Feasibility Study Report
Frank Wear
Yakima, Washington

Prepared for
Washington State Department of Ecology

July 31, 2007
17330-08

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ACRONYMS

AOC	area of concern
bgs	below ground surface
cm/s	centimeters per second
COC	contaminant of concern
CUL	cleanup level
CWCMH	Central Washington Comprehensive Mental Health
DCE	1,2-dichloroethene
DNAPL	dense non-aqueous-phase liquid
Ecology	Washington State Department of Ecology
FS	feasibility study
gpm	gallons per minute
mg/kg	milligrams per kilogram
MTCA	Model Toxics Control Act
PCE	perchloroethylene (tetrachloroethene)
ppb	parts per billion
PRB	permeable reactive barrier
RI	remedial investigation
site	Frank Wear site
TCE	trichloroethene
TPH	total petroleum hydrocarbons
µg/L	micrograms per liter
UST	underground storage tank
VOC	volatile organic compound
WAC	Washington Administrative Code
ZVI	zero-valent iron

FEASIBILITY STUDY FINAL REPORT
FRANK WEAR SITE
YAKIMA, WASHINGTON

1.0 INTRODUCTION

This document presents a Feasibility Study (FS) for the Frank Wear site (site) in Yakima, Washington. This FS was prepared for the Washington State Department of Ecology (Ecology) Toxics Cleanup Program, under Work Assignment Number HART 008 of the Hazardous Site Investigation/Remediation Contract C0700035.

1.1 Purpose

The purpose of this FS is to develop and evaluate various cleanup action alternatives that would reduce or mitigate current and potential future risks to human health and the environment associated with contamination in soil and groundwater at the site. This FS will assist Ecology in selecting the most appropriate cleanup action to be implemented at the site.

1.2 Scope of Work

The scope of work for this FS involved identifying, evaluating, and recommending an appropriate remedial action for the area of concern (AOC) that would meet the Model Toxics Control Act (MTCA) requirements specified in the Washington Administrative Code (WAC) 173-340-350(8). Specific tasks for this FS included:

- Reviewing existing site information to assess current soil and groundwater conditions, interim actions completed at the site, and potential exposure pathways; and to identify the AOC(s) for remediation;
- Developing remedial action objectives and remediation goals based on the Method B cleanup levels established for the site by Ecology;
- Developing cleanup alternatives for the AOC, including containment with groundwater treatment, *in situ* treatment, and source control and treatment, in accordance with the FS Scope of Work (Ecology 2007a);
- Evaluating alternatives using the criteria specified in WAC 173-340-360; and
- Recommending a cleanup alternative for the AOC.

This FS Report includes a general description of the site, its location, history, and previous investigations in Section 2.0; cleanup objectives and remediation goals in Section 3.0; detailed description of the alternatives in Section 4.0; evaluation of the alternatives in Section 5.0; description of a preferred alternative in Section 6.0; and references in Section 7.0. Supporting information is provided in the tables, figures, and appendices at the end of the report.

The detailed description of alternatives in Section 4.0 includes equipment, infrastructure, and implementation until cleanup levels are achieved. Monitoring requirements for each alternative are also included. The evaluation of alternatives in Section 5.0 includes an evaluation of long-term effectiveness of three alternatives and their subparts, with an estimate of restoration time frames. A detailed cost analysis for each of the three alternatives and respective subparts is also provided in Appendix A.

1.3 Limitations

The work performed by Hart Crowser was completed in accordance with generally accepted professional practices related to the nature of the work accomplished, in the same or similar localities, at the time the services were performed. This report is for the specific application to the referenced project and for the exclusive use of Ecology. No other warranty, express or implied, is made.

2.0 SITE BACKGROUND

This section presents background information on the site, including the location, operational history, hydrogeology, and previous environmental investigations and interim actions completed at the site. Existing data were evaluated to identify contaminants and/or hazards posing unacceptable risks to human health or the environment and to identify the AOC(s) for remediation.

2.1 Site Location and Description

The site consists of a 0.16-acre vacant lot at 106 South Third Avenue in Yakima, Washington. The site is situated within the northeast quarter of the southeast quarter of Section 24, Township 13 North, and Range 18 East of the Willamette Meridian, Yakima County, Washington. Figure 1 shows the location of the site. The site is surrounded by a fenced asphalt parking lot to the north; South Third Avenue to the east; a children's bookstore to the south; and an alley to the west. South of the children's bookstore is a former boat dealership property, now occupied by the Central Washington Comprehensive Mental Health facility (CWCMH), which extends south to West Walnut Street. Figure 2 provides a Site Plan view of the current site layout and adjacent properties.

The site formerly consisted of a retail dry cleaning facility, operated by Frank Wear Cleaners. During the period of operation, the facility included a dry cleaning building with an attached boiler room, a gravel parking lot on the west portion of the property, a paved parking lot on the north portion of the property, and a detached equipment storage shed located along the western property boundary adjacent to the alley. Figure 2 shows the locations of the former structures that were in use during the active operations of the dry cleaner. The dry cleaning building was removed in 2000, as a part of an interim action performed at the site. The site is currently vacant except for existing monitoring wells.

The Frank Wear site is part of the larger Yakima Railroad Area (YRRA), a study area established by Ecology to investigate area-wide groundwater contamination. The YRRA consists of 6 square miles of numerous contaminated small sites with commingled perchloroethylene (PCE) plumes centered along the Burlington Northern-Santa Fe Railroad.

2.2 Site History

The Frank Wear site was a dry cleaning business from the early 1940s to 2000. The use of the site prior to 1940 is unknown. The business was owned and operated by the Frank Wear family from the early 1940s to 1980. The dry cleaning operations primarily used Stoddard solvent as the dry cleaning fluid (URS 1994). However, sometime during the 1970s, the business began using PCE as the dry cleaning solvent (Agra 1994). Spent PCE from the dry cleaning operations was reclaimed using a distillation unit. Sludges or still bottoms from this reclamation process were reportedly deposited on the property for dust abatement (Agra 1994). The waste management practices during the period when Stoddard solvent was in use are not known (URS 1994).

From 1980 to 1990 the business was owned and operated by Gregory Stoffers, and PCE was the primary dry cleaning solvent used at the facility. Up until 1985, sludges or still bottoms were removed from the distillation unit and disposed onto the gravel parking area west of the building (URS 1994). From 1985 to 1990, the sludges were transported to a permitted off-site recycling facility by Safety Kleen. Overflow from the dry cleaning machine was also periodically discharged to a catch basin or overflow tray located outside the southwest corner of the building. Occasionally, the catch basin would overflow, potentially causing spills of the PCE-contaminated liquids to the ground surface (Agra 1994). Leaks and spills from the dry cleaning machines and associated equipment would have collected in the numerous floor drains and sumps within the building; these floor drains may have carried PCE-contaminated wastewaters out to the west end of the building.

Previous operations also included the use of two underground storage tanks (USTs); a 500-gallon tank for gasoline and a 1,000-gallon tank for heating oil. The USTs were reportedly removed in 1989 by the property owner (Maxim 1996).

2.3 Site Geology and Hydrogeology

The annual precipitation in the Yakima area averages about 7 to 9 inches. The nearest surface water is the southeasterly flowing Yakima River, located approximately 1 mile east of the site. The Naches River is approximately 1.5 miles to the north of the site.

The topography at the site is generally flat, with elevations ranging between 1,060 and 1,065 feet above mean sea level. The site's geology and shallow upper aquifer consist of unconsolidated alluvium, primarily coarse-grained sands, gravels, and cobbles with occasional interbedded lenses of clay and silt. This alluvium extends from approximately 10 feet to 23 feet below ground surface (bgs) and is representative of the alluvium that blankets most of the Yakima Valley floor (URS 1994). Below this material is the Ellensburg Formation, which consists of similar materials that have been semi-consolidated. The Ellensburg Formation overlies basalt bedrock. The lower basalt aquifer ranges from 300 to 500 feet bgs in this region.

The regional, near-surface, alluvial aquifer is unconfined with depths to groundwater varying between 5 and 15 feet. Groundwater velocities at a nearby facility were estimated to be greater than 345 feet per year. For the regional YRRA, flow velocities were calculated to range from 6 to 12 feet per day (YRRA Work Plan). The regional groundwater flow direction is east toward the Yakima River.

Site groundwater elevations fluctuate seasonally as a result of localized recharge created from irrigation canals. During the winter months (January through March), the water table is typically present at a depth of about 20 to 25 bgs, and the groundwater flow direction is predominantly to the south. From the spring through autumn months, the water table is generally between 12 to 18 feet bgs, and the groundwater flow direction is to the east-southeast. Irrigation ditches throughout the Yakima area are charged in late March and are turned off in early October of each year. Leakages from the charged irrigation ditches have caused these large groundwater level fluctuations and the seasonal change in groundwater flow directions from generally south flowing in winter to east flowing in summer.

The groundwater gradients at the site based on monitoring results varied from 0.008 to 0.025 foot per foot with the steeper gradients occurring in the summer months, consistent with the localized recharge from the irrigation system.

Under natural conditions, groundwater discharges to the Yakima River, which is, at its closest, approximately 11,000 feet east of the site. As groundwater flows in an eastern direction during certain times of the year, this distance was chosen as the most conservative. Based on hydraulic conductivities estimated for other sites in the YRRA of 28 feet per day, a hydraulic gradient of 0.008 foot per foot, and a porosity of 0.35, the calculated groundwater travel time within the upper aquifer is about 240 feet per year. Therefore, it would take at least 47 years for groundwater from the Frank Wear site to reach the Yakima River. This is a rough approximation assuming an average distance to the river from the site as the groundwater flow direction varies throughout the year. Additionally, there is little information on whether utility corridors or irrigation lines in the area serve as preferential pathways or short circuits for impacted groundwater.

2.4 Previous Environmental Investigations and Interim Cleanup Actions

The Frank Wear site was first inspected in 1985 by Ecology as the result of a complaint regarding the disposal of the PCE-contaminated sludges in the back parking lot. Analytical results of soil and liquid samples collected from a surface puddle in the vicinity of the disposal area were not able to confirm the presence of PCE in soils at the site. Subsequent site inspections by Ecology in 1987 and 1989 confirmed the presence of PCE in the soil. The soil samples collected in 1989 were collected from the UST tank excavations up to 12 feet bgs and contained PCE concentrations to 10 milligrams per kilogram (mg/kg) (Agra 1994).

Frank Wear Cleaners was named a potentially liable party by Ecology for the YRRA in 1991. In 1994, Ecology and Frank Wear Cleaners signed an Agreed Order for a remedial investigation (RI). Subsequent remedial investigations and interim remedial measures pursuant to the Agreed Order are described below.

Soil Vapor Survey (1995). A soil vapor survey was performed at the Frank Wear site by Agra Earth and Environmental, Inc. (Agra) in January 1995 as part of the YRRA remedial investigations (Agra 1995). Twenty-five soil vapor samples were collected at the site; 9 samples from beneath the floor of the dry cleaning building at depths of approximately 3.5 feet below the concrete slab, and 16 samples from the parking area to the west of the building at depths of 4 to 7 feet bgs. PCE vapors were detected in all 25 samples at concentrations ranging from 7 to 727 micrograms per liter of air (parts per billion, ppb). Seventeen of the 25 samples had PCE vapor concentrations of less than 45 ppb. Only three samples had PCE vapor concentrations greater than 125 ppb. The distribution of the PCE vapor concentrations suggested two potential source areas: one beneath the northeast portion of the building along a plumbing access trench, and the other on the north end of the property near the former heating oil UST. Significant vapor concentrations did not appear to extend beyond the east, west, and south boundaries of the property, where PCE vapor concentrations were generally low (7 to 44 ppb).

Remedial Investigation and Interim Action Remediation (1995). A RI and interim actions were performed in 1995 on behalf of the facility owner by Huntingdon Engineering and Environmental, Inc., which was acquired by Maxim Technologies, Inc., that same year (Maxim 1996). The purpose of the RI was to characterize the nature and extent of the volatile organic compound (VOC) contamination in soil and groundwater at the site. The RI included the installation of soil test pits and strataprobes, sampling and analysis of soils, and the installation and sampling of four monitoring wells. The screen depths of the monitoring wells were completed from 10 to 35 feet bgs.

The soil characterization results showed elevated concentrations of PCE above the MTCA Method B groundwater protection cleanup level of 0.08 mg/kg in soils underneath the building, underneath the storage shed, and in the parking lot areas. The highest concentration of PCE of 1,260 mg/kg was in soils collected from the test pit near the west end of the building in the location of the former heating oil UST. This was the only area of the site where diesel-range total petroleum hydrocarbons (TPH) were detected in soils above the MTCA Method A cleanup level of 200 mg/kg.

Results of four quarters of groundwater monitoring during this RI indicated that PCE, trichloroethene (TCE), and 1,2-dichloroethene (DCE) were present above analytical method detection limits in the vicinity of the site. PCE was the predominant compound with detection in the samples from the four wells during all four quarters of monitoring. PCE concentrations ranged between 5 micrograms per liter (μg/L) and 1,140 μg/L, with the highest concentrations detected in monitoring well MW-1, located adjacent to the southeast corner of the building (see Figure 2). TCE and DCE were detected in all four wells in at least one of the quarterly monitoring events. TCE concentrations ranged from non-detect to 48.3 μg/L. DCE concentrations ranged from non-detect to 17.9 μg/L.

An evaluation of the quarterly monitoring data showed that VOC concentrations fluctuated dramatically over the year in all four wells, with ranges from 5 to over 1,000 μg/L in the same well. VOC concentrations in monitoring wells MW-2, MW-3, and MW-4 were greater when the groundwater flow direction was to the south. VOC concentrations in MW-1 were greater with groundwater flow direction to the east.

An interim remedial action was performed by Maxim Technologies in September 1995 and included the excavation of 610 tons of soil in the former heating oil UST area, where high concentrations of PCE and TPH-diesel were observed during the test pitting. The excavation included an area of approximately 35 feet by 70 feet with depths ranging from 3 to 12 feet bgs. The extent of the excavation was based on confirmation sampling results. During the excavation, a ruptured 4-inch wastewater sewer line was encountered at 7 to 9 feet bgs in the central portion of the site. This sewer line was believed to transport wastewater from the washing machine inside the building. A second sewer line along the northern boundary of the site was described as the primary sewer line.

The excavated soils were stockpiled and tested to determine disposal options. Approximately 310 tons of the excavated soils were transported off site for disposal at a permitted landfill, based on concentrations of PCE exceeding the MTCA Method B groundwater protection cleanup level. The concentrations of PCE in the remaining 300 tons of the excavated soil did not exceed the MTCA criteria and were deemed acceptable for placement back into the excavation. Approximately 300 tons of clean fill were imported and placed into the excavation to return the area to its previous grade.

Groundwater Interim Remedial Action (1997). In 1997, an interim action to address the elevated concentrations of PCE in groundwater was conducted on the site. Environmental Economic Solutions installed five, 4-inch-diameter PVC C-Sparge wells and a fifth 2-inch-diameter monitoring well to implement an ozone sparging system. The system operated intermittently during 1997 and 1998 with frequent shutdown periods due to mechanical problems. Because of the interruptions to continuous operation, the success of the sparging system was inconclusive. The results of groundwater monitoring performed during and after sparging indicated that PCE concentrations remained in excess of regulatory limits.

Soil Interim Remedial Action (2001). In 2000, the dry cleaner building was demolished. Subsequently, in 2001, as part of the interim remedial action, Fulcrum Environmental Consulting, Inc., removed the building's concrete floor, and sampled and excavated impacted soils that were beneath the concrete floor and in other areas of the site (Fulcrum 2001). Soil samples were collected from targeted areas of concern and analyzed for PCE. Soils that exceeded the YRRA soil cleanup levels for protection of groundwater were excavated and disposed off site. The extent of the excavations was determined by confirmation sampling. Depths of excavations ranged from 2 to 9 feet bgs. Approximately 432 tons of soil were excavated based on exceeding the YRRA soil cleanup levels. However, the PCE concentrations in these soils were determined to be below MTCA Method A cleanup levels and were approved for off-site disposal at an asphalt and gravel recycling facility. Clean fill was imported and used to fill the excavation back to its previous grade.

During the excavation, an abandoned 4-inch diameter sewer line was encountered in the central portion of the property at 4 feet bgs. A former drywell area on the western end of the property was also excavated during this remedial action. The drywell was reportedly used for managing stormwater runoff. A sump area in the former boiler room area was also excavated. No other USTs or related piping were identified during this interim remedial action.

2.5 Summary of Groundwater Monitoring Results

In addition to the four wells previously installed in 1995, five new 2-inch-diameter monitoring wells were installed and four of the five four-inch-diameter ozone-sparging wells were converted to monitoring wells in March 2005. The site's 14 wells have been sampled and analyzed quarterly since July 2005.

PCE concentrations up to 43,500 µg/L remain in the groundwater beneath the site and remain elevated downgradient from the site. Other VOCs of concern in the site's soil and groundwater include:

- Chloroform;
- Cis-1,2-dichlorothene;
- Trichloroethene;
- 1,1,1-Trichloroethane;
- 1,1,1,2-Tetrachloroethane;
- 1,2-Dichlorobenzene;
- Chlorobenzene;
- 1,2-Dichloroethane; and
- Trans-1,3-dichloropropene.

The highest concentrations of PCE in groundwater at the site were detected in MW-10, located within the footprint of the former dry cleaning building and adjacent to the children's bookstore building to the south. Groundwater samples from monitoring wells SPW-12, SPW-13, and SPW-15 consistently have high concentrations of PCE. Off-site monitoring well MW-3 along West Walnut Street, located south of the site, has recently had high concentrations of PCE in groundwater, greater than 1,500 µg/L, in the last two April quarterly monitoring events, when the groundwater flow direction was primarily to the south (Ecology 2007b). Recent groundwater monitoring results are shown on Figure 3.

3.0 CLEANUP LEVELS AND AREAS OF CONCERN

In this section, we define the basis by which the FS was conducted. This includes defining the cleanup levels for the site and the areas of concern for which the remedial alternatives will be applied.

3.1 Cleanup Levels

Cleanup levels (CULs) have been established for VOC contaminants of concern (COCs) in soils and groundwater at the site and are provided in Table 1. The CULs for the COCs are based on the MTCA Method B cleanup levels, with the exception of PCE, which is a site-specific level (Ecology 2007a). The areas of concern where soil and groundwater contaminants exceed these CULs are described in detail below.

3.2 Areas of Concern

3.2.1 Soil Areas of Concern

Soils that were sampled either through previous site characterization or post-excavation confirmation sampling have shown that there are presently no areas on the site where concentrations exceed the established CUL. However, based on the consistently high concentrations of PCE in groundwater in wells MW-10, SP-12, and SP-13, there is a possibility that high concentrations of PCE remain in the soil, either as residual contamination sorbed to the soil mass or as a dense, non-aqueous-phase liquid (DNAPL), acting as a continuing source of the PCE in groundwater in the vicinity of this well. For this FS, an alternative that addresses potential source area soils as an AOC was developed and evaluated.

3.2.2 Groundwater Areas of Concern

An evaluation of the recent groundwater monitoring data from April 2006 to April 2007 indicates that PCE concentrations have exceeded the CUL of 5.0 µg/L in at least one monitoring event in 13 of the site's 14 monitoring wells; MW-6 is the only monitoring well where PCE concentrations do not exceed the CUL. The groundwater plume as defined by the 5.0 µg/L CUL currently extends beyond the property boundaries to the east and south. The full extent of the plume beyond the current site monitoring well network is unknown and potentially influenced by contributions from other sites in the YRRA.

For purposes of this FS, the groundwater AOC targeted for remediation will be those areas where PCE concentrations are the highest and where remediation can more cost-effectively address contaminant mass. These areas include the

Frank Wear property, as well as the children's bookstore and the CWCMH properties to the south. The AOC is therefore, defined as the area from the northern edge of the Frank Wear property south to West Walnut Street, bounded by the alley to the west and South Third Avenue to the east. The total area occupied by the AOC is approximately 51,000 square feet. Of that total, the Frank Wear property occupies approximately 8,800 square feet.

The vertical extent of the contaminant plume has not been defined in previous investigations. Assuming an average thickness of the plume of 40 feet and a porosity of 0.35, the volume of impacted groundwater beneath the Frank Wear property is approximately 1 million gallons. The total groundwater volume within the groundwater AOC is estimated to be approximately 5.3 million gallons.

4.0 DESCRIPTION OF ALTERNATIVES

Ecology identified the cleanup alternatives that are evaluated in this FS (Ecology 2007a). These alternatives are described in the sections below:

- Section 4.1: Alternative 1 — Containment with and without Groundwater Treatment;
- Section 4.2: Alternative 2 — *In Situ* Treatment with and without Natural Attenuation; and
- Section 4.3: Alternative 3 — Source Control and Treatment.

The development of these alternatives included an initial step of identifying and screening potential remedial technologies for soil and groundwater. A broad range of technologies were initially identified, then screened based on technical practicability, effectiveness, and cost. Table 2 provides a summary of the technology screening that was performed.

4.1 Alternative 1 — Containment with and without Groundwater Treatment

This alternative consists of the installation of barrier walls to prevent, or to retard and treat, contaminated groundwater flowing from the Frank Wear site to adjoining properties. The barrier wall systems would be operational until the concentrations of COCs are low enough that natural attenuation will reduce the concentrations to below the CULs for groundwater.

All variations of Alternative 1will include institutional controls and compliance monitoring. Institutional controls usually include on-site features, such as signs and fences, and legal mechanisms, such as lease restrictions, deed restrictions, land use and zoning designations, and building permit requirements.

The different barrier wall types considered in this FS are described in Section 4.1.1. A discussion of the design criteria for each of the barrier wall types is provided in Section 4.1.2. Proposed barrier wall alignments are described in Section 4.1.3. Section 4.1.4 provides a discussion of groundwater extraction requirements. Section 4.1.5 describes the groundwater treatment system for extracted groundwater. Long-term groundwater monitoring requirements are described in Section 4.1.6.

4.1.1 Barrier Wall Types

Three barrier wall systems are considered in this FS: 1A) a continuous soil-bentonite slurry wall around the perimeter of the Frank Wear property and portions of the adjoining properties, 1B) a partial slurry wall around parts of the site to restrict the flow of contaminated groundwater off site with groundwater extraction and treatment, and 1C) a partial wall around portions of the site consisting of slurry wall barriers with permeable reactive iron filing gates.

An alternative to a soil-bentonite cutoff wall would be the installation of steel sheet piling. Difficulties would exist in driving and sealing piling to the depths required at the site, but in discussions with vendors and geotechnical engineers, it would be possible. The advantage of sheet pile walls over slurry walls would is that no soil disposal is associated with sheet pile wall installation. Preliminary construction costs were evaluated for both variations of an impermeable groundwater barrier. Construction and material costs for the two options, including soil disposal cost for the slurry wall, were comparable (within approximately 6 percent). At a feasibility study costing level, the two cost estimates were found to be roughly equal. As the price of steel piling is the major cost driver for sheet pile barriers, lower steel prices could make this a more attractive option.

For this type of application, the major advantage of a slurry barrier is the lower permeability compared with sheet piling. Though the technology has improved in the area of seam sealing, it is assumed that a lower permeability can be achieved with a continuous soil-bentonite wall. All other factors for the barriers being about the same, including the need for hydraulic control, the use of a soil-bentonite barrier was carried forward for this evaluation.

4.1.2 Design Criteria for Barrier Walls

With south to east flowing groundwater and the presence of the children's bookstore building adjacent to the Frank Wear property line to the south, an effective barrier wall must be placed around portions of both properties to fully contain site contamination and potential source areas. Restricting the barrier wall to the Frank Wear property will likely miss areas of impacted groundwater and potential soil sources, as standoff from the bookstore building will be required to prevent undermining of the foundation. Referring to Figures 4 through 6, barrier wall configurations will border the Frank Wear property, the majority of the children's bookstore property, and will be required to traverse the north end of the CWCMH property. These configurations are intended to restrict the flow of contaminated groundwater in the upper 50 feet of the shallow aquifer from migrating off-site. Installation of the barrier wall s for Alternatives 1A, 1B, and 1C assumes the demolition and rebuilding of the covered parking structure behind the children's bookstore building. These configurations represents the minimum footprint that will contain groundwater flowing from the Frank Wear site.

There is limited information on the depth of groundwater contamination at the site. The majority of the site wells with detected PCE contamination are screened to a depth of approximately 30 feet bgs. A review of several of the boring logs from the installation of site wells noted that saturated soils were observed at 20 to 35 feet bgs. There is no apparent confining layer beneath the site that a barrier wall could key into with standard barrier wall technologies. Alternatives 1A, 1B, and 1C consider the installation of hanging barriers to restrict and/or treat the upper aquifer contaminated groundwater from the impacted areas around the Frank Wear site. As the deepest well on the site with detected concentrations of PCE above CULs is screened to approximately 35 feet bgs, the proposed depth for the barrier walls is 50 feet to provide additional coverage. Trenching and installing barrier walls to 50 feet is feasible but will require the use of specialized excavation equipment and, therefore, increase the construction costs for this alternative.

The primary underground utility corridors serving the three impacted properties run along South Third Avenue and the alley to the west of the properties. Additionally, a wooden irrigation line is thought to run along the west side of South Third Avenue in the vicinity of the existing sidewalk. The specific locations of these lines are not known. Installation of a barrier wall in the vicinity of underground utilities is problematic and could be potentially expensive. The utilities would have to be moved, or penetrations through the barrier wall would have to be installed, to accommodate existing utilities.

Slurry Wall Barriers

A slurry wall consists of a vertical trench into which bentonite slurry is pumped to support and maintain sidewalls. Excavated soils mixed with dry bentonite and bentonite slurry, generally to a consistency similar to wet concrete, are placed back into the end of the trench, displacing the slurry forward as the excavation proceeds. Some slurry walls use a mixture of soil, bentonite, and concrete or other additives to achieve specific performance specifications such as permeability. It is recommended that, prior to construction, bench-scale testing be performed with site soils to determine the proper mixture to backfill the trench.

Upon completion, the trench contains a dried, low-permeability mixture of soil and bentonite, and the displaced slurry has coated the walls of the trench with bentonite. The typical permeability of a completed soil bentonite slurry wall will be in the range of 10^{-6} centimeters per second (cm/s) to 10^{-8} cm/s. Bench-scale testing of site soils will determine the wall permeability that can be achieved at this site.

The slurry wall alternative developed for the Frank Wear site is a wall that is about 2 to 3 feet thick and extends 50 feet in depth. Use of site soils in the bentonite backfill mixture would reduce off-site disposal costs for trench spoils and can lower permeability of the wall. To accommodate the construction equipment needed to excavate and backfill the trench, typically a 40-foot-wide corridor around the trench is necessary. Space will also be required to stockpile soil and construct the mixing pond for the slurry. It is likely that the unoccupied Frank Wear property could accommodate these space requirements.

With proper engineering controls, the slurry wall can be installed around utility penetrations. These controls would include controlled excavation in the vicinity of utilities (i.e., air knifing), support for exposed lines, and installation of flexible sleeves for utilities to limit damage with settlement of the slurry wall. Capping of the slurry wall with site soils above the seasonal level of groundwater can dissipate overlying loads to the slurry-encased utilities as well as decrease soil disposal costs.

Costing for Alternatives 1A and 1B assumes that a soil-bentonite backfill would be used to construct the barriers. Although it can be possible to place 100 percent of the excavated soils back into the trench with the backfill, bulking of soils as a result of excavation can preclude this. For costing purposes it is assumed that 70 percent of the excavated soils could be used for backfill on the site. The remaining 30 percent of excavated soil will require disposal at an off-site facility, with an assumption that 70 percent of these soils can be disposed as clean soil. The remainder is assumed to be contaminated but non-hazardous and would require disposal in a non-hazardous waste facility. For those soils that will be used as backfill, if large gravels and cobbles are present, screening may be necessary to remove oversized materials and achieve a desired consistency and grain size distribution for the backfill. No assumption regarding screening is considered for costing purposes.

For Alternative 1B, groundwater that is retained by the wall will require pumping to maintain hydraulic control and subsequent treatment to meet discharge requirements. With the low annual rainfall in the Yakima region (approximately 7 to 9 inches per year), hydraulic control within the enclosed impermeable barrier variation was assumed to be unnecessary. Under Alternative 1A, significantly less than 1 gallon per minute (gpm) of pumping would be required to maintain static groundwater levels. With the hanging nature of the wall it is assumed that hydraulic control could be maintained without the added expense of a groundwater pump-and-treat system.

With institutional controls aimed at preventing breaches to the barrier walls, the slurry wall systems proposed for Alternatives 1A and 1B could be expected to remain effective for the 30-year time frame under consideration.

In summary, slurry walls are a proven technology to retard or prevent off-site migration of contaminated groundwater. Typically, slurry walls are keyed into an aquitard such as bedrock or clay to provide complete containment of impacted groundwater. As a continuous impermeable zone is not present beneath this site, additional characterization of the vertical extent of the groundwater contamination is recommended to determine whether a 50-foot deep barrier wall will provide the necessary coverage. Hanging walls have proven effective to prevent off-site migration of floating contaminants, but would prove ineffective with lower dissolved contamination or a DNAPL phase present below the wall. As previously stated, trenching to 50 feet is possible with the use of specialized construction equipment. This equipment could be expected to trench to depths of 80 to 100 feet depending on digging conditions. Beyond this range, trenching would be economically infeasible for a site of this size.

