Final
Feasibility Study
Technical Memorandum
Kaiser Trentwood Facility
Spokane Valley, Washington

Prepared for
Kaiser Aluminum Washington, LLC

May 2012
2644-120

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FINAL SITE-WIDE FEASIBILITY STUDY TECHNICAL MEMORANDUM
KAISER TRENTWOOD FACILITY
SPOKANE VALLEY, WASHINGTON

I.0 INTRODUCTION

This report presents the results of the site-wide Feasibility Study Technical Memorandum (FSTM) conducted on behalf of Kaiser Aluminum Washington, LLC (Kaiser) at its Trentwood Facility (Facility) located at East 15000 Euclid Avenue in Spokane Valley, Washington.

This FSTM was conducted pursuant to the requirements outlined in Task VIII of Exhibit B to Agreed Order No. DE 2692 between Kaiser and the Washington State Department of Ecology (Ecology), dated August 16, 2005. The Agreed Order requires Kaiser to complete an FSTM that includes a preliminary cleanup level analysis, an applicable, relevant and appropriate requirements (ARAR) analysis, the development of remedial alternatives and a preliminary evaluation of alternatives under MTCA for Ecology's review.

This document is the site-wide FSTM report for soil and groundwater at the Facility. The FSTM is an integral part of the overall feasibility study for the Facility. The FSTM begins the process of developing technology-based remedial alternatives for the soil and groundwater at the site. The development of remedial alternatives is completed and the remedial alternatives are evaluated in the overall feasibility study.

I.1 PURPOSE

The primary purpose of the site-wide FSTM is to:

- Identify constituents of potential concern (COPCs) and screening levels (SLs) for those constituents;
- Identify potential remediation technologies that may be applicable to each constituent of concern (COC) present in soil and groundwater throughout the site;
- Conduct an initial technical screening of the potential remediation technologies to identify those technologies and process options that are judged to be implementable and reliable for each COC present in soil and groundwater throughout the site;

- Define the areas of concern (AOCs) throughout the site, where the COCs are present in soil and groundwater; and

- Develop technology-based remedial alternatives that consist of those remediation technologies and process options judged to be implementable and reliable for soil and groundwater throughout the site.

I.2 REPORT ORGANIZATION

This report is presented in one volume, including the text, tables, and figures, as well as Appendices A through E. The main text of the report is organized using one section for each primary technical aspect. Tables and figures are numbered to correspond to and are presented at the end of their respective section. References are presented in Section 7.0 at the end of the technical discussions. Where appropriate, cross references are made between sections rather than duplicating tables or figures. Primary report sections consist of the following:

- **1.0 CONSTITUENTS OF POTENTIAL CONCERN AND SCREENING LEVELS.** Establishes COCs and SLs for soil and groundwater.

- **2.0 CONTROL OF CONSTITUENTS OF CONCERN IN NEAR-SURFACE SOILS.** Identifies and evaluates technologies and develops remedial alternatives for near-surface soils at the Facility.

- **3.0 CONTROL OF CONSTITUENTS OF CONCERN IN DEEP VADOSE ZONE SOILS.** Identifies and evaluates technologies and develops remedial alternatives for deep vadose zone soils at the Facility.

- **4.0 CONTROL OF CONSTITUENTS OF CONCERN IN SMEAR ZONE SOILS.** Identifies and evaluates technologies and develops remedial alternatives for smear zone soils at the Facility.

- **5.0 CONTROL OF CONSTITUENTS OF CONCERN IN PETROLEUM HYDROCARBON GROUNDWATER PLUMES.** Identifies and evaluates technologies and develops remedial alternatives for petroleum hydrocarbon groundwater plumes at the Facility.

- **6.0 CONTROL OF CONSTITUENTS OF CONCERN IN THE REMELT/HOT LINE GROUNDWATER PLUME.** Identifies and evaluates technologies and develops remedial alternatives for the Remelt/Hot Line groundwater plume at the Facility.

- **7.0 REFERENCES.** Lists references cited in the report and Appendices.

Supporting information and data tables are presented in appendices.

- **Appendix A** describes potential remediation technologies for COCs in near-surface soils.
- **Appendix B** describes the areas of concern for near-surface soils.
- **Appendix C** describes the areas of concern for deep vadose zone soils.
- **Appendix D** describes the areas of concern for smear zone soils.
- **Appendix E** presents the capture zone analysis used to evaluate the petroleum hydrocarbon and Remelt/Hot Line groundwater plumes.

I.3 APPROACH TO THE FSTM RELATIVE TO THE OVERALL FEASIBILITY STUDY

The FSTM divides the soil and groundwater at the Facility into five distinct segments (Sections 2 through 6). The segments were chosen since differing groups of technologies are applied to remediate the COCs contained in the environmental media present in each segment (e.g., near-surface soils, petroleum hydrocarbon groundwater plume, etc.).

The FSTM presents an initial screening of these technologies (based upon technical attributes) to identify those technologies that are judged to be implementable and reliable for each COC present in each segment of the site. The final screening of the technologies will be conducted by and summarized in the overall feasibility study for the site. This final screening will include a cost screening for those technologies judged to be implementable and equally reliable by the FSTM.

The FSTM develops technology-based remedial alternatives for the individual COCs (e.g., VOCs, SVOCs, PCBs, and metals) and mixtures of COCs present (e.g., SVOCs and PCBs) in each segment of the Facility. The overall feasibility study will evaluate these remedial alternatives to identify the most appropriate alternative(s) for each individual COC or mixture of COC present in a specific AOC. The most appropriate remedial alternatives for each segment of the site will be assembled to identify the appropriate area-based remedial alternative(s) for each operating area of the Facility (e.g., Oil House area, Wastewater Treatment area, etc.) and for the petroleum hydrocarbon and the Remelt/Hot Line groundwater plumes.

I.4 LIMITATIONS

Work for this project was performed, and this report prepared, in accordance with generally accepted professional practices for the nature and conditions of the work completed in the same or similar localities, at the time the work was performed. It is intended for the exclusive use of Kaiser Aluminum Washington, LLC for specific application to the referenced property. This report is not meant to represent a legal opinion. No other warranty, express or implied, is made.

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1.0 CONSTITUENTS OF POTENTIAL CONCERN AND SCREENING LEVELS

Section 1 of this report establishes screening levels (SLs) under the Washington State Department of Ecology Model Toxics Control Act (MTCA) for soil and groundwater. SLs were established for the constituent of potential concern (COPC) in each medium by following MTCA requirements. This includes considering site-specific conditions such as land use, and by comparing the risk-based MTCA SLs with other chemical-specific applicable or relevant and appropriate requirements (ARARs). The COPCs in each environmental medium are identified in Section 1.1 and are summarized in Table 1-1.

COPCs that exceed SLs are then evaluated to determine if they are constituents of concern (COCs). Several of the COCs identified at the site are mobile under certain environmental conditions. These include selected metals, volatile organic compounds (VOCs) and semi-volatile organic compounds (SVOCs). For these mobile COCs, the requirement under MTCA to clean up each medium (e.g., groundwater) to concentrations that are protective of other media (e.g., surface water) often result in the most stringent cleanup level.

Finally, the point of compliance (POC) for the SLs is specified. As specified under MTCA, the combination of the SL and the POC form the cleanup standard.

1.1 IDENTIFICATION OF CONSTITUENTS OF CONCERN AND AFFECTED MEDIA

COPCs were identified in the Final Groundwater RI (Hart Crowser 2012a), the Final Soil RI (Hart Crowser 2012b), and the Final Human Health and Ecological Risk Assessments (HHERA) (Pioneer 2012). Chemicals were generally evaluated against the following criteria:

- Soil background concentration comparisons for metals and inorganics. This was a critical step to eliminate metals with concentrations less than or equal to background concentrations from further regulatory concern (WAC173-340-740[5][c], WAC 173-340-745 [6][c]). Ecology has derived natural background concentration ranges for 12 metals in Washington State (Ecology 1994). Natural background concentrations for antimony, barium, selenium, and silver were derived using methods described in WAC 173-340-709. These concentrations are provided in Table C-2 of the Final HHERA. The background soil concentrations of the metals detected at the Kaiser Facility are listed in Table 1-2.

- Frequency of detection evaluation. Chemicals that were not detected with standard EPA test methods in a specific media are eliminated. Chemicals detected at a frequency of five percent or less were retained only if they were COPCs for another media (e.g., soil for the protection of groundwater) detected at a frequency greater than five percent.

- Risk-based screening. Maximum concentrations in soil, groundwater, and soil vapor, were screened against the following conservative risk-based screening levels (RBSLs):

  - Soil: Human health RBSLs were calculated for the industrial worker scenario for the ingestion of soil and dermal contact with soil (total petroleum hydrocarbons (TPH)-only) in accordance with WAC 173-340-745 in the Final HHERA. The benchmark cancer risk used to calculate SLs was 1.0E-06, while the target non-cancer hazard quotient (HQ) was 0.1.

    Other RBSLs were developed for soil for the protection of groundwater by using the MTCA Fixed Parameter 3-Phase Partitioning model (WAC 173-340-747[4]) and MTCA Method B CULs or a maximum contaminant level (MCL) established by the Clean Water Act (CWA) or the Safe Drinking Water Act (SDWA), whichever was lower for groundwater, in the Final Soil RI. The Final Soil RI used MTCA Method A values for TPH.

  - Groundwater: The Final Groundwater RI identified the following potential receptors for groundwater constituents: (1) humans, fauna, or flora consuming groundwater from a theoretical well installed within the area of groundwater contamination, and (2) if constituents of concern were to reach the Spokane River, humans, flora, or fauna exposed to surface water downgradient from the Kaiser Facility. RBSLs were defined for these potential receptors by considering the following standards and requirements:

    - Federal Safe Drinking Water Act MCL (40 CFR part 141);

    - State Safe Drinking Water MCLs (WAC 246-290-310);

    - Federal Safe Drinking Water Act secondary MCL based on aesthetic effects (40 CFR Part 143);

    - MTCA Methods A and B Groundwater Cleanup Levels (WAC 173-340-720);

  - Washington Surface Water Quality Standards (Chapter 173-201A WAC);

  - Clean Water Act Section 304 Standards for Freshwater Human Health and Chronic Aquatic Life;

  - National Toxics Rule (40CFR Part 131) for Freshwater Human Health and Chronic Aquatic Life; and

  - MTCA Method B cleanup levels for surface water (WAC 173-340-730).

- Workplace Air: Potential adverse affects based upon the inhalation of VOCs was evaluated for two sites at the Kaiser Facility: the Oil Reclamation Building and the Truck Shop. Measured soil gas concentrations of petroleum-related and other volatile constituents were attenuated by a factor of 0.01 to estimate the indoor air concentration resulting from the soil gas. This estimated concentration was compared to Washington State Industrial Safety and Health Act permissible exposure levels (PELs) in the HHERA (Section 7.8). The estimated indoor air concentrations were also below MTCA Method B ambient air cleanup levels (CULs).

- Ecological Risk: The Ecological Risk Assessment (ERA) was conducted in accordance with MTCA requirements (WAC 173-340-7490 to 7494). The terrestrial evaluation included an exclusions evaluation (WAC 173-340-7491) and site-specific evaluation (WAC 173-340-7493). The exclusions evaluation identified 19 of 25 areas of the Facility as not requiring further evaluation due to the presence of buildings, pavement, and compacted mineral soil. The chemicals that remained after the above screening were considered to have the potential to affect human health and the environment, and were retained for further evaluation.

The COPCs were identified by: (1) the comparison to background concentrations; (2) the frequency of detection evaluation; and, (3) the risk-based screening summarized in the Final Groundwater RI, the Final Soil RI and the Final HHERA. Table 1-1 indicates which document evaluated the specific COPCs.

Total petroleum hydrocarbon (TPH) concentrations have been measured by a variety of analytical techniques for over 20 years. This historical data (originally reported as total TPH) was reevaluated and compared to individual TPH products identified within the same site, using Ecology-approved Northwest TPH (NWTPH) methods. Diesel-range constituents (NWTPH-Dx) and gasoline-range constituents (NWTPH-Gx), are reported in the Final HHERA (Pioneer 2012, Appendix B). The Final Soil RI considered Stoddard solvents and mineral spirits to have the same soil SL as gasoline, and Kensol oil to have the same soil SL as diesel (Hart Crowser 2012b, Section 1).

1.2 CONSTITUENTS OF CONCERN AND SCREENING LEVELS FOR SOIL

Site-specific SLs for soils are developed in Section 1.2.1. To identify the COCs that must be addressed in this Feasibility Study Technical Memorandum (FSTM); the concentrations of the individual COPCs found at the Kaiser site (Section 1.1) are compared to these SLs in Section 1.2.2. The potential remediation alternatives for each COC are discussed in Sections 2 through 6 of this FSTM.

For the purpose of this FSTM, near-surface soils are considered to be those soils that are in the upper 20 feet of the soil column. The technologies available to treat COCs in soils in the upper 20 feet of the soil column are discussed in Section 2. Section 3 discusses the technologies that are available to treat soils between 20 feet below ground surface (bgs) but above the smear zone (where present). Technologies that are available to treat smear zone soils are discussed in Section 4.

1.2.1 Screening Levels for Soil

Screening levels for soil are derived under MTCA by considering the following pathways:

- Protection of human health during the ingestion of or direct exposure to the upper 15 feet of the soil horizon (Refer to the Final HHERA).
- Protection of groundwater resources based on potential leaching of chemicals from soils to groundwater (refer to the Final Soil RI).
- Protection of workplace air (VOCs only).
- Protection of wildlife during the ingestion of soil or the ingestion of COPCs that have accumulated in food which they consume.

In the development of these MTCA screening levels, the following site-specific information is relevant:

- The Kaiser property and the adjacent properties that make up the site are zoned heavy industrial (refer to Figure 1.1) and have approximately 2.5

million square feet of building space (SAIC 1993). Properties to the east of the Facility are zoned heavy industrial and commercial, whereas properties to the north are zoned commercial and residential. Properties south and west of the Spokane River are zoned commercial. The site has been an industrial area since 1942. The City of Spokane Valley has identified this area for future industrial land use and redevelopment (usually needed to get an "industrial" designation from Ecology). For these reasons, industrial land use exposure assumptions have been applied to the site.

- The Kaiser property is covered by buildings, roads, pavement, active rail-lines, large open areas of compacted mineral soil with no plant growth and little organic matter, and large open areas with grass and brush vegetation. The large areas with no plant growth reduce the potential for ingestion or direct contact to the upper 15 feet of soil by wildlife, and limit the area of the site that can provide wildlife habitat.

- The natural background concentration ranges of several COPCs in soil in the Spokane Valley, including arsenic (1.13 - 10.32 mg/kg), manganese (354.5 - 769.5 mg/kg), cadmium (0.125 - 0.685 mg/kg), and selenium (0.1 – 0.436 mg/kg) are above the soil SL calculated for the protection of groundwater pathway.

- The regional aquifer system is called the Spokane Valley-Rathdrum Prairie (SVRP) aquifer and was designated a Sole Source Aquifer by the U.S. Environmental Protection Agency in 1978 (Kahle et al., 2005). A Sole Source Aquifer is defined as one that supplies at least 50 percent of the drinking water consumed in the area overlying the aquifer (EPA 2009a). The SVRP aquifer provides drinking water for approximately 500,000 residents and covers approximately 370 square miles including the Rathdrum Prairie and Coeur d'Alene areas in Idaho, and the Spokane Valley and northern Spokane areas in Washington (Kahle and Bartolino, 2007).

- The Facility has its own on-site sewage treatment plant and separate wastewater treatment system for the Facility's industrial wastewater. The majority of the stormwater runoff from the mill area flows into storm drains and is conveyed to the lagoon downstream of the industrial wastewater treatment system for eventual discharge into the Spokane River. Precipitation that falls on pervious surfaces, which is not evaporated or transpired by plants, percolates into the SVRP aquifer. There are drywell catch basins located throughout the Facility, including nine drywells located southwest of the Remelt building. The drywell catch basins receive runoff from the adjacent impervious surfaces and some roof runoff from surrounding buildings. Runoff directed to the drywells percolates into the aquifer.

- Groundwater at the site is potable (Hart Crowser 2012a), and its maximum beneficial uses are for drinking water and for recharge of the Spokane River. Since the Spokane River near the Kaiser site is a gaining reach for part of the year it is assumed that groundwater from the site seasonally discharges into the river. Water-supply wells exist in the area.

- The Spokane River, north of the City of Spokane, drains more than 4,000 square miles of land in northeastern Washington and the Idaho panhandle. The river has a long history of water quality concerns, including sludge accumulations, pathogen hazards, low dissolved oxygen, noxious algae blooms, and metal toxicity (Patmont et al., 1987). Most of these concerns have been attributed to municipal wastewater discharges in Spokane and to mining-related sources near Kellogg, Idaho. It should be noted that the Facility groundwater data indicate that the COPCs including free-phase petroleum, SVOCs, and metals (arsenic, iron and manganese) that are located in the Oil House and Wastewater Treatment areas of the site are within the hydraulic control of the interim remedial measure (IRM) that is operating in these areas and that none of these COCs are being discharged to the Spokane River at detectable concentrations via the groundwater pathway (Hart Crowser 2012a, Section 6). Low concentrations of PCBs are infrequently detected in wells near the river. Additional investigations are ongoing to further investigate groundwater quality and fate and transport at these locations.

- The Spokane River is designated as Water Resource Inventory Area 54 in the reaches where discharge from the site occurs (Chapter 173-201A WAC, Table 602). The designated uses for this reach of the river are for aquatic life, recreation, water supply and other uses. SLs for the river are necessary to protect aquatic species and human health through the consumption of aquatic species, and direct contact with and/or ingestion of water.

- Castor oil is used as a releasing agent in the casting/remelt area. Castor oil is not a petroleum product. Toxicity values in MTCA are for petroleum products and can not be applied to castor oil.

Table 1-2 lists the COPCs for soil, and their risk-based MTCA screening level based on one of the following three pathways:

- Ingestion/Direct Contact with Soil. Concentrations are derived using the procedures and default exposure assumptions for industrial sites as defined in WAC 173-340-745. The Final HHERA identified three areas of the site that exceeded RBSLs. The exceedances occurred in the Oil House French Drain area (Aroclor 1248), the Hoffman Tank area (diesel), and in the ORB Man-Made Depressions area (lead).

- Protection of Wildlife. The Final HHERA determined that the risk to wildlife was below the ecological risk criteria that were established.

- Protection of groundwater. Concentrations are derived using the Fixed Parameter 3-Phase Partitioning model (WAC 173-340-747[4] and MTCA Method B CULs, or MCLs established by the CWA or the SDWA, whichever is lower for groundwater). This pathway was determined to have the most impact on the SLs established for soils at the Kaiser site.

  Calculated SLs for the soil for the protection of groundwater pathway were exceeded for arsenic, cadmium, manganese, PCBs, cPAHs, TPHs; other SVOCs (2-methylnapthelene, N-nitrosodiphenylamine); and for VOCs (benzene, PCE, methylene chloride, ethyl benzene, and total xylenes).

- Protection of Workplace Air: Potential adverse effects caused by the inhalation of soil gas vapors were evaluated for two sites at the Kaiser Facility: the Oil Reclamation Building and the Truck Shop. Measured soil gas concentrations of petroleum-related and other volatile constituents were attenuated by a factor of 0.01 to estimate the indoor air concentration resulting from the soil gas. This estimated concentration was compared to Washington State Industrial Safety and Health Act (WISHA) permissible exposure levels (PELs) in the HHERA (Section 7.8). The estimated concentration of BTEX, TCE, TCA, and chloroethane were from 50,000 to more than 2 million times lower than WISHA PEL values. The estimated indoor air concentrations were also below MTCA Method B ambient air CULs.

1.2.2 Constituents of Concern for Soil

The COPCs that were identified for unsaturated soil (from the HHRA, ERA, and soil for the protection of groundwater calculations) and for saturated soil (soil for the protection of groundwater calculations) are listed in Table 1-2. When the concentration of a COPC exceeded the screening level, it is then further evaluated to determine if it is a COC. Each of the COPCs that exceeded the SLs were examined to determine if it was contributing to an actual risk to human health and the environment and whether it should be carried forward as a soil COC.

