construction and operation. Factors such as the availability of services and materials and coordination with other governmental entities are considered.

Alternative HG1, the no action alternative would be the easiest to implement given that no action is performed. Alternative HG2 is only slightly more difficult to implement since limited site activities are required. Some coordination will be needed with regulators to implement administrative requirements. Alternative HG3 is equivalent to HG2 in implementability, since the GETS is already constructed and only standard O&M activities are required.

Alternatives HG3 and HG4 would be the most difficult to implement. These technologies are relatively standard and several contractors are available that have experience with their installations. However, since the wells (and piping for the AS/SVE) for the alternatives will be installed on private properties, near buildings and along road and railroad right of ways, administrative requirements and traffic control requirements will be involved.

Treatment of VOCs in groundwater with EAB is a proven technology. However, to facilitate the proper application of the technology, the installation may need to proceed in phases. During the first phase only one line of wells would be used for amendment addition. The results of the first phase would be used to help guide subsequent phases. The regulatory and permitting requirements associated with installing the amendment injection wells and constructing the treatment system for vapor may be administratively intensive.

5.3.7 Cost

This criterion considers the construction, O&M, and present worth costs associated with each alternative. The present worth has been calculated based on Federal policy which recommends assuming a 7percent discount rate over a 30-year evaluation period. Where applicable, a shorter period was used. Alternative HG1, the no action alternative, has no costs associated with it since no remedial activities would be performed. Alternative HG2, institutional controls, has a present worth of $173,500. Alternative HG3, GETS, has a present worth of $3,708,000 which is due to the high O&M costs for the 30-year period. Alternative HG4, EAB, has a present worth of $4,217,700 and a capital cost of $2,423,900. Alternative HG5, EAB plus AS/SVE, has a present worth of $5,275,500 and a capital cost of $3,344,800.

5.4 Low Concentration Groundwater

This treatment zone is the shallow and lower aquifer extending from the high concentration groundwater treatment zone to the points of compliance wells: Well 12A and proposed compliance wells 1 and 2. The alternatives for this treatment zone are

- Alternative LG1 No Action
- Alternative LG2 Wellhead Treatment at Well 12A

5.4.1 Overall Protection of Human Health and the Environment

A threshold criterion set forth in the NCP is that the selected remedial action must be protective of human health and the environment. This criterion addresses whether each alternative provides adequate protection of human health and the environment, and describes how site risks associated with each exposure pathway are eliminated, reduced, or controlled, through treatment, engineering, and/or institutional controls.

Alternative LG1, the no action alternative, would provide no protection against exposure to contaminated groundwater.

Alternative LG2, the extraction and treatment alternative, provides protectiveness by actively removing contaminants from the groundwater aquifer at Well 12A by treating it with air stripping towers prior to discharge to the distribution system. Alternative LG2 also provides protection of human health and the environment through the implementation of institutional controls to prevent installation of groundwater wells and restrict use of contaminated groundwater. Routine groundwater sampling would provide information about the migration and attenuation of the groundwater plume during and after implementation of source area actions. Strong evidence has been collected that indicates aerobic cometabolic degradation is occurring in this treatment zone.

5.4.2 Compliance with ARARs

This threshold criterion addresses whether a remedy would attain legally applicable or relevant and appropriate requirements of Federal and State requirements, standards, criteria, and limitations which are collectively referred to as "ARARs," or provide grounds for invoking a waiver under CERCLA section 121(d)(4). Any remedial alternative selected by EPA must comply with all ARARs or, under certain circumstances, waive one or more ARARs.

Alternative LG1, the no action alternative, would not comply with chemical-specific ARARs. No location-specific ARARs would apply to this alternative. Also, action-specific ARARs would not apply because no remedial action would be conducted.

Alternative LG2, the groundwater extraction and treatment alternative, is expected to comply with all chemical, location, and action-specific ARARs. These ARARs include water treatment standards and air emission standards.

5.4.3 Long-Term Effectiveness and Permanence

Long-term effectiveness and permanence refers to expected residual risk and the ability of a remedy to maintain reliable protection of human health and the environment over time. This criterion includes the consideration of residual risk that will remain on site following remediation and the adequacy and reliability of controls.

Alternative LG1, the no action alternative, would not provide long-term effectiveness or permanence. The potential for future exposure of contaminated groundwater to receptors would not be eliminated given that no restrictions on well drilling or groundwater use will be implemented other than what currently exists in Tacoma-Pierce County Board of Health Resolution No. 2002-3411, Land Use Regulations and the Washington Administrative Code.

Alternative LG2, the extraction and treatment alternative, would provide the highest degree of long-term effectiveness and permanence. Groundwater extraction and treatment provides a water supply to the public that meets water quality standards. In the aquifer, the operation of Well12A has been shown to mobilize contaminants and increase the rate of contaminant migration towards the well. Effective implementation of this alternative will require coordination with Tacoma Water to implement institutional controls that may include temporary operational guidelines and/or restrictions on Tacoma Water's use of the South Tacoma well field.

5.4.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

This criterion addresses the statutory preference for selecting remedial actions that employ treatment technologies that permanently and significantly reduce the toxicity, mobility, or volume of the hazardous substances. This criterion evaluates the anticipated performance of the treatment technologies that may be included as part of a remedy.

Alternative LG1 provides no reduction in toxicity, mobility, or volume through active treatment, since no action would be taken. Alternative LG2, the extraction and treatment alternative, would reduce the toxicity and volume of contamination in the extracted groundwater through air stripping towers. The operation of Well 12A increases the mobility of contaminants in the aquifer since it creates a steeper hydraulic gradient and draws contaminants from areas of higher concentration.

5.4.5 Short-Term Effectiveness

Short-term effectiveness addresses the period of time needed to implement the remedy and any adverse impacts that may be posed to workers, the community, and the environment during construction and operation of the remedy.

No construction activities would be performed under either alternative so no additional risks to construction workers or the community would occur during implementation. There would be minimal exposure risk to personnel during activities associated with the long-term groundwater monitoring sampling program of Alternative LG2 and while performing O&M at Well 12A.

5.4.6 Implementability

This criterion addresses the technical and administrative feasibility of implementing a remedy from design through construction and operation. Factors such as the availability of services and materials and coordination with other governmental entities are considered.

Alternative LG1 would be the easiest to implement given that no action would be performed.

Alternative LG2 has minor implementability issues associated with the long-term groundwater monitoring program and O&M. There would be some coordination required with Tacoma Water and the Tacoma Board of Health to secure zoning changes preventing well drilling, and institution of deed restrictions to prevent or restrict groundwater use in the plume area.

5.4.7 Cost

This criterion considers the construction, O&M, and present worth costs associated with each alternative. The present worth has been calculated based on Federal policy which recommends assuming a 7 percent discount rate over a 30-year evaluation period.

Alternative LG1, the no action alternative, has no costs associated with it since no remedial activities would be performed. Alternative LG2, Well 12A Treatment, has a present worth of $2,094,200 which is primarily due to the O&M costs applied over the 30-year period. These O&M costs are based on costs incurred in the last three years. If conditions change, then this estimate would change. If pumping increases, the costs would increase and if pumping decreases, the costs would decrease.

5.5 Alternative Groups

Table 5-2 presents the potential groups of alternatives of the various remedial alternatives that can be assembled to develop a plume management strategy and address overall site contamination across the impacted media. While several groups can address contamination, the combination of aggressive mass removal in the source zones (excavation, ITR, and EAB), short-term hydraulic containment with the GETS, and wellhead treatment at Well 12Ain the low concentration zone provides a robust strategy that meets RAOs. Alternative Groups 1 and 2 are No Action and Institutional Controls (under current remediation conditions), respectively. Alternative Groups 3 and 4 provide an aggressive strategy. Both of these groups meet RAOs, but Group 4 is more expensive since capping and AS/SVE are included with the group. A conceptual schedule of remedial activities for Group 3 is presented in Figure 5-1. As shown in the schedule, excavation (and backfill) will be performed, and then ERH will be initiated prior to completing the backfilling. Conceptually, ERH piping will be placed below grade then the excavation will be brought to grade to bury the piping. The first injection of the EAB amendment will occur at approximately the end of the ERH activity. As shown on the schedule, several rounds of performance groundwater sampling and flux measurements will be performed.

5.6 Long Term Decision Guidelines

An overarching plume management strategy that links the target treatment zones and source treatment performance goals with remedial alternatives is proposed. Also, in support of EPA's ongoing movement of green cleanup methods, the strategy will incorporate sustainable practices where applicable. Performance criteria and decision rules will be established for the strategy and alternatives selected as the proposed remedy. The criteria and rules that will be developed will be based on site data and case histories. Site data to refine the criteria and rules will be collected in a pre-design investigation. The items below provide initial guidelines that will be used to specify criteria and rules.

- The ability to modify the overall treatment area or volume in real time during installation of the remediation system (e.g., ITR) will need to be established if the target is not as originally identified. A good communication network between the engineer/scientists, the property owner(s), contractor(s), and regulatory agencies facilitates the modifications.

- An adequate data collection program needs to be established so that the facilities (e.g., soil vapor extraction wells) are installed at adequate locations. For example, when installing vapor extraction wells, soil and/or groundwater screening data should be collected. If contaminants are detected above a specified concentration, additional wells can be installed. Conversely, if contaminants are not detected (or are detected at negligible concentrations), proposed wells may be removed.

- Multiple parameters need to be monitored and considered in assessing performance, as a single monitoring parameter that is sufficient for evaluating performance is not available. For example, based on experience with ITR at other sites, the most important parameters for assessing performance and determining when to terminate treatment are temperature (three-dimensional distribution and average), groundwater concentrations at internal monitoring locations, and mass of water, vapor and contaminant extracted. Additionally, monitoring of chloride over time would be useful as a potential indicator of in situ dechlorination reactions. Because heating will likely not be uniform, temperature monitoring points should be distributed at least one sensor per 100 cubic yards of treated soil, including one sensor for every five feet in the vertical direction.

- Groundwater monitoring data will be evaluated to characterize the decreasing mass, concentrations, and flux. Statistical analyses will be performed on the data following methods that are outline in publications such as Statistical Methods for Groundwater Monitoring (Gibbons 1994).

- Performance goals and monitoring/decision approach should be defined with as much detail as possible so that if actual site conditions are significantly different than anticipated, the project can make adequate adjustments. For example, if the subsurface heats up unevenly, the project team shall be able to change the performance model in real time to be aligned with the overarching performance goal of maximizing mass reduction rather than only staying focused on meeting temperature monitoring goals specified in the contract.

- Real time or close to real time data for some parameters such as temperature and concentration are useful to help the stakeholders make accurate and timely decisions and support a flexible operating strategy.

- Temporal groundwater contaminant concentration data is a key measure of performance. Based on case history, little rebound is observed after ITR treatment. However, even at sites with rebound and potential issues with diffusion from low permeability zones, groundwater concentration data from monitoring wells is a good baseline for interpretation of treatment effectiveness. Other measures, such as contaminant flux, will be added to refine the interpretation of performance.

- Temperature monitoring outside the targeted ITR treatment zone is a good measure of the adequacy of hydraulic control.

An agreement will be prepared between EPA, Washington Department of Ecology and the City of Tacoma on the execution of the remedial action and long-term monitoring. A possible scenario is that EPA will monitor flux, groundwater concentrations, and mass reduction in addition to completing/constructing the remedial action and Ecology and Tacoma will operate the GETS. EPA will use the flux, groundwater and mass data to determine when the GETS can be turned off and will notify Ecology and Tacoma. The data and evaluation used to make the determination will be provided to Ecology and Tacoma. The action will be considered an interim action until the cleanup level is attained at conditional points of compliance well CH2M-2, proposed well IM-1 and proposed wells IM-2. The State would be taking over the site after the GETS is turned off and:

- 90% flux reduction groundwater remediation level is met
- MCLs are met at the compliance wells 12A, new well CW1, and new well CW2

The transfer to the State would be before groundwater cleanup levels are attained at the conditional points of compliance well CH2M-2, new well IM-1 and new well IM-2. This description is a summary of possible future requirements; a more formal and definitive agreement will be discussed and prepared between the stakeholders.

Section 6
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Tables

Table 2-1
Model Toxics Control Act Soil Cleanup Level Comparison

Compound	Method A (mg/kg)	Method B (mg/kg)	Method B modified (mg/kg)
TCE	0.03	77	23
PCE	0.05	1.9	1.7
1,1,2,2-PCA	0.59*	5.0	4.6
cis-1,2-DCE	78*	800	800
trans-1,2-DCE	11*	1600	1600
VC (adulthood)	0.06*	1.4	1.4
VC (lifetime)	0.06*	0.71	0.71

* Values from Oak Ridge Natonal Laboraory (ORNL) Adjusted Residential (June 2008) since Method A values not available. One VC value presented in ORNL, and value posted here for both adulthood and lifetime.

TABLE 2-2
CALCULATION OF SOIL CLEANUP LEVELS (INGESTION EXPOSURE ROUTE) - Method B
South Tacoma Channel / Well 12A Site
Tacoma, Washington

Non-cancer Hazard		
Equation 740-1 Definition:		
C_{soil} = (RfD x ABW x UCF x HQ x AT) / (SIR x AB1 x EF x ED)		
Parameter	**Definition**	**Value**
C_{soil}	Soil cleanup level (mg/kg)	
RfD	Reference Dose (mg/kg-d)	chemical-specific
ABW	Average body weight over the exposure duration (kg)	16
UCF	Unit conversion factor (mg/kg)	1000000
SIR	Soil ingestion rate (mg/day)	200
AB1	Gastrointestinal absobtion fraction (unitless)	1
EF	Exposure frequency (unitless)	1
HQ	Hazard quotient (unitless)	1
AT	Averaging time (yrs)	6
ED	Exposure duration (yrs)	6
Cancer Risk		
Equation 740-2 Definition:		
C_{soil} = (RISK x ABW x AT x UCF) / (CPF x SIR x AB1 x ED x EF)		
C_{soil}	Soil cleanup level (mg/kg)	
RISK	Acceptable cancer risk level (unitless)	0.000001
ABW	Average body weight over exposure duration (kg)	16
AT	Averaging time (yrs)	75
UCF	Unit conversion factor (mg/kg)	1000000
CPF	Carcinogenic potency factor (kg-day/mg)	chemical-specific
SIR	Soil ingestion rate (mg/day)	200
AB1	Gastrointestinal absobtion fraction (unitless)	1
ED	Exposure duration (yrs)	6
EF	Exposure frequency (unitless)	1

Chemical of Concern	**ABS**	**Cancer Risk**		**Noncancer Hazard**	
		CPF (mg/kg-day)$^{-1}$	**C_{soil} (mg/kg)**	**RfD (mg/kg-day)**	**C_{soil} (mg/kg)**
1,1,2,2-Tetrachloroethane	0.03	0.2	**5.0**	NE	NE
cis -1,2,-Dichloroethene	0.0005	NE	NE	0.01	**800**
Tetrachloroethene	0.03	0.54	**1.9**	NE	NE
trans -1,2-Dichloroethene	0.0005	NE	NE	0.02	**1600**
Trichloroethene	0.03	0.013	**77**	NE	NE
Vinyl Chloride (adulthood)	0.0005	0.72	**1.4**	NE	NE
Vinyl Chloride (lifetime)	0.0005	1.4	**0.71**	NE	NE

Toxicity value sources:

1) Integrated Risk Information System (IRIS 2008)

2) Cal/EPA

3) RICEA - Provisional value

NE = Not Evaluated

TABLE 2-3
CALCULATION OF SOIL CLEANUP LEVELS (INGESTION AND DERMAL EXPOSURE ROUTES) - Modified B
South Tacoma Channel / Well 12A Site
Tacoma, Washington

Non-cancer Hazard

Equation 740-4 Definition:

C_{soil} = (HQ x ABW x AT) / (EF x ED) x {[(1/RfDo x (SIR x AB1)/(10^6 mg/kg)] + [(1/RfDd x (SA x AF x ABS)/(10^6 mg/kg)]}

Parameter	Definition	Value
C_{soil}	Soil cleanup level (mg/kg)	
HQ	Hazard quotient (unitless)	1
ABW	Average body weight over the exposure duration (kg)	16
AT	Averaging time (yrs)	6
EF	Exposure frequency (unitless)	1
ED	Exposure duration (yrs)	6
SIR	Soil ingestion rate (mg/day)	200
AB1	Gastrointestinal absobtion fraction (unitless)	1
SA	Dermal surface area (cm^2)	2200
AF	Adherance factor (mg/cm^2-d)	0.2
ABS	Dermal absortion fraction (unitless)	chemical-specific
RfDo	Oral reference dose (mg/kg-d)	chemical-specific
RfDd	Dermal reference dose (mg/kg-d) (RfDo x GI)	chemical-specific
GI	Gastrointestinal absorbtion conversion factor (unitless)	0.8

Cancer Risk

Equation 740-5 Definition:

C_{soil} = (RISK x ABW x AT) / (EF x ED) x [(SIR x AB1 x CPFo)/(10^6 mg/kg) + [(SA x AF x ABS x CPFd) / (10^6 mg/kg)]

Parameter	Definition	Value
C_{soil}	Soil cleanup level (mg/kg)	
RISK	Acceptable cancer risk (unitless)	0.000001
ABW	Average body weight over the exposure duration (kg)	16
AT	Averaging time (yrs)	75
EF	Exposure frequency (unitless)	1
ED	Exposure duration (yrs)	6
SIR	Soil ingestion rate (mg/day)	200
AB1	Gastrointestinal absorbtion fraction (unitless)	1
CPFo	Oral cancer potentecy factor (mg/kg-d)	chemical-specific
CPFd	Dermal cancer potency factor (mg/kg-d) (CPFo / GI)	chemical-specific
GI	Gastrointestinal absorbtion conversion factor (unitless)	0.8
SA	Dermal surface area (cm^2)	2200
AF	Adherance factor (mg/cm^2-d)	0.2
ABS	Dermal absortion fraction (unitless)	chemical-specific

Chemical of Concern	ABS	Cancer Risk			Noncancer Hazard		
		CPFo $(mg/kg\text{-}day)^{-1}$	CPFd $(mg/kg\text{-}day)^{-1}$	C_{soil} (mg/kg)	RfDo (mg/kg-day)	RfDd (mg/kg-day)	C_{soil} (mg/kg)
1,1,2,2-Tetrachloroethane	0.03	0.2	0.25	**4.6**	NE	NE	NE
cis-1,2,-Dichloroethene	0.0005	NE	NE	NE	0.01	0.008	**800**
Tetrachloroethene	0.03	0.54	0.68	**1.7**	NE	NE	NE
trans-1,2-Dichloroethene	0.0005	NE	NE	NE	0.02	0.016	**1600**
Trichloroethene	0.03	0.04	0.05	**23**	NE	NE	NE
Vinyl Chloride (adulthood)	0.0005	0.72	0.90	**1.4**	NE	NE	NE
Vinyl Chloride (lifetime)	0.0005	1.4	1.8	**0.71**	NE	NE	NE

Toxicity value sources:

1) Integrated Risk Information System (IRIS 2008)
2) Cal/EPA
3) RICEA - Provisional value

NE = Not Evaluated

Table 2-4
Soil to Groudwater Pathway Cleanup Levels - Method B

Chemical Specific:												
CAS #:	**Chemical:**	**Oral Reference Dose (RfDo) (mg/kg-day)**	**Oral Cancer Potency Factor (CPFo) (kg-day/mg)**	**Inhalation Reference Dose (RfDi) (mg/kg-day)**	**Inhalation Cancer Potency Factor (CPFi) (kg-day/mg)**	**Inhalation Correction Factor (INH) (unitless)**	**Koc (Soil Organic Carbon-Water Partitioning Coefficient) (L/kg)**	**Henrys Law Constant (unitless) (Hcc) (unitless)**	**Aqueous Solubility (S) (mg/L)**	**Dilution Factor (DF) (unitless)**	**Groundwater Criterion (ug/L)**	**Cleanup Level (CUL) (mg/kg)**
156-59-2	dichloroethylene;1,2-,cis	1.00E-02	Researched-No Data	1.00E-02	Researched-No Data	2.00E+00	3.60E+01	1.70E-01	3.50E+03	2.00E+01	7.00E+01 [1]	1.57E-01
156-59-2	dichloroethylene;1,2-,cis	1.00E-02	Researched-No Data	1.00E-02	Researched-No Data	2.00E+00	3.60E+01	1.70E-01	3.50E+03	1.00E+00	7.00E+01 [1]	7.90E-03
156-60-5	dichloroethylene;1,2-,trans	2.00E-02	Researched-No Data	2.00E-02	Researched-No Data	2.00E+00	3.80E+01	3.90E-01	6.30E+03	2.00E+01	1.00E+03 [1]	2.89E+00
156-60-5	dichloroethylene;1,2-,trans	2.00E-02	Researched-No Data	2.00E-02	Researched-No Data	2.00E+00	3.80E+01	3.90E-01	6.30E+03	1.00E+00	1.00E+03 [1]	1.44E-01
79-34-5	tetrachloroethane;1,1,2,2-	Researched-No Data	2.00E-01	Researched-No Data	2.00E-01	2e+00	7.90E+01	1.40E-02	3.00E+03	2.00E+01	6.70E-02 [2]	2.00E-04
79-34-5	tetrachloroethane;1,1,2,2-	Researched-No Data	2.00E-01	Researched-No Data	2.00E-01	2e+00	7.90E+01	1.40E-02	3.00E+03	1.00E+00	6.70E-02 [2]	1.10E-05
127-18-4	tetrachloroethylene	1.00E-02	5.40E-01	Researched-No Data	2.10E-02	2e+00	2.70E+02	7.50E-01	2.00E+02	2.00E+01	5.00E+00 [1]	5.86E-02
127-18-4	tetrachloroethylene	1.00E-02	5.40E-01	Researched-No Data	2.10E-02	2e+00	2.70E+02	7.50E-01	2.00E+02	1.00E+00	5.00E+00 [1]	2.90E-03
79-01-6	trichloroethylene	3.00E-04	8.90E-02	1.00E-02	8.90E-02	2e+00	9.40E+01	4.20E-01	1.10E+03	2.00E+01	5.00E+00 [1]	2.43E-02
79-01-6	trichloroethylene	3.00E-04	8.90E-02	1.00E-02	8.90E-02	2e+00	9.40E+01	4.20E-01	1.10E+03	1.00E+00	5.00E+00 [1]	1.20E-03
79-01-6	trichloroethylene	3.00E-04	8.90E-02	1.00E-02	8.90E-02	2e+00	9.40E+01	4.20E-01	1.10E+03	2.00E+01	2.40E+00 [3]	1.17E-02
79-01-6	trichloroethylene	3.00E-04	8.90E-02	1.00E-02	8.90E-02	2e+00	9.40E+01	4.20E-01	1.10E+03	1.00E+00	2.40E+00 [3]	6.00E-04

Site Specific Data:			
Total Soil Porosity (n) (unitless)	**Volumetric Water Content (Θw) (L/kg)**	**Dry Soil Bulk Density (ρb) (kg/l)**	**Fraction Soil Organic Carbon (foc) (unitless)**
3.00E-01	5.40E-02	1.88	1.70E-03

Notes:

The Chemical Specific information was extracted from the Cleanup Levels and Risk Calculation (CLARC) database.

"Researched-No Data" means research has been conducted and no data exists in the CLARC database for this parameter.

CUL calculated using the *Workbook for Calculating Cleanup Levels for Individual Hazardous Substance.*

The Site Specific information is referenced in URS, 2005, excpet the Volumetric Water Content which is referenced in EQM, 2004.

The default DF value is 20 in the unsaturated zone and 1 in the saturated zone.

1. MCL - Maximum Contaminant Level
2. ORNL -Oak Ridge National Laboratory
3. Ecology Method B Level for groundwater

Table 2-5
Groundwater Data from February/March 2008

Analyte	MCL (ug/L)	CBW-1	CBW-4	CBW-5	CBW-6	CBW-7-1	CBW-7-2 (DUP)	CBW-9	CBW-10-1	CBW-10-2 (DUP)	CBW-11	CH2M-1	CH2M-2	CH2M-3	CH2M-4	EW-1	EW-2	EW-3	EW-4	EW-5	ICF-2-1	ICF-2-2 (DUP)	ICF-3-1	ICF-3-2 (DUP)	ICF-4	ICF-5D	ICF-5S	KRRF-1	MW-301	MW-302	MW-304	MW-305	MW-306	MW-307	MW-308	MW-89_7	MW-A
1,4-Dioxane (SVOC)	6.1*	1U	1U	1U	1U	0.5J	1U	1U	1U	1U	1U	0.67J	1.3	1U	1U	0.6J	1U	1.2	3.5	8.7	4.7	6.1	1UJ	1U	1.1U	1U	1U	1U	42	360J	13	300J	4.4	10	6.8	1U	7.2
1,1,1,2-Tetrachloroethane	----	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	50U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
1,1,1-Trichloroethane	----	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	50U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
1,1,2-Trichloroethane	----	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	5.3	1U	1U	1U	1U	1J	2.1	8.1	9.3	1U	1U	1U	1U	50U	16	4.5	1U	1U	1.1	1U	1U	1U	1U	1U	1U	1U
1,1-Dichloroethane	----	1U	1U	1U	1U	1.5	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	50U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
1,1-Dichloroethene	----	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	3.3	1U	1U	1U	1U	1.3	1.6	4.6	2.5	170J	170J	1U	1U	50U	1.6	1U	1U	1U	2.7	1U	1U	1U	1U	1U	1U	1U
1,1-Dichloropropanone	----	2UJ	2UJ	2UJ	2UJ	2UJ	2UJ	2UJ	2UJ	2UJ	2UJ	2U	2UJ	2U	2UJ	2UJ	2UJ	2UJ	2UJ	2UJ	2U	2U	2UJ	2UJ	100U	2U	2U	2U	2UJ	2UJ	2U	2U	2U	2U	2UJ	2U	2UJ
1,1-Dichloropropene	----	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	50U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
1,2,3-Trichlorobenzene	----	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	50U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
1,2,3-Trichloropropane	----	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	50U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
1,2,4-Trichlorobenzene	----	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	0.61J	1U	1U	1U	1U	49J	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
1,2-Dibromo-3-chloropropane	----	2UJ	1U	1U	1U	2UJ	2UJ	2U	1U	1U	1U	1U	1U	2U	1U	2U	2U	2U	2U	2U	1U	1U	1U	1U	50U	1U	1U	1U	2UJ	2UJ	2U	2U	2U	2U	1U	2U	2U
1,2-Dichloroethane	----	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	27J	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
1,2-Dichloropropane	----	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	50U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
1,3-Dichloropropane	----	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	50U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
1-Chlorobutane	----	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	5.3	1U	1U	1U	1U	50U	15	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
2,2-Dichloropropane	----	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	50U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
2-Butanone	----	1U	1U	1U	1U	1U	3.1J	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1.1	1U	1U	1U	1U	1U	25J	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
2-Chlorotoluene	----	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	3.3	2.7	1U	1U	1U	1U	50U	1.1	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
2-Hexanone	----	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1UJ	1U	1U	1U	1U	1U	1U	1U	1U	1UJ	1UJ	1U	1U	50U	1UJ	1UJ	1UJ	1U	1U	1U	1U	1U	1U	1U	1U	1U
2-Pentanone, 4-methyl-	----	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1.4	1U	1U	1U	1U	1U	50U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
2-Propanone	----	2U	1U	3.1	1U	2U	3J	2U	1U	1.1	1U	1UJ	1U	2U	1U	2U	2U	2U	2U	2U	1UJ	1UJ	3.2	4		1UJ	1UJ	1UJ	2U	2U	2U	1.4J	2U	2U	1U	2U	1.1J
2-Propenoic acid, 2-methyl-, methyl este	----	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	50U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
4-Chlorotoluene	----	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	2.8	1.8	1U	1U	1U	1U	50U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
Acrylonitrile	----	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1UJ	1U	1U	1U	1U	1U	1U	1U	1U	1UJ	1UJ	1U	1U	50U	1UJ	1UJ	1UJ	1U	1U	1U	1U	1U	1U	1U	1U	1U
Allyl Chloride	----	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	50U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
Benzene	----	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	2.5	5.1	1U	1U	1U	1U	50U	2	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
Benzene, (1-methylethyl)-	----	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	5.2	5.1	1U	1U	0.86J	0.91J	51	1.6	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
Benzene, 1,2,4-trimethyl-	----	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	58	38	1U	1U	5.7	6.2	370	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
Benzene, 1,2-dichloro-	----	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	8	7.6	1U	1U	1U	1U	47J	11	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
Benzene, 1,3,5-trimethyl-	----	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	17	7.2	1U	1U	1U	1U	170	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
Benzene, 1,3-dichloro-	----	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	11J	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
Benzene, 1,4-dichloro-	----	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1.1	1	1U	1U	0.8J	0.9J	13J	1.5	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
Benzene, 1-methyl-4-(1-methylethyl)-	----	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	2.5	0.96J	1U	1U	0.84J	0.85J	61	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
Benzene, chloro-	----	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	2.1	3.1	1U	1U	1U	1U	50U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
Benzene, ethenyl-	----	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	2	1.5	1U	1U	1U	1U	40J	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
Benzene, propyl-	----	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	7	8.4	1U	1U	1U	1U	22J	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
Benzene, tert-butyl-	----	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1.1	1.1	50U	1.3	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
Bromobenzene	----	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	50U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
Bromochloromethane	----	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	50U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
Bromodichloromethane	----	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	50U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
Bromoform	----	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	50U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
Bromomethane	----	1U	2U	2U	2U	1U	1U	1U	2U	2U	2U	2U	2U	1U	2U	1U	1U	1U	1U	1U	2U	2U	2U	2U	100U	2U	2U	2U	1U	1U	1U	1U	1U	1U	2U	1U	1U
Carbon disulfide	----	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	50U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
Carbon Tetrachloride	----	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	50U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
cis-1,2-Dichloroethene	70	1U	1U	7.2	1U	0.84J	1U	1U	1U	1U	1U	210	1.5	1U	1U	24	75	270	2200	2200	1100	1100	1U	1U	69	2100	190	36	1U	17	1U	2.1	1U	1U	6	1U	1U
cis-1,3-Dichloropropene	----	1.1U	1.1U	1.1U	1.1U	1.1U	1.1U	1.1U	1.1U	1.1U	1.1U	1.1U	1.1U	1.1U	1.1U	1.1U	1.1U	1.1U	1.1U	1.1U	1.1U	1.1U	1.1U	1.1U	53U	1.1U	1.1U	1.1U	1.1U	1.1U	1.1U	1.1U	1.1U	1.1U	1.1U	1.1U	1.1U
Dibromochloromethane	----	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	50U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
Dibromomethane	----	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	50U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
Diethyl ether	----	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	50U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
Ethane, 1,1,2,2-tetrachloro-	0.067*	1U	1U	1U	1U	0.85J	1U	1U	1.2	1U	1U	190J	1U	1U	1U	3.3	26	87	150	29	1.6	1.6	1.3	1.2	50U	81	22	3.7	1U	1U	1U	1U	1U	1U	1U	1U	1U
Ethane, 1,2-dibromo-	----	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	50U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
Ethene, 1,2-dichloro-, (E)-	100	1U	0.82J	1U	1U	2.4	1U	1U	2.2	1U	0.83J	150	1U	1U	1U	14	43	130	1400	1400	350	360	1U	1U	34J	170	100	20	1U	5.8	1U	1U	1U	1U	1.7	1U	1U
Ethene, trichloro-	5	1.8	8.9	3	1U	27	1U	1.8	21	1U	8.5	1100	21	4.6	52	73	200	260	100	62	1300	1300	1.3	1.3	50U	190	180	79	1U	15	1U	1U	1U	1U	15	1U	3.8
Ethyl Chloride	----	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	50U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
Ethylbenzene	----	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	45	34	1U	1U	1U	1U	150	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
Ethylmethacrylate	----	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	50U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
Freon 11	----	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1UJ	1U	1U	1U	1U	1U	1U	1U	1U	1UJ	1UJ	1U	1U	50UJ	1UJ	1UJ	1UJ	1U	1U	1U	1U	1U	1U	1U	1U	1U
Freon 113	----	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	50U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
Freon 12	----	1U	1UJ	1UJ	1UJ	1U	1U	1U	1UJ	1UJ	1UJ	1U	1UJ	1U	1UJ	1U	1U	1U	1U	1U	1U	1U	1UJ	1UJ	50UJ	1U	1U	1U	1U	1U	1U	1U	1U	1U	1UJ	1U	1U
Furan, tetrahydro-	----	1U	5U	5U	5U	1U	1U	1U	5U	5U	5U	5U	5U	1U	5U	1U	1U	1U	1U	1U	5U	5U	5U	5U	250U	5U	5U	5U	1U	1U	1U	1U	1U	1U	5U	1U	1U
Hexachlorobutadiene	----	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	50U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
Hexachloroethane	----	2U	1U	1U	1UJ	2U	2U	2U	1U	1U	1U	1UJ	1U	2U	1U	2U	2U	2U	2U	2U	1UJ	1UJ	1U	1U	50U	1UJ	1UJ	1UJ	2U	2U	2U	2U	2U	2U	1U	2U	2U
Methacrylonitrile	----	1U	2U	2U	2U	1U	1U	1U	2U	2U	2U	2U	2U	1U	2U	1U	1U	1U	1U	1U	2U	2U	2U	2U	100U	2U	2U	2U	1U	1U	1U	1U	1U	1U	2U	1U	1U
Methane, chloro-	----	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	50UJ	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
Methane, trichloro-	----	1U	1U	1U	1U	0.83J	2.6	1U	1U	1U	1U	1.3	1U	1U	1U	0.48J	1.2	0.82J	1.3	1.5	1U	1U	1U	1U	50U	6.1	8.6	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
Methyl acrylate	----	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	50U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
Methyl Iodide	----	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1UJ	1U	1U	1U	1U	1U	1U	1U	1U	1UJ	1UJ	1U	1U	50U	1UJ	1UJ	1UJ	1U	1U	1U	1U	1U	1U	1U	1U	1U
Methyl tert butylether (MTBE)	----	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	50U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
Methylene Chloride	----	1U	1U	1U	1U	1U	5.2	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U		1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
MP-Xylene	----	2U	2U	2U	2U	2U	2U	2U	2U	2U	2U	2U	2U	2U	2U	2U	2U	2U	96	31	2U	2U	2U	2U	600	2U	2U	2U	2U	2U	2U	2U	2U	2U	2U	2U	2U
Naphthalene	----	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	37	11	1U	1U	4.2U	4.4U	160U	1.1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
n-Butylbenzene	----	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1.8	1.6	1U	1U	1U	1U	44J	1.6	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
o-Xylene	----	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	53	43	1U	1U	1.5	1.5	510	1.1	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
Pentachloroethane	----	1UJ	1UJ	1UJ	1UJ	1UJ	1UJ	1UJ	1UJ	1UJ	1UJ	1UJ	1UJ	1UJ	1UJ	1UJ	1UJ	1UJ	1UJ	1UJ	1UJ	1UJ	1UJ	1UJ	50U	1UJ	1UJ	1UJ	1UJ	1UJ	1UJ	1UJ	1UJ	1UJ	1UJ	1UJ	1UJ
sec-Butylbenzene	----	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1.8	2	1U	1U	1U	1U	38J	3.3	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
Tetrachloroethene	5	1U	1U	1U	1U	1U	2.2J	1U	1U	1U	1U	36	1U	1U	17J	1.9	9.7	6.2	2.9	4	3.8J	4.4J	2J	1.8J	50U	42J	28J	2.1J	1U	1U	1U	1U	1U	1U	1U	1U	1U
Toluene	----	1U	1U	1U	1U	1U	2.1	1U	1U	1.6	1U	1U	1U	1U	1U	1U	1U	1U	94	81	1U	1U	1U	1U	1600	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
Trans-1,3-Dichloropropene	----	0.94U	0.94U	0.94U	0.94U	0.94U	0.94U	0.94U	0.94U	0.94U	0.94U	0.94U	0.94U	0.94U	0.94U	0.94U	0.94U	0.94U	0.94U	0.94U	0.94U	0.94U	0.94U	0.94U	47U	0.94U	0.94U	0.94U	0.94U	0.94U	0.94U	0.94U	0.94U	0.94U	0.94U	0.94U	0.94U
trans-1,4-Dichloro-2-butene	----	5UJ	5UJ	5UJ	5UJ	5UJ	5UJ	5UJ	5UJ	5UJ	5UJ	5UJ	5UJ	5UJ	5UJ	5UJ	5UJ	5UJ	5UJ	5UJ	5UJ	5UJ	5UJ	5UJ	250UJ	5UJ	5UJ	5UJ	5UJ	5UJ	5UJ	5UJ	5UJ	5UJ	5UJ	5UJ	5UJ
Vinyl Chloride	2	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	4.7	1U	1U	1U	2.7	5.8	21	270	330	51	52	1U	1U	95	91	1.5	1.7	1U	21	1U	2.6	1U	1U	0.81J	1U	1U
TPH-GC/Diesel Range Organics	----	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.83	0.76	0.2U	0.2U	1U	0.94U	320000	0.36	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U
TPH-GC/Motor Oil Range Organics	----	0.49U	0.49U	0.49U	0.49U	0.49U	0.49U	0.49U	0.49U	0.49U	0.49U	0.49U	0.49U	0.49U	0.49U	0.49U	0.49U	0.49U	0.49U	0.49U	0.49U	0.49U	0.49U	0.49U	580000	0.49U	0.49U	0.49U	0.49U	0.49U	0.51U	0.5U	0.49U	0.49U	0.49U	0.49U	0.49U
Unleaded gasoline composite	----	50U	50U	50U	50U	50U	50U	50U	50U	50U	50U	50U	50U	50U	50U	50U	50U	50U	2200J	1200	50U	50U	190	210	11000	490U	50U	50U	50U	50U	50U	50U	50U	50U	50U	50U	50U

Notes:
U= The analyte was not detected at or above the reported value.
J= The identification of the analyte is acceptable; the reported value is an estimate.

*For 1,4-dioxane and 1,1,2,2-tetrachloroethene, MCLs were unavailable and Oak Ridge National Laboratory (ORNL) values as of 6/22/2008 were used instead.

Table 2-5
Well 12A Analytical Data from February/March 2008

Analyte	MCL (ug/L)	MW-B	MW-C	TOW-4	TOW-10	TW T-10	WCC-1A	WCC-1B	WCC-2	WCC-3	WCC-5-1	WCC-5-2	WCC-6	WCSB-9-1	WCSB-9-2	Well 11A	Well 12A	Well 9A
1,4-Dioxane (SVOC)	6.1	1U	1.2	1.1	14	1U	57	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
1,1,1,2-Tetrachloroethane	----	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
1,1,1-Trichloroethane	----	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
1,1,2-Trichloroethane	----	1U	1.1	1.9	1U	1U	1U	0.88J	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
1,1-Dichloroethane	----	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
1,1-Dichloroethene	----	1U	2.7	1.6	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
1,1-Dichloropropanone	----	2U	1U	2U	2U	2U	2UJ	2U	2U	2UJ	1U	2U	2UJ	1U	2U	1U	1U	1U
1,1-Dichloropropene	----	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
1,2,3-Trichlorobenzene	----	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
1,2,3-Trichloropropane	----	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
1,2,4-Trichlorobenzene	----	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
1,2-Dibromo-3-chloropropane	----	2U	1U	1U	2U	2U	2UJ	1U	2U	2U	1U	1U	1U	1U	1U	1U	1U	1U
1,2-Dichloroethane	----	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
1,2-Dichloropropane	----	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
1,3-Dichloropropane	----	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
1-Chlorobutane	----	1U	1U	1.4	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
2,2-Dichloropropane	----	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
2-Butanone	----	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	3.7	1U	1U	1U	1U	1U	1U
2-Chlorotoluene	----	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
2-Hexanone	----	1U	1UJ	1UJ	1U	1U	1U	1UJ	1U	1U	1UJ	1UJ	1U	1UJ	1UJ	1UJ	1UJ	1UJ
2-Pentanone, 4-methyl-	----	1U	1UJ	1U	1U	1U	1U	1U	1U	1U	1UJ	1U	1U	1UJ	1U	1UJ	1UJ	1UJ
2-Propanone	----	2U	1U	1UJ	1.1J	2U	2U	1UJ	2U	2U	0.88J	1.6J	1.5	1U	1UJ	1U	1U	1U
2-Propenoic acid, 2-methyl-, methyl este	----	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
4-Chlorotoluene	----	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
Acrylonitrile	----	1U	1UJ	1UJ	1U	1U	1U	1UJ	1U	1U	1UJ	1UJ	1U	1UJ	1UJ	1U	1U	1U
Allyl Chloride	----	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
Benzene	----	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
Benzene, (1-methylethyl)-	----	1U	1U	1.5	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1UJ	1UJ	1UJ
Benzene, 1,2,4-trimethyl-	----	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
Benzene, 1,2-dichloro-	----	1U	1U	2.3	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
Benzene, 1,3,5-trimethyl-	----	1U	2U	1U	1U	1U	1U	1U	1U	1U	2U	1U	1U	2U	1U	2U	2U	2U
Benzene, 1,3-dichloro-	----	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
Benzene, 1,4-dichloro-	----	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
Benzene, 1-methyl-4-(1-methylethyl)-	----	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
Benzene, chloro-	----	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
Benzene, ethenyl-	----	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
Benzene, propyl-	----	1U	2U	1U	1U	1U	1U	1U	1U	1U	2U	1U	1U	2U	1U	2U	2U	2U
Benzene, tert-butyl-	----	1U	1U	1.1	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1UJ	1U
Bromobenzene	----	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
Bromochloromethane	----	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
Bromodichloromethane	----	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
Bromoform	----	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
Bromomethane	----	1U	1U	2U	1U	1U	1U	2U	1U	1U	1U	2U	2U	1U	2U	1U	1U	1U
Carbon disulfide	----	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
Carbon Tetrachloride	----	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
cis-1,2-Dichloroethene	70	1.2	89	280	1U	1U	5.6	74	1U	1U	4.5	1U	1U	0.94J	1.2	1U	1U	1U
cis-1,3-Dichloropropene	----	1.1U	1.1U	1.1U	1.1U	1.1U	1.1U	1.1U	1.1U	1.1U	1.1U	1.1U	1.1U	1.1U	1.1U	1.1U	1.1U	1.1U
Dibromochloromethane	----	1U	2U	1U	1U	1U	1U	1U	1U	1U	2U	1U	1U	2U	1U	2U	2U	2U
Dibromomethane	----	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
Diethyl ether	----	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
Ethane, 1,1,2,2-tetrachloro-	0.067*	1U	38	31	1U	1U	1U	63J	1U	1U	1	1U	1U	1U	1U	1U	1U	1U
Ethane, 1,2-dibromo-	----	1U	1U	1U	1U	1U	1U	1U	1U	1U	2U	1U	1U	1U	1U	2U	1U	1U
Ethene, 1,2-dichloro-, (E)-	100	0.98J	82	250	1U	1U	4.4	51	1U	1U	3.4	1U	1U	1U	1U	1U	1U	1U
Ethene, trichloro-	5	15	260	59	2.3	1U	15	92	4.1	1.5	31	0.15J	17	33	45	1U	1.4	1.2
Ethyl Chloride	----	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
Ethylbenzene	----	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
Ethylmethacrylate	----	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1UJ	1UJ	1UJ
Freon 11	----	1U	1U	1UJ	1U	1U	1U	1UJ	1U	1U	1U	1UJ	1U	1U	1UJ	1U	1U	1U
Freon 113	----	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
Freon 12	----	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1UJ	1U	1U	1U	1U	1U
Furan, tetrahydro-	----	1U	1UJ	5U	1U	1U	1U	5U	1U	1U	1UJ	5U	5U	1UJ	5U	1U	1U	1U
Hexachlorobutadiene	----	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
Hexachloroethane	----	2U	5U	1UJ	2U	2U	2U	1UJ	2U	2U	5U	1UJ	1U	5U	1UJ	5U	5U	5U
Methacrylonitrile	----	1U	1U	2U	1U	1U	1U	2U	1U	1U	1U	2U	2U	1U	2U	1U	1U	1U
Methane, chloro-	----	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
Methane, trichloro-	----	1U	1U	1U	1U	1U	1U	0.84J	1U	1U	2.3	1.9	2.9	1U	1U	0.85J	1U	1U
Methyl acrylate	----	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
Methyl Iodide	----	1U	1U	1UJ	1U	1U	1U	1UJ	1U	1U	1U	1UJ	1U	1U	1UJ	1U	1U	1U
Methyl tert butylether (MTBE)	----	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
Methylene Chloride	----	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	4.1	1U	1U	1U	1U	1U	1U
MP-Xylene	----	2U	2U	2U	2U	2U	2U	2U	2U	2U	2U	2U	2U	2U	2U	2U	2U	2U
Naphthalene	----	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
n-Butylbenzene	----	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
o-Xylene	----	1U	1U	3.9	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
Pentachloroethane	----	1UJ	5UJ	1UJ	1UJ	1UJ	1UJ	1UJ	1UJ	1UJ	5UJ	1UJ	1UJ	5UJ	1UJ	5UJ	5U	5UJ
sec-Butylbenzene	----	1U	2U	0.92J	1U	1U	1U	1U	1U	1U	2U	1U	1U	2U	1U	2U	2U	2U
Tetrachloroethene	5	1U	8.8J	2.4J	1U	1U	1U	2.2J	1U	1U	1.4J	1U	1U	4.3J	6.6J	1U	1U	1U
Toluene	----	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U
Trans-1,3-Dichloropropene	----	0.94U	0.94U	0.94U	0.94U	0.94U	0.94U	0.94U	0.94U	0.94U	0.94U	0.94U	0.94U	0.94U	0.94U	0.94U	0.94U	0.94U
trans-1,4-Dichloro-2-butene	----	5UJ	2U	5UJ	5UJ	5UJ	5UJ	5UJ	5UJ	5UJ	2U	5UJ	5UJ	2U	5UJ	2U	2U	2U
Vinyl Chloride	2	1U	8.6	140	1U	1U	1.6	6.6	1U	1U	1.1	1U	1U	1U	1U	1U	1U	1U
TPH-GC/Diesel Range Organics	----	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.19U	0.19U	0.19U
TPH-GC/Motor Oil Range Organics	----	0.49U	0.49U	0.49U	0.49U	0.49U	0.49U	0.49U	0.49U	0.49U	0.49U	0.49U	0.49U	0.49U	0.49U	0.46U	0.46U	0.46U
Unleaded gasoline composite	----	50U	50U	120U	50U	50U	50U	50U	50U	50U	50U	50U	50U	50U	50U	50U	50U	50U

Notes: **U=** The analyte was not detected at or above the reported value.
J= The identification of the analyte is acceptable; the reported value is an estimate.

For 1,4-dioxane and 1,1,2,2-tetrachloroethene, MCLs were unavailable and Oak Ridge National Laboratory (ORNL) values as of 6/22/2008 were used instead.

Table 2-6
Contaminant Volume and Mass Estimate - March 2008
Dissolved Groundwater Plume

Concentration (µg/kg)	Cis 1,2 DCE		TCE	
	Aquifer* Volume (acre-feet)	Chemical Mass in Groundwater (kg)	Aquifer* Volume (acre-feet)	Chemical Mass in Groundwater (kg)
>200	159	38	220	70
>300	119	34	135	64
>500	72	28	89	58
>1000	24	15	51	47.7

Concentration (µg/kg)	Total Indicator VOCs		1,4 Dioxane	
	Aquifer* Volume (acre-feet)	Chemical Mass in Groundwater (kg)	Aquifer* Volume (acre-feet)	Chemical Mass in Groundwater (kg)
>200	471	197	35	37
>300	346	186	13.6	1.8
>500	238	170	NA	NA
>1000	143	146	NA	NA

* Soil porosity = 30%

Table 2-7
Contaminant Volume and Mass Estimate - Soil Plume

Concentration (µg/kg)	PCA		TCE	
	Volume (cubic-yards)	Chemical Mass in Soil (kg)	Volume (cubic-yards)	Chemical Mass in Soil (kg)
>1000	33,886	416	38,940	1,014
>3000	16,740	375	18,920	966
>5000	11,890	349	13,590	937
>10000	6,417	293	8,250	882

Conentration is the isoconcentration that defines the plume for the estimates

Table 2-8
Comparison of Contaminant Mass in Soil Samples
Above and Below the Water Table

Above Water Table						
Compound and Sample Set Dates		**Isovolume Level (ug/kg)**	**Total Soil Volume (cubic yards)**	**Total Soil Mass (kg)**	**Chemical Volume (cubic yards)**	**Chemical Mass (kg)**
TCE	(1985-2004)	1.00E+03	1.25E+04	1.77E+07	4.62E-01	3.53E+02
PCA	(1985-2004)	1.00E+03	1.98E+04	2.79E+07	3.63E-01	2.77E+02
cis 1,2 DCE	(2004)	1.00E+03	1.07E+02	1.52E+05	2.76E-04	2.11E-01
PCE	(1997-2004)	1.00E+03	1.71E+03	2.43E+06	8.31E-03	6.35E+00
trans 1,2 DCE	(1985-2004)	1.00E+03	2.35E+05	3.32E+08	2.93E+00	2.24E+03

Below Water Table						
Compound and Sample Set Dates		**Isovolume Level (ug/kg)**	**Total Soil Volume (cubic yards)**	**Total Soil Mass (kg)**	**Chemical Volume (cubic yards)**	**Chemical Mass (kg)**
TCE	(1985-2004)	1.00E+03	3.66E+04	5.17E+07	8.97E-01	6.86E+02
PCA	(1985-2004)	1.00E+03	2.71E+04	3.84E+07	2.33E-01	1.78E+00
cis 1,2 DCE	(2004)	1.00E+03	1.02E+03	1.44E+06	6.53E-03	4.99E+00
PCE	(1997-2004)	1.00E+03	1.07E+04	1.51E+07	9.26E-02	7.08E+01
trans 1,2 DCE	(1985-2004)	1.00E+03	1.52E+05	2.15E+08	2.88E+00	2.20E+03

Isovolume level identifies the minimum plume concentrations for which the calculations were made

Table 3-1
Chemical-Specific ARARs/TBCs

Matrix	Standard, Requirement, Criterion, Or Limitation	Citation Or Reference	Description	Status	Comments
FEDERAL					
Soil	EPA Soil Screening Guidance	EPA/540/R-96/018	Provides methodology for calculating risk-based, site-specific soil screening levels.	TBC	Used to standardize and accelerate site cleanup.
Groundwater	Maximum Contaminant Levels (MCLs)	40 CFR 141.61-.65	MCLs regulate concentration of contaminants in public drinking water supplies but may also be considered for groundwater aquifers used for drinking water.	Relevant and Appropriate	Relevant to VOCs and metals in groundwater.
	Maximum Contaminant Levels Goals (MCLGs)	40 CFR 141.50-.54	MCLGs are health-based criteria that should be evaluated for groundwater contamination.	Relevant and Appropriate	Relevant to contaminants in groundwater.
	Guidance on Remedial Actions for Contaminated Groundwater at Superfund Sites	EPA/540/G-88/003	Provides information on remedial technologies to address groundwater contamination.	TBC	Relevant to contaminants in groundwater.
	Guidelines for Groundwater Classification Under the EPA Groundwater Protection Strategy	813R86001 (nepis.epa.gov)	Presents guidelines for classifying groundwater in one of three classification categories based on ecological importance, replaceability, and vulnerability considerations	TBC	Useful in identifying ARARs and establishing cleanup goals for site groundwater based on policy that different groundwater merit different levels of protection.
Surface Water	Clean Water Act, Ambient Water Quality Criteria (AWQC)	40 CFR Part 131	Establishes Federal AWQC for restoration and maintenance of chemical, physical, and biological integrity of the nation's surface waters	Relevant and Appropriate	Relevant to remedial actions impacting contaminant migration to surface water and groundwater.
	Clean Water Act - Pretreatment Requirements	40 CFR Part 403 and 405-471	Establishes pretreatment requirements for discharge to POTW.	Applicable	Applicable to remedial actions involved discharge to a POTW.