Zero-Valent Iron Permeable Reactive Barrier

A permeable reactive barrier (PRB) is a vertical wall constructed of sand and granular zero-valent iron (ZVI) that will allow groundwater to pass through under natural flow conditions. This technology has been around for about 15 years and has proven effective at degrading chlorinated hydrocarbons such as PCE. As impacted groundwater passes through the granular iron, chlorinated hydrocarbons are degraded to products such as ethene, ethane, methane, and chloride ions. Degradation via the iron filings proceeds by a reductive dehalogenation process, with the iron acting as the electron donor source. In the case of PCE, the chlorine atoms will be replaced by hydrogen and result in conversion to ethene.

Construction methods for PRBs are similar to slurry wall methods. One means of installation is to excavate using a biopolymer slurry to support the trench walls. The granular iron and sand mixture is placed in the trench using a tremie pipe as excavation proceeds. Similar to slurry walls, the iron/sand mixture will displace the biopolymer slurry as it is added to the trench. Residual biopolymer can be broken down with an addition of an enzyme breaker and through natural biodegradation. Oversight and quality control are more intensive for PRB installations compared with slurry walls, as proper material placement and iron/sand mixture content is critical for barrier success.

The major cost component in constructing PRBs is the cost of the iron filings. Because of the distribution of the contamination and potential for upgradient sources at the site, constructing a fully encompassing PRB would likely have little added benefit and would drive the costs up significantly. A common means to reduce costs, while providing comparable groundwater treatment capability, is to use sections of PRBs in conjunction with impermeable slurry walls. Termed "funnel and gate" systems, the impermeable slurry wall sections (i.e., "funnels") will direct groundwater flowing through a site to the PRB (i.e., "gates") for treatment.

Granular iron PRBs are a patented technology provided by Environmental Technologies Inc. of Canada. The thickness of an iron flow-through barrier is based on providing the required residence time inside the wall with the site groundwater flow velocity. Given the porous sands, gravels, and cobbles in the upper aquifer at this site, groundwater velocity is relatively high but within the range of feasible PRB treatment. Based on site parameters it is estimated that a 1.6-foot iron flow-through thickness would provide the required residence time. This thickness would provide an estimated 2-day residence time inside the wall to reduce PCE concentration to below CULs at an assumed average influent PCE concentration of 2,000 µg/L.

The required depth of the funnel and gate system was assumed to be 50 feet, with the top of the barrier at 10 feet bgs. This may be an overly conservative estimate of the amount of required iron filings and could be potentially scaled back with a finer delineation of the depths of groundwater contamination. For example, if contamination was shown to be most prevalent at certain depths during seasonal fluctuations, permeable iron/sand zones could be vertically placed to focus treatment at those depths. Vertical depths where treatment is determined to be unnecessary can be backfilled with clean site soils. Additionally, the horizontal concentration of iron can be varied if site testing indicates groundwater flowing through certain portions of the site will be less contaminated.

The reactivity of the iron filings in PRBs is estimated to remain effective for at least 20 years after installation. Factors that will lower the reactivity will be the formation of precipitates on the iron, typically on the upgradient face. Bench-scale testing of this technology is recommended for the site, which would assess the alkalinity and carbonate levels in the site groundwater and the potential fouling and plugging of the iron barrier. Also, comparisons of PCE concentrations from performance monitoring would provide indication of loss of iron reactivity.

For costing purposes, the assumed life of the PRB at this site is 15 years. Unlike slurry walls, a PRB trench will be backfilled with the iron/sand mixture and excavated soils will require disposal. As with the case for the impermeable barrier options, further site characterization is recommended to determine the vertical extent of the PCE contamination. It is likely that costs for PRB installation could be reduced with additional testing focused on placing iron only in zones deemed necessary to reduce site PCE concentrations below CULs.

4.1.3 Alignment of the Barrier Walls

Groundwater conditions beneath the site (Sections 2.3 through 2.5) were considered along with the practical limitations of both the slurry wall barriers and PRBs to identify the proposed alignments of the barrier walls.

Alternative 1A. This alternative consists of a continuous barrier wall that encircles the Frank Wear property and portions of the children's bookstore and CWCMH properties to the south (about 515 linear feet of barrier). This barrier wall alignment is depicted on Figure 4. The barrier wall contains approximately 35 percent of the groundwater AOC.

Alternative 1B. This alternative consists of a barrier wall on the west and east perimeters of the Frank Wear and children's bookstore properties, with the south leg transecting the CWCMH parking lot. This barrier, which is approximately 300 feet in length, is depicted on Figure 5.

Alternative 1C. This alternative consists of a barrier wall alignment similar to the Alternative 1B partial barrier and is shown on Figure 6. The total length of the system is approximately 300 feet. The west and east legs would consist of low-permeability slurry walls tied into the PRB south leg (approximately 190 feet in length).

4.1.4 Groundwater Extraction Requirements

This section identifies groundwater extraction requirements for maintaining hydraulic control for the different barrier wall alternatives and provides an estimate of the volumes of groundwater that will be extracted. The following discussion is based on the results of simplified modeling of the barrier configurations with Modflow, a two-dimensional finite difference groundwater flow modeling program. Using site parameters, variations in flow due to the presence of both a continuous and an open barrier wall were estimated. A simplifying assumption was made that groundwater predominantly flows to the south.

Alternative 1A. Groundwater pumping would not be required and therefore groundwater treatment is unnecessary. Groundwater pumping would not be required for Alternative 1A due to the low groundwater recharge rates and because the groundwater within the footprint of the continuous barrier is isolated from surrounding groundwater.

Alternative 1B. The barrier wall configurations identified in Alternative 1B would require extraction and treatment of groundwater.

Groundwater extraction rates are estimated to be approximately 25 gpm during periods of high groundwater levels, and approximately 18 gpm during the months of low groundwater levels. For costing purposes an average value of 21.5 gpm is assumed.

The amount of groundwater generated by the partial barrier wall to maintain hydraulic control is a function of the recharge to the shallow aquifer from precipitation (about 17,000 gallons per year assuming 20 percent of annual rainfall recharges the aquifer within the barrier) as well as the amount of groundwater inflow (approximately 11 million gallons per year).

For Alternative 1B, well extraction pumps would be used to extract water directly from five wells located within the barrier perimeter. The extracted groundwater would be pumped to the groundwater treatment system described in Section 4.1.5.

Alternative 1C. The ZVI PRB will allow groundwater to pass through the south leg under normal flow conditions and, therefore, pumping will not be required.

4.1.5 Groundwater Treatment System

For Alternative 1B, a simplified groundwater treatment system is proposed, which consists of the following components:

- Well extraction pumps delivering groundwater from five extraction wells located on the upgradient side of the partial barrier wall;
- Particulate filter for the water stream;
- Air stripping column to remove VOCs from the groundwater;
- Vapor stream activated carbon bed to capture VOCs from the air stripping column, with discharge to the atmosphere;
- Primary and secondary carbon filters for treatment of the water stream following air stripping; and
- Treated water discharge to the sanitary sewer under permit.

Both effluent streams will be regularly tested to ensure they meet regulatory requirements and site CULs. It is assumed that the effluent from the groundwater treatment system will be discharged to the City of Yakima sanitary sewer. A schematic of the proposed treatment system is depicted on Figure 7.

4.1.5 Long-Term Groundwater Monitoring

Alternatives 1A, 1B, and 1C assume a groundwater monitoring period of 30 years from the time of installation. Nine existing wells and three new wells are proposed for long-term monitoring for Alternatives 1A, 1B, and 1C. For Alternatives 1B and 1C, some of the existing monitoring wells upgradient of the barrier wall would be used for hydraulic control. The monitoring wells proposed for sampling in Alternative 1 are shown on Figures 4 through 6.

Four wells will be monitored in the source area upgradient of the barriers. These will likely be the existing wells MW-2, MW-10, SP-12, and potentially SPW-14 or MW-1 if they fall inside the barrier and are otherwise not impacted by barrier installation. Installation of a true upgradient well is proposed north of the site. The current upgradient well, MW-5, with detections of PCE, gives indication of either on-site migration of contamination from another source or is impacted by site contamination and cannot be used for comparison purposes. MW-9 will likely be impacted by barrier installation and will not be replaced. Two new wells will be installed east of the barrier to determine barrier effectiveness during the period of eastern groundwater flow, and one new well to the south to fill the gap between the source area and MW-3 and MW-4. The existing wells MW-3, MW-4, MW-6, and MW-7 are proposed for continued monitoring.

For the partial slurry wall barrier option, wells east and west of the barrier endpoints will provide indication of groundwater flowing around the barrier and the potential need for hydraulic control refinement. MW-7 can likely serve this need to the west of the barrier. The new well in the northeast corner of the Frank Wear property can monitor the east endpoint of the barrier.

4.2 Alternative 2 — In Situ Treatment

Alternative 2 involves *in situ* treatment of soil and groundwater impacted by PCE and other chlorinated hydrocarbons. This alternative considers the following combinations of remedial technologies and delivery methods:

- Alternative 2A – Air sparging and soil vapor extraction combined with ozone injection;

- Alternative 2B – Bioremediation through application of nutrients and chemical substrates;
  - Variation 1 – Delivery through permanent injection wells;
  - Variation 2 – Delivery via a groundwater recirculation system;

- Alternative 2C – Chemical oxidation using permanganate;
  - Variation 1a – Delivery through permanent injection wells;
  - Variation 1b – Injection through temporary borings; and
  - Variation 2 – Delivery via a groundwater recirculation system.

The technical elements of *in situ* treatment are described in Section 4.2.1. *In situ* treatment would be applied to achieve site CULs, as defined in Section 3.1. The various *in situ* treatment options could be applied as stand-alone actions or in successive combination with each other as a treatment train. *In situ* treatment may also be coupled with Alternatives 1 or 3.

Installation of various *in situ* treatment options may require handling of site soils. During installation of wells, soil impacted by chlorinated hydrocarbons or impacted groundwater may be encountered. It would be anticipated that near-surface soils in the areas of former remedial excavation would likely be clean, but deeper soils that are in contact with PCE-impacted groundwater may require off-site disposal as non-hazardous or hazardous waste. Drilling spoils would be observed for signs of impact as well installation work progresses, and would be sampled and characterized to determine appropriate disposal measures.

4.2.1 Components of *In Situ* Treatment

Groundwater COC concentrations above CULs exist over much of the Frank Wear property and extend onto adjacent properties (see Figure 3). Though remediation of shallow impacted soils was conducted at the site, historical groundwater monitoring data indicate that a deeper source area in the soil may remain beneath the former Frank Wear building, in the vicinity of monitoring well MW-10. This suspected source area may extend beneath the children's bookstore building to the south. Additional characterization in this area would be useful to determine the nature and extent of this suspected source area.

The *in situ* treatment options described in Alternative 2 would be implemented to treat site-specific impacted soil and groundwater. Treatment would extend to neighboring properties either incidentally due to groundwater flow, or by conceptual design requirements to install treatment system infrastructure on the neighboring properties. *In situ* treatment would continue until it is determined that the maximum practicable amount of contamination has been removed. Ecology would make this determination. *In situ* treatment remediation time frames are discussed in greater detail in Section 5.3.2. Components of *in situ* treatment are described below.

Alternative 2A – Air Sparging, Soil Vapor Extraction, and Ozone Injection

Air sparging is a well-established remediation technology used to physically remove aqueous volatile contaminants from groundwater. Air sparging involves bubbling atmospheric air through impacted groundwater using air injection wells, and is based on the principle that aqueous volatile compounds will transfer to the vapor phase across the air-water interface of the bubbles as they travel upward through the water column. Soil vapor extraction is employed to capture the sparged air and contaminant vapor as it enters the unsaturated zone above the water column, as well as to remove contaminant vapor originating from soil sources above the water table.

The key components of an air sparging and soil vapor extraction system at the site would include air injection wells installed below the water table, vertical and horizontal vapor extraction wells installed above the water table, an air compressor to provide air flow to the injection wells, and a blower to impart a vacuum on the extraction wells for removal of sparged air and vapor from the subsurface. Soil vapor extraction flow, prior to release to the atmosphere, would be treated using granular activated carbon to remove contaminant vapor via chemical adsorption. Once the adsorptive capacity of the activated carbon is reached, it would be replaced with fresh carbon. Spent carbon is typically regenerated for reuse in other applications. The carbon regeneration process, which would be performed at an off-site facility, involves thermal treatment, in which contaminants are desorbed from the carbon and destroyed.

Ozone injection would be combined with air sparging to enhance *in situ* treatment of PCE and other chlorinated ethenes via chemical oxidation. Ozone is a strong oxidizer that is effective in chemically degrading chlorinated ethenes to innocuous reaction byproducts (water, carbon dioxide, and chloride ion). One or more ozone generators would be used to feed ozone into the air sparging flow as it enters the subsurface. Soil vapor extraction operation would capture any unreacted, volatilized contaminants.

Air sparging wells would be installed in a grid pattern throughout the Frank Wear property to a depth of 40 feet bgs. An on-site pilot-scale test would be conducted during remedial design to determine the site-specific radius of influence per well (and thus well spacing), and to assess treatment design parameters such as sparging flow rate, vapor extraction flow rate, and ozone dosing. Conservatively assuming an approximate radius of influence of 20 feet per well, and a minimum radial overlap of 30 percent, 17 air sparging wells would be installed. Eight vertical soil vapor extraction wells would be installed to a depth of approximately 10 feet bgs along the outer perimeter of air sparging wells, along the property boundary. Four horizontal vapor extraction vents, oriented in a north-south direction, would be installed across the Frank Wear property at a depth of 2 to 3 feet bgs. Conceptual well locations are shown on Figure 8. Well installation and pipe runs would be completed below grade to facilitate the installation of an asphalt cap, which would minimize short-circuiting of atmospheric air into the soil vapor extraction system, and would thus improve its operating efficiency. System process equipment would be housed in an on-site, aboveground enclosure. A process flow diagram is shown on Figure 9.

The system would initially operate on a continuous basis. However, cycling of system operations could be employed as COC concentrations decrease in groundwater, which may enhance removal efficiency. System monitoring would be conducted on a regular basis to assess system operation and to conduct necessary system maintenance.

Alternative 2B – Bioremediation

Bioremediation can be used to degrade PCE through a reductive dechlorination process similar to that which occurs on the iron filing surfaces in a permeable reactive barrier (described above in Section 4.1.2). Certain anaerobic bacteria, such as *dehalococcoides ethenogenes*, are known to degrade PCE by sequentially removing chlorine atoms and replacing them with hydrogen, so that

PCE is converted to TCE, cis-DCE, and vinyl chloride (VC) before arriving at ethene, an end product that is essentially harmless and easily broken down by other indigenous bacteria. These PCE-degrading bacteria are naturally present in soil in many areas in the Pacific Northwest, but require anaerobic conditions to compete with other subsurface bacteria. In areas where these bacteria are not present, dechlorinating bacteria can be readily purchased from several remediation vendors. Cost estimates for Alternative 2 do not include bioaugmentation (addition of non-indigenous bacteria), but this could be performed if desired at minimal additional cost.

Injections of a bacterial food source into the remediation area can promote bacterial growth, using up the oxygen (and other competing electron acceptors such as nitrate and sulfate) and creating anaerobic conditions suitable for dechlorinating bacteria to thrive. A variety of bacterial food sources have been tried at various sites, including molasses, whey, soybean oil, emulsified soybean oil, mulch, lactate, and dextrose. Emulsified soybean oil and dextrose substrates were selected for use in this FS as representatives of slow-release and soluble substrates, respectively. Variation 1 of Alternative 2B considers injection as a delivery method for these substrates. Variation 2 considers use of a groundwater recirculation system to introduce substrate to the subsurface.

Emulsified soybean oil is a commonly used and commercially available remediation substrate, usually provided in 55-gallon drums or larger totes, sometimes with nutrients such as vitamin B12 included. The emulsification process produces small droplets of soybean oil that can be dispersed in water and are smaller than soil matrix pore throats, allowing better dispersion through the subsurface. Emulsified soybean oil is usually diluted with water on site and injected in a series of temporary borings on a one-time basis. The droplets of soybean oil sorb to soil particles and are slowly broken down into smaller, more soluble molecules, providing a long-term continuing source of food for the dechlorinating bacteria over a period of 3 to 5 years. Costs used in the estimate were for EOS 598 B42, an emulsified oil substrate made by EOS Remediation of Raleigh, North Carolina, that has been used on several previous Hart Crowser projects. A proposed injection design (shown on Figure 10) consisting of 21 temporary borings was used, based on a radius of influence of 15 feet per well, with a minimum radial overlap of 30 percent. Injections would be performed between 40 feet bgs and the water table, using a sonic drill rig.

Another method of providing a bacterial food source is through a groundwater recirculation system. Groundwater is continuously extracted from a set of downgradient extraction wells, amended with a soluble remediation substrate such as dextrose, and reinjected into the subsurface at upgradient injection wells. In the preliminary design created for this FS, three existing groundwater monitoring wells (MW-2, SPW-12, and SPW-13) would be used as injection wells. MW-9 and two new wells would be used as extraction wells. The proposed system configuration is shown on Figure 11. Trenching would be necessary to connect the injection and extraction wells to the central treatment system where the dextrose would be added. Costs shown are based on an estimate provided by ETEC LLC, a remediation vendor specializing in this type of system that provides a remediation substrate containing dextrose and nutrients. During recirculation, twice-monthly site visits and monthly sampling events would be conducted. The system would be operated over a period of 12 months, with 500 pounds of dextrose substrate being added each month. Though the dextrose substrate would likely be consumed several months after the recirculation system was turned off, the decay of subsurface biomass built up during the recirculation period could continue to provide treatment for a year or more.

A pilot study would likely be unnecessary before beginning bioremediation treatment, as the unknown parameters (amount of substrate required, whether bioaugmentation is needed, and whether buildup of VC will occur) would be difficult to determine practicably at the pilot study level.

Alternative 2C – Chemical Oxidation using Permanganate

Permanganate is a strong oxidizer that chemically degrades PCE and other chlorinated ethenes to innocuous byproducts such as water, carbon dioxide, and chloride ion. Two forms of permanganate are typically used for *in situ* chemical oxidation: sodium permanganate and potassium permanganate. Sodium permanganate has greater aqueous solubility than potassium permanganate, and is obtainable as a concentrated solution (up to 40 percent by weight). Potassium permanganate is available as a dry, crystalline solid, but has a maximum solubility of approximately 4 percent (ITRC 2005). In the evaluation of this alternative, both sodium and potassium permanganate are considered.

In the *in situ* treatment of groundwater and soil, permanganate is typically applied as an aqueous solution, and can be introduced into the subsurface using a number of different delivery methods. Alternative 2C considers the following delivery method variations:

- Variation 1a – Permanganate application using permanent injection wells;
- Variation 1b – Permanganate injection through temporary borings; and
- Variation 2 – Permanganate application through a groundwater recirculation system using groundwater extraction and injection wells, as described above for the bioremediation option.

Permanganate application through permanent injection wells (Variation 1a) would consist of a grid of injection wells installed throughout the Frank Wear property, as shown on Figure 10. Injection wells would be completed to a depth of 40 feet bgs. An on-site pilot test during remedial design would be conducted to assess the radius of influence per well and the necessary dosing of permanganate to achieve suitable treatment. Assuming a conservative radius of influence of 15 feet per well, with a minimum radial overlap of 30 percent, installation of 21 injection wells is considered in this FS.

Diluted permanganate solution would be prepared on site and injected into multiple wells simultaneously using one or more transfer pumps and a portable manifold system. Depending on whether sodium or potassium permanganate is used, injection volumes would range from approximately 20,000 to 80,000 gallons per injection event. Dilution water would be supplied either by connection to the City's water supply (e.g., via a fire hydrant connection) or by tanker truck. This FS considers injection into all wells, with the possible necessity for multiple injection events over time. However, injection could be directed only to specific wells to target specific impacted areas. Additionally, injection would be performed at least once during the irrigation season, when groundwater elevations are high, to target smear zone soils that may be impacting site groundwater.

Variation 1b involves injection of permanganate via temporary borings. This would consist of advancement of a boring to a depth of 40 feet bgs, with subsequent injection of permanganate solution through the drill rod. As the injection progresses, the drill rod would be gradually withdrawn from the soil to introduce solution across a range of elevations in the subsurface. Due to the existence of cobbles in site soils, which can prove problematic for direct-push or auger boring methods, sonic drilling methods would be used to install the temporary borings. Borings would be completed on a grid similar to the aforementioned grid for permanent injection well installation (Figure 10), and injection volumes would also be similar if injection were to be conducted across the entire grid to a depth of 40 feet bgs. Temporary borings might also be completed in localized sections of the property to target specific impacted areas. This FS considers the possibility of having to completing multiple injection events to attain cleanup goals.

The third permanganate delivery option (Variation 2) involves application of permanganate to the subsurface using a groundwater recirculation system similar to the system described in Alternative 2B, Variation 2 (Figure 11). In this scenario, existing wells MW-2, SPW-12, and SPW-13 would be employed as injection wells. Existing well MW-9, in addition to two new wells that would be installed along the southern boundary of the children's bookstore property, would be used as groundwater extraction wells. Extracted groundwater would be routed to an on-site system enclosure, where it would be amended with either sodium or potassium permanganate in a mixing tank. From the mixing tank, the amended groundwater would be pumped to the three injection wells. The groundwater recirculation system would run continuously and would require periodic system monitoring and maintenance events to ensure proper operation.

4.3 Alternative 3 — Source Control and Treatment

Alternative 3A considers the further characterization, excavation, removal, and disposal of contaminated soil from the Frank Wear property. A variation of this, Alternative 3B, considers follow-up *in situ* soil treatment subsequent to excavation of most of the contaminated soil.

The intent of this alternative is to remove the remaining sources of COCs in soil on the Frank Wear property. Based on past characterization and removals and recent groundwater monitoring, contamination appears to be distributed between the west end of the property, and under and to the north of the former building. The high concentration of PCE in groundwater in wells MW-10, SP-12, and SP-13 indicates possible residual contamination acting as a source in these areas. The purpose of this alternative is to address residual contamination that was potentially missed by previous removal actions.

As previously described in Section 2.2, still bottoms containing PCE were dumped in the gravel lot to the west of the former building during past operations of the dry cleaner. Operations inside the former building may have caused releases to the underlying soil. Sources may have been from the dry cleaning machines and associated equipment to the former floor drains which carried wastewater out the west end of the building.

Several site-specific technical constraints will affect the implementation of this alternative. These constraints are summarized in Section 4.3.1. The components of Alternative 3 are discussed in Section 4.3.2. *In situ* treatment options of Alternative 3B are described in Section 4.3.3.

4.3.1 Technical Constraints Affecting the Implementation of Alternative 3

The excavation of soil on the Frank Wear property would have to overcome several technical constraints including the following: 1) excavations near building foundations; 2) excavations in areas where utilities are known to exist or may be present; 3) excavation work that avoids undue business disruptions to operating facilities at the site; 4) ability to sample and excavate site soils to depth of contamination; and 5) potential to dewater soils if contamination is chased below the vadose zone.

It is estimated that with proper planning, the majority of excavation impacts can be limited to the Frank Wear property for this alternative. While most of the above-defined constraints would be common to all alternatives proposed, Constraint 1, building impacts, and Constraint 4, soil characteristics, have a higher probability of reducing the effectiveness of Alternative 3.

The children's bookstore building is located on the southern boundary of the Frank Wear property. An excavation standoff distance will be required to prevent undermining of the foundation. Engineered shoring of the foundation to broaden the excavation footprint would be expensive and risky. For the purposes of this evaluation the option of shoring the children's bookstore foundation was not explored.

A commonly used approach to evaluate the soil conditions at depth would be to collect soil borings at vertical and horizontal intervals across the site. Characterizing the soil across the site to 12 feet bgs would provide direct indication of whether there is a source present in the vadose zone. Continuing the borings to approximately 20 feet bgs during the dry season would provide indication of a smear zone that causes PCE concentration fluctuations during the seasonal water level changes.

The ability to sample the soil across this site with traditional methods is reduced by the presence of large cobbles below the ground surface. Several drilling contractors with experience in the Yakima area have indicated the relative ineffectiveness of obtaining soil borings in this region, either from a direct-push rig or by hollow-stem auger.

As described in the Maxim RI report (Maxim 1996), use of a strataprobe at this site was assumed to be limited to 4 feet bgs. Though their results show one probe achieved 6 feet bgs, the majority of samples were collected at depths less than 4 feet. Use of push-probe or other soil coring technology to better characterize the site was not considered for this alternative.

4.3.2 Excavation of Soil above Cleanup Levels

Alternative 3A proposes to further characterize site soils and excavate and haul contaminated soil from the Frank Wear property.

The most probable source area on the site appears to be in the vicinity of well MW-10 (see Figure 3) where recent monitoring has detected PCE in the groundwater at concentrations as high as 43,000 μg/L. This appears to be a historical high for the site since more frequent groundwater monitoring began in 2005. This well is located within the footprint of the former building.

This alternative also focuses on the vicinity of wells SPW-12 and SPW-13, upgradient of MW-10. Recent groundwater monitoring (Ecology 2007b) indicated PCE concentrations of approximately 2,500 μg/L in SPW-12 and 1,000 μg/L in SPW-13. Referring to Figure 12, these wells are north of the former dry cleaning building in the Eagles parking lot. The 1995 soil vapor study performed at the site observed two potential source areas of PCE based on high soil vapor concentrations in the general vicinity of these two wells (Agra 1995). PCE waste may also have been dumped in this area as a means of dust control, as discussed in Section 2.2.

October 2006 groundwater monitoring results for MW-2, located in the northwest corner of the site, detected PCE at a concentration of 530 μg/L. This is an order of magnitude increase in PCE concentration compared to monitoring results from the last 6 years. In the January and April 2007 monitoring events, PCE concentrations had dropped to levels of 48 and 31 μg/L, respectively. Based on the recent spike in PCE detected in MW-2, additional characterization of the area may be necessary to determine whether a source area was missed by the previous removals.

Excavation Depth and Volume

Though the two previous soil removal actions (Maxim 1996 and Fulcrum 2001) reported the quantities of soil excavated, the records offer an incomplete picture of the extent of excavation that was completed. Neither Maxim nor Fulcrum provides information on the grading or slope cutback required to achieve target depths and several of the Fulcrum test pits appear to be disproportionately large compared with the number of samples collected. These excavations proceeded until soil confirmation sample results were non-detect for PCE. Within individual test pits, the depth to non-detect samples could vary by as much as 8 feet between adjacent samples. It is uncertain how to interpret several reported depths within a test pit in determining the effectiveness of the excavations and to identify areas for further excavation.

When overlaying the areas excavated by Maxim and Fulcrum, the Frank Wear property is divided into uneven excavated areas finely divided by apparent unexcavated areas. Additionally, the drawings provided in the Fulcrum report depicting the areas of excavation were not to scale and take-off estimations from these drawings for a design would be very approximate. In summary, it would be difficult to design a plan to excavate only in areas of the site that have not been previously excavated.

Without more recent characterization data it is difficult to determine the quantity of soil to excavate. Reliable characterization data of COCs will potentially be difficult to obtain at this site based on the nature of soils at the site and the difficulty in obtaining reliable soil cores. Evaluation of drill cuttings will likely disturb COC constituents too greatly to be an effective means of characterization.

It is proposed that site characterization and remediation occur concurrently, with use of an on-site laboratory to guide excavations with "real-time" analysis. Although excavation is a highly disruptive method for obtaining COC samples, it is likely to be less disruptive than obtaining samples from an air rotary or Odex drilling rig. Excavations guided by an on-site mobile laboratory are proposed to proceed as follows:

- Based on recent groundwater monitoring data showing a potential soil hot spot in the vicinity of MW-10, characterization and excavation should begin in this area while maintaining a buffer with the children's bookstore building.

- Characterize and excavate in the vicinity of SPW-12 and SPW-13, as elevated PCE concentrations have been observed in these wells during recent sampling events.

- Monitoring well SPW-15 has elevated PCE concentration, with a concentration of 327 µg/L reported in January 2007. This well is directly adjacent to the children's bookstore building. The extent of characterization and excavation in this area would be limited due to concerns with undermining the building foundation. It is estimated that excavation in this area could proceed to only 3 to 4 feet bgs.

- Characterize and excavate in the vicinity of MW-2.

To provide a basis for evaluating the costs and feasibility of this alternative, the following assumptions are made:

- The maximum extent of source area contamination accessible for removal by excavation is approximately 12 feet bgs, the seasonal high level for groundwater.

- Soil density is approximately 1.4 tons per cubic yard, and the area of the Frank Wear property is approximately 8,800 square feet.

- As a conservative scenario for costing purposes, approximately half of the property footprint, minus the children's bookstore building buffer, will require excavation to 12 feet bgs. This amounts to approximately 2,250 tons of soil to be removed.

- A conservative buffer adjacent to the children's bookstore building would need to be left in place during excavation. A buffer 70 feet in length by 20 feet in width would leave approximately 870 tons of soil on the Frank Wear property to a depth of 12 feet bgs. It is recommended that plans for excavating adjacent to the children's bookstore building should be reviewed by a structural engineer. The plans will also likely require the approval of the City of Yakima and the building owner.