Several of the COPCs that exceeded the SLs as identified in the Final Groundwater RI by investigating the soil for the protection of groundwater pathway were not carried forward as a COC. Cadmium was excluded as a COC since it has no known on-site source and was judged to be a background constituent. A few soil samples from the site exceed background ranges based on Ecology's soil background document (Ecology 1994) for the Spokane area. The soil screening level for cadmium used in the Soil RI (Hart Crowser 2012b) is based on protection of groundwater using the fixed parameter, three-phase partitioning model in the MTCA. A few of the site soil samples also exceeded this conservative screening level. Empirical data from the site as presented in the Final Site-Wide Groundwater Remedial Investigation Report (Hart Crowser 2012a, page 5-8) indicates only one groundwater result has exceeded the groundwater screening level and that single exceedance was in an upgradient (background) well in 1990. Cadmium detections in soil do not exceed other risk-based values (direct contact and terrestrial ecological) based on available site data. Based on the weight of evidence, the cadmium detected in soil at the Kaiser Facility is likely to be representative of background for the area.

Several VOCs including benzene, PCE, 1,2-DCA, and TCE were excluded due to infrequent historical detections and no known on-site source of the COPC. Gasoline and Stoddard solvent were excluded as a COC for nearly all areas of the site due to their infrequent detection, low magnitude of detected concentrations, limited areal extent, and their association with other known areas of TPH contamination.

Site soil samples were not analyzed for iron. The Final Groundwater RI did examine the effects of iron on human health and the environment. The Groundwater RI concluded that iron should be included as a COC due to its secondary (aesthetic) effects.

Chromium has been excluded for nearly all areas of the site due to its infrequent detection, low magnitude of detected concentrations, and limited areal extent. However, chromium has been included as a COC in the area around the Chromium Transfer Line.

This FSTM has judged that several other SVOCs and VOCs identified by the soil for the protection of groundwater pathway should be excluded since they had no known on-site source, were not widely dispersed, were detected infrequently, and had low magnitude of detected concentrations. The VOCs included methylene chloride, ethyl benzene, and total xylenes. The SVOCs included 2-methylnaphthalene and N-nitrosodiphenylamine.

The following COCs are identified for soil for all or portions of the Kaiser Facility:

- Diesel and heavy oil;
- Gasoline and Stoddard solvent;
- PCBs (total);
- cPAHs;
- Metals causing potential human or ecological health risk (arsenic, chromium, and lead); and
- Metals causing potential adverse secondary (aesthetic) effects to groundwater (iron and manganese).

1.2.3 Point of Compliance for Soil

The standard point of compliance (POC) for soil under MTCA is throughout the site for protection of groundwater and workplace air. The POC for soil cleanup levels based on human exposure during direct contact (WAC 173-340-740[6][b,c,d]) and wildlife exposure due to the ingestion of site soils is from the ground surface to 15 feet below ground surface (bgs).

The selected remedy for the site could leave hazardous substances behind in excess of cleanup standards. Then the cleanup action would be considered to comply with cleanup standards provided that the remedy (e.g., containment) is permanent to the maximum extent practicable using the procedures in WAC 173-340-360; that a compliance monitoring program demonstrates the long-term integrity of the containment system; and that that institutional controls are in place (WAC 173-340-740 [6][f]).

1.3 CONSTITUENTS OF CONCERN AND SCREENING LEVELS FOR GROUNDWATER

The evaluation process for developing site-specific SLs for groundwater is presented in Section 1.3.1. The concentrations of the COPCs identified at the Kaiser Facility that were identified in Section 1.1 are compared to these SLs in Section 1.3.2, to identify the COCs that are addressed by the potential remediation alternatives discussed in Sections 5 and 6 of this FSTM.

1.3.1 Screening Levels for Groundwater

The maximum beneficial uses of groundwater in the alluvial aquifer at the Kaiser Facility are as a potential drinking water source and as a discharge to the Spokane River; therefore, cleanup levels for groundwater are derived under MTCA by considering the following pathways:

- Humans, flora, or fauna consuming groundwater from a potential well installed within the area of groundwater contamination; and

- If constituents of concern were to reach the river, humans, flora, or fauna exposed to surface water downgradient of the Facility.

1.3.1.1 Protection of Drinking Water

MTCA groundwater cleanup standards are defined in WAC 173-340-720. The standards must be at least as protective as the requirements established by the:

- Federal Safe Drinking Water Act MCL (40 CFR part 141);

- State Safe Drinking Water MCLs (WAC 246-290-310);

- Federal Safe Drinking Water Act secondary MCL based on aesthetic effects(40 CFR Part 143);

- MTCA Methods A and B (WAC 173-340-720 (3) and (4); and

- MTCA Surface Water Standards (WAC 173-340-730), unless it can be shown that the COPCs are not likely to reach surface water. (Some PCBs, free-phase petroleum, iron, manganese, and arsenic may not reach the Spokane River via groundwater, according to the Final Groundwater RI, Section 6).

In addition, for those COPCs for which there is no value in MTCA Table 720-1, or in applicable state or federal laws, the CUL cannot be higher than the natural background concentration of the COPC or the laboratory practical quantitation limit (PQL).

1.3.1.2 Protection of Surface Water

Surface water screening levels at the Kaiser Facility were established based upon a consideration of the following regulatory criteria:

- EPA National Recommended Water Quality Criteria (National Toxics Rule) (40 CFR Part 131) for protection of aquatic species in fresh water;

- EPA National Recommended Water Quality Criteria (National Toxics Rule) (40 CFR Part 131) for protection of human health through the consumption of aquatic species;

- Washington Surface Water Quality Standards (Chapter 173-201A WAC);

- Clean Water Act Section 304 Standards for Freshwater Human Health and Chronic Aquatic Life; and

- MTCA Method B cleanup criteria for the protection of human health through the consumption of aquatic species WAC 173-340-730(3).

1.3.1.2 Protection of Workplace Air

Groundwater at the Kaiser Facility is more than 70 feet bgs, and the occurrence of volatile components in groundwater is so low (refer to Final Groundwater RI, Section 5.2) that protection of the groundwater to air pathway has not been considered for VOCs.

1.3.2 Constituents of Concern for Groundwater

The COPCs that were identified for groundwater are listed in Table 1-3. When the concentration of a COPC exceeds the SL, it is then evaluated to determine if it is a COC. Each of the COPCs that exceeded SLs, was examined to determine if it was contributing to an actual risk to human health and the environment and whether it should it should be carried forward as a groundwater COC.

Several COPCs were not carried forward as COCs. Antimony was not carried forward as a COC, since antimony is considered to be a background constituent. The Groundwater Remedial Investigation/Feasibility Study (Hart Crowser 2003, page 3-17) analyzes antimony detections in groundwater and concludes that these detections are a background anomaly. The evaluation of antimony detections in groundwater included a statistical comparison of two groundwater datasets; one from upgradient and one from downgradient of the mill area using the SITE spreadsheet in MTCAStat that was available at that time. The upgradient population displayed a normal distribution and possessed a 95%UCL of 0.01 mg/L. The downgradient well data displayed a log normal distribution and the 95%UCL was also 0.01 mg/L. This indicates the two populations are not statistically different.

Cadmium, chromium, and copper were excluded as COCs by the Final Site-Wide Groundwater Remedial Investigation (Hart Crowser 2012a). VOCs including benzene, PCE, 1,2-DCE, and TCE were excluded due to infrequent historical detections and no known on-site source of the COPC. Gasoline and Stoddard solvent were excluded for nearly all areas of the site due to their infrequent detection, low magnitude of detected concentrations, limited areal extent, and their association with other known areas of TPH contamination.

The following COCs have been identified for groundwater for all or portions of the Kaiser Facility:

- Diesel and heavy oil;
- Gasoline and Stoddard solvent (select areas of the Facility);
- PCBs (total);
- cPAHs; and
- Metals (arsenic, iron, and manganese).

1.3.3 Groundwater Point of Compliance

The POCs for groundwater under MTCA are as follows:

- The default POC under MTCA for groundwater, throughout the site, is from the uppermost level of the saturated zone extending vertically to the lowest depth that could potentially be affected by the site (WAC 173-340-720[8][bJ).

- Where hazardous substances remain onsite as part of the cleanup action, a conditional POC may be established, not to exceed the property boundary (WAC 173-340-720[8][c).

- The conditional POC for groundwater based on protection of surface water is within the surface water as close as technically possible to the point or points where groundwater flows into the surface water (WAC 173-340-720[8][d)(i)) for properties abutting surface water.

This conditional POC for surface water may be used when the following conditions are met:

- Groundwater discharge into surface water has been treated with all known, available, and reasonable methods prior to release. (The effect of this requirement is discussed in Sections 4 and 5.)

- Groundwater discharge into surface water shall not result in exceedances of sediment quality standards under Chapter 173-204 WAC.

- Groundwater monitoring shall be performed to estimate contaminant flux rates and potential bioaccumulation issues.

Finally, when this conditional POC is used, the cleanup levels may not rely on a dilution zone in order to meet surface water standards.

1.4 CONSTITUENT OF CONCERN AND SCREENING LEVELS FOR WORKPLACE AIR

Potential adverse effects based upon the inhalation of soil gas vapors was evaluated for two locations at the Kaiser Facility: the Oil Reclamation Building and the Truck Shop. Measured soil gas concentrations of petroleum-related and other volatile constituents were attenuated by a factor of 0.01 to estimate the indoor air concentration resulting from the soil gas. This estimated concentration was compared to Washington State Industrial Safety and Health Act permissible exposure levels (PELs) in the Final HHERA (Section 7.8). The estimated concentration of benzene, toluene, ethylbenzene, and total xylenes (BTEX), TCE, TCA, and chloroethane were from 50,000 to more than 2 million times lower than WISHA PEL values. The estimated indoor air concentrations were also below MTCA Method B ambient air CULs. As a result these contaminants were not considered to be COCs for the protection of indoor air.

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Table 1-1 - COPCs at the Kaiser Site Identified by the Soil RI, GW RI, HHERA, and ERA

Chemical	**Soil RI** (mg/kg)	**GW RI** (ug/L)	**HHERA** (mg/kg)	**ERA** (mg/kg)
Metals				
Antimony	NO	Yes	NO	NO
Arsenic	Yes	Yes	Yes	Yes
Cadmium	Yes	Yes	NO	NO
Chromium	NO	Yes	NO	NO
Copper	NO	Yes	NO	NO
Iron	NO	Yes	NO	NO
Lead	NO	Yes	Yes	Yes
Manganese	Yes	Yes	NO	NO
Selenium	NO	NO	NO	Yes
Zinc	NO	Yes	NO	NO
PCBs				
Total PCBs	Yes	Yes	(1)	Yes
Aroclor 1248	(1)	(1)	Yes	(1)
Aroclor 1254	(1)	(1)	Yes	(1)
PAHs				
cPAH - TEQ	Yes	Yes	Yes	NO
Other SVOCs				
2-Methylnapthelene	Yes	NO	NO	NO
N-Nitrosodiphenylamine	Yes	NO	NO	NO
TPHs				
TPH-G	Yes	Yes	NO	NO
TPH-D	Yes	Yes	Yes	Yes
TPH- Heavy Oil	Yes	Yes	Yes	NO
Volatiles				
Benzene	No	Yes	NO	NO
1,2-DCA	NO	Yes	NO	NO
PCE	NO	Yes	NO	NO
TCE	NO	Yes	NO	NO
Methylene Chloride	Yes	NO	NO	NO
Total Xylenes	Yes	NO	NO	NO
Conventionals				
Nitrate	NO	Yes	NO	NO

Notes

(1) Total PCB concentrations were evaluated by the soil RI, Groundwater RI, and by the ERA.
Individual Aroclor 1248 and Aroclor 1254 concentrations were evaluated by the HHRA.
As required by the MTCA, total PCBs will be used for cleanup actions and MTCA compliance at the site.

Table 1-2 - Soil Screening Level Concentrations

COPCs	Unsaturated Soil Background (mg/kg) (5)	Ingestion/Direct Contact with Soils (mg/kg) (1)	Protection of Wildlife (mg/kg) (2)	Protection of Groundwater		Screening Levels		Reason for Proposed SLs
				Unsaturated Soil (mg/kg) (3)	Saturated Soil (mg/kg) (4)	Unsaturated soil (mg/kg) (6)	Saturated Soil (mg/kg) (6)	
Metals								
Antimony	3.1 - 7.6	140	N.A.	5.42	N.A.			
Arsenic	**1.13 - 10.32**	**9 (a)**	**7 (c)**	**0.0341**	**0.0017**	**10.32**	**10.32**	natural background concentration
Cadmium	**0.125 - 0.685**	350	14	**0.7**	**0.0349**	**(g)**	**(g)**	
Chromium III		N.A.	N.A.	2000	100			
Chromium VI		1,050	67	N.A.	N.A.			
Copper	**4.04 - 29.03**	12,950	N.A.	260	N.A.			
Iron	9670 - 27000	N.A.	N.A.	N.A.	N.A.	**(j)**	**(j)**	
Lead	**6.75 - 16**	**1,000 (b)**	**118**	250 (f)	250 (f)	**1,000 (i)**	N.A.	Human health risk is present (i)
Manganese	354.5 - 769.5	49,000	1,500	**52.2**	**3**	769.5 (j)	769.5 (j)	natural background concentration
Selenium	0.1 - 0.4362	1750	**0.3**	5	N.A.	**(h)**		
Zinc	**29.7 - 71**	105,000	N.A.	5970	N.A.			
PCBs								
Total PCBs		6.6	**0.34 (d)**	**0.272**	**0.014**	**0.272**	**0.014**	Lowest of Soil SLs
Aroclor 1248		**6.6**	**0.34 (d)**	**0.272**	**0.014**	**0.272**	**0.014**	Lowest of Soil SLs
Aroclor 1254		**6.6**	**0.34 (d)**	**0.272**	**0.014**	**0.272**	**0.014**	Lowest of Soil SLs
PAHs								
cPAH - TEQ		**0.42**	12 (e)	**0.233**	**0.012**	**0.233**	**0.012**	Lowest of Soil SLs
Other SVOCs								
2-Methylnapthalene		N.A.	N.A.	**2190**	**0.112**	**(g)**	**(g)**	
N-Nitrosodiphenylamine		N.A.	N.A.	**536**	N.A.	**(g)**		
TPHs								
Gasoline/Stoddard Solvent		2909	5,000	**100 (f)**	**100 (f)**	**100 (i)(g)**	**100 (i)(g)**	Lowest of Soil SLs
Diesel		**2667**	**6000**	**2000 (f)**	**2000 (f)**	**2000**	**2000**	Lowest of Soil SLs
Heavy Oil		**98,000**	6,000	**2000 (f)**	2000 (f)	**2000**	**2000**	Lowest of Soil SLs
VOCs								
Benzene		136	N.A.	**0.005**	N.A.	**0.005 (g)**	N.A.	Lowest of Soil SLs
Ethyl Benzene		N.A.	N.A.	**5.99**	N.A.	**(g)**		
Methylene Chloride		N.A.	N.A.	**0.022**	N.A.	**(g)**		
PCE		3,500	N.A.	0.9	**0.00005**	**(g)**	**0.00005 (g)**	Lowest of Soil SLs
TCE		1,010	N.A.	N.A.	N.A.	N.A.	N.A.	
Total Xylenes		N.A.	N.A.	**14,500**	N.A.	**(g)**		

Notes:

Bolded text indicates that the criteria have been exceeded at the site (refer to the appropriate RI document for the screening criteria that was used).

N.A. Not detected, or detected at a frequency of less than 5 percent of samples analyzed

(1) Refer to the the HHRA Tables 4.2 and 4.3. Human health risk above criteria found for Aroclor 1248 (Oil House French drain area), diesel (Hoffman Tank area), and for lead (ORB Man-Made Depressions area).

(2) Refer to the Kaiser ERA Tables 11.1 and 11.2. No risk to wildlife above criteria was identified.

(3) Refer to the Kaiser Soil RI Table 1.1.

(4) Refer to the Kaiser Soil RI Table 1.2.

(5) The natural background concentration ranges from Ecology 1994 ranges were used except for background concentrations for antimony and selenium which were derived using methods described in WAC 173-340-709 (Refer to HHERA Appendix C).

(6) Lowest concentration for which an exceedance was observed.

(a) Natural background concentration (Refer to HHERA Appendix C)

(b) MTCA Method A - Industrial properties (Table 745-1E)

(c) MTCA indicator soil concentration (ISC) value for As III used (Table 749-3)

(d) Site-Specific ISC value (shrew) for total PCBs used (refer to the Kaiser HHERA table 11-6)

(e) MTCA ISC value of benzo(a)pyrene used

(f) MTCA Method A (Table 740-1)

(g) Not considered a groundwater COPC, refer to Kaiser Groundwater RI Section 5.2.

(h) Refer to Kaiser HHERA Section 11.

(i) COC present only in the some areas of the site: lead the ORB Man-Made Depressions, and gasoline in Oil House, ORB, Truck Shop and G-1 Transfer Line areas.

(j) Considered a COC in the Kaiser Groundwater RI Section 5.2 for potential adverse secondary (aesthetic) effects.

Table 1-3 - Groundwater Screening Level Concentrations

		Groundwater		Groundwater								Surface		
		Federal and State	Drinking Water Standards	Method A	Method B		Aquatic Life Fresh/ Chronic			Human Health - Fresh Water		Method B		PQL
COPC	Screening Levels (µg/L)	Primary MCL (µg/L)	Secondary MCL (µg/L)	(µg/L)	Carcinogen(µg/L)	Non-carcinogen (µg/L)	Ch. 173-201A WAC (µg/L)^{a}	Clean Water Act §304(µg/L)	National Toxics Rule, 40 CFR 131 (µg/L)	Clean Water Act §304 (µg/L)	National Toxics Rule, 40 CFR 131 (µg/L)	Carcinogen (µg/L)	Non-Carcinogen (µg/L)	
Conventionals		--	--	--	--	--	--	--	--	--	--	--	--	
Nitrate	10000	**10000**	--	--	--	--	--	--	--	**10000**	--	--	--	
Metals (Total and Dissolved)														
Antimony	6	**6**	--	--	--	6.4	--	--	--	5.6	14	--	1000	0.05
Arsenic	0.018	10	--	5	0.058	4.8	190	150	190	**0.018**	**0.018**	0.098	18	0.5
Cadmium	0.25	5	--	5	--	8	0.37	**0.25**	1	--	--	--	20	0.05
Chromium	50	100	--	**50**	--	--	--	--	--	--	--	--	--	0.2
Copper	3.50	1300	1000	--	--	590	**3.5**	9	11	--	--	--	2700	
Iron	300	--	**300**	--	--	--	--	1000	--	**300**	--	--	--	20
Lead	0.54	15		15	--	--	**0.54**	2.5	2.5	--	--	--	--	0.02
Manganese	50	--	**50**	--	--	2200	--	--	--	**50**	--	--	--	0.05
Zinc	32	--	5000	--	--	4800	**32**	120	100	7400	--	--	17000	
cPAHs														
TEQ	0.0028	0.2	--	0.100	0.012	--	--	--	--	0.0038	**0.0028**	0.030	--	0.02
Volatiles														
1,2-Dichloroethane(EDC)	0.38	5	--	5	0.48	160	--	--	--	**0.38**	**0.38**	59	43000	
Benzene	0.8	5	--	5	**0.8**	32	--	--	--	2.2	1.2	23	2000	
Tetrachloroethene	0.081	5	--	5	**0.081**	80	--	--	--	0.690	0.8	0.390	840	
Trichloroethene (TCE)	0.49	5	--	5	**0.49**	2.4	--	--	--	2.5	2.7	6.7	71	
Pesticides/PCBs														
Total PCBs	0.000064	0.5	--	0.1	0.044	--	0.014	0.014	0.14	**0.000064**	0.00017	0.00011	--	0.005
TPH														
Gasoline	800	--	--	**800/1000** $^{(c)}$	--	--	--	--	--	--	--	--	--	
Diesel	500	--	--	**500**	--	--	--	--	--	--	--	--	--	
Heavy Oil	500	--	--	**500**	--	--	--	--	--	--	--	--	--	

Notes

MCL = Maximum Contaminant Level

PQL = Practical Quantitation Limit

-- = No Data

*Based on State MCL. No Federal MCL for constituent.

Bold value represents the most conservative value and is used as the screening level.

[a] Calculations for hardness-dependent metals were based on hardness = 25

Individual formulas are as follows:

Cadmium:

≤ (0.909)(e(0.7852[ln(hardness)]-3.490)) at hardness = 100. Conversions factor (CF) of 0.909 is hardness dependent. CF is calculated for other hardnesses as follows: CF = 1.101672 - [(ln hardness)(0.041838)].