Hazardous Waste	Resource Conservation and Recovery Act (RCRA) - Identification and Listing of Hazardous Waste	40 CFR Part 261-265, 270, and 271	Defines those solid wastes which are subject to regulations as hazardous wastes, and lists specific chemical and industry-source wastes.	Applicable	Applicable to determining whether remediation wastes, such as spent carbon, are considered hazardous under RCRA.
	RCRA - Part 268 Land Disposal Restrictions	40 CFR Part 268	Establishes standards for land disposal of RCRA hazardous waste. Requires treatment to diminish a waste's toxicity and/or minimize contaminant migration.	Applicable	Applicable if remedial activities include land disposal of RCRA hazardous waste, such as that generated from excavation of waste that is characterized as hazardous
Other	Oak Ridge National Laboratory Screening Criteria	http://epa-prgs.ornl.gov/chemicals/index.shtml	Establishes regional chemical screening levels to be used in risk assessments	TBC	May be considered in development of cleanup goals.
WASHINGTON					
	Model Toxics Control Act (MTCA)	MTCA clean up regulations (WA 173-340)	Establishes the methods to determine cleanup standards for soil, groundwater and surface water	Applicable	
	Water Pollution Control Act	Water quality standards for groundwater of the State of Washington (WAC 173-200)	Establishes groundwater quality standards, which together with technology-based treatment standards provide for protection of existing and future use of groundwater. Not directly applicable because it specifically does not apply to clean up actions approved by Ecology under MTCA.	Relevant and Appropriate	

Table 3-2
Location-Specific ARARs/TBCs

Standard, Requirement, Criterion, Or Limitation	Citation Or Reference	Description	Status	Comments
FEDERAL				
Surface Water: Federal Ambient Water Quality Criteria	40 CFR 131	Establishes cleanup levels for surface water.	TBC	May be TBC if contamination of surface water is suspected.
Groundwater: Groundwater Classification Guidelines	N/A	Presents guidelines for classifying groundwater in one of three classification categories based on ecological importance, replaceability, and vulnerability considerations.	TBC	Useful in identifying ARARs and establishing cleanup goals for site groundwater based on policy that different ground waters merit different levels of protection.
WASHINGTON				
None Identified				

Table 3-3
Action-Specific ARARs/TBCs

Matrix	Standard, Requirement, Criterion, Or Limitation	Citation Or Reference	Description	Status	Comments
FEDERAL					
Air	Clean Air Act	42 USC 7401, Section 1 12	Establishes limits on pollutant emissions to atmosphere from specific industrial and commercial activities. Establishes standards to protect public health and welfare, and ambient air quality.	Relevant and Appropriate	Some groundwater treatment alternatives may impact ambient air quality.
	National Ambient Air Quality Standards (NAAQS)	40 CFR Part 50	Establishes primary and secondary NAAQS in Section 109 Clean Air Act.	Applicable	Applicable to groundwater treatment alternatives that may emit pollutants to the air; establishes standards to protect health and welfare.
	National Emission Standards for Hazardous Air Pollutants (NESHAPs)	40 CFR Part 261	Establishes specific emissions levels allowed for toxic air pollutants.	Applicable	Applicable to groundwater treatment alternatives that may emit toxic pollutants to the air.
Surface Water	Clean Water Act and NPDES Requirements	40 CFR 122-125	Regulates discharge of pollutants into navigable waters	Applicable	Substantive requirements will be applicable to any alternative that discharges effluent to surface water.
	Clean Water Act	40 CFR 136	Identifies test procedures to measure specified waste constituents under the NPDES or otherwise, shall be conditioned so that the discharge authorized will meet water quality standards.	Applicable	

Table 3-3
Action-Specific ARARs/TBCs

Matrix	Standard, Requirement, Criterion, Or Limitation	Citation Or Reference	Description	Status	Comments
Groundwater	EPA Underground Injection Control (UIC) Program Regulations	40 CFR 144 and 146	Regulates injections into underground sources of drinking water by specific classes of injection wells.	Relevant and Appropriate	Relevant to any in-situ remediation technologies that involve injection into the drinking water aquifer.
	Transportation of Hazardous Wastes	49 CFR 170-189	Federal Highway Administration, Department of Transportation National Highway Traffic Safety Administration regulations are codified in 23 CFR Parts 1-1399.	Applicable	Applicable to remedial activities that involve the off-site transportation of hazardous waste.
WASHINGTON					
Hazardous Waste	Ecology Dangerous Waste Regulations	WAC 173-303-141 to 270	Establishes guidelines for Treatment, storage and disposal and transportation of Dangerous waste	Applicable	Applicable to hazardous materials generated at the site.
	Ecology Dangerous Waste Regulations	WAC 173-303-080 to -100	Establishes guidelines to determine dangerous waste lists, characteristics, criteria	Applicable	Applicable to hazardous materials generated at the site.
	Land Disposal Restrictions	WAC 173-303-140	Establishes standards for land disposal of Ecology dangerous waste.	Applicable	Applicable if remedial activities include land disposal of Ecology dangerous waste.
Surface Water	Water Pollution Control Act	WAC 173-201A; WAC 173-220;	Establishes water quality standards for surface waters of the state. Waste discharge permits, whether issued pursuant to the NPDES or otherwise, shall be conditioned so that the discharge authorized will meet water quality standards.	Relevant	Substantive requirements will be applicable to any alternative that discharges effluent to surface water.

Table 3-3
Action-Specific ARARs/TBCs

Matrix	Standard, Requirement, Criterion, Or Limitation	Citation Or Reference	Description	Status	Comments
Groundwater	Water Quality Standards for Waters	WAC 173-201	Effluent must meet water quality standards	Relevant	In the absence of an MCL or ambient WQC, EPA Region 10 conducted a risk assessment of the chemical and provides an appropriate treatment goal for the protection of public health, welfare and the environment.
	State Waste Discharge Program	WAC 173-216	Must meet pre-treatment regulations as revised for operations of the secondary sewage treatment plant.	Applicable	Applicable if the option of discharge to the sanitary sewer is chosen, it must be consistent with discharge limitations.
Air	Washington Environmental Quality law	WAC 173-400	General Regulations for Air Pollution Sources	Applicable	Substantive requirements will be applicable if alternative results in emissions from groundwater treatment processes.
	Washington Clean Air Act	WAC 173-460	Controls for New Sources of Toxic Air Pollutants	Applicable	
	Washington Clean Air Act	WAC 173-470	Ambient air quality standards	Applicable	
	State Environmental Policy Act (SEPA)	WAC 192-11	Requires a review of potential damage that occurs to the environment as a result of man's activities. SEPA checklist may be required prior to construction of the remediation system.	Applicable	
LOCAL REGULATIONS					

Table 3-3
Action-Specific ARARs/TBCs

Matrix	Standard, Requirement, Criterion, Or Limitation	Citation Or Reference	Description	Status	Comments
	City of Tacoma		Establishes criteria for review and analysis of all development, including grading, erosion control, and property development. Requires permits for excavation of soil in excess of 50 cubic yards and construction and demolition activities. SEPA checklist required if soil excavation is greater than 500 cubic yards. Permit required for connection if effluent water from the treatment system to the storm drain system. Even though it is necessary to meet the substantive provisions of these permits, appropriate permits should be obtained from the City for future site work in the spirit of cooperation.	Applicable	
	Tacoma Power		Permits required for temporary power connections and wiring for remediation systems.	Applicable	

Table 4-1
Summary of Cost Estimates for Remedial Alternatives

Alternative	Alternative Name	Total Capital Cost	Annual O&M Cost	Present Worth
Filter Cake and Shallow Impacted Soil				
FC1	No Action	$0	$0	$0
FC2	Institutional Controls	$30,600	$39,000	$114,800
FC3	Capping Contaminated Soils In Place	$798,100	$75,400	$1,267,300
FC4	Excavation of Soils, Transportation to and Disposal in RCRA Subtitle C or D Landfill	$2,346,500	$68,900	$2,801,700
Deep Vadose Zone Soil and Upper Saturated Zone East of Time Oil Building				
SG1	No Action	$0	$0	$0
SG2	Institutional Controls	$30,600	$39,000	$114,800
SG3	Insitu Thermal Remediation	$4,106,200	$110,500	$4,662,000
High Concentration Groundwater				
HG1	No Action	$0	$0	$0
HG2	Institutional Controls	$61,300	$52,000	$173,500
HG3	Extraction and Treatment with GETS	$30,600	$339,300	$3,708,000
HG4	Enhanced Anaerobic Bioremediation	$2,423,900	$408,200	$4,217,700
HG5	Enhanced Anaerobic Bioremediation plus Air Sparging and Soil Vapor Extraction	$3,344,800	$545,100	$5,275,500
Low Concentration Groundwater				
LG1	No Action	$0	$0	$0
LG2	Wellhead Treatment at Well 12A	$341,500	$263,900	$2,094,200

Table 5-1
Summary of Comparative Analysis of Alternatives

Alternative	Overall Protection of Human Health and the Environment	Compliance with ARARs	Long-term Effectiveness and Permanence	Reduction of Toxicity, Mobility, or Volume through Treatment	Short-term Effectiveness	Implementability	Present Worth Capital O&M Present Worth
Filter Cake and Shallow Impacted Soil							
Alternative FC1 – No Action	**None** - This threshold criterion is not met	**None** - This threshold criterion is not met	**Not evaluated** - Does not meet threshold criterion	**Not Evaluated** - Does not meet threshold criterion	**Not evaluated** - Does not meet threshold criterion	**Not evaluated** - Does not meet threshold criterion	$0 $0 $0
Alternative FC2 – Institutional Controls	**Low** - Contaminated filter cake and shallow impacted soil would remain in place + Institutional controls restricting human exposure to material would be implemented	**Low** - Chemical-specific ARARs (MTCA B modified level) would not be achieved	**Low** - Institutional controls wouldn't provide long-term effectiveness or permanence as contamination would persist in filter cake and shallow impacted soil	**Low** - TMV would not be reduced through treatment	**Low Impacts** + There would be no remedial activities	**High** + Easily implemented because minimal maintenance is required	$30,600 $39,000 $114,800
Alternative FC3 – Asphalt Cap	**Medium** + Asphalt cap would be used as a cover reducing transport of contaminants to groundwater and eliminating direct contact pathway - Some transport to depth may occur through vapor migration and some minimal leaching	**Medium Low** - Contaminants would most likely persist above chemical-specific ARARs beyond the 30-year evaluation period if no source control is implemented - Some transport to depth may occur through vapor migration and some minimal leaching	**Medium High** +Reduces direct contact - Some, but minimal, O&M required	**Medium** + Mobility of contaminants would be reduced - Volume of contaminated material would remain - Toxicity would not be reduced, but cap would prevent contact	**Medium** - Construction workers would be subject to some direct exposure risk while capping that can be effectively managed using standard health and safety procedures - Emissions during paving would need to be managed to prevent offsite risk + Approximately 1 month to implement	**High** + Construction can be conducted using conventional heavy construction equipment + Administrative requirements associated with this alternative are not significant	$798,100 $75,400 $1,267,300
Alternative FC4 – Excavation and Offsite Disposal	**High** + All contaminated material in zone would be excavated and transported off site for treatment and disposal at a permitted facility + Human health and ecological receptor risk via direct contact with contaminated surface soils would be eliminated + All migration of contaminants to GW and stormwater would be eliminated	**High** + Alternative will comply with ARARs and RAOs	**High** + This remedy would allow for unrestricted use at the site + No O&M would be required + No institutional controls would be required	**High** + TMV of site contaminants would be eliminated by removing contaminants from the site for offsite treatment and disposal	**Medium High** - Construction workers would be subject to some exposure from excavation, but can be managed using standard H&S procedures and protocols - Concerns with effects on local traffic and population due to number of trucks leaving site + Approximately 2 months to implement	**Medium High** + Construction can be conducted using conventional equipment and services - Planning will need to be conducted prior to work to arrange transportation schedules - Significant quantities of clean material would be needed for backfill	$2,346,500 $68,900 $2,801,700

Table 5-1
Summary of Comparative Analysis of Alternatives

Alternative	Overall Protection of Human Health and the Environment	Compliance with ARARs	Long-term Effectiveness and Permanence	Reduction of Toxicity, Mobility, or Volume through Treatment	Short-term Effectiveness	Implementability	Present Worth
Deep Vadose Zone Soil and Upper Saturated Zone							
Alternative SG1 – No Action	**None** - This threshold criterion is not met	**None** - This threshold criterion is not met	**Not evaluated** - Does not meet threshold criterion	**Not Evaluated** - Does not meet threshold criterion	**Not evaluated** - Does not meet threshold criterion	**Not evaluated** - Does not meet threshold criterion	$0 $0 $0
Alternative SG2 – Institutional Controls	**Low** - Contaminated soil and groundwater would remain in place and continue to be a source for downgradient groundwater contamination + Institutional controls would restrict exposure	**Low** - Chemical-specific ARARs (MTCA B modified level) would not be achieved - RAO of mass reduction not met	**Low** - Institutional controls wouldn't provide long-term effectiveness or permanence as contamination would persist in soil and groundwater	**Low** - TMV would not be reduced through treatment	**Low Impacts** + There would be no remedial activities	**High** + Easily implemented because only minimal maintenance is required	$30,600 $39,000 $114,800
Alternative SG3 – In-Situ Thermal Remediation	**High** + Continuing source to groundwater removed or substantially decreased	**High** + Concentrations may decrease to below MTCA B-levels + Will be designed to meet RAO of reducing contaminant mass by more than 90%	**High** + Reduce contaminant concentrations in the soil and groundwater plume + Source area is being removed/reduced	**High** + Toxicity and volume of contaminated soil and groundwater reduced + Extracted VOCs would be transferred to carbon media, which would be regenerated thereby permanently destroying the VOCs	**Medium** + Treatment system could be completed within six months of site mobilization and the ITR heating phase would last approximately six months - Medium to high risk to workers and community since many wells will be installed	**Medium High** + Contractors are available that specialize in this innovative technology - Administrative and technical requirements are moderately intensive due to significant number of wells to drill into subsurface in area with underground utilities	$4,106,200 $110,500 $4,662,000

Table 5-1
Summary of Comparative Analysis of Alternatives

Alternative	Overall Protection of Human Health and the Environment	Compliance with ARARs	Long-term Effectiveness and Permanence	Reduction of Toxicity, Mobility, or Volume through Treatment	Short-term Effectiveness	Implementability	Present Worth
High Concentration Groundwater							
Alternative HG1 – No Action	**None** - This threshold criterion is not met	**None** - This threshold criterion is not met	**Not evaluated** - Does not meet threshold criterion	**Not Evaluated** - Does not meet threshold criterion	**Not evaluated** - Does not meet threshold criterion	**Not evaluated** - Does not meet threshold criterion	$0 $0 $0
Alternative HG2 – Institutional Controls	**Low** - Contaminated Ground water/ saturated soil would remain in place -Contaminants will continue to migrate impact GW - Institutional controls would not be implemented to restrict future site development/use	**Low** - Chemical specific ARARs would not be achieved - Source materials would continue to impact groundwater above risk-based ARARs - RAO of flux reduction will not be met.	**Low** - No Action would not provide long-term effectiveness or permanence - Current soil cap will not be effective over the long term	**None** - TMV of contaminants would not be reduced through treatment	**No Impacts** + There would be no remedial activities, therefore no short-term effectiveness issues	**High** + Easily implemented because minimal action is performed	$61,300 $52,000 $173,500
Alternative HG3 – Groundwater Extraction and Treatment	**Medium** + Extraction system provides some hydraulic control; + Goal is to reduce contaminants below MCL - Some uncertainty in control at south/southwest part of plume -System has operated for 20 years and substantial mass still remains	**Medium Low** + Alternative complies with location- and action-specific ARARs - Contaminants would persist above chemical-specific ARARs within the aquifer beyond the 30-year evaluation period - RAO of flux reduction will not be met.	**Medium Low** + Zone of capture covers area were NAPL is detected + Organic contaminants would be treated - The aquifers will not be remediated where NAPL remains - Long-term O&M of the extraction and treatment system would be required - Life of system may be reached before cleanup goal achieved	**Medium** + Mobility of groundwater contaminants is reduced + Organic fraction on carbon is permanently destroyed when carbon is regenerated - Only the mobile fraction of contaminants would be treated - Presence of NAPL prevents reductions in toxicity and volume	**Low Impacts** + Workers will be exposed to a minimal risk	**High** + Easily implemented +Treatment system already constructed and operational	$30,600 $339,300 $3,708,000
Alternative HG4 – Enhanced Anaerobic Bioremediation	**Medium High** +Destruction of organics would occur, some concentration may remain above MCLs +Food grade substrate will be used therefore, groundwater toxicity will not be increased + EAB can remove NAPL	**Medium High** - Chemical-specific ARARs may not be achieved, but concentrations will be reduced. + Alternative would comply with location- and action-ARARs - RAO of flux reduction will be met	**High** + Mass will be reduced in this source area, thus reducing continued source + Organic contaminants would be treated + Other than long-term groundwater monitoring, no O&M expected after second amendment injection + Takes advantage of natural conditions to reduce concentrations for long-term effectiveness	**High** + TMV of groundwater would be significantly reduced through treatment + Reductions in TMV would be achieved for organic contaminants	**Medium Impacts** + Each of two amendment injection rounds are expected to be completed within approximately 1 -2 months - Medium risk to workers and community since many wells will be installed	**Medium** +Contractors are available with this technology experience +Main construction component is well installation - Wells need to be placed on private property and right of ways which may be difficult administratively	$2,423,900 $408,200 $4,217,700

Table 5-1
Summary of Comparative Analysis of Alternatives

Alternative	Overall Protection of Human Health and the Environment	Compliance with ARARs	Long-term Effectiveness and Permanence	Reduction of Toxicity, Mobility, or Volume through Treatment	Short-term Effectiveness	Implementability	Present Worth
Alternative 5 – Air Sparging and Soil Vapor Extraction plus Enhanced Anaerobic Bioremediation	**Medium High** +Destruction of organics would occur, some concentration may remain above MCLs + Aggressive AS/SVE at Time Oil Building should remove NAPL	**Medium High** - Chemical-specific ARARs may not be achieved, but concentrations will be reduced. + Alternative would comply with location- and action-ARARs - RAO of flux reduction will be met	**Medium Low** + Mass will be reduced in this source area, thus reducing continued source - Trained staff needed for O&M of AS/SVE - The addition of oxygen expected to counteract with the anaerobic conditions, thus reducing or eliminating the effectiveness of this existing natural process	**Medium High** + Toxicity and volume of organic contaminants would be permanently reduced + Organic fraction sorbed in vapor on carbon is permanently destroyed when carbon is regenerated	**Medium to High Impacts** + Each of two amendment injection rounds are expected to be completed within approximately 1 -2 months + AS/SVE will begin to remove contaminants immediately and is assumed to operate approximately 4 years - Medium risk to workers and community since many wells will be advanced -Trenching for piping may expose workers to volatiles	**Medium** +Contractors available with technology experience +Main construction component is well installation and piping +As/SVE component is located on Time Oil property - Amendment injection wells need to be placed on private property and right of ways which may be administratively difficult	\$3,344,800 \$545,100 \$5,275,500

Table 5-1
Summary of Comparative Analysis of Alternatives

Alternative	Overall Protection of Human Health and the Environment	Compliance with ARARs	Long-term Effectiveness and Permanence	Reduction of Toxicity, Mobility, or Volume through Treatment	Short-term Effectiveness	Implementability	Present Worth
Lower Concentration Groundwater							
Alternative LG1 – No Action	**None** - This threshold criterion is not met	**None** - This threshold criterion is not met	**Not evaluated** - Does not meet threshold criterion	**Not Evaluated** - Does not meet threshold criterion	**Not evaluated** - Does not meet threshold criterion	**Not evaluated** - Does not meet threshold criterion	$0 $0 $0
Alternative LG2 – Wellhead Treatment at Well12A	**High** + Safe drinking water supply provided to residents + Institutional controls would be implemented to protect human health + Long-term monitoring would be performed to document potential future offsite contaminant migration	**High** + Drinking water meets MCLs	**Medium High** + Minimal annual O&M needed - Stripping towers have operated since the early 1980s and some upgrades may be needed within 30 year evaluation period + Strong evidence supports aerobic degradation is active in low concentration plume and will continue.	**Medium** + Mobility reduced by removing VOCs from subsurface + VOCs removed from water via air stripping + Aerobic degradation will also reduce VOC concentrations in the low concentration plume if source removal is implemented	**Low Impacts** + Minimal exposure risk to O&M workers + Sampling personnel exposed to minimal risk - Long-term groundwater monitoring may continue for more than 30 years	**High** + Treatment unit already in place and operational	$341,500 $263,900 $2,094,200

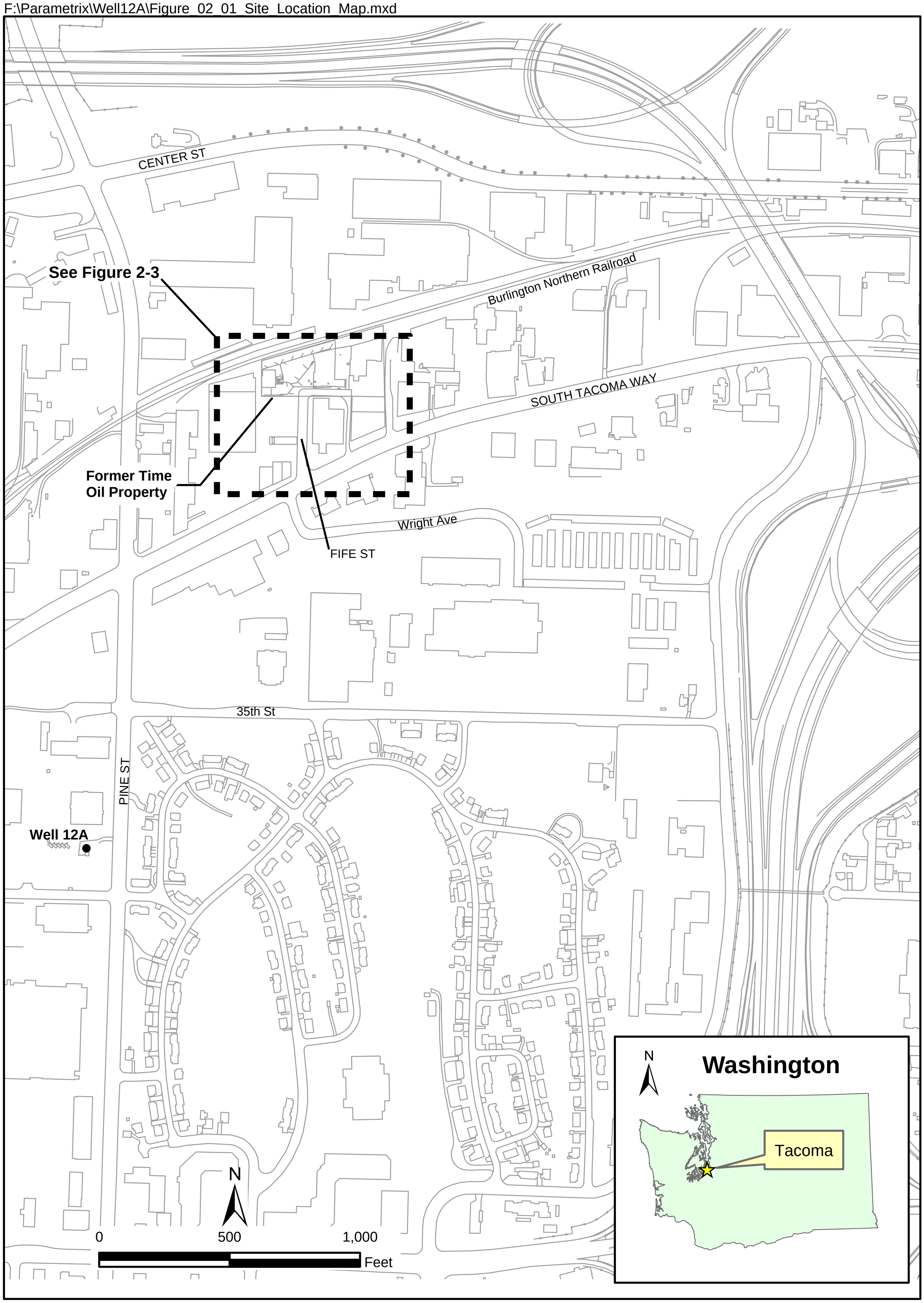
Table 5-2
Alternative Groups and Cost Estimates

Group	Treatment Zones				FFS Estimate
	Filter Cake and Shallow Soil	**Deep soil and high concentration groundwater (TCE and cis-1,2DCE > 300 ug/l) east of Time Oil Building**	**High concentration groundwater (TCE and cis-1,2DCE > 300 ug/l) groundwater west and south of Time Oil Building**	**Low Concentration (TCE and cis-1,2DCE < 300 ug/l) groundwater**	
1	No Action	No Action	No Action	No Action	$0
2	Institutional Controls	Institutional Controls	- Extraction and Treatment with GETS - Institutional Controls	- Wellhead Treatment - Institutional Controls	$5.1 million
3	- Excavation - Institutional Controls	- In-situ Thermal Remediation - Institutional Controls	- Enhanced Anaerobic Bioremediation (west and south of the building); - Extraction and Treatment with GETS (time limited) - Institutional Controls	- Wellhead treatment - Long term monitoring; - Institutional Controls	$14.0 million
4	- Excavation - Capping - Institutional Controls	- In-situ Thermal Remediation; - Institutional Controls	- Air Sparge/Soil Vapor Extraction (west of building) - Enhanced Anaerobic Bioremediation (south of building) - Extraction and Treatment with existing GETS (time limited) - Institutional Controls	- Wellhead treatment - Long term monitoring - Institutional Controls	$16.4 million

Estimate is Net Present Worth

Figures

F:\Parametrix\Well12A\Figure_02_01_Site_Location_Map.mxd



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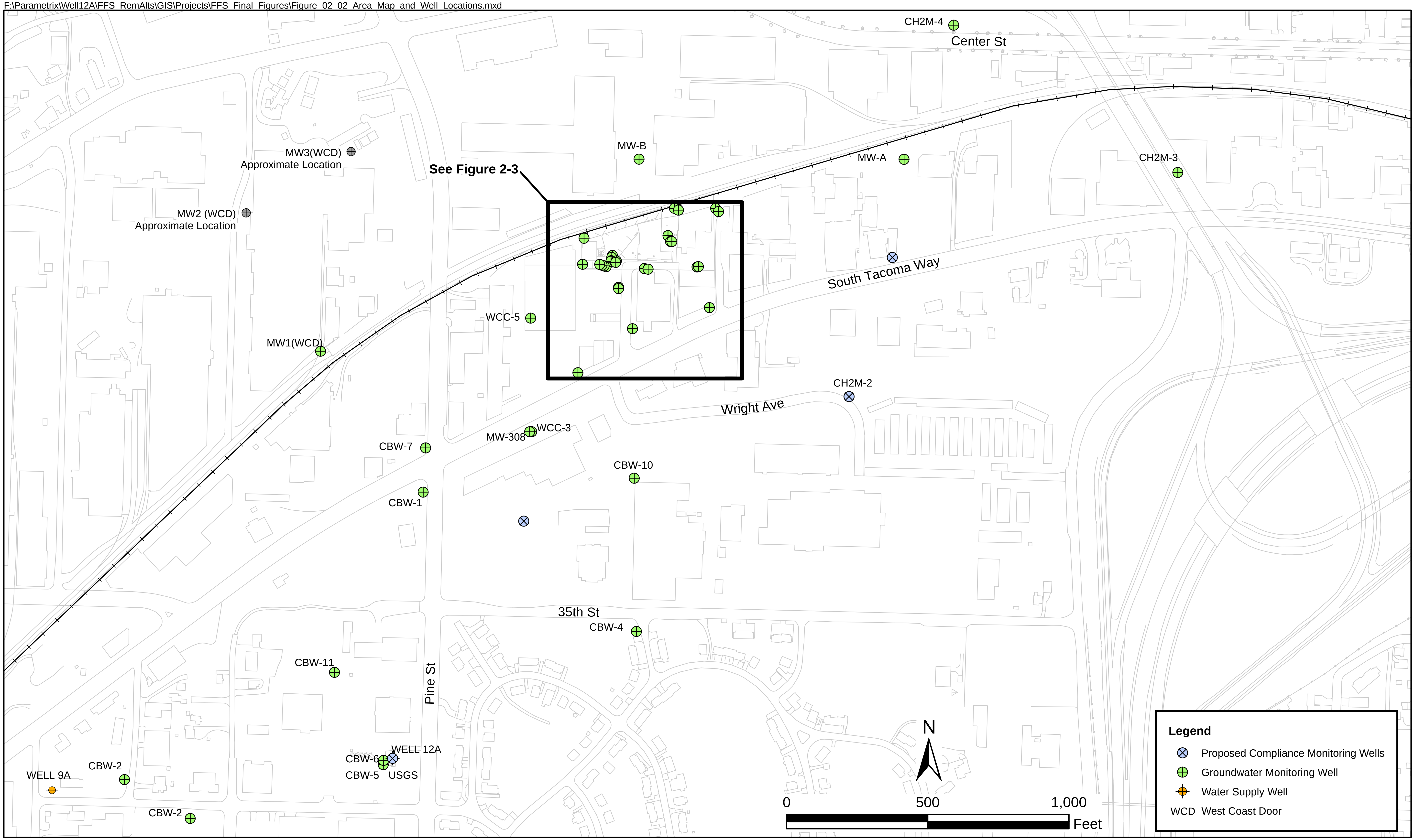
Well 12A Superfund Site
Tacoma, Washington

Figure 2-1
Location Map

F:\Parametrix\Well12A\FFS_RemAlts\GIS\Projects\FFS_Final_Figures\Figure_02_02_Area_Map_and_Well_Locations.mxd



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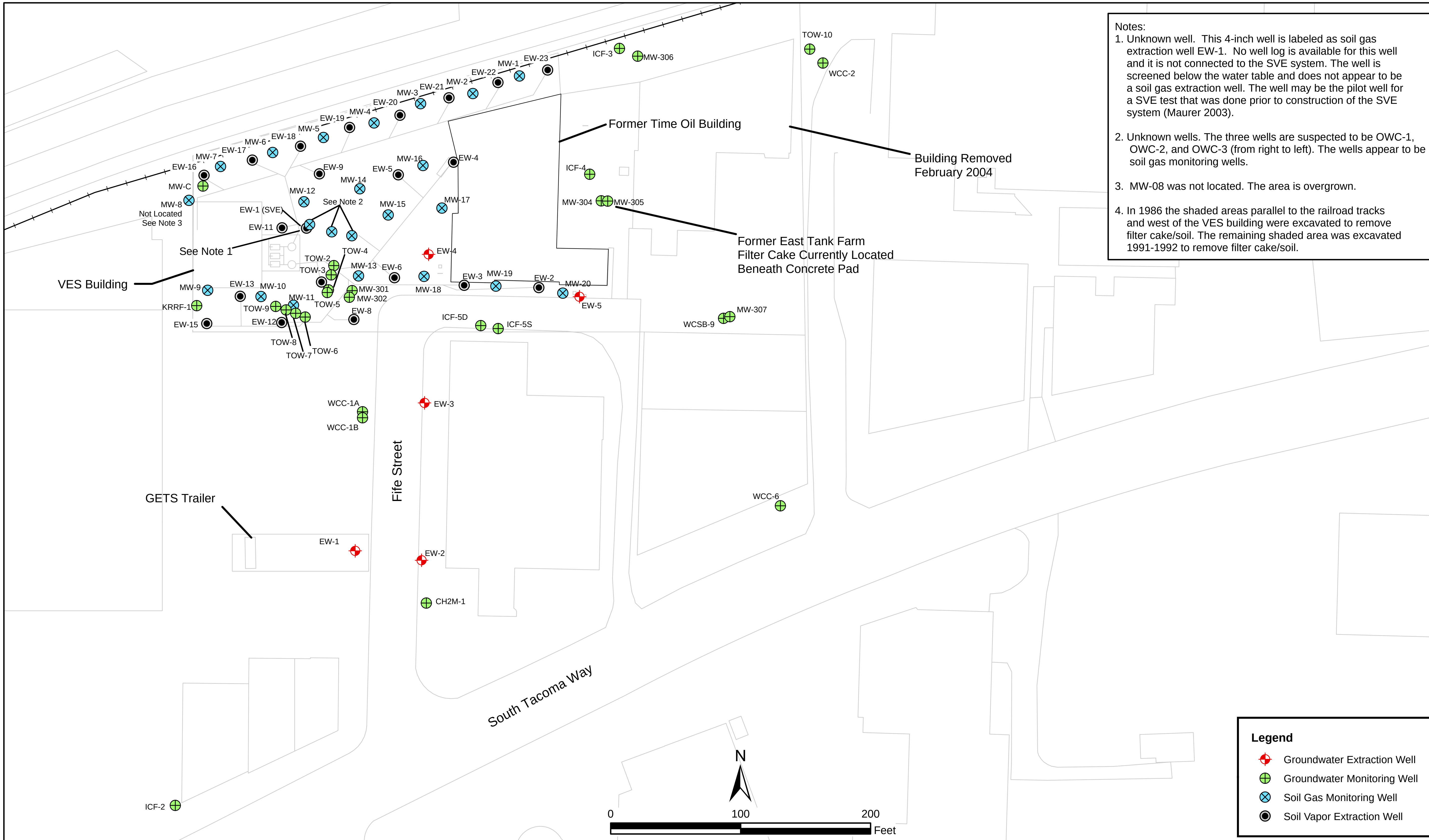
Well 12A Superfund Site
Tacoma, Washington

Figure 2-2
Area Map and Well Locations



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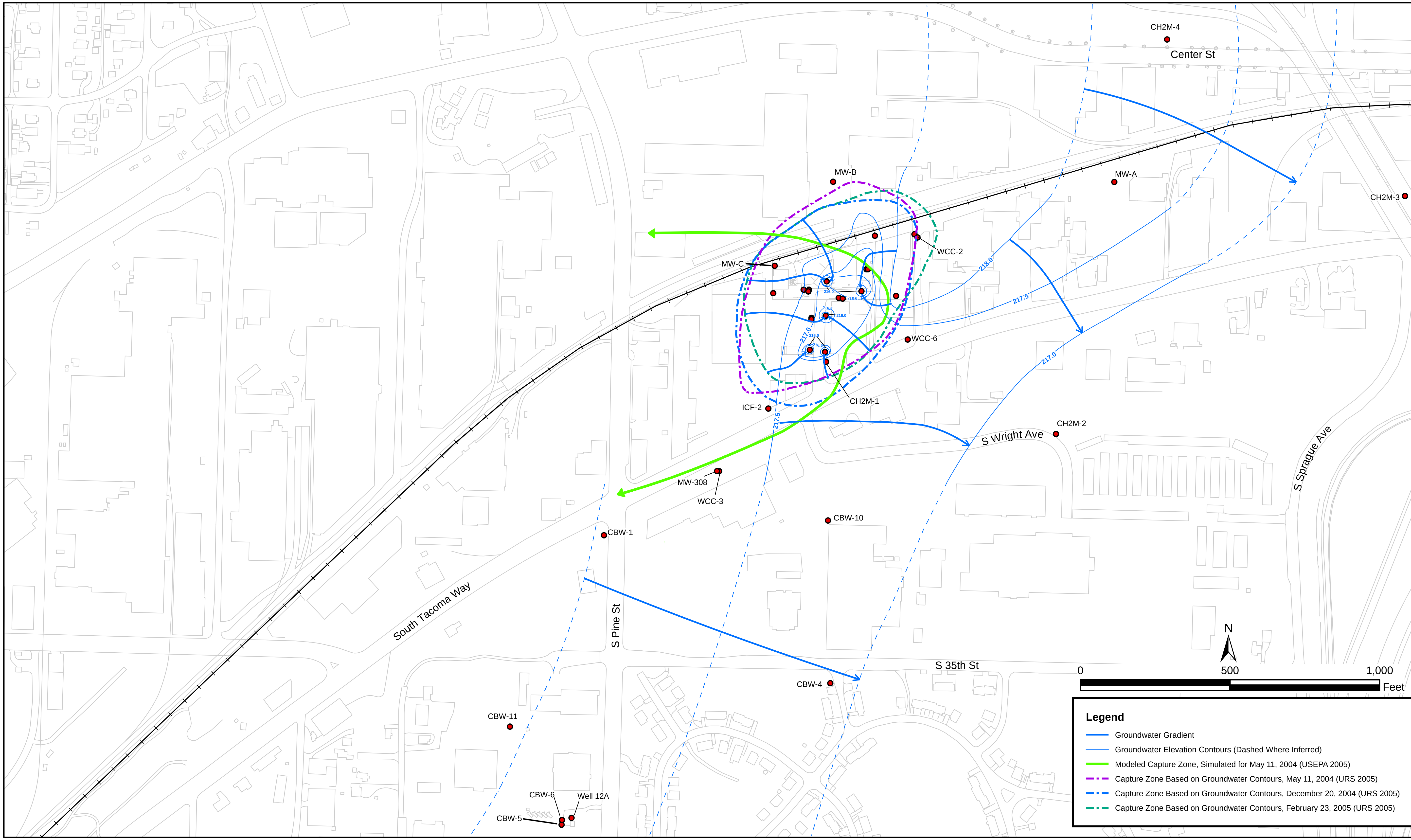
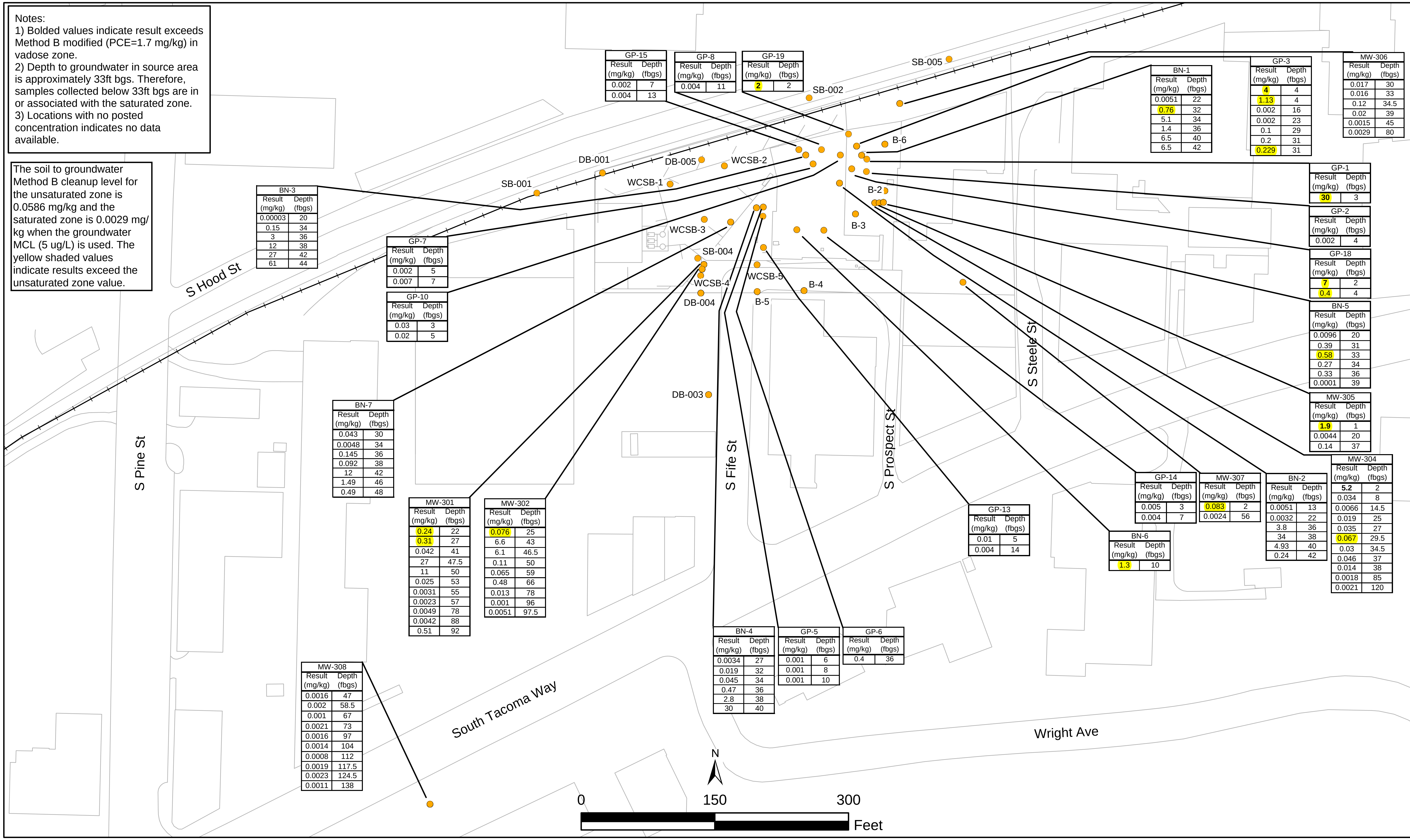
Well 12A Superfund Site
Tacoma, Washington

Figure 2-3
Site Map and Well Locations



Well 12A Superfund Site
Tacoma, Washington

Figure 2-4
Groundwater Flow Gradients and Capture Zone Extent



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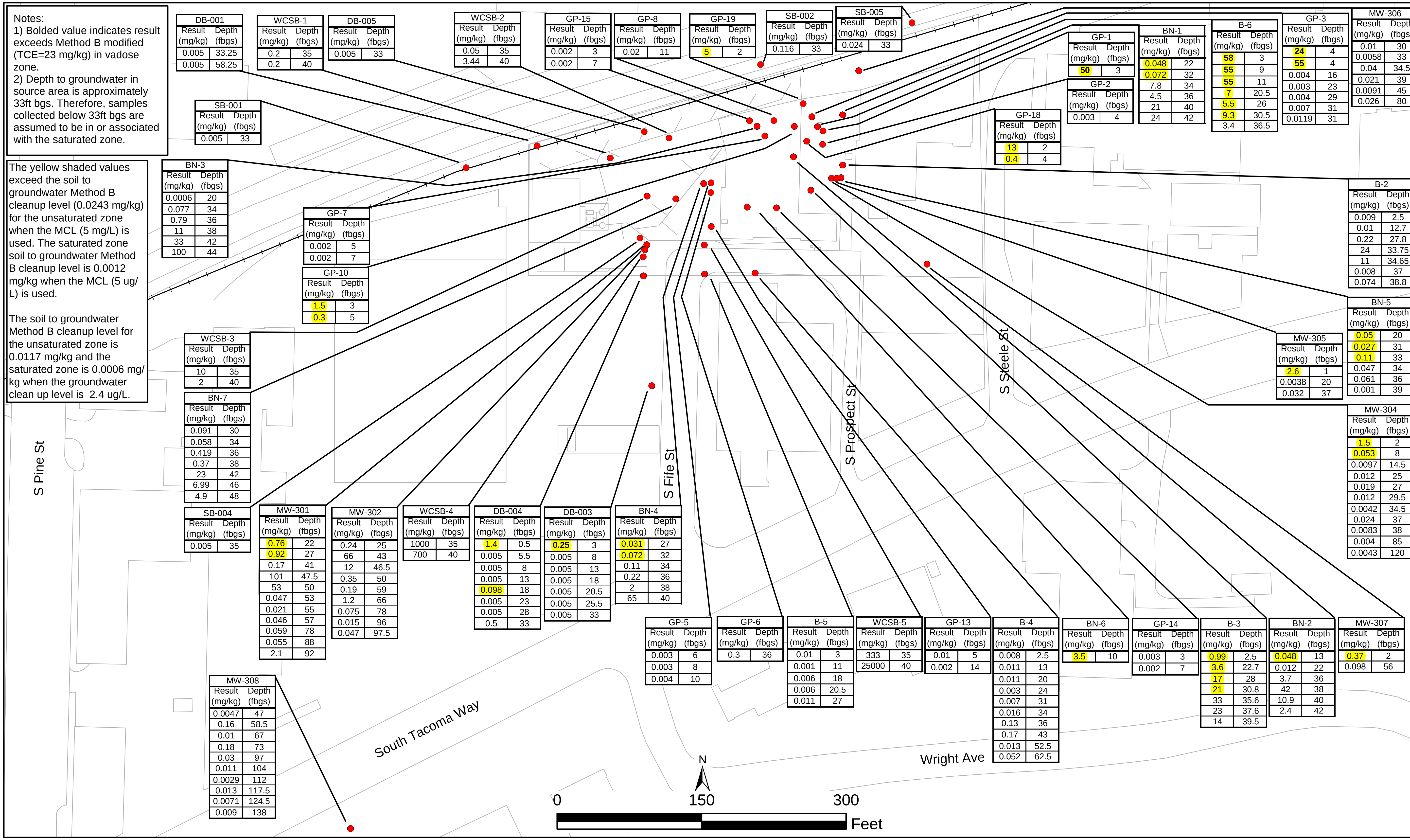
Well 12A Superfund Site
Tacoma, Washington

Figure 2-5
Tetrachloroethylene in Soil



Notes:
1) Bolded value indicates result exceeds Method B modified (TCE=23 mg/kg) in vadose zone.
2) Depth to groundwater in source area is approximately 33ft bgs. Therefore, samples collected below 33ft bgs are assumed to be in or associated with the saturated zone.

The yellow shaded values exceed the soil to groundwater Method B cleanup level (0.0243 mg/kg) for the unsaturated zone when the MCL (5 mg/L) is used. The saturated zone soil to groundwater Method B cleanup level is 0.0012 mg/kg when the MCL (5 ug/L) is used.

The soil to groundwater Method B cleanup level for the unsaturated zone is 0.0117 mg/kg and the saturated zone is 0.0006 mg/kg when the groundwater clean up level is 2.4 ug/L.