- The previous two removals excavated approximately 1,000 tons of soil combined. Seventy percent of the excavated soil from the Frank Wear property required disposal as non-hazardous waste. The remaining 30 percent met applicable MTCA criteria and was reused on the site for backfill. For cost estimating purpose, 70 percent of the soils to be excavated would be disposed off site as non-hazardous waste, and the remaining 30 percent would meet applicable MTCA criteria and be managed on the site.

Soil Stockpiling

Considering the use of a mobile laboratory, it will be possible to quickly characterize and segregate excavated soil into separate stockpiles for either off-site disposal or for use as backfill. The size and placement of stockpiles will depend on the scale of the excavations necessary to remove soils above CULs.

If backfilling proceeds in conjunction with the excavations, it is likely that stockpiling of materials can be handled on the Frank Wear property with little disruption to neighboring tenants. If excavation is to proceed on a greater scale (i.e., excavating the entire footprint), use of the Eagles parking area to the north may be necessary to accommodate the larger volumes of soil.

Time Frame and Duration

The limiting factor in performing Alternative 3 may be the rate at which the mobile laboratory can process samples. The average mobile laboratory can process approximately 21 samples in an 8-hour day using EPA Method 8260 for VOCs. Additionally, to maximize contaminant removal within the excavation, it would be beneficial to proceed at a rate that allows adequate soil characterization. This will aid in better delineation of the suspected source area and could potentially reduce the amount of materials to dispose as non-hazardous waste. Assuming an excavation and characterization rate of 200 tons per day the project could be completed in approximately 2.5 to 3 weeks. This includes excavation, characterization, hauling of impacted soil off site, and backfilling.

Dewatering Concerns

Excavation of remaining source areas is assumed to occur above the seasonal high water level and dewatering is not expected to be a concern. Previous excavations to 12 feet bgs have occurred at the site without encountering groundwater during the time of year when water levels can be expected to be low. As a matter of planning deeper excavations at this site, it is recommended that they occur during the drier months to avoid the need to dewater and treat contaminated groundwater.

Disposal Facility and Hauling Method

Using the assumed ratio of 70:30 for managing soils off site as non-hazardous waste to managing soils on site as fill, approximately 1,600 tons of site soil would require off-site disposal. It is assumed that 650 tons of excavated soil would meet applicable MTCA criteria and be placed back into the excavation. The non-hazardous waste soil will be transported to the Rabanco facility in Roosevelt, Washington, for disposal, which is approximately 110 miles from the site. It is estimated that hauling 1,600 tons of material will take 5 days.

Backfilling

It is estimated that approximately 2,000 tons of fill will be needed to bring the excavation back to the original grade, which accounts for compaction requirements. Excavated soil meeting applicable MTCA criteria will be used for a portion of the backfill. Additional clean soils will be imported to the site from a local borrow pit.

4.3.3 Alternative 3B – *In Situ* Treatment of Remaining Soils

The location of the children's bookstore on the property line with the Frank Wear site will preclude the excavation of approximately 870 tons of material. Based on recent groundwater data, this area may contain a source of PCE impacting groundwater. To address the soil that cannot be safely excavated, Alternative 3B considers *in situ* treatment of the soil with potassium permanganate, in addition to those elements previously described for Alternative 3A.

Following the excavation of soil under Alternative 3A, an injection system will be installed parallel to the children's bookstore along the length of the buffer zone under Alternative 3B. Details of Alternatives 3A and 3B are shown on Figure 12. The injection system will consist of horizontal perforated PVC piping running the length of the buffer area in a bed of pea gravel or suitable site material of a permeable nature. The depth of the injection piping will depend on the depth of contamination identified in the area during excavation. The intent will be to install the system above the contamination and allow the zone of percolation of aqueous potassium permanganate to treat the widest area possible.

Design of the system may call for several parallel sections of pipe along the approximately 70- to 80-foot length of the buffer area to ensure adequate oxidant delivery to the buffer area soils. The piping would be capped on one end (likely at the east edge of the buffer) with the delivery end tied into an injection port at ground surface (likely in the central portion of the property). The injection port will consist of required valves and manifolded pipe sections, if applicable, to regulate oxidant flow to the system.

Potassium permanganate is typically delivered in solid form and will require mixing on site. It is assumed that injections can occur under gravity flow from an on-site holding tank. Treatment of site soils with this system during periods of high groundwater levels (approximately 12 feet bgs) can lessen the amount of solution required to saturate the vadose zone. Another consideration would be to add additional solution during the high water season with the intent of providing treatment of smear zone soils as well as groundwater. During periods of low groundwater, depth to water at the site can be expected to be greater than 20 feet bgs. Treatment during this period should ensure adequate solution delivery to saturate the vadose zone down to the water table. This would provide treatment of the smear zone (approximately 12 feet to over 20 feet bgs), which may act as a source of PCE when water levels rise. If existence a larger source area is confirmed in the smear zone during excavation, an expanded potassium permanganate infiltration system can be installed in other areas of the site prior to backfilling.

For the purposes of costing, it is assumed that two injections would occur subsequent to excavation in the children's bookstore buffer area, one during the high groundwater period and one during the period of low groundwater. A contingency is included to provide two additional injections after the first year. A more detailed description on the uses and risks of potassium permanganate as an *in situ* oxidizer is presented in Sections 4.2 and 5.3 under the discussions of the *in situ* chemical oxidation option in Alternative 2.

4.3.4 Long-Term Groundwater Monitoring

Alternatives 3 would assume a groundwater monitoring period of 30 years from completion of the soil excavations. If it is determined through excavation and additional site characterization that the majority of the source has been removed, the duration of monitoring would likely be reduced. Significant excavation within the Frank Wear property boundary may impact several of the existing wells. For costing purposes, it is assumed that five new wells would be installed on the Frank Wear property subsequent to excavation to replace wells possibly destroyed during excavation. One well would be installed in the central portion of the CWCMH property to the south to better monitor the area between the site and downgradient wells MW-3 and MW-4. Additionally, a new upgradient well would be installed to the north of the site. The existing wells SPW-12, SPW-13, MW-3, MW-4, MW-6, and MW-9 are proposed for continued monitoring. In summary, 13 wells are proposed for long-term monitoring for Alternative 3. Long-term monitoring would be assumed to occur on a quarterly basis for the first ten years. For Alternative 3A, monitoring in years 11 through 30 would occur on a semi-annual basis.

5.0 EVALUATION OF ALTERNATIVES

The three remedial alternatives (with variations) that are being considered by this FS are evaluated in this section. Descriptions of the evaluation criteria used to evaluate the alternatives are provided in Section 5.1. Subsequent sections present evaluations of the three remedial alternatives as follows:

- Section 5.2: Alternative 1 — Containment with and without Groundwater Treatment;
- Section 5.3: Alternative 2 — *In Situ* Treatment; and
- Section 5.4: Alternative 3 — Source Control and Treatment.

5.1 Description of Evaluation Criteria

Ecology identified the criteria that should be used to evaluate remediation alternatives within the MTCA regulation (WAC 173-340-360). The purpose of the evaluation is to identify the advantages and disadvantages of each alternative and thereby assist in the decision-making process. The criteria are applied to Alternatives 1 through 3 in Sections 5.2 through 5.4. The specific criteria are all considered important, but they are grouped into three sets of criteria that are weighted differently in the decision-making process. These criteria are:

- Threshold requirements:
  - Protect human health and the environment;
  - Comply with cleanup standards (WAC 173-340-700 through 173-340-760);
  - Comply with applicable state and federal laws (WAC 173-340-710); and
  - Provide for compliance monitoring (WAC 173-340-410 and 173-340-720 through 173-340-760).

- Other requirements:
  - Use permanent solutions to the maximum practical extent. If a disproportional cost analysis is used, then evaluate:
    - Protectiveness;
    - Permanence;
    - Cost;
    - Effectiveness over the long term;
    - Management of short-term risks;
    - Technical and administrative implementability; and
  - Consideration of public concerns.

- Restoration time frame.

Alternatives 1 through 3 will include institutional controls and compliance monitoring. Institutional controls usually include on-site features, such as signs and fences, and legal mechanisms, such as lease restrictions, deed restrictions, land use and zoning designations, and building permit requirements. Ecology will determine the appropriate institutional controls for the site. Compliance monitoring is described in Section 5.1.4.

An alternative must meet the threshold criteria to be eligible for selection as a remedy. The expected performance of each alternative is assessed to identify its ability to comply with cleanup standards and applicable state and federal laws. If the alternative is considered to comply, the subsequent evaluation of the alternative will be based on the remaining eight evaluation factors. The alternative that most closely satisfies these criteria will be the preferred alternative for the site.

5.1.1 Overall Protection of Human Health and the Environment

This evaluation criterion (WAC 173-340-360(3)(f)(i)) assesses the degree to which existing risks are reduced, the time required to reduce risks at the facility and attain cleanup standards, on- and off-site risks resulting from implementing the alternative, and improvement of overall environmental quality.

5.1.2 Comply with Cleanup Standards

Ecology has established cleanup standards in the MTCA regulation. These standards are summarized in WAC 173-340-700 through 173-340-760. Ecology has established CULs for soil and groundwater at the site that would ensure compliance with these cleanup standards. These CULs are listed in Table 1.

5.1.3 Comply with Applicable State and Federal Laws

This evaluation determines the extent to which an alternative complies with applicable state and federal laws as specified in WAC 173-340-710. Included in this evaluation are laws applicable to water discharges and air emission requirements for remediation systems. The evaluation also includes an identification and assessment of substantive permitting requirements that may be applicable to the remedial alternative. WAC 173-340-710(9) provides for exemptions to the procedural requirements of the permits; these requirements will also be identified.

5.1.4 Compliance Monitoring

All of the alternatives include compliance monitoring. Compliance monitoring requirements are described in the following sections for each of the individual alternatives. The cost of implementing the compliance monitoring considered appropriate for each alternative was included in the conceptual-level cost estimate prepared for that alternative.

For all of the alternatives, the point of compliance for soil is throughout the site for protection of groundwater and ambient air, and from the ground surface to a depth of 15 feet bgs for the protection of human health based on direct contact exposure.

As defined under MTCA 173-340-720(8), the standard point of compliance for site shallow groundwater is throughout the site.

5.1.5 Permanence

Permanence (WAC 173-340-360(3)(f)(ii)) is the degree to which an alternative permanently reduces the toxicity, mobility, or volume of hazardous substances, including adequacy of the alternative in destroying the hazardous substances, reduction or elimination of hazardous substance releases and sources of releases, degree of irreversibility of waste treatment processes, and the characteristics and quantity of treatment residuals generated.

5.1.6 Cost

This criterion (WAC 173-340-360(3)(f)(iii)) includes the cost of construction and the net present value of any long-term costs. A discount rate of five percent was used in the net present value analysis. Long-term costs include operation and maintenance costs, equipment replacement costs, the cost of maintaining institutional controls, and compliance monitoring costs.

5.1.7 Effectiveness over the Long Term

This criterion (WAC 1173-340-360(3)(iv)) assesses the degree of certainty that the alternative will be successful, reliability of the alternative during its operating time on the site, magnitude of the residual risk with the alternative in place, and the effectiveness of controls required to manage residual wastes.

The following types of cleanup actions, in descending order of preference, can be used to assess the relative degree of long-term effectiveness: reuse or recycling; destruction or detoxification; immobilization or solidification; on-site or off-site disposal in an engineered, lined, and monitored facility; on-site isolation or containment with attendant engineering controls; and institutional controls and monitoring.

5.1.8 Management of Short-Term Risks

This criterion described in WAC 173-340-360(3)(f)(v) assesses the risks to human health and the environment associated with the alternative during construction and implementation, and the effectiveness of measures that will be taken to manage such risks.

5.1.9 Technical and Administrative Implementability

This criterion (WAC 173-340-360(3)(f)(vi)) considers whether the alternative is technically possible, including availability of necessary off-site facilities, services, and materials; administrative and regulatory requirements; scheduling; size; complexity; monitoring requirements; access for construction operations and monitoring; and integration with existing facility operations and other current or potential remedial actions.

5.1.10 Consideration of Public Concerns

This criterion (WAC 173-340-360(3)(f)(vii)) addresses the public's concerns, if any, about the preferred alternative identified by Ecology. It will be addressed during the comment period for the Proposed Plan and is not further addressed in this report.

5.1.11 Restoration Time Frame

The time expected for restoration to be complete is assessed (WAC 173-340-360(4)). This time frame must be reasonable when the nine factors summarized in WAC 173-340-360(4)(b) are considered. In some instances where CULs cannot be technically achieved, concentrations that are technically possible to achieve shall be met within a reasonable time frame considering the nine factors specified in WAC 173-340-360(4)(b).

5.2 Alternative 1 — Containment with and without Groundwater Controls

This alternative consists of the installation of barrier walls to prevent, or to retard and treat, groundwater flowing from the Frank Wear property to adjoining properties. The barrier systems would be operational until the concentrations of COCs are low enough that natural attenuation can further reduce the concentrations to below the CULs for groundwater.

Three barrier systems are considered: 1A) a continuous slurry wall around the perimeter of the Frank Wear property and portions of the adjoining properties, 1B) a partial slurry wall around parts of the site to restrict the flow of contaminated groundwater off site with groundwater extraction and treatment, and 1C) a partial wall around portions of the site consisting of slurry wall barriers with permeable reactive iron filing gates. Barrier wall alignments are depicted on Figures 4, 5, and 6.

Groundwater pumping from selected wells will be used to maintain hydraulic control within the barrier for Alternative 1B. The extracted groundwater will be treated with the system that was described in Section 4.1.5. A schematic of this groundwater treatment system is shown on Figure 7 and is expected to treat approximately 31,000 gallons per day. Alternatives 1A and 1C will not require treatment of groundwater.

The groundwater treatment system will be discharged to the City of Yakima's sanitary sewer under permit. The effluent from the system will be monitored in accordance with the permit requirements, assumed to be once per month for the total VOCs.

Groundwater monitoring will also be performed. Quarterly samples will be obtained at 12 monitoring wells during the first 10 years following remedial action with semi-annual samples collected during Years 11 through 30.

5.2.1 Expected Performance of Alternative 1

Alternative 1 does not directly reduce the quantity or volume of COCs in soil within the barrier. Alternatives 1A and 1B prevent the horizontal flow of groundwater in the upper aquifer from exiting the footprint of the barrier but do not address the vertical flow of groundwater in this apparently unconfined aquifer to the deeper aquifer. Alternative 1C actively treats groundwater exiting the site as it flows through the permeable zero-valent iron barrier.

Alternative 1A provides for a continuous barrier to horizontal groundwater flow in the upper 50 feet of the aquifer around the site. Once the continuous barrier is installed, groundwater outside the barrier will be prevented from commingling with groundwater within the barrier. Thus, Alternative 1A will assure that COCs in the groundwater retained within the barrier do not impact downgradient groundwater. Alternative 1 does not inhibit the flow of groundwater in the groundwater AOC outside of the barrier, toward the Yakima River, or groundwater flow downward to the deeper aquifer.

Alternative 1B provides hydraulic containment of groundwater from the combination of a partial barrier and hydraulic control. Alternative 1B is also expected to largely prevent COCs in site groundwater from migrating off the site. Since the barrier installed in this alternative is discontinuous, the possibility exists for some groundwater to escape the barrier. This possibility is considered to be low, given the location selected for the barrier wall, the operation of groundwater extraction wells within the barrier, the collection and treatment of the groundwater pumped from the wells, and the materials of construction selected for the barrier.

Alternative 1C provides a permeable reactive barrier downgradient from the source area. This reactive barrier is flanked by two sections of slurry wall to direct water flowing through the site to the iron filing wall for treatment. Alternative 1C is expected to reduce PCE concentrations in groundwater flowing through the site to below CULs. Similar to Alternative 1B, the discontinuous configuration of the barrier may permit groundwater to flow around the barrier. Again, this possibility is considered low due to the permeable nature of the iron filings wall downgradient of the source area, which will permit groundwater to pass through under natural flow conditions. Alternative 1C will not restrict groundwater flow downward to the lower aquifer.

5.2.2 Evaluation of Alternative 1

Alternative 1 is evaluated in this section using the criteria defined in Section 5.1. A summary of the evaluation of Alternative 1 is provided in Table 3.

Overall Protection of Human Health and the Environment

Alternative 1 does not directly reduce the quantity, volume, or toxicity of COCs that may remain in the soil inside the barrier. Residual contamination may remain in the vadose zone on the Frank Wear property and continue to act as a source for the groundwater.

Alternative 1 does prevent the horizontal flow of groundwater in the upper 50 feet of the aquifer from exiting the footprint of the barrier. Elevated concentrations of COCs will remain in groundwater both inside and outside the barrier for Alternative 1A. Alternatives 1B and 1C provide increased protection beyond the protection provided by Alternative 1A, since a physical barrier is placed around portions of the property followed by *ex situ* and *in situ* groundwater treatment, respectively. Alternative 1A will prevent or restrict the transport of COCs in groundwater from the Frank Wear property, but will not directly address contamination that resides throughout the Frank Wear property as the methods proposed in Alternative 2 do.

Alternative 1B and 1C will directly treat the groundwater that is contained on the Frank Wear property. For Alternatives 1A, it is likely that natural attenuation of COCs in groundwater within the continuous barrier will occur, but at a very slow rate. This attenuation may be offset by the possible presence of residual soil contamination that can release COCs to groundwater. Because of the anticipated slow rate of natural attenuation of COCs and the limited effectiveness of contaminant removal associated groundwater extraction and treatment, Alternative 1B is not expected to achieve CULs for groundwater within the barrier for a very long period of time.

It is estimated that approximately 80 percent of the groundwater within the AOC will continue to flow toward the Yakima River when the barrier is installed. This groundwater is expected to take approximately 50 years to reach the river if short-circuiting does not occur. It is likely that natural attenuation will reduce the concentration of COCs in this groundwater, but it is not possible to determine the amount of time it would take to reduce concentrations to CULs.

Alternative 1 provides a lesser degree of long-term effectiveness than Alternative 2, which actively destroys COCs in groundwater, and Alternative 3, which excavates and disposes of COCs in soils in an off-site engineered, lined, and monitored landfill facility.

Comply with Cleanup Standards and Applicable State and Federal Laws

Alternative 1 does not actively address the COCs in soil at the site, so soil COC concentrations may exceed CULs throughout the site.

Alternative 1B includes the *ex situ* treatment of extracted groundwater with discharge to the local sanitary sewer system. A pretreatment discharge permit will be obtained from the applicable jurisdiction. Air emissions from the air stripping unit will be evaluated to determine compliance with applicable air emission requirements. Additional treatment of the air stream may be necessary to meet emission requirements.

Permanence

Alternatives 1A, 1B, and 1C do not actively treat soils at the site. Alternative 1A will not provide any treatment of groundwater at the site. Alternative 1B treats contaminants in groundwater that is extracted from within the barrier. The contaminants are removed from groundwater by activated carbon adsorption treatment. Thus, the COCs are not destroyed on site; rather, the COCs are destroyed during the regeneration of the spent carbon at an off-site facility. Alternative 1C provides *in situ* removal of COCs in the groundwater flowing from the site. Of the three variations of this alternative, variation 1C offers a more permanent solution over 1A and 1B with the *in situ* removal of contaminants from groundwater.

Alternative 1 is significantly less permanent than Alternative 2, which actively treats the soil and groundwater within the AOC, or Alternative 3, which removes and disposes of contaminated soil within the Frank Wear property.

Cost

A cost estimate and supporting assumptions for this alternative are presented in Appendix A. The conceptual-level (± 35 percent) cost estimate for a continuous barrier (Alternative 1A) around the site is $1.8 million.

The conceptual-level (± 35 percent) cost estimate for a discontinuous barrier around portions of the site with groundwater extraction and treatment (Alternative 1B) is $2.6 million.

The conceptual-level (± 35 percent) cost estimate for a permeable reactive barrier around portions of the site (Alternative 1C) is $3.0 million.

It should be noted that these cost estimates assume 30 years of groundwater compliance monitoring and 30 years of active groundwater extractions and treatment for Alternative 1B. As discussed below, the restoration time frame for Alternative 1 is expected to more than 30 years. Estimated costs for Alternative 1 variations will increase significantly if more than 30 years of groundwater treatment and compliance monitoring are required.

Effectiveness over the Long Term

The technologies employed by Alternative 1 have been successfully demonstrated at this scale at many other locations. It is very likely that the continuous barrier (Alternative 1A) would be effective in containing the upper groundwater within its perimeter. Alternative 1B (discontinuous barrier) is also expected to be effective in containing groundwater on the site with hydraulic control measures.

Alternative 1 does not actively address the COCs in soils on the Frank Wear property. These soils may continue to pose potential risks to human health and the environment and may continue to act as a contaminant source to the groundwater.

Alternative 1 does contain groundwater within the barrier wall. However, impacted groundwater within the AOC, but outside of the barrier wall, will continue to flow toward the Yakima River. This groundwater will continue to pose potential risks to human health and the environment. Institutional controls aimed at protecting the property owner and the adjacent properties owners and their workers (e.g., asphalt pavement, building foundations, excavation controls) will be effective in mitigating the risks posed by the soils and groundwater within the AOC to site workers and visitors to the site.

Alternative 1 provides a lesser degree of long-term effectiveness than Alternative 2, which actively destroys COCs in soil and groundwater to a broader area within the AOC, and Alternative 3, which excavates and disposes of COCs in soils in an engineered, lined, and monitored landfill facility.

Management of Short-Term Risks

Short-term risks to human health and the environment will occur if Alternative 1 is selected. There are potential short-term risks to construction workers during site earthwork but these risks would be minimized with proper construction techniques and appropriate health and safety procedures. The extent of buried utility lines within the proposed barrier footprints is not known. The installation of a barrier wall in the vicinity of these buried lines will expose site workers to the risks inherent in this activity. Developing detailed work plans that will identify the location of known utility lines can mitigate these risks. The work plan can also identify contingency procedures that will be used to incrementally install the barrier in a way that anticipates that some buried utilities may not have been identified on site drawings or detected when underground utility lines were located by geophysical means. A health and safety plan would be developed to address these risks, and the risks associated with working in an area where COCs are known to be present at concentrations above CULs in soil and groundwater.

Active institutional controls and a monitoring program will provide additional protection to property owners and the public who visit the site.

Alternative 1 has more potential short-term risks to human health and the environment than does Alternative 3 (excavation of site soils) based on the scale and depth of excavation. The installation of a barrier wall is considered to have less potential for short-term risks than the operation of a treatment system for a period of several years (Alternative 2).

Technical and Administrative Implementability

Slurry wall and permeable reactive barrier walls are well-developed technologies that could be implemented with a high degree of confidence for this alternative. Trenching to 50 feet will require the use of specialized excavation equipment, but is highly feasible. Bench-scale testing and further site characterization will definitively define the performance specification of each barrier.

The Frank Wear property is located in a commercial area. Access to services, materials, supplies, and skilled labor would be possible. Access for construction, operations, and monitoring would also be possible.

Installation of the barrier wall would be staged to limit interruption of the operations of the adjacent facilities to the extent practicable but some business and traffic interruptions are likely to occur.

In comparing the alternatives, Alternative 1 would require greater design efforts and engineering oversight during construction compared to Alternative 2 and 3.

Restoration Time Frame

Alternative 1 does not directly reduce the toxicity, mobility, or volume of the COCs contained in soil on the site. A source present on the Frank Wear property would be expected to release contaminants to groundwater for an extended period of time. The groundwater treatment components of Alternatives 1B and 1C will be required to operate during this extended period of time. For Alternative 1A, it is likely that the concentration of COCs in the soil or in groundwater below the site will exceed CULs for more than 30 years after the barrier is installed.

Approximately 5.3 million gallons of groundwater reside in the groundwater AOC that will be outside of the barrier proposed by Alternative 1 (refer to Section 3.2.2). It is estimated that approximately 80 percent of this groundwater will continue to flow toward the Yakima River after the barrier is installed. This groundwater is expected to take approximately 50 years to reach the river, although short-circuiting by surface drainages could reduce the time for groundwater COCs to reach the waterway. It is likely that natural attenuation will reduce the concentration of COCs in this groundwater, but it is not possible to determine the amount of time it would take to reduce groundwater concentrations to CULs.

5.3 Alternative 2 — In Situ Treatment

Alternative 2 involves *in situ* treatment of soil and groundwater impacted by PCE and other chlorinated hydrocarbons. This alternative considers the following combinations of remedial technologies and delivery methods:

- Alternative 2A – Air sparging and soil vapor extraction combined with ozone injection;

- Alternative 2B – Bioremediation through application of nutrients and chemical substrates;
  - Variation 1 – Delivery through permanent injection wells;
  - Variation 2 – Delivery via a groundwater recirculation system;

- Alternative 2C – Chemical oxidation using permanganate;
  - Variation 1a – Delivery through permanent injection wells;
  - Variation 1b – Injection through temporary borings; and
  - Variation 2 – Delivery via a groundwater recirculation system.

Alternative 2 was described in detail in Section 4.2 and shown on Figures 8 through 11. Additional site characterization and pilot testing would be conducted prior to and during design of the full-scale remedial installation for most of the options identified above.

For *in situ* treatment options that involve ongoing operation of treatment system equipment, system performance monitoring would be conducted on a monthly or twice-monthly basis (Alternative 2A; Alternative 2B, Variation 2; and Alternative 2C, Variation 2). During performance monitoring events, system equipment operation would be assessed, and any maintenance items would be addressed. For the soil vapor extraction system in Alternative 2A, monitoring of system emissions would be conducted during these events, and may involve collection of summa canister samples of effluent vapor for laboratory analysis or field measurement of emission PCE concentrations using compound-specific colorimetric tubes. Performance sample collection would occur on at least a quarterly basis. Extraction well groundwater samples from the bioremediation groundwater recirculation system would be collected on a monthly basis.

This FS assumes that groundwater compliance monitoring would be conducted on a quarterly basis. The point of compliance is assumed to be throughout the Frank Wear property. Monitoring would involve collection of samples from site groundwater monitoring wells for laboratory analysis by EPA Method 8260B for VOCs. Other analyses may include testing for chromium VI, which could potentially be released from site soils during *in situ* chemical oxidation. This FS assumes that groundwater compliance monitoring would continue for five years after the completion of *in situ* treatment.

5.3.1 Expected Performance of *In Situ* Treatment

The *in situ* treatment options considered in Alternative 2 consist of relatively well-established remediation technologies. Based on experience at sites similar to Frank Wear, it is expected that *in situ* treatment will reduce contaminant mass at the site by either removing mass from the subsurface or by destroying it in place.

One factor on which the success of *in situ* treatment strongly depends is the delivery of the treatment agent (e.g., air, ozone, bioremediation substrate, or permanganate) to the targeted subsurface location where contamination resides. The geology at the Frank Wear site consists of unconsolidated coarse-grained sands, gravels, and cobbles with occasional interbedded lenses of clay and silt. The hydraulic conductivity at a nearby site was estimated to be at least 10^{-2} cm/s. These characteristics indicate high permeability of site soils, which would support injection of air, ozone, biological substrate, permanganate, or combinations thereof.

For some remedial alternatives, pilot-scale testing during remedial design would be conducted to verify the treatability of site groundwater and soil using the technologies described in Alternative 2. Pilot-scale testing would also be conducted to determine design parameters of the selected remedial option, such as radius of influence per well or injection point and the appropriate dosing of the treatment agent being injected, taking into account any subsurface characteristics that might interfere with treatment.

Alternative 2A – Air Sparging, Soil Vapor Extraction, and Ozone Injection

This FS assumes that the air sparging and soil vapor extraction system, combined with ozone injection, would operate for five years. An air sparging/soil vapor extraction system by itself removes VOCs from the subsurface via mass transport processes. This system, however, has limitations, in that as contaminant concentrations in soil and groundwater decrease, it becomes more difficult, and increasingly less cost effective, to remove additional contaminant mass. Soil and groundwater COC concentrations approach asymptotic levels, beyond which additional mass removal becomes less efficient. As such, air sparging and soil vapor extraction systems typically reach a point of diminishing returns, where system operation becomes cost-ineffective. At this point, it is possible that CULs would not have been attained, and subsequent polishing steps would be required. Combining air sparging and soil vapor extraction with ozone injection may enhance *in situ* treatment by supplementing physical removal of COCs with chemical destruction of COCs in place.

Alternative 2B – Bioremediation

This FS assumes that biological substrates would be delivered either in a one-time set of injections (for emulsified oil) or using a continuous delivery strategy (for dextrose). Bioremediation methods result in *in situ* conversion and destruction of contaminants, and tend to promote desorption of soil-sorbed contaminants, thereby avoiding problems with contaminant concentrations approaching asymptotic levels. Though bioremediation is a proven technology, it is difficult to predict the speed and degree of cleanup that will be achieved, based on the complexity of subsurface bacterial communities.

It is possible that multiple injections of emulsified oil would be necessary. However, based on its slow-release nature, it is likely that one thorough round of injections would be sufficient for 3 to 5 years of treatment. Dextrose is a soluble substrate that is readily bioavailable, and does not last long in the subsurface. However, the biomass produced by either emulsified oil or dextrose does tend to be long-lasting, and studies have shown that as bacterial biomass dies over time, it is a very effective electron donor in itself.

Biological reductive dechlorination of PCE proceeds through TCE, cis-DCE, and VC. TCE and VC are more toxic than PCE through some exposure routes, so partial biological treatment that did not proceed to completion has the potential to make the contamination worse. A wide treatment area, frequent groundwater monitoring, and a contingency plan such as an air sparging system (included in the bioremediation options) can help mitigate this risk.