Chromium III

≤ (0.860)e(0.8190[ln(hardness)]+ 1.561)

Copper

≤ (0.960)(e(0.8545[ln(hardness)] - 1.465))

Lead

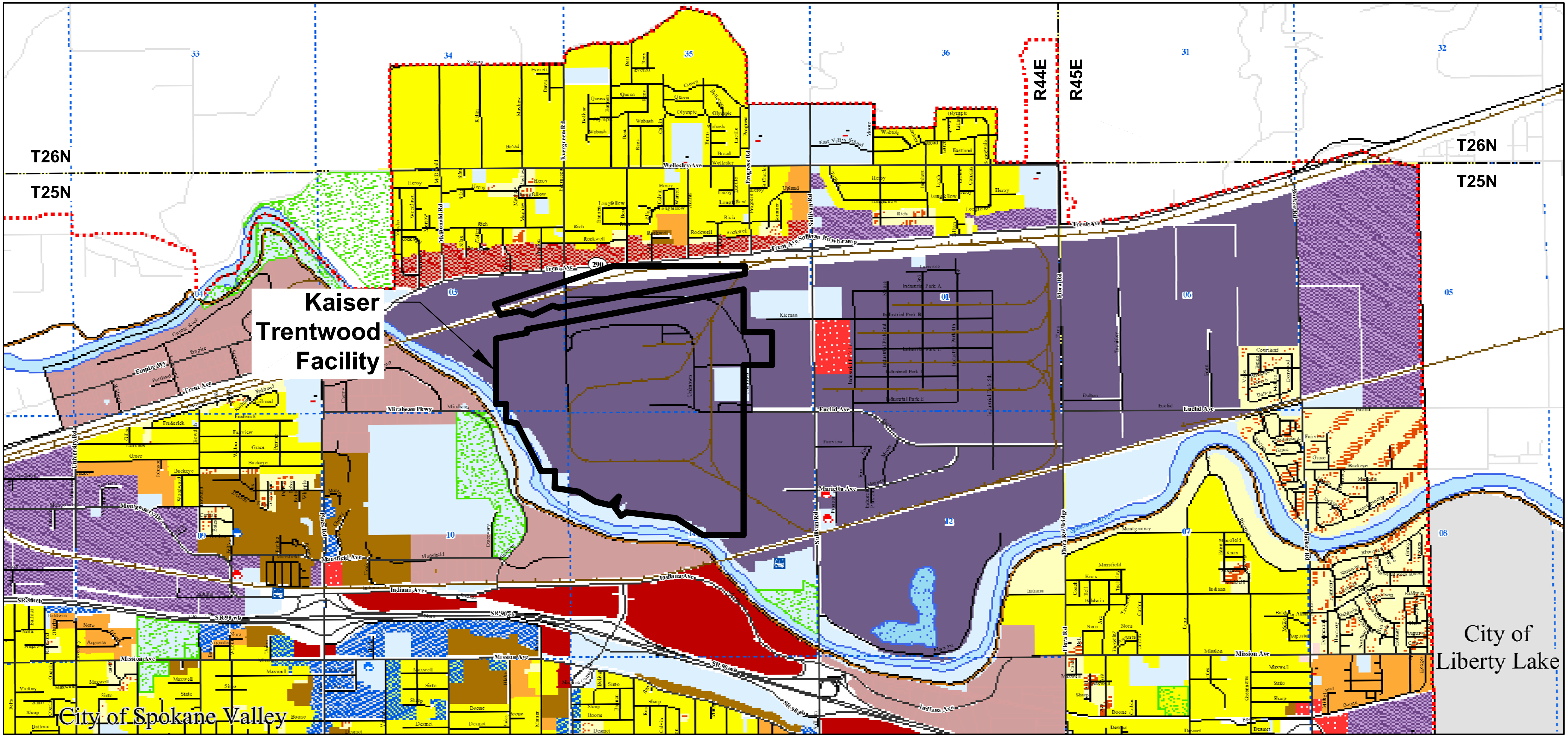
≤ (0.791)(e(1.273[ln(hardness)] - 4.705)) at hardness = 100. Conversion factor (CF) of 0.791 is hardness dependent. CF is calculated for other hardnesses as follows: CF = 1.46203 - [(ln hardness)(0.145712)].

[b] Screening levels are based on mixures of cPAH values based on Toxicity Equivalency Quotient (TEQ) calculation from WAC 173-304-708 as calculated in Table 1-4. The reference compound for Total cPAHs is benzo(a)pyrene (BaP).

[c] Benzene present/no benzene present

Analytes in bold type are considered to be COCs for Groundwater at the Kaiser site.

City of Spokane Valley Zoning for Kaiser Property and Surrounding Area



EAL 09/28/09 2644116-065.dwg

🟨 R-2 - Single-family Residential Suburban District

🟨 R-3 - Single-family Residential District

▨ R-4 - Single-family Residential Urban District

🟧 MF-1 - Multi-family Medium Density Residential District

🟫 MF-2 - Multi-family High Density Residential District

■ MUC - Mixed Use Center District

▨ CMU - Corridor Mixed Use District

▨ GO - Garden Office District

▨ O - Office District

■ NC - Neighborhood Commercial District

▨ C - Community Commercial District

🟥 RC - Regional Commercial District

▨ I-1 - Light Industrial District

🟪 I-2 - Heavy Industrial District

■ CF - Community Facilities District

N

0 2000 4000

Approximate Scale in Feet

Source: City of Spokane Valley "Zoning Map", 01/20/09. Map website: *http://www.spokanevalley.org/uploads/Community_Development/Documents/GIS/ZoningMap.pdf.*
Zoning district information from Spokane Valley Municipal Code (19.20.010)

HARTCROWSER

2644-116 ***12/09***

Figure 1-1

CONTENTS

CONTENTS (Continued)

TABLES

CONTENTS (Continued)

TABLES (Continued)

CONTENTS (Continued)

TABLES (Continued)

FIGURES

2.0 CONTROL OF CONSTITUENTS OF CONCERN IN NEAR-SURFACE SOILS

This feasibility study/technical memorandum (FSTM) evaluates the potential application of remedial technologies to address environmental issues throughout the 512-acre Kaiser Site. The discussion that follows divides the site into eight general operating areas as described in Section 1.2 of the Final Kaiser Soil RI (Hart Crowser 2012b):

- Oil Reclamation Building and surrounding areas;
- Former Rail Car Unloading area;
- Cold Mill/Finishing area;
- Oil House area;
- Wastewater Treatment area;
- Truck Shop area;
- Former Discharge Ravine areas; and
- Remelt/Hot Line area

Within several of these eight general operating areas are subsites that will be evaluated separately due to differing Constituents of Concern (COCs), COC sources, or other chemical or physical differences. The general operating areas with applicable subsites are listed in Table 2-1 and mapped on Figure 2-1.

This section evaluates remedial technologies that could be applicable to COCs in near-surface (upper 20 feet) soil. Section 2 is organized as follows:

- Section 2.1 – Potential Remediation Technologies for COCs in Near-Surface Soils
- Section 2.2 – Potential Remediation Technologies for SVOCs in Near-Surface Soils
- Section 2.3 – Potential Remediation Technologies for PCBs in Near-Surface Soils

- Section 2.4 – Approach to Screening Technologies for Remediating Near-Surface soil
- Section 2.5 –Screening Technologies for Remediating Near-Surface Soils
- Section 2.6 - Description of Areas of Concern for Near-Surface Soils
- Section 2.7 – Development of Remedial Alternatives

Constituents of Potential Concern (COPCs) in soils on the Kaiser Site are identified in Section 1.1. Risk-based screening levels (RBSLs) are then established for the COPCs in each medium (e.g., soil, groundwater) by following MTCA requirements, by considering site-specific conditions such as land use, and by comparing the risk-based MTCA screening levels (SLs) with other chemical-specific applicable or relevant and appropriate requirements (ARARs). COPCs that exceed SLs were further evaluated to determine if they were COCs. The COCs identified for near-surface soils in Section 1.2.2 fall under the following groupings:

- Volatile Organic Compounds (VOCs);
- Semivolatile Organic Compounds (SVOCs);
- Total Polychlorinated Biphenyls (PCBs);
- Metals (arsenic, lead, chromium, iron, and manganese).

VOCs

Past investigations have identified several areas of the site that contain VOCs in the shallow soil above SLs. For the purposes of the FSTM technology evaluation, light-end TPH compounds in the gasoline range (e.g., gasoline and Stoddard solvent/mineral spirits) will be evaluated against technologies pertaining to VOCs. The areas identified with VOC exceedances include the Man-Made Depressions, Oil Reclamation Building, Oil House (20,000-Gallon Leaded Gasoline UST), and Truck Shop, (Figure 2-1). The VOCs of concern in near-surface soil are gasoline and Stoddard/mineral spirit-range petroleum hydrocarbons. Benzene, toluene, ethylbenzene, and xylenes (BTEX), methylene chloride, and tetrachloroethene (PCE) were detected in a few scattered locations at the site at concentrations that exceeded the soil to groundwater SL, but these chemicals are not considered to be COCs as discussed in Section 1.1.

SVOCs

For the purposes of this FSTM and remediation technology evaluations, SVOCs are considered to include carcinogenic Polycyclic Aromatic Hydrocarbon (cPAHs) and TPH in the diesel- and heavy oil-ranges that have been identified as COCs. There are seven cPAHs that have been identified by the EPA as known or probable human carcinogens recognized as capable of causing cancer in humans. These cPAHs include benzo(a)anthracene, benzo(b)fluoranthene, benzo-(k)fluoranthene, benzo(a)pyrene, chrysene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene. In accordance with Ecology regulations (WAC 173-340-708(8)(e)(iii)), detected concentrations of these seven cPAHs were combined into one concentration using a toxic equivalency (TEQ) approach for the purposes of the soil to groundwater pathway screening. Areas with cPAH SL exceedances include the Man-Made Depressions area of the ORB, Rail Car Unloading area, and the Continuous Can Process Line (Figure 2-1).

Other SVOCs detected in shallow soil at concentrations exceeding the soil to groundwater SL include 2-methylnaphthalene (one SL exceedance in the ORB area) and N-Nitrosodiphenylamine (two exceedances; one in the ORB area and one in the Truck Shop area). As discussed in Section 1.1, these chemicals are not considered to be COCs by this FSTM.

TPH concentrations in soil have been evaluated at Kaiser for over 20 years. Several different TPH-containing products were used across the Facility, ranging from gasoline to heavy oils. The composition of the various TPH-containing products present at the site varies widely and is directly related to the associated toxicity and mobility of TPH compounds through the soil. By far, the majority of TPH compounds found in impacted soil at Kaiser are in the diesel- and heavy oil-range and at least one TPH compound has been identified at every investigation site at Kaiser. Due to their similar physical properties, diesel- and heavy oil-range TPH compounds (e.g., Kensol, diesel, heavy oil, Bunker C) are evaluated by technologies pertaining to SVOCs in the remedial technology evaluation presented in Section 2.2 of this FSTM. Note that castor oil (identified by the same analysis method used for diesel and heavy oil-range compounds) is a vegetable (non-petroleum)-based oil and is used as a releasing agent in the aluminum casting process.

Refer to Section 1.5 of the Final Soil RI (Hart Crowser 2012b) for a more complete description of the various analysis methods used for TPH compounds over the years and how screening levels were applied to the detection of TPH in the soil.

Polychlorinated Biphenyls (PCBs)

Soil testing at Kaiser conducted since the late 1980s has included analysis for the various Aroclors that were commonly used by industry before they were banned in the United States in the 1970s. Aroclors are mixtures of different chlorinated biphenyls that were sold in the United States under the trade name Aroclor followed by a four-digit number (e.g., Aroclor 1248). The first two digits refer to the number of carbon atoms in the biphenyl molecule and the second two digits refer to the mass percentage of chlorine in the PCB mixture. Therefore, Aroclor 1248 contains 12 carbon atoms and 48 percent chlorine by mass. The exception to this nomenclature is Aroclor 1016, which contains 12 carbon atoms and 42 percent chlorine by mass. Many of the technologies applicable for remediation of SVOCs in soil apply to PCB remediation.

The areas at Kaiser identified with shallow soil PCBs exceedances include the Oil House Drum Storage/French Drain area, Former South and West Discharge Ravines, and the Remelt/Casting areas (Figure 2-1).

Metals

Lead in the Man-Made Depressions area was identified as a potential COC as a result of the Human Health Risk Assessment. A relatively small quantity of lead that exceeds its risk-based screening level is present in the Man-Made Depressions area of the ORB (refer to Appendix B). The lead area of concern (AOC) is adjacent to an SVOC AOC.

Chromium is present at a concentration above its SL in a small area adjacent to the foundation of Building 2118-C (refer to Appendix B). This area was previously excavated to remove contaminants. The remaining chromium appears to be located below the bottom of the previous excavation.

Arsenic is present at concentrations above its SL in three locations within the Wastewater Treatment area; the Field Constructed Tank (FCT) area, the Hoffman Tank area, and the H_2S Scrubber Building area (refer to Appendix B). The arsenic AOC in the FCT area contains the SVOC AOC in the FCT area. The arsenic AOC present in the Hoffman Tank area is co-located within an SVOC AOC. The arsenic AOC in the H_2S Scrubber Building area is small in size, isolated from other AOCs, and was established based upon results from one sample location.

Cadmium was excluded as a COC since it has no on-site source and was judged to be a background constituent. There is no known source of cadmium at the Kaiser site and there were only a few soil samples with minor exceedances to the background ranges (Ecology 1994) for the Spokane Area and SL, which is based on the fixed parameter, three-phase model in the MTCA (see Section 1.2.2 for more detail).

Iron and manganese were considered (by the Final Groundwater RI) as presenting secondary (aesthetic) effects to groundwater. The manganese concentrations measured in site soils were within the natural background concentration range of this element in the Spokane area. Site soil samples were not analyzed for iron.

Contaminant-specific technologies to remediate the relatively small and isolated (from one another) AOCs where lead, chromium and arsenic are present at concentrations above SLs are not discussed in this FSTM. The remediation of the small arsenic AOCs (FCT and Hoffman Tank areas) that are co-located with SVOC AOCs, and the lead AOC that is adjacent to an SVOC AOC (Man-Made Depressions area), is judged to be incidental to the remediation of the SVOC AOCs. The technologies used to remediate the SVOC AOC will also be used to remediate the lead and arsenic AOCs.

It was judged that the remediation of the isolated chromium AOC, and the arsenic AOC in the H_2S Scrubber Building area would be accomplished by the same technologies used to remediate the SVOCs in near-surface soils (refer to Section 2.5.2.4). A separate discussion of the application of these technologies to these small isolated AOCs was considered to be unnecessary.

Summary

This FSTM focuses on remedial alternatives that will effectively treat VOCs (gasoline and Stoddard solvents), SVOCs (cPAHs, diesel, and heavy oil), PCBs and metals. The areas of the site where potential COCs within these groups can be found are listed in Table 2-1.

The technologies that may be appropriate for remediating COCs in soil are discussed in Section 2.1; the technologies that are judged to be most appropriate for remediating SVOCs in soil are discussed in Section 2.2; and finally, technologies judged to be most appropriate for remediating PCBs in near-surface soil are discussed in Section 2.3.

The approach used to screen the technologies identified in Sections 2.1 to 2.3 is described in Section 2.4. The screening of these technologies is in Section 2.5.

2.1 POTENTIAL REMEDIATION TECHNOLOGIES FOR COCS IN NEAR-SURFACE SOILS

VOCs, SVOCs and PCBs in soil have been successfully remediated at many sites. Different technologies have been used to contain, treat, and destroy these contaminants. The use of these technologies to remediate VOCs, SVOCs, and PCBs in soil has been well documented.

This documentation has been compiled to create technology identification and screening tools. Many of these tools are available on the Internet. The Federal Remediation Technologies Roundtable (FRTR) publishes a "Remediation Technologies Screening Matrix and Reference Guide" (FRTR 2009a). The EPA Technology Innovation Office operates a Hazardous Waste Cleanup Information (CLU-IN) Web site that compiles information on a wide array of remediation technologies (CLU-IN 2009). The Center for Public Environmental Oversight (CPEO) is an organization that promotes and facilitates public participation in the oversight of environmental activities, including but not limited to the remediation of federal facilities, private Superfund sites, and brownfields. CPEO’s Technology Tree Matrix is a tool for identifying technologies to characterize and clean up hazardous waste sites (CPEO 2009), and the EPA Annual Status Report (ASR) Remediation Database – Update 2003, documents status and achievements of treatment technologies and Superfund sites (EPA 2003).

The EPA has gained considerable experience on remedial cleanup approaches and technologies and has found that there are categories of sites that have similar characteristics, such as types of contaminants present, past industrial use, or environmental media affected for which a “presumptive remedy” approach is appropriate. The presumptive remedy approach involves the selection of remedies that have already been proven to be both feasible and cost-effective for specific site types and/or contaminants. EPA encourages the use of presumptive remedies to streamline site investigations and make remedy selection quicker and more consistent.

The EPA has published several manuals that summarize the presumptive remedies considered appropriate for the remediation of VOCs, SVOCs, and PCBs in soils. These manuals include:

- Presumptive Remedies: site Characterization and Technology Selection for CERCLA Sites with VOCs in Soils (EPA 1993b);

- Presumptive Remedies for Soil and Sediments at Wood Treater Sites (EPA 1995a) - Applicable to SVOCs in soils;

- Presumptive Remedy: Supplemental Bulletin Multi-Phase Extraction (MPE) for VOCs in Soil and Groundwater (EPA 1997b);

- Technology Alternatives for the Remediation of PCB Contaminated Soil and Sediment (Dàvila et al. 1993); and

- Presumptive Remedy for Metal in Soil Sites (EPA 1999c)

These sources and others were used to develop the list of potential technologies for remediating VOC, SVOC, and PCB COCs in near-surface soils. The technologies listed in Table 2-2 contain the technologies recommended by the FRTR, CLU-IN, and the CPEO, as well as other technologies used by Hart Crowser to successfully remediate source area soil at this and other sites. The Monitoring and Institutional Controls general response actions are also included in Table 2-2.

Appendix A provides a description of, and references for, the remediation technologies listed in Table 2-2. Appendix A is organized as follows:

- Section A.1 – Containment Technologies

- Section A.2 – *In situ* Treatment Technologies

- Section A.3 – Excavation and On-Site Treatment Technologies

- Section A.4 – On-Site Treatment of Extracted Soil Vapor

- Section A.5 – Excavation and Off-Site Treatment/Disposal

2.2 PRESUMPTIVE REMEDIES FOR SVOCs IN NEAR-SURFACE SOILS

The remediation of SVOCS (diesel- and heavy oil-range TPH and cPAHs) in soil has been evaluated thoroughly and the available technologies have been assembled into the following general response actions: institutional controls, containment, *in situ* treatment, excavation, and on- and off-site treatment. In addition, there is the on-site treatment of vapor extracted from soil. All of these technologies are described in Appendix A. Some of the technologies described in Appendix A are presumptive remedies for SVOCs. These presumptive remedies are discussed in this section.

The EPA has identified several presumptive remedies for SVOCs and other compounds typically found at wood treatment facilities (EPA 1995a).

Contaminants found at wood treatment facilities that are also common to Kaiser include TPHs and cPAHs. The presumptive remedies developed for wood treating sites that may be applicable for SVOC-impacted soil at Kaiser include bioremediation, thermal desorption, incineration, and immobilization. These technologies are discussed below and in Sections A.1 to A.3.

Immobilization technologies (e.g., solidification/stabilization) are more suited to inorganic contaminants and will not be considered for SVOC-impacted soil that does not also contain arsenic, manganese, or iron at concentrations that exceed SLs at Kaiser.

2.2.1 Bioremediation

The EPA has selected bioremediation as the primary presumptive remedy for treating soils at wood treatment sites contaminated with SVOCs, based in part on the wide use and past successes of bioremediation technologies for organic compounds associated with wood treatment. These techniques are generally not applicable to soil impacted by metals. The bioremediation technology can be either an *in situ* or *ex situ* process depending on site constraints. *In situ* processes can include the addition of nutrients or oxygen to the subsurface to stimulate microbial activity. *Ex situ* bioremediation techniques for soil following excavation include slurry-phase and solid phase bioremediation (EPA, 1996d). These technologies are described in Appendix A and in Table 2-2.

2.2.2 Thermal Desorption

If bioremediation is not possible at a site, the EPA considers thermal desorption to be the next most appropriate presumptive remedy for SVOC compounds. Thermal desorption, as described in Appendix A, is an *ex situ* process and involves the heating of excavated soil to convert volatile and semi-volatile compounds into the gas phase. The captured off gases can then be condensed for disposal, adsorbed in activated carbon beds, or treated with biofilters (EPA 1995a). Thermal desorption works best for soil with a high proportion of sand and gravel (Blanchard and Stamnes 1997; and EPA 1995b), which is the predominant soil type found at Kaiser.