DB-001

Result (mg/kg)	Depth (fbgs)
0.005	33.25
0.005	58.25

WCSB-1

Result (mg/kg)	Depth (fbgs)
0.2	35
0.2	40

DB-005

Result (mg/kg)	Depth (fbgs)
0.005	33

WCSB-2

Result (mg/kg)	Depth (fbgs)
0.05	35
3.44	40

GP-15

Result (mg/kg)	Depth (fbgs)
0.002	3
0.002	7

GP-8

Result (mg/kg)	Depth (fbgs)
0.02	11

GP-19

Result (mg/kg)	Depth (fbgs)
5	2

SB-002

Result (mg/kg)	Depth (fbgs)
0.116	33

SB-005

Result (mg/kg)	Depth (fbgs)
0.024	33

GP-1

Result (mg/kg)	Depth (fbgs)
50	3

GP-2

Result (mg/kg)	Depth (fbgs)
0.003	4

BN-1

Result (mg/kg)	Depth (fbgs)
0.048	22
0.072	32
7.8	34
4.5	36
21	40
24	42

B-6

Result (mg/kg)	Depth (fbgs)
58	3
55	9
55	11
7	20.5
5.5	26
9.3	30.5
3.4	36.5

GP-3

Result (mg/kg)	Depth (fbgs)
24	4
55	4
0.004	16
0.003	23
0.004	29
0.007	31
0.0119	31

MW-306

Result (mg/kg)	Depth (fbgs)
0.01	30
0.0058	33
0.04	34.5
0.021	39
0.0091	45
0.026	80

SB-001

Result (mg/kg)	Depth (fbgs)
0.005	33

GP-18

Result (mg/kg)	Depth (fbgs)
13	2
0.4	4

BN-3

Result (mg/kg)	Depth (fbgs)
0.0006	20
0.077	34
0.79	36
11	38
33	42
100	44

GP-7

Result (mg/kg)	Depth (fbgs)
0.002	5
0.002	7

GP-10

Result (mg/kg)	Depth (fbgs)
1.5	3
0.3	5

B-2

Result (mg/kg)	Depth (fbgs)
0.009	2.5
0.01	12.7
0.22	27.8
24	33.75
11	34.65
0.008	37
0.074	38.8

BN-5

Result (mg/kg)	Depth (fbgs)
0.05	20
0.027	31
0.11	33
0.047	34
0.061	36
0.001	39

MW-305

Result (mg/kg)	Depth (fbgs)
2.6	1
0.0038	20
0.032	37

WCSB-3

Result (mg/kg)	Depth (fbgs)
10	35
2	40

BN-7

Result (mg/kg)	Depth (fbgs)
0.091	30
0.058	34
0.419	36
0.37	38
23	42
6.99	46
4.9	48

MW-304

Result (mg/kg)	Depth (fbgs)
1.5	2
0.053	8
0.0097	14.5
0.012	25
0.019	27
0.012	29.5
0.0042	34.5
0.024	37
0.0083	38
0.004	85
0.0043	120

SB-004

Result (mg/kg)	Depth (fbgs)
0.005	35

MW-301

Result (mg/kg)	Depth (fbgs)
0.76	22
0.92	27
0.17	41
101	47.5
53	50
0.047	53
0.021	55
0.046	57
0.059	78
0.055	88
2.1	92

MW-302

Result (mg/kg)	Depth (fbgs)
0.24	25
66	43
12	46.5
0.35	50
0.19	59
1.2	66
0.075	78
0.015	96
0.047	97.5

WCSB-4

Result (mg/kg)	Depth (fbgs)
1000	35
700	40

DB-004

Result (mg/kg)	Depth (fbgs)
1.4	0.5
0.005	5.5
0.005	8
0.005	13
0.098	18
0.005	23
0.005	28
0.5	33

DB-003

Result (mg/kg)	Depth (fbgs)
0.25	3
0.005	8
0.005	13
0.005	18
0.005	20.5
0.005	25.5
0.005	33

BN-4

Result (mg/kg)	Depth (fbgs)
0.031	27
0.072	32
0.11	34
0.22	36
2	38
65	40

MW-308

Result (mg/kg)	Depth (fbgs)
0.0047	47
0.16	58.5
0.01	67
0.18	73
0.03	97
0.011	104
0.0029	112
0.013	117.5
0.0071	124.5
0.009	138

GP-5

Result (mg/kg)	Depth (fbgs)
0.003	6
0.003	8
0.004	10

GP-6

Result (mg/kg)	Depth (fbgs)
0.3	36

B-5

Result (mg/kg)	Depth (fbgs)
0.01	3
0.001	11
0.006	18
0.006	20.5
0.011	27

WCSB-5

Result (mg/kg)	Depth (fbgs)
333	35
25000	40

GP-13

Result (mg/kg)	Depth (fbgs)
0.01	5
0.002	14

B-4

Result (mg/kg)	Depth (fbgs)
0.008	2.5
0.011	13
0.011	20
0.003	24
0.007	31
0.016	34
0.13	36
0.17	43
0.013	52.5
0.052	62.5

BN-6

Result (mg/kg)	Depth (fbgs)
3.5	10

GP-14

Result (mg/kg)	Depth (fbgs)
0.003	3
0.002	7

B-3

Result (mg/kg)	Depth (fbgs)
0.99	2.5
3.6	22.7
17	28
21	30.8
33	35.6
23	37.6
14	39.5

BN-2

Result (mg/kg)	Depth (fbgs)
0.048	13
0.012	22
3.7	36
42	38
10.9	40
2.4	42

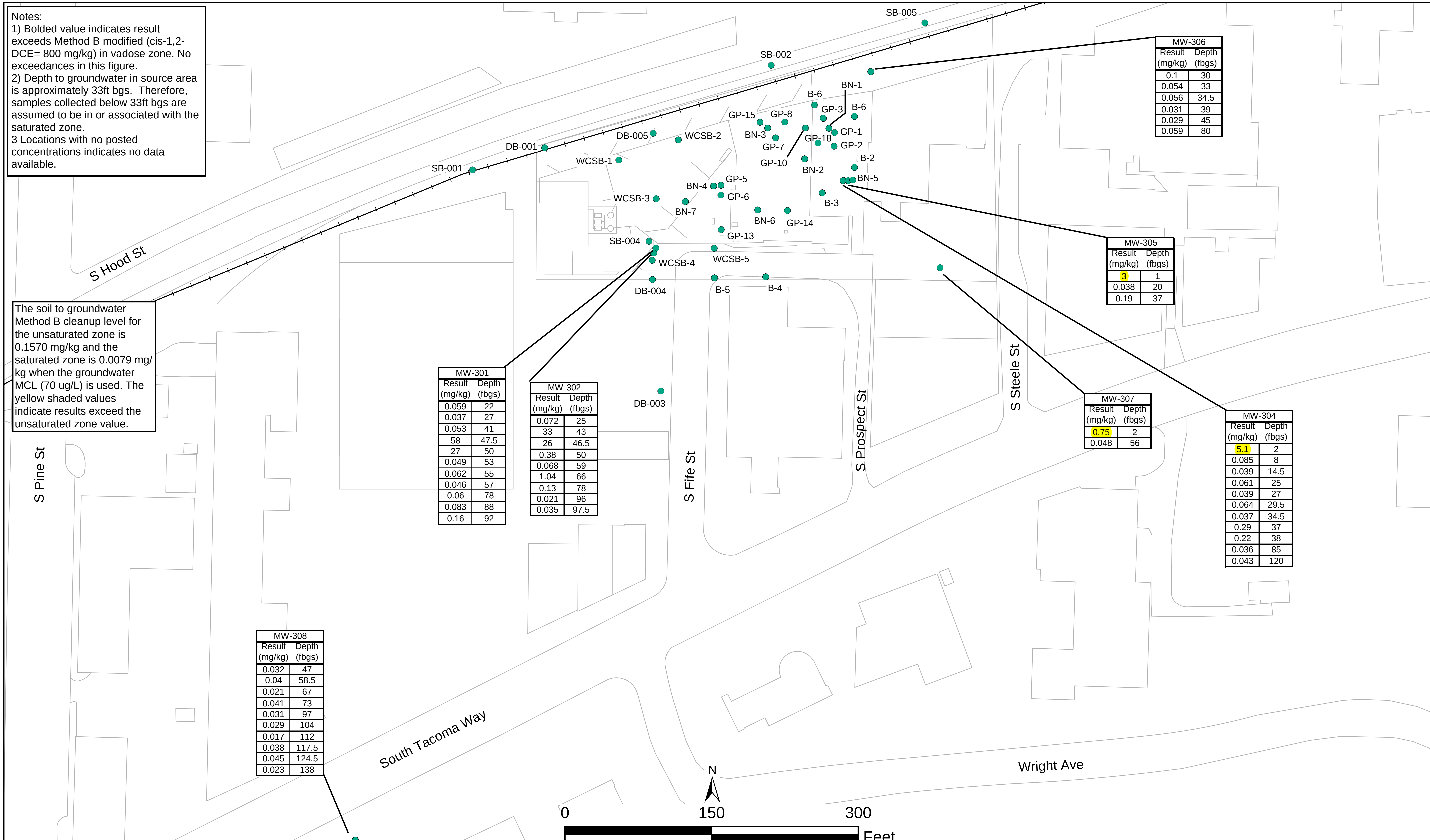
MW-307

Result (mg/kg)	Depth (fbgs)
0.37	2
0.098	56

CDM

Well 12A Superfund Site
Tacoma, Washington

Figure 2-6
Trichloroethylene in Soil



Notes:
1) Bolded value indicates result exceeds Method B modified (cis-1,2-DCE= 800 mg/kg) in vadose zone. No exceedances in this figure.
2) Depth to groundwater in source area is approximately 33ft bgs. Therefore, samples collected below 33ft bgs are assumed to be in or associated with the saturated zone.
3 Locations with no posted concentrations indicates no data available.

The soil to groundwater Method B cleanup level for the unsaturated zone is 0.1570 mg/kg and the saturated zone is 0.0079 mg/kg when the groundwater MCL (70 ug/L) is used. The yellow shaded values indicate results exceed the unsaturated zone value.

MW-306

Result (mg/kg)	Depth (fbgs)
0.1	30
0.054	33
0.056	34.5
0.031	39
0.029	45
0.059	80

MW-305

Result (mg/kg)	Depth (fbgs)
3	1
0.038	20
0.19	37

MW-301

Result (mg/kg)	Depth (fbgs)
0.059	22
0.037	27
0.053	41
58	47.5
27	50
0.049	53
0.062	55
0.046	57
0.06	78
0.083	88
0.16	92

MW-302

Result (mg/kg)	Depth (fbgs)
0.072	25
33	43
26	46.5
0.38	50
0.068	59
1.04	66
0.13	78
0.021	96
0.035	97.5

MW-307

Result (mg/kg)	Depth (fbgs)
0.75	2
0.048	56

MW-304

Result (mg/kg)	Depth (fbgs)
5.1	2
0.085	8
0.039	14.5
0.061	25
0.039	27
0.064	29.5
0.037	34.5
0.29	37
0.22	38
0.036	85
0.043	120

MW-308

Result (mg/kg)	Depth (fbgs)
0.032	47
0.04	58.5
0.021	67
0.041	73
0.031	97
0.029	104
0.017	112
0.038	117.5
0.045	124.5
0.023	138

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Figure 2-7
Cis-1,2-Dichloroethylene in Soil

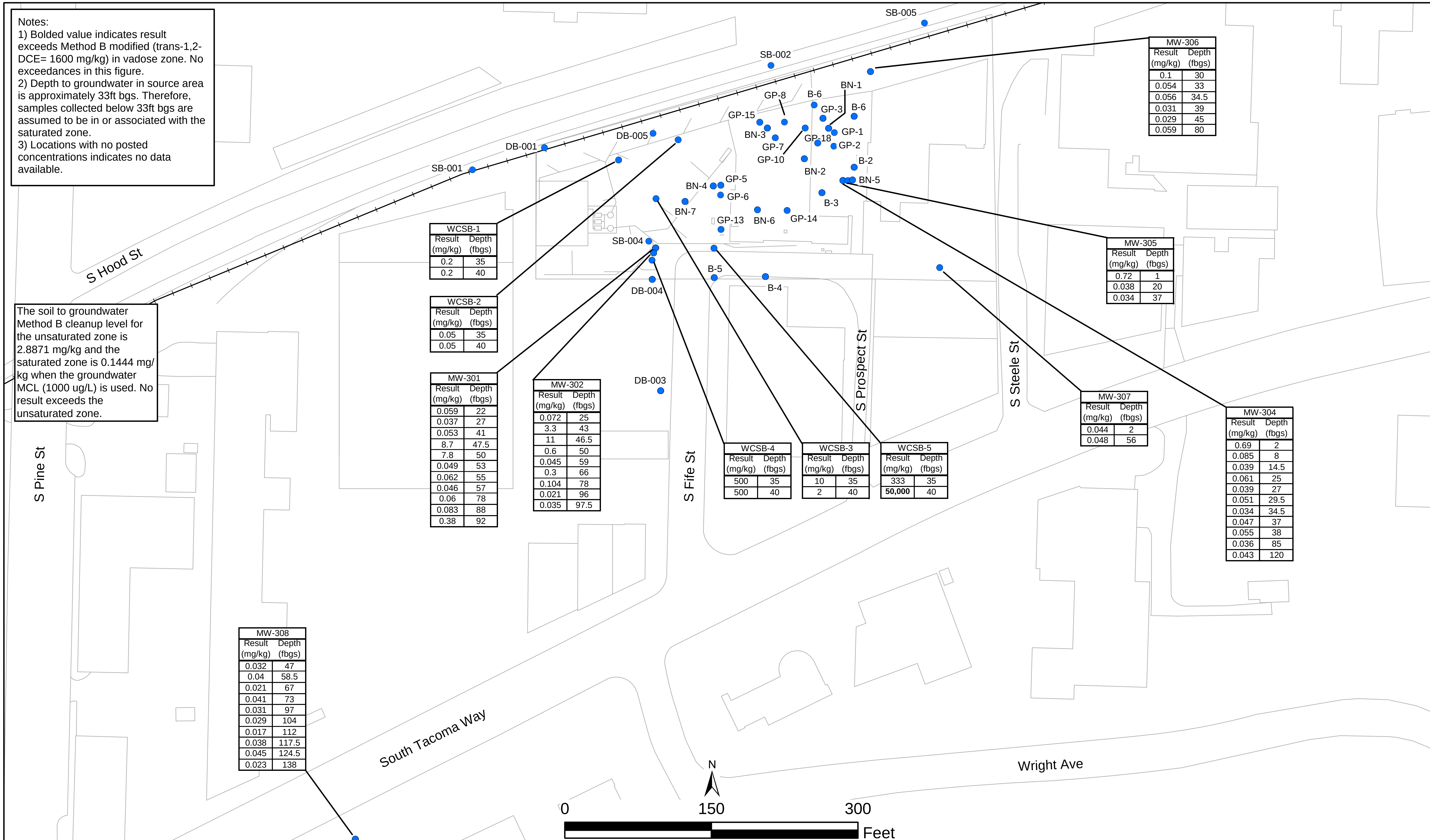

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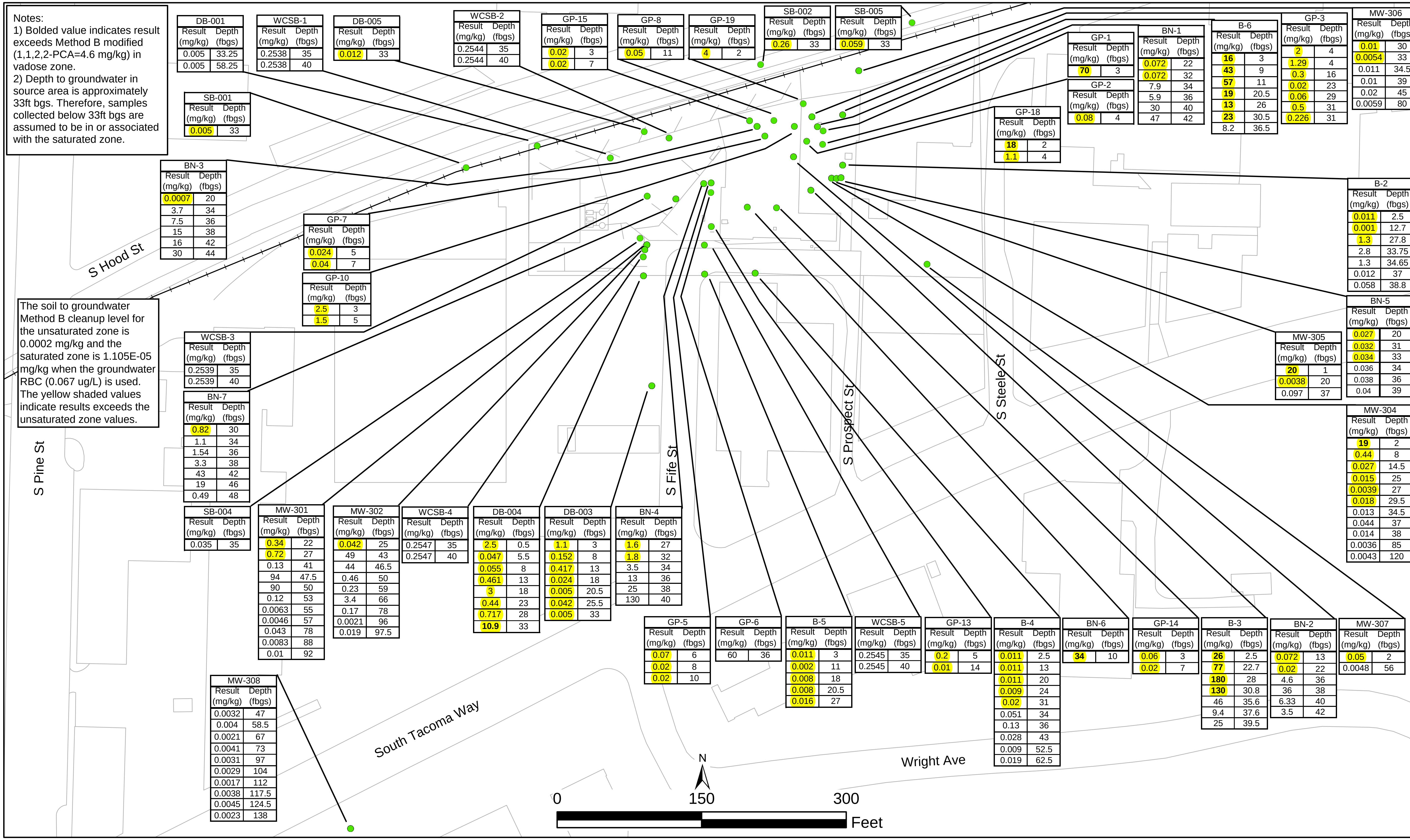
Figure 2-8
Trans-1,2-Dichloroethylene in Soil



DB-001

Result (mg/kg)	Depth (fbgs)
0.005	33.25
0.005	58.25

WCSB-1

Result (mg/kg)	Depth (fbgs)
0.2538	35
0.2538	40

DB-005

Result (mg/kg)	Depth (fbgs)
0.012	33

WCSB-2

Result (mg/kg)	Depth (fbgs)
0.2544	35
0.2544	40

GP-15

Result (mg/kg)	Depth (fbgs)
0.02	3
0.02	7

GP-8

Result (mg/kg)	Depth (fbgs)
0.05	11

GP-19

Result (mg/kg)	Depth (fbgs)
4	2

SB-002

Result (mg/kg)	Depth (fbgs)
0.26	33

SB-005

Result (mg/kg)	Depth (fbgs)
0.059	33

GP-1

Result (mg/kg)	Depth (fbgs)
70	3

GP-2

Result (mg/kg)	Depth (fbgs)
0.08	4

BN-1

Result (mg/kg)	Depth (fbgs)
0.072	22
0.072	32
7.9	34
5.9	36
30	40
47	42

B-6

Result (mg/kg)	Depth (fbgs)
16	3
43	9
57	11
19	20.5
13	26
23	30.5
8.2	36.5

GP-3

Result (mg/kg)	Depth (fbgs)
2	4
1.29	4
0.3	16
0.02	23
0.06	29
0.5	31
0.226	31

MW-306

Result (mg/kg)	Depth (fbgs)
0.01	30
0.0054	33
0.011	34.5
0.01	39
0.02	45
0.0059	80

GP-18

Result (mg/kg)	Depth (fbgs)
18	2
1.1	4

SB-001

Result (mg/kg)	Depth (fbgs)
0.005	33

BN-3

Result (mg/kg)	Depth (fbgs)
0.0007	20
3.7	34
7.5	36
15	38
16	42
30	44

GP-7

Result (mg/kg)	Depth (fbgs)
0.024	5
0.04	7

GP-10

Result (mg/kg)	Depth (fbgs)
2.5	3
1.5	5

WCSB-3

Result (mg/kg)	Depth (fbgs)
0.2539	35
0.2539	40

BN-7

Result (mg/kg)	Depth (fbgs)
0.82	30
1.1	34
1.54	36
3.3	38
43	42
19	46
0.49	48

SB-004

Result (mg/kg)	Depth (fbgs)
0.035	35

MW-301

Result (mg/kg)	Depth (fbgs)
0.34	22
0.72	27
0.13	41
94	47.5
90	50
0.12	53
0.0063	55
0.0046	57
0.043	78
0.0083	88
0.01	92

MW-302

Result (mg/kg)	Depth (fbgs)
0.042	25
49	43
44	46.5
0.46	50
0.23	59
3.4	66
0.17	78
0.0021	96
0.019	97.5

WCSB-4

Result (mg/kg)	Depth (fbgs)
0.2547	35
0.2547	40

DB-004

Result (mg/kg)	Depth (fbgs)
2.5	0.5
0.047	5.5
0.055	8
0.461	13
3	18
0.44	23
0.717	28
10.9	33

DB-003

Result (mg/kg)	Depth (fbgs)
1.1	3
0.152	8
0.417	13
0.024	18
0.005	20.5
0.042	25.5
0.005	33

BN-4

Result (mg/kg)	Depth (fbgs)
1.6	27
1.8	32
3.5	34
13	36
25	38
130	40

MW-308

Result (mg/kg)	Depth (fbgs)
0.0032	47
0.004	58.5
0.0021	67
0.0041	73
0.0031	97
0.0029	104
0.0017	112
0.0038	117.5
0.0045	124.5
0.0023	138

GP-5

Result (mg/kg)	Depth (fbgs)
0.07	6
0.02	8
0.02	10

GP-6

Result (mg/kg)	Depth (fbgs)
60	36

B-5

Result (mg/kg)	Depth (fbgs)
0.011	3
0.002	11
0.008	18
0.008	20.5
0.016	27

WCSB-5

Result (mg/kg)	Depth (fbgs)
0.2545	35
0.2545	40

GP-13

Result (mg/kg)	Depth (fbgs)
0.2	5
0.01	14

B-4

Result (mg/kg)	Depth (fbgs)
0.011	2.5
0.011	13
0.011	20
0.009	24
0.02	31
0.051	34
0.13	36
0.028	43
0.009	52.5
0.019	62.5

BN-6

Result (mg/kg)	Depth (fbgs)
34	10

GP-14

Result (mg/kg)	Depth (fbgs)
0.06	3
0.02	7

B-3

Result (mg/kg)	Depth (fbgs)
26	2.5
77	22.7
180	28
130	30.8
46	35.6
9.4	37.6
25	39.5

BN-2

Result (mg/kg)	Depth (fbgs)
0.072	13
0.02	22
4.6	36
36	38
6.33	40
3.5	42

MW-307

Result (mg/kg)	Depth (fbgs)
0.05	2
0.0048	56

B-2

Result (mg/kg)	Depth (fbgs)
0.011	2.5
0.001	12.7
1.3	27.8
2.8	33.75
1.3	34.65
0.012	37
0.058	38.8

BN-5

Result (mg/kg)	Depth (fbgs)
0.027	20
0.032	31
0.034	33
0.036	34
0.038	36
0.04	39

MW-305

Result (mg/kg)	Depth (fbgs)
20	1
0.0038	20
0.097	37

MW-304

Result (mg/kg)	Depth (fbgs)
19	2
0.44	8
0.027	14.5
0.015	25
0.0039	27
0.018	29.5
0.013	34.5
0.044	37
0.014	38
0.0036	85
0.0043	120

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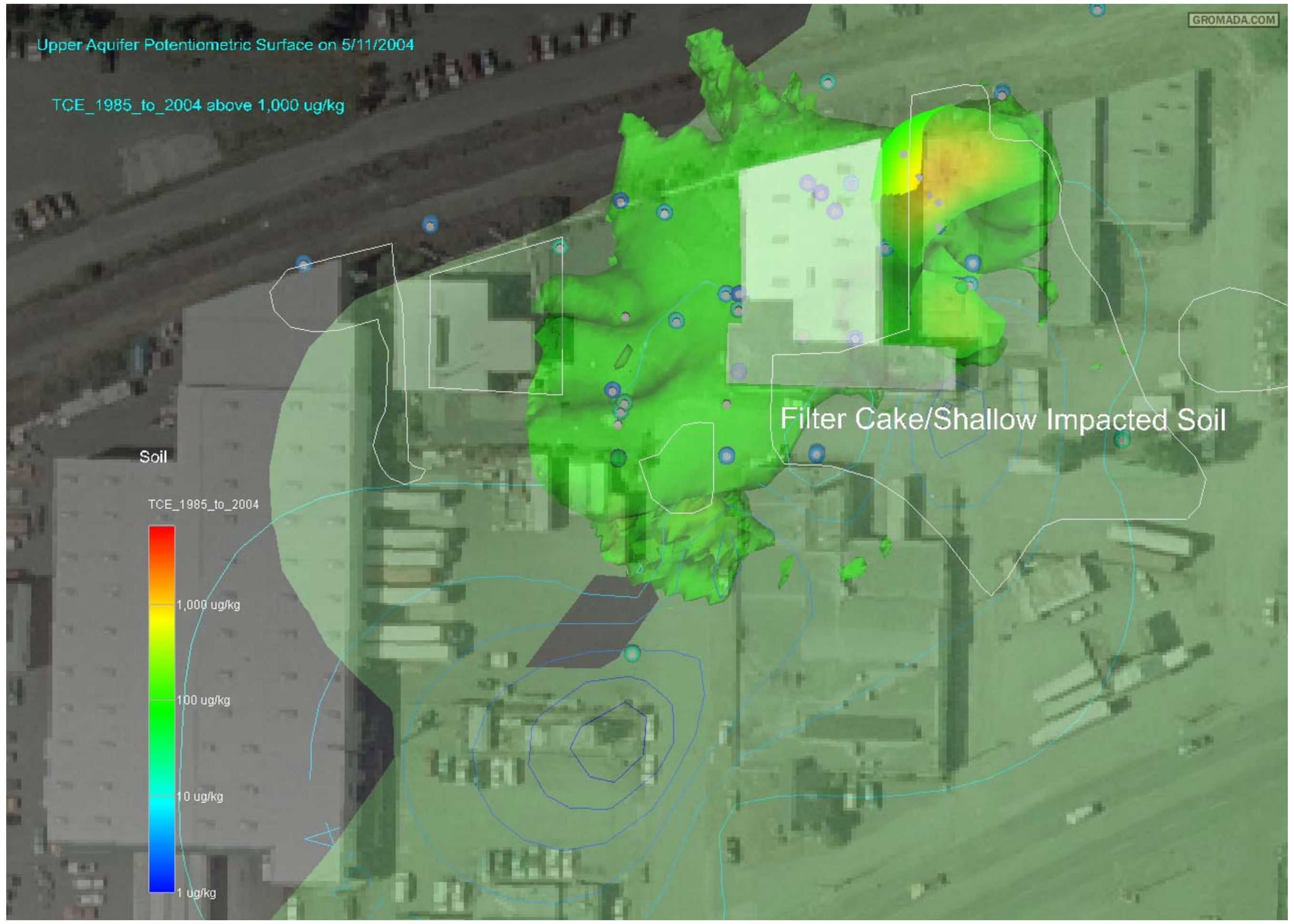
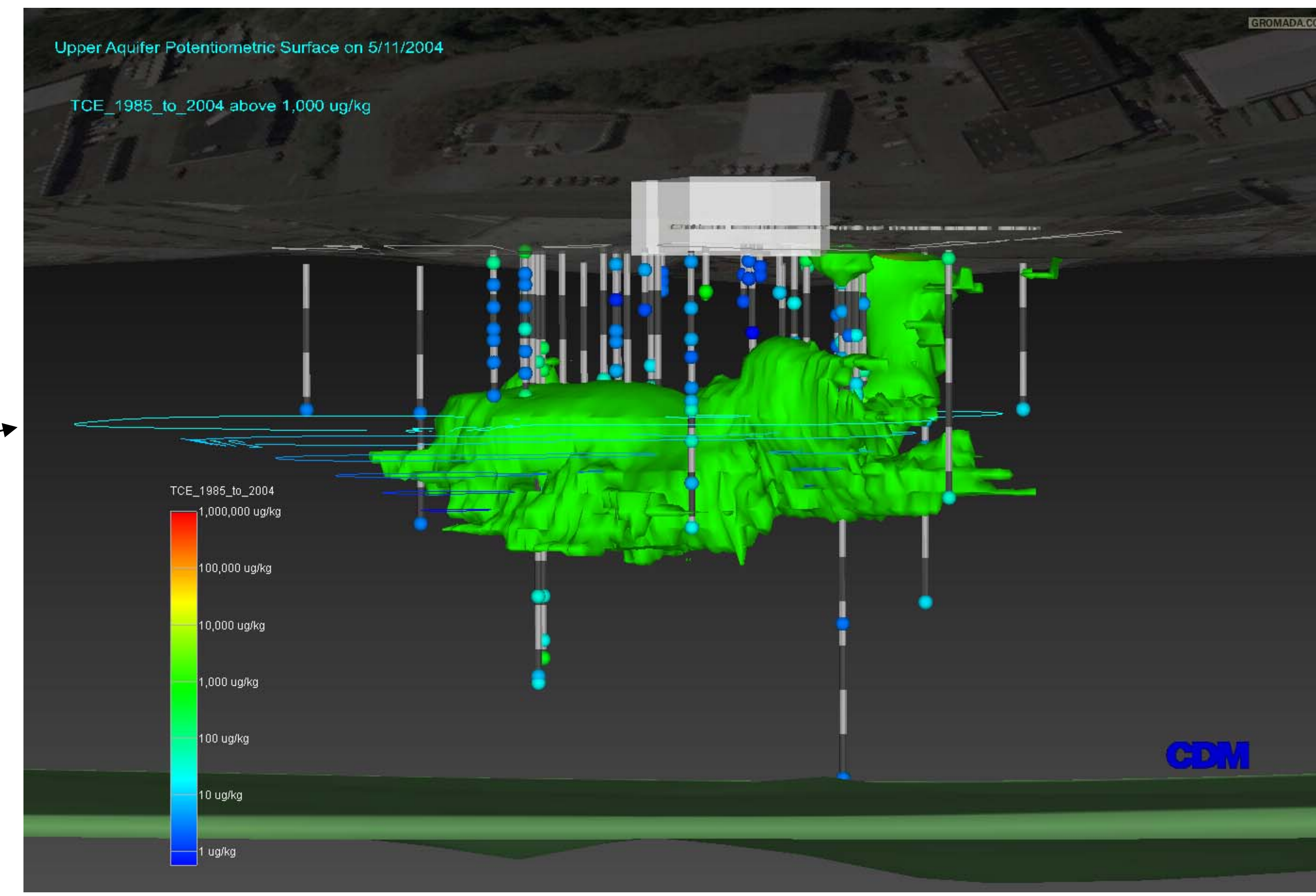
Figure 2-9
1,1,2,2-Tetrachloroethane in Soil



N

Plan view of TCE in soil

View northwest at TCE in soil



Water table

Horizontal Scale

0 100 200 ft

Vertical Scale for Section: Each dark gray (and light gray) interval on well bores represent 10 ft

This figure was prepared using static images saved from an EVS three-dimensional model.

Plume shown is TCE > 1000 ug/kg in soil above and below the water table
Light green unit is semi-confining layer

N

Plan view of PCA in soil

Horizontal Scale

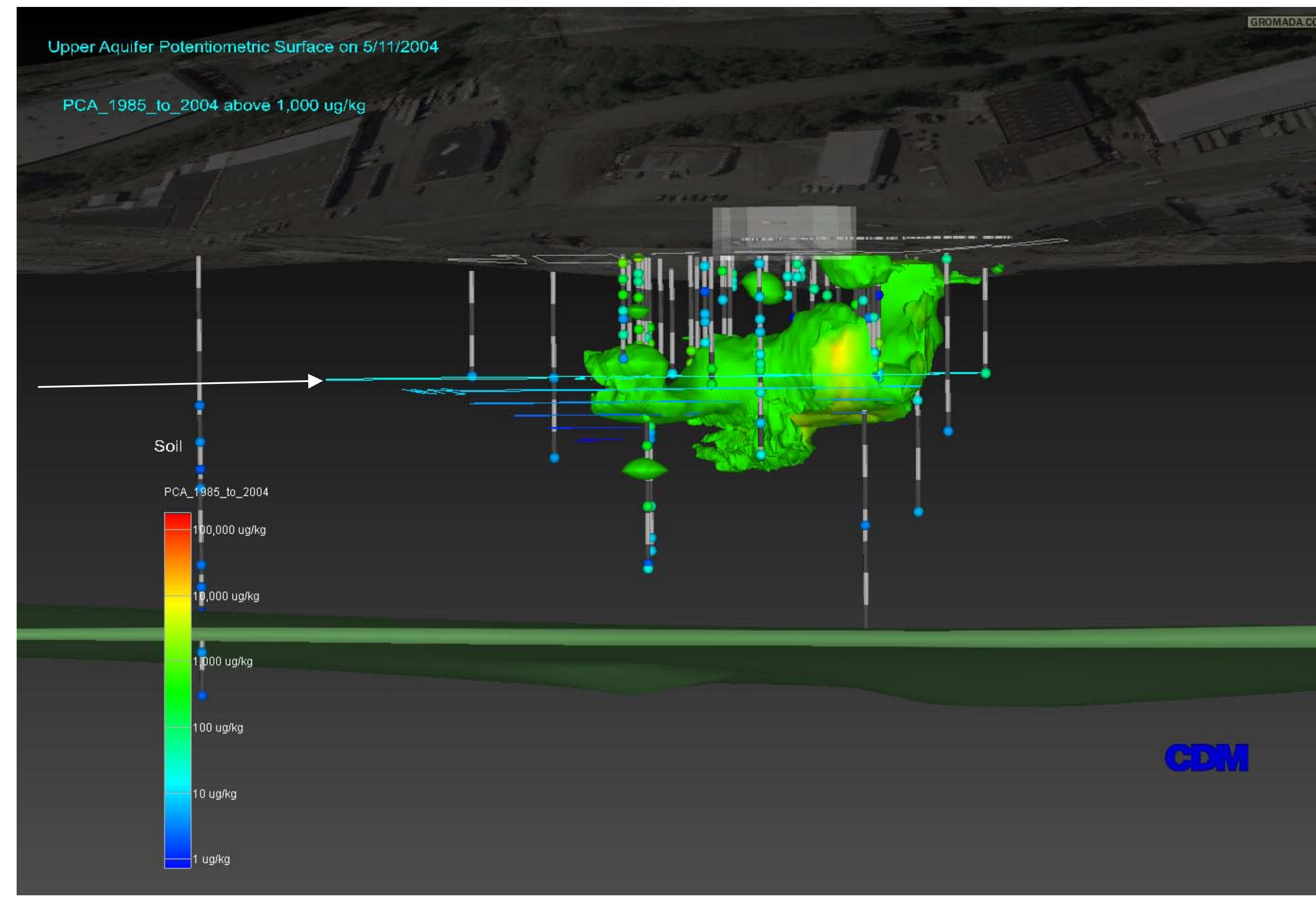
0 100 200 ft

Vertical Scale for Section: Each dark gray (and light gray) interval on well bores represent 10 ft

This figure was prepared using static images exported from an EVS three-dimensional model.

View northwest at PCA in soil

Water table



Plume shown is PCA > 1000 ug/kg in soil above and below the water table
Light green unit is semi-confining layer

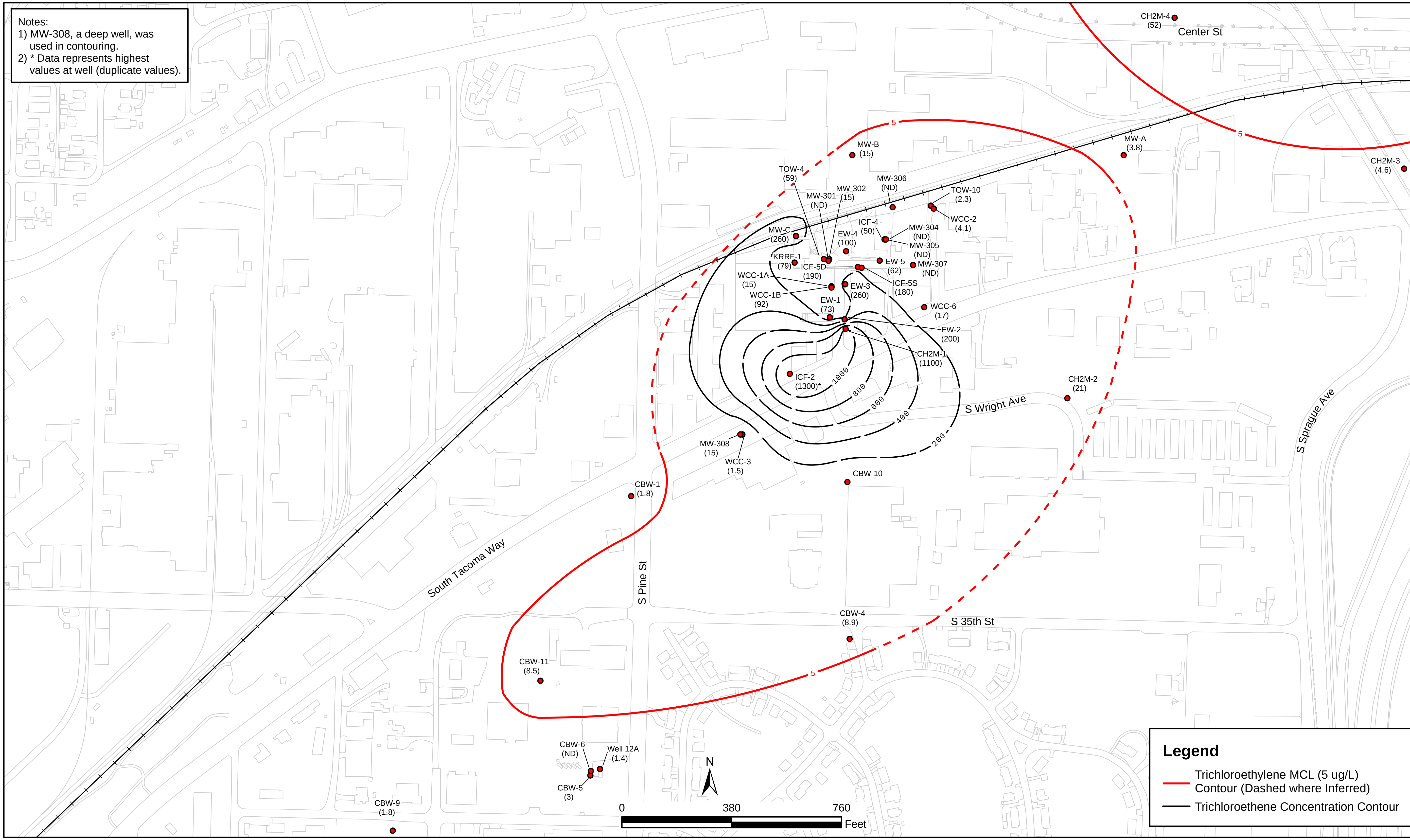


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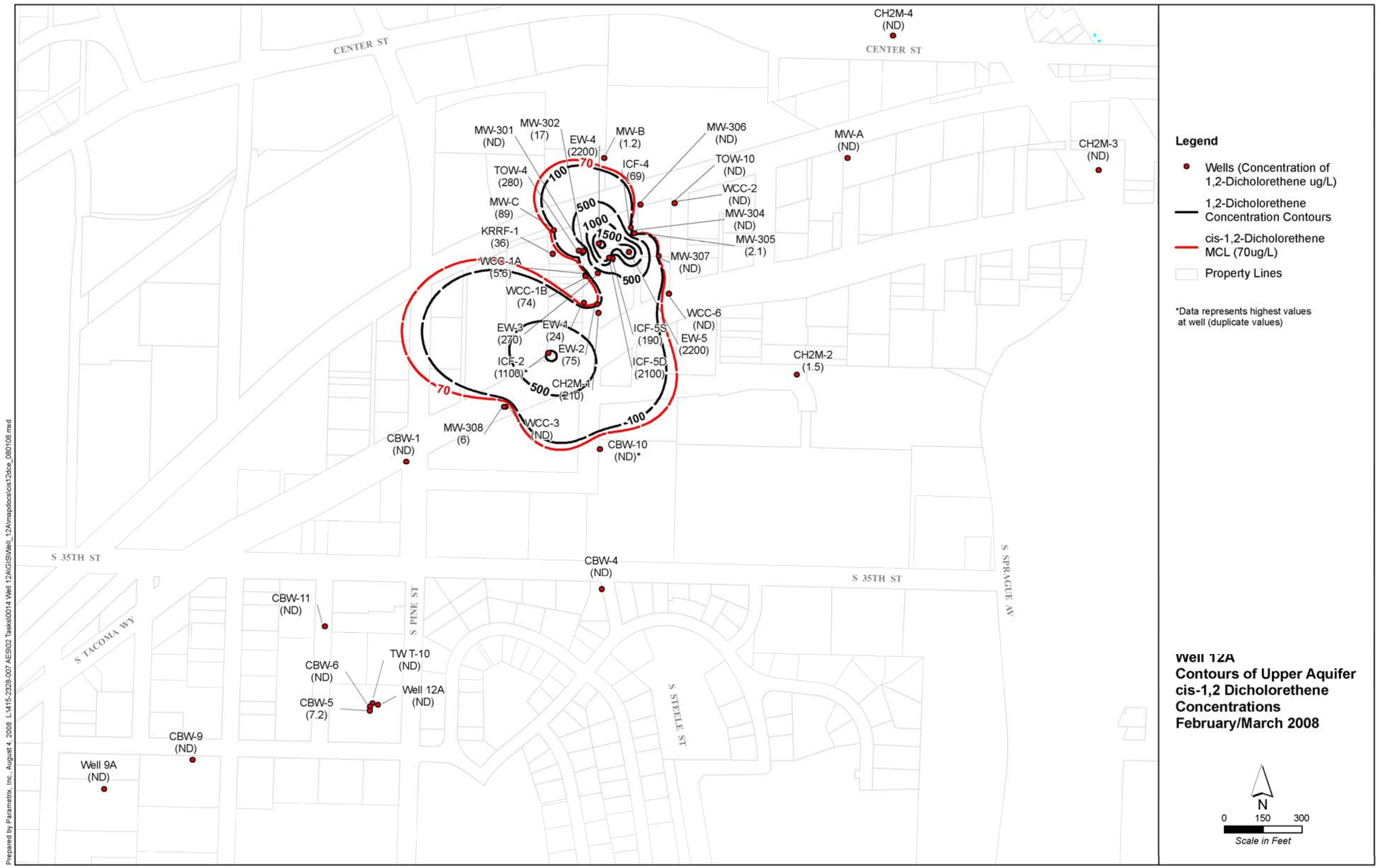
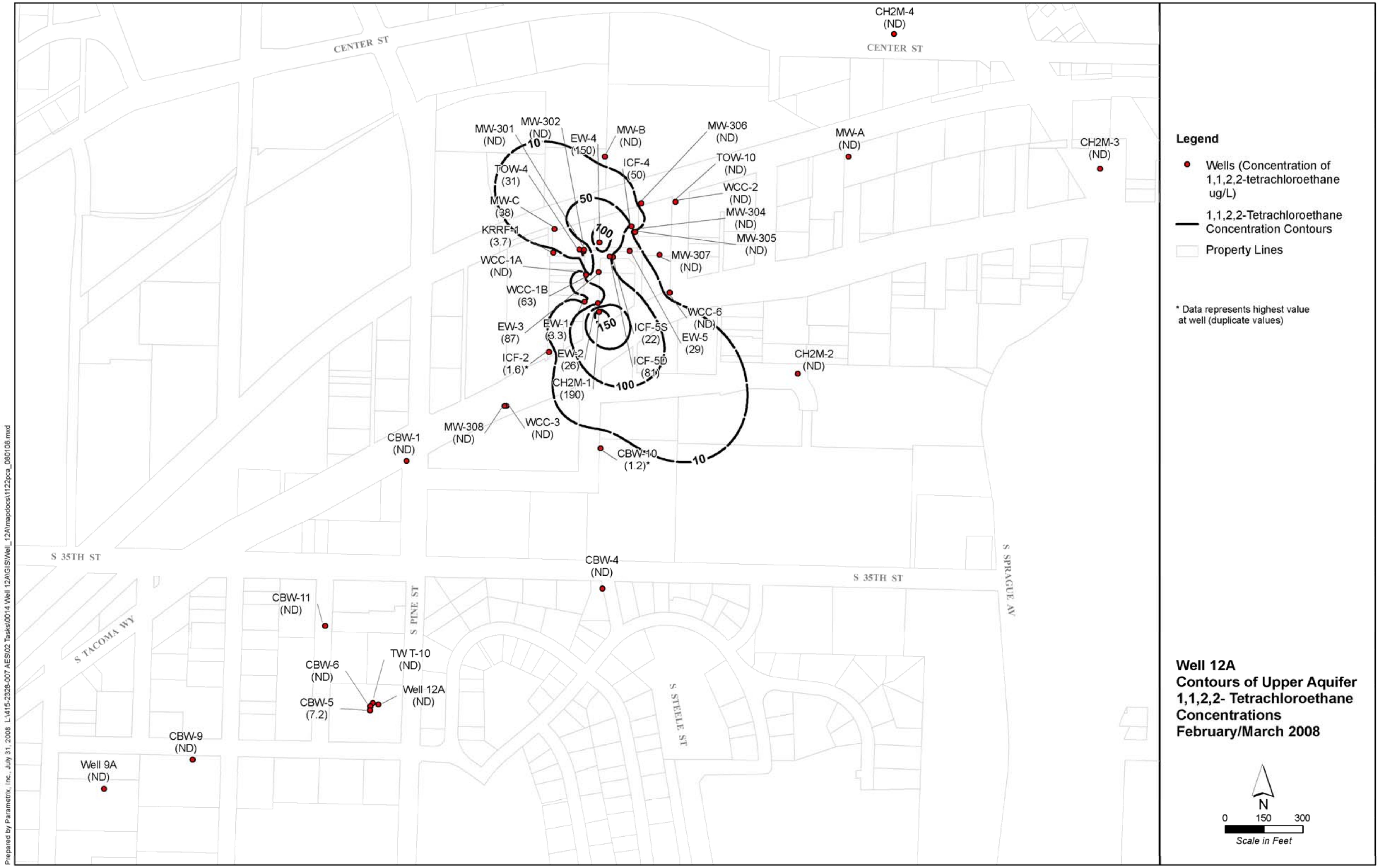
Figure 2-12
Trichloroethylene in Groundwater



Source: Parametrix 2008.



Source: Parametrix 2008.