Alternative 2C – Chemical Oxidation using Permanganate

Alternative 2C conservatively assumes that five permanganate injections would be conducted over a period of 3 years. The variation in which permanganate would be applied using a groundwater recirculation system assumes an operating period of 2 years. Multiple injection events are assumed to address potential rebound of groundwater COC concentrations after initial treatment. Rebound may occur as a result of altering subsurface chemical equilibrium conditions during treatment. For example, since permanganate is a non-selective oxidizer, it may react with the organic content of site soil, onto which COCs may be sorbed, which would result in the release of COCs to groundwater. This FS assumes that additional injections would occur at 6-month intervals during the first year after the initial injection, and then annually for the subsequent 2 years.

A potential byproduct of chemical oxidation using permanganate is the formation of manganese dioxide precipitate. Solid precipitation would reduce hydraulic conductivity by reducing soil porosity; however, with the high soil permeability at the Frank Wear site, this is not expected to be a significant issue.

Both ozone and permanganate are non-selective oxidizers, and may react with other oxidizable species in the subsurface (e.g., organic compounds or reduced metals present in soil or groundwater) in addition to the site COCs. This non-selectivity would be factored into the oxidant demand, a treatment parameter that would be assessed as part of pilot-scale testing. Oxidant non-selectivity may also lower cost effectiveness of treatment as COC concentrations decrease, particularly if subsurface oxidant demand were to remain high. However, site geology indicates that soil organic content may be low, which would be further assessed during additional site characterization and pilot-scale testing.

In situ chemical oxidation may produce chromium VI from reduced chromium potentially present in site soil. Chromium VI is a soluble, and thus mobile, form of chromium, and is a known human carcinogen. Presence of chromium in site soil and groundwater should be assessed during additional site characterization and pilot-scale testing. In addition, soil reduction capacity would need to be assessed to estimate how far chromium VI could travel with groundwater flow before being reduced to its immobile and non-carcinogenic form (chromium III).

5.3.2 Evaluation of Alternative 2

Alternative 2 is evaluated in this section using the criteria defined in Section 5.1. A summary of the evaluation of Alternative 2 is provided in Table 3.

Overall Protection of Human Health and the Environment

Alternative 2 would directly reduce the quantity, toxicity, and volume of contaminants in soil and groundwater at the site. However, a risk inherent in biological reduction of PCE is that it could potentially lead to accumulation of TCE or VC if it did not proceed to completion. Chemical oxidation has the potential to release aqueous chromium VI if reduced chromium is present in site soils.

Alternative 2 assumes a treatment depth of 40 feet bgs, which is the depth to which air sparging wells and permanganate injection wells would be installed. With high soil permeability, it is assumed that much of the groundwater above this depth would be treatable within the Frank Wear property. The air sparging, emulsified oil, and permanganate injection options assume installation of remediation wells throughout the Frank Wear property. The groundwater recirculation options for dextrose or permanganate application would also treat the area beneath the former Frank Wear building, where a suspected source area may be located, and the area beneath the children's bookstore building.

Permanganate would have greater potential of providing treatment within neighboring properties, as it is more stable than ozone, and thus would be able to travel further with groundwater flow before being completely consumed through chemical oxidation reactions. This would depend on the organic content of the soil, which would have a strong influence on the rate of consumption of permanganate over time and distance.

Alternative 2 would provide increased protection to human health and the environment relative to the impermeable barriers described in Alternatives 1 or the source control measures described in Alternative 3, since substantial destruction of COCs in soil and groundwater would occur during *in situ* treatment at the site. The treatment achieved by the permeable reactive barrier described in Alternative 1 would be comparable to Alternative 2, but it would occur on a much longer time frame and would not address COC concentrations in site soil. In general, the benefit to human health and the environment from Alternative 2 occurs within a relatively short time frame (compared to Alternatives 1 or 3).

Alternative 2 would not have a negative impact on the potential for natural attenuation at the site. Although ozone and permanganate are strong oxidizers, remedial applications of these oxidizers are not strong enough to cause sterilization of the subsurface microbial community. Additionally, introduction of ozone to the subsurface, along with sparged air, can provide oxygen to stimulate aerobic biodegradation of some COCs.

Comply with Cleanup Standards and Applicable State and Federal Laws

Air sparging and soil vapor extraction would reduce COC concentrations in site soil and groundwater. However, it is known that COC concentrations typically approach asymptotic levels during application of this remedial technology at similar sites, which does not eliminate the possibility that CULs might not be attained. Injection of ozone with sparged air to facilitate *in situ* chemical oxidation may provide additional reduction of COC concentrations at the site.

Relative to physical methods such as air sparging, bioremediation is relatively well suited to removing small amounts of remaining contamination, and is sometimes used as a “polishing” step after other remedial techniques. A point of diminishing returns can be reached if running a recirculation system while concentrations decrease. However, both emulsified oil and dextrose tend to provide some continuing treatment after injections have stopped, through decay of accumulated biomass.

In situ chemical oxidation through application of permanganate may achieve lower COC concentrations than air sparging and soil vapor extraction. However, the cost-effectiveness of permanganate application decreases as COC concentrations decrease, particularly if subsurface oxidant demand is high.

Because these alternatives are performed *in situ*, there are no water discharge permitting requirements associated with the implementation of these alternatives. Alternative 2A, which includes soil vapor extraction, would be evaluated for air emissions to determine compliance with applicable air emission requirements. Additional treatment of the air stream may be necessary to meet emission requirements. All of the options under Alternative 2 would require registration of injection wells with Ecology’s Underground Injection Control Program.

Permanence

Alternative 2 directly reduces the quantity, toxicity, and volume of COCs in site soil and groundwater by either removing COCs from the subsurface or by destroying COC mass in place. This provides greater permanence of treatment than Alternatives 1 or 3 would provide. The permeable reactive barrier described in Alternative 1, however, would provide comparable treatment permanence, except that it would not address impacted soils at the site.

Cost

The estimated conceptual-level cost (± 35 percent) of each variation of Alternative 2 is presented in Appendix A and summarized below:

- Alternative 2A - Air sparging, soil vapor extraction, ozone injection – $1.3 million;

- Alternative 2B - Bioremediation
  - Emulsified oil injections $0.86 million;
  - Groundwater recirculation with dextrose $0.79 million;

- Alternative 2C, Variation 1a - Permanganate injection via permanent wells
  - Sodium permanganate $1.4 million;
  - Potassium permanganate $1.0 million;

- Alternative 2C, Variation 1b - Permanganate injection via temporary borings
  - Sodium permanganate $1.8 million;
  - Potassium permanganate $1.5 million;

- Alternative 2C, Variation 2 - Permanganate application through groundwater recirculation
  - Sodium permanganate $0.99 million;
  - Potassium permanganate $0.86 million.

Effectiveness over the Long Term

Alternative 2 would provide for long-term reduction of COC concentrations by means of active remediation that would permanently remove COC mass or destroy it in place. The technologies considered in Alternative 2 are well-understood and have been demonstrated to be effective at sites similar to Frank Wear. Alternative 2 would be more effective over the long term than Alternatives 1 or 3; however, the permeable reactive barrier described in Alternative 1 may provide active treatment of groundwater for 15 years or more, which would help protect against rebound in groundwater COC concentrations or against migration of COCs onto Frank Wear from off site.

Alternative 2 would not have a negative impact on the potential for natural attenuation at the site, which would enhance long-term effectiveness of treatment. Though ozone and permanganate are strong oxidizers, remedial applications of these oxidizers are not strong enough to cause sterilization of the subsurface microbial community. Additionally, introduction of ozone to the subsurface, along with sparged air, can provide oxygen to stimulate aerobic biodegradation of some COCs.

Management of Short-Term Risks

Short-term risks to human health and the environment would occur if Alternative 2 were implemented. These short-term risks would be present during pilot-scale testing, installation of system infrastructure, and system operation. Detailed work plans would be developed to identify potential implementation issues, and to provide procedures that would be used to resolve these issues. Health and safety plans would be prepared to address risks associated with working in areas where COCs are known to be present at concentrations above CULs in soil and groundwater. Active institutional controls and a worker monitoring program would provide additional protection to site workers and the public.

Short-term risks associated with Alternative 2 may be greater than those associated with Alternatives 1 or 3 due to the longer active treatment periods required in Alternative 2.

Technical and Administrative Implementability

The remedial technologies considered in Alternative 2 are well understood and have been implementable at sites similar to Frank Wear; however, additional site characterization and pilot-scale testing would be required to more fully assess the technical implementability of Alternative 2 specifically at the Frank Wear site. Due to the presence of gravels and cobbles in site soils, drilling operations for well installation at the site would be limited to air rotary or sonic drilling. These types of drilling would be implementable, but at a higher cost than hollow-stem auger drilling or using direct-push technology.

Following completion of pilot-scale testing and remedial design, installation of the air sparging, soil vapor extraction, and ozone injection system could be completed in several months to one year. Installation time would include system startup and optimization, during which time system settings would be adjusted to provide maximum treatment at the greatest possible efficiency. The biological substrate and permanganate injection options could likely be implemented within 6 months after completion of pilot-scale testing and remedial design. Installation and operation of the various options under Alternative 2 would be conducted in a manner to minimize disruptions to activities taking place on neighboring properties.

The options under Alternative 2 would require registration of injection wells with Ecology's Underground Injection Control Program. Additionally, installation of the air sparging and soil vapor extraction system, and the groundwater recirculation systems, may require acquisition of grading and building permits for installation activities such as trenching for sub-grade piping installation and electrical work.

Alternative 2 has greater technical implementability than Alternative 1, which would need to overcome greater technical obstacles to install barriers to depths of over 40 feet bgs. Alternatives 2 and 3 may have comparable implementability.

Restoration Time Frame

Alternative 2 provides active remediation that either removes COC mass from the subsurface or destroys it in place. The restoration time frames provided by the various options under Alternative 2 would be much shorter than those provided by Alternatives 1 or 3, in which COC mass is either only contained, or only groundwater, and not soil, COC mass is treated.

Alternative 2 assumes that the air sparging and soil vapor extraction system with ozone injection would operate for approximately 5 years. It is possible that CULs might not have been reached after this time, and additional polishing steps would be required, which extend restoration time by one or more years. Treatment time frames for biological treatment are difficult to estimate, but an estimated period of approximately 3 years has been used for this FS. As a conservative estimate, it is assumed that CULs would be achieved within 3 years during implementation of the permanganate injection options, and within 2 years during permanganate application using a groundwater recirculation system.

5.4 Alternative 3 — Source Control and Treatment

Alternative 3 consists of the excavation and removal of contaminated soils from the Frank Wear property. The intent of this alternative is to remove the source of chlorinated hydrocarbon contamination in soils on the Frank Wear property from the surface down to approximately 12 feet bgs, which is the upper level of the water table during periods of irrigation. Section 4.3 described Alternative 3 in greater detail.

Alternative 3A considers the further characterization, excavation, removal, and disposal of contaminated soil from the Frank Wear property. A variation of this, Alternative 3B, considers follow up *in situ* soil treatment subsequent to excavation of most of the contaminated soil.

The intent of this alternative is to remove the source of COCs in soil on the Frank Wear property. Based on past characterization and removals and recent groundwater monitoring, contamination appears to be distributed between the west end of the property and under and adjacent to the former building. The purpose of this alternative would be to address residual contamination that was potentially missed by previous removal actions.

The most probable source area on the site appears to be in the vicinity of well MW-10 (see Figure 3) where recent monitoring has detected PCE in the groundwater at concentrations as high as 43,000 µg/L. Additional focus of this alternative would be in the vicinity of the wells SPW-12 and SPW-13 upgradient of MW-10. Recent groundwater monitoring indicated PCE concentrations of approximately 2,500 µg/L in SPW-12 and 1,000 µg/L in SPW-13 (Ecology 2007b). The area to the west of the former dry cleaning building was excavated during a 1995 removal action and previous to that for the removal of a UST (Maxim 1996). Records of the excavations in this area are incomplete and additional characterization and removal may be warranted.

A conservative buffer adjacent to the children's bookstore building would need to be left in place during excavation to prevent undermining of its foundation. The buffer would need to be approximately 70 feet in length by 20 feet in width, and would leave approximately 870 tons of soil on the Frank Wear property down to 12 feet bgs. Alternative 3B would address sources of contamination in the buffer area with multiple injections of potassium permanganate.

Based on difficulties in obtaining soil samples at depth, concurrent site characterization and remediation would occur with use of an on-site laboratory to guide excavations with "real-time" analysis. Excavations guided by an on-site mobile laboratory would address residual contamination in the near-surface soils starting in the above-defined suspected source areas. Further excavation would proceed as necessary to address other areas based on the findings of characterization.

Alternatives 3A assumes groundwater monitoring 30 years from the completion the soil excavation and removal. Long-term monitoring of 13 wells is assumed to occur on a quarterly basis for the first 10 years. Subsequent to that, monitoring would occur on a semi-annual basis.

5.4.1 Expected Performance of Alternative 3

Alternative 3 will directly reduce the quantity or volume of COCs in soil within the boundary of the Frank Wear property. This alternative does not destroy

COCs nor does it prevent the subsequent horizontal flow of contaminated groundwater in the upper aquifer from exiting the Frank Wear site.

Alternative 3A provides for excavation and disposal of Frank Wear property soils to a depth of 12 feet bgs that are present at concentrations above CULs. The total mass of soil that could be excavated under Alternative 3A is approximately 2,250 tons.

The intent of this alternative is to remove the source of COCs present in vadose zone soils on the Frank Wear property. Without recent soil characterization data, it is unknown at this time what mass of PCE would be removed under this alternative. The purpose of this alternative would be to address residual contamination that was potentially missed by previous near-surface excavations at the site.

If a large source of PCE is present in the unsaturated zone, the removal of this soil would directly reduce the amount of PCE contamination continuing to impact groundwater. With the large fluctuations in groundwater levels at this site, a deeper source area may be present in the periodically saturated zone between approximately 12 feet bgs and 20 feet bgs. This alternative would not directly address PCE contamination in this smear zone.

A buffer area adjacent to the children's bookstore cannot be excavated to depths that would undermine the building foundation. Near-surface contamination may be removed, but it is estimated that only the upper few feet can be safely excavated. This buffer area may present the highest likelihood of containing contamination in the unsaturated zone based on recent groundwater data. The remaining soil contamination and a potential source area in the periodically saturated zone would continue to contribute contaminants to groundwater flowing through these properties.

Alternative 3B will directly address the buffer zone with several application of an *in situ* oxidizer. This technology can be applied both to the unsaturated soils and to the periodically saturated zone beneath the site.

In summary, the removal of a near-surface PCE source will directly reduce a contributing element to site groundwater degradation. This alternative does not directly address contaminated groundwater currently present or the off-site migration of impacted groundwater.

5.4.2 Evaluation of Alternative 3

Alternative 3 is evaluated in this section using the criteria defined in Section 5.1. A summary of the evaluation of Alternative 3 is provided in Table 3.

Overall Protection of Human Health and the Environment

Alternative 3 directly reduces the quantity of contaminants in the soil on the site. Alternative 3 would initially provide increased protection to human health and the environment relative to Alternatives 1 and 2 since it physically removes soil COCs from the Frank Wear property. Furthermore, this alternative will potentially eliminate or significantly reduce the soil source of PCE to the groundwater flowing through the Frank Wear property. This alternative does not address groundwater contamination on the Frank Wear or adjacent properties.

Unlike Alternatives 1 and 2, this alternative does not prevent, treat, or hydraulically restrict the horizontal flow of groundwater through the site. Elevated concentrations of COCs will initially remain in the groundwater on Frank Wear and adjacent properties.

Comply with Cleanup Standards and Applicable State and Federal Laws

Ecology has developed CULs for soil and groundwater at the site. Without recent soil characterization data, it is unknown at this time what mass of PCE would be removed with this alternative. Alternative 3A will assure that the concentration of PCE in the unsaturated soil on portions of the Frank Wear property that are excavated will be below CULs. Alternative 3B will further treat soil that cannot be safely excavated to meet the defined CULs for the site.

Elevated concentrations (above CULs) of COCs are expected to remain in groundwater on Frank Wear and adjacent properties under both variation of this alternative.

The off-site disposal of contaminated soils will comply with applicable solid waste disposal requirements.

Permanence

Alternative 3 would directly remove the mass of COCs from the unsaturated soil acting as a source on the Frank Wear property. It is assumed that the excavated soils in Alternative 3 would be disposed in an off-site, engineered, lined, and monitored landfill. Following excavation, clean site soil and clean structural fill would be backfilled into the excavation. Groundwater COCs and sources of soil

COCs outside of the excavation would not be addressed by this alternative and would continue to be present at concentrations that exceed CULs.

In regard to the site soils, this alternative provides more permanence than Alternatives 1 and 2 since COCs are removed from the property and disposed off site. This alternative provides less permanence with regards to groundwater than Alternative 1C and Alternative 2, which actively treats groundwater within the AOC.

Cost

A cost estimate and supporting assumptions for this alternative are presented in Appendix A.

The conceptual-level (± 35 percent) cost estimate for characterization, excavation, and disposal of soils from portions of the site is $1.2 million. The follow on *in situ* treatment of remaining soils add approximately $100,000 to the above costs.

It should be noted that these cost estimates assume 30 years of groundwater compliance monitoring and additional applications of *in situ* soil treatment. The long-term monitoring component accounts for approximately $0.92 million to $0.97 million for Alternatives 3A and 3B, respectively. As discussed above, with significant removal of the source area, the restoration time frame, and monitoring period, would likely be reduced.

Effectiveness over the Long Term

Removal of soils above CULs or removal of the most contaminated soils on the Frank Wear property would reduce the potential for exposure and the amount of COCs that may potentially leach into groundwater.

Alternative 3 does not actively address COCs in groundwater within the Frank Wear property, or soil and groundwater COCs located on adjacent properties. The presence of these COCs at concentrations above CULs will continue to pose potential risks to human health and the environment.

With potentially up to 12 feet of clean fill added to the site, institutional controls aimed at preventing exposure to surface or near-surface contamination can be lessened. Compared with Alternatives 1 and 2, restrictions on access and development can likely be relaxed.

It is estimated that compliance monitoring would be necessary for up to 30 years following remedial action to monitor groundwater COC concentrations as groundwater travels through the site.

With the removal of a possibly large source in the soil, cleanup goals would be expected to be met on a shorter time frame than Alternatives 1A or 1B.

Management of Short-Term Risks

Similar to Alternative 1, risks to human health and the environment will occur if this alternative is selected. Excavation and capping of the buried utility lines on the Frank Wear property will expose site workers to risks inherent in this activity. Additionally, exposure risks to COCs will be present to site workers conducting the excavation and characterization. A health and safety plan would be developed to address these risks, and the risks associated with working in an area where COCs are known to be present at concentrations above CULs in soil and groundwater.

Alternative 3 has less potential short-term risks to human health and the environment than does Alternative 1 (groundwater barrier installation) due to the scale and depth of excavation required in barrier construction. This alternative is also considered to have less potential for short-term risks than the operation of a treatment system for a period of several years (Alternative 2).

Technical and Administrative Implementability

Technologies employed by this alternative are common to the construction industry, and with controls in place to prevent worker exposure, can be readily implemented. The Frank Wear property is located in a mixed commercial and light industrial area in the City of Yakima. Access to services, materials, supplies, and skilled labor would be possible.

Excavation and hauling would be staged to limit disruptions in the operations of the adjacent facilities to the extent practicable, but some business and traffic disruptions are likely to occur. It is estimated that hauling potentially up to 1,600 tons of material will take 5 days.

In comparison to other alternatives, Alternative 3 would require less design efforts and engineering oversight during construction than Alternatives 1 and 2.

Restoration Time Frame

Alternative 3 directly reduces the volume of the COCs contained in soil on the Frank Wear property. Reduction of COC volume would take place in a short time frame, since reduction would occur during implementation of the remedial action Residual COCs may remain in soil outside of excavation limits.

Groundwater is not directly addressed by Alternative 3. Sources of soil contamination outside the excavation would continue to degrade groundwater within the AOC potentially for a long period of time. Groundwater is expected to take more than approximately 50 years to reach the Yakima River, although short-circuiting by surface drainages could reduce the time for groundwater COCs to reach the river. It is likely that some natural attenuation will reduce concentration of COCs in this groundwater, but it is not possible to determine the amount of time it would take to reduce COC concentrations to CULs.

6.0 PREFERRED ALTERNATIVE

Based on the evaluation of all of the alternatives, Variation 2 of Alternative 2B (*in situ* bioremediation using a groundwater recirculation system with dextrose) provides the lowest cost alternative that is protective and satisfies the evaluation criteria described in Section 5.1. *In situ bioremediation* is a well-established remediation technology that is effective in reducing contaminant mass and concentrations through the conversion and destruction of chlorinated VOC contaminants, and desorption of soil-sorbed contaminants. Substrate delivery via recirculation provides an effective and flexible option for ensuring treatment of contaminants throughout the treatment zone.

In this alternative, groundwater is continuously extracted from three downgradient extraction wells, amended with dextrose, and reinjected into the subsurface at three upgradient injection wells. Existing groundwater monitoring wells, MW-2, SPW-12, and SPW-13 would be used as injection wells. MW-9 and two new wells would be used as extraction wells. Injections and recirculation would occur over a 12-month period, with 500 pounds of dextrose substrate added each month. It was assumed that after 12 months, the recirculation system would be turned off and that the dextrose substrate would likely be consumed within several months after this time. It is anticipated that the decay of subsurface biomass built up during the recirculation period would continue to provide treatment for a year or more. In the event that contaminant concentrations persist, additional dextrose injections and recirculation could be implemented. Additionally, if PCE breakdown products, primarily VC, accumulated to levels of concern, then recirculation of the groundwater could continue without dextrose injections. This will provide hydraulic control and ensure that complete reduction of all chlorinated VOCs to ethene, ethane, and methane occurs throughout the treatment zone.

The expected performance of the *in situ* bioremediation alternative in attaining site CULs within the AOC, and within a reasonable time frame is high. Based on experiences at other sites with similar geology and contaminant concentrations, we anticipate that this alternative will have a probability of 95 percent or more in attaining the CULs within a 3 to 5 year period. Although *in situ* bioremediation is a proven technology, its overall performance with respect to the degree of cleanup and remediation time frame will be a function of the site geology and the ability to distribute dextrose throughout the treatment zone, and the presence of residual or unknown sources of contaminants.

The total cost for this alternative, including capital and long-term compliance monitoring costs, was estimated to be $790,000. Therefore, this alternative is the preferred alternative for addressing soil and groundwater contamination at the Frank Wear site.

Variation 2 of Alternatives 2C (*in situ* chemical oxidation using potassium permanganate injections with a recirculation system), and Variation 1 of Alternative 2B (*in situ* bioremediation using emulsified oil injections), provide the next two lowest cost alternatives that are protective and satisfy the evaluation criteria. If the preferred alternative cannot be implemented at the site, then either one of these two alternatives is preferred.

7.0 REFERENCES

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Table 1 – MTCA Method B Cleanup Levels (CULs)
Frank Wear Site

Chemical Group	Contaminant of Concern	Soil CUL in µg/kg	Groundwater CUL in µg/L
VOC	Perchloroethylene (PCE)	19.6	5.0*
VOC	Chloroform	717	7.17
VOC	cis-1,2-dichloroethene	8,000	80
VOC	Trichloroethene (TCE)	398	3.98
VOC	1,1,1-trichloroethane	720,000	7,200
VOC	1,1,1,2-tetrachloroethane	168	1.68
VOC	1,2-dichlorobenzene	72,000	720
VOC	Chlorobenzene	16,000	160
VOC	1,2-dichloroethane	48.1	0.481
VOC	trans-1,3-dichloropropene	24.3	0.243

* This is not a MTCA Method B Groundwater Cleanup Level, but a site-specific one.

Table 2 - Remedial Technology Screening Summary
Frank Wear Site

General Response Action	Remedial Technology	Process Options	Description	Retained	Screening Comments [a]	FS Alternative [b]
No Action	None	None	Rely on natural attenuation to reduce concentration to acceptable levels.	Yes	Retained for baseline comparison.	All
Institutional Controls	Access Restrictions	Deed restrictions	Provide restrictions to prevent access to groundwater and impacted soil.	Yes	Would be combined with other technologies.	All
	Alternate Water Supply	Hook up distribution system, new supply well	Provide an alternate supply of drinking water.	No	Impacted groundwater is not a drinking water source at the site.	NA
	Monitoring	Monitoring wells	Ongoing monitoring.	Yes	Would be combined with other technologies.	All
Containment	Capping	Soil, clay cap, asphalt, concrete, synthetic liner, multilayer cap	Placement of cap or soil cover to minimize infiltration and contaminant migration.	Yes	Would be combined with other technologies (e.g., air sparging and soil vapor extraction).	2
	Vertical Barriers	Slurry wall, sheet piling	Placement of vertical, low-permeability barriers to minimize contaminant migration.	Yes	May be combined with hydraulic control technologies.	1
	Hydraulic Control	Extraction wells/trenches, reinjection wells/trenches	Modify the groundwater gradient to minimize off-site migration of contaminants.	Yes	May be combined with other technologies (e.g., vertical barriers).	1
In Situ Treatment	Air Sparging	In well, in formation	Removal of volatile contaminants through air injection, recovery of air at the surface.	Yes	Potentially effective, implementable, and cost-effective. Air/vapor recovery via soil vapor extraction and capping.	2
	Enhanced Bioremediation	Carbon source/nutrient addition, anaerobic, in well, circulation wells, injection in formation	Enhance biodegradation through modification of subsurface chemistry.	Yes	Potentially effective, implementable, and cost-effective.	2
	Chemical Treatment	Oxidation, reduction, in well, circulation wells, injection in formation	Injection of chemicals for *in situ* treatment of contaminants.	Yes	Potentially effective, implementable, and cost-effective.	2
	Thermal Treatment	Injection of hot air/water/steam, electrical resistance heating, radio frequency heating	Removal of strippable contaminants through application of heat, recovery of vapor at surface.	No	Low cost-effectiveness. Generally higher costs compared to other *in situ* treatment technologies.	NA
	Hydrofracturing	Variety of fluids, pumping schedules	Improve soil permeability to enhance contact between contaminant and remediation technology.	No	Site soils already have relatively high permeability.	NA
	Permeable Reactive Barriers	Zero-valent iron, carbon/nutrient source	Install reactive barrier across flow path of contaminant plume for abiotic/biotic treatment.	Yes	Potentially effective, implementable, and cost-effective.	1

Table 2 - Remedial Technology Screening Summary
Frank Wear Site

General Response Action	Remedial Technology	Process Options	Description	Retained	Screening Comments [a]	FS Alternative [b]
	Soil Vapor Extraction	Horizontal vents, vertical vents	Removal of volatile contaminants through extraction, recovery of vapor at surface.	Yes	Would be combined with other technologies (e.g., air sparging and capping).	2
	Soil Flushing	Water, surfactants, solvents	Removal of leachable contaminants, recovery of leachate at surface.	No	Low effectiveness; higher risk of contaminant mobilization.	NA
Ex Situ Treatment [c]	Air Stripping	Packed tower, diffused aeration, tray aeration, spray aeration	Removal of volatile contaminants through volatilization in above-ground reactor.	Yes	Potentially effective, implementable, and cost-effective.	1
	Bioremediation	Fixed-film, anaerobic filters	Biological treatment of groundwater in above-ground bioreactor.	No	Difficult implementability and low cost-effectiveness.	NA
	Adsorption	Activated carbon, other media	Removal of adsorbable contaminants using a series of carbon canisters.	Yes	Potentially effective, implementable, and cost-effective.	1
	Advanced Oxidation	Ozone, hydrogen peroxide, UV light combinations	Break down organic contaminants through chemical oxidation.	No	Difficult implementability and low cost-effectiveness. High maintenance requirements and costs.	NA
	Ion Exchange	Cationic, anionic	Removal of exchangeable ions by passing groundwater through a resin bed.	No	Not effective for PCE.	NA
	Membrane Processes	Reverse osmosis, ultrafiltration, pervaporation	Removal of dissolved contaminants through various membrane separation processes.	No	Difficult implementability and low cost-effectiveness (typically combined with soil flushing technology).	NA
	Chemical Treatment	Oxidation, reduction	Addition of chemicals for *ex situ* treatment of contaminants.	No	Difficult implementability and low cost-effectiveness. High maintenance requirements and costs.	NA
	Soil Vapor Extraction	Vented soil stockpiles	Removal of volatile contaminants through application of vacuum, recovery of vapor.	Yes	Potentially effective, implementable, and cost-effective. Dependent on excavated soil contaminant concentrations.	3
	Soil Washing	Water, surfactants, solvents	Removal of leachable contaminants, recovery of leachate.	No	Difficult implementability and low cost-effectiveness. Not applicable to site conditions.	NA
	Soil Thermal Desorption	Rotary dryer, thermal screw	Removal of volatile contaminants through application of heat, recovery of volatiles.	No	Difficult implementability and low cost-effectiveness.	NA
	Soil Off-Site Disposal	Landfill, incineration, biological treatment	Impacted soil is removed from the site, treated, and disposed of at a licensed facility.	Yes	Potentially effective, implementable, and cost-effective.	3

Table 2 - Remedial Technology Screening Summary
Frank Wear Site

General Response Action	Remedial Technology	Process Options	Description	Retained	Screening Comments [a]	FS Alternative [b]
Air Emissions/Off-Gas Treatment [d]	Adsorption	Activated carbon	Removal of adsorbable contaminants using a series of carbon canisters.	Yes	Potentially effective, implementable, and cost-effective.	2 & 3
	Oxidation	Catalytic, thermal, internal combustion, UV	Organic contaminants are destroyed in a high-temperature combustor.	No	Low cost-effectiveness. High maintenance requirements and costs.	NA
	High-Energy Destruction	Plasma	High-voltage electricity is used to destroy organic contaminants.	No	Low cost-effectiveness. High maintenance requirements and costs.	NA

Notes:
NA - Not applicable.
a) Technical feasibility criteria evaluated as part of initial technology screening include technology effectiveness (short- and long-term, reduction in toxicity, mobility, and/or volume), implementability, and cost.
b) Feasibility study (FS) remedial alternatives are (1) containment with groundwater treatment, (2) in situ treatment, and (3) source control and treatment.
c) Ex situ remedial technologies assume groundwater pumping and/or soil excavation.
d) Air emissions/off-gas treatment technologies assume capture and treatment of contaminant vapors generated by other remedial technologies.