Depending on the target contaminants, thermal desorption is classed as high temperature thermal desorption (HTTD) (320° to 560°C) and low temperature thermal desorption (LTTD) (90° and 320°C). HTTD has been effective in treating soil impacted by SVOCs, PAHs, and PCBs. LTTD can be used to treat VOCs and hydrocarbon fuels. LTTD is less effective at treating SVOC-contaminated soil (FRTR 2009). These techniques do not generally destroy organic contaminants, but separate them from the soil to facilitate reuse of the soil or disposal at lower cost. Like bioremediation techniques, thermal desorption will not be effective on metals. These technologies are further described in Appendix A and in Table 2-2.

2.2.3 Incineration

Incineration has been used to treat soil impacted by organic contaminants by firing it in the presence of oxygen and a flame at temperatures typically greater than 600°C (EPA 1995a). Organic contaminants are volatilized and combusted requiring off-gas treatment by an air pollution control system. Incineration has been shown to reduce SVOC contaminant levels to the parts per billion or parts per trillion level.

Like the previous two technologies in this section, incineration will not destroy metals but will produce residuals depending on the makeup of the soil being treated (EPA 1995a). Treating large volumes of contaminated soil by incineration could be prohibitively costly; therefore this technology may be more appropriate in treating soil from hotspots.

2.2.4 Near-Surface Soil SVOC Treatment Technologies Summary

A presumptive remedy approach will be evaluated for near-surface soil impacted by SVOCs at Kaiser following the approach developed by EPA for sites contaminated with SVOCs. The technologies described in this section (Table 2-2, Sections 2.2.1 to 2.2.2) may be applicable as stand-alone treatment methods for near-surface soil, or as part of a process in a treatment train approach for soil that may contain more than one COC.

The cPAHs present in near-surface soil in some locations at Kaiser are constituents that are common to wood treatment sites. The soil at Kaiser that contains cPAHs is generally also impacted by diesel- and heavy oil-range hydrocarbons. Diesel- and heavy oil-range hydrocarbons are mixtures of straight chain and cyclic alkanes and aromatic compounds including cPAHs. Diesel- and heavy oil-range hydrocarbons have also been successfully treated by the presumptive remedies (bioremediation, thermal desorption, incineration) described in this section.

The approach used to screen the technologies discussed in this section, as well as the other potential technologies listed in Table 2-2 is described in Section 2.4. The screening of these technologies occurs in Section 2.5.

2.3 POTENTIAL REMEDIATION TECHNOLOGIES FOR PCBS IN NEAR-SURFACE SOILS

The remediation of polychlorinated biphenyls (PCBs) in soil has been evaluated and the available technologies have been assembled into the following general response actions: institutional controls, containment, *in situ* treatment, and excavation for either on- and/or off-site treatment. In addition, there is the on-site treatment of vapor extracted from soil. All of these technologies are described in Appendix A. Specifically, *in situ* vitrification and thermal treatment have been tested or used in the *in situ* treatment of PCBs, and the following methods have been tested or used in the *ex situ* treatment of PCB-impacted soil (FRTR 2009c, CPEO 2009, and EPA 1990 and 2003):

- Solidification/Stabilization
- Off-site Incineration
- On-site Incineration
- Thermal Desorption
- Slurry Phase Bioreactor (with co-metabolites and specialized organisms)
- Chemical Extraction
- Dehalogenation (APEG has been field tested)
- Solvent Extraction
- Pyrolysis
- Soil Washing
- Bioremediation
- Solvated Electron Treatment

From the technologies listed above, *ex situ* incineration (on-site and off-site) and thermal desorption have been documented to have high PCB removal/destruction efficiency. A properly operated incinerator can meet a 99.999 percent destruction and removal efficiency (DRE) that is required for PCBs, and the XTRAX^{TM} Process, an HTTD process, has been shown to remove over 99 percent of PCBs from soil (FRTR 2009).

Solidification and stabilization (S/S) has been used for the treatment of PCB-impacted soils (EPA 2000). At the time of this evaluation, PCB concentrations that had been treated ranged from 100 to 1100 ppm. Generally, most S/S technologies contain but do not destroy organics and pesticides, except vitrification which destroys most organic contaminants (FRTR 2009).

General Electric (GE) owned and operated a transformer service shop located in Spokane, Washington from 1961 to 1980. This site is located about 6 miles downstream (west) of Kaiser on the south side of the Spokane River. The GE site is discussed in this FSTM because it is located within the Spokane aquifer with geology similar to the Kaiser site, is near the Spokane River, has had documented PCB contamination in soil and groundwater, and has completed remedial actions. Information learned during the investigation and cleanup of the GE site in Spokane is relevant to the Kaiser site and it is important to take advantage of what was learned during the investigation and cleanup of that site. Oils containing PCBs and TPH were released to soils during service operations (Ecology 2009). PCBs were also found in groundwater.

During the 1990s, GE installed and operated an *in situ* vitrification (ISV) system to remediate PCB contaminated soil. Currently, the cleanup of the site is considered complete and monitoring continues to ensure protection of human health and the environment (Ecology 2009 and Gregory 2003).

Ecology's 1993 Cleanup Action Plan (CAP), prepared in accordance with MTCA, established ISV as the preferred method to treat site soils. However, after an ISV demonstration test in 1994, Ecology modified the remedy and consent decree in an Explanation of Significant Differences (Ecology 1996) to allow off-site disposal of soils with low concentrations of PCBs because of the substantial and disproportionate costs associated with the treatment of low-concentration PCB soils. Soils bearing high concentrations of PCBs, which otherwise would have been incinerated under TSCA rules, were vitrified on site in late 1996.

Neighboring properties that fell into the treatment area were excavated in 1997; however, on the GE-owned property, a significantly greater volume was encountered than predicted by remedial investigation data. So GE petitioned Ecology for a change in the cleanup level. Ecology denied this request; however, Ecology did evaluate the protectiveness of containment measures implemented by GE and agreed that the containment was protective. Ecology published a second Explanation of Significant Differences in late 1998 outlining this change, which became final after the public notice and comment period ended (Ecology 1999). The Construction Complete determination was issued shortly thereafter (Gregory 2003).

According to a draft version of Ecology's Second Periodic Review of the site, approximately 2,500 tons were vitrified on site and 27,400 tons of low-concentration soils were excavated and disposed of off site in 1997 (Ecology 2008b).

TSCA Requirements for Institutional Controls, Capping and Off-Site Disposal

For lower PCB soil concentrations where on-site soil treatment may not be appropriate, soils may remain in place or be disposed of off site. In these cases, PCB regulations in Title 40 of the Code of Federal Regulations, Part 761 (40 CFR Part 761) promulgated under the Toxic Substances and Control Act of 1976 (TSCA) will serve as an ARAR. Specifically, 40 CFR Part 761 will serve as an ARAR for parts of the site where PCB concentrations are greater than TSCA action levels. TSCA cleanup levels depend on how contaminated property will be used (occupancy) and the type of media that is contaminated.

As part of this remediation evaluation, the November 2005 PCB Site Revitalization Guideline under TSCA was reviewed (EPA 2005). This document serves as a guide for regulations in 40 CFR Part 761.

The remediation technologies addressed in 40 CFR Part 761 that may be applicable to this feasibility study are institutional controls, capping, and off-site disposal, which are discussed below. Other issues addressed in 40 CFR Part 761 that may apply to remediation efforts at Kaiser are recordkeeping, storage of PCB waste, cleanup notification and marking.

TSCA Requirements for Institutional Controls, Capping and Off-Site Disposal

PCB-impacted soils at low concentrations may be left in place under TSCA; however, remediation requirements such as institutional controls, capping, and cleanup must be met. Remediation requirements further depend on future land use of the site. These requirements are summarized in the following table:

TSCA Capping Requirements

Occupancy Level (see 40 CFR §761 .61(a))	PCB Concentrations	Action Required by TSCA
High	≤ 1 mg/kg	Cleanup verification
	> 1 mg/kg but ≤ 10 mg/kg	Cover area with an appropriate cap and cleanup verification
Low	≤ 25 mg/kg	Institutional control and cleanup verification
	> 25 mg/kg but ≤ 50 mg/kg	Site is marked with fence and sign (refer to PCB guideline under TSCA Figure 1, p. 7), implement institutional control and cleanup verification
	> 25 mg/kg but ≤ 100 mg/kg	Cover area with appropriate cap, implement institutional control and cleanup verification

Since most near-surface soil at Kaiser contains less than 1 mg/kg of PCB, no additional treatment or containment of this soil would be required by TSCA. A small quantity of soil at the site does contain PCBs at concentrations above the soil criteria for the protection of human health (Oil House French Drain area), and the soil criteria for the protection of groundwater (Discharge Ravine areas, Remelt/Casting areas).

TSCA requirements for off-site disposal of PCB-impacted soils are summarized below.

TSCA requirements for off-site disposal of PCB-impacted soils

PCB Concentrations[1]	Disposal Requirements
< 50 mg/kg	Permitted municipal or non-municipal solid waste non-hazardous waste facility (Subtitle D landfill)
≥ 50 mg/kg, ≤ 500 mg/kg	Subtitle C Hazardous Waste landfill.
> 500 mg/kg	Incinerator or Subtitle C Hazardous Waste landfill if all free flowing liquid is removed (i.e., pass the paint filter test).

[1] Note that the PCB concentrations listed here refer to *in situ* concentrations as determined through past investigations. They do not refer to stockpile concentrations following excavation.

Nearly all of the PCB-impacted soil at the Kaiser site contains less than 50 mg/kg of PCBs. If this soil is excavated and sent off site for disposal it could be disposed of at a Subtitle D Landfill as long as the landfill does not impose any additional waste acceptance criteria.

2.4 APPROACH TO SCREENING TECHNOLOGIES FOR REMEDIATING NEAR-SURFACE SOILS

MTCA (WAC 173-340-350/360) and EPA guidance on conducting FSs under CERCLA (EPA 1988b) provide the methodology for screening remedial technologies. The approach used is depicted on Figure 2-2. The first step is to identify the physical conditions at the site that limit or support particular technologies. The Kaiser property is an active facility that is located in an industrial area. The facility contains structures, roads, rail lines, and aboveground and underground utilities that will limit accessibility. The potential exposure of employees and site visitors to contaminants must be avoided. These property-specific conditions along with the hydrology and geology of the site affect the selection of remediation alternatives. These conditions are discussed for each of the AOCs at the Kaiser site in Section 2.5.1.

The second step is to identify the waste characteristics that limit the effectiveness or feasibility of a technology. The gasoline, Stoddard solvent, diesel, heavy oil, cPAHs, and PCBs in the AOCs are present in surface and subsurface soil and in groundwater. The chemical properties of these COCs and the characteristics of site soil and groundwater that will affect the selection of a remediation technology are discussed in Section 2.5.1.

The third step in the technology screening process is to assess the implementability of technologies judged to be potentially applicable to the remediation of COCs in the AOC. The physical conditions at the site and the characteristics of the COCs will limit the number of technologies that are potentially applicable. The implementability (i.e., the relative ease of installation and the time required to achieve a given level of performance) of a technology is assessed based on site conditions. Implementability considers (a) the technology's constructability (i.e., ability to build, construct or implement the technology under actual site conditions); (b) the time required to achieve the required level of performance as defined by the cleanup levels and points of compliance (POCs) (for the Kaiser site, the required level of performance is summarized in Tables 1.2 and 1.3 and the POCs are discussed in Sections 1.2.3 and 1.3.3); (c) the ability of the technology to be permitted; (d) the availability of the technology; and (e) other technology-specific factors.

The fourth step of the screening process is to assess the reliability of the technologies that are judged to be implementable. The EPA states that an evaluator should identify the level of technology development, its performance record, and the inherent construction, operation, and maintenance problems of each technology considered. Technologies that are unreliable, perform poorly, or are not fully demonstrated should be eliminated (EPA 1988b).

Finally, the cost-effectiveness of technologies judged to be equally reliable should be assessed. For instance, if two technologies are judged to be equally reliable, but Technology A costs significantly more to implement than Technology B, Technology A may be screened out by this criterion. Cost-effectiveness was not assessed as part of this FSTM. Cost-effectiveness will be used to further screen the implementable and reliable technologies identified by the FSTM (where appropriate) as part of the overall feasibility study for the Kaiser site.

2.5 SCREENING TECHNOLOGIES FOR REMEDIATING NEAR-SURFACE SOILS

In this section, the technologies identified in Sections 2.1 through 2.3 are screened using the approach summarized in Section 2.4. The physical aspects of the Kaiser Facility, the chemical properties of COCs and the properties of the near-surface soil in the AOCs are identified and used to eliminate certain technologies from further consideration in Section 2.5.1as prescribed by the MTCA (WAC 173-340-350(8)(c)(i)(B).

The technologies that are judged to be potentially appropriate for the physical and chemical features of the Kaiser AOCs are evaluated for implementability and reliability (if implementable), in Section 2.5.2. Many technologies judged reliable for treating individual COCs (e.g., gasoline, Stoddard solvent, diesel, heavy oil, cPAHs, or PCBs) in soil were also judged reliable for treating other COCs. These common technologies are identified in Section 2.5.2.4 and will form the core of the remedial alternatives developed in Section 2.7

2.5.1 Site-Specific Technical Constraints for Technologies

The physical and chemical features of the Kaiser Facility influence the selection of the remedial technologies identified in Sections 2.1 through 2.3. There are three groups of physical factors that influence proper selection of a remedial technology: 1) factors associated with the active use of the Facility; 2) factors limiting access to and removal of contaminated soil; and 3) site-specific geologic and hydrologic conditions promoting or prohibiting the applicability of certain remedial technologies. In addition to these physical factors, various chemical attributes of the COCs influence the selection of a remedial alternative. Table 2-3 summarizes the infrastructure, activities, and access to contaminated soil in each operating area of the site. Table 2-4 presents the Chemical and Physical properties of each of the COPCs. A summary of the site-specific physical and chemical evaluation of potential remediation technologies for soil and for groundwater is provided in Tables), 2-5 (VOCs), 2-6 (SVOCs), and 2-7 (PCBs).

2.5.1.1 An Active Facility

Kaiser's 512-acre Trentwood Facility is the largest flat-rolled aluminum mill in the western United States. The mill buildings (encompassing the Remelt, Hot Line, and Cold Mill areas) cover approximately 65 acres and are where the majority of the heavy industrial activities occur (Figure 2-1). Other structures on the site include oil and wastewater processing buildings, aboveground storage tanks, engineering and administration buildings, the metallurgical laboratory building, and other ancillary structures cover approximately 5 acres. The Kaiser Trentwood Facility has about 2.5 million square feet of building space (SAIC 1993). Asphalt roadways and concrete paved areas cover an additional area of approximately 70 acres. A 2.5-acre lined wastewater lagoon is located at the west central edge of the property and is in continual use as part of the facility's Industrial Wastewater Treatment (IWT) operations.

Rail spur lines are located throughout the mill area with connections to Burlington Northern Santa Fe's lines located to the north and south of Kaiser. Numerous aboveground and underground utilities exist throughout the facility. A gate located in the northwest area of the facility provides employee access. Heavy construction and industrial equipment is often in operation around the facility for capital improvement projects, maintenance, and in support of daily production operations. Production operations at the facility are generally around the clock, 365 days a year.

As described above and in the Final Soil RI (Hart Crowser 2012b), the 512-acre Kaiser site is divided into the following eight general operating areas:

- Oil Reclamation Building and surrounding areas;
- Rail Car Unloading area;
- Cold Mill/Finishing area;
- Oil House area;
- Wastewater Treatment area;
- Truck Shop area;
- Former Discharge Ravines; and
- Remelt/Hot Line area.

Within these eight operating areas are 29 subsites that have been identified during past remedial investigations as warranting further action under Kaiser's Agreed Order with Ecology. The general operating areas with applicable subsites are listed in Table 2-1 and located on Figure 2-1. The operating areas of the Kaiser site where the COCs are present at concentrations above proposed SLs are further described in Section 2.6 and Appendix B. Section 2.7 provides the basis for developing remedial alternatives for each AOC and describes the proposed remedial alternatives for the site as well.

Four subsites: the 1980 Fuel Oil Spill in the Oil Reclamation Building area, the Transformer Yard in the Cold Mill area, the 100,000-Gallon Fuel Oil aboveground storage tank (AST) in the Rail Car Unloading area, and the 500-Gallon Diesel underground storage tank (UST) in the Oil House area did not contain COCs in the near-surface soil. Therefore, these areas will not be further addressed in this section.

Below is a brief description of the operation and activities of Kaiser's eight general operating areas.

Oil Reclamation Building Area

The Oil Reclamation Building (ORB) and surrounding area is located in the northwest portion of the Trentwood Facility and contains six sites which are evaluated in this FSTM: The Oil Reclamation Building (ORB), the Man-Made Depressions, the 1980 Fuel Oil Spill, and the G1 through G3 Transfer Lines. The ORB serves as an intermediate collection facility for oily wastewater from various locations in the mill. From the ORB, oily wastewater is transferred to the IWT for further processing.

Infrastructure within this area includes the ORB, the Air Compressor building to the immediate east of the ORB, the Cryogenic Plant west of the ORB, paved areas and roadways surrounding the ORB, a buried 24-inch water line, which is one of the main water feeds to the mill, remnants of the inactive G1 through G3 Transfer Lines (portions of these lines have been removed during previous investigations), the active, aboveground G4 Transfer Lines, rail spurs, and various overhead and buried utilities. A large portion of this area is bare ground and is actively used for the storage and management of equipment.

Activity in this area is minimal and mainly consists of periodic operation and maintenance of the oily wastewater transfer processes that convey oily water from various locations in the mill to the IWT. Additional activities consist of contractor operations in a fenced area designated for that purpose, operation of the Cryogenic Plant, and equipment staging and laydown by Kaiser employees and contractors, to the west of the ORB.

Rail Car Unloading Area

The Rail Car Unloading (RCU) area comprises the Rail Car Unloading (RCU) facility and the 100,000-Gallon Fuel Oil AST. The RCU area building and associated infrastructure are located south and west of the 1 million-gallon tank and east of Evergreen Way in the west-central area of the Trentwood Facility. This area of the facility was historically used to unload fuel that arrived at the plant by rail car or truck. According to historical documents and utility maps, fuel oil was delivered and was distributed to storage areas and the plant through several underground pipelines. The RCU area has not been used for fuel management since the 1970s.

Surface features in the RCU area include the former RCU Station (Pump House Building 2162), a rail line spur, several aboveground pipeline manifolds, and other ancillary equipment. A 24-inch cooling water line traverses the area west to east and is located due south of the 1 million-gallon tank. Currently, the Pump House Building, the East and West Fuel Lines, and the rail line spur remain in place; however, several of the RCU surface features were removed during the Phase II investigation work. The majority of this area is bare ground. There is minimal activity on or access to this area, although Evergreen Way to the immediate west sees heavy vehicle traffic.

Cold Mill/Finishing Area

The Cold Mill/Finishing area is located on the southern portion of the Trentwood Plant Facility. Areas of the Cold Mill and Finishing areas investigated previously and evaluated in this FSTM consist of the Cold Mill Transfer Lines, the Transformer Yard, the former Continuous Can Process Line (CCPL), the Chromium Transfer Line, and the former Coater Line Tank.

The Cold Mill/Finishing area consists of a cluster of large industrial buildings with several large open courtyards. The courtyards are completely surrounded by the Cold Mill buildings. Activities within the Cold Mill/Finishing buildings are heavy industrial in nature in support of production and shipping operations. Activities in the open courtyards are limited to maintenance, equipment staging and laydown, and several outdoor break areas for employees. The courtyards consist mainly of bare ground with minimal vegetation. There is limited asphalt paving in the courtyards at the periphery of some of the buildings.

Oil House Area

The Oil House and associated systems are located directly east of the Hot Line area. The Oil House is located toward the central area of the plant and adjacent to the Tank Farm. Currently, the Oil House area primarily consists of one building (Oil House) and the Tank Farm; however, several USTs and other associated features surrounded the building in the past. The areas surrounding the Oil House and to the west of the Tank Farm are asphalt paved. The surface to the northwest and north of the Tank Farm consists of bare ground with sparse vegetation. Other infrastructure in this area consists of numerous aboveground and buried utilities.