F:\Parametrix\Well12A\FFS_RemAlts\GIS\Projects\Figure_Z_1_4_Dioxane_Results.mxd

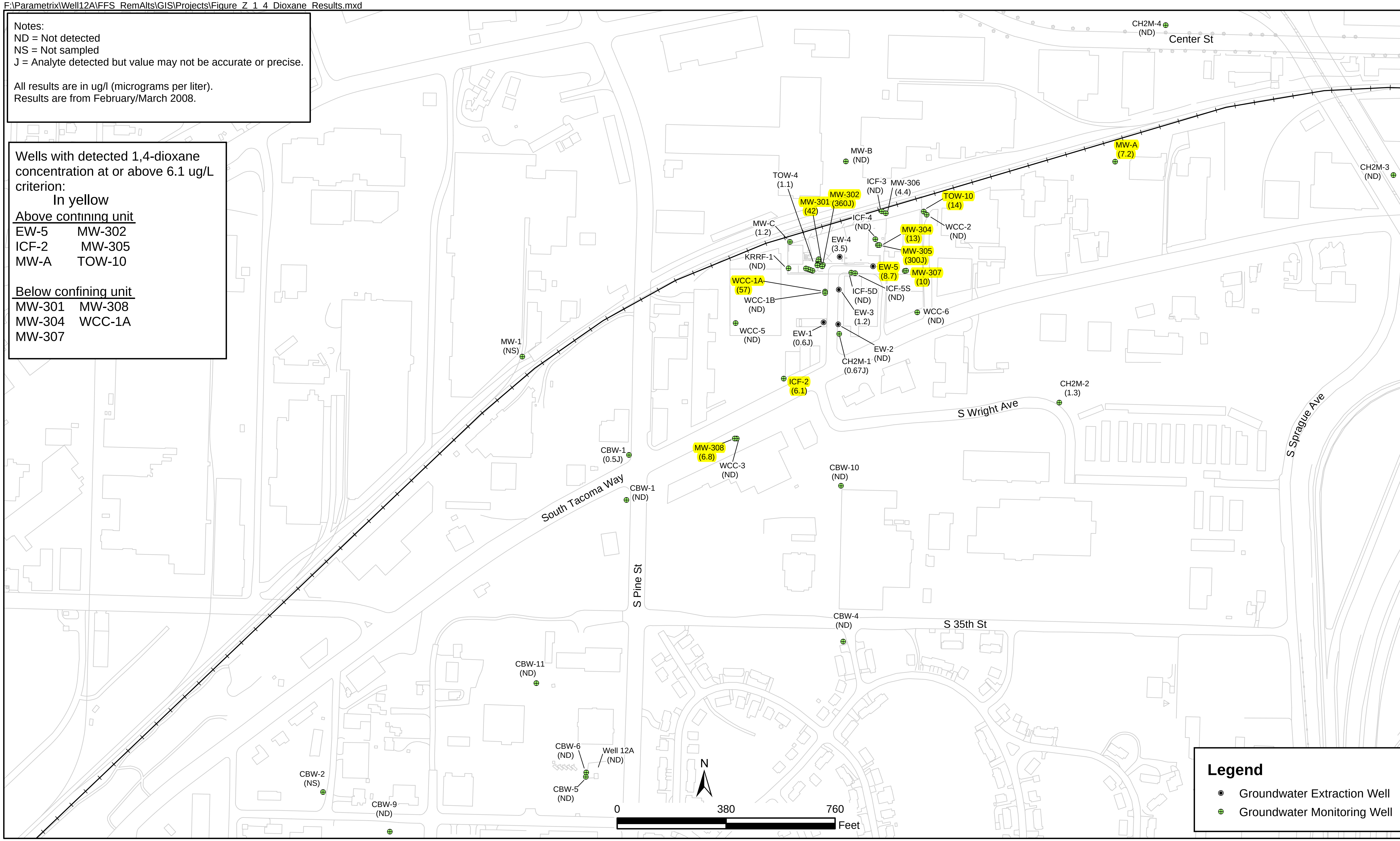


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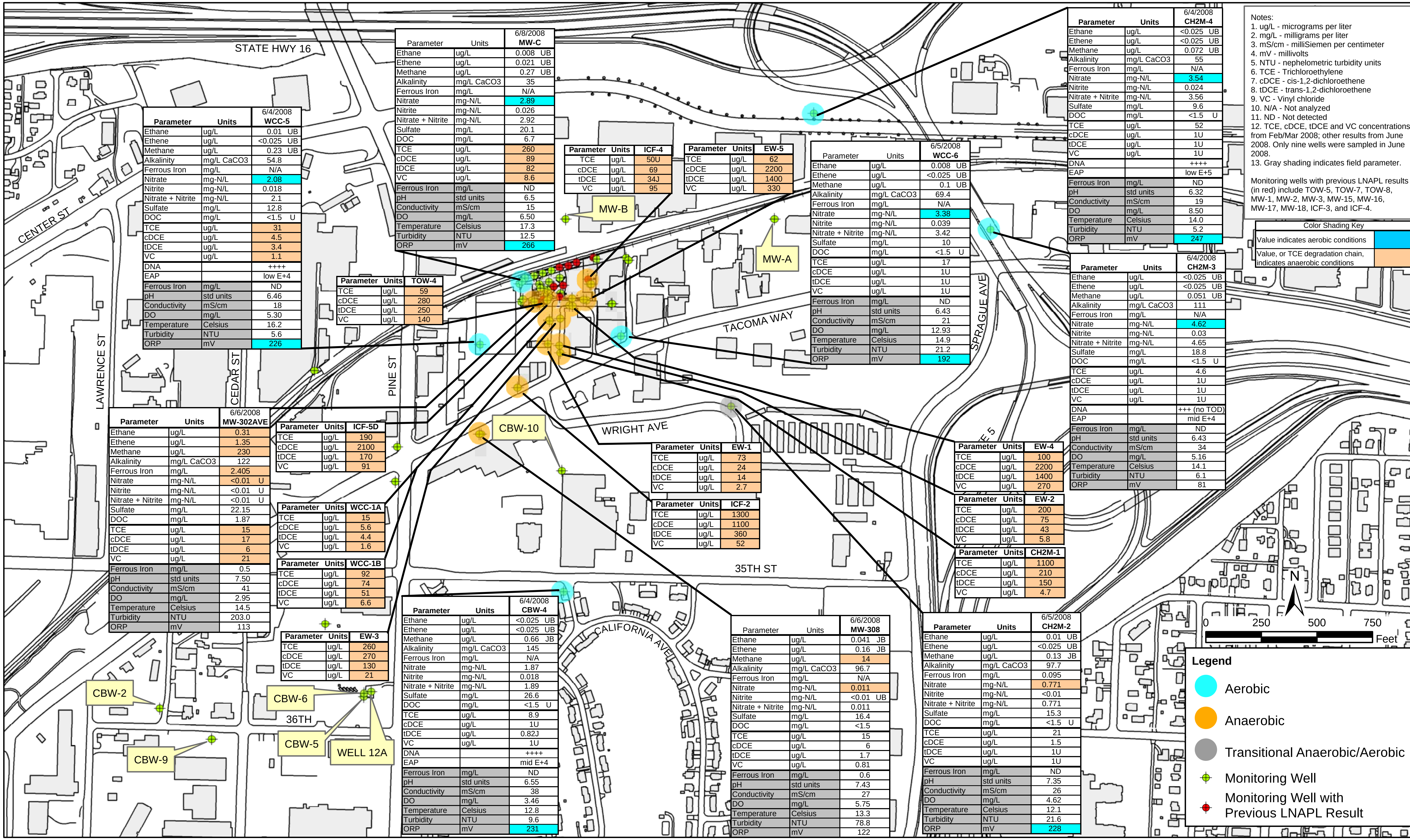
Figure 2-15
1,4-Dioxane in Groundwater
February/March 2008



Parameter	Units	6/4/2008 WCC-5
Ethane	ug/L	0.01 UB
Ethene	ug/L	<0.025 UB
Methane	ug/L	0.23 UB
Alkalinity	mg/L CaCO3	54.8
Ferrous Iron	mg/L	N/A
Nitrate	mg-N/L	2.08
Nitrite	mg-N/L	0.018
Nitrate + Nitrite	mg-N/L	2.1
Sulfate	mg/L	12.8
DOC	mg/L	<1.5 U
TCE	ug/L	31
cDCE	ug/L	4.5
tDCE	ug/L	3.4
VC	ug/L	1.1
DNA		++++
EAP		low E+4
Ferrous Iron	mg/L	ND
pH	std units	6.46
Conductivity	mS/cm	18
DO	mg/L	5.30
Temperature	Celsius	16.2
Turbidity	NTU	5.6
ORP	mV	226

Parameter	Units	6/8/2008 MW-C
Ethane	ug/L	0.008 UB
Ethene	ug/L	0.021 UB
Methane	ug/L	0.27 UB
Alkalinity	mg/L CaCO3	35
Ferrous Iron	mg/L	N/A
Nitrate	mg-N/L	2.89
Nitrite	mg-N/L	0.026
Nitrate + Nitrite	mg-N/L	2.92
Sulfate	mg/L	20.1
DOC	mg/L	6.7
TCE	ug/L	260
cDCE	ug/L	89
tDCE	ug/L	82
VC	ug/L	8.6
Ferrous Iron	mg/L	ND
pH	std units	6.5
Conductivity	mS/cm	15
DO	mg/L	6.50
Temperature	Celsius	17.3
Turbidity	NTU	12.5
ORP	mV	266

Parameter	Units	TOW-4
TCE	ug/L	59
cDCE	ug/L	280
tDCE	ug/L	250
VC	ug/L	140

Parameter	Units	ICF-4
TCE	ug/L	50U
cDCE	ug/L	69
tDCE	ug/L	34J
VC	ug/L	95

Parameter	Units	EW-5
TCE	ug/L	62
cDCE	ug/L	2200
tDCE	ug/L	1400
VC	ug/L	330

Parameter	Units	6/5/2008 WCC-6
Ethane	ug/L	0.008 UB
Ethene	ug/L	<0.025 UB
Methane	ug/L	0.1 UB
Alkalinity	mg/L CaCO3	69.4
Ferrous Iron	mg/L	N/A
Nitrate	mg-N/L	3.38
Nitrite	mg-N/L	0.039
Nitrate + Nitrite	mg-N/L	3.42
Sulfate	mg/L	10
DOC	mg/L	<1.5 U
TCE	ug/L	17
cDCE	ug/L	1U
tDCE	ug/L	1U
VC	ug/L	1U
Ferrous Iron	mg/L	ND
pH	std units	6.43
Conductivity	mS/cm	21
DO	mg/L	12.93
Temperature	Celsius	14.9
Turbidity	NTU	21.2
ORP	mV	192

Parameter	Units	6/4/2008 CH2M-4
Ethane	ug/L	<0.025 UB
Ethene	ug/L	<0.025 UB
Methane	ug/L	0.072 UB
Alkalinity	mg/L CaCO3	55
Ferrous Iron	mg/L	N/A
Nitrate	mg-N/L	3.54
Nitrite	mg-N/L	0.024
Nitrate + Nitrite	mg-N/L	3.56
Sulfate	mg/L	9.6
DOC	mg/L	<1.5 U
TCE	ug/L	52
cDCE	ug/L	1U
tDCE	ug/L	1U
VC	ug/L	1U
DNA		++++
EAP		low E+5
Ferrous Iron	mg/L	ND
pH	std units	6.32
Conductivity	mS/cm	19
DO	mg/L	8.50
Temperature	Celsius	14.0
Turbidity	NTU	5.2
ORP	mV	247

Parameter	Units	6/4/2008 CH2M-3
Ethane	ug/L	<0.025 UB
Ethene	ug/L	<0.025 UB
Methane	ug/L	0.051 UB
Alkalinity	mg/L CaCO3	111
Ferrous Iron	mg/L	N/A
Nitrate	mg-N/L	4.62
Nitrite	mg-N/L	0.03
Nitrate + Nitrite	mg-N/L	4.65
Sulfate	mg/L	18.8
DOC	mg/L	<1.5 U
TCE	ug/L	4.6
cDCE	ug/L	1U
tDCE	ug/L	1U
VC	ug/L	1U
DNA		+++ (no TOD)
EAP		mid E+4
Ferrous Iron	mg/L	ND
pH	std units	6.43
Conductivity	mS/cm	34
DO	mg/L	5.16
Temperature	Celsius	14.1
Turbidity	NTU	6.1
ORP	mV	81

Parameter	Units	6/6/2008 MW-302AVE
Ethane	ug/L	0.31
Ethene	ug/L	1.35
Methane	ug/L	230
Alkalinity	mg/L CaCO3	122
Ferrous Iron	mg/L	2.405
Nitrate	mg-N/L	<0.01 U
Nitrite	mg-N/L	<0.01 U
Nitrate + Nitrite	mg-N/L	<0.01 U
Sulfate	mg/L	22.15
DOC	mg/L	1.87
TCE	ug/L	15
cDCE	ug/L	17
tDCE	ug/L	6
VC	ug/L	21
Ferrous Iron	mg/L	0.5
pH	std units	7.50
Conductivity	mS/cm	41
DO	mg/L	2.95
Temperature	Celsius	14.5
Turbidity	NTU	203.0
ORP	mV	113

Parameter	Units	ICF-5D
TCE	ug/L	190
cDCE	ug/L	2100
tDCE	ug/L	170
VC	ug/L	91

Parameter	Units	WCC-1A
TCE	ug/L	15
cDCE	ug/L	5.6
tDCE	ug/L	4.4
VC	ug/L	1.6

Parameter	Units	WCC-1B
TCE	ug/L	92
cDCE	ug/L	74
tDCE	ug/L	51
VC	ug/L	6.6

Parameter	Units	EW-3
TCE	ug/L	260
cDCE	ug/L	270
tDCE	ug/L	130
VC	ug/L	21

Parameter	Units	6/4/2008 CBW-4
Ethane	ug/L	<0.025 UB
Ethene	ug/L	<0.025 UB
Methane	ug/L	0.66 JB
Alkalinity	mg/L CaCO3	145
Ferrous Iron	mg/L	N/A
Nitrate	mg-N/L	1.87
Nitrite	mg-N/L	0.018
Nitrate + Nitrite	mg-N/L	1.89
Sulfate	mg/L	26.6
DOC	mg/L	<1.5 U
TCE	ug/L	8.9
cDCE	ug/L	1U
tDCE	ug/L	0.82J
VC	ug/L	1U
DNA		++++
EAP		mid E+4
Ferrous Iron	mg/L	ND
pH	std units	6.55
Conductivity	mS/cm	38
DO	mg/L	3.46
Temperature	Celsius	12.8
Turbidity	NTU	9.6
ORP	mV	231

Parameter	Units	EW-1
TCE	ug/L	73
cDCE	ug/L	24
tDCE	ug/L	14
VC	ug/L	2.7

Parameter	Units	ICF-2
TCE	ug/L	1300
cDCE	ug/L	1100
tDCE	ug/L	360
VC	ug/L	52

Parameter	Units	EW-4
TCE	ug/L	100
cDCE	ug/L	2200
tDCE	ug/L	1400
VC	ug/L	270

Parameter	Units	EW-2
TCE	ug/L	200
cDCE	ug/L	75
tDCE	ug/L	43
VC	ug/L	5.8

Parameter	Units	CH2M-1
TCE	ug/L	1100
cDCE	ug/L	210
tDCE	ug/L	150
VC	ug/L	4.7

Parameter	Units	6/6/2008 MW-308
Ethane	ug/L	0.041 JB
Ethene	ug/L	0.16 JB
Methane	ug/L	14
Alkalinity	mg/L CaCO3	96.7
Ferrous Iron	mg/L	N/A
Nitrate	mg-N/L	0.011
Nitrite	mg-N/L	<0.01 UB
Nitrate + Nitrite	mg-N/L	0.011
Sulfate	mg/L	16.4
DOC	mg/L	<1.5
TCE	ug/L	15
cDCE	ug/L	6
tDCE	ug/L	1.7
VC	ug/L	0.81
Ferrous Iron	mg/L	0.6
pH	std units	7.43
Conductivity	mS/cm	27
DO	mg/L	5.75
Temperature	Celsius	13.3
Turbidity	NTU	78.8
ORP	mV	122

Parameter	Units	6/5/2008 CH2M-2
Ethane	ug/L	0.01 UB
Ethene	ug/L	<0.025 UB
Methane	ug/L	0.13 JB
Alkalinity	mg/L CaCO3	97.7
Ferrous Iron	mg/L	0.095
Nitrate	mg-N/L	0.771
Nitrite	mg-N/L	<0.01
Nitrate + Nitrite	mg-N/L	0.771
Sulfate	mg/L	15.3
DOC	mg/L	<1.5 U
TCE	ug/L	21
cDCE	ug/L	1.5
tDCE	ug/L	1U
VC	ug/L	1U
Ferrous Iron	mg/L	ND
pH	std units	7.35
Conductivity	mS/cm	26
DO	mg/L	4.62
Temperature	Celsius	12.1
Turbidity	NTU	21.6
ORP	mV	228

Notes:
1. ug/L - micrograms per liter
2. mg/L - milligrams per liter
3. mS/cm - milliSiemen per centimeter
4. mV - millivolts
5. NTU - nephelometric turbidity units
6. TCE - Trichloroethylene
7. cDCE - cis-1,2-dichloroethene
8. tDCE - trans-1,2-dichloroethene
9. VC - Vinyl chloride
10. N/A - Not analyzed
11. ND - Not detected
12. TCE, cDCE, tDCE and VC concentrations from Feb/Mar 2008; other results from June 2008. Only nine wells were sampled in June 2008.
13. Gray shading indicates field parameter.

Monitoring wells with previous LNAPL results (in red) include TOW-5, TOW-7, TOW-8, MW-1, MW-2, MW-3, MW-15, MW-16, MW-17, MW-18, ICF-3, and ICF-4.

Color Shading Key
- Value indicates aerobic conditions
- Value, or TCE degradation chain, indicates anaerobic conditions

Legend
- Aerobic
- Anaerobic
- Transitional Anaerobic/Aerobic
- Monitoring Well
- Monitoring Well with Previous LNAPL Result

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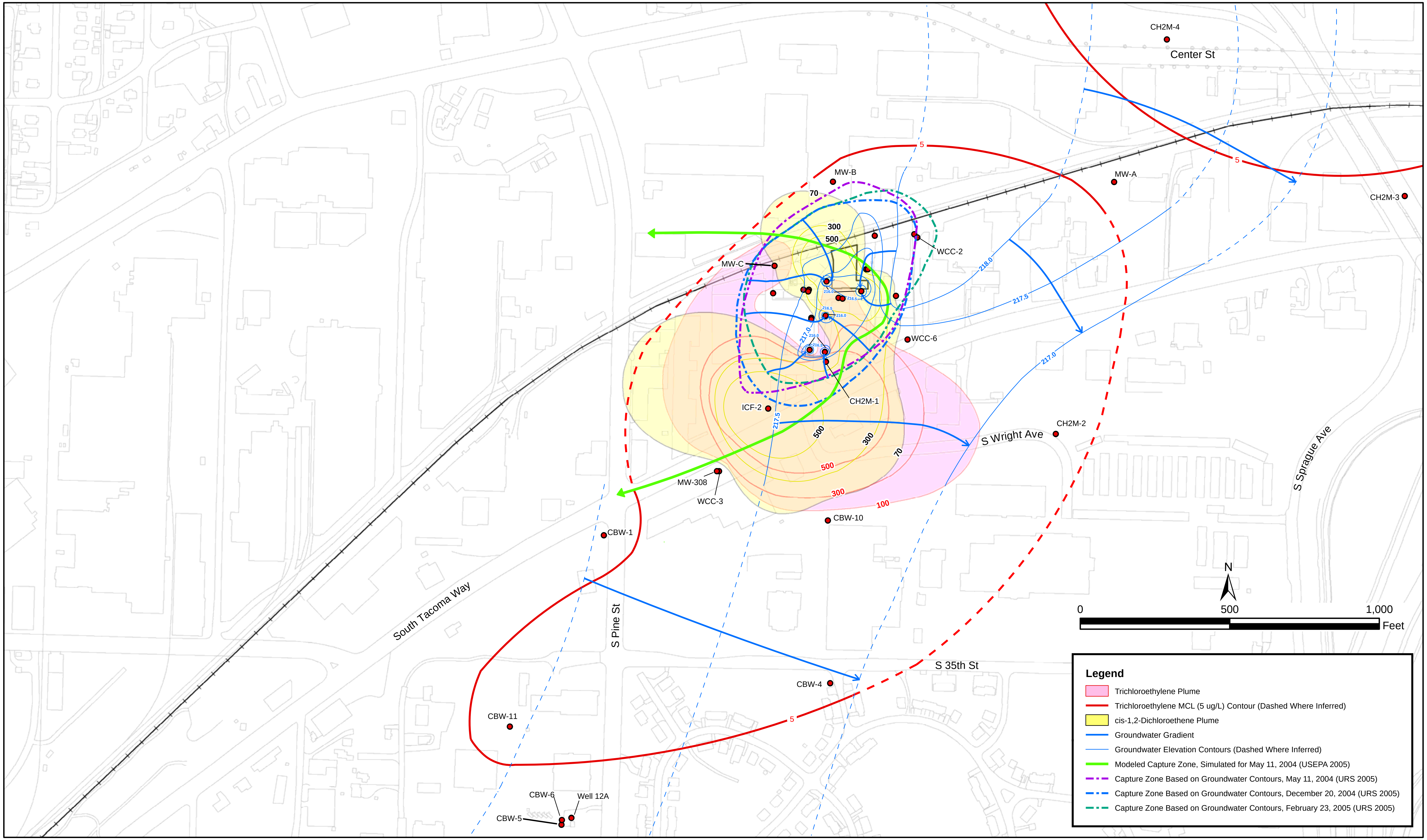
Well 12A Superfund Site
Tacoma, Washington

Figure 2-16
Monitored Natural Attenuation Evaluation Summary
June 2008



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Well 12A Superfund Site
Tacoma, Washington

Figure 2-17
Groundwater Contamination and Flow Gradients

Plan view of PCA in soil

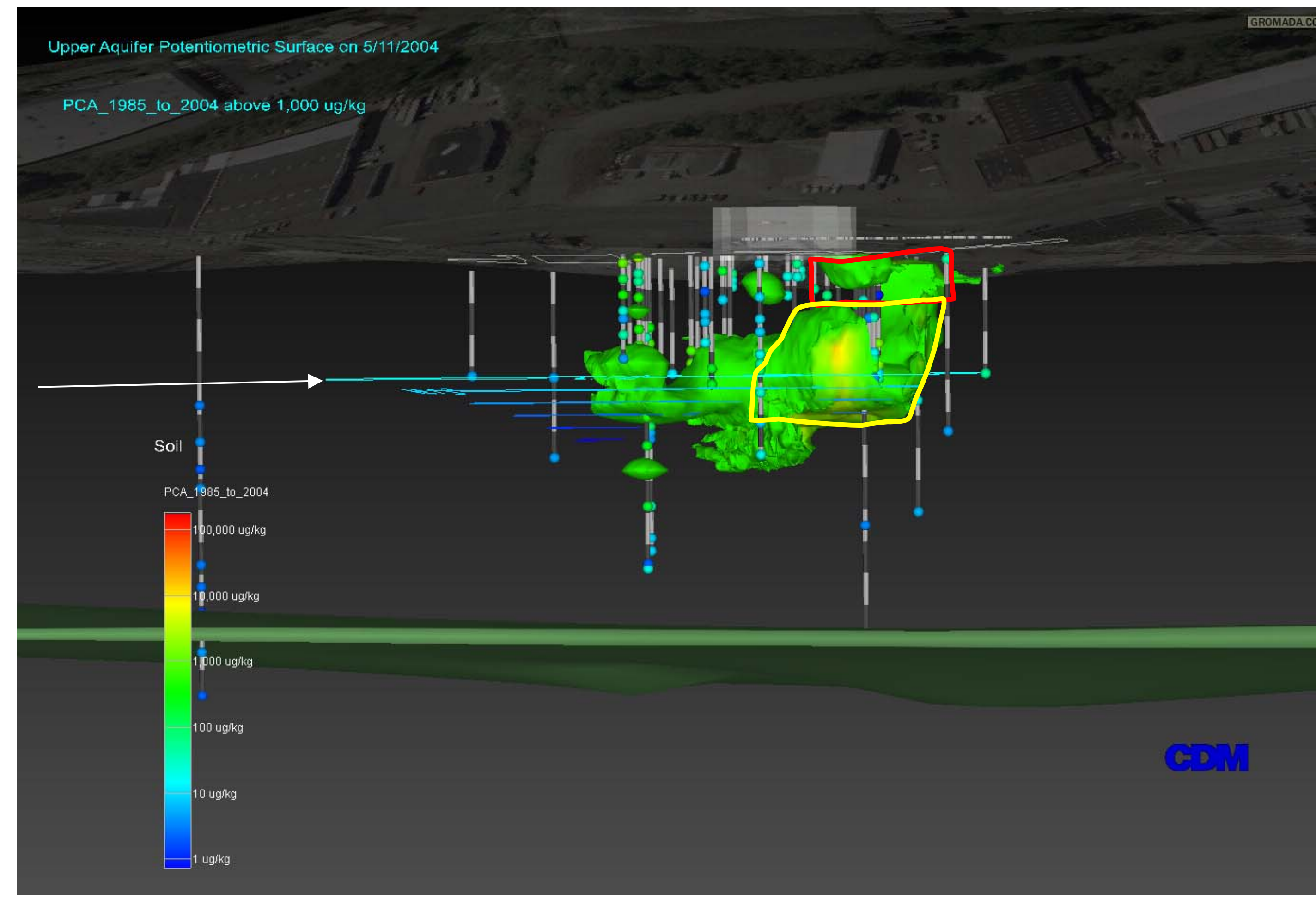
N

- Shallow soil/filter cake treatment zone

- Deep vadose and upper saturated zone soil on east side of Time Oil Building Since the extent into the saturated zone is being delineated by soil concentrations, it is included as a soil treatment zone.

View northwest at PCA in soil

Water table



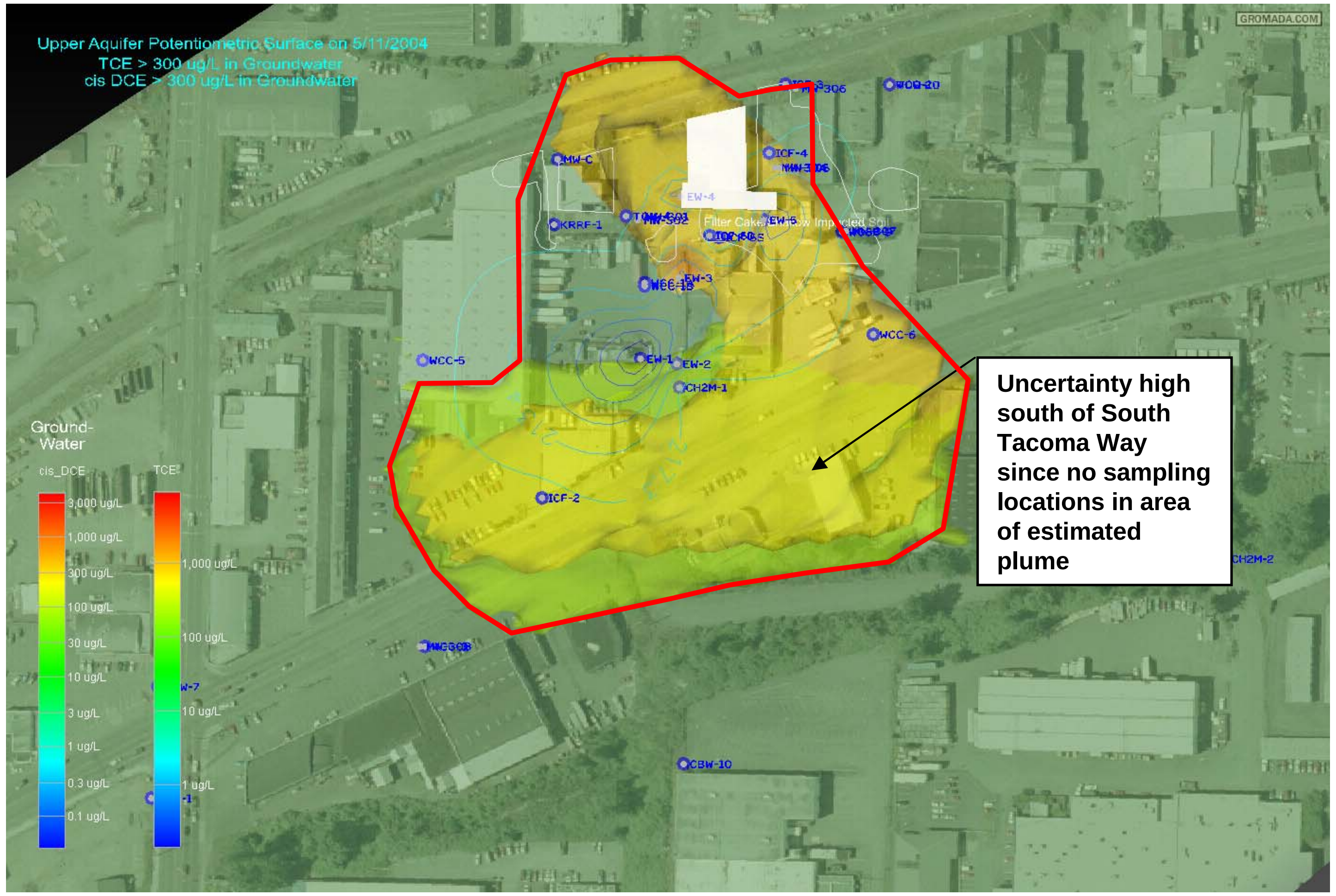
Horizontal Scale

0 100 200 ft

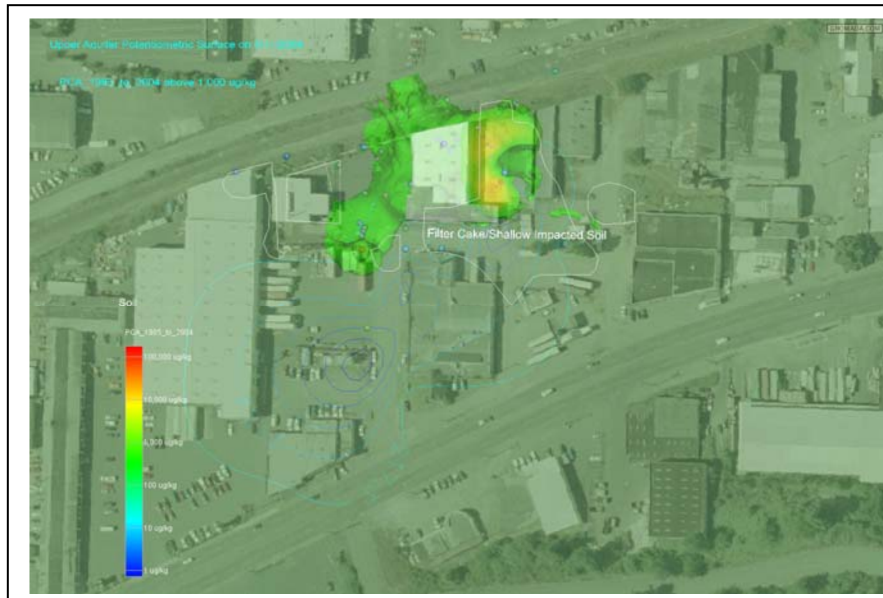
Vertical Scale for Section: Each dark gray (and light gray) interval on well bores represent 10 ft

This figure was prepared using static images exported from an EVS three-dimensional model.

Plume shown is PCA > 1000 ug/kg in soil above and below the water table
Light green unit is semi-confining layer



Plan view of TCE and cis-1,2-DCE in groundwater



1,1,2,2,PCA in soil for comparison to groundwater contamination and proposed treatment zones

This figure was prepared using static images exported from an EVS three-dimensional model.

N

Horizontal Scale

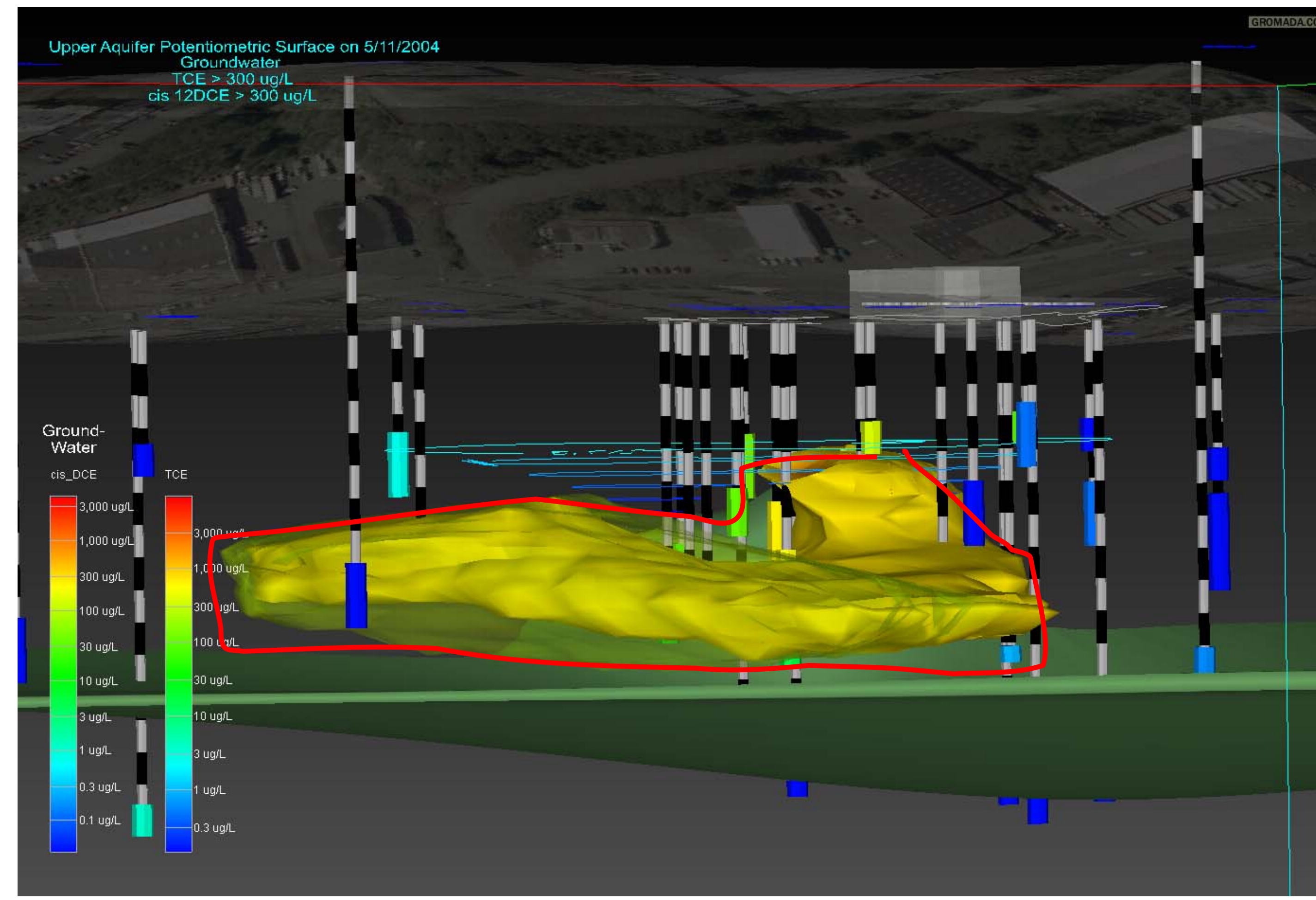
0 100 200 ft

Vertical Scale for Section: Each dark gray (and light gray) interval on well bores represent 10 ft

-Proposed High Concentration Groundwater Treatment Zone

Low concentration treatment zone is area outside of high concentration treatment zone

View northwest at TCE and cis-1,2-DCE in groundwater



Groundwater plumes shown in both larger images are cis-1,2-DCE (yellow) and TCE (green) > 300 ug/l in groundwater. Light green unit is semi-confining layer

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Tacoma, Washington

Figure 3-2
Proposed Treatment Zones in High Concentration and Low Concentration Groundwater Plume

This figure was prepared using static images saved from an EVS three-dimensional model.

Plan view of TCE and cis-1,2-DCE in groundwater (blue) and 1,1,2,2 PCA in soil (green/yellow/red)

N

Horizontal Scale

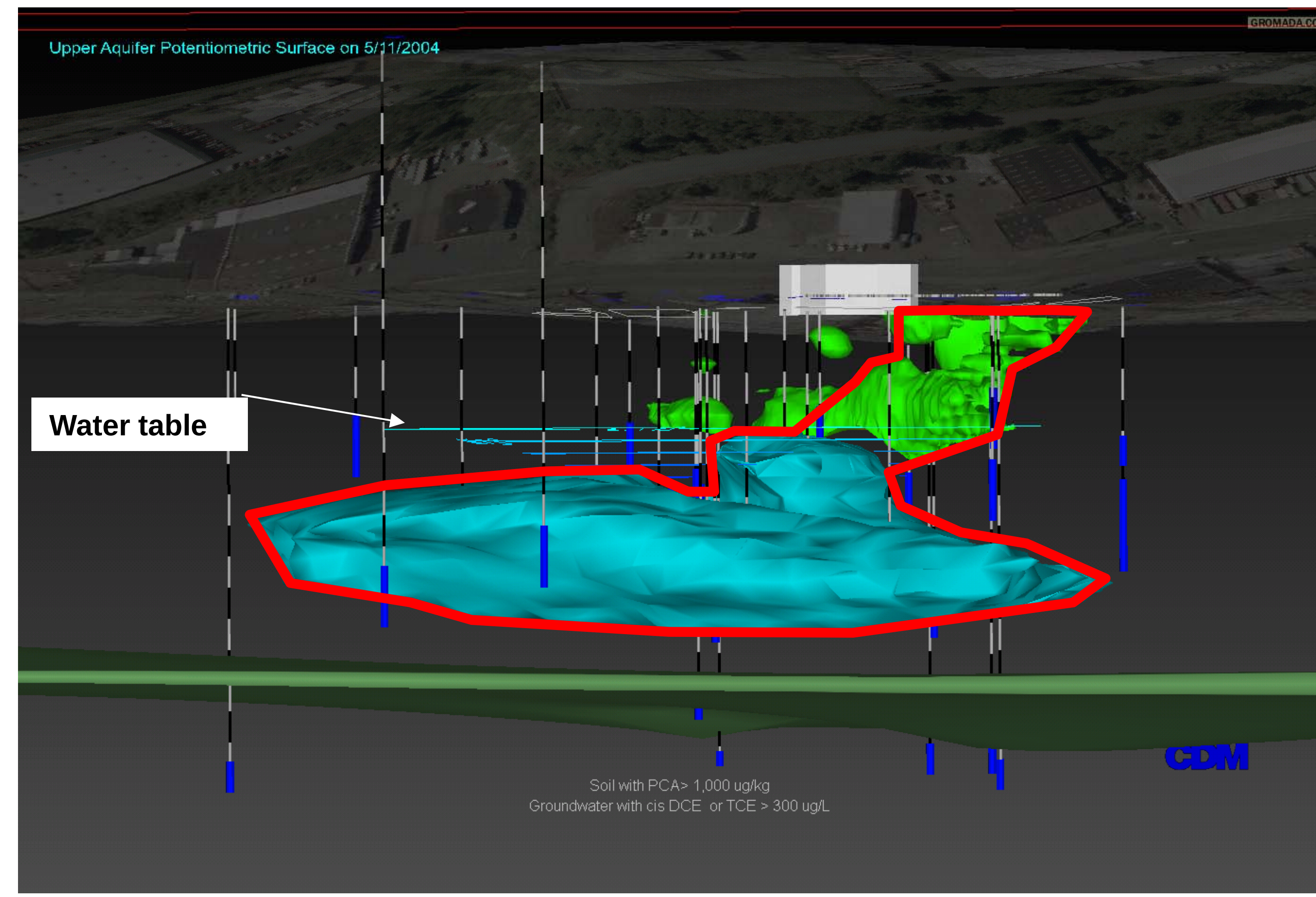
0 100 200 ft

Vertical Scale for Section: Each dark gray (and light gray) interval on well bores represent 10 ft

- Proposed Treatment Zone Compilation (three zones)

Low concentration groundwater treatment zone (the fourth zone) is outside of highlighted (in red) compilation

View northwest at TCE and cis-1,2-DCE in groundwater (blue) and 1,1,2,2 PCA in soil (green above water table)



Plumes shown are TCE or cis-1,2-DCE > 300 ug/l in groundwater and 1,1,2,2 PCA > 1,000 ug/kg in soil

RAO Summary of the Four Proposed Treatment Zones

Filter Cake/Shallow Soil

Eliminate the risk of direct contact with filter cake at and near the surface. Eliminating the direct contact risk will also reduce possible vapor intrusion issues. EPA is addressing vapor intrusion under a separate activity when targeted soil and groundwater contamination is addressed. Prevent or minimize the migration of contamination from highly contaminated shallow source areas into the deeper vadose zone to prevent further degradation of deep soil and groundwater

Deep Vadose Soil and Upper Saturated Soil East of Time Oil Building

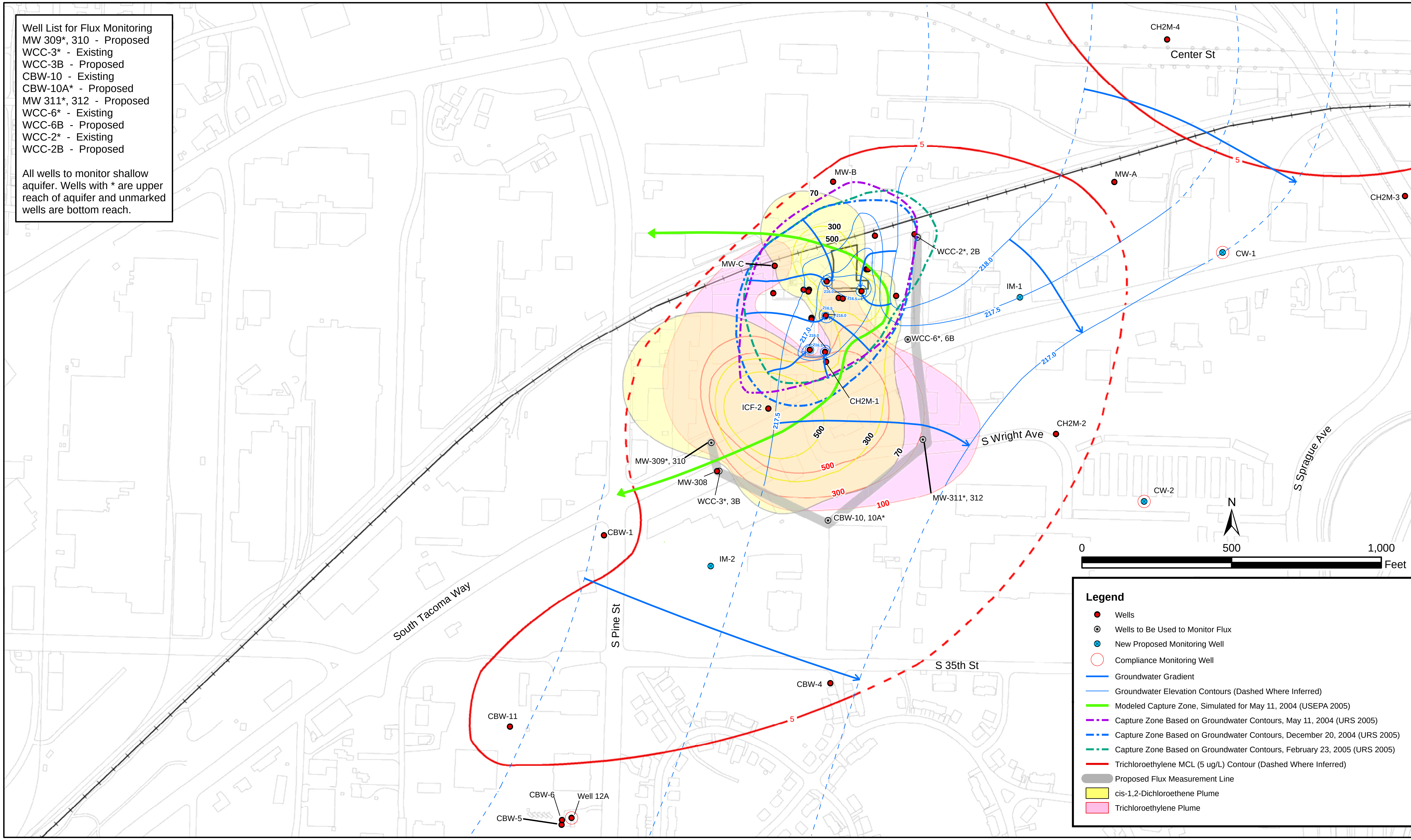
Eliminate/minimize the mass of contaminants to reduce the mass flux from this high concentration area

High Concentration Groundwater Zone

Reduce the mass flux by ninety percent (a groundwater remediation level) from the high concentration area soils/groundwater through a specific plane into the dissolved phase treatment zone. The proposed plane is at or near the current location of the 300 ug/l Isoconcentration for TCE and cis-1,2-DCE.

Low Concentration Groundwater Plume

Reduce contaminant concentrations so that the concentrations at the plume perimeter (defined by Well 12A, new well CW-1, and new well CW-2) meet MCLs (a groundwater remediation level).



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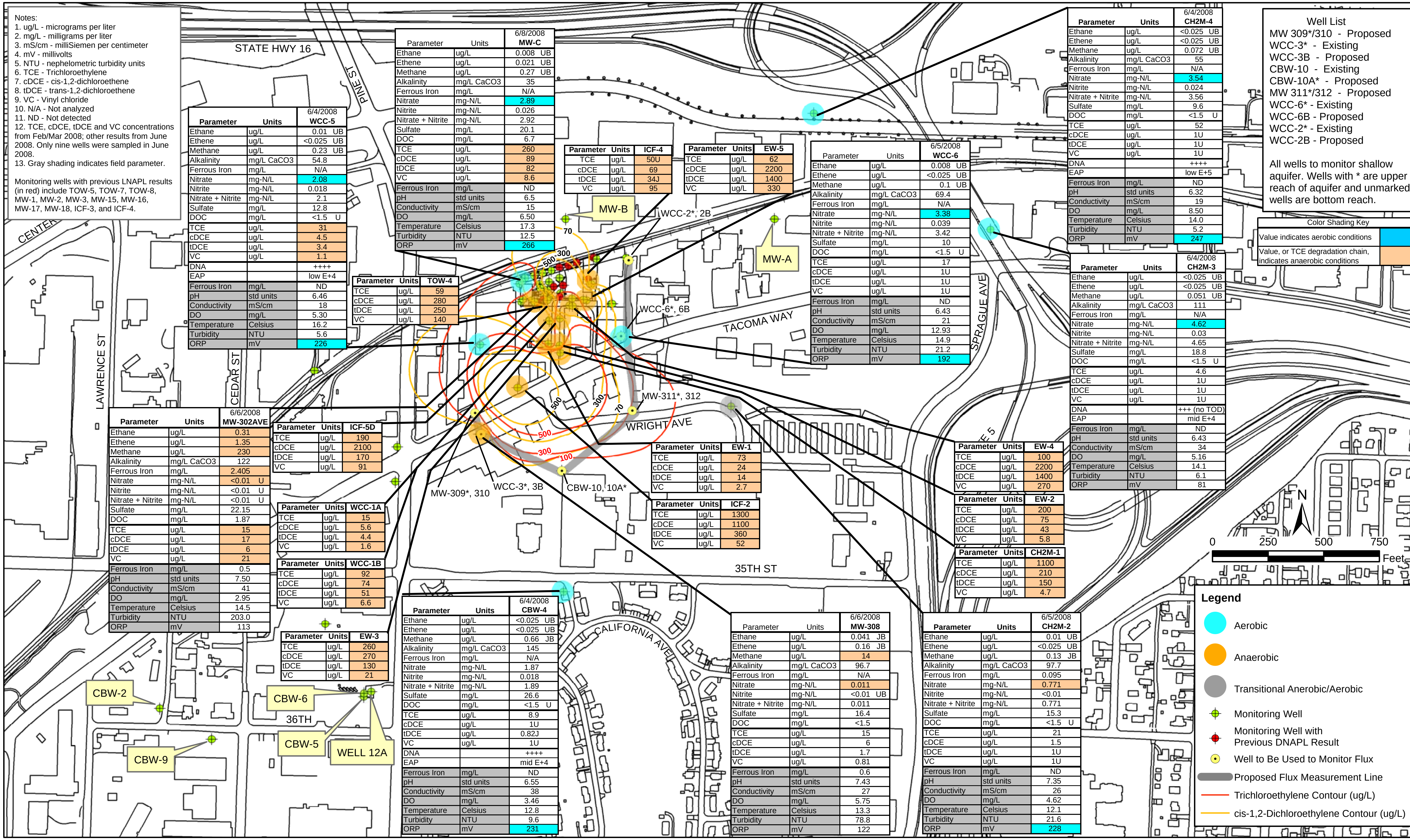
Well 12A Superfund Site
Tacoma, Washington

Figure 3-4
Groundwater Contamination and Flow Gradients
with Flux Measurement Line



Parameter	Units	6/4/2008 WCC-5
Ethane	ug/L	0.01 UB
Ethene	ug/L	<0.025 UB
Methane	ug/L	0.23 UB
Alkalinity	mg/L CaCO3	54.8
Ferrous Iron	mg/L	N/A
Nitrate	mg-N/L	2.08
Nitrite	mg-N/L	0.018
Nitrate + Nitrite	mg-N/L	2.1
Sulfate	mg/L	12.8
DOC	mg/L	<1.5 U
TCE	ug/L	31
cDCE	ug/L	4.5
tDCE	ug/L	3.4
VC	ug/L	1.1
DNA		++++
EAP		low E+4
Ferrous Iron	mg/L	ND
pH	std units	6.46
Conductivity	mS/cm	18
DO	mg/L	5.30
Temperature	Celsius	16.2
Turbidity	NTU	5.6
ORP	mV	226

Parameter	Units	6/8/2008 MW-C
Ethane	ug/L	0.008 UB
Ethene	ug/L	0.021 UB
Methane	ug/L	0.27 UB
Alkalinity	mg/L CaCO3	35
Ferrous Iron	mg/L	N/A
Nitrate	mg-N/L	2.89
Nitrite	mg-N/L	0.026
Nitrate + Nitrite	mg-N/L	2.92
Sulfate	mg/L	20.1
DOC	mg/L	6.7
TCE	ug/L	260
cDCE	ug/L	89
tDCE	ug/L	82
VC	ug/L	8.6
Ferrous Iron	mg/L	ND
pH	std units	6.5
Conductivity	mS/cm	15
DO	mg/L	6.50
Temperature	Celsius	17.3
Turbidity	NTU	12.5
ORP	mV	266

Parameter	Units	TOW-4
TCE	ug/L	59
cDCE	ug/L	280
tDCE	ug/L	250
VC	ug/L	140

Parameter	Units	ICF-4
TCE	ug/L	50U
cDCE	ug/L	69
tDCE	ug/L	34J
VC	ug/L	95

Parameter	Units	EW-5
TCE	ug/L	62
cDCE	ug/L	2200
tDCE	ug/L	1400
VC	ug/L	330

Parameter	Units	6/5/2008 WCC-6
Ethane	ug/L	0.008 UB
Ethene	ug/L	<0.025 UB
Methane	ug/L	0.1 UB
Alkalinity	mg/L CaCO3	69.4
Ferrous Iron	mg/L	N/A
Nitrate	mg-N/L	3.38
Nitrite	mg-N/L	0.039
Nitrate + Nitrite	mg-N/L	3.42
Sulfate	mg/L	10
DOC	mg/L	<1.5 U
TCE	ug/L	17
cDCE	ug/L	1U
tDCE	ug/L	1U
VC	ug/L	1U
Ferrous Iron	mg/L	ND
pH	std units	6.43
Conductivity	mS/cm	21
DO	mg/L	12.93
Temperature	Celsius	14.9
Turbidity	NTU	21.2
ORP	mV	192

Parameter	Units	6/4/2008 CH2M-4
Ethane	ug/L	<0.025 UB
Ethene	ug/L	<0.025 UB
Methane	ug/L	0.072 UB
Alkalinity	mg/L CaCO3	55
Ferrous Iron	mg/L	N/A
Nitrate	mg-N/L	3.54
Nitrite	mg-N/L	0.024
Nitrate + Nitrite	mg-N/L	3.56
Sulfate	mg/L	9.6
DOC	mg/L	<1.5 U
TCE	ug/L	52
cDCE	ug/L	1U
tDCE	ug/L	1U
VC	ug/L	1U
DNA		++++
EAP		low E+5
Ferrous Iron	mg/L	ND
pH	std units	6.32
Conductivity	mS/cm	19
DO	mg/L	8.50
Temperature	Celsius	14.0
Turbidity	NTU	5.2
ORP	mV	247

Parameter	Units	6/4/2008 CH2M-3
Ethane	ug/L	<0.025 UB
Ethene	ug/L	<0.025 UB
Methane	ug/L	0.051 UB
Alkalinity	mg/L CaCO3	111
Ferrous Iron	mg/L	N/A
Nitrate	mg-N/L	4.62
Nitrite	mg-N/L	0.03
Nitrate + Nitrite	mg-N/L	4.65
Sulfate	mg/L	18.8
DOC	mg/L	<1.5 U
TCE	ug/L	4.6
cDCE	ug/L	1U
tDCE	ug/L	1U
VC	ug/L	1U
DNA		+++ (no TOD)
EAP		mid E+4
Ferrous Iron	mg/L	ND
pH	std units	6.43
Conductivity	mS/cm	34
DO	mg/L	5.16
Temperature	Celsius	14.1
Turbidity	NTU	6.1
ORP	mV	81

Parameter	Units	6/6/2008 MW-302AVE
Ethane	ug/L	0.31
Ethene	ug/L	1.35
Methane	ug/L	230
Alkalinity	mg/L CaCO3	122
Ferrous Iron	mg/L	2.405
Nitrate	mg-N/L	<0.01 U
Nitrite	mg-N/L	<0.01 U
Nitrate + Nitrite	mg-N/L	<0.01 U
Sulfate	mg/L	22.15
DOC	mg/L	1.87
TCE	ug/L	15
cDCE	ug/L	17
tDCE	ug/L	6
VC	ug/L	21
Ferrous Iron	mg/L	0.5
pH	std units	7.50
Conductivity	mS/cm	41
DO	mg/L	2.95
Temperature	Celsius	14.5
Turbidity	NTU	203.0
ORP	mV	113