Table 3 - Summary of Detailed Analysis of Alternatives
Frank Wear Site

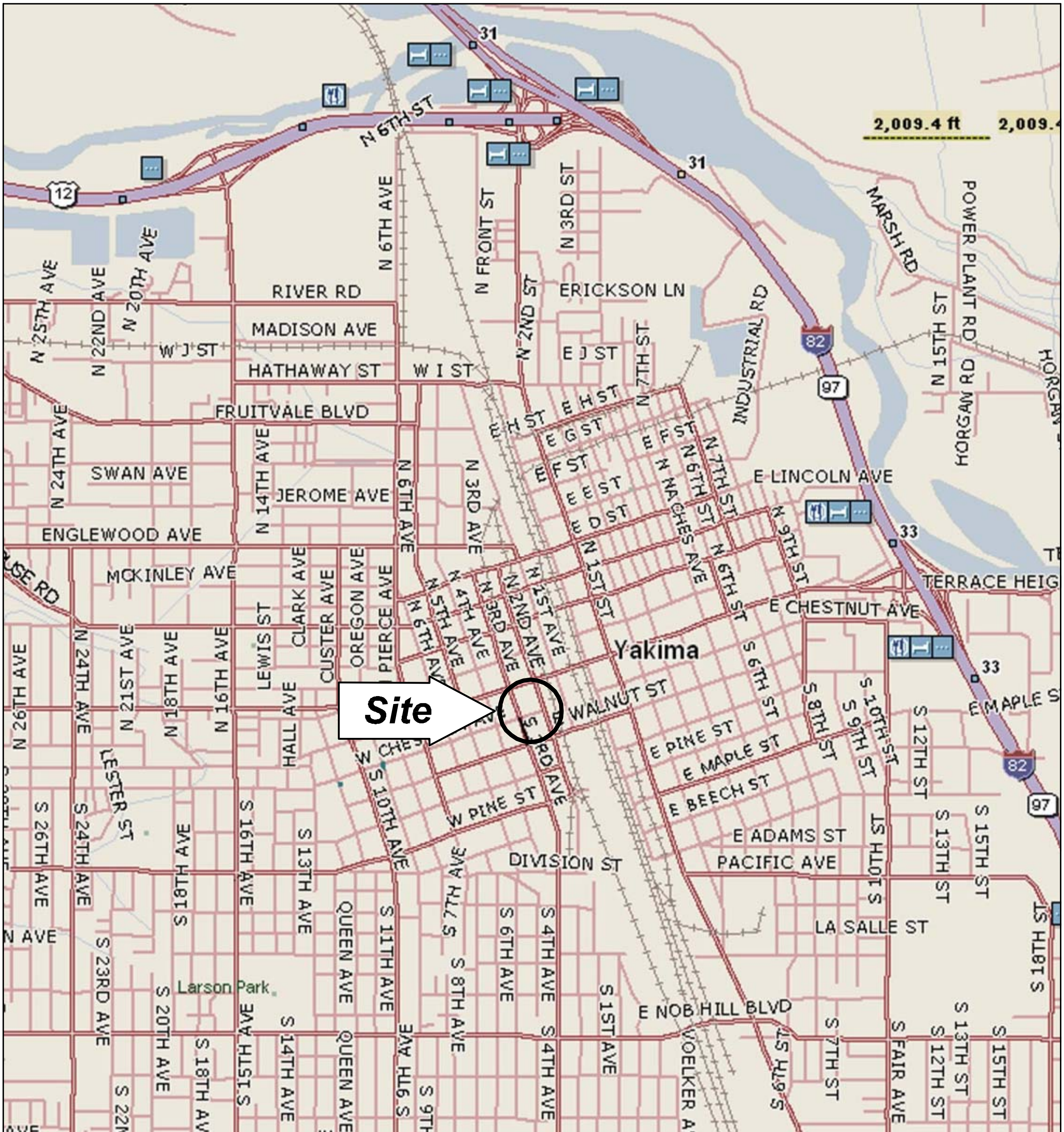
Criteria	Alternative 1A	Alternative 1B	Alternative 1C	Alternative 2A	Alternative 2B	Alternative 2C	Alternative 3A	Alternative 3B
Overall Protection of Human Health and the Environment	Alternative 1A does not directly reduce the quantity, volume, or toxicity of COCs that may remain in the soil inside the barrier. Alternative 1A does prevent the horizontal flow of groundwater in the upper 50 feet of the aquifer from exiting the footprint of the barrier. Elevated concentrations of COCs will remain in groundwater both inside and outside the barrier for Alternative 1A.	Alternative 1B does not directly reduce the quantity, volume, or toxicity of COCs that may remain in the soil inside the barrier. Alternative 1B does allow off-site groundwater to flow onto the site but will prevent the horizontal flow of groundwater in the upper 50 feet of the aquifer from exiting the footprint of the barrier. Elevated concentrations of COCs in groundwater will be treated inside the barrier. Elevated concentrations of COCs in groundwater outside of the barrier will not be treated by this alternative.	Alternative 1C does not directly reduce the quantity, volume, or toxicity of COCs that may remain in the soil inside the barrier. Alternative 1C does provide *in-situ* treatment of impacted groundwater exiting the footprint of the barrier. Elevated concentrations of COCs will remain in groundwater outside the barrier for Alternative 1C.	Alternative 2A would directly reduce the quantity, toxicity, and volume of contaminants in soil and groundwater on the Site. However, chemical oxidation has the potential to release aqueous chromium VI if reduced chromium is present in site soils.	Alternative 2B would directly reduce the quantity, toxicity, and volume of contaminants in soil and groundwater on the Site. However, a risk inherent in biological reduction of PCE is that it could potentially lead to accumulation of TCE or VC if it did not proceed to completion.	Alternative 2 would directly reduce the quantity, toxicity, and volume of contaminants in soil and groundwater on the Site. However, chemical oxidation has the potential to release aqueous chromium VI if reduced chromium is present in site soils.	Alternative 3A directly reduces the quantity of contaminants in the soil on the Site. Unlike Alternatives 1 and 2, this alternative does not prevent, treat, or hydraulically restrict the horizontal flow of groundwater through the Site. Elevated concentrations of COCs will initially remain in the groundwater on Frank Wear and adjacent properties. Alternative 3A is likely to leave contaminated soil on the Frank Wear property adjacent to the neighboring building.	Alternative 3B directly reduces the quantity of contaminants in the soil on the Site. Unlike Alternatives 1 and 2, this alternative does not prevent, treat, or hydraulically restrict the horizontal flow of groundwater through the Site. Elevated concentrations of COCs will initially remain in the groundwater on Frank Wear and adjacent properties.
Comply with Cleanup Standards	Alternative 1A does not actively address the COCs in soil at the Site, so soil COC concentrations may exceed CULs throughout the Site. Alternative 1A will prevent COCs in groundwater within the barrier footprint from reaching the Yakima River.	Alternative 1A does not actively address the COCs in soil at the Site, so soil COC concentrations may exceed CULs throughout the Site. Alternative 1B will retain and treat groundwater within the barrier footprint. Groundwater outside of the barrier will not be addressed by this alternative.	Alternative 1C does not actively address the COCs in soil at the Site, so soil COC concentrations may exceed CULs throughout the Site. Alternative 1C will likely ensure that groundwater exiting the site through the PRB will meet CULs. Groundwater outside of the barrier footprint will not be addressed by this alternative.	Air sparging and soil vapor extraction would reduce COC concentrations in Site soil and groundwater. However, it is known that COC concentrations typically approach asymptotic levels during application of this remedial technology at similar sites, which does not eliminate the possibility that CULs might not be attained. Injection of ozone with sparged air to facilitate *in situ* chemical oxidation may provide additional reduction of COC concentrations at the Site.	Relative to physical methods such as air sparging, bioremediation is relatively well suited to removing small amounts of remaining contamination, and is sometimes used as a "polishing" step after other remedial techniques. A point of diminishing returns can be reached if running a recirculation system while concentrations decrease. However, both emulsified oil and dextrose tend to provide some continuing treatment after injections have stopped, through decay of accumulated biomass.	*In situ* chemical oxidation through application of permanganate may achieve lower COC concentrations than air sparging and soil vapor extraction. However, the cost-effectiveness of permanganate application decreases as COC concentrations decrease, particularly if subsurface oxidant demand is high.	Alternative 3A will assure that the concentration of PCE in the unsaturated soils that can be safely excavated on the Frank Wear property are below CULs. This alternative does not address contaminated groundwater and it is likely that concentrations will remain above the CULs following remedial action.	Alternative 3B will assure that the concentration of PCE in the unsaturated soils on the Frank Wear property are below CULs. This alternative does not address contaminated groundwater and it is likely that concentrations will remain above the CULs following remedial action.

Table 3 - Summary of Detailed Analysis of Alternatives
Frank Wear Site

Criteria	Alternative 1A	Alternative 1B	Alternative 1C	Alternative 2A	Alternative 2B	Alternative 2C	Alternative 3A	Alternative 3B
Permanence	Alternative 1A does not actively treat soils at the Site and will not provide any treatment of groundwater at the Site.	Alternative 1B does not actively treat soils at the Site. Alternative 1B treats the portion of the contaminants present within the groundwater that is extracted from within the barrier. The contaminants are removed from groundwater by activated carbon. Groundwater outside of the barrier will not be addressed by this alternative.	Alternative 1C does not actively treat soils at the Site. Alternative 1C provides *in situ* removal of COCs in the groundwater flowing from the Site through the PRB. Groundwater outside of the barrier will not be addressed by this alternative.	Alternative 2A directly reduces the quantity, toxicity, and volume of COCs in Site soil and groundwater by either removing COCs from the subsurface or by destroying COC mass in place.	Alternative 2B directly reduces the quantity, toxicity, and volume of COCs in Site soil and groundwater by destroying COC mass in place.	Alternative 2C directly reduces the quantity, toxicity, and volume of COCs in Site soil and groundwater by destroying COC mass in place.	Alternative 3A would directly remove the majority of the COCs from the unsaturated soil on the Frank Wear property acting as a source. It is assumed that Alternative 3A would dispose of excavated soils from the Frank Wear property in an engineered, lined, and monitored Subtitle D landfill.	Alternative 3B would directly remove or treat with *in situ* methods the COCs from the unsaturated soil on the Frank Wear property acting as a source. It is assumed that Alternative 3B would dispose of excavated soils from the Frank Wear property in an engineered, lined, and monitored Subtitle D landfill. This alternative would also provide for on-site destruction of COCs.
Effectiveness over the Long Term	Alternative 1A would be effective in containing the upper groundwater within its perimeter. Alternative 1A does not actively address the COCs in soils on the Frank Wear property. These soils may continue to pose potential risks to human health and the environment and may continue to act as a source to the groundwater. Alternative 1A does contain groundwater within the barrier. However, impacted groundwater within the AOC but outside of the barrier will continue to flow toward the Yakima River.	Alternative 1B would be effective in containing the upper groundwater within its perimeter and extracting and treating impacted groundwater. Alternative 1B does not actively address the COCs in soils on the Frank Wear property. These soils may continue to pose potential risks to human health and the environment and may continue to act as a source to the groundwater. The contaminants will be removed with the groundwater treatment system by activated carbon. This activated carbon will be regenerated off-site. Impacted groundwater within the AOC but outside of the barrier will continue to flow toward the Yakima River.	Alternative 1C would be effective in containing and treating the upper groundwater within its perimeter. Alternative 1C does not actively address the COCs in soils on the Frank Wear property or impacted groundwater within the AOC but outside of the barrier. Alternative 1C will destroy COCs flowing from the Frank Wear property with *in situ* methods.	Alternative 2A would provide for long-term reduction of contaminant concentrations by means of active remediation that would permanently remove COC mass or destroy it in place. The technologies considered in Alternative 2A are understood well and have been known to be effective at sites similar to Frank Wear.	Alternative 2B would provide for long-term reduction of contaminant concentrations by means of active remediation that would destroy COC mass in place. The technologies considered in Alternative 2B are understood well and have been known to be effective at sites similar to Frank Wear.	Alternative 2C would provide for long-term reduction of contaminant concentrations by means of active remediation that would destroy COC mass in place. The technologies considered in Alternative 2C are understood well and have been known to be effective at sites similar to Frank Wear.	Removal of soils above CULs or removal of the most contaminated soils on the Frank Wear property would reduce the potential for exposure and the amount of COCs that may potentially leach into groundwater. Alternative 3A does not actively address COCs in groundwater within the Frank Wear property, or soil and groundwater COCs located on adjacent properties. The presence of these COCs at concentrations above CULs will continue to pose potential risks to human health and the environment.	Removal or treatment of soils above CULs on the Frank Wear property would reduce the potential for exposure and the amount of COCs that may potentially leach into groundwater. Alternative 3B does not actively address COCs in groundwater within the Frank Wear property, or soil and groundwater COCs located on adjacent properties. The presence of these COCs at concentrations above CULs will continue to pose potential risks to human health and the environment.

Table 3 - Summary of Detailed Analysis of Alternatives
Frank Wear Site

Criteria	Alternative 1A	Alternative 1B	Alternative 1C	Alternative 2A	Alternative 2B	Alternative 2C	Alternative 3A	Alternative 3B
Management of Short-Term Risks	Short-term risks to human health and the environment will occur if Alternative 1A is selected. The risks are associated with buried utility lines, excavation to 50-feet BGS, and worker contact with COCs. Developing detailed work plans and a site health and safety plan will mitigate these risks.	Short-term risks to human health and the environment will occur if Alternative 1B is selected. The risks are associated with buried utility lines, excavation to 50-feet BGS, and worker contact with COCs. Developing detailed work plans and a site health and safety plan will mitigate these risks.	Short-term risks to human health and the environment will occur if Alternative 1C is selected. The risks are associated with buried utility lines, excavation to 50-feet BGS, and worker contact with COCs. Developing detailed work plans and a site health and safety plan will mitigate these risks.	Short-term risks to human health and the environment would occur if Alternative 2A were implemented. These short-term risks would be present during pilot-scale testing, installation of system infrastructure, and system operation. Risk would be managed through preparation of contingency and health and safety plans, in addition to implementation of institutional controls.	Short-term risks to human health and the environment would occur if Alternative 2B were implemented. These short-term risks would be present during installation of system infrastructure and system operation. Risk would be managed through preparation of contingency and health and safety plans, in addition to implementation of institutional controls.	Short-term risks to human health and the environment would occur if Alternative 2C were implemented. These short-term risks would be present during pilot-scale testing, installation of system infrastructure, and system operation. Risk would be managed through preparation of contingency and health and safety plans, in addition to implementation of institutional controls.	Excavation and capping of the buried utility lines on the Frank Wear property will expose site workers to risks inherent in this activity. Additionally, exposure risks to COCs will be present to site workers conducting the excavation and characterization. A health and safety plan would be developed to address these risks.	Excavation and capping of the buried utility lines on the Frank Wear property will expose site workers to risks inherent in this activity. Additionally, exposure risks to COCs will be present to site workers conducting the excavation and characterization. A health and safety plan would be developed to address these risks.
Technical and Administrative Implementability	Installation of slurry walls is a well-developed technology that could be implemented with a high degree of confidence for this alternative. Trenching to 50 feet will require the use of specialized excavation equipment but is highly feasible. Bench-scale testing and further site characterization will definitively define the performance specification of each barrier.	Installation of slurry walls is a well-developed technology that could be implemented with a high degree of confidence for this alternative. Trenching to 50 feet will require the use of specialized excavation equipment but is highly feasible. Bench scale testing and further site characterization will definitively define the performance specification of each barrier.	Installation of slurry walls and permeable reactive barriers are well-developed technologies that could be implemented with a high degree of confidence for this alternative. Trenching to 50 feet will require the use of specialized excavation equipment but is highly feasible. Bench-scale testing and further site characterization will definitively define the performance specification of each barrier.	The remedial technologies considered in Alternative 2A are well understood and have been implementable at sites similar to Frank Wear; however, additional Site characterization and pilot-scale testing would be required to more fully assess the technical implementability of Alternative 2A specifically at the Site. Alternative 2A would require registration of injection wells with Ecology's Underground Injection Control Program.	The remedial technologies considered in Alternative 2B are well understood and have been implementable at sites similar to Frank Wear; however, additional Site characterization would be required to more fully assess the technical implementability of Alternative 2B specifically at the Site. Alternative 2B would require registration of injection wells with Ecology's Underground Injection Control Program.	The remedial technologies considered in Alternative 2C are well understood and have been implementable at sites similar to Frank Wear; however, additional Site characterization and pilot-scale testing would be required to more fully assess the technical implementability of Alternative 2C specifically at the Site. Alternative 2C would require registration of injection wells with Ecology's Underground Injection Control Program.	Risks to human health and the environment will occur if this alternative is selected. Excavation and capping of the buried utility lines on the Frank Wear property will expose site workers to risks inherent in this activity. Additionally, exposure risks to COCs will be present to site workers conducting the excavation and characterization. Detailed work plans and a health and safety plan would be developed to address and mitigate these risks.	Risks to human health and the environment will occur if this alternative is selected. Excavation and capping of the buried utility lines on the Frank Wear property will expose site workers to risks inherent in this activity. Additionally, exposure risks to COCs will be present to site workers conducting the excavation and characterization. Detailed work plans and a health and safety plan would be developed to address and mitigate these risks.
Restoration Time Frame	Alternative 1A does not directly reduce the toxicity, mobility, or volume of the COCs contained in soil on the Site or groundwater outside of the barrier footprint. Estimated restoration timeframe is 30 years.	Alternative 1B does not directly reduce the toxicity, mobility, or volume of the COCs contained in soil on the Site or groundwater outside of the barrier footprint. Estimated restoration timeframe is 30 years.	Alternative 1C does not directly reduce the toxicity, mobility, or volume of the COCs contained in soil on the Site or groundwater outside of the barrier footprint. Estimated restoration timeframe is 30 years.	Estimated 10 years, including groundwater compliance monitoring.	Estimated 8 years, including groundwater compliance monitoring.	Estimated 8 years, including groundwater compliance monitoring.	Estimated 30 years, including groundwater compliance monitoring.	Estimated 30 years, including groundwater compliance monitoring.
Conceptual-Level Cost (NPV, +/-35 percent)	$1.8 million	$2.6 million	$3.0 million	$1.3 million	$0.79 million to $0.86 million	$0.86 million to $1.8 million	$1.2 million	$1.3 million



Source: Base map prepared from Delorme Street Atlas USA, 2006.

WASHINGTON

N

0 2000 4000

Scale in Feet

Frank Wear Site

Yakima, Washington

Vicinity Map

17330-08 7/07

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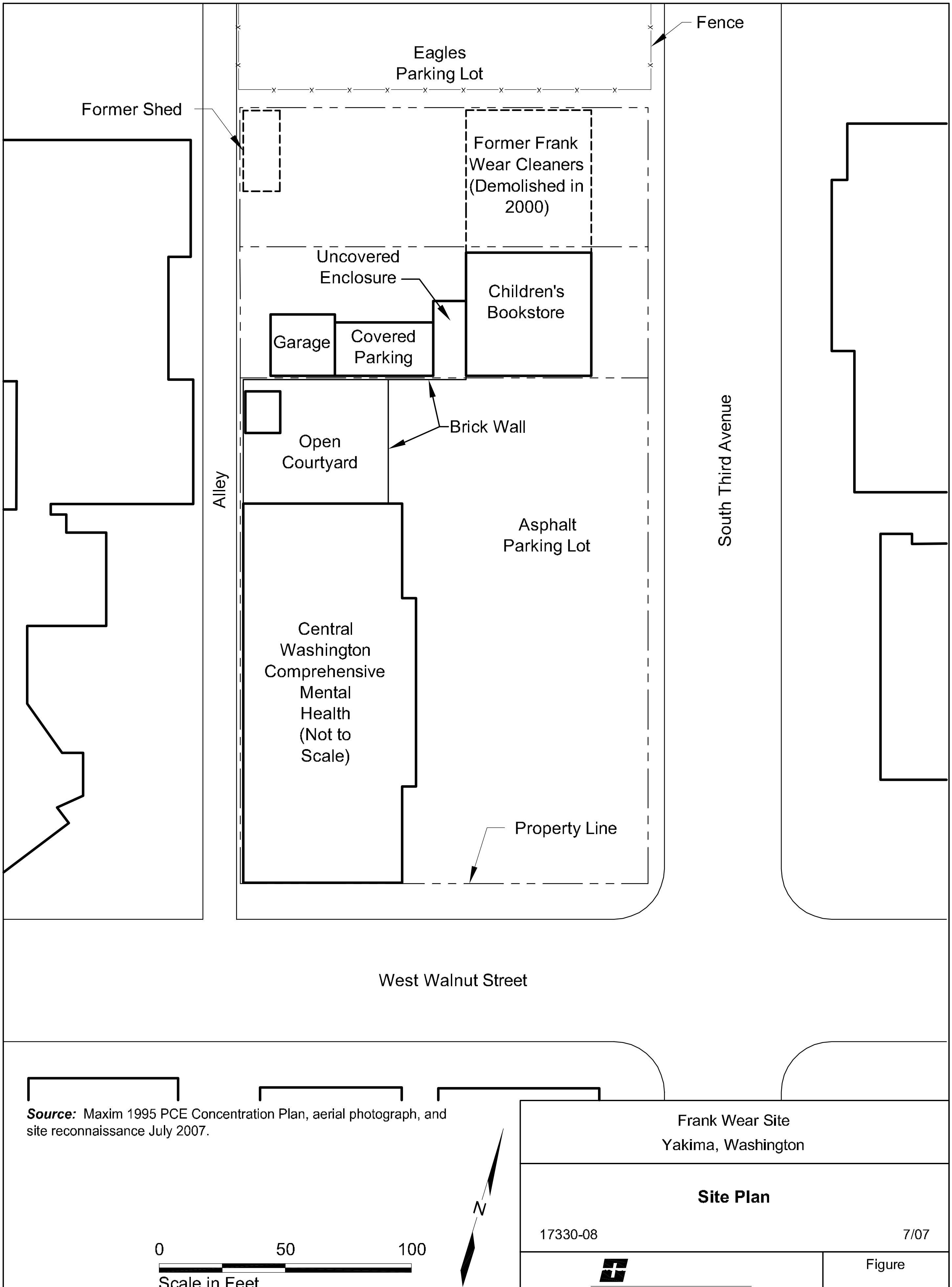
Figure

1

EAL 07/31/07 1733008-002.dwg



Source: Maxim 1995 PCE Concentration Plan, aerial photograph, and site reconnaissance July 2007.

Frank Wear Site
Yakima, Washington

Site Plan

17330-08 7/07

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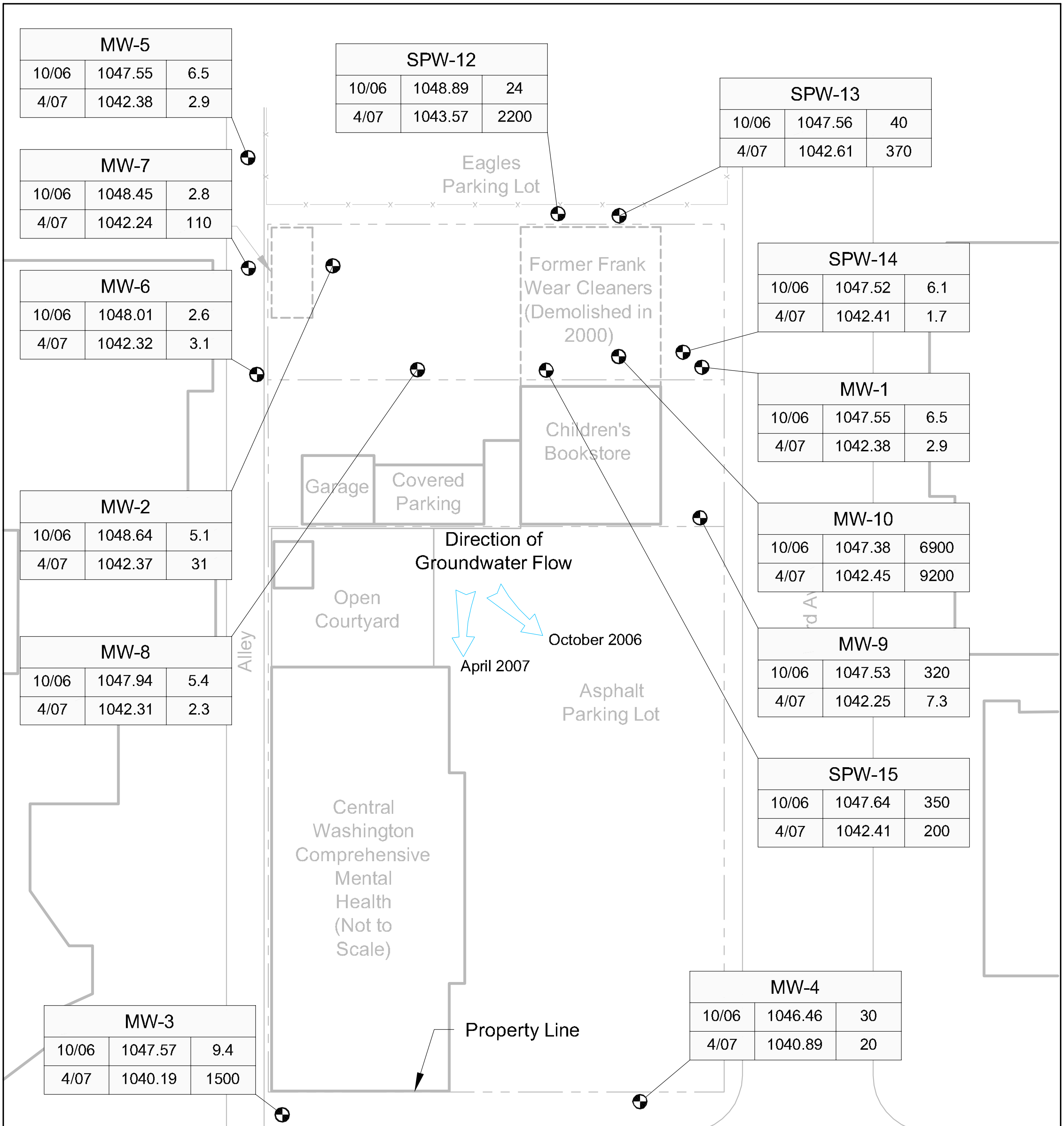
Figure **2**

EAL 07/31/07 1733008-001.dwg



Source: Maxim 1995 PCE Concentration Plan, aerial photograph, and site reconnaissance July 2007.

0 50 100
Scale in Feet

MW-8 ⊕ Groundwater Monitoring Well Location and Number

MW-1		
10/06	1047.55	6.5
4/07	1042.38	2.9

Monitoring Well Number
PCE Concentration in µg/L
Groundwater Elevation in Feet
Date Sampled

N

Notes:
1. Monitoring well locations are approximate.