Activities within this area are generally moderate compared to Mill production areas and include oil handling operations, maintenance, oil receiving, and equipment staging and laydown (mainly to the north of the Oil House). Vehicle and equipment traffic on the roadways surrounding the Oil House is heavy in support of Mill operations.

Wastewater Treatment Area

The Wastewater Treatment area is located in the west central portion of the site. Areas evaluated in this FSTM as part of the Wastewater Treatment area include the Field Constructed Tanks, the Hoffman Tank, and the Hydrogen Sulfide Scrubber Building. Infrastructure within this area consists of the buildings, aboveground tanks, buried and aboveground utilities (including remnants of the former buried G1 through G3 lines and the aboveground G4 lines), roadways and asphalt paving, and a wastewater lagoon associated with the IWT operations.

The former Field Constructed Tanks (FCTs), to the northeast of the IWT plant, were demolished in 2008. This area now consists of bare ground with the exception of a portion of the concrete pad from the west FCT which remains to protect a 24-inch cooling water line that traverses the site. Activities and vehicle and equipment traffic in this area are moderate in comparison to other areas of the facility.

Truck Shop Area

The Truck Shop area of the plant is located to the east of the Hot Line area and south of the Remelt area. The area is used for vehicle maintenance and consists of an enclosed steam-cleaning room, an equipment repair area (inside the main plant building), and an office structure. A concrete tank is located east of the steam-cleaning room and is connected to the pad through a pipe running east beneath the office structure. The 2,000-gallon concrete tank was taken out of service but remains in place, with access through a manhole at the surface. The bottom of the tank is estimated to be approximately 13 feet below grade. The tank was designed to accumulate cleaning-related materials from the Truck Shop and pump them to the ORB using on a plant-controlled switch.

Overhead utilities and adjacent building foundations would limit access in this area. Activity in this area is associated with vehicle and equipment repair and is considered moderate. Vehicle traffic is minimal.

Former Discharge Ravines

The approximate location of both ravines is shown on Figure 2-1. The former West Discharge Ravine (WDR) is located north and northwest of the wastewater lagoon and started near the sanitary wastewater treatment plant. The WDR trends south and west toward the Spokane River. These ravines were used to discharge process water to the Spokane River prior to construction of the first industrial wastewater treatment plant in 1973.

The former South Discharge Ravine (SDR) is located directly south of the plant. The open channel section of the ravine starts at the south fence line and runs generally north-south through Washington State Parks and Recreation property toward the Spokane River.

There is no infrastructure in the ravines though they are adjacent to unpaved perimeter roadways and fence lines. Additionally, Kaiser's current IWT outfall pipe and off-gas structure is located along the top of the slope of the southern WDR sidewall. Further excavations during the 2007 WDR Interim Action were halted in the lower WDR due to slope stability concerns and protection of these utilities. No Mill related activities have taken place in the former discharge ravines since 1973.

Remelt/Hot Line Area

The Remelt/Hot Line area is located within the north and central areas of the Facility. The Remelt department runs east-west and is the northernmost portion of the plant. The Hot Line section runs north-south and is located in the central area of the plant. The Remelt area is where primary (virgin) or recycled aluminum is melted and cast into ingots for later processing within the plant. The Hot Line is the area of the plant where the aluminum ingots are rolled into plates, sheets, and coils in the hot rolling mills. Activities inside of the Remelt/Hot Line buildings and immediately surrounding these buildings are heavy industrial. The areas surrounding the Remelt/Hot Line buildings are used for primary aluminum storage, scrap storage and processing, and equipment staging and laydown. Vehicle and equipment traffic in these areas is heavy.

Summary

The presence of heavy equipment, vehicular traffic, Kaiser employees and contractors, rail lines, overhead and buried utilities, and the AOCs located across the facility will require a staged or phased approach to site-wide remediation. The selected remedies for AOCs must also be conducive to staggered construction and installation. The presence of Kaiser employees and contractors, delivery drivers, rail cars and railroad personnel within the boundaries of the various AOCs require that the selected remedial technologies and alternatives be implemented with the institutional and engineering controls necessary to limit exposure of site workers to the COCs. In addition to access and site safety issues, the location of facility structures and their proximity to the AOCs have a significant influence on remedial technology selection.

Section 2 of the 2003 RI/FS (Hart Crowser 2003) provides a more complete description of the facility history and changes to the operation at Trentwood that have occurred since initial construction in 1942. A summary of the infrastructure and activities in each operating area is presented in Table 2-3.

2.5.1.2 Access to Contaminated Soil

Access to areas containing near-surface contaminated soil is severely restricted in several of the AOCs by existing structures (e.g., buildings and industrial equipment). Subsurface utilities (storm drains, water, power, and sewer lines) and aboveground structures (tanks, power, roadways and railroad spurs servicing Kaiser) additionally restrict access to soil within AOCs outside of the main mill buildings and limit the placement options for *in situ* treatment technologies. The heavy use and industrial nature of ongoing activities in most AOCs requires remedial actions to be compatible with heavy equipment and vehicle traffic.

The excavation of near-surface soils adjacent to building foundations must not undermine the integrity of the foundation. This FSTM is based on the assumption that a 45-degree rule would be employed while excavating near foundations. For instance, the bottom of a twenty-foot-deep excavation could not be excavated closer than twenty feet from the foundation. This twenty foot exclusion zone has been included on the figures used to show the AOC for each COC within Kaiser operating areas.

An assessment of access to contaminated near-surface soil in each operating area is presented in Table 2-3.

2.5.1.3 Topographic, Geologic, and Hydrogeologic Conditions that Affect Selection of Remedial Technologies

As described above, the site is an active aluminum facility that is zoned heavy industrial. Generally, the Facility consists of process units, some of which are enclosed, pavement and open field areas, aboveground piping and utilities, rail lines and access roads. The Facility has approximately 2.5 million square feet of building space (SAIC 1993) and approximately 3 million square feet of pavement.

Soils underlying the facility are highly permeable and consist of poorly sorted sand and gravel with occasional sand lenses and appear to grade finer with depth beneath the Facility. Gravel with scattered open work zones has been encountered in the Hot Line, Remelt, and Truck Shop areas in the upper 90 feet and between 110 to 150 feet below ground surface (e.g., HL-MW-27D and HL-MW-28DD). The open work zones are interpreted to be poorly sorted gravels with little or no fines.

The soils are also low in organic content. This, in combination with the high permeability of the soil, causes contaminants with low volatility and heavy molecular weights, such as diesel and PCBs, to move relatively quickly downward through the soil until they reach the water table. When they reach the water table, immiscible contaminants form a free phase hydrocarbon layer on the water surface that can migrate laterally and create a smear zone vertically on the soil matrix.

In the unsaturated zone, volatile constituents tend to evaporate, less polar constituents sorb onto soil, and droplets of free phase liquid become trapped in soil pore spaces. If the petroleum hydrocarbon liquid comes into contact with groundwater, the soluble constituents dissolve and migrate with groundwater flow and establish equilibrium with vapor and sorbed phases.

The Facility is underlain by the Spokane Valley-Rathdrum Prairie (SVRP) aquifer. Based on a geophysical survey completed in 1994, is estimated that bedrock 200 to 350 feet below the Facility defines the local aquifer boundary. The depth to groundwater decreases from approximately 60 to 70 feet on the east and north sides of the property to 45 to 55 feet on the south and west. The water table parallels the topography’s sloping surface towards the river. Therefore, during near-surface soil remediation activities, interference with groundwater should not be a concern.

The Facility has two wastewater treatment systems; one for processing sanitary wastes, and one for industrial wastewater. Stormwater runoff and process water flow into storm drains and then to the industrial wastewater treatment system. Precipitation that falls on pervious surfaces, which is not evaporated or transpired by plants, percolates into the SVRP aquifer. There are drywell catch basins located throughout the Facility, including nine drywells located southwest of the Remelt building. Stormwater runoff from paved areas drains into a drywell catch basin and percolates into the aquifer.

The topography near the west and south discharge ravine areas indicate there were once streams that flowed into the Spokane River, but are no longer flowing. Currently there are no streams that flow through the Facility.

River Environment

The river environment comprises the Spokane River between River Mile (RM) 86 and 87. River flow is directly influenced by releases from the Idaho Post Falls Dam (RM 101) located downstream from Lake Coeur d'Alene (Ecology 2008a). Spokane Falls are located approximately 10 miles (RM 74) downstream and serve as a natural barrier to anadromous fish migration. The section of the river channel located west of the Facility is moderately to highly incised and contains little floodplain habitat (Spokane Conservation District 2005). The dominant river substrate consists of cobbles and boulders. In general, the current is swift along this portion of the river. The reach of the Spokane River located south of the Facility contains a larger floodplain as a result of less incisement.

The section of the Spokane River adjacent to Kaiser is designated by Ecology (173-201A-600 WAC) for the following uses: salmonid spawning and rearing, primary contact recreation, domestic, industrial, agricultural, and stock supply, wildlife habitat, fish harvesting, commerce/navigation, boating, and aesthetic uses.

2.5.1.4 Chemical and Physical Properties and Their Impact on Remedial Technologies

The principal COCs present at the Kaiser Facility in near-surface soils are volatile VOCs, SVOCs (specifically diesel- to heavy oil-range hydrocarbons and cPAHs), PCBs, and metals. Several physical and chemical properties of these COCs that will affect their fate and transport in near-surface soils and impact the selection of treatment technologies for these COCs are summarized in Table 2-4. For petroleum hydrocarbons, properties depend on individual components, so the table presents chemical and physical properties by equivalent carbon (EC) fraction (i.e., by fractions having intrinsically similar physical and chemical properties).

VOCs

At the facility, commonly found VOCs are gasoline-range hydrocarbons including mineral spirits and Stoddard solvent and associated aromatics benzene, toluene, ethylbenzene, and xylenes (BTEX). Gasoline-range petroleum hydrocarbons contain approximately 4 to 13 carbon atoms (ATSDR 1995). The VOCs present have high vapor pressures, are moderately soluble, and are only moderately adsorbed to subsurface soil (refer to Table 2-4). As a result of these characteristics, the VOCs can potentially exist in three phases: dissolved in the aqueous phase, mixed with other gases in the vapor phase, and sorbed to soil particles (i.e., solid phase).

The chemical and physical properties of VOCs influence how they migrate and which methods are most effective for their removal. In general, VOCs are not responsive to *in situ* solidification technologies such as vitrification, grouting, or cement injection; are not affected by pH adjustments or chemical transformations other than chemical oxidation or reduction; and are not sufficiently ionic in the dissolved state to be recoverable by ion exchange media.

SVOCs - PAHs

PAHs are composed of hydrogen and carbon arranged in the form of two or more fused benzene rings in linear, angular, or cluster arrangements, which may or may not have substituted groups attached to one or more rings (Eisler 1987). Low molecular weight PAHs (LPAHs) are more mobile in the environment as compared to the high molecular weight PAHs (HPAHs). HPAHs are relatively immobile because of their large molecular volumes and their extremely low volatility and solubility. The cPAHs are classified in the HPAH group (Eisler 1987).

The source of cPAHs at the Facility is associated with petroleum hydrocarbons. The fate and transport properties of cPAHs are similar to that of PCBs. cPAHs have low solubility in water (less than 0.2 mg/l), strongly bind to organic matter (very high Koc values), and resist natural degradation processes. Because of the lack of organic carbon content in the aquifer, dissolved and colloidal transport of cPAHs is likely to be important. It is likely that cPAHs will be influenced by colloidal transport in a fashion similar to PCBs.

EPA presumptive remedies for cPAHs are bioremediation, thermal desorption, incineration, and immobilization (EPA 1995a).

SVOCs - Diesel to Heavy Oil Hydrocarbons

Petroleum hydrocarbons are present in some locations in soil and groundwater at the Facility, and, of the various types of petroleum hydrocarbons, diesel, and heavy oil have been identified as COCs. The diesel-range petroleum hydrocarbons specifically include Kensol. Kensol is a brand of lubricant, which was historically used at the Facility as a lubricant for cold rolling aluminum and was identified in historical environmental releases at the Facility. Use of Kensol at the Facility has been discontinued and has been replaced with Magiesol, which also is a petroleum-based product with properties similar to Kensol.

Generally, the composition of diesel- and heavy oil-range petroleum hydrocarbons consist mostly of aliphatic organic compounds (approximately 64 to 90 percent and 73 to 80 percent, respectively), with the remainder consisting of mostly aromatics (ATSDR 1995 and 1997). Diesel-range petroleum hydrocarbons primarily contain approximately 9 to 20 carbon atoms, whereas heavy oil-range petroleum hydrocarbons may contain approximately 15 to 50 carbon atoms (ATSDR 1995 and 1997).

Petroleum mixtures may contain constituents that have significant solubility in water but, as a whole, the mixtures tend to be sparingly soluble. Similarly, petroleum hydrocarbon mixtures contain components with a range of volatilities, as determined by their respective vapor pressures. Generally, the lighter end and less polar components exhibit greater vapor pressures and thus a greater tendency to evaporate. These compounds are liquid at room temperature and less dense than water so when in contact with groundwater these compounds float on the surface, and can spread laterally. These properties affect the choice of remediation technologies.

In general, SVOCs are not responsive to vapor extraction technologies due to low vapor pressure, and are not affected by pH adjustments or chemical transformations other than chemical oxidation or reduction.

Like cPAHs, EPA presumptive remedies for diesel and heavy hydrocarbons are bioremediation, thermal desorption, incineration, and immobilization of inorganic constituents (EPA 1995a).

PCBs

PCBs are a class of synthetic chlorinated aromatic compounds that have had widespread industrial and commercial applications based on their high thermal stability; strong resistance to oxidation, acids, bases, and other chemical reagents; as well as excellent electrical insulating (dielectric) properties. PCBs at the Kaiser Facility have been found in some locations in the soil and groundwater, and mixed with hydrocarbons.

PCBs comprise up to 209 compounds called congeners. Properties that influence the environmental fate and transport of individual chlorinated biphenyl congeners are primarily vapor pressure, solubility, and adsorption or partitioning to solids and organic matter. They generally have low water solubility and vapor pressure, strongly adsorb to organic matter, are very stable or persistent when released to the environment, and therefore, are slow to degrade. Individual values for these primary fate and transport parameters are most strongly influenced by the degree of chlorination. Solubility and vapor pressure both decrease with increasing chlorine content while adsorption and partitioning to solids and organic matter increase with increasing chlorine content. PCBs are extremely hydrophobic and adsorb strongly to soil and soil organic matter and move in groundwater as a dissolved species or by colloidal transport.

Water solubilities have been reported (Monsanto 1972) for Aroclors 1242 (200 ug/L), 1248 (100 ug/L), 1254 (40 ug/L), and 1260 (25 ug/L) although results are probably biased due to selective dissolution of only the lower molecular weight components in the Aroclor mixtures. Aroclors are denser than water. While pure chlorinated biphenyls are solids at room temperature, Aroclor mixtures are fluid oils (1221, 1232, 1242, 1248), viscous liquids (1254), or sticky resins (1260 and 1262).

As a result of these characteristics, PCBs are not readily responsive to remediation technologies such as soil vapor extraction, air sparging, soil washing, or chemical oxidation.

2.5.2 Screening of Remedial Technologies for COCs in the AOCs

This section evaluates those technologies not rejected on the basis of the site-specific physical/chemical constraints (summarized in Tables 2-5, 2-6, and 2-7) for implementability and reliability, (using the technology evaluation approach shown on Figure 2-2). Cost-effectiveness was not assessed as part of this FSTM. Cost-effectiveness will be used to further screen the implementable and reliable technologies identified by the FSTM (where appropriate) as part of the overall feasibility study for the Kaiser site.

Implementability is evaluated in terms of four attributes by asking the following questions:

- Can the process option be constructed at the Kaiser site?

- Will the process option work as intended at the Kaiser site?
- Will the process option be acceptable to regulatory agencies?
- Is the process option available in the marketplace?

Based on these answers, each process option is either accepted or rejected as being implementable.

Next, reliability is evaluated in terms of three attributes by asking the following questions:

- Has the process option been used at the scale required at Kaiser?
- Are the process option operation and maintenance requirements infrequent and straightforward?
- Has the process option been proven effective under site conditions similar to those at Kaiser?

Based on the answers, each process option is either accepted or rejected as being reliable.

Similar process options that are reliable and implementable require further evaluation on the basis of cost. This further evaluation (where appropriate) will be presented in the overall feasibility study for the Kaiser site.

2.5.2.1 Technologies for Remediating VOCs in Near-Surface Soil

Technologies and the associated process options for remediating VOC-contaminated soil in the AOCs are evaluated for implementability in Tables 2-8a through 2-8k. Each table provides information to justify why each process option should be accepted or rejected for the Kaiser site. These tables indicate that the following process options for remediating VOCs in near-surface soils are judged to be implementable at the Kaiser site.

Technology	Process Option Accepted
Monitoring	Protection, Performance, Confirmational
Institutional Controls	Access and Use Restrictions, Best Management Practices (BMPs)
Capping	Asphalt, Concrete, Multilayer
Monitored Natural Attenuation	Monitored Natural Attenuation
Soil Vapor Extraction (SVE)	Vertical Vents
SVE Off-Gas Treatment Technologies	
Adsorption Technology	Granular Activated Carbon
Thermal Oxidation	Direct Flame, Flameless, Catalytic,
Advanced Oxidation	Photocatalytic Oxidation

The technologies and associated process options judged to be implementable are evaluated for reliability in Tables 2-9a through 2-9h. Photocatalytic oxidation was rejected on the basis of reliability, as shown in Table 2-9h, since this process option is still in the development stage and has not been successfully operated at full-scale in a physical and chemical setting similar to that at the Kaiser site.

The remaining process options are combined in various ways to create the feasible remedial alternatives discussed below. Table 2-10 summarizes the technology screening process and identifies the technologies and process options judged to be appropriate for the treatment of VOC contaminated near-surface soil at the Kaiser site.

2.5.2.2 Technologies for Remediating SVOCs in Near-Surface Soil

Technologies and the associated process options for remediating SVOC-contaminated soil in the AOCs are evaluated for implementability in Tables 2-11a through 2-11f. Each table provides information to justify why each process option should be accepted or rejected for the Kaiser site. These tables indicate that the following process options for remediating SVOCs in near-surface soils are judged to be implementable at the Kaiser site.

Technology	Process Option Accepted
Monitoring	Protection, Performance, Confirmational
Institutional Controls	Access and Use Restrictions, BMPs
Capping	Asphalt, Concrete, Multilayer
Monitored Natural Attenuation	Monitored Natural Attenuation
Mechanical Screening	Mechanical Screening
On-Site *Ex situ* Bioremediation	Biopiles, Landfarming, Slurry Phase Reactors
On-Site *Ex situ* Thermal	Thermal Desorption, Pyrolysis
Off-Site *Ex situ* Disposal	Landfill
Off-Site *Ex situ* Thermal	Incineration

The technologies and associated process options judged to be implementable are evaluated for reliability in Tables 2-12a through 2-12e. Two *ex situ* bioremediation process options (slurry phase reactors and biopiles) and one thermal process option (pyrolysis) were rejected on the basis of reliability (refer to tables 2-12c and 2-12d), since they were more complex processes than other similar processes, and in the case of slurry phase reactors and pyrolysis, had not been demonstrated to be effective at large-scale industrial facilities like Kaiser.

Table 2-13 summarizes the technology screening process and identifies the technologies and process options judged to be appropriate for the treatment of diesel/heavy oil and cPAHs contaminated near-surface soil at the Kaiser site.

2.5.2.3 Technologies for Remediating PCBs in Near-Surface Soil

Technologies and the associated process options for remediating PCB-contaminated soil in the AOCs are evaluated for implementability in Tables 2-14a through 2-14e. Each table provides information to justify why each process option should be accepted or rejected for the Kaiser site. These tables indicate that the following process options for remediating PCBs in near-surface soils are judged to be implementable at the Kaiser site.

Technology	Process Option Accepted
Monitoring	Protection, Performance, Confirmational
Institutional Controls	Access Restrictions and Use Restrictions, BMPs
Capping	Asphalt, Concrete, Multilayer
Monitored Natural Attenuation	Monitored Natural Attenuation
Mechanical Screening	Mechanical Screening
On-Site *ex situ* Bioremediation	Slurry Phase Bioreactor
On-Site *ex situ* Dehalogenation	Base Catalyzed Decomposition (BCD), Alkaline Polyethylene Glycol (APEC)
On-Site *ex situ* Thermal	High Temperature Thermal Desorption
Off-site *ex situ* Thermal	Incineration
Off-site Disposal	Subtitle D Landfill

The technologies and associated process options judged to be implementable are evaluated for reliability in Tables 2-15a through 2-15g. The on-site bioremediation, thermal treatment, and dehalogenation technologies were rejected on the basis of reliability (refer to Tables 2-15b, 2-15e, 2-15c and 2-15d respectively). These options were judged to be complex operations with limited demonstrated success in remediating soils with low concentrations of PCBs at large-scale industrial facilities like Kaiser.