Parameter	Units	ICF-5D
TCE	ug/L	190
cDCE	ug/L	2100
tDCE	ug/L	170
VC	ug/L	91

Parameter	Units	WCC-1A
TCE	ug/L	15
cDCE	ug/L	5.6
tDCE	ug/L	4.4
VC	ug/L	1.6

Parameter	Units	WCC-1B
TCE	ug/L	92
cDCE	ug/L	74
tDCE	ug/L	51
VC	ug/L	6.6

Parameter	Units	EW-3
TCE	ug/L	260
cDCE	ug/L	270
tDCE	ug/L	130
VC	ug/L	21

Parameter	Units	6/4/2008 CBW-4
Ethane	ug/L	<0.025 UB
Ethene	ug/L	<0.025 UB
Methane	ug/L	0.66 JB
Alkalinity	mg/L CaCO3	145
Ferrous Iron	mg/L	N/A
Nitrate	mg-N/L	1.87
Nitrite	mg-N/L	0.018
Nitrate + Nitrite	mg-N/L	1.89
Sulfate	mg/L	26.6
DOC	mg/L	<1.5 U
TCE	ug/L	8.9
cDCE	ug/L	1U
tDCE	ug/L	0.82J
VC	ug/L	1U
DNA		++++
EAP		mid E+4
Ferrous Iron	mg/L	ND
pH	std units	6.55
Conductivity	mS/cm	38
DO	mg/L	3.46
Temperature	Celsius	12.8
Turbidity	NTU	9.6
ORP	mV	231

Parameter	Units	EW-1
TCE	ug/L	73
cDCE	ug/L	24
tDCE	ug/L	14
VC	ug/L	2.7

Parameter	Units	ICF-2
TCE	ug/L	1300
cDCE	ug/L	1100
tDCE	ug/L	360
VC	ug/L	52

Parameter	Units	EW-4
TCE	ug/L	100
cDCE	ug/L	2200
tDCE	ug/L	1400
VC	ug/L	270

Parameter	Units	EW-2
TCE	ug/L	200
cDCE	ug/L	75
tDCE	ug/L	43
VC	ug/L	5.8

Parameter	Units	CH2M-1
TCE	ug/L	1100
cDCE	ug/L	210
tDCE	ug/L	150
VC	ug/L	4.7

Parameter	Units	6/6/2008 MW-308
Ethane	ug/L	0.041 JB
Ethene	ug/L	0.16 JB
Methane	ug/L	14
Alkalinity	mg/L CaCO3	96.7
Ferrous Iron	mg/L	N/A
Nitrate	mg-N/L	0.011
Nitrite	mg-N/L	<0.01 UB
Nitrate + Nitrite	mg-N/L	0.011
Sulfate	mg/L	16.4
DOC	mg/L	<1.5
TCE	ug/L	15
cDCE	ug/L	6
tDCE	ug/L	1.7
VC	ug/L	0.81
Ferrous Iron	mg/L	0.6
pH	std units	7.43
Conductivity	mS/cm	27
DO	mg/L	5.75
Temperature	Celsius	13.3
Turbidity	NTU	78.8
ORP	mV	122

Parameter	Units	6/5/2008 CH2M-2
Ethane	ug/L	0.01 UB
Ethene	ug/L	<0.025 UB
Methane	ug/L	0.13 JB
Alkalinity	mg/L CaCO3	97.7
Ferrous Iron	mg/L	0.095
Nitrate	mg-N/L	0.771
Nitrite	mg-N/L	<0.01
Nitrate + Nitrite	mg-N/L	0.771
Sulfate	mg/L	15.3
DOC	mg/L	<1.5 U
TCE	ug/L	21
cDCE	ug/L	1.5
tDCE	ug/L	1U
VC	ug/L	1U
Ferrous Iron	mg/L	ND
pH	std units	7.35
Conductivity	mS/cm	26
DO	mg/L	4.62
Temperature	Celsius	12.1
Turbidity	NTU	21.6
ORP	mV	228

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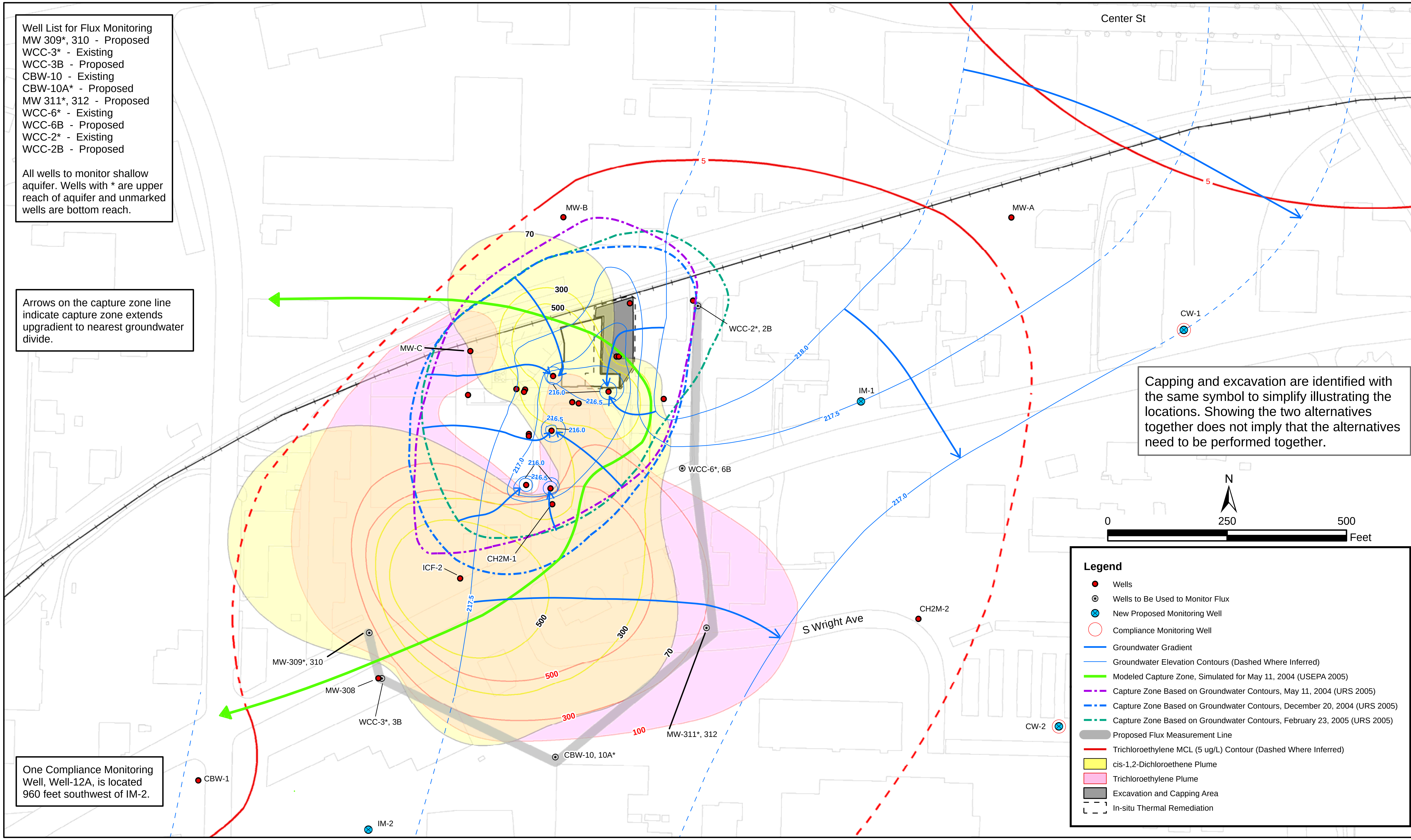
Well 12A Superfund Site
Tacoma, Washington

Figure 3-5
Intrinsic Bioremediation Parameters
and Flux Measurement Location



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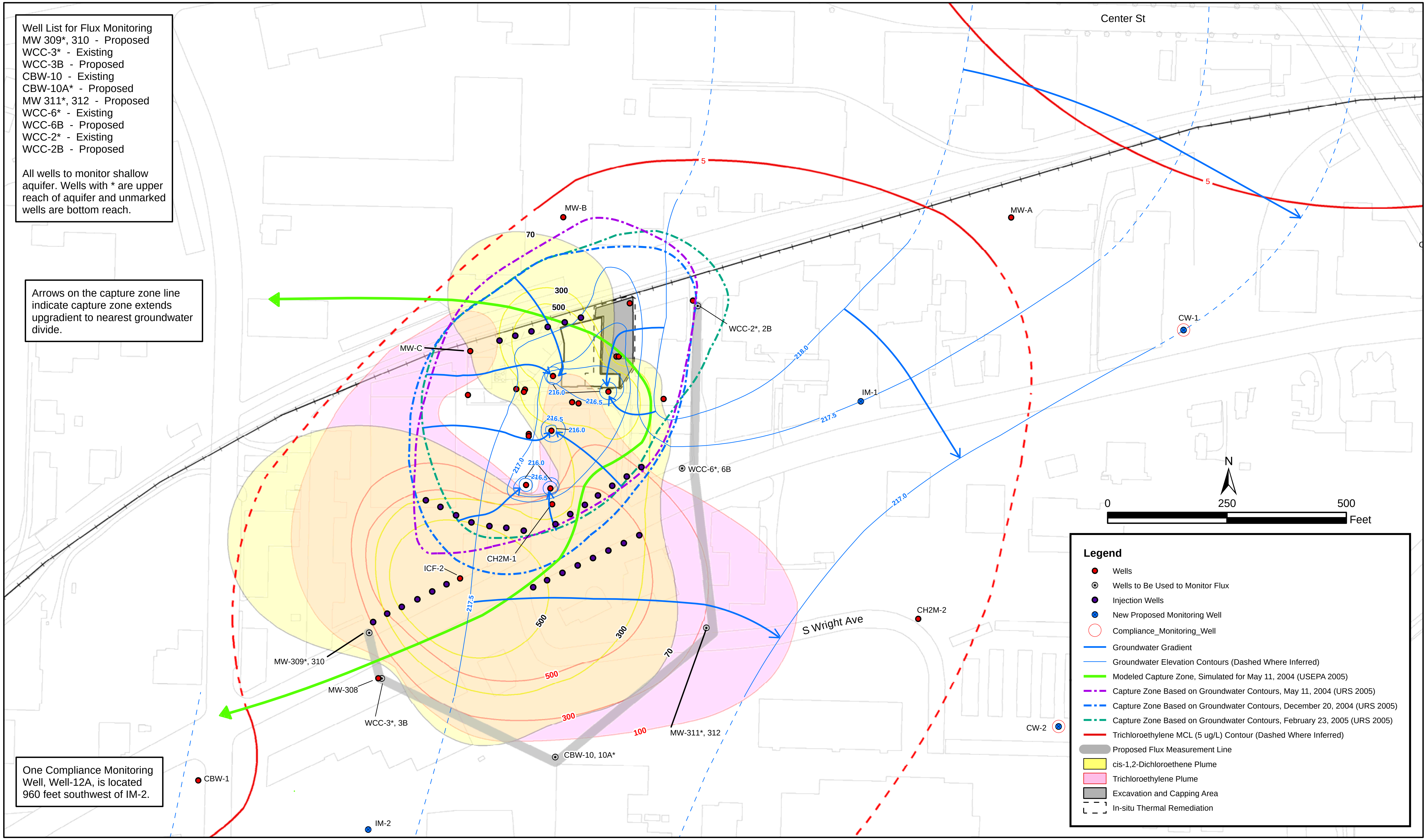
Well 12A Superfund Site
Tacoma, Washington

Figure 4-1
Excavation, Capping and In-situ Thermal Remediation Alternatives



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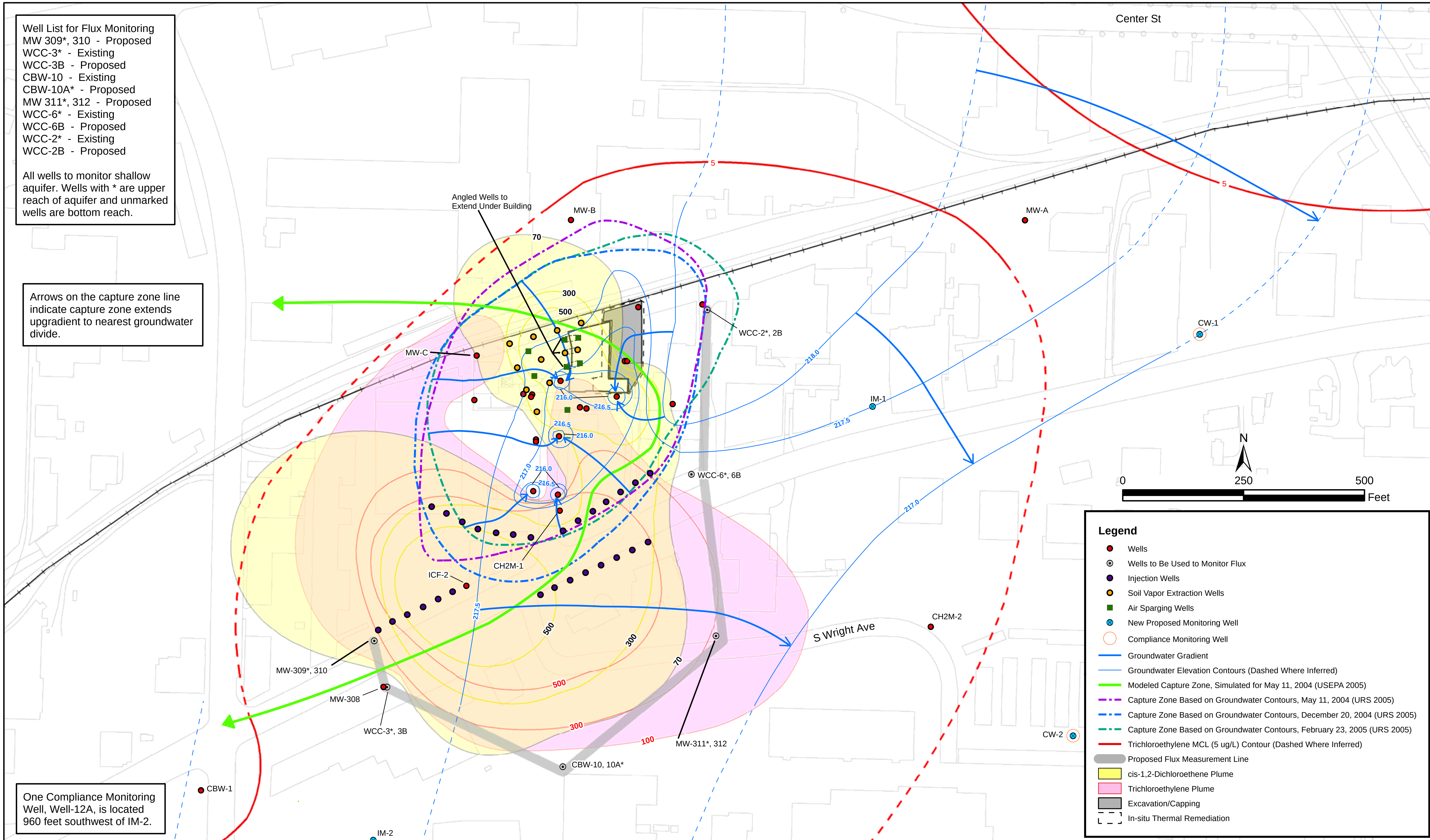
Well 12A Superfund Site
Tacoma, Washington

Figure 4-2
Enhanced Anaerobic Bioremediation Alternative



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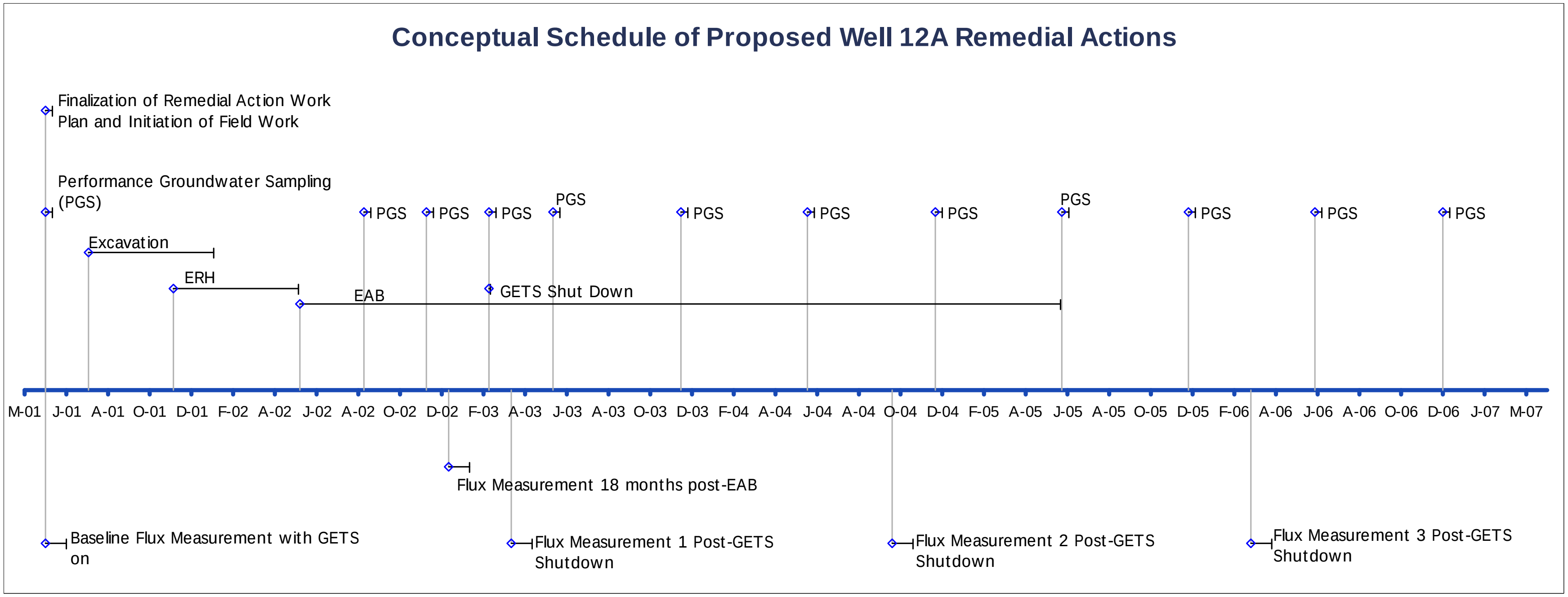
Well 12A Superfund Site
Tacoma, Washington

Figure 4-3
Air Sparging and Soil Vapor Extraction Alternative
with Enhanced Bioremediation



NOTES:
-01, 02 implies Year 1, Year 2, etc.
-Baseline flux monitoring at initiation of activities
- Monthly GW performance monitoring for the six months of ERH
-PGS quarterly for EAB in YR01 and biannual thereafter

The State would be taking over the site after the GETS is turned off and

•90% flux reduction groundwater remediation level is met
•MCLs are met at the compliance wells 12A, new well CW1, and new well CW2

Appendix A
Contaminant Source Strength and Timing and Sensitivity Analysis Memorandum

CDM

993 Old Eagle School Road, Suite 408
Wayne, Pennsylvania 19087
tel: 610 293-0450
fax: 610 293-1920

August 4, 2008

Kira Lynch
US EPA Region 10
Office of Environmental Cleanup (ECL-113)
1200 Sixth Avenue, Suite 900
Seattle WA 98101

Subject: Well 12A Focused Feasibility Study Technical Memorandum – Contaminant Source Strength and Timing and Sensitivity Analysis

Dear Ms. Lynch:

Please find enclosed the Draft Well 12A Technical Memorandum- Contaminant Source Strength and Timing and Sensitivity Analysis. This draft memorandum is being submitted to you as a partial fulfillment of the reporting requirements for this assignment.

If you have any questions, call me at (610) 293-0450.

Sincerely,

Aaron R. Frantz, P.E., P.G.
Project Manager
CDM Federal Programs Corporation

Draft Technical Memorandum
Contaminant Source Strength and Timing and Sensitivity Analysis

Purpose

The objectives of this contaminant transport groundwater modeling task are to:

- Estimate the contaminant source timing and strength
- Analyze the sensitivity of the model to source strength

This memorandum documents the modeling activities that were completed for the source timing and strength evaluation and the sensitivity analysis. After the model is accepted, it may be used as a tool to evaluate remedial alternatives. For example, if the contaminant (e.g., TCE) source is removed and groundwater concentrations are reduced by ninety percent, what will be fate of the plume. The alternative evaluation simulations may be run in the future and a second memorandum will be prepared to document the simulation results.

Conceptual Model

A conceptual model that included steady-state numerical models of the Well 12A hydrogeologic system was presented as part of the Draft Final Field Investigation and Capture Zone Analysis Report Commencement Bay, South Tacoma Channel/Well 12A Superfund Site Tacoma, Washington (URS, 2005). The conceptual model presented the modeler's understanding of the occurrence and movement of groundwater in the area of interest and is based on regional data, site-specific data and general hydrogeologic knowledge. The Draft Final Field Investigation and Capture Zone Analysis Report did not address site contamination or contaminant transport.

Site Contamination

Source timing and strength were estimated based on aquifer solute transport parameters and current TCE distributions in groundwater. Using these values, the TCE release pattern using current mass and distribution of TCE was estimated.

Aquifer Transport Properties

TCE is adsorbed on sites within the aquifer matrix, limiting its mobility in groundwater. This adsorption may occur on sites such as natural organic carbon coatings on aquifer materials, but may also occur to a lesser degree on inorganic surfaces such as clay or iron minerals. The chemical characteristic that defines the degree to which the chemical are adsorbed is the organic carbon partitioning coefficient (Koc), which is reported in numerous sources for the chemicals of interest. This coefficient defines the degree to which a chemical will partition onto the solid phase adsorption sites. At concentrations observed at the site, this process is assumed to be linear, instantaneous and reversible. A bulk measure of the adsorption capacity of the aquifer material may be estimated using the Koc and the organic carbon concentration in the soil. This term is described as the soil – water partitioning coefficient (Kd). Kd may be estimated by multiplying the fraction of organic carbon present in the soil by the Koc value for the chemical of interest.

Once Kd has been estimated for the chemicals of interest and the aquifer material at the site, the velocity of the contaminants may be estimated. These equilibrium sorption processes have the effect of slowing movement of contaminants relative to the groundwater velocity. The ratio of the velocity of the groundwater to that of the contaminant front is referred to as the retardation factor, R. A value of 1 for R indicates

$$R = 1 + \frac{Kd * Density}{TotalPorosity}$$

the contaminant moves at the same velocity as groundwater. The R value can be estimated from the following equation:

Where:

R – Ratio of average groundwater velocity to average contaminant velocity

Kd – soil water partitioning coefficient

Density – dry bulk density of aquifer soil

Total Porosity – total porosity of aquifer material

Values for the aquifer parameters were determined from laboratory analysis of aquifer materials collected during field activities for the Draft Final Field Investigation and Capture Zone Analysis Report (URS, 2005). The K_{oc} value for TCE was chosen from a table entitled Physical Chemical Data for Volatile Organic Compounds posted on the EPA Region 9 website.

r_b = 1.88 gram/milliliter
n_e = 0.21
K_{oc} = 170 millilter/gram (F_{oc} = 0.0017)

Incorporating these values, a retardation factor of 3.5 was calculated. This high capacity for adsorption of TCE on the aquifer matrix will result in slowed flushing of the aquifer, following elimination of the source of additional mass.

In addition, TCE may readily degrade under the proper biogeochemical conditions in aquifers. A reasonable half-life for TCE in aerobic groundwater is 7 years and would tend to decrease the effective TCE velocity in groundwater.

Lastly, the effect of dispersion spreads contaminant mass beyond the region it would normally occupy due to advection alone. Dispersion occurs in three directions (longitudinal, transverse and vertical). Longitudinal dispersivity is the largest and transverse and vertical are commonly considered to be one and two orders of magnitude lower, respectively. Longitudinal dispesivity is defined as

$$\text{Dispersivity} = 0.83\ (\log\ (\text{plume length}))^{2.414}$$

where length is in meters (Xu and Eckstein 1995).

Therefore, using a plume length of 2,640 ft (805 m), longitudinal dispersivity is 35.8 ft. Transverse and vertical dispersivity is suggested to be 3.6 and 0.1 ft, respectively.

Groundwater Travel Time

Travel times were estimated for groundwater moving from the former Time Oil site to Well 12A. The contaminant release date was estimated by dividing the travel distance by the travel time according to the following relationship:

$$\text{Time} = \text{Distance}/V_{pore}$$

Groundwater velocity was determined by the following relationship:

$$V_{pore} = Ki/ne$$

where

K = hydraulic conductivity
i = hydraulic gradient
ne = effective porosity

- Based on water elevations collected when Well 12A was pumping and the GETS was not operating (July 9, 1985), the groundwater gradient from source to sink (Well 12A) is 0.0023.

- Numeric groundwater flow modeling indicates that aquifer materials located between the source area and Well 12A have an average hydraulic conductivity of 550 feet/day.

- The effective porosity of site materials was determined as part of laboratory analyses conducted on aquifer samples collected from the former Time Oil Site during field activities conducted as part of the Capture Zone Analysis Report (URS 2005). The average effective porosity for aquifer materials is approximately 0.21.

Incorporating these values, V_{pore} = 6.0 feet/day. This rate is the average velocity of a conservative tracer traveling from the former Time Oil site to Well 12A. Well 12A operates, on average, 90 days per year. Therefore, this flow scenario applies, on average, 90 days per year. As a result, source area groundwater travels approximately 540 ft toward Well 12A each year.

However, the transport of TCE is retarded by interaction with aquifer solids. The retardation factor (R_f) affects travel velocity according to the following relationship:

$V_{TCE} = (V_{pore})(R_f)$
V_{TCE} = (6.0 feet/day)/3.5
V_{TCE} = 1.7 feet/day or 154 feet/year

The distance from the presumed source area within the former Time Oil site and well 12A is approximately 2,600 feet. Using these values yields:

Time = Distance/V_{TCE}
Time = 2,640 feet/(154 feet/year)
Time = 17 years

This travel time assumes that a contaminant particle travels toward Well 12A when the well is operating and when it is shut off, the contaminant stops at its current location and does not migrate from that position. When Well 12A is re-started, then the particle is remobilized and continues to travel toward the pumping well. This stopping and starting continues until the particle is captured by the well. In reality, the particle does not stop moving when Well 12A is shut off. Rather, the particle moves eastward (away from Well 12A) under the ambient gradient when the well is shut down. If the well operates a limited amount of time, then intuitively, the particle would not reach the pumping well. Rather, the particle would have a significant amount of time to travel eastward beyond the Well 12A influence and the limited time of pumping would not be sufficient to overcome the natural prevailing gradient.

Released TCE Mass
This travel time of 17 years appears to coincide with the time between when Time Oil Company acquired the majority of the property (1964) until when Well 12A contamination was first identified (1981).

The total TCE mass released includes all mass released from the former Time Oil site from initial release, until February 2008 (date of most recent groundwater sampling). According to site records, TCE was detected at well 12A in July, 1981. Using the transport time of approximately 17 years, the suspected release of TCE began around 1964. The model was constructed to simulate a release date of January 1963 to allow for monitoring early arrival times.

Calculating the total released mass was accomplished by choosing a reasonable decay constant for TCE and back-calculating from the present estimated TCE mass, as calculated using Environmental Visualization System (EVS) software.

- Using the 2008 groundwater data, the EVS software calculates a mass of 60 kilograms of TCE remaining in the portion of the groundwater plume containing TCE concentrations greater than 10 ug/L TCE.

- A half-life of seven years is typical for TCE dissolved in aerobic aquifers.

- Since the estimated release date of 1963, approximately 6.5 half-lives have elapsed.

- Using a half-life of seven years, an original mass of 5,500 kg of TCE would account for a remaining mass of 60 kg.

- 5,500 kg of TCE corresponds to approximately 21 drums of TCE.

This back calculation provides an approximation of the mass that may have entered into the system. However, it is recognized that the estimates may differ since it does not take into account variables such as a changing mass input over time (e.g., 500 kg of TCE entered the system in 1965 and 500 kg of TCE entered the system in 1975).

Numerical Model Source Term

To design the source term, the mass flux through the source was estimated according to the source geometry, the source area flow velocity, and source concentration.

- The EVS visualizations show the portion of the 2008 TCE plume with concentrations greater than 1000 ug/L to be approximately 220 feet in width (perpendicular to groundwater flow).

- The location of the source was simulated to extend 220 feet from the area of excavated soil eastward across the former Time Oil building.

- Two hydraulic zones split the source area in approximately equal portions. One zone is 400 feet/day and the other is 40 feet/day. For the source area mass flux calculation, the lower hydraulic gradient was considered to predominate. This conclusion was based on the observed GETS well yields, which are quite low. As a result a conductivity of 40 feet/day was used for the source area. Groundwater velocity was determined by the following relationship:

  $V_{pore} = Ki/ne$
  $V_{pore} = (100 \text{ feet/day})(0.0006)/0.21$
  $V_{pore} = 0.32 \text{ feet/day}$

- The saturated cross sectional area of the source is 220 feet in width and 70 feet in thickness. The resulting cross-sectional area is 15,400 square feet. The discharge through the source term equals the cross sectional area multiplied by the pore water velocity:

$Q = (\text{source cross section})(V_{pore})$

The resulting discharge through the source is 5.02×10^7 L/year

- To match the estimated release history, the source term for the model provided approximately 5,100kg of TCE throughout the model's 45 year simulation. A decaying source term was used. The release starts in January 1963 at a concentration of 2,500 ug/L. The source concentration drops to 1,500 ug/L in November, 1997, corresponding to the cessation of soil vapor extraction.

- The total mass released equals the product of the discharge through the source term, the flow duration, and the source concentration.

TCE mass = (Q)(source duration)(source concentration)
TCE mass = (5.02×10^7 liter/year)(35 yr)(2,500 ug/L) = 4393 kg
TCE mass = (5.02×10^7 liter/year)(10 yr)(1,500 ug/L) = 753 kg
TCE mass = 5,146 kg

Transient Simulations

The transient model was based on the steady-state model that was calibrated to match conditions in July 9, 1985, when Well 12A was pumping and the GETS was not pumping. Aquifer storage parameters were added to the steady state model based on the results of a single long-term aquifer test performed in the upper aquifer. These storage values were estimated by matching the simulated response of four monitoring wells (CH2M-1, IDF-5S, MW-305, and WCC-1A) to the measured aquifer responses at these wells during cessation of the GETS in February 2008. A single storage value was used for the entire site, as it was assumed that the lower aquifer had the same storage value. The best match was achieved using a specific yield (S_y) of 0.1. Figure 1 displays the matches of measured and simulated data using S_y of 0.1.

Pumping Conditions

The transient simulation covers changing pumping conditions over 45 years. The details of which are as follows:

- Beginning in 1963, Well 12A is pumping at 4,000 gallons per minute (gpm) for 90 days per year. Well 12A does not pump for the remaining 275 days. The cycle is repeated for the remainder of the simulation (until 2008).

- Beginning in 1988, the GETS system (approximated by one boundary condition) begins pumping continuously at 38 gallons per minute until 1995.

- Beginning in 1995, the GETS system (approximated by one boundary condition) begins pumping at 75 gallons per minute. This pumping continued for the remainder of the simulation.

- Beginning in 1963, Tacoma Wells 2B, 9A, 4A, and 6A/11A are pumping year-round, at a single discharge rate. The discharge rate is one half of each well's measured discharge rate as measured on July 9, 1985. Drawdown induced by steady-state pumping of these wells at a reduced discharge rate was found to be indistinguishable from pumping these wells at a higher rate, for 90 days per year. The steady-state pumping rates included in the model were 644 gpm for Well 2B, 295 gpm for Well 9A, 56 gpm for well 4A, and 4,220 gpm for well 6A/11A.

Individual Simulations
Attempts to match simulated TCE distribution with measured TCE distribution were not successful using realistic Well 12A pumping rates and duration. In an attempt to learn as much as possible from the transient simulations, various scenarios were simulated. Both advective travel times and simulated solute transport are presented. The advective travel times provide a visualization of groundwater flow; retardation, dispersion and decay are not included in advective transport.

- Figure 2 shows particle tracks emanating from the site and from a point to the east of the site. The simulation shows the effects of 45 years of Well 12A pumping at 4,000 gpm, 90 days per year. No particles travel to Well 12A; the eastward ambient gradient prevails. Therefore, the sink values (both time and strength) that are located southeastward of the Time Oil site are not sufficient to support the transport of contaminants to Well 12A, or another site feature has not been identified and is not incorporated into the model. For example, perhaps discrete zones, which have not been identified by site investigation, of high hydraulic conductivity are present that provide a pathway from the site to Well 12A.

- A second simulation was run to estimate the pumping time needed to begin to achieve capture. Figure 3 presents the results of simulation two. The simulation shows the effects of 45 years of Well 12A pumping at 4,000 gpm, 182.5 days per year. Even under this unrealistic pumping scenario, only particles far to the east of the former Time Oil site are captured by Well 12A.

- As a third metric, a third simulation was run to evaluate the effects of 45 years of Well 12A pumping at 4000 gallons per day, 305 days per year. Under this unrealistic pumping scenario, particles from the former Time Oil site are captured by Well 12A.

- Although advective transport evaluations indicated prevailing gradients to the east TCE transport was considered to evaluate the effects of transport properties. Figure 5 shows the TCE distribution resulting from a transient TCE source term located at the former Time Oil site. The simulation shows the effects of 45 years of Well 12A pumping at 4000 gallons per day, 90 days per year. No TCE goes to Well 12A.

- Figure 6 shows the TCE distribution resulting from a transient TCE source term located at the former Time Oil site. The simulation shows the effects of 45 years of Well 12A pumping at 4000 gallons per day, 305 days per year.

Conclusions

Several conclusions, which are presented as finding and recommendations, were developed from this modeling task.

Findings

- When Well 12A is operating, groundwater velocity to the well is estimated to be 6 ft/day. The retarded velocity for TCE is estimated to be 1.7 ft/day.
- Travel times suggest the source to start in the early to mid-1960s, which is when the Time Oil Company took control of a majority of the property.
- Well 12A operates approximately 3 months/year. When the well is operating, the hydraulic gradient at the site is to the southeast toward the sink. When the well is not operating, the ambient gradient is to the east.
- Estimates suggest that the ambient gradient prevails and dissolved contaminants would not migrate from the Time Oil property to Well 12A under current known conditions. However, if an unidentified feature exists that creates a pathway from the property to the well, then contaminants will migrate as seen in well concentrations.

Recommendations

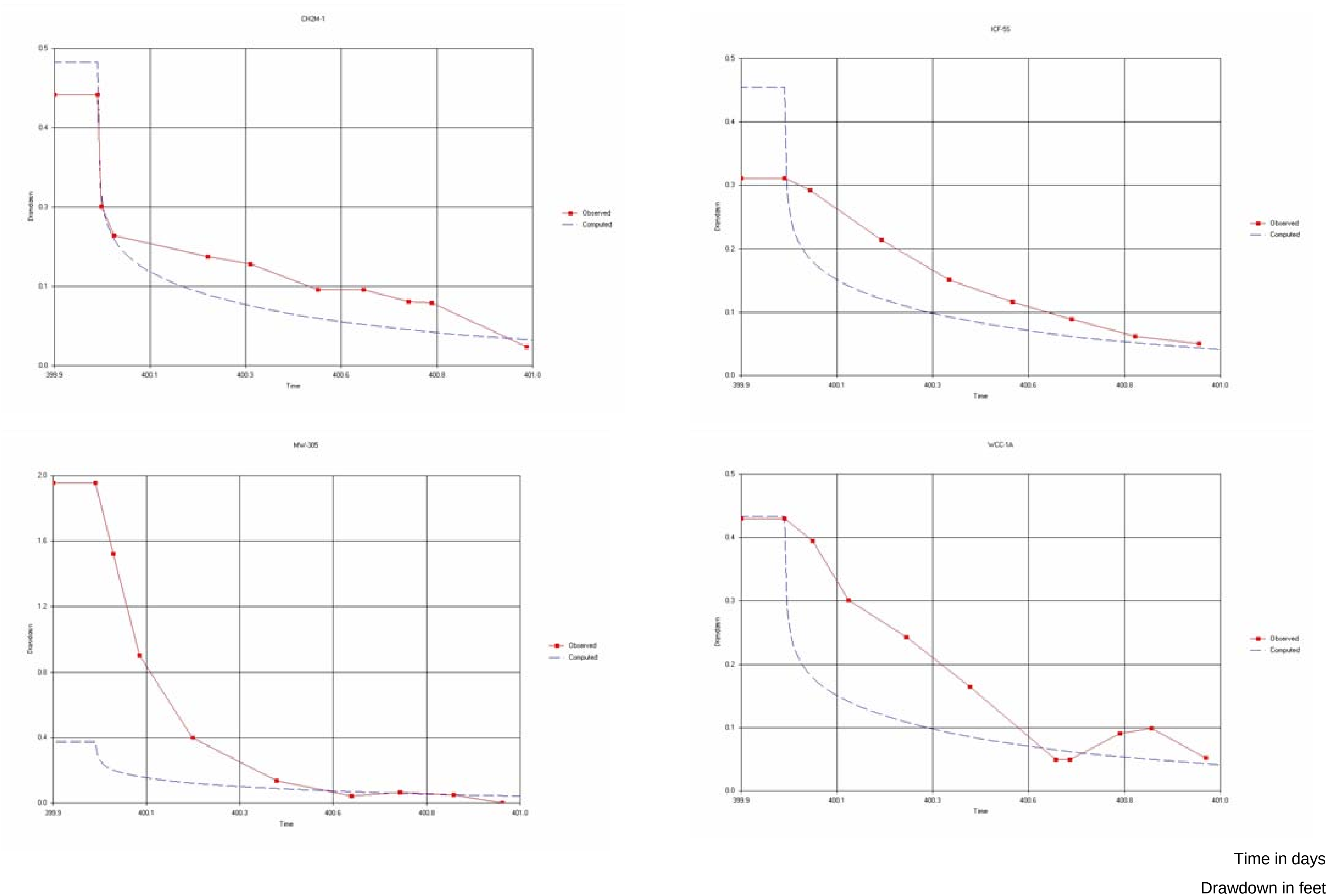
- Contact the City of Tacoma and allow them to verify the extraction well pumping rates
- Research if regional maps have been prepared that maps the potentiometric surface under the pumping conditions of the Tacoma wells and determine if a prevailing gradient is toward Well 12A due to pumping or if the eastward ambient conditions prevail
- If extraction well rates are verified and/or regional data suggest a prevailing gradient eastward, then the analytical information in this memorandum shall be used to assist in evaluating remedial alternatives.

References

URS Inc., 2005. *Draft Final Field Investigation and Capture Zone Analysis Report Commencement Bay, South Tacoma Channel/Well 12A Superfund Site Tacoma, Washington.* Report prepared for EPA Region Region 10. September.

U.S. Environemntal Protection Agency Region 9. Region 9 PRGs 2004 Table: TRICHLORETHYLENE. Website http://www.epa.gov/region09/waste/sfund/prg/files/04prgtable.pdf Accessed June 2008.

http://www.epa.gov/ATHENS/learn2model/part-two/onsite/longdisp.htm

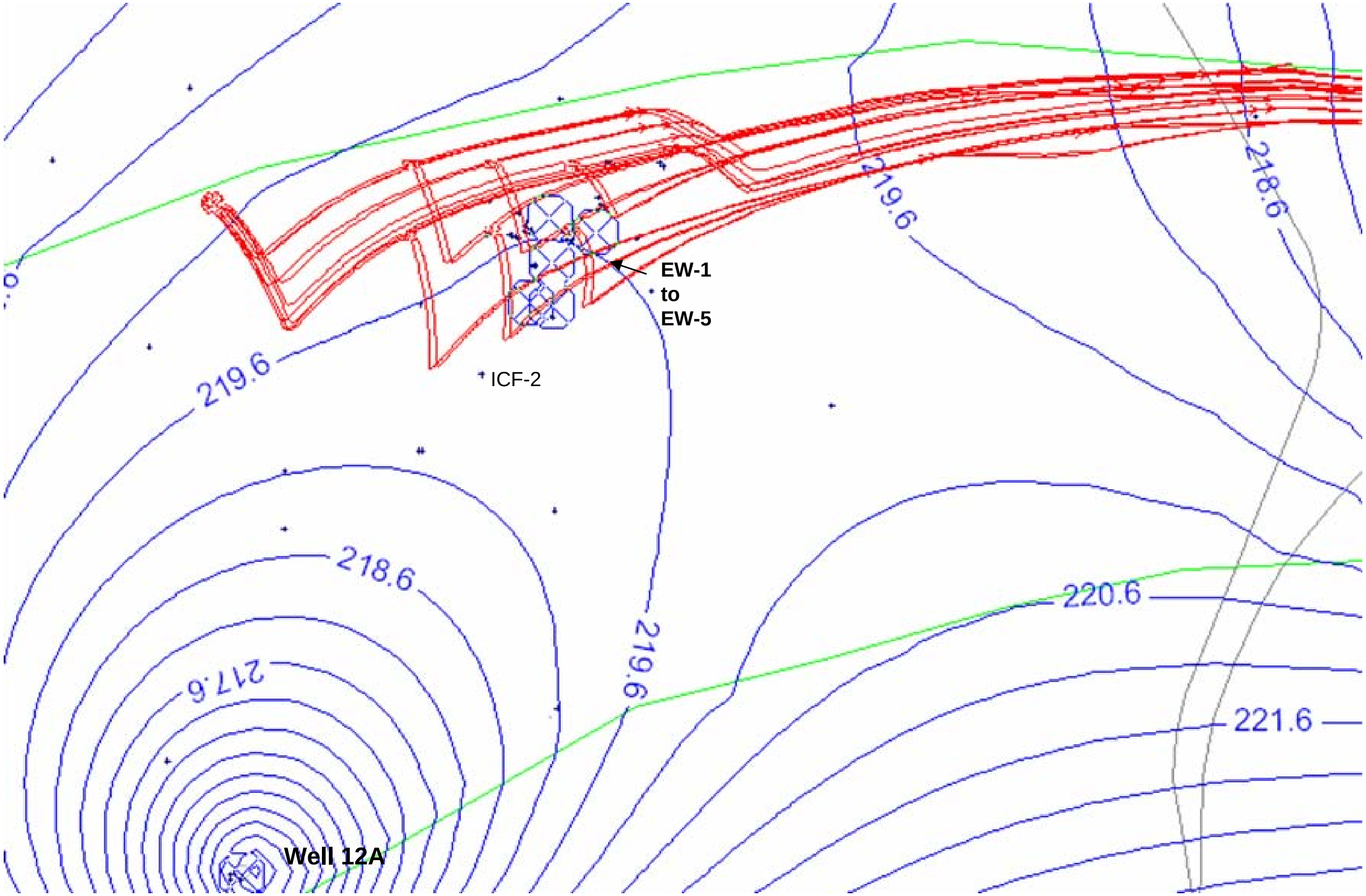


Well 12A Superfund Site

Tacoma, Washington

Figure 1

Simulate and Measured Hydrographs of Monitoring Wells after Cessation of GETS in February 2008