Frank Wear Site
Yakima, Washington

Recent Groundwater Elevations and PCE Concentrations

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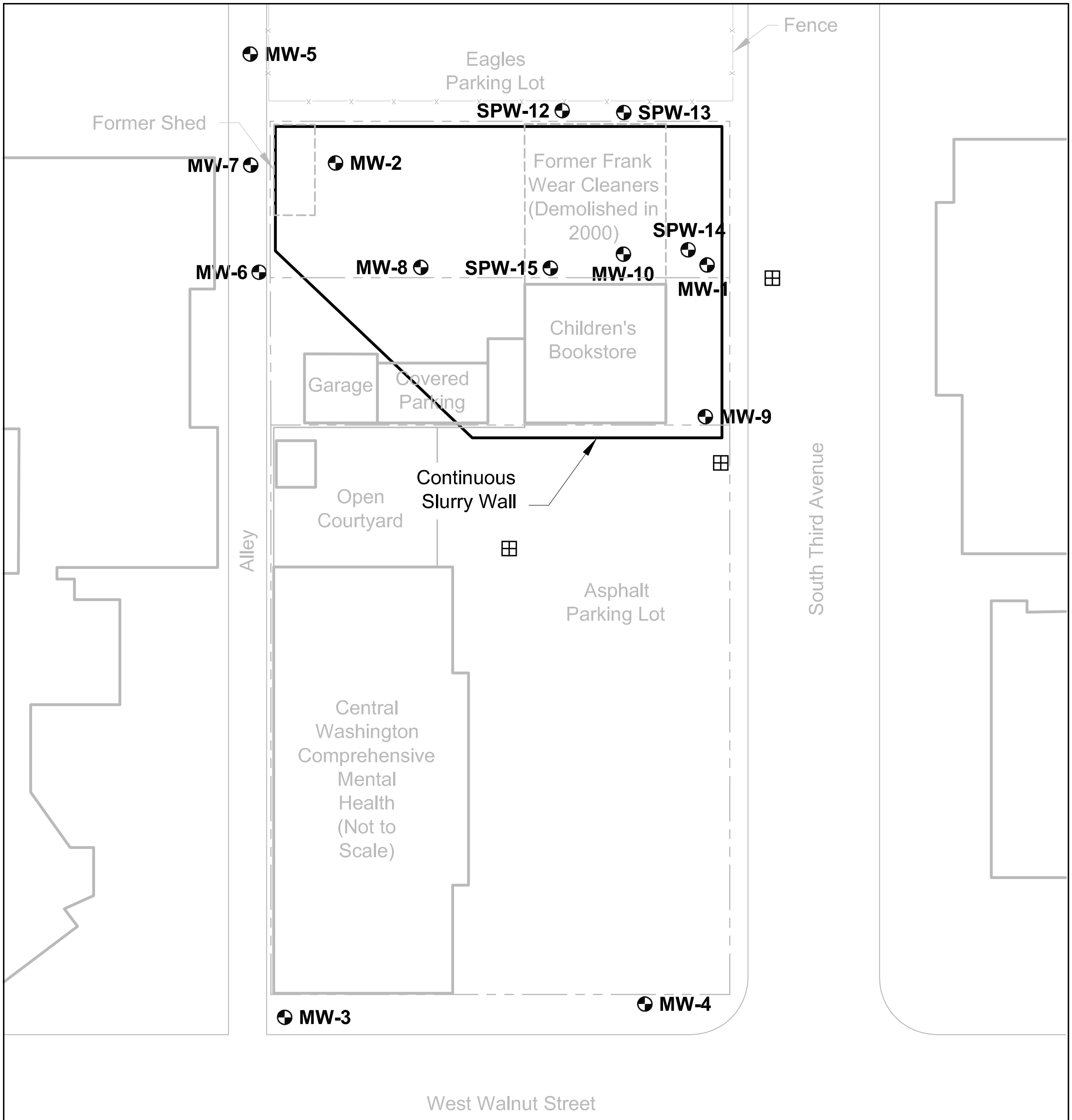
Figure
3

EAL 07/31/07 1733008-012.dwg



Source: Maxim 1995 PCE Concentration Plan, aerial photograph, and site reconnaissance July 2007.

0 50 100
Scale in Feet

MW-8 ⊕ Existing Monitoring Well Location and Number

⊞ Proposed Monitoring Well Location

Notes:
1. Barrier construction assumes demo and reconstruction of the covered parking structure on the Children's Bookstore property.
2. New upgradient monitoring well should replace MW-5 in an upgradient location not impacted by PCE. Not shown on figure.

N

Frank Wear Site
Yakima, Washington

Full Barrier Location Plan

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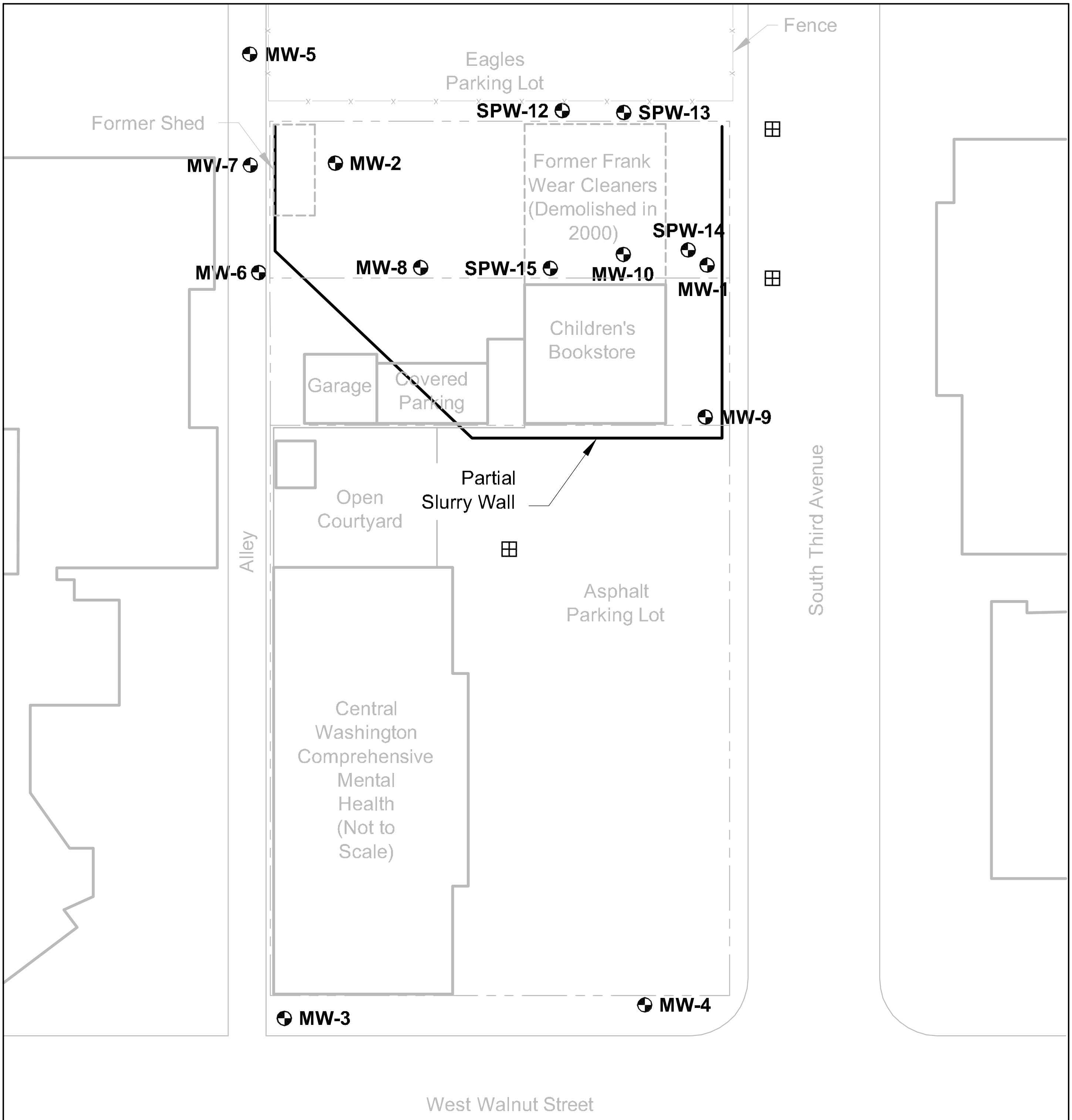
Figure
4

EAL 07/31/07 1733008-003.dwg



Source: Maxim 1995 PCE Concentration Plan, aerial photograph, and site reconnaissance July 2007.

MW-8 ⊕ Existing Monitoring Well Location and Number

⊞ Proposed Monitoring Well Location

Notes:

1. Barrier construction assumes demo and reconstruction of the covered parking structure on the Children's Bookstore property.
2. New upgradient monitoring well should replace MW-5 in an upgradient location not impacted by PCE. Not shown on figure.
3. It is estimated that five extraction wells will be required to maintain hydraulic control. Extraction wells can be converted from existing wells or newly installed. Not shown on figure.

Frank Wear Site
Yakima, Washington

Partial Barrier Location Plan

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Figure **5**

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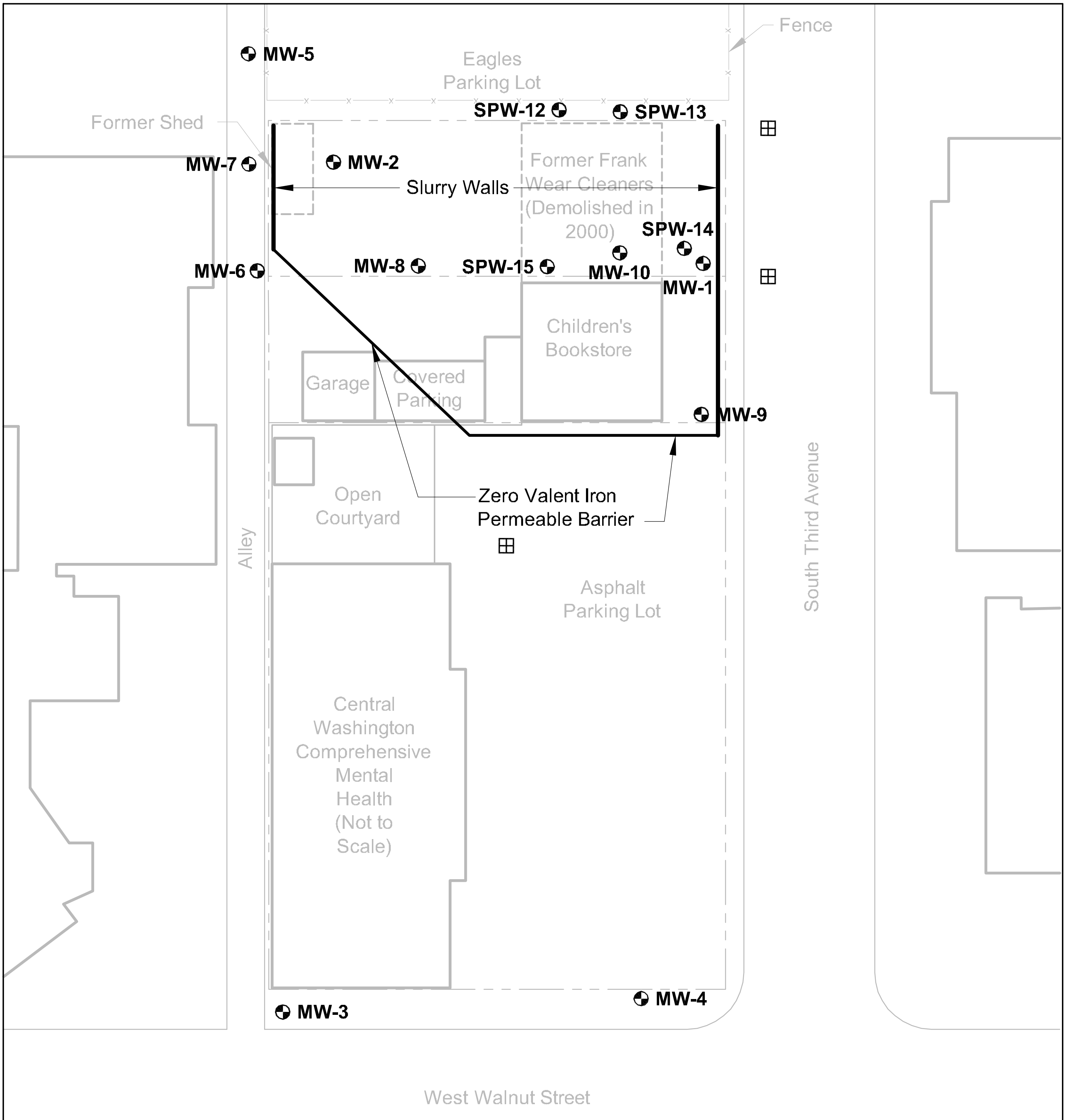

Source: Maxim 1995 PCE Concentration Plan, aerial photograph, and site reconnaissance July 2007.

MW-8 ⊕ Existing Monitoring Well Location and Number

⊞ Proposed Monitoring Well Location

Notes:

1. Barrier construction assumes demo and reconstruction of the covered parking structure on the Children's Bookstore property.
2. New upgradient monitoring well should replace MW-5 in an upgradient location not impacted by PCE. Not shown on figure.
3. It is estimated that five extraction wells will be required to maintain hydraulic control. Extraction wells can be converted from existing wells or newly installed. Not shown on figure.

Frank Wear Site
Yakima, Washington

Permeable Reactive Barrier Location Plan

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Figure 6

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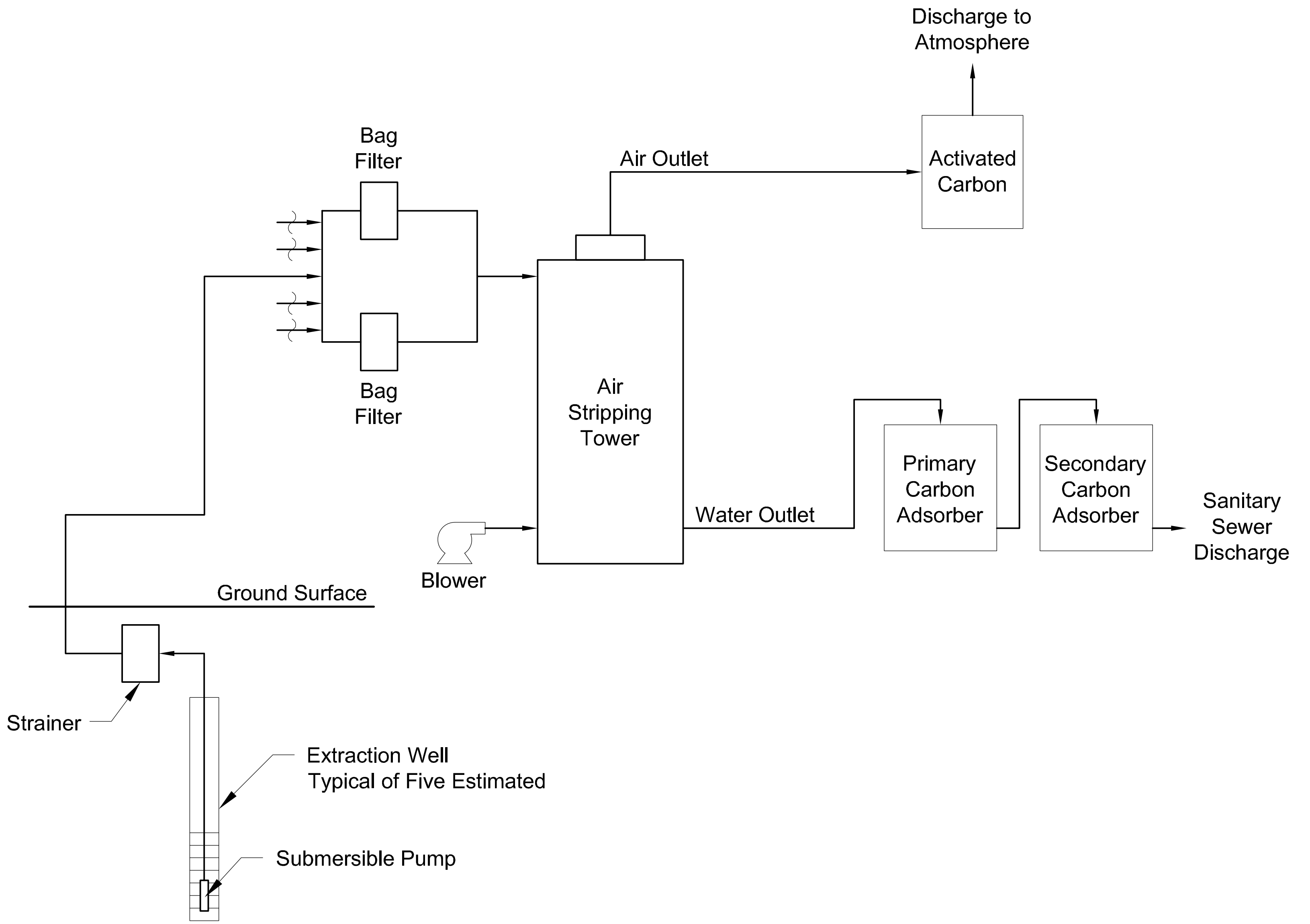

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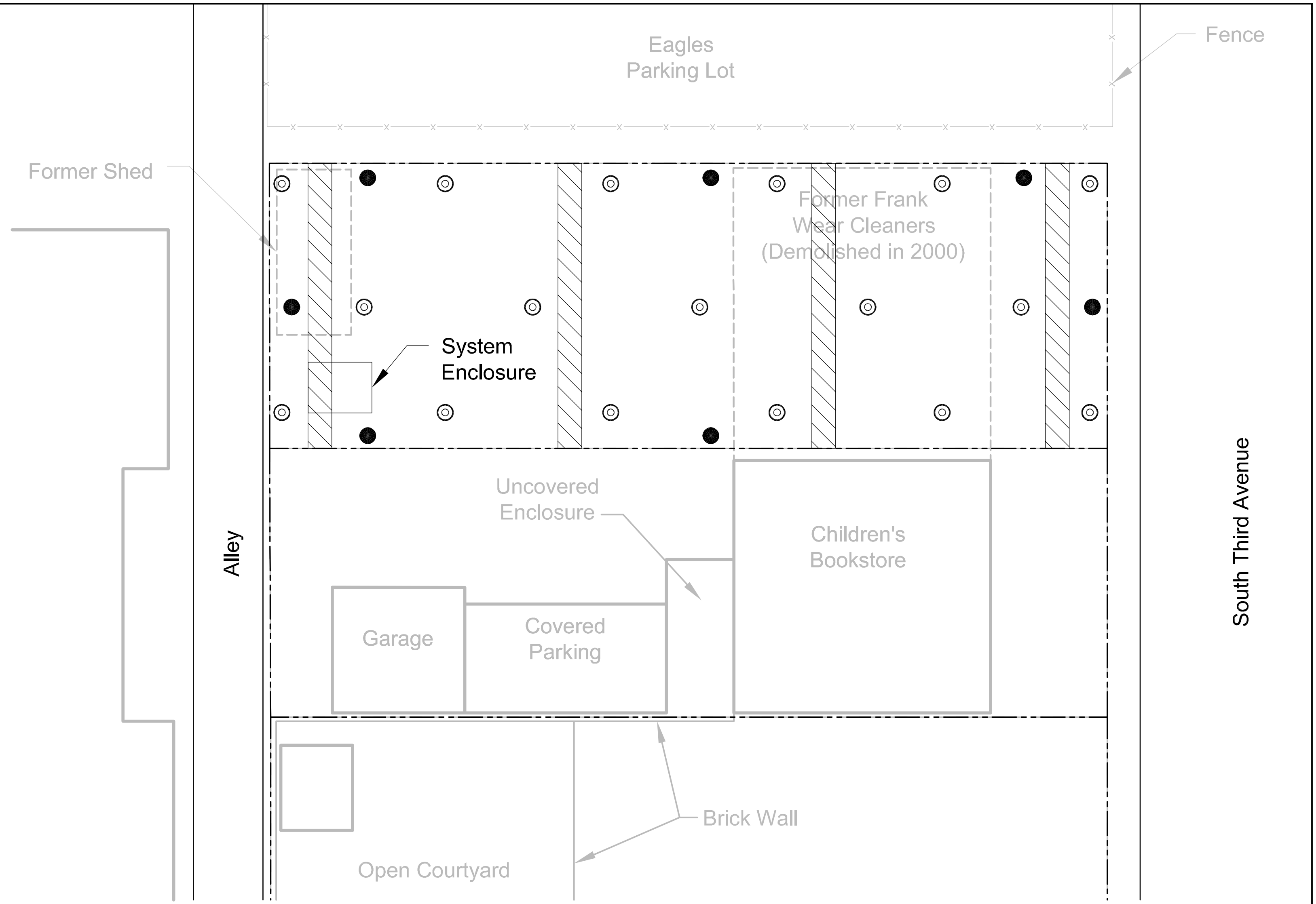
Process Flow Diagram for Groundwater Treatment

Frank Wear Site
Yakima, Washington

Figure 7

EAL 07/31/07 1733008-009.dwg



Source: Maxim 1995 PCE Concentration Plan, aerial photograph, and site reconnaissance July 2007.

N

0 30 60
Scale in Feet

Proposed Air Sparging Well Location

Proposed Soil Vapor Extraction Well Location (Vertical)

Proposed Soil Vapor Extraction Vent Location (Horizontal)

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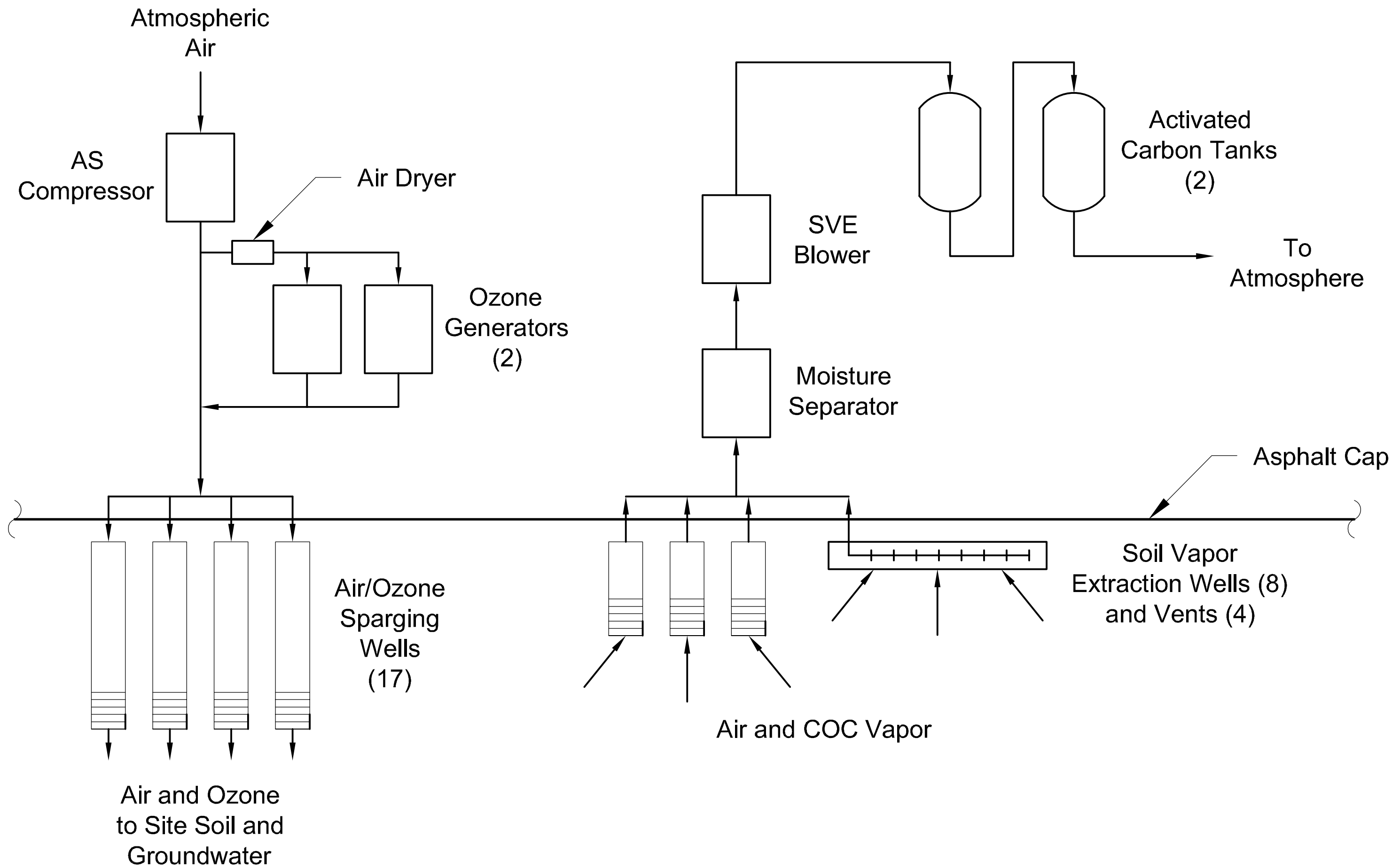
Air Sparging and Soil Vapor Extraction Well Location Plan

Frank Wear Site
Yakima, Washington

Figure **8**

EAL 07/31/07 1733008-007.dwg



Frank Wear Site
Yakima, Washington

Process Flow Diagram for Air Sparging, Soil Vapor Extraction, and Ozone Injection

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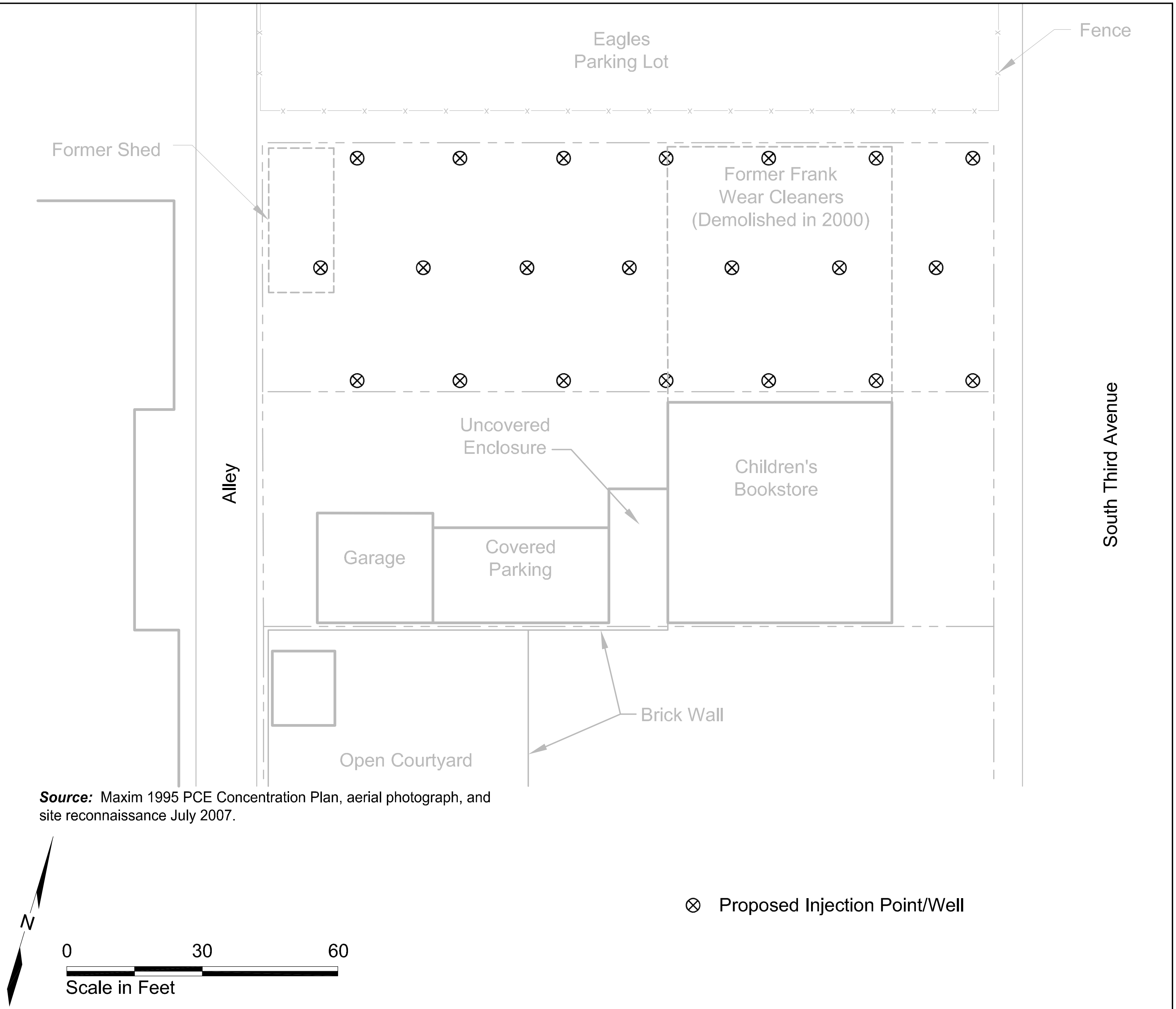
Figure **9**

EAL 07/31/07 1733008-008.dwg



Source: Maxim 1995 PCE Concentration Plan, aerial photograph, and site reconnaissance July 2007.