Table 2-16 summarizes the technology screening process and the technologies and process options judged to be appropriate for the treatment of PCB contaminated soil at the Kaiser site.

2.5.2.4 Remediation Technologies Common for VOCs, SVOCs, PCBs, and Metals

The technologies accepted for the remediation of VOCs in near-surface soils are listed in Table 2-10; and include capping, monitored natural attenuation, and SVE with thermal treatment or adsorption of VOCs in the extracted soil vapor.

The areas identified with VOC SL exceedances include the Man-Made Depressions, Oil Reclamation Building, Oil House, and Truck Shop areas (Figure 2-1).

Four general response actions judged acceptable for VOCs also were judged acceptable for one or more of the other COCs (diesel/heavy oil, cPAHs, PCBs, metals). The common response actions include:

- Monitoring (compliance, performance) - diesel/heavy oil, cPAHs, PCBs, metals
- Capping (asphalt, concrete, multi-layer) – diesel/heavy oil, cPAHs, PCBs, metals
- Monitored Natural Attenuation – diesel/heavy oil, cPAHs
- Institutional Controls – diesel/heavy oil, cPAHs, PCBs, Metals

There were additional common response actions for and diesel/heavy oil, cPAHs, PCBs and metals. These common response actions include:

- Excavation and On- or Off-site Treatment (mechanical screening)
- Off-site Disposal (Subtitle D Landfill)

Off-site treatment (incineration) is a common response action for diesel/heavy oil, cPAHs, and PCBs.

2.6 DESCRIPTION OF AREAS OF CONCERN FOR NEAR-SURFACE SOILS

The AOCs for near-surface soils at the Kaiser site are those areas that contain COCs (refer to Table 1.2) at concentrations above SLs that have been established for the site. The remedial objectives for these AOCs are summarized in terms of COCs, SLs, and POCs in Section 1.

This FS has divided the Kaiser site into eight general operating areas (refer to Table 2-1). The locations of the AOCs within each general operating area are depicted on Figures 2-3 through 2-10 as follows:

Figures 2-3a to 2-3d: ORB Area

Figure 2-4: Rail Car Unloading Area

Figures 2-5a to 2-5c Cold Mill/Finishing Area

Figures 2-6a to 2-6d: Oil House Area

Figures 2-7a to 2-7d: Wastewater Treatment Area

Figure 2-8: Truck Shop Area

Figures 2-9a to 2-9b: Discharge Ravines

Figures 2-10a to 2-10c: Remelt/Hot Line Area

The AOCs depicted on Figures 2-3 through 2-10 were developed by using a "half the distance" rule to define a boundary between sample locations that are known to contain COPCs at concentrations above potential SLs, and sample locations where COPCs are known to be present at concentrations below potential SLs. The half the distance rule was applied blindly to define each AOC. In instances where the number of sample locations are few and located far apart it is likely that the application of this rule resulted in an overestimate of the size of the AOC.

The next step in defining the AOCs was to estimate the vertical extent of the area of SL exceedance. Data from adjacent sampling locations and data from above and below the 20-foot depth horizon in the same boring were evaluated to estimate the vertical extent of contamination in each boring. In the case where a clean sample was located above or below a contaminated sample, half the vertical distance between the clean and dirty sample locations was used as an estimate of the depth of contamination. In the event that clean samples, vertically bracketed by contaminated samples, were found in a boring, then one half of the reporting limit for that COC was used to calculate the average COC concentration for that boring.

There are numerous paved areas located throughout the Kaiser facility. These paved areas are depicted on Figure 2-11 in relation to the AOCs at the site described in Appendix B.

The specific COPCs that are present in each AOC, and the sampling location where the COPC was identified are shown on Figures 2-3 to 2-10 and are listed in Table 2-17.

The available sampling data (Hart Crowser 2012b), together with the AOCs depicted on Figures 2-3 to 2-10 was used to compute a rough order of magnitude (ROM) (+/- 50 percent) estimate of the total mass of contaminants contained in the upper 20 feet of soil in the soil AOCs. This estimate is presented in Table 2-18.

This approach to the calculation of the average concentration of the COC represents an overestimate of the concentration that is actually present at a sample location for a number of reasons. The soil matrix at Kaiser consists mostly of gravel and cobbles (Hart Crowser 2012a). The COCs in the sample were associated with the sand and organic material (if any) that was present in the sample. The gravel and cobble portion of the sample was not sent to the lab for analysis since cobbles would not fit in the sample jar and gravel would have to be pulverized in the lab prior to analysis. As a result, the concentration of COCs reported by the lab is an overestimate of the actual *in situ* concentration of the contaminant. Nonetheless, the lab values were reported in the Final Groundwater and Soil RIs (Hart Crowser 2012a and 2012b) since they represent a conservative estimate of the actual concentration of the COC present at the site, and contribute to a conservative approach to estimating risks to human health and the environment posed by the COC.

In many instances the near-surface soil data was collected 10 to 20 years ago as part of site characterization work. Petroleum contamination is known to degrade over time if left in place. The natural degradation of the sample over time has likely reduced the original concentration of the near-surface soil sample. The quantity of this reduction cannot be estimated precisely. This conservative method of estimating mass of contaminants is not based on actual site conditions. It is used in this FSTM to allow us to apply a consistent, yet conservative, method to all AOC mass calculations. This is necessary to allow for a relative comparison of risk and contaminant mass between the various AOCs.

The COC loadings listed in Table 2-18 are allotted to the AOCs within the eight general operating areas of the site that contained that COC. The calculation assumptions used to develop this estimate are summarized in Appendix B and in Table B-1, the spreadsheet constructed to perform the loading calculations.

The soil samples used to calculate the loadings were collected by various investigators over an extended period of time. Nonetheless, it was judged that the information in Tables 2-17, 2-18 and B-1 would provide useful insights into the historical distribution of COCs at the site.

The total ROM mass of contaminants in near-surface soil at the Kaiser site is approximately 422 thousand pounds (211 tons). Approximately 97 percent of this contamination has been reported to be heavier TPHs (diesel, heavy oil, Kensol). VOCs comprise approximately 1,700 pounds of the total mass (about

0.4 percent), cPAHs comprise approximately 6 pounds of the total mass of contaminants, PCBs comprise approximately 2,500 pounds (about 0.6 percent) of the total mass of contaminants, and metals (arsenic, lead, and total chromium) comprise approximately 9,900 pounds (about 2.4 percent).

The heavier TPHs are found within each of the eight general operating areas. VOCs are found primarily in the ORB, Oil House (20,000 Gallon Gasoline UST), and Truck Shop areas. PCBs are found primarily in the Oil House (French Drain area), former Discharge Ravines, and Remelt/Hot Line areas. The small quantities of cPAHs found were located in the ORB (Man-Made Depressions), Rail Car Unloading, and Cold Mill Finishing areas. Arsenic is found in the Wastewater Treatment area. Lead is found in the ORB (Man-Made Depressions). Chromium is found in the Chromium Transfer Lines area.

In most instances the VOCs and PCBs were found in AOCs that also contained SVOCs (diesel, Kensol, and/or heavy oil). The comingling of the COC groups impacts the evaluation and selection of remedial alternatives presented in Section 2.7.

The information contained on Figures 2-3 through 2-10 and Tables 2-17, 2-18 and B-1 is summarized for each COC detected in each operating area in Appendix B:

- Section B.1 – VOCs
- Section B.2 – SVOCs
- Section B.3 – PCBs

2.7 DEVELOPMENT OF REMEDIAL ALTERNATIVES

The technologies and process options that are potentially applicable to the remediation of the soils in the AOCs at the Kaiser Facility are identified in Section 2.5. These technologies and process options were initially screened to account for site-specific technical constraints and for the chemical properties of the COCs in Section 2.5.1. The technologies and process options judged to be implementable and reliable for the remediation of soils in the AOCs (refer to Section 2.5.2) are assembled into remedial alternatives is this section. The basis for developing alternatives follows the logic shown on Figure 2-12 and is described below.

A large number of remedial actions have been completed at the Kaiser Facility since 1989. The majority of the actions are discussed in the Final Soil RI (Hart Crowser 2012b). The only formal Interim Remedial Action (WAC 173-340-430) completed to date is at the West Discharge Ravine. The remedial alternatives developed in this section will continue the process of treating the VOCs, cPAHs, diesel/heavy oil, and PCBs that was begun by the interim remedial actions.

2.7.1 Alternative Development Process

Step 1 – Define the Cleanup Criteria

The first step in developing remedial alternatives is to define the COCs that must be addressed by, and the SLs and POCs that will define the goals of, the alternatives. The COCs identified for the near-surface soils at the Kaiser Facility were discussed in Sections 1.2.2. The proposed SLs and POCs were developed in Section 1.2.1 and 1.3.1, respectively. The environmental media potentially affected by the COCs in near-surface soils at the Facility are soil and groundwater in each AOC, and downgradient groundwater that exits to the Spokane River. The primary COC groups present in Facility soil are VOCs (gasoline and Stoddard solvent), SVOCs (mostly cPAHs and diesel/heavy oil), PCBs, and metals (e.g., lead and chromium) (refer to Section 2.6 and Table 2-17).

The proposed point of compliance for soil is throughout the site for the protection of groundwater and vapors, and from the ground surface to 15 feet below ground surface for soil cleanup levels based on human exposure due to direct contact (WAC 173-340-740[6][b,d]). From a pragmatic sense, soil that affects ambient and indoor air concentrations are those in the vadose zone between the water table and the ground surface of the site (WAC 173-340-740[6][c]). The point of compliance for soil cleanup levels based on terrestrial ecological considerations will be in compliance with WAC 173-340-7490, where appropriate.

Step 2 – Determine if Source Control is Required

The available soil gas data (discussed in Section 1) indicate that the concentrations of VOC COCs in ambient and indoor air are at levels that are considered to be below levels of concern for human receptors that have been established by NIOSH, OSHA, and WISHA (see Section 7.8 of the HHERA [Pioneer 2012]). This implies that the concentration of VOCs in soil and groundwater in the AOC are at levels that present acceptable risk to workers and the public and that additional remediation is not needed to reduce the risk to human health and the environment to acceptable levels.

The concentrations of VOCs, SVOCs, certain metals, and PCBs in soil in some areas of the Facility exceed the proposed soil SLs for the protection of drinking water and surface water. The areas where these exceedances have occurred are discussed in Appendix B. Consequently, remedial alternatives that will reduce COC concentrations to levels that are below the calculated SLs will be evaluated.

Step 3 – Define the Objectives for Remediating the Area of Concern

The objective of the technology-based remedial alternatives that will be developed in this section is to reduce the concentration of VOCs, diesel/heavy oil, cPAHs, PCBs, and metals in near-surface soil in the AOCs to levels below the SL proposed for each COC. These proposed SLs are listed in Table 1-2.

Step 4 – Assemble Technologies into Alternatives

The remediation technologies judged to be appropriate for the remediation of near-surface soil are summarized in Section 2.5.2. These technologies can be assembled into alternatives that are likely to be effective for remediating the COCs present at the Kaiser Facility.

The FSTM develops technology-based remedial alternatives for near-surface soil in Section 2.7.2 for the individual COCs (e.g., VOCs, SVOCs, PCBs, and metals) and mixtures of COCs present (e.g., SVOCs and PCBs) at the Facility. The analysis and development of these alternatives will be completed in the overall feasibility study (Step 6).

Step 5 – Complete Analysis and Development of Alternatives

The overall feasibility study will evaluate the remedial alternatives assembled in Step 5 to identify the most appropriate alternative(s) for each individual COC or mixture of COCs present in the near-surface soil of each AOC at the Facility. The feasibility study will repeat this evaluation for each segment (e.g., deep vadose zone soil, smear zone soil, groundwater plumes, etc.) of the AOC, evaluating the technology-based alternatives assembled in FSTM Sections 2 through 6. The most appropriate technology-based remedial alternatives for each segment will then be assembled to identify the most appropriate area-based remedial alternative(s) for each AOC of the Facility.

Step 6 – Establish Contingencies for Future Remediation

If necessary, contingency actions will be established in the Cleanup Action Plan (CAP) that would be available during future remediation in the event that the nature and extent of the COCs in an AOC have not been accurately defined. A concern is that if the nature and extent of the COCs in an AOC have not been accurately defined, the selected remedial alternative may not reduce the concentration of COCs at the POCs in a reasonable time period.

Contingencies would be established to modify the selected remedial alternative by changing its period of operation or its size. For example, if the nature and extent of COCs in an AOC were overestimated, the remediation system that would be installed could be operated for a shorter period of time. If the AOC occupies a larger area or contains COCs in higher concentrations than were anticipated, the remediation system that would be installed could be operated for a longer period of time, or additional systems could be installed if required.

Step 7 – Establish a Compliance Monitoring Plan

A compliance monitoring plan must be established that will confirm that the objectives of remediating the AOCs are met.

2.7.2 Remedial Alternatives for Near-Surface Soil

MTCA requires that a reasonable number of alternatives shall be evaluated taking into account the characteristics and complexity of the Facility, including current site conditions and physical constraints (WAC 173-340-350[8][c][i][B]). These factors were discussed in Section 2.5.1.

The technology-based remedial alternatives developed in this section range from Alternative A1 (institutional controls, monitoring, and MNA) to a baseline alternative (A6), which includes institutional controls, monitoring, MNA, excavation, off- site treatment (incineration), and off- site disposal. The individual COCs that are addressed by each of the Alternatives, A1 through A6, are summarized in Table 2-19. For near-surface soils, Alternative A6 is judged to be the most practical permanent cleanup action for PCBs and SVOCs. Alternative A3 is judged to be the most practical permanent cleanup action for VOCs, and Alternatives A4a and A4b are judged to be the most practical permanent cleanup actions for metals (WAC 173-340-350[8][c][ii][A]).

Alternatives A1 and A2

Alternative A1, which consists of institutional controls, monitoring, and MNA, is included since many viable remedies at the Kaiser Facility will contain these elements. Alternative A2 comprises containment, institutional controls, monitoring, and MNA. It adds the additional protection of containment to

Alternative A1. Alternatives A1 and A2 are common for all the COC groups (VOCs, SVOCs, PCBs, and metals).

Alternatives A3, A4a, and A4b

Alternative A3 adds *in situ* treatment (SVE plus off-gas treatment) to Alternative A2 in AOCs that contain VOC COCs at concentrations above SLs.

Excavation and off-site disposal, institutional controls, monitoring, and MNA are included in Alternative A4a for those AOCs where VOCs are not present, or are present at levels below SLs, and where no COC (e.g., VOC, SVOC, PCB, lead, or chromium) will remain in the vadose zone soils below 20 feet at concentrations above SLs.

Alternative A4b adds containment to Alternative A4a for those AOCs where COCs will remain in vadose zone soils below 20 feet at concentrations above SLs. Note that it has been assumed that mechanical screening will remove cobbles prior to the off-site disposal of the soil that is excavated.

Alternatives A5a, A5b, and A6

Alternative A5 adds excavation and on-site treatment to Alternatives A1 or A2 for AOCs that contain SVOCs. Alternative A5a will evaluate *ex situ* bioremediation (landfarming). Alternative A5b will evaluate *ex situ* thermal desorption as a treatment method. Alternative A1 will be part of Alternative A5 when no COCs at concentrations above SLs will remain in soil at depths below 20 feet. Alternative A2 will be part of Alternative A5 when COCs at concentrations above SLs will remain in soil at depths below 20 feet.

Alternative A6 will evaluate off-site incineration, which will destroy any VOCs, SVOCs, or PCBs present in the soil that is treated by this technology. Alternative A6 includes Alternatives A1 or A2. Alternative A1 will be part of Alternative A6 when no COCs at concentrations above SLs will remain in soil at depths below 20 feet. Alternative A2 will be part of Alternative A6 when COCs at concentrations above SLs will remain in soil at depths below 20 feet.

Note that it has been assumed that mechanical screening will remove cobbles prior to the on- or off-site treatment of the soil that is excavated.

Applicability and Combination of Multiple Alternatives

Evaluation of the various alternatives may show that multiple alternatives are applicable for an individual COC. Similarly, if there is more than one type of

COC in an AOC, it is possible that a single or a combination of alternatives could be considered. For instance, technology-based Alternatives A1, A2, and A4a or A4b could be used individually or in combination to address lead or chromium in near-surface soils. As a further example, one AOC in the ORB operating area (refer to Figure 2-3d) contains both VOCs and SVOCs in near-surface soils at concentrations exceeding SLs. The VOC AOCs are contained within a larger SVOC AOC. In this example, technology-based Alternatives A1,A2, or A3 could be used alone or in combination to remediate the VOC-impacted areas, while Alternatives A1, A2, A4a, A4b, A5a, A5b, or A6 could be used alone or in combination to remediate the overall SVOC AOC, including the VOC impacted areas (if VOCs are co-mingled with SVOCs).

The overall feasibility study will evaluate the technology-based remedial alternatives described above to assess whether or not, or to what extent, the alternatives meet the minimum requirements for cleanup action under MTCA (WAC-173-340-360[2]). One outcome of this evaluation will be to identify the most appropriate alternative(s) for each COC. It is expected that Alternatives A1 and A2 will be carried forward for each COC group. For SVOCs, it is expected that the evaluation will differentiate among Alternatives A4 (a or b), A5 (a or b), and A6, and will identify the most appropriate alternative. Similarly, it is expected that the overall feasibility study will identify the most appropriate alternative among the potentially applicable alternatives for PCBs (A1, A2, A4a, A4b, and A6) and metals (A1, A2, A4a, and A4b). The most appropriate alternative(s) for each COC group will then be bundled to create the proposed area-based remedy for each of the AOCs identified for near-surface soils, as described above for an AOC in the ORB operating area.

2.7.3 Compliance Monitoring

Monitoring is needed to assure compliance with CULs, to assess the performance of a remediation technology as it is operating, and to measure the continued effectiveness over time of permanent features added to the AOC (e.g., capping). Monitoring is an integral element of Alternatives A1 through A6. A comprehensive monitoring program consists of protection monitoring, performance monitoring, and confirmational monitoring. This comprehensive monitoring program is based on an adaptive monitoring and management strategy that will:

- Focus the monitoring program, and ultimately site closure, on clearly articulated goals and objectives.

- Support a tiered sampling and analysis scheme to facilitate efficient, cost-effective evaluation of site conditions and to assure the generation of appropriate quantities and quality of data based upon those conditions.

- Provide flexibility to periodically re-evaluate goals and modify monitoring activities to reflect changing site conditions and needs.

Compliance monitoring is a required part of any cleanup action (WAC 173-340-410) conducted under MTCA. As described above, compliance monitoring consists of protection, performance, and confirmational monitoring. Protection monitoring is conducted to confirm that human health and the environment are adequately protected during the construction, operation, and maintenance periods of a cleanup action. The purpose of protection monitoring is to determine whether the cleanup action has attained cleanup standards and, if appropriate, whether remediation levels or other performance standards have been attained.

The performance of a remediation technology must be controlled and assessed as the technology is operating on site. Performance monitoring will become part of the overall monitoring program. The operating and performance parameters that are monitored will depend on the particular technology used. If the addition of a permanent feature, like a cap, is part of the remedy for a site, the monitoring of the feature will also be a part of the monitoring plan.

Confirmational monitoring is conducted to confirm the long-term effectiveness of the cleanup action once cleanup standards have been attained. Compliance monitoring plans are prepared to define how confirmational monitoring will be conducted. These plans must contain the following elements: (1) a sampling and analysis plan meeting the requirements of WAC 173-340-820, and (2) an explanation of the data analysis and evaluation procedures that will be used to interpret the monitoring information that is collected.

Only the elements of the Compliance Monitoring Plan are discussed in this FSTM. The details of the Cap Monitoring and the Performance Monitoring Plans will be defined in the CAP.