Well 12A pumping for 45 years at 90 days per year

Arrow interval represents one year travel time

CDM

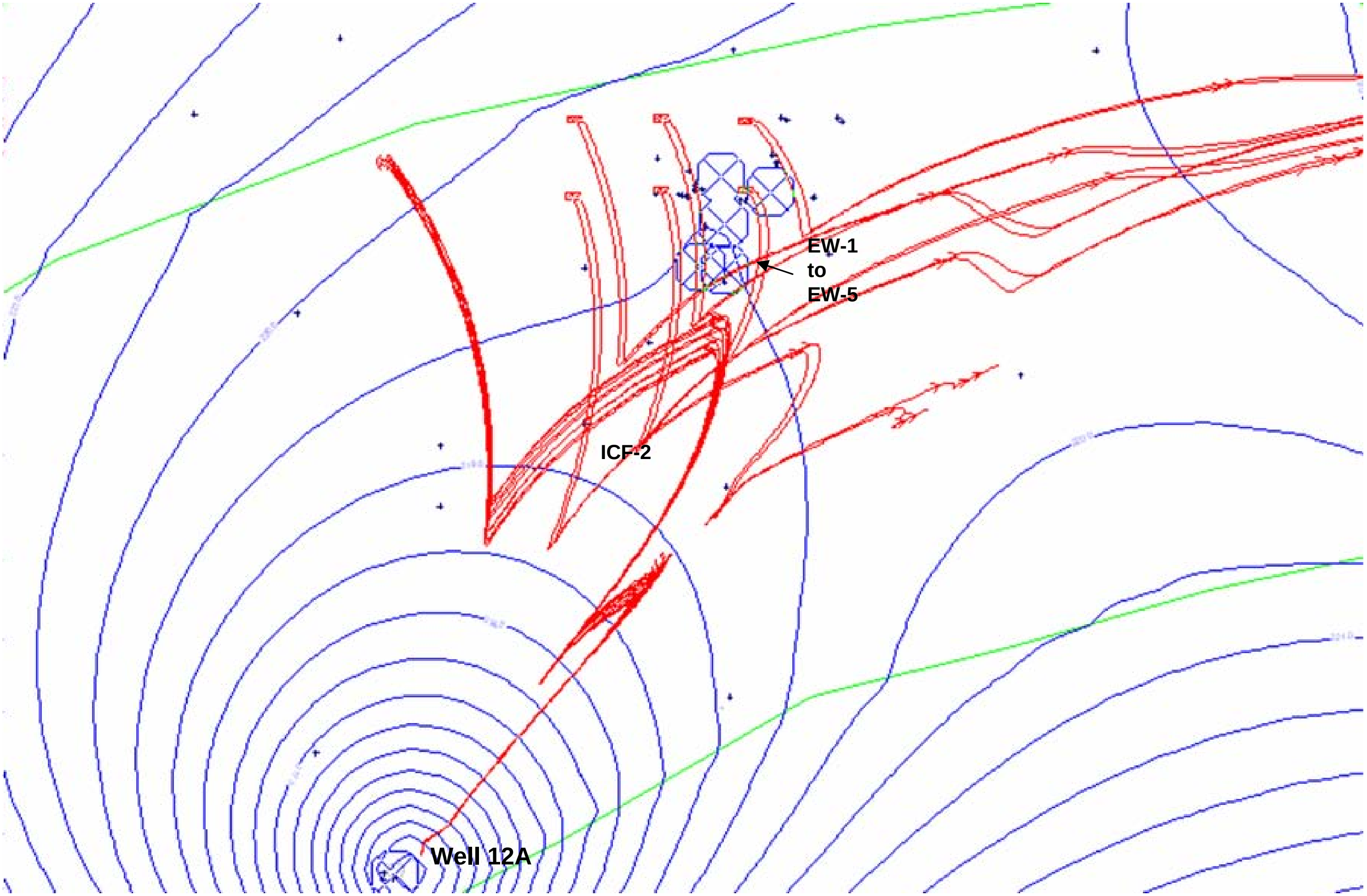
Well 12A Superfund Site

Tacoma, Washington

Figure 2

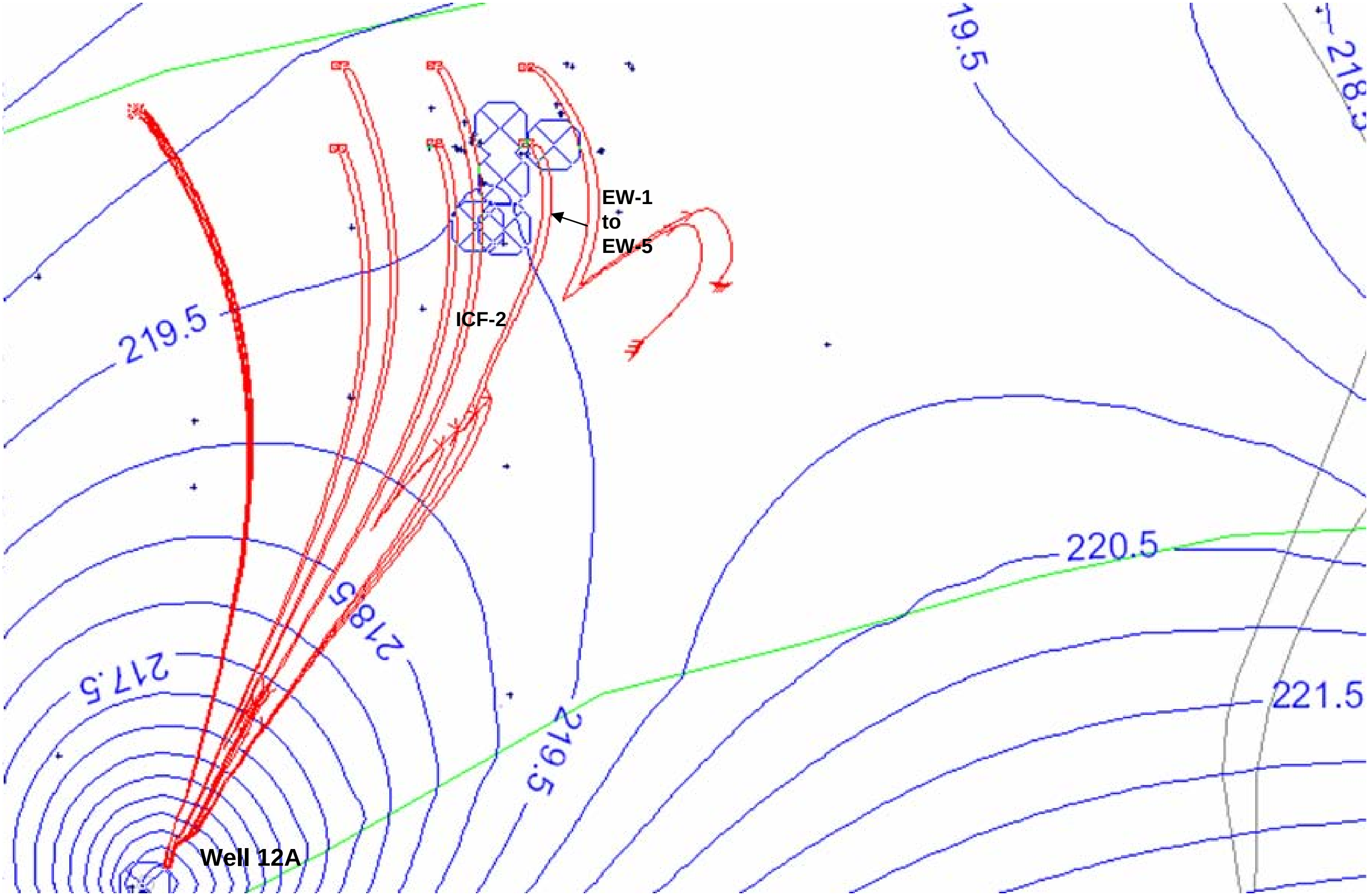
Simulation 1

Estimated Pathlines



Well 12A pumping for 45 years at 182 days per year

Arrow interval represents one year travel time



Well 12A pumping for 45 years at 305 days per year

Arrow interval represents one year travel time

CDM

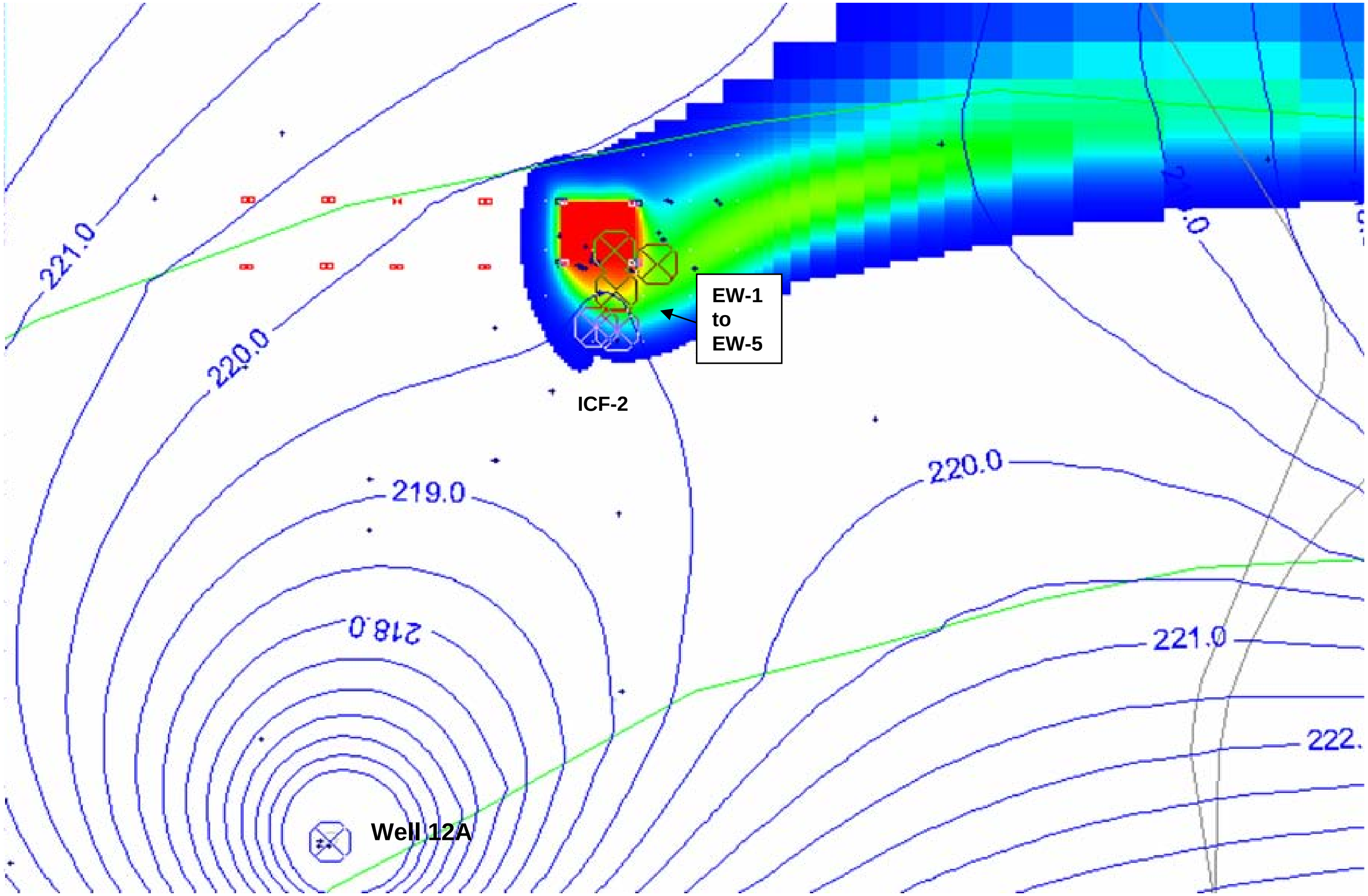
Well 12A Superfund Site

Tacoma, Washington

Figure 4

Simulation 3

Estimated Pathlines



Well 12A pumping for 45 years at 305 days per year

Concentrations are TCE from 10 to 1,500 ug/l

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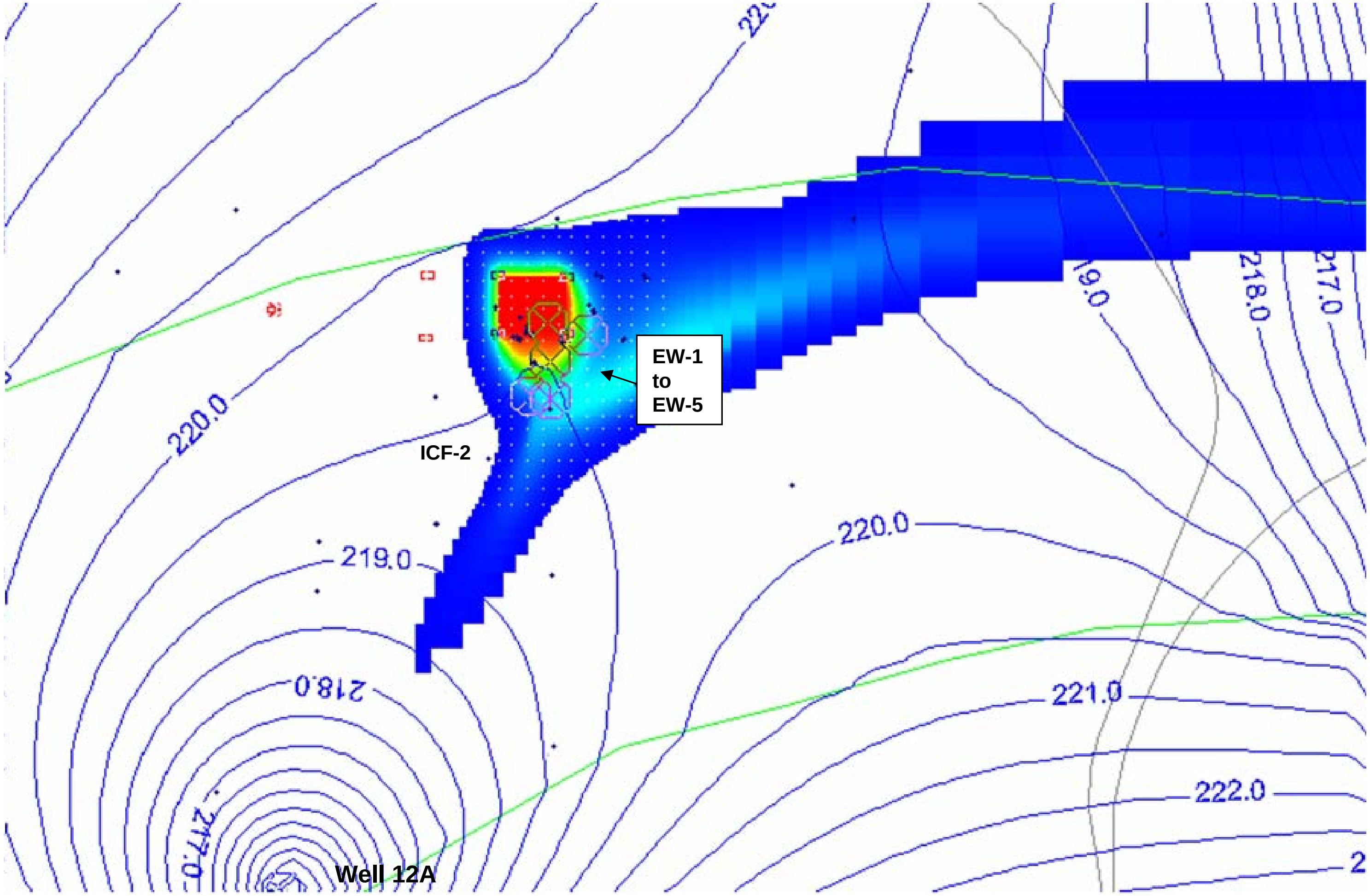
Well 12A Superfund Site

Tacoma, Washington

Figure 5

Simulation 4

Estimated Pathlines



Well 12A pumping for 45 years at 305 days per year

Concentrations are TCE from 10 to 1,500 ug/l

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Well 12A Superfund Site

Tacoma, Washington

Figure 6

Simulation 5

Estimated Pathlines

Appendix B
Monitored Natural Attenuation Evaluation Memorandum

CDM

993 Old Eagle School Road, Suite 408
Wayne, Pennsylvania 19087
tel: 610 293-0450
fax: 610 293-1920

August 4, 2008

Kira Lynch
US EPA Region 10
Office of Environmental Cleanup (ECL-113)
1200 Sixth Avenue, Suite 900
Seattle WA 98101

Subject: Well 12A Focused Feasibility Study Monitored Natural Attenuation Evaluation Memorandum

Dear Ms. Lynch:

Please find enclosed the Draft Well 12A Focused Feasibility Study Monitored Natural Attenuation Evaluation Memorandum. This draft memorandum is being submitted to you as a partial fulfillment of the reporting requirements for this assignment.

If you have any questions, call me at (610) 293-0450.

Sincerely,

Aaron R. Frantz, P.E., P.G.
Project Manager
CDM Federal Programs Corporation

Revised Draft
Well 12A Monitored Natural Attenuation Evaluation Memorandum
July 29, 2008

Groundwater samples were collected on June 4, 5 and 6, 2008 from wells at the Well 12A Superfund site in Tacoma, Washington and analyzed for monitored natural attenuation (MNA) parameters, enzyme activity, and microbial DNA. The purpose of the event was to collect data to determine where biological degradation is occurring and characterize the areas and degree of activity. The monitored natural attenuation parameters are reported in this memorandum and the enzyme activity and DNA analyses are also summarized. The enzyme activity probe (EAP) analyses and molecular assays are detailed in *Enzyme Activity Probe Assessment of Groundwater: Parametrix/CDM* by North Wind, Inc. and dated July 11, 2008. The groundwater samples were collected in accordance with the *Quality Assurance Project Plan Addendum Monitored Natural Attenuation Supplemental Sampling Event* dated May 30, 2008 and prepared by CDM.

The data reported for the analyses is presented in attached Table 1 and Figure 1. In general, the information in the figure is similar to the data in the table. The figure illustrates the sampling point locations relative to each other and the source area. Volatile organic compound (VOC) concentrations that can be used to assess biological degradation are also presented in the table and figure. The VOC data are for samples collected in February/March 2008. No samples for VOC analyses were collected from wells during the June 2008 MNA event.

Several observations can be made on the biological degradation conditions on inspection of the data. General observations and the groupings of wells (aerobic, anaerobic and transitional conditions) are identified below.

General Observations

- Peripheral wells surrounding the Time Oil property show aerobic conditions, with TCE present in low concentrations
- Wells within the source area tend to be anaerobic, with a full range of TCE degradation products (cis & trans 1,2-DCE, Vinyl Chloride, and gases where measured)

Wells with aerobic conditions (clockwise from north):

- **CH2M-4** - NO_3 3.54 mg-N/l, ORP 247, TCE primary contaminant (this location may be in an area of a separate VOC source)
- **CH2M-3** – NO_3 4.62 mg-N/l, ORP 81 (unusually low), TCE primary contaminant
- **WCC-6** – NO_3 3.38 mg-N/l, ORP 192, TCE primary contaminant
- **CBW-4** - NO_3 1.87 mg-N/l, ORP 231, TCE primary contaminant
- **WCC-5** - NO_3 2.08 mg-N/l, ORP 226, with TCE, cis and trans-1, 2DCE, and VC
- **MW-C** - NO_3 2.89 g-N/l, ORP 266, with TCE, cis & trans-1, 2DCE, and VC
- Additional aerobic condition observations for the aforementioned six wells

- **CH2M-4, CH2M-3, WCC-5, and CBW-4** – EAP analyses show significant activity of aerobic cometabolic microorganism populations that may be contributing to the attenuation of TCE.
- **CH2M-4, CH2M-3, WCC-6, and CBW-4** - located at distal locations from the Time Oil property, and contain no TCE degradation products. These well conditions are likely indicative of the aerobic conditions present in the regional aquifer.
- **WCC-5 and MW-C** - located west of the Time Oil property. The NO_3 and ORP values are indicative of aerobic conditions, but the presence of TCE degradation products that would normally readily degrade under aerobic conditions indicate that these wells are in a transition state. Alternatively, the wells may be close enough to a continuing source so that the migrating degradation products are continually replenished.

Transition well:

- **CH2M-2** – Southeast of Time Oil, has lower NO_3 (0.771 mg-N/l), and only a small amount of cis-1, 2DCE (1.5 ug/l), but elevated ORP of 228.

Wells with anaerobic conditions:

- **MW-302** – North end of Fife Street, southeast of the VES building, has (average of duplicate samples) low NO_3 concentrations (<0.1 mg-N/l), elevated Ferrous^{++} ion (2.405 mg/l), the lowest dissolved oxygen (2.95 mg/l) of any of the wells sampled, low concentrations of ethene and ethane, elevated concentrations of methane (230 ug/l), with TCE, cis and trans-1, 2DCE, and VC. The presence of SO_4 (22.15 mg/l) indicates that conditions are not uniformly methanogenic.
- **MW-308** – Southwest of the site, below the semi-confining unit, has low NO_3 concentrations (0.011 mg-N/l), very low (J-value) concentrations of ethene and ethane, 14 ug/l of methane, with TCE, cis and trans-1, 2DCE, and VC.
- **EW-4, EW-5, ICF-5D** – Moderate concentrations of TCE, high concentrations of cis and trans-1, 2DCE, VC, and PCA. Concentrations of cis-1, 2DCE are 10 to 20 times TCE, indicating significant reductive dechlorination of TCE has occurred. In EW-4 and EW-5, concentrations of trans 1, 2-DCE are 68% of cis-1,2DCE, which is an unusually high ratio (the concentrations of cis-1,2DCE are usually about 30 times trans-1,2DCE). This ratio could be caused by site bacterial cultures that produce a higher concentration of trans-1,2DCE. Alternatively, cis-1,2DCE is more readily degraded to VC, and the higher trans-1,2DCE concentrations may indicate that there once were much higher concentrations of TCE that had degraded to cis-1,2DCE, VC, and ethene/ethane, and that concentrations of the more recalcitrant trans-1,2DCE gradually accumulated over time.
- **EW-3, EW-2, EW-1** – Moderate concentrations of TCE, equal to or approximately three times cis-1, 2DCE. Reductive dechlorination has occurred, but not to the same degree as in EW-4 or EW-5. In all three wells, trans-1,2DCE concentrations are approximately 50% of cis-1,2DCE.
- **ICF-2** – High concentrations of TCE (1300), with slightly lower concentrations of cis-1, 2DCE (1100). Concentrations of trans-1,2DCE are only 33% of cis-1,2DCE. These ratios may indicate that dechlorination has been not been as strong in this well, with TCE not degrading to the same extent as in other wells.

- **CH2M-1** – High concentrations of TCE (1100 ug/l), with concentrations of cis-1,2DCE (210) that are 19% of TCE.
- **ICF-4** – Low concentrations of TCE (50 ug/l), slightly higher concentrations of cis 1, 2-DCE (69 ug/l), trans-1,2DCE (34 ug/l) at half of the cis-1,2DCE concentration, and higher concentrations of VC (95 ug/l) may indicate ongoing reductive dechlorination.

Conclusion

The data indicate that significant reductive dechlorination is or has been ongoing at the Well 12A site, and therefore, the site is not biologically limited. The lack of strongly reducing conditions indicate that there is currently limited electron donor remaining to sustain dechlorination. Current reducing conditions may be due to endogenous decay, where current organisms are stimulated by the dying biomass of previous activity.

The MNA evaluation can be used to guide the development of objectives for a remedial action and the formulation of a plume management strategy. Currently, the data suggest the following approach is appropriate

- Target destruction of contaminant mass in the source areas – emphasize reduction of TCE and PCE to below regulatory criteria. Could be accomplished by targeting source areas (lenses and aqueous phase) by introducing electron donor, or targeted application of thermal remediation

- Reduce mass flux migrating outside of source area, especially TCE and PCE. Any cis 1, 2 DCE or VC that migrates from anaerobic zones to aerobic zones should quickly degrade

- Monitor MNA of TCE by cometabolic degradation in the aerobic zones on the periphery of the primary plumes

This approach will be evaluated against other site data (e.g., contaminant movement) to develop remedial action objectives and a comprehensive plume management strategy.

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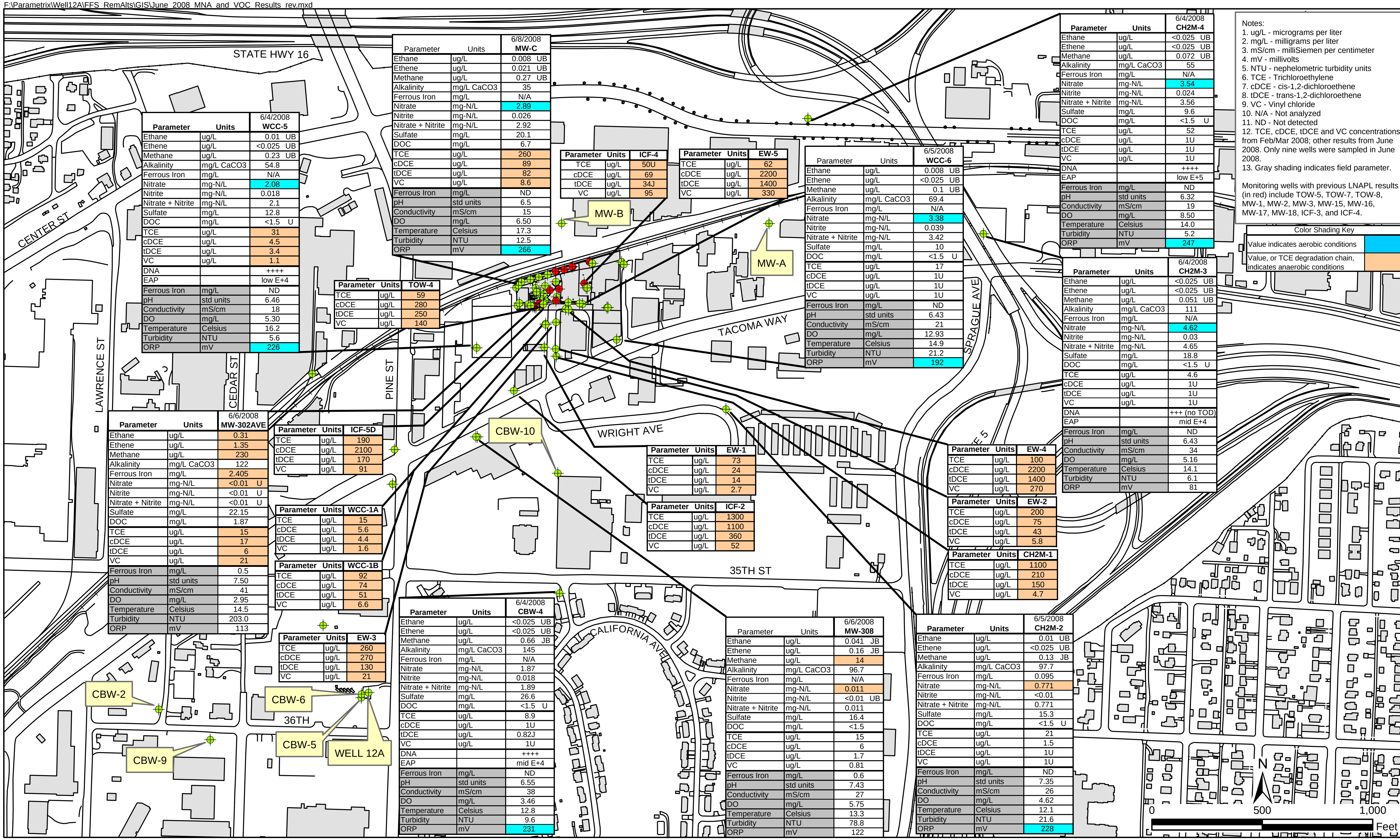

Notes:
1. ug/L - micrograms per liter
2. mg/L - milligrams per liter
3. mS/cm - milliSiemen per centimeter
4. mV - millivolts
5. NTU - nephelometric turbidity units
6. TCE - Trichloroethylene
7. cDCE - cis-1,2-dichloroethene
8. tDCE - trans-1,2-dichloroethene
9. VC - Vinyl chloride
10. N/A - Not analyzed
11. ND - Not detected
12. TCE, cDCE, tDCE and VC concentrations from Feb/Mar 2008; other results from June 2008. Only nine wells were sampled in June 2008.
13. Gray shading indicates field parameter.

Monitoring wells with previous LNAPL results (in red) include TOW-5, TOW-7, TOW-8, MW-1, MW-2, MW-3, MW-15, MW-16, MW-17, MW-18, ICF-3, and ICF-4.

Color Shading Key
- Value indicates aerobic conditions
- Value, or TCE degradation chain, indicates anaerobic conditions

Parameter	Units	6/8/2008 MW-C
Ethane	ug/L	0.008 UB
Ethene	ug/L	0.021 UB
Methane	ug/L	0.27 UB
Alkalinity	mg/L CaCO3	35
Ferrous Iron	mg/L	N/A
Nitrate	mg-N/L	2.89
Nitrite	mg-N/L	0.026
Nitrate + Nitrite	mg-N/L	2.92
Sulfate	mg/L	20.1
DOC	mg/L	6.7
TCE	ug/L	260
cDCE	ug/L	89
tDCE	ug/L	82
VC	ug/L	8.6
Ferrous Iron	mg/L	ND
pH	std units	6.5
Conductivity	mS/cm	15
DO	mg/L	6.50
Temperature	Celsius	17.3
Turbidity	NTU	12.5
ORP	mV	266

Parameter	Units	6/4/2008 WCC-5
Ethane	ug/L	0.01 UB
Ethene	ug/L	<0.025 UB
Methane	ug/L	0.23 UB
Alkalinity	mg/L CaCO3	54.8
Ferrous Iron	mg/L	N/A
Nitrate	mg-N/L	2.08
Nitrite	mg-N/L	0.018
Nitrate + Nitrite	mg-N/L	2.1
Sulfate	mg/L	12.8
DOC	mg/L	<1.5 U
TCE	ug/L	31
cDCE	ug/L	4.5
tDCE	ug/L	3.4
VC	ug/L	1.1
DNA		++++
EAP		low E+4
Ferrous Iron	mg/L	ND
pH	std units	6.46
Conductivity	mS/cm	18
DO	mg/L	5.30
Temperature	Celsius	16.2
Turbidity	NTU	5.6
ORP	mV	226

Parameter	Units	ICF-4
TCE	ug/L	50U
cDCE	ug/L	69
tDCE	ug/L	34J
VC	ug/L	95

Parameter	Units	EW-5
TCE	ug/L	62
cDCE	ug/L	2200
tDCE	ug/L	1400
VC	ug/L	330

Parameter	Units	6/5/2008 WCC-6
Ethane	ug/L	0.008 UB
Ethene	ug/L	<0.025 UB
Methane	ug/L	0.1 UB
Alkalinity	mg/L CaCO3	69.4
Ferrous Iron	mg/L	N/A
Nitrate	mg-N/L	3.38
Nitrite	mg-N/L	0.039
Nitrate + Nitrite	mg-N/L	3.42
Sulfate	mg/L	10
DOC	mg/L	<1.5 U
TCE	ug/L	17
cDCE	ug/L	1U
tDCE	ug/L	1U
VC	ug/L	1U
Ferrous Iron	mg/L	ND
pH	std units	6.43
Conductivity	mS/cm	21
DO	mg/L	12.93
Temperature	Celsius	14.9
Turbidity	NTU	21.2
ORP	mV	192

Parameter	Units	6/4/2008 CH2M-4
Ethane	ug/L	<0.025 UB
Ethene	ug/L	<0.025 UB
Methane	ug/L	0.072 UB
Alkalinity	mg/L CaCO3	55
Ferrous Iron	mg/L	N/A
Nitrate	mg-N/L	3.54
Nitrite	mg-N/L	0.024
Nitrate + Nitrite	mg-N/L	3.56
Sulfate	mg/L	9.6
DOC	mg/L	<1.5 U
TCE	ug/L	52
cDCE	ug/L	1U
tDCE	ug/L	1U
VC	ug/L	1U
DNA		++++
EAP		low E+5
Ferrous Iron	mg/L	ND
pH	std units	6.32
Conductivity	mS/cm	19
DO	mg/L	8.50
Temperature	Celsius	14.0
Turbidity	NTU	5.2
ORP	mV	247

Parameter	Units	6/4/2008 CH2M-3
Ethane	ug/L	<0.025 UB
Ethene	ug/L	<0.025 UB
Methane	ug/L	0.051 UB
Alkalinity	mg/L CaCO3	111
Ferrous Iron	mg/L	N/A
Nitrate	mg-N/L	4.62
Nitrite	mg-N/L	0.03
Nitrate + Nitrite	mg-N/L	4.65
Sulfate	mg/L	18.8
DOC	mg/L	<1.5 U
TCE	ug/L	4.6
cDCE	ug/L	1U
tDCE	ug/L	1U
VC	ug/L	1U
DNA		+++ (no TOD)
EAP		mid E+4
Ferrous Iron	mg/L	ND
pH	std units	6.43
Conductivity	mS/cm	34
DO	mg/L	5.16
Temperature	Celsius	14.1
Turbidity	NTU	6.1
ORP	mV	81

Parameter	Units	TOW-4
TCE	ug/L	59
cDCE	ug/L	280
tDCE	ug/L	250
VC	ug/L	140

Parameter	Units	6/6/2008 MW-302AVE
Ethane	ug/L	0.31
Ethene	ug/L	1.35
Methane	ug/L	230
Alkalinity	mg/L CaCO3	122
Ferrous Iron	mg/L	2.405
Nitrate	mg-N/L	<0.01 U
Nitrite	mg-N/L	<0.01 U
Nitrate + Nitrite	mg-N/L	<0.01 U
Sulfate	mg/L	22.15
DOC	mg/L	1.87
TCE	ug/L	15
cDCE	ug/L	17
tDCE	ug/L	6
VC	ug/L	21
Ferrous Iron	mg/L	0.5
pH	std units	7.50
Conductivity	mS/cm	41
DO	mg/L	2.95
Temperature	Celsius	14.5
Turbidity	NTU	203.0
ORP	mV	113

Parameter	Units	ICF-5D
TCE	ug/L	190
cDCE	ug/L	2100
tDCE	ug/L	170
VC	ug/L	91

Parameter	Units	WCC-1A
TCE	ug/L	15
cDCE	ug/L	5.6
tDCE	ug/L	4.4
VC	ug/L	1.6

Parameter	Units	WCC-1B
TCE	ug/L	92
cDCE	ug/L	74
tDCE	ug/L	51
VC	ug/L	6.6

Parameter	Units	EW-3
TCE	ug/L	260
cDCE	ug/L	270
tDCE	ug/L	130
VC	ug/L	21

Parameter	Units	6/4/2008 CBW-4
Ethane	ug/L	<0.025 UB
Ethene	ug/L	<0.025 UB
Methane	ug/L	0.66 JB
Alkalinity	mg/L CaCO3	145
Ferrous Iron	mg/L	N/A
Nitrate	mg-N/L	1.87
Nitrite	mg-N/L	0.018
Nitrate + Nitrite	mg-N/L	1.89
Sulfate	mg/L	26.6
DOC	mg/L	<1.5 U
TCE	ug/L	8.9
cDCE	ug/L	1U
tDCE	ug/L	0.82J
VC	ug/L	1U
DNA		++++
EAP		mid E+4
Ferrous Iron	mg/L	ND
pH	std units	6.55
Conductivity	mS/cm	38
DO	mg/L	3.46
Temperature	Celsius	12.8
Turbidity	NTU	9.6
ORP	mV	231

Parameter	Units	EW-1
TCE	ug/L	73
cDCE	ug/L	24
tDCE	ug/L	14
VC	ug/L	2.7

Parameter	Units	ICF-2
TCE	ug/L	1300
cDCE	ug/L	1100
tDCE	ug/L	360
VC	ug/L	52

Parameter	Units	6/6/2008 MW-308
Ethane	ug/L	0.041 JB
Ethene	ug/L	0.16 JB
Methane	ug/L	14
Alkalinity	mg/L CaCO3	96.7
Ferrous Iron	mg/L	N/A
Nitrate	mg-N/L	0.011
Nitrite	mg-N/L	<0.01 UB
Nitrate + Nitrite	mg-N/L	0.011
Sulfate	mg/L	16.4
DOC	mg/L	<1.5
TCE	ug/L	15
cDCE	ug/L	6
tDCE	ug/L	1.7
VC	ug/L	0.81
Ferrous Iron	mg/L	0.6
pH	std units	7.43
Conductivity	mS/cm	27
DO	mg/L	5.75
Temperature	Celsius	13.3
Turbidity	NTU	78.8
ORP	mV	122

Parameter	Units	EW-4
TCE	ug/L	100
cDCE	ug/L	2200
tDCE	ug/L	1400
VC	ug/L	270

Parameter	Units	EW-2
TCE	ug/L	200
cDCE	ug/L	75
tDCE	ug/L	43
VC	ug/L	5.8

Parameter	Units	CH2M-1
TCE	ug/L	1100
cDCE	ug/L	210
tDCE	ug/L	150
VC	ug/L	4.7

Parameter	Units	6/5/2008 CH2M-2
Ethane	ug/L	0.01 UB
Ethene	ug/L	<0.025 UB
Methane	ug/L	0.13 JB
Alkalinity	mg/L CaCO3	97.7
Ferrous Iron	mg/L	0.095
Nitrate	mg-N/L	0.771
Nitrite	mg-N/L	<0.01
Nitrate + Nitrite	mg-N/L	0.771
Sulfate	mg/L	15.3
DOC	mg/L	<1.5 U
TCE	ug/L	21
cDCE	ug/L	1.5
tDCE	ug/L	1U
VC	ug/L	1U
Ferrous Iron	mg/L	ND
pH	std units	7.35
Conductivity	mS/cm	26
DO	mg/L	4.62
Temperature	Celsius	12.1
Turbidity	NTU	21.6
ORP	mV	228

CDM

Well 12A Superfund Site
Tacoma, Washington

Figure 1
Monitored Natural Attenuation Evaluation Summary
June 2008

Table 1
Well 12A VOC and MNA Groundwater Data

																									Field Parameters											
Well ID	Land Surface Elevation (ft)	Sample Collection depth (ft)	Sample Collection Elevation (ft)	PCE (ug/L)	TCE (ug/L)	cDCE (ug/L)	tDCE (ug/L)	1,1DCE (ug/L)	VC (ug/L)	PCA (ug/L)	Total Chlorinateds (ug/L)	Cl # (1)	1,4-dioxane (ug/L)	Previous LNAPL	Ethane (ug/L)	Ethene (ug/L)	Methane (ug/L)	Alkalinity (mg/L CaCO3)	Fe++ (mg/L)	NO3 (mg-/L)	NO2 (mg-/L)	NO2+NO3 (mg-/L)	SO4 (mg/L)	DOC (mg/L)	Fe ++ (mg/L)	pH (std units)	Conduct (mS/cm)	DO (mg/L)	ORP (mV)	Temperature (Celsius)	Turbidity (NTU)	DNA	EAP	PA (Cells/mL)	3HPA (Cells/mL)	CINN (Cells/mL)
EW-1	257.01	90.51	166.5	1.9	73	24	14	1 U	2.7	3.3	119.9	2.53	0.6	NR	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
EW-2	255.73	84.23	171.5	9.7	200	75	43	1.3	5.8	26	360.8	2.53	0.5	NR	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
EW-3	255.0	80.46	174.5	6.2	260	270	130	1.6	21	87	775.8	2.26	1.2	NR	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
EW-4	255.2	80.72	174.5	2.9	100	2200	1400	4.6	270	150	4127.5	1.96	3.5	NR	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
EW-5	254.5	81	173.5	4	62	2200	1400	2.5	330	29	4027.5	1.89	8.7	NR	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
CBW-1	259.4	49.93	209.5	1 U	1.8	1 U	1 U	1 U	1 U	1 U	7.8	3.00	0.5	NR	--	--	--	--	--	--	--	--	--	--		6.41	0.3	4.4	*	15.46		--	--	--	--	--
CBW-4	341.4	176.9	164.5	1 U	8.9	1 U	0.82 J	1 U	1 U	1 U	14.72	2.89	0.5	NR	<0.025 UB	<0.025 UB	0.66 UB	145	N/A	1.87	0.018	1.89	26.6	<1.5 U	0	6.55	0.38	3.46	231	12.8	9.6	++++	mid E+4	5.87E+04	9.98E+04	1.65E+04
CBW-5	312.1	185.61	126.5	1 U	3	7.2	1 U	1 U	1 U	1 U	15.2	2.24	0.5	NR	--	--	--	--	--	--	--	--	--	--	--	7.92	0.584	0.68	*	11.48	--	--	--	--	--	--
CBW-6	311.1	149.56	161.5	1 U	1 U	1 U	1 U	1 U	1 U	1 U	7	0.00	0.5	NR	--	--	--	--	--	--	--	--	--	--	--	6.72	3.49	0.28	*	13.31	--	--	--	--	--	--
CBW-7	256.6	87.5	169.06	2.2 J	27	0.84 J	2.4	1 U	1 U	0.85 J	35.29	2.92	0.5	NR	--	--	--	--	--	--	--	--	--	--	--	6.6	0.308	0.91	*	14.56	--	--	--	--	--	--
CBW-9	314.0	151.1	162.86	1 U	1.8	1 U	1 U	1 U	1 U	1 U	7.8	3.00	0.5	NR	--	--	--	--	--	--	--	--	--	--	--	6.77	0.368	0.33	*	15.61	--	--	--	--	--	--
CBW-10	337.0	160.51	176.5	1 U	21	1 U	2.2	1 U	1 U	1.2	28.4	2.88	0.5	NR	--	--	--	--	--	--	--	--	--	--	--	6.5	0.311	0.5	*	13.43	--	--	--	--	--	--
CBW-11	311.4	152	159.38	1 U	8.5	1 U	0.83 J	1 U	1 U	1 U	14.33	2.88	0.5	NR	--	--	--	--	--	--	--	--	--	--	--	6.64	0.246	0.32	*	13.56	--	--	--	--	--	--
CH2M-1	256.2	82.72	173.5	36	1100	210	150	3.3	4.7	190 J	1694	2.70	0.67	NR	--	--	--	--	--	--	--	--	--	--	--	6.18	0.257	0.36	*	14.2	--	--	--	--	--	--
CH2M-2	339.5	191.01	148.5	1 U	21	1.5	1 U	1 U	1 U	1 U	27.5	2.91	1.3	NR	0.01 UB	<0.025 UB	0.13 JB	97.7	0.095	0.771	<0.01	0.771	15.3	<1.5 U	0	7.35	0.26	4.62	228	12.1	21.6	--	--	--	--	--
CH2M-3	247.2	83.74	163.5	1 U	4.6	1 U	1 U	1 U	1 U	1 U	10.6	3.00	0.5	NR	<0.025 UB	<0.025 UB	0.051 UB	111	N/A	4.62	0.03	4.65	18.8	<1.5 U	0	6.43	0.340	5.16	81	14.1	6.1	+++ (no TOD)	mid E+4	6.11E+04	7.37E+04	3.33E+04
CH2M-4	249.8	85.34	164.5	17 J	52	1 U	1 U	1 U	1 U	1 U	74	3.21	0.5	NR	<0.025 UB	<0.025 UB	0.072 UB	55	N/A	3.54	0.024	3.56	9.6	<1.5 U	0	6.32	0.190	8.50	247	14.0	5.2	++++	low E+5	1.26E+05	1.26E+05	8.90E+04
ICF-2	256.9	65	191.91	4.4 J	1300	1100	360	170.5 J	52	1.6	2988.5	2.33	6.1	NR	--	--	--	--	--	--	--	--	--	--	--	6.62	0.304	0.15	*	14.4	--	--	--	--	--	--
ICF-3	250.3	31.5	218.79	2 J	1.3	1 U	1 U	1 U	1 U	1.3	8.6	3.55	0.5	X	--	--	--	--	--	--	--	--	--	--	--	4.96	0.227	0.17	*	15.75	--	--	--	--	--	--
ICF-4	254.7	34.18	220.5	50 U	50 U	69	34 J	1 U	95	50 U	349	1.84	0.5	X	--	--	--	--	--	--	--	--	--	--	--	6.23	0.481	0.12	*	17.52	--	--	--	--	--	--
ICF-5D	254.7	50.19	204.5	42 J	190	2100	170	1.6	91	81	2675.6	2.02	0.5	NR	--	--	--	--	--	--	--	--	--	--	--	6.28	0.354	0.14	*	14.88	--	--	--	--	--	--
ICF-5S	254.9	36.37	218.5	28 J	180	190	100	1 U	1.5	22	522.5	2.37	0.5	NR	--	--	--	--	--	--	--	--	--	--	--	5.84	0.341	0.36	*	15.31	--	--	--	--	--	--
KRRF-1	254.4	73.9	180.5	2.1 J	79	36	20	1 U	1.7	3.7	143.5	2.49	0.5	NR	--	--	--	--	--	--	--	--	--	--	--	6.43	0.26	0.1	*	14.35	--	--	--	--	--	--
MW-A	249.8	57	192.78	1 U	3.8	1 U	1 U	1 U	1 U	1 U	9.8	3.00	7.2	NR	--	--	--	--	--	--	--	--	--	--	--	7.47	0.135	0.32	*	12.05	--	--	--	--	--	--
MW-B	243.1	48.5	194.56	1 U	15	1.2	0.98 J	1 U	1 U	1 U	21.18	2.84	0.5	NR	--	--	--	--	--	--	--	--	--	--	--	6.85	0.303	0.26	*	14.92	--	--	--	--	--	--
MW-C	252.1	41.6	210.48	8.8 J	260	89	82	2.7	8.6	38	489.1	2.49	1.2	NR	0.008 UB	0.021 UB	0.27 UB	35	N/A	2.89	0.026	2.92	20.1	6.7	0	6.05	0.150	6.50	266	17.3	12.5	--	--	--	--	--
TOW-10	255.5	71	184.5	1 U	2.3	1 U	1 U	1 U	1 U	1 U	8.3	3.00	14	NR	--	--	--	--	--	--	--	--	--	--	--	6.93	0.223	0.3	*	13.34	--	--	--	--	--	--
TOW-4	254.5	70	184.54	2.4 J	59	280	250	1.6	140	31	764	1.78	1.1	NR	--	--	--	--	--	--	--	--	--	--	--	6.48	0.259	0.17	*	13.54	--	--	--	--	--	--
TWT-10	323.5	167	156.5	1 U	1 U	1 U	1 U	1 U	1 U	1 U	7	0.00	0.5	NR	--	--	--	--	--	--	--	--	--	--	--	6.72	0.374	0.19	*	12.32	--	--	--	--	--	--
WCC-1A	255.1	124.5	130.57	1 U	15	5.6	4.4	1 U	1.6	1 U	29.6	2.36	57	NR	--	--	--	--	--	--	--	--	--	--	--	7.66	0.161	0.13	*	13.59	--	--	--	--	--	--
WCC-1B	255.0	57.6	197.36	2.2 J	92	74	51	1 U	6.6	63 J	289.8	2.29	0.5	NR	--	--	--	--	--	--	--	--	--	--	--	6.42	0.308	0.17	*	14.34	--	--	--	--	--	--
WCC-2	251.8	43.32	208.5	1 U	4.1	1 U	1 U	1 U	1 U	1 U	10.1	3.00	0.5	NR	--	--	--	--	--	--	--	--	--	--	--	6.49	0.249	3.73	*	13.98	--	--	--	--	--	--
WCC-3	256.7	40	216.71	1 U	1.5	1 U	1 U	1 U	1 U	1 U	7.5	3.00	0.5	NR	--	--	--	--	--	--	--	--	--	--	--	6.54	0.394	3.4	*	16.5	--	--	--	--	--	--
WCC-5	257.5	46.02	211.5	1.4 J	31	4.5	3.4	1 U	1.1	1 U	43.4	2.68	0.5	NR	0.01 UB	<0.025 UB	0.23 UB	54.8	N/A	2.08	0.018	2.1	12.8	<1.5 U	0	6.46	0.180	5.30	226	16.2	5.6	++++	low E+4	1.91E+04	4.96E+04	2.26E+04
WCC-6	256.9	58.4	198.53	1 U	17	1 U	1 U	1 U	1 U	1 U	23	3.00	0.5	NR	0.008 UB	<0.025 UB	0.1 UB	69.4	N/A	3.38	0.039	3.42	10	<1.5 U	0	6.43	0.210	12.93	192	14.9	21.2	--	--	--	--	--
WCSB-9	254.9	35	219.94	6.6 J	45	1.2	1 U	1 U	1 U	1 U	56.8	3.07	0.5	NR	--	--	--	--	--	--	--	--	--	--	--	6.23	0.228	5.05	*	14.21	--	--	--	--	--	--
MW-301	254.5	144.5	109.95	1 U	1 U	1 U	1 U	1 U	1 U	1 U	7	0.00	42	NR	--	--	--	--	--	--	--	--	--	--	--	7.49	0.161	0.17	*	13.52	--	--	--	--	--	--
MW-302	254.4	103	151.4	1 U	15	17	5.8	2.7	21	1 U	63.5	1.58	360	NR	0.31	1.35	230	122	2.405	<.01 U	<.01 U	<.01 U	22.15	1.87	0.5	7.50	0.410	2.95	113	14.5	203.0	--	--	--	--	--
MW-304	254.9	145.5	109.37	1 U	1 U	1 U	1 U	1 U	1 U	1 U	7	0.00	13	NR	--	--	--	--	--	--	--	--	--	--	--	7.52	0.143	0.26	*	11.15	--	--	--	--	--	--
MW-305	254.9	104.5	150.41	1 U	1 U	2.1	1 U	1 U	2.6	1 U	9.7	1.34	300	NR	--	--	--	--	--	--	--	--	--	--	--	7.73	0.318	0.5	*	12.22	--	--	--	--	--	--
MW-306	253.8	144.5	109.27	1 U	1 U	1 U	1 U	1 U	1 U	1 U	7	0.00	4.4	NR	--	--	--	--	--	--	--	--	--	--	--	7.55	0.164	0.13	*	13.3	--	--	--	--	--	--
MW-307	255.3	150	105.28	1 U	1 U	1 U	1 U	1 U	1 U	1 U	7	0.00	10	NR	--	--	--	--	--	--	--	--	--	--	--	7.51	0.132	0.21	*	12.51	--	--	--	--	--	--
MW-308	257.0	151.25	105.78	1 U	15	6	1.7	1 U	0.81	1 U	26.51	2.01	6.8	NR	0.041 JB	0.16 JB	14	96.7	N/A	0.011	<.01 UB	0.011	16.4	<1.5	0.6	7.43	0.270	5.75	122	13.3	78.8	--	--	--	--	--
MW-89.7	315.0	56.29	258.71	1 U	1 U	1 U	1 U	1 U	1 U	1 U	7	0.00	0.5	NR	--	--	--	--	--	--	--	--	--	--	--	6.88	1.259	0.11	*	15.1	--	--	--	--	--	--
WELL_12A	323.5	157.5	166	1 U	1.4	1 U	1 U	1 U	1 U	1 U	7.4	3.00	0.5	NR	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
WELL_9A	294.0	181.5	112.5	1 U	1.2	1 U	1 U	1 U	1 U	1 U	7.2	3.00	0.5	NR	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

Notes:
X - LNAPL Present (Light Non Aqueous Phase Liquid)
N/A - Not Available
PCE - Tetrachloroethene; TCE- Trichloroethene; cDCE- Cis-1,2 dichloroethene; tDCE- Trans-1,2-dichloroethene; VC- Vinyl Chloride; PCA -Perchloroethane
Field Parameter data - June 2008
Field Parameter data - Feb/Mar 2008
Value indicates Aerobic conditions
Value, or TCE degradation chain, Indicates Anaerobic conditions
-- Indicates Data not collected
EAP - Enzyme Activity Probe; PA - Phenylacetylene; 3HPA: 3- Hydroxy-Phenylacetylene; CINN: Cinnamonitrile;
+ A positive result indicates the gene of interest was amplified and no recorded result indicates amplification was not successful
(for e.g., Well CH2M3 DNA = (+++ no TOD) implies amplification was not successful by TOD)
Genes of interest
sMMO soluble methane monooxygenase
PHE Toluene 2,3,4-monooxygenase
TOD Tolune/xylene monooxygenase
RMO Toluene 3,4 monooxygenase

- MNA Data only collection in June 2008 at nine wells
- MW 302 Results are an average of environmental samples and duplicate for MNA data (June 2008)
- CBW-7, ICF-2, ICF-3 and WCC-5 results are the higher of the environmental sample and duplicate for chlorinated compounds (Feb/Mar 2008)
(1) - Cl# (chloride number) is based on PCE, TCE, cDCE, tDCE, 11DCE and VC concentrations
* - ORP data from Feb/Mar 2008 not used
NR - None Reported.
J - Analyte present. Reported value may not be accurate or precise.
U - Not detected at or above the reported value

Anaerobic indicators: Methane > 0.5 ug/L, Fe++ > 2 mg/L, NO3 < 1 mg-N/L, SO4 <20 mg/L, DO < 1 mg/L
All Sample Parameters
Analytes that were not detected at or above the reported value were qualified as "U".

Ethane Specific Parameters
Non-detect samples or those detected at >2x RL were not qualified.
Sample results detected at concentrations <RL were qualified "UB".
Sample results detected at <2x RL were qualified as estimated, "JB".

Ethene & Methane Specific Parameters
Non-detect samples or samples at concentrations >5x trip blank concentration were not qualified.
Sample results detected at concentrations <RL were qualified "UB".
Sample results detected at concentrations >RL but less than trip blank concentration were reported as non-detects, or "UB".
Sample results detected at concentrations >RL but <5x trip blank concentration were qualified as estimated, "JB".

Previous LNAPL Detected Wells : ICF -3, ICF -4; NAPL has been detected at other site wells in source area, But they have been abandoned and were not sampled in 2008

CDM

Appendix C
Johnson and Ettinger Screening Results Memorandum

CDM

993 Old Eagle School Road, Suite 408
Wayne, Pennsylvania 19087
tel: 610 293-0450
fax: 610 293-1920

August 4, 2008

Kira Lynch
US EPA Region 10
Office of Environmental Cleanup (ECL-113)
1200 Sixth Avenue, Suite 900
Seattle WA 98101

Subject: Johnson and Ettinger Screening Results Memorandum Well 12A Focused Feasibility Study

Dear Ms. Lynch:

Please find enclosed the revised draft of the Well 12A Johnson and Ettinger Screening Results Memorandum. The draft memorandum was submitted to you on June 13, 2008. This memorandum is being submitted as partial fulfillment of the reporting requirements for this assignment.

If you have any questions, call me at (610) 293-0450.

Sincerely,

Aaron R. Frantz, P.E., P.G.
Project Manager
CDM Federal Programs Corporation

Revised Draft
Well 12A Johnson and Ettinger Screening Results Memorandum
August 4, 2008

The health risk at the Well 12A Site due to vapor intrusion was evaluated using the Johnson and Ettinger model (EPA 2004) since volatile organic compounds (VOCs) may migrate from groundwater through the subsurface and into buildings at the Site.

Introduction

Groundwater contaminant concentrations are historically highest near the machine shop which is located immediately south of the former Time Oil Building. The machine shop is a 200 feet long x 140 feet wide one-story structure. Therefore, the maximum detected groundwater concentrations of the February/March 2008 sampling events for the six main chlorinated VOCs (trichloroethene, tetrachloroethene, 1,1,2,2-tetrachloroethane; *cis*-1,2-dichloroethene, *trans*-1,2-dichloroethene, and vinyl chloride) within 100 feet in depth and in close proximity to the machine shop building were compared to generic screening levels provided by EPA in Table 2c of *Subsurface Vapor Intrusion Guidance* (2002). Target groundwater concentrations corresponding to a cancer risk of 10^{-6} or a hazard quotient of 1 in Table 2c are used as screening levels. This screen indicates that there is a potential for migration of vapors for all six chlorinated VOCs in the vicinity of the machine shop.

Johnson and Ettinger Modeling

The Johnson and Ettinger model (EPA 2004) is used to estimate the indoor air concentrations of volatile chemicals from groundwater. The model is calibrated to parameters listed in Table 1. The maximum concentrations are served as inputs for the Johnson and Ettinger model. The calculated indoor air concentrations (Table 2) are used to estimate potential risks for identified potential receptors at the site, onsite workers and nearby residents (adult and child, 0 to 6 years old).

Exposure assumptions were taken from EPA documents (EPA 1989, 1991, 1997). EPA's standard default assumptions (EPA 1991) are used, where available. Otherwise values from the most recent guidance available were used. Risks for all receptors are estimated using reasonable maximum exposure (RME) assumptions. Risks are also estimated using central tendency exposure (CTE) assumptions in cases where the RME assumptions resulted in risk estimates above EPA thresholds. CTE risks represent typical exposure patterns rather than reasonable maximum exposures. The hazard index (HI) for all receptors are also estimated using RME assumptions. HIs are also estimated using CTE assumptions in cases where the RME assumptions resulted in HIs above EPA thresholds. The calculated cancer risks and non-cancer health hazards are presented in Tables 3, 4, and 5 for onsite workers, adult residents, and child residents, respectively.