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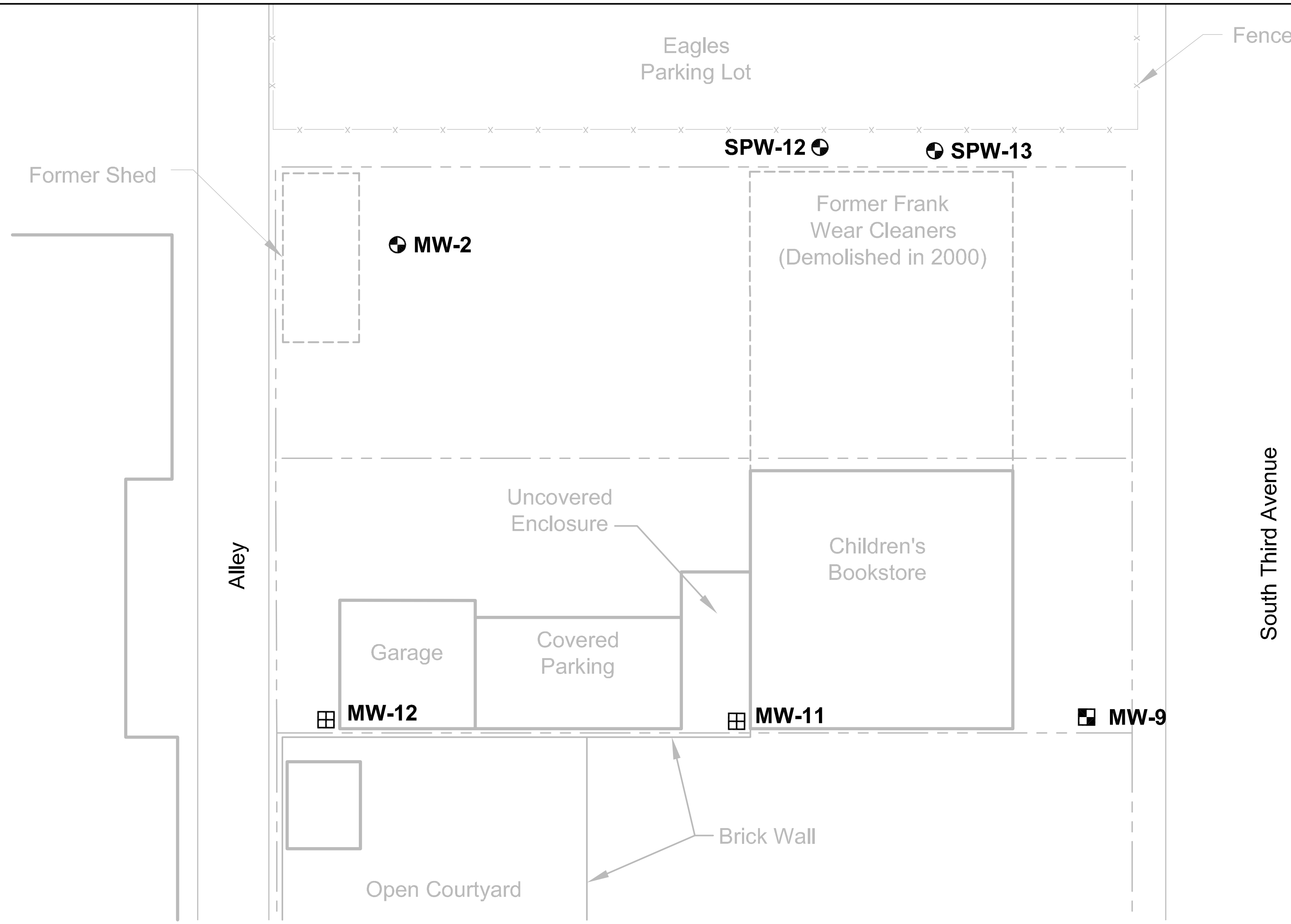
Injection Point/Well Location Plan

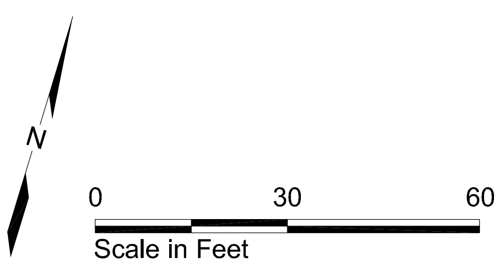
Frank Wear Site
Yakima, Washington

Figure **10**

EAL 07/31/07 1733008-010.dwg



Source: Maxim 1995 PCE Concentration Plan, aerial photograph, and site reconnaissance July 2007.



MW-2 Existing Injection Well Location and Number

MW-9 Existing Extraction Well Location and Number

MW-11 Proposed Extraction Well Location and Number

Frank Wear Site
Yakima, Washington

Bioremediation and Chemical Oxidation Groundwater Recirculation Well Location Plan

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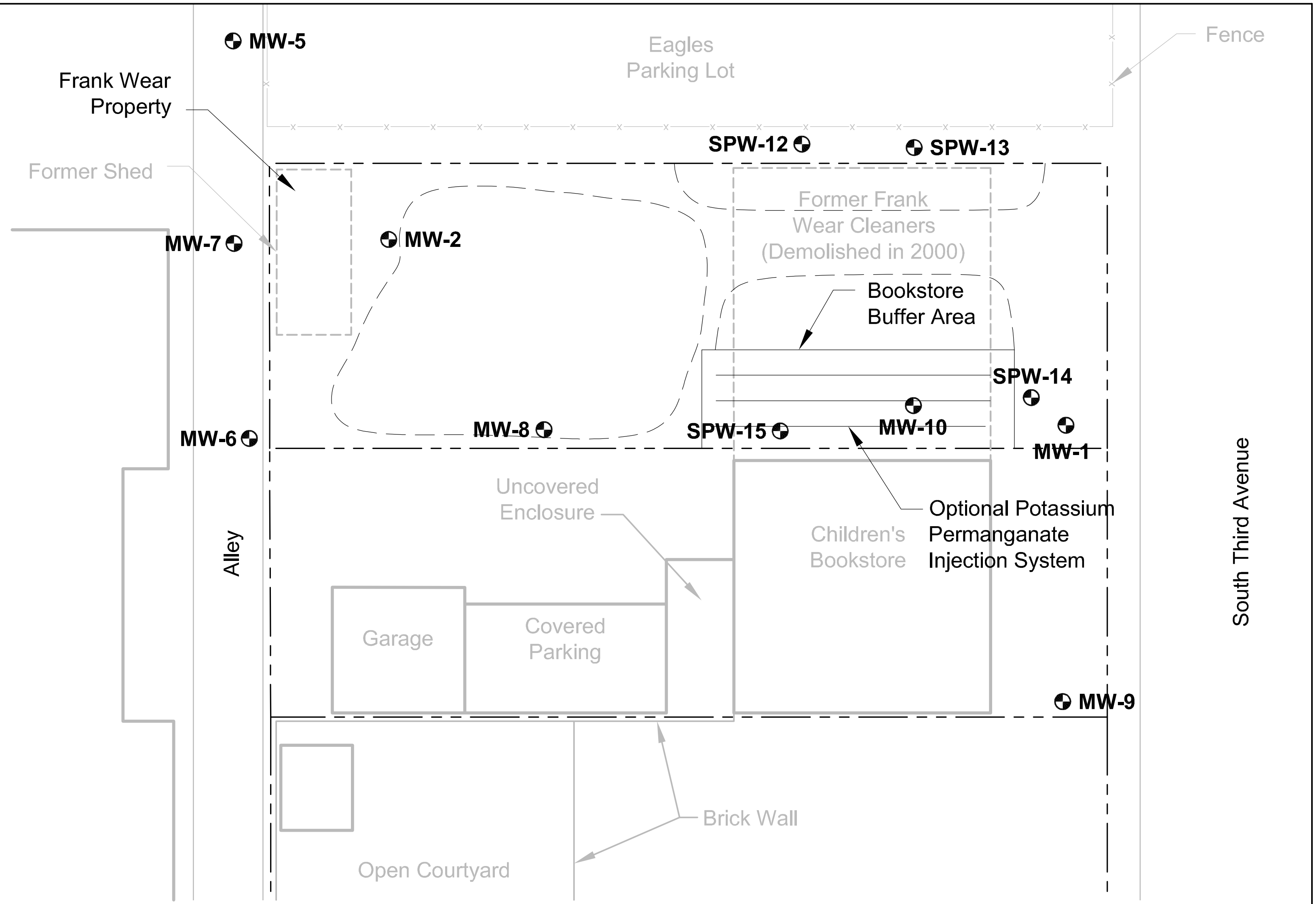
Figure **11**



Source: Maxim 1995 PCE Concentration Plan, aerial photograph, and site reconnaissance July 2007.

0 30 60
Scale in Feet

MW-2 ⊕ Existing Monitoring Well Location and Number

— — — Proposed Areas of Excavation

Notes:

1. Limits of excavation would be the Frank Wear property boundary.
2. An approximate 20- x 70-foot buffer will be left adjacent to the bookstore to prevent foundation damage.
3. Critical wells damaged or destroyed during excavation would be replaced in their approximate current locations. These wells include MW-10, SPW-15, MW-1, MW-2, and MW-8.

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7/07

Proposed Excavation Plan

Frank Wear Site
Yakima, Washington

Figure
12

APPENDIX A
COST ESTIMATES FOR ALTERNATIVES 1 THROUGH 3

Table A - Cost Estimate Summary for Alternatives 1 through 3

Site: Frank Wear Site

Location: 106 South 3rd Avenue, Yakima, WA

Phase: Feasibility Study (-35% to +35%)

Base Year: 2007

DESCRIPTION	ESTIMATED COST	-35%	+35%	COST TABLE REFERENCE
Alt 1A Continuous slurry wall barrier around site perimeter	**$ 1,769,951**	$ 1,150,468	$ 2,389,434	Table A.1a
Alt 1B Partial slurry wall barrier with groundwater treatment	**$ 2,611,290**	$ 1,697,338	$ 3,525,241	Table A.1b
Alt 1C Funnel and gate system around portions of site perimeter	**$ 2,950,791**	$ 1,918,014	$ 3,983,568	Table A.1c
Alt 2A Air sparging and soil vapor extraction with ozone injection	**$ 1,306,683**	$ 849,344	$ 1,764,022	Table A.2a
Alt 2B-1 Emulsified oil injections	**$ 864,509**	$ 561,931	$ 1,167,087	Table A.2b.1
Alt 2B-2 Groundwater recirculation with dextrose	**$ 790,126**	$ 513,582	$ 1,066,670	Table A.2b.2
Alt 2C-1a In-situ chemical oxidation via permanganate injection wells				
Sodium permanganate	**$ 1,360,916**	$ 884,595	$ 1,837,237	Table A.2c.1a
Potassium permanganate	**$ 1,048,610**	$ 681,596	$ 1,415,623	Table A.2c.1a
Alt 2C-1b In-situ chemical oxidation via permanganate injection borings				
Sodium permanganate	**$ 1,837,529**	$ 1,194,394	$ 2,480,664	Table A.2c.1b
Potassium permanganate	**$ 1,484,318**	$ 964,807	$ 2,003,830	Table A.2c.1b
Alt 2C-2 In-situ chemical oxidation via permanganate recirculation				
Sodium permanganate	**$ 989,105**	$ 642,918	$ 1,335,292	Table A.2c.2
Potassium permanganate	**$ 855,694**	$ 556,201	$ 1,155,187	Table A.2c.2
Alt 3A Excavation and disposal of site soils with groundwater monitoring	**$ 1,173,838**	$ 762,994	$ 1,584,681	Table A.3a
Alt 3B Excavation and disposal of site soils with in-situ soil treatment & groundwater monitoring	**$ 1,278,426**	$ 830,977	$ 1,725,875	Table A.3b

Table A.1a - Cost Estimate for Continuous Slurry Wall Barrier around Frank Wear and Adjoining Properties.

Site: Frank Wear Site

Location: 106 South 3rd Avenue, Yakima, WA

Phase: Feasibility Study (-35% to +35%)

Base Year: 2007

Description: Alternative 1 Variation A consists of a slurry wall around the entire perimeter of the Frank Ware property and portions of the adjoining properties. This alternative will include quarterly groundwater sampling years 1-10, and semi-annual groundwater sampling in years 11-30.

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL
Site Prep				
Permits	1	lump sum	$ 5,000	$ 5,000
Utility locate	1	lump sum	$ 500	$ 500
Temporary fencing	1	lump sum	$ 1,000	$ 1,000
Site Prep Subtotal				**$ 6,500**
Slurry Wall Installation				
Contractor mobilization/demobilization	1	lump sum	$ 60,000	$ 60,000
Slurry wall barrier	25,750	sq. ft.	$ 16	$ 412,000
Soil testing for disposal	12	ea.	$ 415	$ 4,984
Utility work	1	lump sum	$ 15,000	$ 15,000
Transport & disposal of contaminated soil (non-hazardous)	967	tons	$ 60	$ 58,041
Transport & disposal of clean soil	415	tons	$ 11	$ 4,560
Demo and replacement of covered parking structure	1	LS	$ 50,000	$ 50,000
Sidewalk	660	SF	$ 3.60	$ 2,376
Repaving	570	SF	$ 2	$ 1,140
Slurry Wall Installation Subtotal				**$ 608,101**
Monitoring Well Installation				
Monitoring wells (2")	3	ea.	$ 4,945	**$ 14,834**
Total Construction Cost				**$ 629,435**
Other Remediation Costs				
Project management and design	--	--	12%	$ 75,532
Construction oversight	--	--	10%	$ 62,944
Contingency	--	--	15%	$ 94,415
Other Remediation Cost Subtotal				**$ 232,891**
Total Capital Cost				**$ 862,326**
Additional Costs	**Sum PV Factor = 15.37**		**i = 5%**	
Compliance Monitoring Costs (30 Years)				
Years 1-10 - Quarterly sampling	1	Annual	$ 590,087	$ 590,087
Years 11-30 - Semi-annual sampling	1	Annual	$ 298,375	$ 298,375
5 Yr MTCA review, reporting, & negotiating	1	Annual	$ 19,163	$ 19,163
Annual Monitoring Cost Subtotal				**$ 907,625**
Total Remediation Cost				**$ 1,769,951**
Low (-35%)				**$ 1,150,468**
High (+35%)				**$ 2,389,434**

Table A.1a - Cost Estimate for Continuous Slurry Wall Barrier around Frank Wear and Adjoining Properties.

Notes:
Cost for slurry wall includes excavation 3 foot wide by 50 foot deep around site perimeter (515 feet), stockpiling of excavated soil, slurry mixing, slurry backfill, and finish to below gravel/pavement grade. Output is assumed to be 100-125 LF/day for slurry wall construction.
Utility work includes uncovering, breaking and capping, and reconnecting following barrier installation and recovering. Number may be conservative based on actual location and number of utilities.
Assume soil density of 1.4 ton/cy.
Soil sampling will be for VOC, RCRA 8 metals, and assumes 3 samples for TCLP-metals. Includes sample courier.
From Site to Roosevelt Transfer Station, approx 110 miles RT. A rate of $100.50/hour for a 3-axle 16 ton dump truck which includes rental, O&M, the operator, and an oiler/spotter for loading. Disposal of non-hazardous soil based on verbal quote from Rabanco.

Table A.1b - Cost Estimate for Partial Slurry Wall Barrier around Frank Wear and Adjoining Properties.

Site:	Frank Wear Site	**Description:** Alternative 1 Variation B consists of a partial slurry wall around the down gradint sides of the Frank Ware property and portions of the adjoining properties. The groundwater retained/retarded by the wall will be treated. This alternative will include quarterly groundwater sampling years 1-10, and semi-annual groundwater sampling in years 11-30.
Location:	106 South 3rd Avenue, Yakima, WA	
Phase:	Feasibility Study (-35% to +35%)	
Base Year:	2007	

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL
Site Prep				
Permits	1	lump sum	$ 5,000	$ 5,000
Utility locate	1	lump sum	$ 500	$ 500
Temporary fencing	1	lump sum	$ 1,000	$ 1,000
Site Prep Subtotal				**$ 6,500**
Slurry Wall Installation				
Contractor mobilization/demobilization	1	lump sum	$ 60,000	$ 60,000
Slurry wall barrier	15,000	sq. ft.	$ 16	$ 240,000
Soil testing for disposal	11	ea.	$ 415	$ 4,565
Transport & disposal of contaminated soil (non-haz)	242	tons	$ 60	$ 14,490
Transport & disposal of clean soil	564	tons	$ 11	$ 6,199
Utility work	1	lump sum	$ 15,000	$ 15,000
Demo and replacement of covered parking structure	1	LS	$ 50,000	$ 50,000
Sidewalk	660	SF	$ 3.60	$ 2,376
Repaving	570	SF	$ 2	$ 1,140
Slurry Wall Installation Subtotal				**$ 393,770**
Pump and Treat System				
Permanent Treatment System				
Extraction wells (8")	5	ea.	$ 4,500	$ 22,500
System installation	1	lump sum	$ 110,000	$ 110,000
Treated water cost	11,300,400	gal./yr	$ 0.005	$ 55,725
Permanent Treatment System Subtotal				**$ 188,225**
Engineering and Support Costs				
Pilot scale testing	1	lump sum	$ 10,000	$ 10,000
Permanent Treatment Total				**$ 198,225**
Monitoring Well Installation				
Monitoring wells (2")	4	ea.	$ 4,945	**$ 19,779**
Total Construction Cost				**$ 618,274**
Other Remediation Costs				
Project management and design	--	--	12%	$ 74,193
Construction oversight	--	--	10%	$ 61,827
Contingency	--	--	15%	$ 92,741
Other Remediation Cost Subtotal				**$ 228,761**
Total Capital Cost				**$ 847,035**
Additional Costs				
Groundwater Treatment Costs	**Sum PV Factor = 15.37**		**i = 5%**	
Net present value - 30 years of operation	11,300,400	gal./yr	$ 0.005	**$ 856,630**

Table A.1b - Cost Estimate for Partial Slurry Wall Barrier around Frank Wear and Adjoining Properties.

Compliance Monitoring Costs (30 Years)						
Years 1-10 - Quarterly sampling	1	Annual	$	590,087	$	590,087
Years 11-30 - Semi-annual sampling	1	Annual	$	298,375	$	298,375
5 Yr MTCA review, reporting, & negotiating	1	Annual	$	19,163	$	19,163
Annual Monitoring Cost Subtotal					**$**	**907,625**
Total Remediation Cost					**$**	**2,611,290**
Low (-35%)					**$**	**1,697,338**
High (+35%)					**$**	**3,525,241**

Notes:
Cost for slurry wall includes excavation 3 foot wide by 50 foot deep around portions of the site (300 feet), stockpiling of excavated soil, slurry mixing, slurry backfill, and finish to below gravel/pavement grade. Output is assumed to be 100-125 LF/day for slurry wall construction.
Utility work includes uncovering, breaking and capping, and reconnecting following barrier installation and recovering. Number may be conservative based on actual location and number of utilities.
Assume soil density of 1.4 ton/cy.
Soil sampling will be for VOC, RCRA 8 metals, and assumes 3 samples for TCLP-metals. Includes sample courier.
From Site to Roosevelt Transfer Station, approx 110 miles RT. A rate of $100.50/hour for a 3-axle 16 ton dump truck which includes rental, O&M, the operator, and an oiler/spotter for loading. Disposal of non-hazardous soil based on verbal quote from Rabanco.

Table A.1c - Cost Estimate for PRB and Slurry Wall around Frank Wear and Adjoining Properties.

Site: Frank Wear Site

Location: 106 South 3rd Avenue, Yakima, WA

Phase: Feasibility Study (-35% to +35%)

Base Year: 2007

Description: Alternative 1 Variation C consists of partial sections of slurry barriers with permeable iron filings gates in select areas around portions of the site. The groundwater flowing through the site will be directed to the permeable zero valent iron sections. This alternative will include quarterly groundwater sampling years 1-10, and semi-annual groundwater sampling in years 11-30.

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL
Site Prep				
Permits	1	lump sum	$ 5,000	$ 5,000
Utility locate	1	lump sum	$ 500	$ 500
Temporary fencing	1	lump sum	$ 1,000	$ 1,000
Site Prep Subtotal				**$ 6,500**
Reactive Barrier/Slurry Wall System Installation				
Contractor mobilization/demobilization	1	lump sum	$ 60,000	$ 60,000
Slurry wall barrier	8,250	sq. ft.	$ 16	$ 132,000
Iron	870	tons	$ 800	$ 696,000
Permeable reactive barrier	9,500	sq. ft.	$ 25	$ 237,500
PRB technology licensing fee (15% of construction & mat. costs)	-	-	15%	$ 168,825
Pilot scale testing	1	lump sum	$ 20,000	$ 20,000
Utility work	1	lump sum	$ 15,000	$ 15,000
Soil testing for disposal	12	ea.	$ 415	$ 4,980
Transport & disposal of contaminated soil (non-haz)	1500	tons	$ 60	$ 89,972
Transport & disposal of clean soil	643	tons	$ 11	$ 7,069
Demo and replacement of covered parking structure	1	LS	$ 50,000	$ 50,000
Sidewalk	660	SF	$ 3.60	$ 2,376
Repaving	570	SF	$ 2	$ 1,140
Reactive Barrier/Slurry Wall System Installation Subtotal				**$ 1,484,862**
Monitoring Well Installation				
Monitoring wells (2")	3	ea.	$ 4,945	**$ 14,834**
Total Capital Cost				**$ 1,491,362**
Other Remediation Costs				
Project management and design	--	--	12%	$ 178,963
Construction oversight	--	--	10%	$ 149,136
Contingency	--	--	15%	$ 223,704
Other Remediation Cost Subtotal				**$ 551,804**
Total Construction Cost				**$ 2,043,166**
Additional Costs	**Sum PV Factor = 15.37**		**i = 5%**	
Compliance Monitoring Costs (30 Years)				
Years 1-10 - Quarterly sampling	1	Annual	$ 590,087	$ 590,087
Years 11-30 - Semi-annual sampling	1	Annual	$ 298,375	$ 298,375
5 Yr MTCA review, reporting, & negotiating	1	Annual	$ 19,163	$ 19,163
Annual Monitoring Cost Subtotal				**$ 907,625**
Total Remediation Cost				**$ 2,950,791**
Low (-35%)				**$ 1,918,014**
High (+35%)				**$ 3,983,568**

Table A.1c - Cost Estimate for PRB and Slurry Wall around Frank Wear and Adjoining Properties.

Notes:
Cost for slurry wall includes excavation 3 foot wide by 50 foot deep around portions of the site perimeter (165 feet), stockpiling of excavated soil, slurry mixing, slurry backfill, and finish to below gravel/pavement grade. PRB installation includes excavation 3 foot wide by 50 foot deep around portions of the site perimeter (190 feet). Output is assumed to be 100-125 LF/day for slurry wall construction and 40-50 LF/day for PRB construction.
Utility work includes uncovering, breaking and capping, and reconnecting following barrier installation and recovering. Number may be conservative based on actual location and number of utilities.
Assume soil density of 1.4 ton/cy.

Table A.2a.1 - Cost Estimate for Air Sparging and Soil Vapor Extraction System with Ozone Injection

Site: Frank Wear Site

Location: 106 South 3rd Avenue, Yakima, WA

Phase: Feasibility Study (-35% to +35%)

Base Year: 2007

Description: Air sparging, soil vapor extraction system with ozone injection installed within the Frank Wear property boundary, consisting of 17 air sparging wells, 8 soil vapor extraction wells, and 4 soil vapor extraction vents, for treatment of PCE-impacted groundwater. Infrastructure would be completed below grade, with asphalt cap installed afterwards. System would operate continuously, with performance monitoring conducted on a monthly basis, and groundwater compliance monitoring conducted on a quarterly basis.

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL
Site Prep				
Permitting	1	lump sum	$ 5,000	$ 5,000
Utility locate	1	lump sum	$ 500	$ 500
Install temporary site fence	1	lump sum	$ 2,000	$ 2,000
Power and phone line installation	1	lump sum	$ 10,000	$ 10,000
Site Prep Subtotal				**$ 17,500**
AS/SVE System Installation				
Contractor and driller mobilization/demobilization	1	lump sum	$ 3,575	$ 3,575
Install AS wells	17	each	$ 2,774	$ 47,158
Install SVE vertical wells	8	each	$ 1,162	$ 9,296
Groundwater monitoring well installation	1	each	$ 3,900	$ 3,900
Install AS/SVE sub-grade pipe runs and SVE vents	1	lump sum	$ 20,000	$ 20,000
Install asphalt cap	1	lump sum	$ 35,000	$ 35,000
System enclosure and foundation	1	lump sum	$ 3,000	$ 3,000
AS/SVE system equipment	1	lump sum	$ 15,000	$ 15,000
Ozone generating equipment	1	lump sum	$ 30,000	$ 30,000
System equipment installation	1	lump sum	$ 10,000	$ 10,000
Soil testing for disposal	1	lump sum	$ 1,400	$ 1,400
Loading, transport, and disposal of clean soil	321	ton	$ 11	$ 3,530
Loading, transport, and disposal of contaminated soil (non-	15	ton	$ 60	$ 886
AS/SVE System Installation Subtotal				**$ 182,745**
Capital Cost Subtotal				**$ 200,245**
Other Capital Costs				
Pilot testing	1	lump sum	$ 20,000	$ 20,000
Ecology oversight	1	lump sum	$ 30,000	$ 30,000
Project management and design (% of capital cost)	20%			$ 40,049
Engineering during construction (% of capital cost)	10%			$ 20,025
Contingency	15%			$ 46,548
Other Capital Costs Subtotal				**$ 156,621**
Total Capital Cost				**$ 356,866**
Annual Operation, Maintenance, and Performance Monitoring Costs				
Performance monitoring	1	lump sum	$ 20,088	$ 20,088
Utilities	105,120	kW-hr	$ 0.08	$ 8,410
Equipment maintenance and repair	1	lump sum	$ 2,000	$ 2,000
Waste disposal	1	lump sum	$ 12,344	$ 12,344
Project management and technical support (% of OMM cost)	10%			$ 4,284
Contingency	15%			$ 7,069
Annual Operation, Maintenance, and Performance Monitoring Cost Subtotal				**$ 54,195**
Other Operation, Maintenance, and Performance Monitoring Costs				
System startup and optimization (first year only)	1	lump sum	$ 16,358	$ 16,358
Other Operation, Maintenance, and Performance Monitoring Cost Subtotal				**$ 16,358**
Total Operation, Maintenance, and Monitoring Present Value (5 Years)				**$ 262,724**

Table A.2a.1 - Cost Estimate for Air Sparging and Soil Vapor Extraction System with Ozone Injection

Compliance Monitoring Present Value (10 years)						
Years 1-10 - Quarterly groundwater sampling	1	lump sum	$	645,384	$	645,384
Compliance Monitoring Present Value Total (10 years)					**$**	**645,384**
Periodic Item Present Value						
Five-year review report (year 5)	1	lump sum	$	5,667	$	5,667
AS/SVE system decommissioning (year 10)	1	lump sum	$	36,041	$	36,041
Periodic Item Present Value Total					**$**	**41,708**
Total Estimated Remediation Present Value					**$**	**1,306,683**
Low (-35%)					**$**	**849,344**
High (+35%)					**$**	**1,764,022**

Notes:
This cost estimate assumes the following:
1) Installation of AS wells would be to 40 feet bgs, vertical SVE wells to 10 feet bgs, and horizontal SVE vents at 3 feet bgs.
2) Asphalt cap installation would include compacted base course.
3) AS/SVE + ozone injection system major equipment items would include AS compressor, SVE blower, SVE moisture separator, ozone generators (2), aboveground piping and fittings, and system instrumentation.
4) Soil density of 1.4 ton/cy was used in soil disposal estimates.
5) Soil disposal characterization sample analyses would include VOCs and Toxicity Characteristic Leaching Procedure (TCLP).
6) AS/SVE + ozone injection pilot testing would be completed as part of remedial design.
7) System performance monitoring would be completed on a monthly basis during the assumed system operating period of 5 years.
8) System waste disposal cost items would include spent activated carbon, condensate water accumulated by the SVE moisture separator, oily water accumulated by AS system filters, and completion of annual dangerous waste reporting to Ecology. Purge and decontamination water disposal costs included as part of groundwater compliance monitoring costs.
9) Groundwater compliance monitoring would be conducted on a quarterly basis during years 1 - 10.
10) Groundwater compliance monitoring sample analyses would include VOCs and total chromium.
11) System decommissioning would include dismantling and removal of aboveground system components, abandonment of AS/SVE wells, and preparation of a remediation closure report.
12) Present value calculated at a discount rate 5%.
13) Sales tax is not included.

Table A.2b.1 - Cost Estimate for Emulsified Oil Injections

Site: Frank Wear Site **Location:** 106 South 3rd Avenue, Yakima, WA **Phase:** Feasibility Study (-35% to +35%) **Base Year:** 2007	**Description:** Alternative 2 Variation B1 consists of a set of emulsified oil injections performed using a sonic drill rig. Because of site geology, push probes would be unlikely to succeed, so air rotary or sonic drilling would be required. Either technology would likely work, but sonic was selected for this estimate because it is likely to produce smaller IDW volumes. The intended treatment area measures about 150 feet by 60 feet. Emulsified oil is expected to last 3 or more years in the subsurface. Groundwater compliance monitoring would be conducted for 5 years after treatment in the subsurface is expected to have ended.