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Table 2-1 - Kaiser General Operating Areas, Sites Considered in the Feasibility Study, and Near-Surface COCs Identified for Each Site

General Operating Area	Sites Located Within Operating Area	COCs Identified in Near-Surface Soils (upper 20 feet)
Oil Reclamation Building and Surrounding Area	Man-Made Depressions	Gasoline, Diesel, Heavy Oil, cPAH, Lead
	G1 Tranfer Line	Stoddard, Kensol, Heavy Oil [a]
	G2 Transfer Lines	Heavy Oil
	G3 Transfer Lines	Diesel, Heavy Oil [b]
	1980 Fuel Oil Spill	None
	Oil Reclamation Building (ORB)	Diesel, Heavy Oil, Gasoline
Former Rail Car Unloading Area	Rail Car Unloading	Diesel, Heavy Oil, cPAH
	100,000 Gallon Fuel Oil AST	None
Cold Mill/Finishing Area	Cold Mill Transfer Lines	Kensol[c]
	Transformer Yard	None
	Continuous Can Process Line	cPAH
	Chromium Transfer Line	Total Chromium
	Cold Mill Electrical Grounding Pit	Diesel, Heavy Oil
	Former Coater Line Tank	None
Oil House Area	Oil House UST	None
	20,000-Gallon Gasoline UST	Gasoline
	Tank Farm Kensol Spill	Diesel/Heavy Oil[d]
	500-Gallon Diesel UST	None
	Eight USTs	Kensol
	Drum Storage and French Drain	PCBs, Diesel/Heavy Oil[d]
Wastewater Treatment Area	Field-Constructed Tanks	Diesel, Heavy Oil, Diesel/Heavy Oil[d], Arsenic
	Hoffman Tank	Diesel/Heavy Oil[d], Arsenic
	Hydrogen Sulfide Scrubber Building	Diesel, Heavy Oil, Arsenic
Truck Shop Area	Truck Shop	Stoddard, Heavy Oil
Former Discharge Ravine Areas	West Discharge Ravine	PCBs
	South Discharge Ravine	PCBs, Heavy Oil
Remelt/Hotline Area	Remelt/Hotline Area Wells and Borings	PCBs, Heavy Oil
	DC4 Area	PCBs
	DC1 Area	PCBs

Notes

[a] The G1 Transfer Line is addressed under the ORB Area.

[b] The east end of G3 Transfer Line addressed under ORB Area.

[c] Impacts from the Cold Mill Transfer Lines addressed under the Oil House Area - Tank Farm Kensol Spill

[d] Diesel/Heavy Oil indicates that some of the TPH data from this location was obtained via EPA Method 418.1 which reports soil concentrations as "Total TPH." Therefore, individual TPH compounds cannot be distinguished. Based on data from nearby sites and the past history of these sites, it was assumed that the TPH present was in the diesel to heavy oil range.

Table 2-2 - Preliminary Identification of Remedial Technologies for Near-Surface Soils

General Response Action	Remedial Technology	Process Options	Description
Monitoring	Monitoring	Protection, performance, and confirmational.	Provide for protection, performance, and confirmational monitoring.
Institutional Controls	Access and Use Restrictions	Fencing, signs, deed restrictions.	Physical and administrative measures to prevent access or exposure to contaminated soil.
	Best Management Practices	Spill prevention, leak detection, double walled pipes, proper storage of chemicals and solvents.	Some measures currently in place. QA/QC Plan must continue to be enforced.
Containment	Capping	Soil, clay, asphalt, concrete, synthetic liner, or multi-layer cap.	Placement of a cap or soil cover to minimize infiltration and prevent direct contact.
	Landfill Cap Enhancements	Run-on and run-off controls, vegetative cover.	Designed to reduce or eliminate contaminant migration by controlling and channeling runoff.
	Solidification/ Stabilization	Cement- and lime-based processes, microencapsulation, sorption.	Add reagents to physically/chemically bind contaminants in place and minimize migration.
In situ Soils Treatment	Vitrification	Combined with soil vapor extraction.	Use high energy to melt soil in place and vaporize VOC and SVOC COCs.
	In situ Bioremediation	Liquid-phase bioremediation, bioventing, enhanced bioremediation, phytoremediation.	Enhance biodegradation through modification of subsurface environmental conditions.
	Monitored Natural Attenuation	Monitor natural processes.	Naturally occurring processes in soil and groundwater which reduce mass, toxicity, mobility, volume or concentration; processes include biodegradation, dispersion, dilution, adsorption and volatilization.
	Soil Vapor Extraction (SVE)	Horizontal vents, vertical vents.	Removal of volatile contaminants through vacuum extraction in the vadose zone.
	Steam Injection	Combined with soil vapor extraction.	Removal of strippable contaminants using steam and recovery of condensate at surface.
	Six Phase Soil Heating	Combined with soil vapor extraction.	Removal of strippable contaminants using resistive heating and recovery of vapors and condensate at surface.

Table 2-2 - Preliminary Identification of Remedial Technologies for Near-Surface Soils

General Response Action	Remedial Technology	Process Options	Description
In situ Soils Treatment (continued)	Soil Flushing	Water, surfactants, solvents.	Removal of leachable contaminants using surfactants and recovery of leachate at surface.
	Pneumatic Fracturing	Pressurized air or steam.	Pretreatment of in-place soils to enhance performance of other *in situ* processes.
	Chemical Treatment	Oxidation, reduction, pH adjustment.	Injection of chemicals for *in situ* treatment of contaminants.
	Electro-Kinetic	Enhanced with surfactants and reagents.	Low intensity direct electric current is applied to electrodes placed across area of contaminated soil. Ionized contaminants migrate to electrodes. Will work in low-permeability soil materials.
Excavation and On-Site Soils Treatment	Mechanical Screening	Dry, wet sieving.	Segregate coarse materials from contaminated soil as pretreatment for treatment/disposal.
	Ex situ Bioremediation	Landfarming, slurry bioreactor bioventing, biopiles.	Enhance biodegradation by processing soils in an aboveground bioreactor.
	Solvent Extraction	“BEST Process,” Critical fluid extraction.	Extract organics into solvent, with subsequent recovery of organics.
	Dehalogenation	“APEG Process,” "BCD" Process.	Chemical dehalogenation through reaction of reagent with soil in aboveground reactor.
	High Temperature Thermal Desorption	Rotary dryer (indirect or direct fired), Thermal screw (indirect heating) (FRTR 2009b).	Heat soils to 320° to 560°C to volatilize SVOCs, PAHs, and PCBs, recovery in gas treatment system.
Excavation and On-Site Soils Treatment (continued)	Low Temperature Thermal Desorption	Rotary dryer (indirect or direct fired), Thermal screw (indirect heating) (FRTR 2009b).	Heat soils to 90° to 320°C to volatilize VOCs and hydrocarbons, recovery in gas treatment system.
	Pyrolysis	Rotary kiln, fluidized bed furnace, molten salt destruction.	Heat soils under pressure above 800°F in the absence of oxygen to decompose organic materials.
	Incineration	Rotary kiln, fluidized bed.	Heat soils to above 1,600°F and ultimately combust organic contaminants.
	Soil Washing	Water, surfactants, thermally enhanced.	Removal of leachable contaminants using water, surfactants in aboveground reactor.

Table 2-2 - Preliminary Identification of Remedial Technologies for Near-Surface Soils

General Response Action	**Remedial Technology**	**Process Options**	**Description**
	Chemical Treatment	Hydrogen peroxide, potassium permanganate.	*Ex-situ* chemical oxidation/reduction to convert contaminants to less toxic compounds.
	Solvated Electron Treatment (SET)	Ammonia mixed with anhydrous calcium or sodium.	In a sealed vessel, solvated electrons serve as a strong reducing agent and react with halogens and organic molecules.
	Solidification/ Stabilization	Cement- and lime-based processes, microencapsulation, sorption.	Add reagents to physically/chemically bind contaminants in-place and minimize migration.
On-Site Treatment of Extracted Soil Vapor	Condensation	Refrigerated condenser.	Condensation of VOCs from air using refrigeration.
	Adsorption	Granular activated carbon, other adsorbents, regenerative systems.	Removal of adsorbable compounds using canisters in series.
	Thermal Oxidation	Direct flame, flameless.	Vapor heated above 1,400°F to oxidize organics; will require HCl controls.
	Catalytic Oxidation	Various catalysts, fixed or fluidized beds, hybrid thermal.	Vapor heated up to 800°F to oxidize organics; will require HCl controls.
	Advanced Oxidation	UV light, ozonation, photocatalytic.	Vapor passed through catalyst while exposed to high-intensity UV light and/or ozone.
	Biofiltration	Bioreactor, soil pile.	Gases are passed through a soil bed where contaminants are sorbed and degraded.
Excavation and Off-Site Treatment/Disposal of Soil	Off-Site Incineration	Rotary kiln, liquid injection, fluidized bed, infrared incinerators.	Off-site treatment of excavated soil in an incinerator.
	Re-Use Facility	Asphalt incorporation, thermal desorption, cement incorporation.	Off-site treatment of excavated soil at a treatment or recycling facility.
	Landfill	Chemwaste Landfill; Oregon Roosevelt Regional Landfill, WA.	Off-site disposal of excavated soils at an RCRA-permitted landfill or solid waste (industrial) landfill, depending on soil characteristics.

Table 2-3 - Infrastructure, Activities, and Access to Contaminated Near-Surface Soils at the Sites Considered in the Feasibility Study

General Operating Area	**Sites Located Within Operating Area**	**Infrastructure**[a]	**Activities**	**Access to Near-Surface Contaminated Soil**
Oil Reclamation Building and Surrounding Area	Oil Reclamation Building (ORB)	ORB, Air Compressor Building, surrounding paved areas and roadway, aboveground and buried utilities.	Minimal - periodic access by the Industrial Wastewater Treatment (ITW) workers.	Limited by paved areas, proximity to buildings and concrete secondary containment trenches surrounding the ORB on three sides.
	Man-Made Depressions	None	Minimal - this area and immediate vicinity is used periodically for equipment laydown or as a staging area for contractors.	Yes
	G1 Transfer Line	Except for roadways and small paved areas surrounding some buildings, the majority of the path followed by the G1 Transfer Line consists of bare soil. Underground utilities in area.	Generally no activities along the line with the exception of where the line approach roads and buildings.	Yes
	G2 Transfer Lines	Except for roadways and small paved areas surrounding some buildings, the majority of the path followed by the G2 Transfer Line consists of bare soil. Underground utilities in area.	Generally no activities along the line with the exception of where the line approach roads and buildings.	Yes
	G3 Transfer Lines	Except for roadways and small paved areas surrounding some buildings, the majority of the path followed by the G3 Transfer Line consists of bare soil. Underground utilities in area.	Generally no activities along the line with the exception of where the line approach roads and buildings.	Yes
Former Rail Car Unloading Area	Rail Car Unloading	Rail lines, buried 24-inch cooling water line.	None	Yes with removal of rail lines and provided the 24-inch cooling water line is not impacted.
Cold Mill/Finishing Area	Cold Mill Transfer Lines	Former transfer lines terminate in the Cold Mill and at the Tank Farm. Area with identified COCs is directly adjacent to the Tank Farm.	Minimal - access related to Tank Farm operations.	Yes - but limited by proximity to the Tank Farm.
	Continuous Can Process Line	Site is located inside the Cold Mill. Area of impacted soil is covered by concrete floor and machinery.	Heavy industrial	No
	Chromium Transfer Line	Inside open-air courtyard surrounded by the Cold Mill. High-voltage electrical conduits, Cold Mill foundation	Break area for Cold Mill workers	Limited - Area with identified near-surface soil COCs is adjacent to the Cold Mill foundation.
	Cold Mill Electrical Grounding Pit	2.5-foot diameter manhole located in a basement area of the Cold Mill.	Activities above this basement area are heavy industrial.	No
	Former Coater Line Tank	Inside open-air courtyard surrounded by the Cold Mill. No infrastructure in immediate vicinity of the former 200-gallon UST.	Break area for Cold Mill workers	Yes
Oil House Area	Drum Storage and French Drain	Directly adjacent to the Oil House, buried utilities, asphalt and concrete paving.	Moderate activity associated with Oil House operations.	Limited
	Oil House UST	Former tank location is partially covered by grass, partially covered by gravel adjacent to the roadway. Overhead utilities, buried utilities.	Moderate activity associated with adjacent roadway and extraction and skimming well houses to the west.	Yes
	20,000-Gallon Gasoline UST	Due north of the Tank Farm, partially covered by asphalt.	Minimal - access related to Tank Farm operations.	Yes
	Tank Farm Kensol Spill	Tank Farm, paved roadway.	Minimal - access related to Tank Farm operations.	Yes - but limited by proximity to the Tank Farm.
	Eight USTs	Directly adjacent to the Oil House, buried utilities, asphalt paving.	Moderate activity associated with Oil House operations.	Limited - restricted by Oil House building foundations.
Wastewater Treatment Area	Field-Constructed Tanks	Area with identified COCs close to buried 24-inch cooling water line, storm sewer.	None	Yes if underground utility impacts are mitigated.
	Hoffman Tank	Adjacent to IWT Building, partially covered by asphalt. Environmental PVC liner and cap installed in the early 1990s.	Moderate activity associated with IWT operations.	No
	Hydrogen Sulfide Scrubber Building	H2S Building, surrounding paving.	Moderate activity associated with IWT operations.	No
Truck Shop Area	Truck Shop	Adjacent to buildings, overhead and buried utilities.	Moderate activity associated with vehicle maintenance.	No
Former Discharge Ravine Areas	West Discharge Ravine	Unpaved roadways, Kaiser fence line	None	Yes - but limitations exist due to ravine sidewall stability.
	South Discharge Ravine	Kaiser fence line	None	Yes
Remelt/Hot Line Area	Remelt/Hot Line Area Wells and Borings	Remelt area wells/borings located in and around the Remelt furnaces and other industrial equipment inside the Mill. Hotline area wells/borings scattered from the west edge of the Remelt/Hotline area of the Mill and west nearly to the river. Some area close to buildings and utilities but the majority of the area is open and unpaved.	Heavy industrial inside the Mill, moderate activity outside of the Mill in the vicinity of laydown areas and roadways.	No inside of the Mill. Yes elsewhere.
	DC4 Area	In the vicinity of the DC4 Furnace, covered by concrete floor and industrial equipment.	Heavy industrial	No
	DC1 Area	In the vicinity of the DC1 Furnace, covered by concrete floor and industrial equipment.	Heavy industrial	No

Notes:

[a] Includes infrastructure overlaying the site or in the immediate vicinity which could impact access.

Table 2-4 - Chemical and Physical Properties of COPCs

Analyte	CAS Number	Molecular Weight in g/mol	Boiling Point in °C	Melting Point in °C	Specific Gravity	Form at 20°C	Vapor Pressure in atm	Volatile[c]	Aqueous Solubility in mg/L	Henry's Law Constant in atm-m^3/mol	Partitioning Coefficient Organic Carbon to Water (Koc) in L/kg	Mobility in Water
Selected Petroleum Hydrocarbon Constituents[a]												
Benzene	71432	78	80 [b]	5.5 [b]	0.88	liquid	0.1	moderate	1,750	5.56E-03	62	high
Toluene	108883	92	111 [b]	-95 [b]	0.87	liquid	0.03	moderate	526	6.63E-03	140	high
Ethylbenzene	100414	106	136 [b]	-94 [b]	0.87	liquid	0.009	low	169	7.88E-03	204	moderate
Total Xylenes	NA	106			0.88	liquid		low	171	6.80E-03	233	moderate
n-Hexane	110543	86	69 [d]	-95 [d]	0.66	liquid	0.2	moderate	9.5	1.80E+00	3,410	low
Kensol 51 [e]	64741442		> 271	-12	0.82	liquid	<1 mmHg	not volatile	insoluble		NA	insoluble
Selected cPAH constituents [d]												
Benzo(b)fluoranthene	205992	252.3	NA	168	NA	solid	6.58E-10	not volatile	1.40E-02	2.47E-07	357,537 [d]	insoluble
Benzo(a)pyrene	50328	252.32	495	179	1.35	solid	7.22E-12	not volatile	3.80E-03	2.17E-07	968,774 [d]	insoluble
Chrysene	218019	228.3	448	258.2	1.27	solid	8.30E-12	not volatile	2.00E-03	7.26E-10	1,860,000 [e]	insoluble
Aliphatics Hydrocarbons[f]												
EC > 5-6		81			0.67	liquid		moderate	3.60E+01	8.05E-01	800	low
EC > 6-8		100			0.70	liquid		moderate	5.40E+00	1.22E+00	3,800	low
EC > 8-10		130			0.73	liquid		low	4.30E-01	1.95E+00	30,200	insoluble
EC > 10-12		160			0.75	liquid		low	3.40E-02	2.93E+00	234,000	insoluble
EC > 12-16		200			0.77	liquid		low	7.60E-04	1.27E+01	5,370,000	insoluble
EC > 16-21		270			0.78	liquid		low	1.30E-06	1.20E+02	9,550,000,000	insoluble
EC > 21-34		400			0.79	liquid		low	1.50E-11	2.44E+03	10,700,000,000	insoluble
Aromatic Hydrocarbons[f]												
EC > 8-10		120			0.87	liquid		moderate	6.50E+01	1.17E-02	1,580	low
EC > 10-12		130			0.90	liquid		moderate	2.50E+01	3.41E-03	2,510	low
EC > 12-16		150			1.00	liquid		moderate	5.80E+00	1.29E-03	5,010	insoluble
EC > 16-21		190			1.16	liquid		low	5.10E-01	3.17E-04	15,800	insoluble
EC > 21-34		240			1.30	liquid		low	6.60E-03	1.63E-05	126,000	insoluble
PCB Congener[g,h]												
Monochlorobiphenyls						solid	1.82E-06 to 1.38E-05	not volatile	1.34E+00 to 4.83E+00	5.73E-04 to 7.36E-04	25,119 to 33,113	insoluble
Trichlorobiphenyl						solid	1.36E-07 to 1.38E-06	not volatile	4.44E-02 to 4.00E-01	1.00E-04 to 2.50E-04	1 to 181,970	insoluble
Pentachlorobiphenyls						solid	8.59E-09 to 1.47E-07	not volatile	2.62E-03 to 5.42E-02	4.70E-05 to 1.20E-04	1 to 891,251	insoluble
Heptachlorobiphenyls						solid	8.26E-10 to 7.16E-09	not volatile	3.14E-04 to 4.54E-03	1.30E-06 to 3.33E-05	1 to 4,570,882	insoluble
Decachlorobiphenyl						solid	1.39E-10	not volatile	7.43E-06	2.18E-06	1	insoluble

Notes:
a) Molecular Weight, Density, Solubility, Henry's Law Constant and Koc derived from Table 747-4 (Petroleum EC Fraction Physical/Chemical Values) in WAC 173-340-900 and from Ecology 2007a, Part IX Tables.
b) From CRC Handbook of Chemistry and Physics published by Cleveland Chemical and Rubber Company.
c) Volatile designation determined by vapor pressure: not volatile <0.001 atm, low 0.001 to 0.01 atm, moderate 0.01 to 0.2 atm, high >0.2 atm
d) From Montgomery Groundwater Chemicals Desk Reference, 1996
e) From Material Safety Data Sheet (MSDS)
f) Table derived from Table 747-4 (Petroleum EC Fraction Physical/Chemical Values) in WAC 173-340-900 and from Ecology 2007a, Part IX Tables.
g) Koc data from Hansen et al. 1999 and Solubility, Vapor pressure, Henry's Law Constant data from Oberg 2001. Some Solubility, Vapor Pressure, and Henry's Law Constant values are based on predicted or calculated value.
h) Congeners are individual PCB compounds. Aroclors are a mixture of different congeners. The following lists selected Aroclors with their respective average number of chlorine atoms per molecule: Aroclor 1221, 1.15; Aroclor 1242, 3.1; Aroclor 1262, 6.8.
Note that Aroclors are not solids at room temperature.
EC - Equivalent carbon.
Shaded area indicates data are not available or not applicable.