The cancer risks for all receptors are above the EPA target range of 1×10^{-6} to 1×10^{-4} under the RME and CTE scenario, except for onsite worker where the cancer risk falls within the EPA target range of 1×10^{-6} to 1×10^{-4} under the CTE scenario. The major risk driver for the estimated risk is TCE. Therefore, further investigation for vapor intrusion may be warranted at the site.

The total HIs for all receptors is below the threshold of unity (1) under RME scenario, except for child residents. However, under the CTE scenario, the HIs is below the threshold of unity for child residents. This indicates that non-cancer health effects will most likely not occur for all receptors at the site.

Model Uncertainty

Groundwater data from February/March 2008 were used for this evaluation since it is the most current data set available. The building considered in the evaluation was used since it was at the core of the highest concentrations of CVOCs detected in groundwater. If other data or risk scenarios were incorporated into the evaluation, greater risk may be estimated. Other data or risk scenarios may include, for example:

- Groundwater contaminated with TCE, and other constituents, at higher concentrations than what was reported/detected in 2008
- DNAPL with TCE below the former Time Oil building
- Contaminated soil below the former Time Oil building
- Elevated soil gas concentrations below the former Time Oil building

Incorporating these elements into the evaluation would likely result in risks higher than currently estimated.

Additionally, residential exposure was one of the scenarios evaluated in this screening, but the scenario may not be representative since the site is zoned for industrial use and it has not been confirmed that people are living on the property.

Lastly, the Johnson and Ettinger Model was developed for screening level analysis. The tool is a one-dimensional solution to diffusive and convective transport of vapors into indoor air and has inherent assumptions and limitations associated with contaminant distribution, lithologic characteristics, transport properties and pathways, and building characteristics. Therefore, the results of the model should be considered as a general evaluation of site issues. Additional and more specific analyses (e.g., building vapor sampling) may be required to quantify the risk.

References

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EPA. 2004. User's Guide for Evaluating Subsurface Vapor Intrusion Into Buildings (Revised). Website *http://www.epa.gov/oswer/riskassessment/airmodel/pdf/2004_0222_3phase_users_guide.pdf*. February 22.

TABLE 1

INPUT PARAMETERS FOR VAPOR INTRUSION FROM GROUNDWATER

South Tacoma Channel / Well 12A Site

Tacoma, Washington

Parameter		Units	Default	Value Used	Basis/Source of Value Used
Depth below grade to bottom of enclosed space floor	L_F	cm	15	15	Default (EPA 2004) depth to base of foundation - slab-on-grade scenario
Depth below grade to water table	L_{WT}	cm	NA (site-specific)	1,067	February/March 2008 water level
Average soil/groundwater temperature	T_S	^oC	10	16.3	URS 2005
Thickness of soil stratum A (soil type below the enclosed space floor)	h_A	cm	NA (site-specific)	1,067	URS 2005
Thickness of soil stratum B	h_B	cm	NA (site-specific)	0	No second layer between groundwater and ground surface.
Thickness of soil stratum C	h_C	cm	NA (site-specific)	0	No third layer between groundwater and ground surface.
Stratum A SCS soil type (used to est. soil vapor permeability)			NA (site-specific)	S	The unsaturated zone is primarily sand and gravel (URS 2005)
Stratum A soil dry bulk density	ρ_b^A	g/cm^3	1.66	1.86	URS 2005
Stratum A soil total porosity	n^A	unitless	0.375	0.3	URS 2005
Stratum A soil water-filled porosity	θ_w^A	cm^3/cm^3	0.054	0.054	Deafult (EPA 2004)
Stratum B SCS soil type			NA	NA	No second layer.
Stratum B soil dry bulk density	ρ_b^B	g/cm^3	NA	NA	
Stratum B soil total porosity	n^B	unitless	NA	NA	
Stratum B soil water-filled porosity	θ_w^B	cm^3/cm^3	NA	NA	
Stratum C SCS soil type			NA	NA	No third layer.
Stratum C soil dry bulk density	ρ_b^C	g/cm^3	NA	NA	
Stratum C soil total porosity	n^C	unitless	NA	NA	
Stratum C soil water-filled porosity	θ_w^C	cm^3/cm^3	NA	NA	
Enclosed space floor thickness	L_{crack}	cm	10	10	Default (EPA 2004)
Soil-bldg pressure differential	ΔP	$g/cm\text{-}s^2$	40	40	Default (EPA 2004) - equal to 4 Pa
Enclosed space floor length	L_B	cm	NA (site-specific)	4,206	Measured from site map
Enclosed space floor width	W_B	cm	NA (site-specific)	3,962	Measured from site map
Enclosed space height	H_B	cm	NA (site-specific)	244	Single story structure
Floor-wall seam crack width	w	cm	0.1	0.1	Default (EPA 2004)
Indoor air exchange rate	ER	1/h	0.25	0.25	Default (EPA 2004)

EPA 2004: User's Guide for Evaluating Subsurface Vapor Intrusion Into Buildings (Revised). February 22.
http://www.epa.gov/oswer/riskassessment/airmodel/pdf/2004_0222_3phase_users_guide.pdf

URS. 2005. Draft Final Field Investigation and Capture Zone Analysis Report, Commencement Bay South Tacoma Channel/Well 12A Superfund Site Tacoma, Washington. September

See following page for supporting documentation.

1. Depth Below Grade to Water Table

Elevation of GW table below building based on February/March 2008 water levels = 217 ft NGVD

Elevation of land surface based on site topograhy = 252 ft NGVD

252 - 217 = 35 ft =1,067 cm

2. Groundwater temperature = 16.3 ^{0}C (URS 2005 - Table 31-2; mean of source area wells)

3. Thickness of soil stratum: - sat. and vadose zone in consistent stratum, therefore 35 ft = 1,067 cm

4. Dry bulk density and total porosity

	Tot Porosity	Dry Bulk Density
	unitless	g/cm^3
302PTS-1	0.386	1.66
302PTS-2	0.384	1.66
302PTS-3	0.298	1.89
305PTS-1	0.328	1.84
306PTS-1	0.206	2.14
307PTS-1	0.278	1.95
308PTS-1	0.293	1.9
GEO AVG	0.30	1.86

Values from URS 2005

5. Water filled porosity - no value in URS 2005, therefore use EPA Default vlaue 0.054 cm^3/cm^3

6. Enclosed space floor length - building is comprised of three rectangular sections that total to an area of 17,904 SQ FT

The width and length of the three sections (in FT) are 50 x 30; 120 x 132 and 20 x 30.

Use L = 138 ft = 4,206 cm

Use W = 130 ft = 3,962 cm

138 ft x 130 ft = 17,940 SQ FT

7. Groundwater Concentrations for the Six Main Site CVOCs at Wells within 100 feet of J-E Screning Building

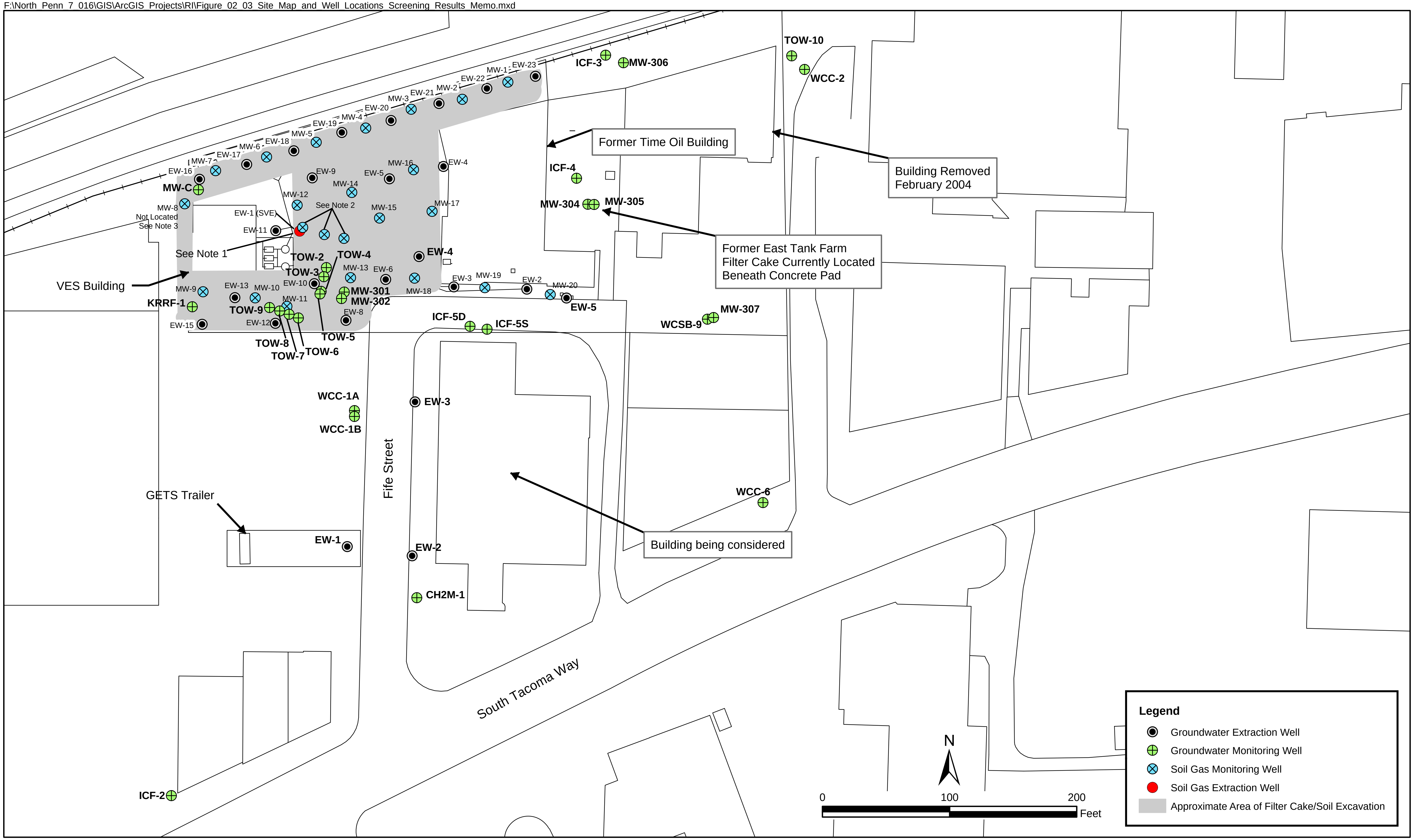
Station ID	Units	PCE	TCE	Cis-1,2-DCE	Trans-1,2-DCE	Vinyl-Cl	1,1,2,2-PCA
CH2M-1	ug/L	36	1100	210	150	4.7	190
EW-1	ug/L	1.9	73	24	14	2.7	3.3
EW-2	ug/L	9.7	200	75	43	5.8	26
EW-3	ug/L	6.2	260	270	130	21	87
EW-4	ug/L	2.9	100	2200	1400	270	150
WCC-1A	ug/L	1	15	5.6	4.4	1.6	1
WCC-1B	ug/L	2.2	92	74	51	6.6	63
MW-302	ug/L	1	15	17	5.8	21	1
ICF-5D	ug/L	42	190	2100	170	91	81
ICF-5S	ug/L	28	180	190	100	1.5	22

Highest value for contaminant

Deep well; do not use

Concentrations from February/March 2008 Sampling Event

F:\North_Penn_7_016\GIS\ArcGIS_Projects\RI\Figure_02_03_Site_Map_and_Well_Locations_Screening_Results_Memo.mxd



CDM

Well 12A Superfund Site
Tacoma, Washington

Figure 1
Site Map and Well Locations

General UCL Statistics for Full Data Sets

User Selected Options

From File	WorkSheet.wst
Full Precision	OFF
Confidence Coefficient	95%
Number of Bootstrap Operations	2000

PCE

General Statistics

Number of Valid Samples	10	Number of Unique Samples	9
Raw Statistics		**Log-transformed Statistics**	
Minimum	1	Minimum of Log Data	0
Maximum	42	Maximum of Log Data	3.738
Mean	13.09	Mean of log Data	1.725
Median	4.55	SD of log Data	1.447
SD	15.92		
Coefficient of Variation	1.216		
Skewness	1.096		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Shapiro Wilk Test Statistic	0.762	Shapiro Wilk Test Statistic	0.898
Shapiro Wilk Critical Value	0.842	Shapiro Wilk Critical Value	0.842
Data not Normal at 5% Significance Level		**Data appear Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	22.32	95% H-UCL	114.4
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	41.76
95% Adjusted-CLT UCL	23.24	97.5% Chebyshev (MVUE) UCL	54.02
95% Modified-t UCL	22.61	99% Chebyshev (MVUE) UCL	78.1
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.565	**Data appear Gamma Distributed at 5% Significance Level**	
Theta Star	23.18		
nu star	11.3		
Approximate Chi Square Value (.05)	4.767	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0267	95% CLT UCL	21.37
Adjusted Chi Square Value	4.055	95% Jackknife UCL	22.32
		95% Standard Bootstrap UCL	20.89
Anderson-Darling Test Statistic	0.601	95% Bootstrap-t UCL	26.59
Anderson-Darling 5% Critical Value	0.76	95% Hall's Bootstrap UCL	20.02
Kolmogorov-Smirnov Test Statistic	0.224	95% Percentile Bootstrap UCL	21.69
Kolmogorov-Smirnov 5% Critical Value	0.277	95% BCA Bootstrap UCL	22.47
Data appear Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	35.04
		97.5% Chebyshev(Mean, Sd) UCL	44.54
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	63.19
95% Approximate Gamma UCL	31.02		
95% Adjusted Gamma UCL	36.46		
Potential UCL to Use		Use 95% Approximate Gamma UCL	31.02

General UCL Statistics for Full Data Sets

User Selected Options

From File	WorkSheet.wst
Full Precision	OFF
Confidence Coefficient	95%
Number of Bootstrap Operations	2000

TCE

General Statistics

Number of Valid Samples	10	Number of Unique Samples	9

Raw Statistics		**Log-transformed Statistics**	
Minimum	15	Minimum of Log Data	2.708
Maximum	1100	Maximum of Log Data	7.003
Mean	222.5	Mean of log Data	4.714
Median	140	SD of log Data	1.295
SD	318.9		
Coefficient of Variation	1.433		
Skewness	2.785		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Shapiro Wilk Test Statistic	0.608	Shapiro Wilk Test Statistic	0.923
Shapiro Wilk Critical Value	0.842	Shapiro Wilk Critical Value	0.842
Data not Normal at 5% Significance Level		**Data appear Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	407.4	95% H-UCL	1294
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	654
95% Adjusted-CLT UCL	483.3	97.5% Chebyshev (MVUE) UCL	838.9
95% Modified-t UCL	422.2	99% Chebyshev (MVUE) UCL	1202
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.663	**Data appear Gamma Distributed at 5% Significance Level**	
Theta Star	335.7		
nu star	13.25		
Approximate Chi Square Value (.05)	6.064	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0267	95% CLT UCL	388.4
Adjusted Chi Square Value	5.243	95% Jackknife UCL	407.4
		95% Standard Bootstrap UCL	377.4
Anderson-Darling Test Statistic	0.489	95% Bootstrap-t UCL	754.3
Anderson-Darling 5% Critical Value	0.753	95% Hall's Bootstrap UCL	1084
Kolmogorov-Smirnov Test Statistic	0.205	95% Percentile Bootstrap UCL	412.1
Kolmogorov-Smirnov 5% Critical Value	0.275	95% BCA Bootstrap UCL	478
Data appear Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	662.1
		97.5% Chebyshev(Mean, Sd) UCL	852.3
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	1226
95% Approximate Gamma UCL	486.3		
95% Adjusted Gamma UCL	562.5		
Potential UCL to Use		Use 95% Approximate Gamma UCL	486.3

General UCL Statistics for Full Data Sets

User Selected Options	
From File	WorkSheet.wst
Full Precision	OFF
Confidence Coefficient	95%
Number of Bootstrap Operations	2000

cis-1,2-DCE

General Statistics

Number of Valid Samples	10	Number of Unique Samples	10
Raw Statistics		**Log-transformed Statistics**	
Minimum	5.6	Minimum of Log Data	1.723
Maximum	2200	Maximum of Log Data	7.696
Mean	516.6	Mean of log Data	4.789
Median	132.5	SD of log Data	1.946
SD	865.8		
Coefficient of Variation	1.676		
Skewness	1.736		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Shapiro Wilk Test Statistic	0.604	Shapiro Wilk Test Statistic	0.952
Shapiro Wilk Critical Value	0.842	Shapiro Wilk Critical Value	0.842
Data not Normal at 5% Significance Level		**Data appear Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	1018	95% H-UCL	24331
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	2042
95% Adjusted-CLT UCL	1128	97.5% Chebyshev (MVUE) UCL	2691
95% Modified-t UCL	1044	99% Chebyshev (MVUE) UCL	3966
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.377	**Data appear Gamma Distributed at 5% Significance Level**	
Theta Star	1369		
nu star	7.548		
Approximate Chi Square Value (.05)	2.476	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0267	95% CLT UCL	966.9
Adjusted Chi Square Value	2.002	95% Jackknife UCL	1018
		95% Standard Bootstrap UCL	943.1
Anderson-Darling Test Statistic	0.63	95% Bootstrap-t UCL	4203
Anderson-Darling 5% Critical Value	0.787	95% Hall's Bootstrap UCL	4382
Kolmogorov-Smirnov Test Statistic	0.249	95% Percentile Bootstrap UCL	943.6
Kolmogorov-Smirnov 5% Critical Value	0.283	95% BCA Bootstrap UCL	1133
Data appear Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	1710
		97.5% Chebyshev(Mean, Sd) UCL	2226
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	3241
95% Approximate Gamma UCL	1575		
95% Adjusted Gamma UCL	1948		
Potential UCL to Use		Use 95% Adjusted Gamma UCL	1948

General UCL Statistics for Full Data Sets

User Selected Options

From File	WorkSheet.wst
Full Precision	OFF
Confidence Coefficient	95%
Number of Bootstrap Operations	2000

trans-1,2-DCE

General Statistics

Number of Valid Samples	10	Number of Unique Samples	10

Raw Statistics		Log-transformed Statistics	
Minimum	4.4	Minimum of Log Data	1.482
Maximum	1400	Maximum of Log Data	7.244
Mean	206.8	Mean of log Data	4.043
Median	75.5	SD of log Data	1.739
SD	423.6		
Coefficient of Variation	2.048		
Skewness	3.042		

Relevant UCL Statistics

Normal Distribution Test		Lognormal Distribution Test	
Shapiro Wilk Test Statistic	0.498	Shapiro Wilk Test Statistic	0.951
Shapiro Wilk Critical Value	0.842	Shapiro Wilk Critical Value	0.842
Data not Normal at 5% Significance Level		**Data appear Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	452.4	95% H-UCL	4106
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	683
95% Adjusted-CLT UCL	564.9	97.5% Chebyshev (MVUE) UCL	894.4
95% Modified-t UCL	473.9	99% Chebyshev (MVUE) UCL	1309
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.412	**Data appear Gamma Distributed at 5% Significance Level**	
Theta Star	501.5		
nu star	8.249		
Approximate Chi Square Value (.05)	2.88	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0267	95% CLT UCL	427.2
Adjusted Chi Square Value	2.358	95% Jackknife UCL	452.4
		95% Standard Bootstrap UCL	409.9
Anderson-Darling Test Statistic	0.595	95% Bootstrap-t UCL	1385
Anderson-Darling 5% Critical Value	0.778	95% Hall's Bootstrap UCL	1394
Kolmogorov-Smirnov Test Statistic	0.263	95% Percentile Bootstrap UCL	462.6
Kolmogorov-Smirnov 5% Critical Value	0.281	95% BCA Bootstrap UCL	596
Data appear Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	790.8
		97.5% Chebyshev(Mean, Sd) UCL	1043
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	1540
95% Approximate Gamma UCL	592.4		
95% Adjusted Gamma UCL	723.6		
Potential UCL to Use		Use 95% Adjusted Gamma UCL	723.6

General UCL Statistics for Full Data Sets

User Selected Options

From File	WorkSheet.wst
Full Precision	OFF
Confidence Coefficient	95%
Number of Bootstrap Operations	2000

VC

General Statistics

Number of Valid Samples	10	Number of Unique Samples	9
Raw Statistics		**Log-transformed Statistics**	
Minimum	1.5	Minimum of Log Data	0.405
Maximum	270	Maximum of Log Data	5.598
Mean	42.59	Mean of log Data	2.326
Median	6.2	SD of log Data	1.717
SD	84.35		
Coefficient of Variation	1.981		
Skewness	2.662		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Shapiro Wilk Test Statistic	0.561	Shapiro Wilk Test Statistic	0.918
Shapiro Wilk Critical Value	0.842	Shapiro Wilk Critical Value	0.842
Data not Normal at 5% Significance Level		**Data appear Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	91.49	95% H-UCL	665.9
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	118.3
95% Adjusted-CLT UCL	110.5	97.5% Chebyshev (MVUE) UCL	154.8
95% Modified-t UCL	95.23	99% Chebyshev (MVUE) UCL	226.4
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.383	**Data Follow Appr. Gamma Distribution at 5% Significance Level**	
Theta Star	111.1		
nu star	7.669		
Approximate Chi Square Value (.05)	2.545	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0267	95% CLT UCL	86.46
Adjusted Chi Square Value	2.062	95% Jackknife UCL	91.49
		95% Standard Bootstrap UCL	83.21
Anderson-Darling Test Statistic	0.83	95% Bootstrap-t UCL	397.9
Anderson-Darling 5% Critical Value	0.786	95% Hall's Bootstrap UCL	302.2
Kolmogorov-Smirnov Test Statistic	0.268	95% Percentile Bootstrap UCL	87.21
Kolmogorov-Smirnov 5% Critical Value	0.283	95% BCA Bootstrap UCL	120.4
Data follow Appr. Gamma Distribution at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	158.9
		97.5% Chebyshev(Mean, Sd) UCL	209.2
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	308
95% Approximate Gamma UCL	128.3		
95% Adjusted Gamma UCL	158.4		
Potential UCL to Use		Use 95% Adjusted Gamma UCL	158.4

General UCL Statistics for Full Data Sets

User Selected Options

From File	WorkSheet.wst
Full Precision	OFF
Confidence Coefficient	95%
Number of Bootstrap Operations	2000

1,1,2,2-PCA

General Statistics

Number of Valid Samples	10	Number of Unique Samples	9

Raw Statistics		Log-transformed Statistics	
Minimum	1	Minimum of Log Data	0
Maximum	190	Maximum of Log Data	5.247
Mean	62.43	Mean of log Data	3.08
Median	44.5	SD of log Data	1.993
SD	65.74		
Coefficient of Variation	1.053		
Skewness	0.97		

Relevant UCL Statistics

Normal Distribution Test		Lognormal Distribution Test	
Shapiro Wilk Test Statistic	0.872	Shapiro Wilk Test Statistic	0.863
Shapiro Wilk Critical Value	0.842	Shapiro Wilk Critical Value	0.842
Data appear Normal at 5% Significance Level		**Data appear Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	100.5	95% H-UCL	5666
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	400.8
95% Adjusted-CLT UCL	103.4	97.5% Chebyshev (MVUE) UCL	528.8
95% Modified-t UCL	101.6	99% Chebyshev (MVUE) UCL	780.4
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.478	**Data appear Normal at 5% Significance Level**	
Theta Star	130.5		
nu star	9.568		
Approximate Chi Square Value (.05)	3.673	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0267	95% CLT UCL	96.63
Adjusted Chi Square Value	3.066	95% Jackknife UCL	100.5
		95% Standard Bootstrap UCL	94.42
Anderson-Darling Test Statistic	0.373	95% Bootstrap-t UCL	110.5
Anderson-Darling 5% Critical Value	0.77	95% Hall's Bootstrap UCL	117.1
Kolmogorov-Smirnov Test Statistic	0.172	95% Percentile Bootstrap UCL	95.13
Kolmogorov-Smirnov 5% Critical Value	0.279	95% BCA Bootstrap UCL	100.4
Data appear Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	153
		97.5% Chebyshev(Mean, Sd) UCL	192.3
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	269.3
95% Approximate Gamma UCL	162.6		
95% Adjusted Gamma UCL	194.8		
Potential UCL to Use		Use 95% Student's-t UCL	100.5

TABLE 2

INDOOR AIR EXPOSURE POINT CONCENTRATIONS FROM VAPOR INTRUSION

South Tacoma Channel / Well 12A Site

Tacoma, Washington

Chemical	Maximum Concentration (1) (µg/L)	Vapor Intrusion Screening Level (2) (µg/L)	Exceeds screening level?	Estimated Indoor Air Concentration (3) ($\mu g/m^3$)
1,1,2,2-Tetrachloroethane	190	3	YES	0.21
cis -1,2,-Dichloroethene	2,200	210	YES	20.4
Tetrachloroethene	42	0.11	YES	1.37
trans -1,2-Dichloroethene	1,400	180	YES	27.4
Trichloroethene	1,100	0.053	YES	23.2
Vinyl Chloride	270	0.25	YES	21.2

(1) Maximum detected concentration from shallow groundwater

(2) EPA. 2002. Draft Guidance for Evaluating the Vapor Instrusion to Indoor Air Pathway from Groundwater
http://www.epa.gov/correctiveaction/eis/vapor/tables.pdf
Table 2c: Generic Screening Levels and Summary Sheet. Based on noncancer hazard index of 1 and cancer risk of $1x10^{-6}$.
For value based upon MCL, refers to Table 2a (present screening values for the $1x10^{-4}$ risk level) and then adjust the value to a $1x10^{-6}$ value.

(3) Estimated using exposure point concentration in EPA's Johnson & Ettinger vapor intrusion model spreadsheet:
http://www.epa.gov/oswer/riskassessment/airmodel/johnson_ettinger.htm

TABLE 3

CALCULATION OF CHEMICAL CANCER RISKS AND NON-CANCER HAZARDS - ONSITE WORKERS

South Tacoma Channel / Well 12A Site

Tacoma, Washington

Equation Definition:

Excess Risk = (CA x CSF x IR x ET x CF1 x EF x ED) / (BW x AT_C)

HQ = (CA x IR x CF1 x EF x ED) / (RfD x BW x AT_{NC})

Parameter	Definition	Value	Source
CA	chemical-specific concentration in air (µg/m^3)	chemical-specific	J&E Model
CSF	inhalation cancer slope factor (mg/kg/day)$^{-1}$	chemical-specific	-
RfD	inhalation reference dose (mg/kg/day)	chemical-specific	-
IR	inhalation rate (m^3/hr)	0.83	EPA 1997
ET	exposure time (hr/day)	8	EPA 1997
CF1	conversion factor (mg/µg)	1E-03	-
EF	exposure frequency (d/yr)	250	EPA 1991
ED	exposure duration (yrs)	25	EPA 1991
BW	body weight (kg)	70	EPA 1991
AT_C	cancer -averaging time (days)	25,550	EPA 1989
AT_{NC}	Noncancer average time (days)	9,125	EPA 1989

Chemical of Concern	Indoor Air Concentration (µg/m^3)	Cancer Risk: Unit Risk (µg/m^3)$^{-1}$	Cancer Risk: CSF (mg/kg-day)$^{-1}$	Cancer Risk: Excess Cancer Risk	Noncancer Hazard: Inhalation RfC (mg/m^3)	Noncancer Hazard: Extrapolated RfD (mg/kg-day)	Noncancer Hazard: Hazard Quotient
1,1,2,2-Tetrachloroethane	0.21	7.4E-06	2.6E-02	1.3E-07	NA	NA	NA
cis -1,2,-Dichloroethene	20.4	NA	NA	NA	NA	NA	NA
Tetrachloroethene	1.37	5.9E-06	2.1E-02	6.6E-07	NA	NA	NA
trans -1,2-Dichloroethene	27.4	NA	NA	NA	NA	NA	NA
Trichloroethene	23.2	1.1E-04	4.0E-01	2.2E-04	4.0E-02	1.1E-02	0.13
Vinyl Chloride	21.2	4.4E-06	1.5E-02	7.6E-06	1.0E-01	2.9E-02	0.05

Total Excess Cancer Risk = **2E-04**

Hazard Index = **0.2**

Exposure Parameter Sources:

EPA 1989. Risk Assessment Guidance for Superfund, Volume 1: Human Health Evaluation Manual, Part A.

EPA 1991. Risk Assessment Guidance for Superfund, Volume 1: Human Health Evaluation Manual, Supplemental Guidance, Standard Default Exposure Factors. Interim Final.

EPA 1997. Exposure Factors Handbook. Vol. 1: General Factors. ORD. EPA/600/P-95/002Fa.

Toxicity Value Sources:

EPA. 2001. Trichloroethylene Health Risk Assessment: Synthesis and Characterization. EPA/600/P-01/002. External Review Draft. August.

EPA. 2008. Integrated Risk Information System (IRIS). June 10.

TABLE 4

CALCULATION OF CHEMICAL CANCER RISKS AND NON-CANCER HAZARDS - RESIDENTIAL ADULTS

South Tacoma Channel / Well 12A Site

Tacoma, Washington

Equation Definition:

Excess Risk = (CA x CSF x IR x ET x CF1 x EF x ED) / (BW x AT_C)

HQ = (CA x IR x CF1 x EF x ED) / (RfD x BW x AT_{NC})

Parameter	Definition	Value	Source
CA	chemical-specific concentration in air (µg/m^3)	chemical-specific	J&E Model
CSF	inhalation cancer slope factor $(mg/kg/day)^{-1}$	chemical-specific	-
RfD	inhalation reference dose (mg/kg/day)	chemical-specific	-
IR	inhalation rate (m^3/hr)	0.83	EPA 1997
ET	exposure time (hr/day)	24	EPA 1997
CF1	conversion factor (mg/µg)	1E-03	-
EF	exposure frequency (d/yr)	350	EPA 1991
ED	exposure duration (yrs)	24	EPA 1991
BW	body weight (kg)	70	EPA 1991
AT_C	cancer -averaging time (days)	25,550	EPA 1989
AT_{NC}	Noncancer average time (days)	8,760	EPA 1989

Chemical of Concern	Indoor Air Concentration (µg/m^3)	Cancer Risk: Unit Risk $(µg/m^3)^{-1}$	Cancer Risk: CSF $(mg/kg\text{-}day)^{-1}$	Cancer Risk: Excess Cancer Risk	Noncancer Hazard: Inhalation RfC (mg/m^3)	Noncancer Hazard: Extrapolated RfD (mg/kg-day)	Noncancer Hazard: Hazard Quotient
1,1,2,2-Tetrachloroethane	0.21	7.4E-06	2.6E-02	5.1E-07	NA	NA	NA
cis -1,2,-Dichloroethene	20.4	NA	NA	NA	NA	NA	NA
Tetrachloroethene	1.37	5.9E-06	2.1E-02	2.6E-06	NA	NA	NA
trans -1,2-Dichloroethene	27.4	NA	NA	NA	NA	NA	NA
Trichloroethene	23.2	1.1E-04	4.0E-01	8.7E-04	4.0E-02	1.1E-02	0.6
Vinyl Chloride	21.2	4.4E-06	1.5E-02	3.1E-05	1.0E-01	2.9E-02	0.2

Total Excess Cancer Risk = **9E-04** **Hazard Index =** **0.8**

Exposure Parameter Sources:

EPA 1989. Risk Assessment Guidance for Superfund, Volume 1: Human Health Evaluation Manual, Part A.

EPA 1991. Risk Assessment Guidance for Superfund, Volume 1: Human Health Evaluation Manual, Supplemental Guidance, Standard Default Exposure Factors. Interim Final.

EPA 1997. Exposure Factors Handbook. Vol. 1: General Factors. ORD. EPA/600/P-95/002Fa.

Toxicity Value Sources:

EPA. 2001. Trichloroethylene Health Risk Assessment: Synthesis and Characterization. EPA/600/P-01/002. External Review Draft. August.

EPA. 2008. Integrated Risk Information System (IRIS). June 10.

TABLE 5

CALCULATION OF CHEMICAL CANCER RISKS AND NON-CANCER HAZARDS - RESIDENTIAL CHILDREN

South Tacoma Channel / Well 12A Site

Tacoma, Washington

Equation Definition:

Excess Risk = (CA x CSF x IR x ET x CF1 x EF x ED) / (BW x AT_C)

HQ = (CA x IR x CF1 x EF x ED) / (RfD x BW x AT_{NC})

Parameter	Definition	Value	Source
CA	chemical-specific concentration in air (µg/m^3)	chemical-specific	J&E Model
CSF	inhalation cancer slope factor $(mg/kg/day)^{-1}$	chemical-specific	-
RfD	inhalation reference dose (mg/kg/day)	chemical-specific	-
IR	inhalation rate (m^3/hr)	0.5	EPA 1997
ET	exposure time (hr/day)	24	EPA 1997
CF1	conversion factor (mg/µg)	1E-03	-
EF	exposure frequency (d/yr)	350	EPA 1991
ED	exposure duration (yrs)	6	EPA 1991
BW	body weight (kg)	15	EPA 1991
AT_C	cancer -averaging time (days)	25,550	EPA 1989
AT_{NC}	Noncancer average time (days)	2,190	EPA 1989

Chemical of Concern	Indoor Air Concentration (µg/m^3)	Cancer Risk: Unit Risk $(\mu g/m^3)^{-1}$	Cancer Risk: CSF $(mg/kg\text{-}day)^{-1}$	Cancer Risk: Excess Cancer Risk	Noncancer Hazard: Inhalation RfC (mg/m^3)	Noncancer Hazard: Extrapolated RfD (mg/kg-day)	Noncancer Hazard: Hazard Quotient
1,1,2,2-Tetrachloroethane	0.21	7.4E-06	2.6E-02	3.6E-07	NA	NA	NA
cis -1,2,-Dichloroethene	20.4	NA	NA	NA	NA	NA	NA
Tetrachloroethene	1.37	5.9E-06	2.1E-02	1.9E-06	NA	NA	NA
trans -1,2-Dichloroethene	27.4	NA	NA	NA	NA	NA	NA
Trichloroethene	23.2	1.1E-04	4.0E-01	6.1E-04	4.0E-02	1.1E-02	1.6
Vinyl Chloride	21.2	4.4E-06	1.5E-02	2.1E-05	1.0E-01	2.9E-02	0.6

Total Excess Cancer Risk = **6E-04**

Hazard Index = **2**

Exposure Parameter Sources:

EPA 1989. Risk Assessment Guidance for Superfund, Volume 1: Human Health Evaluation Manual, Part A.

EPA 1991. Risk Assessment Guidance for Superfund, Volume 1: Human Health Evaluation Manual, Supplemental Guidance, Standard Default Exposure Factors. Interim Final.

EPA 1997. Exposure Factors Handbook. Vol. 1: General Factors. ORD. EPA/600/P-95/002Fa.

Toxicity Value Sources:

EPA. 2001. Trichloroethylene Health Risk Assessment: Synthesis and Characterization. EPA/600/P-01/002. External Review Draft. August.

EPA. 2008. Integrated Risk Information System (IRIS). June 10.

TABLE 3

CALCULATION OF CHEMICAL CANCER RISKS AND NON-CANCER HAZARDS - ONSITE WORKERS

South Tacoma Channel / Well 12A Site

Tacoma, Washington

Equation Definition:

Excess Risk = (CA x CSF x IR x ET x CF1 x EF x ED) / (BW x AT_C)

HQ = (CA x IR x CF1 x EF x ED) / (RfD x BW x AT_{NC})

Parameter	Definition	Value	Source
CA	chemical-specific concentration in air ($\mu g/m^3$)	chemical-specific	J&E Model
CSF	inhalation cancer slope factor $(mg/kg/day)^{-1}$	chemical-specific	-
RfD	inhalation reference dose (mg/kg/day)	chemical-specific	-
IR	inhalation rate (m^3/hr)	0.63	EPA 1997
ET	exposure time (hr/day)	8	EPA 1997
CF1	conversion factor (mg/μg)	1E-03	-
EF	exposure frequency (d/yr)	225	EPA 1997
ED	exposure duration (yrs)	9	EPA 1997
BW	body weight (kg)	70	EPA 1991
AT_C	cancer -averaging time (days)	25,550	EPA 1989
AT_{NC}	Noncancer average time (days)	3,285	EPA 1989

Chemical of Concern	Indoor Air Concentration ($\mu g/m^3$)	Cancer Risk: Unit Risk $(\mu g/m^3)^{-1}$	Cancer Risk: CSF $(mg/kg\text{-}day)^{-1}$	Cancer Risk: Excess Cancer Risk	Noncancer Hazard: Inhalation RfC (mg/m^3)	Noncancer Hazard: Extrapolated RfD (mg/kg-day)	Noncancer Hazard: Hazard Quotient
1,1,2,2-Tetrachloroethane	0.21	7.4E-06	2.6E-02	3.1E-08	NA	NA	NA
cis-1,2,-Dichloroethene	20.4	NA	NA	NA	NA	NA	NA
Tetrachloroethene	1.37	5.9E-06	2.1E-02	1.6E-07	NA	NA	NA
trans-1,2-Dichloroethene	27.4	NA	NA	NA	NA	NA	NA
Trichloroethene	23.2	1.1E-04	4.0E-01	5.3E-05	4.0E-02	1.1E-02	0.09
Vinyl Chloride	21.2	4.4E-06	1.5E-02	1.9E-06	1.0E-01	2.9E-02	0.03

Total Excess Cancer Risk = **6E-05**

Hazard Index = **0.1**

Exposure Parameter Sources:

EPA 1989. Risk Assessment Guidance for Superfund, Volume 1: Human Health Evaluation Manual, Part A.

EPA 1991. Risk Assessment Guidance for Superfund, Volume 1: Human Health Evaluation Manual, Supplemental Guidance, Standard Default Exposure Factors. Interim Final.

EPA 1997. Exposure Factors Handbook. Vol. 1: General Factors. ORD. EPA/600/P-95/002Fa.

Toxicity Value Sources:

EPA. 2001. Trichloroethylene Health Risk Assessment: Synthesis and Characterization. EPA/600/P-01/002. External Review Draft. August.

EPA. 2008. Integrated Risk Information System (IRIS). June 10.

TABLE 4

CALCULATION OF CHEMICAL CANCER RISKS AND NON-CANCER HAZARDS - RESIDENTIAL ADULTS

South Tacoma Channel / Well 12A Site

Tacoma, Washington

Equation Definition:

Excess Risk = (CA x CSF x IR x ET x CF1 x EF x ED) / (BW x AT_C)

HQ = (CA x IR x CF1 x EF x ED) / (RfD x BW x AT_{NC})

Parameter	Definition	Value	Source
CA	chemical-specific concentration in air (µg/m^3)	chemical-specific	J&E Model
CSF	inhalation cancer slope factor (mg/kg/day)$^{-1}$	chemical-specific	-
RfD	inhalation reference dose (mg/kg/day)	chemical-specific	-
IR	inhalation rate (m^3/hr)	0.63	EPA 1997
ET	exposure time (hr/day)	16	EPA 1997
CF1	conversion factor (mg/µg)	1E-03	-
EF	exposure frequency (d/yr)	350	EPA 1991
ED	exposure duration (yrs)	9	EPA 1991
BW	body weight (kg)	70	EPA 1991
AT_C	cancer -averaging time (days)	25,550	EPA 1989
AT_{NC}	Noncancer average time (days)	3,285	EPA 1989

Chemical of Concern	Indoor Air Concentration (µg/m^3)	Cancer Risk: Unit Risk (µg/m^3)$^{-1}$	Cancer Risk: CSF (mg/kg-day)$^{-1}$	Cancer Risk: Excess Cancer Risk	Noncancer Hazard: Inhalation RfC (mg/m^3)	Noncancer Hazard: Extrapolated RfD (mg/kg-day)	Noncancer Hazard: Hazard Quotient
1,1,2,2-Tetrachloroethane	0.21	7.4E-06	2.6E-02	9.7E-08	NA	NA	NA
cis -1,2,-Dichloroethene	20.4	NA	NA	NA	NA	NA	NA
Tetrachloroethene	1.37	5.9E-06	2.1E-02	5.0E-07	NA	NA	NA
trans -1,2-Dichloroethene	27.4	NA	NA	NA	NA	NA	NA
Trichloroethene	23.2	1.1E-04	4.0E-01	1.6E-04	4.0E-02	1.1E-02	0.3
Vinyl Chloride	21.2	4.4E-06	1.5E-02	5.8E-06	1.0E-01	2.9E-02	0.1

Total Excess Cancer Risk = 2E-04

Hazard Index = 0.4

Exposure Parameter Sources:

EPA 1989. Risk Assessment Guidance for Superfund, Volume 1: Human Health Evaluation Manual, Part A.

EPA 1991. Risk Assessment Guidance for Superfund, Volume 1: Human Health Evaluation Manual, Supplemental Guidance, Standard Default Exposure Factors. Interim Final.

EPA 1997. Exposure Factors Handbook. Vol. 1: General Factors. ORD. EPA/600/P-95/002Fa.

Toxicity Value Sources:

EPA. 2001. Trichloroethylene Health Risk Assessment: Synthesis and Characterization. EPA/600/P-01/002. External Review Draft. August.

EPA. 2008. Integrated Risk Information System (IRIS). June 10.

TABLE 5

CALCULATION OF CHEMICAL CANCER RISKS AND NON-CANCER HAZARDS - RESIDENTIAL CHILDREN

South Tacoma Channel / Well 12A Site

Tacoma, Washington

Equation Definition:

Excess Risk = (CA x CSF x IR x ET x CF1 x EF x ED) / (BW x AT_C)

HQ = (CA x IR x CF1 x EF x ED) / (RfD x BW x AT_{NC})

Parameter	Definition	Value	Source
CA	chemical-specific concentration in air (µg/m^3)	chemical-specific	J&E Model
CSF	inhalation cancer slope factor $(mg/kg/day)^{-1}$	chemical-specific	-
RfD	inhalation reference dose (mg/kg/day)	chemical-specific	-
IR	inhalation rate (m^3/hr)	0.3	EPA 1997
ET	exposure time (hr/day)	16	EPA 1997
CF1	conversion factor (mg/µg)	1E-03	-
EF	exposure frequency (d/yr)	350	EPA 1991
ED	exposure duration (yrs)	6	EPA 1991
BW	body weight (kg)	15	EPA 1991
AT_C	cancer -averaging time (days)	25,550	EPA 1989
AT_{NC}	Noncancer average time (days)	2,190	EPA 1989

Chemical of Concern	Indoor Air Concentration (µg/m^3)	Cancer Risk: Unit Risk $(µg/m^3)^{-1}$	Cancer Risk: CSF $(mg/kg\text{-}day)^{-1}$	Cancer Risk: Excess Cancer Risk	Noncancer Hazard: Inhalation RfC (mg/m^3)	Noncancer Hazard: Extrapolated RfD (mg/kg-day)	Noncancer Hazard: Hazard Quotient
1,1,2,2-Tetrachloroethane	0.21	7.4E-06	2.6E-02	1.4E-07	NA	NA	NA
cis -1,2,-Dichloroethene	20.4	NA	NA	NA	NA	NA	NA
Tetrachloroethene	1.37	5.9E-06	2.1E-02	7.4E-07	NA	NA	NA
trans -1,2-Dichloroethene	27.4	NA	NA	NA	NA	NA	NA
Trichloroethene	23.2	1.1E-04	4.0E-01	2.4E-04	4.0E-02	1.1E-02	0.6
Vinyl Chloride	21.2	4.4E-06	1.5E-02	8.6E-06	1.0E-01	2.9E-02	0.2

Total Excess Cancer Risk = 3E-04

Hazard Index = 0.9

Exposure Parameter Sources:

EPA 1989. Risk Assessment Guidance for Superfund, Volume 1: Human Health Evaluation Manual, Part A.

EPA 1991. Risk Assessment Guidance for Superfund, Volume 1: Human Health Evaluation Manual, Supplemental Guidance, Standard Default Exposure Factors. Interim Final.

EPA 1997. Exposure Factors Handbook. Vol. 1: General Factors. ORD. EPA/600/P-95/002Fa.

Toxicity Value Sources:

EPA. 2001. Trichloroethylene Health Risk Assessment: Synthesis and Characterization. EPA/600/P-01/002. External Review Draft. August.

EPA. 2008. Integrated Risk Information System (IRIS). June 10.

Appendix D
Hydrogeological Analysis

Hydrogeological Analysis

Purpose: Estimate steady state contaminant concentrations reductions necessary at east side of plume and south-southwest side of plume to achieve TCE concentrations to below the MCL of 5 ug/l

Steady state transport solution along the centerline of a plume (Domenico 1987)

$$C(x) = C_0 \exp\{x/2\alpha_x[1-\sqrt{1+4\lambda\alpha_x/v}]\}$$
$$\{erf[Y/4)\sqrt{\alpha_y x}]erf[(Z/4)/\sqrt{\alpha_z x}]\}$$

where,

C_0=	initial concentration (ug/l);
Y =	length of source area perpendicular to groundwater flow (feet);
Z =	depth of source area below water table (feet);
x =	location along x axis (feet) from source on plume centerline
$\alpha_{x,y,z}$ =	dispersivity in x, y and z directions (feet)
v =	velocity of contaminant (feet/day)[1] (v_{gw}/R_f)
λ =	decay constant (day^{-1})

East gradient direction:

C_0=	300 ug/l	Average concentration where subsurface turns from anaerobic to aerobic zone
Y =	1050 ft	Distance from CBW-10 to WCC-2
Z =	33 ft	Midpoint depth of saturated zone (estimated to be average source depth)
x =	520 ft	Distance from 300 ug/l isoconcentration to CH2M-2
$\alpha_{x,y,z}$ =	36, 3.6, 0.4	Contaminant Source Strength and Sensitivity Analysis (CDM 2008)
v =	0.04 ft/d	Contaminant Source Strength and Sensitivity Analysis (CDM 2008)
λ =	8.25 yrs	Biodegradation rate needed to achieve the observed 21 ug/l TCE concentration (Feb/Mar 2008) with the given parameters and solution

South-southwest gradient

C_0=	300 ug/l	Average concentration where subsurface turns from anaerobic to aerobic zone
Y =	535 ft	Distance from CBW-10 to MW-309 (proposed well)
Z =	33 ft	Midpoint depth of saturated zone (estimated to be average source depth)
x =	1140 ft	Distance from 300 ug/l isoconcentration to CH2M-2
$\alpha_{x,y,z}$ =	36, 3.6, 0.4	Contaminant Source Strength and Sensitivity Analysis (CDM 2008)
v =	0.42 ft/d	Contaminant Source Strength and Sensitivity Analysis (CDM 2008)
λ =	1.5 yrs	Biodegradation rate needed to achieve the observed 8.5 ug/l TCE concentration (Feb/Mar 2008) with the given parameters and solution This rate is different than the east direction, but has been accepted since the value is within published literature values and rates can differ in aquifers. However, the different values suggest different hydrogeological characteristics between the east and south-southwest areas of the aquifer, which has been recognized previously.

Compound (direction)	Variables									
	C_0	Y	Z	x	v_{gw}	R_f	α_x	α_y	α_z	λ
units	ug/l	feet	feet	feet	feet/day	unitless	feet	feet	feet	/day
TCE (east)	70	1050	33	520	0.14	3.5	36	3.6	0.4	0.00023
TCE (southwest)	160	535	33	1140	1.48	3.5	36	3.6	0.4	0.0013

Estimated TCE concentration at CH2M-2 with given values 4.9 ug/l
Estimated TCE concentration at CBW-11 with given values 4.8 ug/l

Therefore, on the east side, concentrations need to be decreased from 300 ug/l down to 70 ug/l, a reduction of 80% and on the south-southwest side, concentrations need to decrease from 300 ug/l down to 160 ug/l, a reduction of 50%.

As reported by The EPA Center for Subsurface Modeling Support (CSMoS): CSMoS acknowledges that the Domenico-based models are approximate analytical solutions of the advective-dispersive solute transport equation; therefore, they could generate an error for a given set of input parameters when compared with the exact solutions. The error is largely sensitive to high values of longitudinal dispersivity (Srinivasan et al., 2007 and West et al., 2007). However, CSMoS noticed that the error is insignificant when longitudinal dispersion is reasonably low (see Figures 2b and 5b of Srinivasan et al., 2007). Furthermore, longitudinal dispersivity is a calibration parameter, not a parameter that is measured in the field, in real-world modeling applications. Therefore, CSMoS believes that the Domenico-based models in their current forms are reasonable for screening level tools.