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL
Site Prep				
Permits	1	lump sum	$ 3,000	$ 3,000
Utility locate	1	lump sum	$ 500	$ 500
Temporary fencing (for storage of emulsified oil during injections)	1	lump sum	$ 750	$ 750
Water tank (for dilution of emulsified oil during injections)	1	lump sum	$ 500	$ 500
Site Prep Subtotal				**$ 4,750**
Emulsified Oil Injections				
Drilling contractor mobilization/demobilization	1	lump sum	$ 3,000	$ 3,000
Drilling contractor costs (21 injections)	1	lump sum	$ 70,000	$ 70,000
Install 2 additional downgradient monitoring wells	1	lump sum	$ 9,000	$ 9,000
On-site oversight of injections and well installation	12	days	$ 1,500	$ 18,000
Emulsified oil substrate	80	55 gal. drum	$ 1,250	$ 100,000
Shipping of emulsified oil to site	80	55 gal. drum	$ 250	$ 20,000
Emulsified Oil Injections Subtotal				**$ 220,000**
Total Capital Cost				**$ 224,750**
Other Remediation Costs				
Project management and design	--	--	12%	$ 26,970
Contingency for extra treatment in case of vinyl chloride		--	25%	$ 56,188
Contingency	--	--	15%	$ 33,713
Other Remediation Cost Subtotal				**$ 116,870**
Total Construction Cost				**$ 341,620**
Compliance Monitoring Costs (8 Years)				
Years 1-8 - Quarterly sampling	1	lump sum	$ 517,222	$ 517,222
Compliance Monitoring Cost Subtotal				**$ 517,222**
Periodic Item Present Value				
Five-year review report (year 5)	1	lump sum	$ 5,667	$ 5,667
Periodic Item Present Value Total				**$ 5,667**
Total Remediation Cost				**$ 864,509**
Low (-35%)				**$ 561,931**
High (+35%)				**$ 1,167,087**

Notes:
Present value analysis assumes discount rate of 5%. Quarterly sampling would include all site wells except SPW-14. Wells would be sampled for VOCs and selected biological parameters including nitrate, sulfate, methane, ethane, ethene, and total organic carbon.

Table A.2b.2 - Cost Estimate for Groundwater Recirculation with Dextrose

Site: Frank Wear Site

Location: 106 South 3rd Avenue, Yakima, WA

Phase: Feasibility Study (-35% to +35%)

Base Year: 2007

Description: Alternative 2 Variation B2 consists of recirculating injection of a soluble bioremediation substrate such as dextrose. The intended treatment area measures about 150 feet by 60 feet, with an additional 50 foot by 50 foot area under the existing children's bookstore building. For the purposes of this estimate, it is assumed that wells MW-2, SPW-12, and SPW-13 would be used for injections. MW-9 and two new wells drilled south of the children's bookstore building would be used as extraction wells. The recirculation system would run for 12 months, with residual biomass in the subsurface providing continuing treatment beyond that time. Groundwater compliance monitoring would be conducted for 5 years after treatment in the subsurface is expected to have ended (at about 3 years).

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL
Site Prep				
Permits	1	lump sum	$ 3,000	$ 3,000
Utility locate	1	lump sum	$ 500	$ 500
Temporary fencing (to house recirculation system)	1	lump sum	$ 1,000	$ 1,000
Site Prep Subtotal				**$ 4,500**
Recirculation System Installation				
Recirculation system mobilization/demobilization	1	lump sum	$ 1,000	$ 1,000
Recirculation system installation	1	lump sum	$ 4,500	$ 4,500
Electrician to connect remediation system to grid	1	lump sum	$ 1,000	$ 1,000
Install 2 additional extraction wells and 2 additional downgradient monitoring wells				
Drilling contractor mobilization/demobilization	1	lump sum	$ 3,000	$ 3,000
Drilling contractor costs	1	lump sum	$ 18,000	$ 18,000
Trenching for connection of injection and extraction wells	1	lump sum	$ 10,000	$ 10,000
Analytical and disposal of soil cuttings produced while trenching	1	lump sum	$ 500	$ 500
On site oversight of drilling and remediation system installation	5	days	$ 1,500	$ 7,500
Recirculation System Installation Subtotal				**$ 45,500**
Recirculation System Operation				
Recirculation system rental costs	12	months	$ 2,800	$ 33,600
Soluble remediation substrate	6,000	lbs	$ 2	$ 12,000
GW monitoring/ operation of recirculation system (2 visits/month)	12	months	$ 2,000	$ 24,000
Local contractor to check on system, if needed (2 visits/month)	12	months	$ 500	$ 6,000
Recirculation System Operation Subtotal				**$ 75,600**
Total Capital Cost				**$ 125,600**
Other Remediation Costs				
Project management and design	--	--	12%	$ 15,072
Contingency for extra treatment in case of vinyl chloride accumulation		--	25%	$ 31,400
Contingency	--	--	15%	$ 18,840
Other Remediation Cost Subtotal				**$ 65,312**
Total Construction Cost				**$ 190,912**
Compliance Monitoring Costs (8 Years)				
First 12 months - Monthly sampling	9	events	$ 7,111	$ 64,000
Years 1-8 - Quarterly sampling	1	lump sum	$ 517,222	$ 517,222
Compliance Monitoring Cost Subtotal				**$ 581,223**
Periodic Item Present Value				
Five-year review report (year 5)	1	lump sum	$ 5,667	$ 5,667
System decommissioning (year 8)	1	lump sum	$ 12,325	$ 12,325
Periodic Item Present Value Total				**$ 17,991**

Table A.2b.2 - Cost Estimate for Groundwater Recirculation with Dextrose

Total Remediation Cost	**$**	**790,126**
Low (-35%)	**$**	**513,582**
High (+35%)	**$**	**1,066,670**

Notes:
Present value analysis assumes discount rate of 5%. Monthly groundwater sampling during system operation would include the extraction wells (MW-8, MW-9, and the two new wells south of the children's bookstore) as well as MW-1, SPW-15, and MW-10. Quarterly sampling would include all site wells except SPW-14. Wells would be sampled for VOCs and selected biological parameters including nitrate, sulfate, methane, ethane, ethene, and total organic carbon.

Table A.2c.1a - Cost Estimate for In Situ Chemical Oxidation via Permanganate Injection Wells

Site: Frank Wear Site

Location: 106 South 3rd Avenue, Yakima, WA

Phase: Feasibility Study (-35% to +35%)

Base Year: 2007

Description: Injection of permanganate solution to facilitate treatment of PCE-impacted soil and groundwater through *in situ* chemical oxidation. Permanganate solution would be applied to groundwater through a grid of 21 injection wells installed within the Frank Wear property boundary to a depth of 40 feet. Multiple applications of solution would be applied over a 2 to 3 year period with concurrent groundwater monitoring. Groundwater compliance monitoring would be conducted on a quarterly basis for 5 years after completion of permanganate applications.

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL
Site Prep				
Permitting	1	lump sum	$ 3,000	$ 3,000
Utility locate	1	lump sum	$ 500	$ 500
Temporary storage enclosure	1	lump sum	$ 3,000	$ 3,000
Site Prep Subtotal				**$ 6,500**
Injection Well Installation				
Drilling contractor mobilization/demobilization	1	lump sum	$ 3,075	$ 3,075
Install injection wells	21	each	$ 3,207	$ 67,347
Install groundwater monitoring well	1	each	$ 3,900	$ 3,900
Soil testing for disposal	1	lump sum	$ 1,400	$ 1,400
Loading, transport, and disposal of clean soil	2	ton	$ 11	$ 22
Loading, transport, and disposal of contaminated soil (non-haz)	16	ton	$ 60	$ 960
Injection Well Installation Subtotal				**$ 76,704**
Capital Cost Subtotal				**$ 83,204**
Other Capital Costs				
Pilot testing	1	lump sum	$ 20,000	$ 20,000
Project management and design (% of capital cost)	15%			$ 12,481
Engineering during construction (% of capital cost)	10%			$ 8,320
Contingency	15%			$ 18,601
Other Capital Costs Subtotal				**$ 59,402**
Total Capital Cost				**$ 142,606**
Option 1 - Sodium Permanganate Injection				
Sodium permanganate (40% solution)	38,219	lb	$ 2.36	$ 90,196
Sodium permanganate shipping	1	lump sum	$ 4,000	$ 4,000
Solution preparation and transfer equipment rental	1	lump sum	$ 5,770	$ 5,770
Generator rental	1	weeks	$ 450	$ 450
Dilution water	18,330	gal	$ 0.007	$ 128
Injection labor and direct costs (4 days)	1	lump sum	$ 5,088	$ 5,088
Waste disposal	1	lump sum	$ 2,775	$ 2,775
Project management and technical support (% of OMM cost)	10%			$ 10,841
Contingency	15%			$ 17,887
Sodium Permanganate Injection Subtotal				**$ 137,135**
Total Sodium Permanganate Injection Present Value (5 Injections over 3 Years)				**$ 659,865**

Table A.2c.1a - Cost Estimate for In Situ Chemical Oxidation via Permanganate Injection Wells

Option 2 - Potassium Permanganate Injection						
Potassium permanganate (dry solid)	17,177	lump sum	$	1.99	$	34,182
Potassium permanganate shipping	1	lump sum	$	3,000	$	3,000
Solution preparation and transfer equipment rental	1	lump sum	$	4,886	$	4,886
Generator rental	2	weeks	$	450	$	900
Dilution water	80,324	gal	$	0.003	$	248
Injection labor and direct costs (7 days)	1	lump sum	$	10,108	$	10,108
Waste disposal	1	lump sum	$	3,775	$	3,775
Project management and technical support (% of OMM cost)	10%				$	5,710
Contingency	15%				$	9,421
Potassium Permanganate Injection Subtotal					**$**	**72,231**
Total Potassium Permanganate Injection Present Value (5 Injections over 3 Years)					**$**	**347,558**
Compliance Monitoring Present Value (8 years)						
Years 1-8 - Quarterly groundwater sampling	1	lump sum	$	540,454	$	540,454
Compliance Monitoring Present Value Total (8 years)					**$**	**540,454**
Periodic Item Present Value						
Five-year review report (year 5)	1	lump sum	$	5,667	$	5,667
System decommissioning (year 8)	1	lump sum	$	12,325	$	12,325
Periodic Item Present Value Total					**$**	**17,991**
Total Estimated Remediation Present Value - Sodium Permanganate					**$**	**1,360,916**
Low (-35%)					**$**	**884,595**
High (+35%)					**$**	**1,837,237**
Total Estimated Remediation Present Value - Potassium Permanganate					**$**	**1,048,610**
Low (-35%)					**$**	**681,596**
High (+35%)					**$**	**1,415,623**

Notes:
This cost estimate assumes the following:
1) Injection and groundwater monitoring wells would be installed using air rotary drilling methods.
2) Soil density of 1.4 ton/cy was used in soil disposal estimates.
3) Soil disposal characterization sample analyses would include VOCs and Toxicity Characteristic Leaching Procedure (TCLP).
4) Pilot testing would be completed as part of remedial design.
5) Two injection events would conducted in year 1, two in year 2, and one in year 3, for a total of five injection events over three years.
6) Dilution water would be provided via metered fire hydrant connection.
7) Waste disposal items would include recycling/disposal of empty permanganate containers and completion of annual dangerous waste reporting to Ecology. Purge and decontamination water disposal costs included as part of groundwater compliance monitoring costs.
8) Groundwater compliance monitoring would be conducted on a quarterly basis during years 1 - 8.
9) Groundwater compliance monitoring sample analyses would include VOCs and total chromium.
10) System decommissioning would include abandonment of injection wells and preparation of a remediation closure report.
11) Present value calculated at a discount rate 5%.
12) Sales tax is not included.

Table A.2c.1b - Cost Estimate for In Situ Chemical Oxidation via Permanganate Injection Borings

Site:	Frank Wear Site	**Description:** Injection of permanganate solution to facilitate treatment of PCE-impacted groundwater through *in situ* chemical oxidation. Permanganate solution would be applied to groundwater through a grid of 21 temporary borings completed within the Frank Wear property boundary to a depth of 40 feet. Multiple applications of solution would be applied over a 2 to 3 year period with concurrent groundwater monitoring. Groundwater compliance monitoring would be conducted on a quarterly basis for 5 years after completion of permanganate applications.
Location:	106 South 3rd Avenue, Yakima, WA	
Phase:	Feasibility Study (-35% to +35%)	
Base Year:	2007	

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL
Site Prep				
Permitting	1	lump sum	$ 3,000	$ 3,000
Utility locate	1	lump sum	$ 500	$ 500
Temporary storage enclosure	1	lump sum	$ 3,000	$ 3,000
Site Prep Subtotal				**$ 6,500**
Option 1 - Sodium Permanganate Injection				
Drilling contractor mobilization/demobilization	1	lump sum	$ 3,075	$ 3,075
Install groundwater monitoring well	1	each	$ 3,900	$ 3,900
Sodium permanganate (40% solution)	38,219	lb	$ 2.36	$ 90,196
Sodium permanganate shipping	1	lump sum	$ 4,000	$ 4,000
Solution preparation and transfer equipment rental	1	lump sum	$ 5,770	$ 5,770
Generator rental	2	weeks	$ 450	$ 900
Dilution water	18,330	gal	$ 0.007	$ 128
Sodium permanganate injection (8 days)	1	lump sum	$ 67,837	$ 67,837
Waste disposal	1	lump sum	$ 2,775	$ 2,775
Project management and design (% of capital cost)	15%			$ 26,787
Engineering during construction (% of capital cost)	10%			$ 17,858
Contingency	15%			$ 33,484
Sodium Permanganate Injection Subtotal				**$ 256,710**
Option 2 - Potassium Permanganate Injection				
Drilling contractor mobilization/demobilization	1	lump sum	$ 3,075	$ 3,075
Install groundwater monitoring well	1	each	$ 3,900	$ 3,900
Potassium permanganate (dry solid)	17,177	lb	$ 1.99	$ 34,182
Potassium permanganate shipping	1	lump sum	$ 3,000	$ 3,000
Solution preparation and transfer equipment rental	1	lump sum	$ 6,599	$ 6,599
Generator rental	3	weeks	$ 450	$ 1,350
Dilution water	80,324	gal	$ 0.003	$ 248
Potassium permanganate injection (13 days)	1	lump sum	$ 71,387	$ 71,387
Waste disposal	1	lump sum	$ 3,775	$ 3,775
Project management and design (% of capital cost)	15%			$ 19,127
Engineering during construction (% of capital cost)	10%			$ 12,752
Contingency	15%			$ 23,909
Potassium Permanganate Injection Subtotal				**$ 183,305**
Capital Cost Subtotal - Sodium Permanganate				**$ 263,210**
Capital Cost Subtotal - Potassium Permanganate				**$ 189,805**
Other Capital Costs				
Pilot testing	1	lump sum	$ 20,000	$ 20,000
Other Capital Costs Subtotal				**$ 20,000**
Total Capital Cost - Sodium Permanganate				**$ 283,210**
Total Capital Cost - Potassium Permanganate				**$ 209,805**
Total Additional Sodium Permanganate Injection Present Value (4 Injections over 3 Years)				**$ 1,003,303**
Total Additional Potassium Permanganate Injection Present Value (4 Injections over 3 Years)				**$ 723,497**

Table A.2c.1b - Cost Estimate for In Situ Chemical Oxidation via Permanganate Injection Borings

Compliance Monitoring Present Value (8 years)						
Years 1-8 - Quarterly groundwater sampling	1	lump sum	$	540,454	$	540,454
Compliance Monitoring Present Value Total (8 years)					**$**	**540,454**
Periodic Item Present Value						
Five-year review report (year 5)	1	lump sum	$	5,667	$	5,667
Remediation closure report (year 8)	1	lump sum	$	4,895	$	4,895
Periodic Item Present Value Total					**$**	**10,562**
Total Estimated Remediation Present Value - Sodium Permanganate					**$**	**1,837,529**
Low (-35%)					**$**	**1,194,394**
High (+35%)					**$**	**2,480,664**
Total Estimated Remediation Present Value - Potassium Permanganate					**$**	**1,484,318**
Low (-35%)					**$**	**964,807**
High (+35%)					**$**	**2,003,830**

Notes:
This cost estimate assumes the following:
1) Injection borings would be installed using sonic drilling methods.
2) Pilot testing would be completed as part of remedial design.
3) Two injection events would conducted in year 1, two in year 2, and one in year 3, for a total of five injection events over three years.
4) Dilution water would be provided via metered fire hydrant connection.
5) Waste disposal items would include recycling/disposal of empty permanganate containers and completion of annual dangerous waste reporting to Ecology. Purge and decontamination water disposal costs included as part of groundwater compliance monitoring costs.
6) Groundwater compliance monitoring would be conducted on a quarterly basis during years 1 - 8.
7) Groundwater compliance monitoring sample analyses would include VOCs and total chromium.
8) System decommissioning would include abandonment of injection wells and preparation of a remediation closure report.
9) Present value calculated at a discount rate 5%.
10) Sales tax is not included.

Table A.2c.2 - Cost Estimate for In Situ Chemical Oxidation via Permanganate Recirculation

Site: Frank Wear Site **Location:** 106 South 3rd Avenue, Yakima, WA **Phase:** Feasibility Study (-35% to +35%) **Base Year:** 2007	**Description:** Application of permanganate via groundwater recirculation system. The intended treatment area measures about 150 feet by 60 feet, with an additional 50 foot by 50 foot area under the existing A.W. Andersen & Sons building. For the purposes of this estimate, it is assumed that wells MW-2, SPW-12, and SPW-13 would be used for injections. MW-9 and two new wells drilled south of the A.W. Andersen & Sons building could be used as extraction wells. This estimate assumes that the recirculation system would run for two years. Groundwater compliance monitoring would be conducted on a quarterly basis for 5 years after treatment in the subsurface is expected to have ended.

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL
Site Prep				
Permitting	1	lump sum	$ 5,000	$ 5,000
Utility locate	1	lump sum	$ 500	$ 500
Install temporary site fence	1	lump sum	$ 2,000	$ 2,000
Power and phone line installation	1	lump sum	$ 10,000	$ 10,000
Site Prep Subtotal				**$ 17,500**
Groundwater Recirculation System Installation				
Recirculation system mobilization/demobilization	1	lump sum	$ 1,000	$ 1,000
Driller mobilization/demobilization	1	lump sum	$ 3,075	$ 3,075
Recirculation system installation	1	lump sum	$ 4,500	$ 4,500
Install extraction wells	2	each	$ 4,402	$ 8,804
Groundwater monitoring well installation	2	each	$ 3,900	$ 7,800
Install sub-grade pipe runs for injection/extraction wells	1	lump sum	$ 15,000	$ 15,000
System enclosure and foundation	1	lump sum	$ 3,000	$ 3,000
Soil testing for disposal	1	lump sum	$ 1,400	$ 1,400
Loading, transport, and disposal of clean soil	147	ton	$ 11	$ 1,617
Loading, transport, and disposal of contaminated soil (non-haz)	3	ton	$ 60	$ 180
Groundwater Recirculation System Installation Subtotal				**$ 46,376**
Capital Cost Subtotal				**$ 63,876**
Other Capital Costs				
Pilot testing	1	lump sum	$ 20,000	$ 20,000
Project management and design (% of capital cost)	20%			$ 12,775
Engineering during construction (% of capital cost)	10%			$ 6,388
Contingency	15%			$ 15,456
Other Capital Costs Subtotal				**$ 54,619**
Total Capital Cost				**$ 118,495**
Option 1 - Annual Operation with Sodium Permanganate				
Recirculation system rental costs	12	months	$ 2,800	$ 33,600
Sodium permanganate (40% solution)	36,174	lb	$ 2.36	$ 85,371
Sodium permanganate shipping	1	lump sum	$ 4,000	$ 4,000
Performance monitoring	1	lump sum	$ 18,288	$ 18,288
Utilities	8,760	kW-hr	$ 0.08	$ 701
Equipment maintenance and repair	1	lump sum	$ 2,000	$ 2,000
Waste disposal	1	lump sum	$ 2,775	$ 2,775
Project management and technical support (% of OMM cost)	10%			$ 14,674
Contingency	15%			$ 24,211
Option 1 - Annual Operation with Sodium Permanganate Subtotal				**$ 185,620**

Table A.2c.2 - Cost Estimate for In Situ Chemical Oxidation via Permanganate Recirculation

Option 2 - Annual Operation with Potassium Permanganate						
Recirculation system rental costs	12	months	$	2,800	$	33,600
Potassium permanganate (dry solid)	16,258	lb	$	1.99	$	32,354
Potassium permanganate shipping	1	lump sum	$	3,000	$	3,000
Performance monitoring	1	lump sum	$	18,288	$	18,288
Utilities	8,760	kW-hr	$	0.08	$	701
Equipment maintenance and repair	1	lump sum	$	2,000	$	2,000
Waste disposal	1	lump sum	$	2,775	$	2,775
Project management and technical support (% of OMM cost)	10%				$	9,272
Contingency	15%				$	15,298
Option 2 - Annual Operation with Potassium Permanganate Subtotal					**$**	**117,288**
Other Operation Costs						
System startup and optimization (first year only)	1	lump sum	$	9,918	$	9,918
Other Operation Cost Subtotal					**$**	**9,918**
Total Sodium Permanganate Operation Present Value (2 Years)					**$**	**372,320**
Total Potassium Permanganate Operation Present Value (2 Years)					**$**	**238,909**
Compliance Monitoring Present Value (7 years)						
Years 1-7 - Quarterly groundwater sampling	1	lump sum	$	484,022	$	484,022
Compliance Monitoring Present Value Total (7 years)					**$**	**484,022**
Periodic Item Present Value						
Five-year review report (year 5)	1	lump sum	$	5,667	$	5,667
System decommissioning (year 7)	1	lump sum	$	8,601	$	8,601
Periodic Item Present Value Total					**$**	**14,268**
Total Estimated Remediation Present Value - Sodium Permanganate					**$**	**989,105**
Low (-35%)					**$**	**642,918**
High (+35%)					**$**	**1,335,292**
Total Estimated Remediation Present Value - Potassium Permanganate					**$**	**855,694**
Low (-35%)					**$**	**556,201**
High (+35%)					**$**	**1,155,187**

Notes:
This cost estimate assumes the following:
1) Extraction and groundwater monitoring wells would be installed using air rotary drilling methods.
2) Soil density of 1.4 ton/cy was used in soil disposal estimates.
3) Soil disposal characterization sample analyses would include VOCs and Toxicity Characteristic Leaching Procedure (TCLP).
4) Pilot testing would be completed as part of remedial design.
5) Waste disposal items would include recycling/disposal of empty permanganate containers and completion of annual dangerous waste reporting to Ecology. Purge and decontamination water disposal costs included as part of groundwater compliance monitoring costs.
6) Groundwater compliance monitoring would be conducted on a quarterly basis during years 1 - 7.
7) Groundwater compliance monitoring sample analyses would include VOCs and total chromium.
8) System decommissioning would include abandonment of extraction wells and preparation of a remediation closure report.
9) Present value calculated at a discount rate 5%.
10) Sales tax is not included.

Table A.3a - Cost Estimate for Source Control via Excavation

Site:	Frank Wear Site	**Description:** Alternative 3 Variation A consists of additional soil characterization and excavation and disposal of contaminated soils from the Frank Wear property. This alternative will include quarterly groundwater sampling years 1-10, and semi-annual groundwater sampling in years 11-30.	
Location:	106 South 3rd Avenue, Yakima, WA		
Phase:	Feasibility Study (-35% to +35%)		
Base Year:	2007		

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL
Site Prep				
Permits	1	lump sum	$ 5,000	$ 5,000
Utility locate	1	lump sum	$ 500	$ 500
Temporary fencing	1	lump sum	$ 1,000	$ 1,000
Site Prep Subtotal				**$ 6,500**
Site Characterization & Excavation				
Contractor mobilization/demobilization	1	lump sum	$ 7,500	$ 10,000
Mobile laboratory	10	day	$ 1,844	$ 18,438
Excavation	1600	cy	$ 7	$ 10,560
Utility work	1	lump sum	$ 6,000	$ 6,000
Soil testing for disposal	12	ea.	$ 415	$ 4,980
Transport & disposal of contaminated soil (non-haz)	1568	tons	$ 60	$ 94,080
Transport & disposal of clean soil	672	tons	$ 11	$ 7,392
Structural fill - delivery & compaction	2,000	Ton	$ 20	$ 40,000
Sidewalk	330	SF	$ 3.60	$ 1,188
Site Characterization & Excavation Subtotal				**$ 151,450**
Monitoring Well Installation				
Monitoring wells (2")	7	ea.	$ 4,945	**$ 34,614**
Total Construction Cost				**$ 192,563**
Other Remediation Costs				
Project management and design	--	--	10%	$ 19,256
Construction oversight	--	--	8%	$ 15,405
Contingency	--	--	15%	$ 28,884
Other Remediation Cost Subtotal				**$ 63,546**
Total Capital Cost				**$ 256,109**
Additional Costs	**Sum PV Factor = 15.37**		**i = 5%**	
Compliance Monitoring Costs (30 Years)				
Years 1-10 - Quarterly sampling	1	Annual	$ 596,844	$ 596,844
Years 11-30 - Semi-annual sampling	1	Annual	$ 301,722	$ 301,722
5 Yr MTCA review, reporting, & negotiating	1	Annual	$ 19,163	$ 19,163
Annual Monitoring Cost Subtotal				**$ 917,729**
Total Remediation Cost				**$ 1,173,838**
Low (-35%)				**$ 762,994**
High (+35%)				**$ 1,584,681**

Notes:
Assume excavate & characterize 50% of Frank Wear property soil to 12 ft. BGS.
Utility work includes uncovering, breaking and capping, and reconnecting following barrier installation and recovering.
Assume soil density of 1.4 ton/cy.
Soil sampling will be for VOC, RCRA 8 metals, and assumes 3 samples for TCLP-metals. Includes sample courier.
From Site to Roosevelt Transfer Station, approx 110 miles RT. A rate of $100.50/hour for a 3-axle 16 ton dump truck which includes rental, O&M, the operator, and an oiler/spotter for loading. Disposal of non-hazardous soil based on verbal quote from Rabanco.

Table A.3b - Cost Estimate for Source Control and Groundwater Treatment

Site: Frank Wear Site	**Description:** Alternative 3B consists of additional soil characterization and excavation and disposal of contaminated soils from the Frank Wear property. Remaining soils that are not excavated will receive in situ treatment with potassium permanganate. This alternative will include quarterly groundwater sampling years 1-10, and semi-annual groundwater sampling in years 11-30.
Location: 106 South 3rd Avenue, Yakima, WA	
Phase: Feasibility Study (-35% to +35%)	
Base Year: 2007	

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL
Site Prep				
Permits	1	lump sum	$ 5,000	$ 5,000
Utility locate	1	lump sum	$ 500	$ 500
Temporary fencing	1	lump sum	$ 1,000	$ 1,000
Site Prep Subtotal				**$ 6,500**
Site Characterization & Excavation				
Contractor mobilization/demobilization	1	lump sum	$ 7,500	$ 10,000
Mobile laboratory	10	day	$ 1,844	$ 18,438
Excavation	1600	cy	$ 7	$ 10,560
Utility work	1	lump sum	$ 6,000	$ 6,000
Soil testing for disposal	12	ea.	$ 415	$ 4,980
Transport & disposal of contaminated soil (non-haz)	1568	tons	$ 60	$ 94,080
Transport & disposal of clean soil	672	tons	$ 11	$ 7,392
Structural fill - delivery & compaction	2,000	Ton	$ 20	$ 40,000
Sidewalk	330	SF	$ 3.60	$ 1,188
Site Characterization & Excavation Subtotal				**$ 151,450**
Soil Treatment				
4" PVC perforated pipe	300	LF	$ 10	$ 3,000
Pea gravel	120	Ton	$ 13	$ 1,560
Potassium permanganate (dry solid)	7,000	lbs	$ 1.99	$ 13,930
Potassium permanganate shipping	1	lump sum	$ 3,000	$ 3,000
Solution preparation and transfer equipment rental	1	lump sum	$ 4,886	$ 4,886
Generator rental	2	weeks	$ 450	$ 900
Dilution water	33,000	gal	$ 0.003	$ 102
Injection labor and direct costs (7 days)	1	lump sum	$ 10,108	$ 10,108
Waste disposal	1	lump sum	$ 3,775	$ 3,775
Potassium Permanganate Injection Subtotal				**$ 41,261**
Monitoring Well Installation				
Monitoring wells (2")	7	ea.	$ 4,945	**$ 34,614**
Total Construction Cost				**$ 233,824**
Other Remediation Costs				
Project management and design	--	--	10%	$ 23,382
Construction oversight	--	--	8%	$ 18,706
Contingency	--	--	15%	$ 35,074
Other Remediation Cost Subtotal				**$ 77,162**
Total Capital Cost				**$ 310,986**
Additional Costs	**Sum PV Factor = 15.37**		**i = 5%**	
Compliance Monitoring Costs (30 Years)				
Years 1-10 - Quarterly sampling	1	Annual	$ 596,844	$ 596,844
Years 11-30 - Semi-annual sampling	1	Annual	$ 301,722	$ 301,722
5 Yr MTCA review, reporting, & negotiating	1	Annual	$ 19,163	$ 19,163
Additional permanganate treatment	1	Annual	$ 49,711	$ 49,711
Annual Monitoring Cost Subtotal				**$ 967,440**

Table A.3b - Cost Estimate for Source Control and Groundwater Treatment

Total Remediation Cost	**$**	**1,278,426**
Low (-35%)	**$**	**830,977**
High (+35%)	**$**	**1,725,875**

Notes:
Assume excavate & characterize 50% of Frank Wear property soil to 12 ft. BGS.
Utility work includes uncovering, breaking and capping, and reconnecting following barrier installation and recovering.
Assume soil density of 1.4 ton/cy.
Soil sampling will be for VOC, RCRA 8 metals, and assumes 3 samples for TCLP-metals. Includes sample courier.
From Site to Roosevelt Transfer Station, approx 110 miles RT. A rate of $100.50/hour for a 3-axle 16 ton dump truck which includes rental, O&M, the operator, and an oiler/spotter for loading. Disposal of non-hazardous soil based on verbal quote from Rabanco.