Appendix E
Screening of Technologies and Process Options

Appendix E Table 1 of 2
Screening of Technologies and Process Options Applicable to Soil

General Response Action	Technology Type	Process Option	Description	Effectiveness	Implementability	Cost	Retained for Filter Cake and Shallow Soils	Retained for Deep Vadose Zone and Upper Saturated Soils
No Action	No Action	No Action	No action is performed at the site.	Not effective, but required for consideration by the NCP as a baseline for comparison. Unlikely to be acceptable due to the level of contaminants on site.	Easily implemented	None	Y	Y
Institutional Controls	Institutional Controls	Deed Restrictions	Restricts land use at the site.	Effective in limiting future development of the site. However, this process alone would not eliminate the potential for exposure to contaminants.	Easily implemented	Low	Y	Y
		Deed Notice	Provides information on a parcel.	Effective for relaying information about a property.	Easily implemented	Low	Y	Y
		Zoning	Limits use of a property.	Effective if enforced.	Moderately difficult to implement since it requires the cooperation of the municipality	Low	Y	Y
Containment	Capping	Asphalt Cap	Pave area to prevent exposure to contaminated materials and limit water infiltration.	Limits contact with contaminated materials in shallow soil and minimizes water infiltration into subsurface, with the use of a relatively thin cap construction.	Easily implemented	Low	Y	Y

Appendix E Table 1 of 2
Screening of Technologies and Process Options Applicable to Soil

General Response Action	Technology Type	Process Option	Description	Effectiveness	Implementability	Cost	Retained for Filter Cake and Shallow Soils	Retained for Deep Vadose Zone and Upper Saturated Soils
Containment (continued)	Capping (continued)	Clay Cap	Uses a layer of clay to prevent exposure to contaminated materials and limit water infiltration.	Limits contact with contaminated materials in shallow soil and minimizes water infiltration into subsurface..	Moderately difficult to implement given current site development.	Moderate	N	N
		Geomembrane Cap	Uses textile material and associated sub-base and topsoil layers to prevent exposure to contaminated materials and limit water infiltration.	Limits contact with contaminated materials in shallow soil and minimizes water infiltration into subsurface, with the use of a relatively thin cap construction.	Moderately difficult to implement given current site development.	Moderate	N	N
		Soil/Crushed Concrete Cap	Uses a layer of soil or crushed concrete to limit exposure to contaminated materials.	Limits contact with contaminated materials in shallow soil. Would not prevent water infiltration into the subsurface.	Moderately difficult to implement given current site development.	Low	N	N

Appendix E Table 1 of 2
Screening of Technologies and Process Options Applicable to Soil

General Response Action	Technology Type	Process Option	Description	Effectiveness	Implementability	Cost	Retained for Filter Cake and Shallow Soils	Retained for Deep Vadose Zone and Upper Saturated Soils
Removal	Excavation	Excavation	Excavation of contaminated soil using typical construction equipment	Effective technique for removing contaminated soil and/or filter cake from the site	Easily implemented with standard earth moving equipment and/or hand tools for filter cake and shallow impacted soils. Difficult to implement for soils beneath existing buildings and below the water table.	Low (shallow) to High (deep)	Y	N
	Consolidation	Consolidation	Process of moving materials from various areas of the site in order to reduce the area to be capped or contained	Effective as a means of reducing the area to be capped. Minimal additional benefit given the limited unpaved area.	Easily implemented with standard earth moving equipment for filter cake and shallow impacted soils. Difficult to implement for soils beneath existing buildings and below the water table.	Low to Moderate	N	N
Treatment	Thermal	In-situ Vitrification	A high temperature process that melts contaminated soil in-situ, forming an unleachable monolith.	Effective in destroying organic compounds. Off-gas treatment may be necessary to capture any organics that are vaporized during treatment. Saturated soil may lead to higher costs.	Relatively difficult to implement due to limited availability of specialized equipment and operators	High	N	N

Appendix E Table 1 of 2
Screening of Technologies and Process Options Applicable to Soil

General Response Action	Technology Type	Process Option	Description	Effectiveness	Implementability	Cost	Retained for Filter Cake and Shallow Soils	Retained for Deep Vadose Zone and Upper Saturated Soils
Treatment (continued)	Thermal (continued)	In-situ Steam Injection	Injection of steam heats the soil and groundwater and enhances the release of contaminants from the soil matrix by decreasing viscosity and accelerating volatilization.	Very effective in mobilizing residual DNAPL for collection and treatment. Requires vapor-phase or dual-phase extraction and treatment.	Relatively easy to implement if size of treatment zone is limited. Can be applied under roads and existing buildings. Similar to ERH; can use in high groundwater flux if ERH not implementable	Moderate to High	N	N
		In-situ Electrical Resistance Heating	Uses arrays of electrodes to apply electrical current to the subsurface. Heat generated by electrical resistance in the soil creates steam in-situ and works similarly to steam injection.	Very effective in mobilizing residual DNAPL for collection and treatment. Requires vapor-phase or dual-phase extraction and treatment.	Relatively easy to implement if size of treatment zone is limited. Can be applied under roads and existing buildings. Groundwater flux high, but appropriate	Moderate to High	N	Y
		Exsitu Incineration	High temperature (2000 °F) burning of soil that destroys organic materials. Can be conducted either on site or off site.	Very effective in destroying organics. Treated soil would be backfilled or disposed following incineration.	Anticipate difficulty obtaining local acceptance to site an incinerator for onsite treatment, while offsite treatment would be readily implementable.	Very High	N	N

Appendix E Table 1 of 2
Screening of Technologies and Process Options Applicable to Soil

General Response Action	Technology Type	Process Option	Description	Effectiveness	Implementability	Cost	Retained for Filter Cake and Shallow Soils	Retained for Deep Vadose Zone and Upper Saturated Soils
Treatment (continued)	Thermal (continued)	Low Temperature Thermal Desorption	Low temperature (300-600 °C) process that volatilizes organic materials, which are captured and processed in an offgas treatment system or recycled.	Effective in treating organics. Off-gas treatment may be necessary to capture any organics that are vaporized during treatment.	Moderately difficult to implement.	Moderate	N	N
	Biological	In-situ Bioremediation	Uses injection of an electron donor and nutrients to stimulate indigenous bacteria.	Most effective on dissolved-phase organics. Recent studies show that it can be effective in source areas with residual NAPL as well. Difficult to non-applicable in vadose zone	Relatively easy to implement using readily available equipment. Amendment delivery can be challenging in heterogeneous formations.	Moderate	N	N
		Ex-situ Bioremediation	Employs the construction of biological treatment cells to break down organic material.	Effective in treating organics	Slightly difficult to implement, due to area required for construction of treatment cells. Building limits accessibility	Moderate	N	N

General Response Action	Technology Type	Process Option	Description	Effectiveness	Implementability	Cost	Retained for Filter Cake and Shallow Soils	Retained for Deep Vadose Zone and Upper Saturated Soils
	Physical	In-situ Soil Vapor Extraction	Establishes a vacuum in vadose zone to volatilize and extract VOCs from soil.	Effective for removing volatiles from vadose zone. Limited effectiveness below the water table as a stand-alone remedy, but may be used in conjunction with other remedies to recover vapor phase (ERH and air sparge) contaminants. May reduce effectiveness of anaerobic degradation. Was very effective on west side of Time Oil building	Relatively easy to implement.	Moderate	Y	Y
Treatment (continued)	Physical (continued)	In-situ Soil Flushing	Process that injects water/surfactants into the subsurface soil. Requires use of extraction wells or trenches to capture contaminants in the groundwater.	Effective for removing some contaminants from soil, but may lead to increased chance of mobilizing contaminants into groundwater. Not as effective when soil contains moderate to high clay content.	Somewhat difficult to implement due to specialized equipment required and permitting concerns.	Moderate	N	N

Appendix E Table 1 of 2
Screening of Technologies and Process Options Applicable to Soil

General Response Action	Technology Type	Process Option	Description	Effectiveness	Implementability	Cost	Retained for Filter Cake and Shallow Soils	Retained for Deep Vadose Zone and Upper Saturated Soils
	Chemical	In-situ Chemical Oxidation	An oxidizing agent (e.g., hydrogen peroxide, Fenton's Reagent, potassium permanganate, persulfate, or ozone) is injected into the subsurface. Organic compounds are destroyed upon reaction with the oxidant.	Effective organic destruction if adequate contact between reagents and contaminants occurs. Can adversely impact anaerobic degradation in source area.	Relatively easy to implement using readily available equipment. Delivery can be challenging in heterogeneous formations. Administrative difficulties can be anticipated, including injection permits for reagents.	Moderate to High	N	N
Disposal	Disposal	Offsite Disposal	Disposal of material (treated or untreated) at an offsite permitted facility.	Effective as means of minimizing exposure to contaminants and eliminating pathway for transport of contaminants to groundwater.	Offsite disposal is relatively easy to implement, but may require treatment prior to disposal to meet LDRs.	High	Y	N
Disposal (continued)	Disposal (continued)	Onsite Engineered Cell	An engineered waste cell that is constructed onsite with a bottom liner and cover system to receive treated or untreated material.	Effective as means of minimizing exposure to contaminants and eliminating pathway for transport of contaminants to groundwater.	Requires significant contaminated materials handling. May be difficult to implement due to long-term land use issues and can result in higher final site elevation due to liner and cover system.	High	N	N

General Response Action	Technology Type	Process Option	Description	Effectiveness	Implementability	Cost	Retained for Filter Cake and Shallow Soils	Retained for Deep Vadose Zone and Upper Saturated Soils
		Backfill	Disposal of treated material onsite.	Effective method of disposing of treated soil provided MTCA levels are met.	Relatively easy to implement provided that material has been treated to regulatory levels.	Low	N	N

Appendix E Table 2 of 2
Screening of Technologies and Process Options Applicable to Groundwater

General Response Action	Technology Type	Process Option	Description	Effectiveness	Implementability	Cost	Retained for High Concentration Groundwater	Retained for Low Concentration Groundwater
No Action	No Action	No Action	No action is performed at the site.	Not effective, but required for consideration by the NCP as a baseline for comparison. Unlikely to be acceptable due to the level of contaminants on site.	Easily implemented	None	Y	Y
Institutional Controls	Institutional Controls	Deed Restrictions	Restricts land use at the site.	Effective in limiting future development of the site. However, this process alone would not eliminate the potential for exposure to contaminants.	Easily implemented	Low	Y	Y
		Deed Notice	Provides information on a parcel.	Effective for relaying information about a property.	Easily implemented	Low	Y	Y
		Zoning	Limits use of a property.	Effective if enforced.	Moderately difficult to implement since it requires the cooperation of the municipality	Low	Y	Y

Appendix E Table 2 of 2
Screening of Technologies and Process Options Applicable to Groundwater

General Response Action	Technology Type	Process Option	Description	Effectiveness	Implementability	Cost	Retained for High Concentration Groundwater	Retained for Low Concentration Groundwater
Monitored Natural Attenuation	Monitored Natural Attenuation	Monitored Natural Attenuation	Natural destructive (biodegradation and chemical reactions) and nondestructive mechanisms (dilution, dispersion, volatilization, and adsorption) that reduce contaminant levels.	Can be effective where natural conditions promote contaminant degradation	Easily implemented	Low	N	N
Containment	Vertical Barrier	Slurry Wall	A subsurface barrier consisting of a trench filled with a slurry of either a soil/ bentonite mixture or a cement/ bentonite mixture, which provides a physical barrier to the contaminated groundwater. May require groundwater extraction to maintain hydraulic control.	Slurry wall barrier is effective in preventing additional groundwater contamination from migrating offsite or for diverting uncontaminated groundwater around a contaminant source. Limited effectiveness if confining layer is not continuous below source area.	Difficult to implement due to depth. Slurry wall would be keyed into confining layer present at the site.	High	N	N

Appendix E Table 2 of 2
Screening of Technologies and Process Options Applicable to Groundwater

General Response Action	Technology Type	Process Option	Description	Effectiveness	Implementability	Cost	Retained for High Concentration Groundwater	Retained for Low Concentration Groundwater
Containment (continued)	Vertical Barrier (continued)	Grout Curtain	A grout curtain is a solid, low-permeability subsurface vertical barrier formed by injecting grout (e.g., Portland cement) through well points or an injection auger. May require groundwater extraction to maintain hydraulic control.	Grout curtain barrier is effective in preventing additional groundwater contamination from migrating offsite or for diverting uncontaminated groundwater around a contaminant source. Limited effectiveness if confining layer is not continuous below source area.	Grout curtains are not subject to the depth limitations of other vertical barriers considered, but it may be difficult to verify whether or not a continuous barrier has been formed.	Moderate to High	N	N

Appendix E Table 2 of 2
Screening of Technologies and Process Options Applicable to Groundwater

General Response Action	Technology Type	Process Option	Description	Effectiveness	Implementability	Cost	Retained for High Concentration Groundwater	Retained for Low Concentration Groundwater
Collection/ Extraction	Extraction	Extraction Wells	Use of wells to extract contaminated groundwater from the aquifer or to create hydraulic barriers, preventing contaminated groundwater from migrating offsite.	An existing groundwater extraction and treatment system has been operating onsite for 20 years. If enhancements are made, the use of extraction wells is expected to be somewhat effective for collection of contaminated groundwater. The presence of residual NAPL will provide a continuing source of groundwater contamination, limiting extraction effectiveness for long-term source removal.	Readily implementable. Would require long-term use of extraction wells.	Moderate to High	Y	N

Appendix E Table 2 of 2
Screening of Technologies and Process Options Applicable to Groundwater

General Response Action	Technology Type	Process Option	Description	Effectiveness	Implementability	Cost	Retained for High Concentration Groundwater	Retained for Low Concentration Groundwater
Collection/ Extraction (continued)	Enhanced Extraction	Surfactant Flushing	Injection of surfactant(s) into a zone of contaminated groundwater to mobilize and solubilize contaminants, followed by downgradient extraction of the contaminated groundwater and surfactant mixture.	Increases the movement of viscous and low-solubility organic contaminants. Effective in removing organics from the subsurface when used in conjunction with collection methods such as extraction wells.	Moderately easy to implement. Can potentially reduce pump-and-treat times, but administrative difficulties are anticipated. Addition of surfactant(s) may require an EPA Underground Injection Control (UIC) permit.	Moderate to High	N	N

Appendix E Table 2 of 2
Screening of Technologies and Process Options Applicable to Groundwater

General Response Action	Technology Type	Process Option	Description	Effectiveness	Implementability	Cost	Retained for High Concentration Groundwater	Retained for Low Concentration Groundwater
Collection/ Extraction (continued)	Enhanced Extraction (continued)	In-situ Pressure Pulse Technology	Application of mechanical vibration in injection wells through the use of hydraulically or pneumatically actuated sudden movement of a displacement piston to create a large impulse and mixing zone.	Possibly effective for enhancing pump and treatment systems which have limitations due to presence of residual NAPL. May be applied in conjunction with surfactant flushing to improve and control dispersal of the surfactant(s) in low permeability conditions. Full-scale implementation has not yet been applied.	Relatively easy to implement, but requires specialized equipment.	Moderate to High	N	N

Appendix E Table 2 of 2
Screening of Technologies and Process Options Applicable to Groundwater

General Response Action	Technology Type	Process Option	Description	Effectiveness	Implementability	Cost	Retained for High Concentration Groundwater	Retained for Low Concentration Groundwater
Treatment	Biological	In-situ Bio-remediation	Uses injection of an electron donor and nutrients to stimulate indigenous bacteria.	Significant reductive dechlorination is or has been occurring naturally in the primarily anaerobic source area and there is evidence to support TCE degradation aerobic zones on the periphery of the primary plume. Enhancing these natural processes is likely to be very effective.	Relatively easy to implement using readily available equipment. Remedial delivery can be challenging in heterogeneous formations.	Moderate	Y	N

Appendix E Table 2 of 2
Screening of Technologies and Process Options Applicable to Groundwater

General Response Action	Technology Type	Process Option	Description	Effectiveness	Implementability	Cost	Retained for High Concentration Groundwater	Retained for Low Concentration Groundwater
Treatment (continued)	Physical/ Chemical (In-situ)	In-Situ Permeable Reactive Barrier	A containment wall constructed perpendicular to the flow path of a plume that directs the contaminants to move through the reactive gates (treatment weir) for treatment. Contaminants are removed through reaction with the permeable reactive medium.	Effective in treating contaminated groundwater released from a NAPL source area, but are not effective for treating residual NAPL material. Treatment zones in the barrier, such as zero valent iron or carbon media can be used to treat contaminants that move through the zones.	Difficult to implement due to depth	Moderate to high	N	N

Appendix E Table 2 of 2
Screening of Technologies and Process Options Applicable to Groundwater

General Response Action	Technology Type	Process Option	Description	Effectiveness	Implementability	Cost	Retained for High Concentration Groundwater	Retained for Low Concentration Groundwater
Treatment (continued)	Physical/ Chemical (In-situ) (continued)	In-situ Chemical Oxidation	An oxidizing agent (e.g., hydrogen peroxide, Fenton's Reagent, potassium permanganate, persulfate, or ozone) is injected into the subsurface. Organic compounds are destroyed upon reaction with the oxidant.	Effective organic destruction if adequate contact between reagents and contaminants occurs. Less effective at treating free product NAPL as large quantities of oxidant would be required. One of few treatment technologies applicable to 1,4-dioxane. Can interfere with anaerobic degradation processes.	Relatively easy to implement using readily available equipment. Chemical delivery can be challenging in heterogeneous formations. Administrative difficulties can be anticipated, including injection permits for reagents.	Moderate to High	N	N

General Response Action	Technology Type	Process Option	Description	Effectiveness	Implementability	Cost	Retained for High Concentration Groundwater	Retained for Low Concentration Groundwater
Treatment (continued)	Physical/ Chemical (In-situ) (continued)	Air Sparging	Air sparging involves the injection of air or oxygen into the contaminated aquifer. Injected air strips volatile and semivolatile organic contaminants in-situ and helps to flush the contaminants into the unsaturated zone. SVE is usually is implemented in conjunction with air sparging to remove the vapor-phase contamination from the vadose zone and to mitigate impacts to surface receptors.	Effective for volatile organics. Oxygen added to the contaminated groundwater and vadose-zone soils also can enhance aerobic biodegradation of contaminants below and above the water table, but will have adverse effects to anaerobic degradation. Air stripping could be used effectively in the source area groundwater plume or as a barrier between the Time Oil property and Well 12A. Could increase exposure to surface receptors if not implemented in conjunction with SVE.	Relatively easy to implement. Well locations would be limited by existing development.	Moderate	Y	N

Appendix E Table 2 of 2
Screening of Technologies and Process Options Applicable to Groundwater

General Response Action	Technology Type	Process Option	Description	Effectiveness	Implementability	Cost	Retained for High Concentration Groundwater	Retained for Low Concentration Groundwater
Treatment (continued)	Physical/ Chemical (Ex-Situ)	Carbon Adsorbtion	Extracted groundwater or off-gas is pumped through a reactor vessel containing granular activated carbon (GAC) to which contaminants adsorb and are removed.	Effective removal of most organics, but is susceptible to biological and inorganic fouling. Not effective in removing 1,4-dioxane. Very limited capacity for adsorption of vinyl chloride	Readily implementable. Existing GETS system currently uses liquid-phase carbon adsorbtion.	Low	Y	N
		Air Stripping	Mass transfer of volatile contaminants from water to air by increasing surface area of the groundwater exposed to air.	Effective removal of most organics, but is susceptible to biological and inorganic fouling. Not effective in removing 1,4-dioxane.	Readily implementable. Could be added to existing GETS system to improve performance and possibly reduce O&M costs. Air stripping currently used at Well 12A	Low	Y	Y

Appendix E Table 2 of 2
Screening of Technologies and Process Options Applicable to Groundwater

General Response Action	Technology Type	Process Option	Description	Effectiveness	Implementability	Cost	Retained for High Concentration Groundwater	Retained for Low Concentration Groundwater
Treatment (continued)	Physical/ Chemical (Ex-Situ)	Ex-Situ Advanced Oxidation	Advanced Oxidation Processes including ultraviolet (UV) radiation, ozone, and/or hydrogen peroxide are used to destroy organic contaminants as water flows into a treatment tank.	Effective treatment of most organics. One of few treatment technologies applicable to 1,4-dioxane.	Relatively easy to implement using commercially available systems	Moderate to High	N	N
Disposal	Disposal	Offsite Disposal	Disposal of treated water or treatment waste residuals to offsite facility by truck or storm/sanitary sewer.	Effective method for disposing of waste residuals and treated water. Water may require pre-treatment to meet the facility acceptance requirements.	Readily implementable. Existing GETS system currently discharges to storm sewer.	Low to Moderate	Y	N
Disposal	Disposal (continued)	Onsite Disposal	Disposal of treated water onsite into the subsurface using injection wells or an infiltration gallery.	Effectiveness could be limited by biofouling of injection wells an/or infiltration galleries.	Moderately easy to implement, but may require ongoing maintenance.	Moderate	N	N

Appendix F
Cost Estimates

Appendix F
Cost Estimates

Appendix F provides supporting information for one of the EPA Primary Balancing Criteria, Cost. An estimate of the cost for each alternative is determined so that the cost can be compared to the level of protectiveness that each alternative provides. The typical cost estimate made during the FFS is intended to provide an accuracy of +50 percent to -30 percent, as discussed in the EPA RI/FS guidance document. The types of costs that are assessed include the capital costs, operation and maintenance (O&M) costs, and present worth. For the present worth analysis, a 7% discount rate was used, and the evaluation period is 30 years, unless otherwise stated.

Several resources were accessed to develop cost estimates for the FFS in addition to general engineering experience. Main components of the alternatives are identified below and the resources that were used to develop the costs are listed.

Treatment Zone with Alternative Components/Items	Resource
Filter Cake and Shallow Impacted Soil	
Placing Asphalt Cap (items a through h)	Means CostWorks Version 11.0 release update 2008 Cost Data
Excavation, disposal and backfill (Items a through i)	Means CostWorks Version 11.0 release update 2008 Cost Data
Deep Vadose Zone and Upper Saturated Soil	
Insitu Thermal Remediation (items a through n)	Estimate from Thermal Remediation Services, Inc. received October 31, 2008
High Concentration Groundwater	
Groundwater Extraction and Treatment O&M (items a through d)	Estimate from Chuck Hinds of Washington State Department of Ecology (current system operators) received October 30, 2008
Mass Flux Measurements (items a and b)	Estimates based on values for similar work provided in *Final East Gate Disposal Yard Thermal Remediation Performance Assessment After Action Report* (USACE, et al 2008)
Enhanced Anaerobic Bioremediation (items a through e)	Iceland Coin Laundry Superfund Site FS by CDM
Air Sparge/Soil Vapor Extraction (items a through n)	Vienna PCE Superfund Site FS by CDM (also SVE well installation, sparge well installation, blower and control panel were checked in Means CostWorks Version 11.0 release update 2008 Cost Data)
Low Concentration Groundwater	
Well 12A Stripping Towers O&M	Estimate based on incurred costs received from Tacoma Water on October 14, 2008

Cost Estimate for Alternative FC2
Filter Cake and Shallow Impacted Soil
Institutional Controls

Item	Quantity	Unit Cost	Units	Capital Cost	O&M Cost	
					Annual	Present Worth
(1) Institutional Controls						
(a) Deed restrictions	1	$20,000	LS	$20,000		
(b) 5-year review (every 5 years for 30 years)	1	$20,000	LS		$30,000	$64,740
Subtotal (1)					$30,000	$64,740
CONSTRUCTION SUBTOTAL				$20,000		
Contractor Submittals, H&S, and Construction QA/QC	2% of Construction Subtotal*			$400		
Contractor Overhead	2% of Construction Subtotal*			$400		
Contractor Profit	4% of Construction Subtotal*			$800		
Contingency	40% of Construction Subtotal			$8,000		
CONSTRUCTION TOTAL				$29,600		
Project Management	1% of Construction Total*			$296		
Engineering	1.5% of Construction Total*			$444		
Services During Construction	1% of Construction Total*			$296		
TOTAL CAPITAL COSTS				$30,636		
OPERATION & MAINTENANCE SUBTOTAL					$30,000	$64,740
O&M Project Management and Support	5% of O&M Subtotal				$1,500	$3,237
O&M Contingency	25% of O&M Subtotal				$7,500	$16,185
TOTAL ESTIMATED COSTS				$30,636	$39,000	$84,162
NET PRESENT WORTH				$114,798		

* This percentage rate is lower than some other alternatives to more accurately reflect the costs that are estimated for the type of services associated with this alternative.

Cost Estimate for Alternative FC3
Filter Cake and Shallow Impacted Soil
Placing Asphalt Cap

Item	Quantity	Unit Cost	Units	Capital Cost	O&M Cost Annual	O&M Cost Present Worth
(1) Placing asphalt cap						
(a) Mobilization	1	$90,000	LS	$90,000		
(b) Crushed stone base course	11,350	$12	SF	$136,768		
(c) Bituminous concrete base course	230	$59	TON	$13,570		
(d) Wear course	115	$65	TON	$7,475		
(e) Vibratory roller	2	$672	WK	$1,344		
(f) Asphalt transport (in truck deliveries)	20	$330	TRK	$6,600		
(g) Health and safety	1	$50,000	LS	$50,000		
(h) Erosion control	1	$5,000	LS	$5,000		
Subtotal (1)				$310,757		
(2) Long-term Monitoring (30 years)						
(a) Develop Sampling Plan	1	$15,000	LS	$15,000		
(b) Annual Sampling (4 wells)						
(1) sample collection	1	$6,000	event		$6,000	$74,454
(2) sample analysis	4	$500	EA		$2,000	$24,818
Subtotal (2)				$15,000	$8,000	$99,272
(3) O&M of Cap (one event every 5 years for 30 years)					$5,000	$10,790
(4) Reporting						
(a) Review data and prepare annual reports	1	$15,000	LS		$15,000	$186,136
(b) 5-year review (every 5 years for 30 years)	1	$30,000	LS		$30,000	$64,740
Subtotal (3)					$50,000	$261,666
CONSTRUCTION SUBTOTAL				$325,757		
Contractor Submittals, H&S, and Construction QA/QC	10% of Construction Subtotal			$32,576		
Contractor Overhead	15% of Construction Subtotal			$48,863		
Contractor Profit	10% of Construction Subtotal			$32,576		
Contingency	40% of Construction Subtotal			$130,303		
CONSTRUCTION TOTAL				$570,074		
Project Management	10% of Construction Total			$57,007		
Engineering	15% of Construction Total			$85,511		
Services During Construction	15% of Construction Total			$85,511		
TOTAL CAPITAL COSTS				$798,103		
OPERATION & MAINTENANCE SUBTOTAL					$58,000	$360,938

Cost Estimate for Alternative FC3
Filter Cake and Shallow Impacted Soil
Placing Asphalt Cap

Item	Quantity	Unit Cost	Units	Capital Cost	O&M Cost	
					Annual	Present Worth
O&M Project Management and Support	5% of O&M Subtotal				$2,900	$18,047
O&M Contingency	25% of O&M Subtotal				$14,500	$90,234
TOTAL ESTIMATED COSTS				$798,103	$75,400	$469,219
NET PRESENT WORTH				$1,267,323		

Cost Estimate for Alternative FC4
Filter Cake and Shallow Impacted Soil
Excavation and Offsite Disposal

Item	Quantity	Unit Cost	Units	Capital Cost	O&M Cost	
					Annual	Present Worth
(1) Excavation						
(a) Mobilization	1	$90,000	LS	$90,000		
(b) Excavation	4,200	$2	BCY	$8,400		
(c) Borrow material transportation	5,250	$13	ECY	$68,250		
(d) Backfill excavation	5,250	$34	ECY	$178,500		
(e) Base course to 6 in deep	11,350	$12	SF	$136,768		
(f) 2A gravel furnish and deliver	400	$10	TON	$4,040		
(g) Health and safety	1	$50,000	LS	$50,000		
(h) Offsite disposal at Subtitle D landfill (in truck deliveries)	360	$330	TRK	$118,800		
(i) Transportation of material to disposal	6,400	$45	TON	$288,000		
Subtotal (1)				$942,758		
(2) Long-term Monitoring (30 years)						
(a) Develop Sampling Plan	1	$15,000	LS	$15,000		
(b) Annual Sampling (4 wells)						
(1) sample collection	1	$6,000	event		$6,000	$74,454
(2) sample analysis	4	$500	EA		$2,000	$24,818
Subtotal (2)				$15,000	$8,000	$99,272
(3) Reporting						
(a) Review data and prepare annual reports	1	$15,000	LS		$15,000	$186,136
(b) 5-year review (every 5 years for 30 years)	1	$30,000	LS		$30,000	$64,740
Subtotal (3)					$45,000	$250,876
CONSTRUCTION SUBTOTAL				$957,758		
Contractor Submittals, H&S, and Construction QA/QC	10% of Construction Subtotal			$95,776		
Contractor Overhead	15% of Construction Subtotal			$143,664		
Contractor Profit	10% of Construction Subtotal			$95,776		
Contingency	40% of Construction Subtotal			$383,103		
CONSTRUCTION TOTAL				$1,676,076		
Project Management	10% of Construction Total*			$167,608		
Engineering	15% of Construction Total*			$251,411		
Services During Construction	15% of Construction Total*			$251,411		
TOTAL CAPITAL COSTS				$2,346,506		
OPERATION & MAINTENANCE SUBTOTAL					$53,000	$350,148

Cost Estimate for Alternative FC4
Filter Cake and Shallow Impacted Soil
Excavation and Offsite Disposal

Item	Quantity	Unit Cost	Units	Capital Cost	O&M Cost	
					Annual	Present Worth
O&M Project Management and Support	5% of O&M Subtotal				$2,650	$17,507
O&M Contingency	25% of O&M Subtotal				$13,250	$87,537
TOTAL ESTIMATED COSTS				$2,346,506	$68,900	$455,192
NET PRESENT WORTH				$2,801,698		

Cost Estimate for Alternative SG2

Deep Vadose Soil and Upper Saturated Soil East of Time Oil Building

Institutional Controls

Item	Quantity	Unit Cost	Units	Capital Cost	O&M Cost Annual	O&M Cost Present Worth
(1) Institutional Controls						
(a) Deed restrictions	1	$20,000	LS	$20,000		
(b) 5-year review (every 5 years for 30 years)	1	$30,000	LS		$30,000	$64,740
Subtotal (1)					$30,000	$64,740
CONSTRUCTION SUBTOTAL				$20,000		
Contractor Submittals, H&S, and Construction QA/QC	2% of Construction Subtotal*			$400		
Contractor Overhead	2% of Construction Subtotal*			$400		
Contractor Profit	4% of Construction Subtotal*			$800		
Contingency	40% of Construction Subtotal			$8,000		
CONSTRUCTION TOTAL				$29,600		
Project Management	1% of Construction Total*			$296		
Engineering	1.5% of Construction Total*			$444		
Services During Construction	1% of Construction Total*			$296		
TOTAL CAPITAL COSTS				$30,636		
OPERATION & MAINTENANCE SUBTOTAL					$30,000	$64,740
O&M Project Management and Support	5% of O&M Subtotal				$1,500	$3,237
O&M Contingency	25% of O&M Subtotal				$7,500	$16,185
TOTAL ESTIMATED COSTS				$30,636	$39,000	$84,162
NET PRESENT WORTH				$114,798		

* This percentage rate is lower than some other alternatives to more accurately reflect the costs that are estimated for the type of services associated with this alternative.

Cost Estimate for Alternative SG3
Deep Vadose Soil and Upper Saturated Soil East of Time Oil Building
Insitu Thermal Remediation

Item	Quantity	Unit Cost	Units	Capital Cost	O&M Cost	
					Annual	Present Worth
(1) Insitu Thermal Remediation						
(a) Mobilization	1	$381,000	LS	$381,000		
(b) Design, work plans, permits	1	$80,000	LS	$80,000		
(c) Subsurface Installation	1	$169,000	LS	$169,000		
(d) Surface Installation and Startup	1	$304,000	LS	$304,000		
(e) Remediation System Operation	1	$472,000	LS	$472,000		
(f) Trenching and Restoration (50% below grade):	1	$43,000	LS	$43,000		
(g) Drilling and Soil Sampling:	1	$304,000	LS	$304,000		
(h) Drill Cuttings and Waste Disposal:	1	$35,000	LS	$35,000		
(i) Electrical Utility Connection to PCU:	1	$30,000	LS	$30,000		
(j) Electrical Energy Usage:	1	$294,000	LS	$294,000		
(k) Carbon Usage, Transportation & Regeneration:	1	$13,000	LS	$13,000		
(l) Water/Condensate Disposal:	1	$1,000	LS	$1,000		
(m) Other Operational Costs:	1	$22,000	LS	$22,000		
(n) Demobilization and final report	1	$94,000	LS	$94,000		
Subtotal (1)				$2,242,000		
(2) Long-term Groundwater Monitoring						
(a) Develop Sampling Plan	1	$20,000	LS	$20,000		
(b) Annual Sampling (10 wells, years 1 through 6)						
(1) sample collection	1	$10,000	event		$10,000	$47,665
(2) sample analysis	10	$500	EA		$5,000	$23,833
Subtotal (2)				$20,000	$15,000	$71,498
(3) Reporting						
(a) Review data and prepare annual reports	1	$20,000	LS		$20,000	$248,181
(b) 5-year review (every 5 years for 30 years)	1	$50,000	LS		$50,000	$107,891
Subtotal (3)					$70,000	$356,072
CONSTRUCTION SUBTOTAL				$2,262,000		

Cost Estimate for Alternative SG3
Deep Vadose Soil and Upper Saturated Soil East of Time Oil Building
Insitu Thermal Remediation

Item	Quantity	Unit Cost	Units	Capital Cost	O&M Cost	
					Annual	Present Worth
Contractor Submittals, H&S, and Construction QA/QC	1% of Construction Subtotal*			$22,620		
Contractor Overhead	1.5% of Construction Subtotal*			$33,930		
Contractor Profit	1% of Construction Subtotal*			$22,620		
Contingency	40% of Construction Subtotal			$904,800		
CONSTRUCTION TOTAL				$3,245,970		
Project Management	10% of Construction Total			$324,597		
Engineering	1.5% of Construction Total*			$48,690		
Services During Construction	15% of Construction Total			$486,896		
TOTAL CAPITAL COSTS				$4,106,152		
OPERATION & MAINTENANCE SUBTOTAL					$85,000	$427,570
O&M Project Management and Support	5% of O&M Subtotal				$4,250	$21,378
O&M Contingency	25% of O&M Subtotal				$21,250	$106,892
TOTAL ESTIMATED COSTS				$4,106,152	$110,500	$555,841
NET PRESENT WORTH				$4,661,993		

* Items are less than typical, since costs are included with contractor estimate which is in Subtotal (1)

Cost estimate is based on the electrical resistance heating method

Cost Estimate for Alternative HG2
High Concentration Groundwater
Institutional Controls

Item	Quantity	Unit Cost	Units	Capital Cost	O&M Cost	
					Annual	Present Worth
(1) Institutional Controls						
(a) Deed restrictions	1	$40,000	LS	$40,000		
(b) 5-year review (every 5 years for 30 years)	1	$40,000	LS		$40,000	$86,320
Subtotal (1)					$40,000	$86,320
CONSTRUCTION SUBTOTAL				$40,000		
Contractor Submittals, H&S, and Construction QA/QC	2% of Construction Subtotal*			$800		
Contractor Overhead	2% of Construction Subtotal*			$800		
Contractor Profit	4% of Construction Subtotal*			$1,600		
Contingency	40% of Construction Subtotal			$16,000		
CONSTRUCTION TOTAL				$59,200		
Project Management	1% of Construction Total*			$592		
Engineering	1.5% of Construction Total*			$888		
Services During Construction	1% of Construction Total*			$592		
TOTAL CAPITAL COSTS				$61,272		
OPERATION & MAINTENANCE SUBTOTAL					$40,000	$86,320
O&M Project Management and Support	5% of O&M Subtotal				$2,000	$4,316
O&M Contingency	25% of O&M Subtotal				$10,000	$21,580
TOTAL ESTIMATED COSTS				$61,272	$52,000	$112,216
NET PRESENT WORTH				$173,488		

* This percentage rate is lower than some other alternatives to more accurately reflect the costs that are estimated for the type of services associated with this alternative.

Cost Estimate for Alternative HG3

High Concentration Groundwater

Groundwater Extraction and Treatment System Operation and Maintenance

Item	Quantity	Unit Cost	Units	Capital Cost	O&M Cost Annual	O&M Cost Present Worth
(1) Groundwater Extraction and Treatment O&M (30 years)						
(a) Carbon changes	3	$42,000	YR		$126,000	$1,563,539
(b) Supplies and repairs	1	$5,000	YR		$5,000	$62,045
(c) Utilities	1	$10,000	YR		$10,000	$124,090
(d) Labor	1	$45,000	YR		$45,000	$558,407
Subtotal (1)					$186,000	$2,308,082
(2) Long-term Groundwater Monitoring						
(a) Develop Sampling Plan	1	$20,000	LS	$20,000		
(b) Annual Sampling (10 wells)						
(1) sample collection	1	$10,000	event		$10,000	$124,090
(2) sample analysis	10	$500	EA		$5,000	$62,045
Subtotal (2)				$20,000	$15,000	$186,136
(3) Reporting						
(a) Review data and prepare annual reports	1	$20,000	LS		$20,000	$248,181
(b) 5-year review (every 5 years for 30 years)	1	$40,000	LS		$40,000	$86,320
Subtotal (3)					$60,000	$334,501
CONSTRUCTION SUBTOTAL				$20,000		
Contractor Submittals, H&S, and Construction QA/QC	2% of Construction Subtotal*			$400		
Contractor Overhead	2% of Construction Subtotal*			$400		
Contractor Profit	4% of Construction Subtotal*			$800		
Contingency	40% of Construction Subtotal			$8,000		
CONSTRUCTION TOTAL				$29,600		
Project Management	1% of Construction Total*			$296		
Engineering	1.5% of Construction Total*			$444		
Services During Construction	1% of Construction Total*			$296		
TOTAL CAPITAL COSTS				$30,636		

High Concentration Groundwater

Groundwater Extraction and Treatment System Operation and Maintenance

Item	Quantity	Unit Cost	Units	Capital Cost	O&M Cost	
					Annual	Present Worth
OPERATION & MAINTENANCE SUBTOTAL					$261,000	$2,828,718
O&M Project Management and Support	5% of O&M Subtotal				$13,050	$141,436
O&M Contingency	25% of O&M Subtotal				$65,250	$707,180
TOTAL ESTIMATED COSTS				$30,636	$339,300	$3,677,334
NET PRESENT WORTH				$3,707,970		

* This percentage rate is lower than some other alternatives to more accurately reflect the costs that are estimated for the type of services associated with this alternative.

Cost Estimate for Alternative HG4
High Concentration Groundwater
Enhanced Anaerobic Bioremediation

Item	Quantity	Unit Cost	Units	Capital Cost	O&M Cost Annual	O&M Cost Present Worth
(1) Enhanced Anaerobic Bioremediation						
(a) Mobilization	1	$50,000	LS	$50,000		
(b) Injection Well Installation	34	$7,980	EA	$271,320		
(c) MW Installation	8	$14,110	EA	$112,880		
(d) Amendment Injection (2 rounds)	2	$395,580	RD	$791,160		
(e) Pilot-scale treatability test	1	$50,000	LS	$50,000		
(f) Confirmation Sampling (pre-, and 8 qtrly events)						
(1) sample collection	9	$25,000	event	$225,000		
(2) sample analysis (10 monitoring wells)	90	$800	sample	$72,000		
Subtotal (1)				$1,572,360		
(2) Mass Flux Measurement (5 events at 12 wells over 6 years)						
(a) Flux work plan development	1	$10,000	LS	$10,000		
(a) Flux device installation/removal	1	$8,000	EA		$8,000	$38,132
(b) Sample analysis	12	$1,000	EA		$12,000	$57,198
Subtotal (2)				$10,000	$20,000	$95,331
(3) Groundwater Extraction and Treatment O&M (5 years)	1	$209,000	YR		$209,000	$856,941
Subtotal (3)					$209,000	$856,941
(4) Long-term Groundwater Monitoring						
(a) Develop Sampling Plan	1	$20,000	LS	$20,000		
(b) Annual Sampling (10 wells, years 1 through 6)						
(1) sample collection	1	$10,000	event		$10,000	$47,665
(2) sample analysis	10	$500	EA		$5,000	$23,833
Subtotal (4)				$20,000	$15,000	$71,498
(5) Reporting						
(a) Review data and prepare annual reports	1	$20,000	LS		$20,000	$248,181
(b) 5-year review (every 5 years for 30 years)	1	$50,000	LS		$50,000	$107,891
Subtotal (5)					$70,000	$356,072
CONSTRUCTION SUBTOTAL				$1,582,360		

Cost Estimate for Alternative HG4

High Concentration Groundwater

Enhanced Anaerobic Bioremediation

Item	Quantity	Unit Cost	Units	Capital Cost	O&M Cost	
					Annual	Present Worth
Contractor Submittals, H&S, and Construction QA/QC	2% of Construction Subtotal*			$31,647		
Contractor Overhead	2% of Construction Subtotal*			$31,647		
Contractor Profit	4% of Construction Subtotal*			$63,294		
Contingency	40% of Construction Subtotal			$632,944		
CONSTRUCTION TOTAL				$2,341,893		
Project Management	1% of Construction Total*			$23,419		
Engineering	1.5% of Construction Total*			$35,128		
Services During Construction	1% of Construction Total*			$23,419		
TOTAL CAPITAL COSTS				$2,423,859		
OPERATION & MAINTENANCE SUBTOTAL					$314,000	$1,379,842
O&M Project Management and Support	5% of O&M Subtotal				$15,700	$68,992
O&M Contingency	25% of O&M Subtotal				$78,500	$344,960
TOTAL ESTIMATED COSTS				$2,423,859	$408,200	$1,793,795
NET PRESENT WORTH				$4,217,654		

* This percentage rate is lower than some other alternatives to more accurately reflect the costs that are estimated for the type of services associated with this alternative.

Cost Estimate for Alternative HG5
High Concentration Groundwater
Enhanced Anaerobic Bioremediation with Air Sparging and Soil Vapor Extraction

Item	Quantity	Unit Cost	Units	Capital Cost	O&M Cost Annual	O&M Cost Present Worth
(1) Enhanced Anaerobic Bioremediation						
(a) Mobilization	1	$50,000	LS	$50,000		
(b) Injection Well Installation	28	$7,980	EA	$223,440		
(c) MW Installation	8	$14,110	EA	$112,880		
(d) Amendment Injection (2 rounds)	2	$336,243	RD	$672,486		
(e) Pilot-scale treatability test	1	$50,000	LS	$50,000		
(f) Confirmation Sampling (pre-, and 8 qtrly events)						
(1) sample collection	9	$25,000	event	$225,000		
(2) sample analysis (10 monitoring wells)	90	$800	sample	$72,000		
Subtotal (1)				$1,405,806		
(2) In Situ Air Sparging and Soil Vapor Extraction System Installation and 4 years of Operation						
(a) Mobilization	1	$50,000	LS	$50,000		
(b) Air sparging well installation	5	$18,110	EA	$90,550		
(c) Soil Vapor Extraction Well installation	10	$4,000	EA	$40,000		
(d) Site Services	4	$50,000	MO	$200,000		
(e) Pilot Testing	1	$100,000	LS	$100,000		
(f) Piping to Each Air Sparging/SVE Point	1,000	$50	LF	$50,000		
(g) Building for Air Sparging/SVE Air Handling System	5,000	$25	SF	$125,000		
(h) Air Blower	2	$4,100	EA	$8,200		
(i) Control Panel	1	$5,000	EA	$5,000		
(j) Gas Phase Carbon Adsorption	2	$12,000	EA	$24,000		
(k) Installation and Incidentals (piping, electrical)	1.0	$37,200	EA	$37,200		
(l) Treatment System Operator (20 hours/week)	1,040	$50	HR		$52,000	$176,135
(m) Carbon Media Replacement	1,000	$3	LB		$3,300	$11,178
(n) Utilities and Maintenance	1	$50,000	YR		$50,000	$169,361
Subtotal (2)				$729,950	$105,300	$356,673
(3) Mass Flux Measurement (5 events at 12 wells over 6 years)						
(a) Flux work plan development	1	$10,000	LS	$10,000		
(a) Flux device installation/removal	1	$8,000	EA		$8,000	$38,132
(b) Sample analysis	12	$1,000	EA		$12,000	$57,198
Subtotal (3)				$10,000	$20,000	$95,331

Cost Estimate for Alternative HG5
High Concentration Groundwater
Enhanced Anaerobic Bioremediation with Air Sparging and Soil Vapor Extraction

Item	Quantity	Unit Cost	Units	Capital Cost	O&M Cost Annual	O&M Cost Present Worth
(4) Groundwater Extraction and Treatment O&M (5 years)	1	$209,000	YR		$209,000	$856,941
Subtotal (4)					$209,000	$856,941
(5) Long-term Groundwater Monitoring						
(a) Develop Sampling Plan	1	$20,000	LS	$20,000		
(b) Annual Sampling (10 wells, years 1 through 6)						
(1) sample collection	1	$10,000	event		$10,000	$47,665
(2) sample analysis	10	$500	EA		$5,000	$23,833
Subtotal (5)				$20,000	$15,000	$71,498
(6) Reporting						
(a) Review data and prepare annual reports	1	$20,000	LS		$20,000	$248,181
(b) 5-year review (every 5 years for 30 years)	1	$50,000	LS		$50,000	$107,891
Subtotal (6)					$70,000	$356,072
CONSTRUCTION SUBTOTAL				$1,415,806		
Contractor Submittals, H&S, and Construction QA/QC	10% of Construction Subtotal			$141,581		
Contractor Overhead	15% of Construction Subtotal			$212,371		
Contractor Profit	10% of Construction Subtotal			$141,581		
Contingency	40% of Construction Subtotal			$566,322		
CONSTRUCTION TOTAL				$2,477,661		
Project Management	10% of Construction Total			$247,766		
Engineering	15% of Construction Total			$371,649		
Services During Construction	10% of Construction Total			$247,766		
TOTAL CAPITAL COSTS				$3,344,842		
OPERATION & MAINTENANCE SUBTOTAL					$419,300	$1,485,142
O&M Project Management and Support	5% of O&M Subtotal				$20,965	$74,257
O&M Contingency	25% of O&M Subtotal				$104,825	$371,285
TOTAL ESTIMATED COSTS				$3,344,842	$545,090	$1,930,685
NET PRESENT WORTH				$5,275,526		

Cost Estimate for Alternative LG2
Low Concentration Groundwater
Well12A Treatment Operation and Maintenance

Item	Quantity	Unit Cost	Units	Capital Cost	O&M Cost	
					Annual	Present Worth
(1) Well 12A Air Stripping Towers O&M (30 years)						
(a) Supplies	1	$500	YR		$500	$6,205
(b) Utilities	1	$20,000	YR		$20,000	$248,181
(c) Labor	1	$2,500	YR		$2,500	$31,023
Subtotal (1)					$23,000	$285,408
(2) Long-term Groundwater Monitoring						
(a) Develop Sampling Plan	1	$20,000	LS	$20,000		
(b) Annual Sampling (4 wells)						
(1) sample collection	1	$8,000	event		$8,000	$99,272
(2) sample analysis	4	$500	EA		$2,000	$24,818
Subtotal (2)				$20,000	$10,000	$124,090
(3) Reporting						
(a) Review data and prepare annual reports	1	$20,000	LS		$20,000	$248,181
(b) 5-year review (every 5 years for 30 years)	1	$40,000	LS		$40,000	$86,320
Subtotal (3)					$60,000	$334,501
CONSTRUCTION SUBTOTAL				$20,000		
Contractor Submittals, H&S, and Construction QA/QC	2% of Construction Subtotal*			$400		
Contractor Overhead	2% of Construction Subtotal*			$400		
Contractor Profit	4% of Construction Subtotal*			$800		
Contingency	40% of Construction Subtotal			$8,000		
CONSTRUCTION TOTAL				$29,600		
Project Management	1% of Construction Total*			$296		
Engineering	1.5% of Construction Total*			$444		
Services During Construction	1% of Construction Total*			$296		
TOTAL CAPITAL COSTS				$30,636		

Low Concentration Groundwater

Well12A Treatment Operation and Maintenance

Item	Quantity	Unit Cost	Units	Capital Cost	O&M Cost Annual	O&M Cost Present Worth
OPERATION & MAINTENANCE SUBTOTAL					$93,000	$743,999
O&M Project Management and Support	5% of O&M Subtotal				$4,650	$37,200
O&M Contingency	25% of O&M Subtotal				$23,250	$186,000
TOTAL ESTIMATED COSTS				$30,636	$120,900	$967,199
NET PRESENT WORTH				$997,835		

* This percentage rate is lower than some other alternatives to more accurately reflect the costs that are estimated for the type of services associated with this alternative.

Cost Estimate for Alternative LG2
Low Concentration Groundwater
Long Term Plume Monitoring Component

Item	Quantity	Unit Cost	Units	Capital Cost	O&M Cost Annual	O&M Cost Present Worth
(1) Compliance Well Installation (4 Wells)						
(a) Mobilization	1	$10,000	LS	$10,000		
(b) MW Installation	4	$18,000	EA	$72,000		
(c) IDW Management	1	$30,000	LS	$30,000		
Subtotal (1)				$112,000		
(2) Long-term Groundwater Monitoring						
(a) Develop Sampling Plan	1	$20,000	LS	$20,000		
(b) Annually (20 wells, years 1 through 30)						
(1) sample collection (assume existing wells will be used)	1	$10,000	event		$10,000	$124,090
(2) sample analysis	20	$500	EA		$10,000	$124,090
Subtotal (2)				$20,000	$20,000	$248,181
(3) Institutional Controls						
(a) Deed Restrictions	1	$25,000	LS	$25,000		
(b) Review Data and Prepare Reports (annually)	1	$20,000	EA		$20,000	$248,181
(c) 5-Year Review Reporting (every 5 years for 30 years)	1	$50,000	LS		$50,000	$107,891
Subtotal (3)				$25,000	$70,000	$356,072
CONSTRUCTION SUBTOTAL				$157,000	$90,000	
Contractor Submittals and H&S (included above)	0% of Construction Subtotal*			$0		
Contractor Overhead	15% of Construction Subtotal			$23,550		
Contractor Profit	10% of Construction Subtotal			$15,700		
Contingency	40% of Construction Subtotal			$62,800		
CONSTRUCTION TOTAL				$259,050		
Project Management	10% of Construction Total			$25,905		
Engineering	5% of Construction Total*			$12,953		
Services During Construction	5% of Construction Total*			$12,953		
TOTAL CAPITAL COSTS				$310,860		
OPERATION & MAINTENANCE SUBTOTAL					$110,000	$604,252
O&M Project Management and Support	5% of O & M Subtotal				$5,500	$30,213
O&M Contingency	25% of O & M Subtotal				$27,500	$151,063
TOTAL ESTIMATED COSTS				$310,860	$143,000	$785,528

NET PRESENT WORTH	$1,096,388

* This percentage rate is lower than some other alternatives to more accurately reflect the costs that are estimated for the type of services associated with this alternative.
The monitoring costs on this sheet are for the aquifer which supplies water to Well12A. Additional long term costs are presented in Item 2 of Well12A Treatment Operation and Maintenance, which are costs for monitoring at Well12A.