Table 2-5 - Physical/Chemical Screening Criteria of Remedial Technologies for VOC-Impacted Near-Surface Soil

General Response Action	Remedial Technology	Description	Screening Comments	Technology Retained
Monitoring	Monitoring	Provide for protection, performance, and confirmational monitoring. Soil samples will be collected to test for compliance with cleanup levels.	Required by MTCA as part of threshold requirements. Access to surrounding properties may also be required.	Yes
Institutional Controls	Access and Use Restrictions	Provide physical barriers and/or administrative restrictions to prevent direct contact.	The facility is currently restricted from public access. Evaluate additional controls for the protection of site workers.	Yes
	Best Management Practices (BMPs)	Spill prevention, leak detection, double walled pipes, proper storage of chemicals and solvents.	Some measures currently in place. QA/QC Plan must continue to be enforced.	Yes
Containment	Capping	Placement of a cap or soil cover to minimize infiltration and prevent direct contact.	Potentially effective for reducing volatilization of VOCs, reduces leaching to groundwater from impacted soils. Stormwater is currently managed in some paved areas. Evaluate additional stormwater controls for areas of proposed new capping. Evaluate AOCs currently covered by paving or buildings for protectiveness.	Yes
	Landfill Cap Enhancements	Water harvesting (runoff enhancement) and vegetative cover.	Technology does not prevent contact with VOC-impacted near-surface soils. Vegetative cover is not practical in most industrial areas of the facility.	No
	Solidification/ Stabilization	Add reagents that will physically/chemically bind contaminants in place and minimize mobility.	Difficult access for construction in many areas. VOCs usually not reactive with inorganic stabilization/solidification agents.	No

General Response Action	Remedial Technology	Description	Screening Comments	Technology Retained
In situ Treatment of Soils	Vitrification	Use high energy to melt soil in place and minimize migration.	Stray current and heat may impact infrastructure; would likely volatilize versus immobilize most VOCs; requires off-gas capture/treatment.	No
	In situ Bioremediation	Enhance biodegradation through modification of subsurface environmental conditions.	Technology has been demonstrated to be effective in remediating soil impacted by VOCs.	Yes
	Monitored Natural Attenuation	Naturally occurring processes in soil and groundwater that reduce mass, toxicity, mobility, volume or concentration of contaminants. Includes biodegradation, dispersion, dilution, adsorption and volatilization.	VOCs are known to naturally degrade in the soil environment.	Yes
	Soil Vapor Extraction (SVE)	Removal of volatile contaminants by extracting soil vapor with a vacuum pump. Extracted vapor is treated.	Proven effective for VOC removal from vadose soils only. Will reduce/control ambient and indoor air risks in addition to recovering volatiles for treatment. Limited access for subsurface installations due to presence of buildings and traffic. EPA presumptive remedy for VOCs in soil.	Yes
	Steam Injection	Removal of strippable contaminants using steam, recovery of condensate at surface.	Access limited by infrastructure and buried utilities. Requires off-gas capture and may increase indoor air exposure.	No

Table 2-5 - Physical/Chemical Screening Criteria of Remedial Technologies for VOC-Impacted Near-Surface Soil

General Response Action	Remedial Technology	Description	Screening Comments	Technology Retained
In situ Treatment of Soils (continued)	Six Phase Soil Heating	Removal of strippable contaminants using heat, recovery of condensate at surface.	Due to congested infrastructure and safety concerns with stray electrical current use is prohibitive. Limited to accessible areas, requires capture and treatment of extracted vapors.	No
	Soil Flushing	Removal of leachable contaminants using surfactants. Leachate is recovered at the surface.	Access to impacted soils limited by infrastructure. Saturation of vadose soil would occur near and beneath buildings and roadways and may create potential for settlement. Potential for contaminant spreading in highly porous substrate if capture is ineffective.	No
	Pneumatic Fracturing	Pretreatment of in-place soils to enhance performance of other *in situ* processes.	Not needed because of highly permeable nature of native soil.	No
	Chemical Treatment	Injection of chemicals for *in situ* treatment of contaminants.	Demonstrated effective for VOCs. Highly porous nature of soil will enhance lateral distribution of treatment fluids from each injection location. The congested infrastructure will limit injection locations in areas of concern.	Yes
	Electro-Kinetic	Direct current used to cause contaminants to migrate to electrodes where they are treated.	VOCs are not ionized and will not migrate in an electric field.	No
Excavation and On-Site Treatment of Soil	Mechanical Screening	Segregate coarse-grain soil from contaminated soil as pretreatment for treatment/disposal.	Restricted to excavatable soils only. Has been demonstrated effective at Kaiser for less volatile COCs. During the excavation and screening process, most VOCs would be emitted to atmosphere.	No
	Ex situ Bioremediation	Enhance biodegradation by processing soils in an above-ground bioreactor.	Restricted to excavatable soils only. During the excavation process, most VOCs would be emitted to atmosphere.	No

Table 2-5 - Physical/Chemical Screening Criteria of Remedial Technologies for VOC-Impacted Near-Surface Soil

General Response Action	Remedial Technology	Description	Screening Comments	Technology Retained
Excavation and On-Site Treatment of Soil (continued)	Solvent Extraction	Extract organics into solvent, with subsequent recovery of organics.	Restricted to excavatable soils only. During the excavation process, most VOCs would be emitted to atmosphere.	No
	Solidification/ Stabilization	Add reagents that will physically/chemically bind contaminants in place and minimize mobility.	Treatment typically used for inorganic impacted soils. May be difficult to bind VOCs to non-organic matrix.	No
	Dehalogenation	Chemical dehalogenation through reaction of reagent with soil in above-ground reactor.	Halogenated VOCs are not present in significant quantities at this site.	No
	High Temperature Thermal Desorption	Rotary dryer (indirect or direct fired), Thermal screw (indirect heating) (FRTR 2009b).	Restricted to excavatable soils only. During the excavation process, most VOCs would be emitted to atmosphere. Would require treatment of off gas.	No
	Low Temperature Thermal Desorption	Rotary dryer (indirect or direct fired), Thermal screw (indirect heating) (FRTR 2009b).	Restricted to excavatable soils only. During the excavation process, most VOCs would be emitted to atmosphere. Would require treatment of off gas.	No
	Pyrolysis	Rotary kiln, fluidized bed furnace, molten salt destruction.	Restricted to excavatable soils only. During the excavation process, most VOCs would be emitted to atmosphere. Would require treatment of off gas.	No
	Incineration	Heat soils to above 1600°F to combust organic contaminants.	Restricted to excavatable soils only. During the excavation process, most VOCs would be emitted to atmosphere. Would require treatment of off gas.	No
	Soil Washing	Removal of leachable contaminants using water and surfactants in an aboveground reactor.	Restricted to excavatable soils only. During the excavation process, most VOCs would be emitted to atmosphere. Large volume of soil, low concentration of VOCs would limit utility of this process.	No
	Chemical Treatment	Chemical oxidation or reduction to convert contaminants to less toxic compounds.	Restricted to excavatable soils only. During the excavation process, most VOCs would be emitted to atmosphere.	No

Table 2-5 - Physical/Chemical Screening Criteria of Remedial Technologies for VOC-Impacted Near-Surface Soil

General Response Action	Remedial Technology	Description	Screening Comments	Technology Retained
Excavation and On-Site Soils Treatment (continued)	Solvated Electron Treatment (SET)	Ammonia mixed with anhydrous calcium or sodium.	Primarily used for halogenated contaminates. Halogenated VOCs are not a significant COC at this site.	No
On-Site Treatment of Extracted Soil Vapor	Condensation	Condensation of VOCs from air using refrigeration.	Not effective for low concentrations of solvent vapors (<10,000 ppm); not demonstrated effective for petroleum hydrocarbons.	No
	Adsorption	Removal of adsorbable compound using canister in series, may require disposal.	Demonstrated effective for petroleum hydrocarbons.	Yes
	Thermal Oxidation	Vapor heated above 1,400°F to oxidize organics; requires emission controls.	Demonstrated effective for VOCs.	Yes
	Catalytic Oxidation	Vapor heated up to 800°F to oxidize organics, requires HCI controls.	Potentially effective for VOCs at this site.	Yes
	Advanced Oxidation	Vapor is passed through catalyst while exposed to high-intensity UV light or ozone.	Potentially effective for VOCs at this site.	Yes
	Biofiltration	Gases are passed through a soil bed where contaminants are sorbed and degraded.	Potentially effective for VOCs at this site.	Yes
Excavation and Off-Site Treatment/ Disposal of Soil	Landfill	Off-site disposal of excavated soils at an RCRA-permitted landfill or solid waste (industrial) landfill depending on soil characteristics.	Restricted to excavatable soils only. During the excavation process, most VOCs would be emitted to atmosphere. Off-site disposal is a low-ranking alternative under MTCA.	No
	Off-Site Incineration	Off-site treatment of excavated soil in an incinerator.	Restricted to excavatable soils only. During the excavation process, most VOCs would be emitted to atmosphere.	No
	Re-Use Facility	Off-site treatment of excavated soil at a treatment or recycling facility.	Restricted to excavatable soils only. During the excavation process, most VOCs would be emitted to atmosphere.	No

Table 2-6 - Physical/Chemical Screening Criteria of Remedial Technologies for SVOC-Impacted Near-Surface Soil

General Response Action	Remedial Technology	Description	Screening Comments	Technology Retained
Monitoring	Monitoring	Provide for protection, performance, and confirmational monitoring. Soil samples will be collected to test for compliance with cleanup levels.	Required by MTCA as part of threshold requirements. Access to surrounding properties may also be required.	Yes
Institutional Controls	Access and Use Restrictions	Provide physical barriers and/or administrative restrictions to prevent direct contact.	The facility is currently restricted from public access. Evaluate additional controls for the protection of site workers.	Yes
	Best Management Practices (BMPs)	Spill prevention, leak detection, double walled pipes, proper storage of chemicals and solvents.	Some measures currently in place. QA/QC Plan must continue to be enforced.	Yes
Containment	Capping	Placement of a cap or soil cover to minimize infiltration and prevent direct contact.	Required to eliminate dermal and ingestion pathways for surface soils, reduces leaching to GW by impacted soils. Stormwater is currently managed in some paved areas. Evaluate additional stormwater controls for areas of proposed new capping. Evaluate AOCs currently covered by paving or buildings for protectiveness.	Yes
	Landfill Cap Enhancements	Water harvesting (runoff enhancement) and vegetative cover.	Technology does not prevent contact with SVOC-impacted near surface soils. Vegetative cover is not practical in most industrial areas of the facility.	No
	Solidification/ Stabilization	Add reagents that will physically/chemically bind contaminants in place and minimize mobility.	Potentially effective for some SVOCs. Limited to accessible areas; restricted by structures, roadways and buried utilities.	No
In situ Treatment of Soils	Vitrification	Use high energy to melt soil in place and minimize migration.	Stray current and heat may impact infrastructure; requires off-gas capture.	No

Table 2-6 - Physical/Chemical Screening Criteria of Remedial Technologies for SVOC-Impacted Near-Surface Soil

General Response Action	Remedial Technology	Description	Screening Comments	Technology Retained
In situ Treatment of Soils (continued)	*In situ* Bioremediation	Enhance biodegradation through modification of subsurface environmental conditions.	Technology has been demonstrated to be effective in remediating soil impacted by SVOCs.	Yes
	Monitored Natural Attenuation	Naturally occurring processes in soil and groundwater that reduce mass, toxicity, mobility, volume or concentration of contaminants. Includes biodegradation, dispersion, dilution, adsorption and volatilization.	SVOCs are known to naturally degrade in the soil environment.	Yes
	Soil Vapor Extraction (SVE)	Removal of volatile contaminants by extracting soil vapor with a vacuum pump. Assumed that extracted vapor treatment is part of this remedial technology.	Not effective for SVOCs because vapor pressure and Henry's Law constants are too low.	No
	Steam Injection	Removal of strippable contaminants using steam, recovery of condensate at surface.	Access limited by infrastructure and buried utilities. Requires off-gas capture and may increase indoor air exposure.	No
	Six Phase Soil Heating	Removal of strippable contaminants using heat, recovery of condensate at surface.	Due to congested infrastructure and safety concerns with stray electrical current, use is prohibitive. Limited to accessible areas, requires capture and treatment of extracted vapors.	No
	Soil Flushing	Removal of leachable contaminants using surfactants. Leachate is recovered at the surface.	Access to impacted soils limited by infrastructure. Saturation of vadose soil would occur near and beneath buildings and roadways and may create potential for settlement. Potential for contaminant spreading in highly porous substrate if capture is ineffective.	No
	Pneumatic Fracturing	Pretreatment of in-place soils to enhance performance of other *in situ* processes.	Not needed because of highly permeable nature of native soil.	No

Table 2-6 - Physical/Chemical Screening Criteria of Remedial Technologies for SVOC-Impacted Near-Surface Soil

General Response Action	Remedial Technology	Description	Screening Comments	Technology Retained
In situ Treatment of Soils (continued)	Chemical Treatment	Injection of chemicals for *in situ* treatment of contaminants.	Fenton's reagent has been demonstrated effective for SVOCs. COCs such as diesel/heavy oil are more likely to be in liquid phase attached to soil particles and therefore available for contact with treatment chemical. Highly porous nature of soil will enhance lateral distribution of treatment fluids from each injection location. The congested infrastructure will limit injection locations in some areas of concern.	Yes
	Electro-Kinetic	Direct current used to cause contaminants to migrate to electrodes where they are treated.	SVOCs are not ionized and will not migrate in an electric field.	No
Excavation and On-Site Treatment/ Disposal of Soil	Mechanical Screening	Segregate coarse-grain soil from contaminated soil as pretreatment for treatment/disposal.	Restricted to excavatable soils only. Has been demonstrated effective at Kaiser for concentrating SVOC COCs in soil for disposal. Removes large cobbles that make up to 20 percent of the soil matrix.	Yes
	Ex situ Bioremediation	Enhance biodegradation by processing soils in an aboveground bioreactor.	Restricted to excavatable soils only. White Rot fungus and other fungi have been demonstrated to readily degrade SVOCs when mixed with impacted soil. This is a presumptive remedy for SVOC impacted soil.	Yes
	Solvent Extraction	Extract organics into solvent, with subsequent recovery of organics.	Restricted to excavatable soils only. Large volume of soil and low concentration of COCs present make soil-solvent contact difficult.	No
	Dehalogenation	Chemical dehalogenation through reaction of reagent with soil in aboveground reactor.	Chlorinated SVOCs are not present in significant quantities at this facility.	No
	High Temperature	Rotary dryer (indirect or direct fired), Thermal	Restricted to excavatable soils only. Demonstrated	Yes

Table 2-6 - Physical/Chemical Screening Criteria of Remedial Technologies for SVOC-Impacted Near-Surface Soil

General Response Action	Remedial Technology	Description	Screening Comments	Technology Retained
	Thermal Desorption	screw (indirect heating) (FRTR 2009b).	effective for SVOCs. Off gas must be treated.	
	Low Temperature Thermal Desorption	Rotary dryer (indirect or direct fired), Thermal screw (indirect heating) (FRTR 2009b).	Restricted to excavatable soils only. Demonstrated effective for SVOCs. Off gas must be treated	Yes
	Pyrolysis	Rotary kiln, fluidized bed furnace, molten salt destruction.	Restricted to excavatable soils only. Demonstrated effective for SVOCs. Off gas must be treated	Yes
	Incineration	Heat soils to above 1600°F to combust organic contaminants.	Restricted to excavatable soils only. Demonstrated effective for SVOCs. Off gas must be treated	Yes
	Soil Washing	Removal of leachable contaminants using water and surfactants in an aboveground reactor.	Restricted to excavatable soils only. Demonstrated effective for SVOCs.	Yes
Excavation and On-Site Treatment/ Disposal of Soil (continued)	Chemical Treatment	Chemical oxidation or reduction to convert contaminants to less toxic compounds.	Restricted to excavatable soils only. Demonstrated effective for SVOCs.	Yes
	Solvated Electron Treatment (SET)	Ammonia mixed with anhydrous calcium or sodium.	Primarily used for halogenated contaminants. Chlorinated SVOCs (other than PCBs) are not present on the site.	No
	Solidification/ Stabilization	Add reagents that will physically/chemically bind contaminants in place and minimize mobility.	Treatment typically used for inorganic impacted soils. May be difficult to bind SVOCs to non-organic matrix.	No
On-Site Treatment of Extracted Soil Vapor	Condensation	Condensation of VOCs from air using refrigeration.	Not effective for low concentrations of SVOC vapors (<10,000 ppm); not demonstrated effective for petroleum hydrocarbons. Vapor extraction is not effective because vapor pressure and Henry's constant are too low.	No
	Adsorption	Removal of adsorbable compound using canister in series, may require disposal.	Potentially effective for SVOC degradation products.	No/Yes[a]
	Thermal Oxidation	Vapor heated above 1,400°F to oxidize organics; requires emission controls.	Potentially effective for SVOC degradation products.	No/Yes[a]

Table 2-6 - Physical/Chemical Screening Criteria of Remedial Technologies for SVOC-Impacted Near-Surface Soil

General Response Action	Remedial Technology	Description	Screening Comments	Technology Retained
	Catalytic Oxidation	Vapor heated up to 800°F to oxidize organics, requires HCl controls.	Potentially effective for SVOC degradation products.	No/Yes[a]
	Advanced Oxidation	Vapor is passed through catalyst while exposed to high-intensity UV light or ozone.	Potentially effective for SVOC degradation products.	No/Yes[a]
	Biofiltration	Gases are passed through a soil bed where contaminants are sorbed and degraded.	Potentially effective for SVOC degradation products.	No/Yes[a]
Excavation and Off-Site Treatment/ Disposal of Soil	Landfill	Off-site disposal of excavated soils at an RCRA-permitted landfill or solid waste (industrial) landfill depending on soil characteristics.	Restricted to excavatable soils only. Direct rail shipment to RCRA-permitted Subtitle C landfill possible from Kaiser and has been used for past remedial actions.	Yes
	Off-Site Incineration	Off-site treatment of excavated soil in an incinerator.	Restricted to excavatable soils only.	Yes
	Re-Use Facility	Off-site treatment of excavated soil at a treatment or recycling facility.	Restricted to excavatable soils only. Potential for recycling of soil impacted with only Diesel/Heavy Oil at a local asphalt batching facility. Asphalt facilities will not take soil cross contaminated with other COCs.	No

[a] No applies to extracted soil vapor. Yes applies to off gas treatment for on-site *ex situ* thermal processes.

Table 2-7 - Physical/Chemical Screening Criteria of Remedial Technologies for PCB-Impacted Near-Surface Soil

General Response Action	Remedial Technology	Description	Screening Comments	Technology Retained
Monitoring	Monitoring	Provide for protection, performance, and confirmational monitoring. Soil samples will be collected to test for compliance with cleanup levels.	Required by MTCA as part of threshold requirements. Access to surrounding properties may also be required.	Yes
Institutional Controls	Access and Use Restrictions	Provide physical barriers and/or administrative restrictions to prevent direct contact.	Must follow TSCA institutional control requirements. Kaiser facility property already restricted.	Yes
	Best Management Practices (BMPs)	Spill prevention, leak detection, double walled pipes, proper storage of chemicals and solvents.	Some measures currently in place. QA/QC Plan must continue to be enforced.	Yes
Containment	Capping	Placement of a cap or soil cover to minimize infiltration and prevent direct contact.	Potentially effective for reducing physical contact with PCBs. Must follow TSCA capping requirements.	Yes
	Landfill Cap Enhancements	Water harvesting (runoff enhancement) and vegetative cover.	Technology does not prevent contact with PCB-impacted near surface soils. Vegetative cover is not practical in most industrial areas of the facility.	No
	Solidification/ Stabilization	Add reagents that will physically/chemically bind contaminants in-place and minimize mobility.	Potentially effective for PCBs. Limited to accessible areas; restricted by structures, roadways and buried utilities.	No
In situ Treatment of Soils	Vitrification	Use high energy to melt soil in-place and minimize migration.	Stray current and heat may impact rail lines and buried utilities; requires off-gas capture; off gas may be toxic (dioxin and furans). Technology has been used in Eastern Washington for treatment of PCB-impacted soils.	No

Table 2-7 - Physical/Chemical Screening Criteria of Remedial Technologies for PCB-Impacted Near-Surface Soil

General Response Action	Remedial Technology	Description	Screening Comments	Technology Retained
In situ Treatment of Soils (continued)	*In situ* Bioremediation	Enhance biodegradation through modification of subsurface environmental conditions.	Limited effectiveness with PCBs. Most often used to treat PAHs, non halogenated SVOCs and BTEX.	No
	Monitored Natural Attenuation	Naturally occurring processes in soil and groundwater that reduce mass, toxicity, mobility, volume or concentration of contaminants. Includes biodegradation, dispersion, dilution, adsorption and volatilization.	Available evidence shows limited natural biological decomposition of PCBs.	Yes
	Soil Vapor Extraction (SVE)	Removal of volatile contaminants by extracting soil vapor with a vacuum pump.	Access may be limited for subsurface installations due to presence of buildings, railroads, and traffic. As stand-alone treatment method, not effective for PCBs due to low vapor pressure.	No
	Steam Injection	Removal of strippable contaminants using steam, recovery of condensate at surface.	Access may be limited by buildings, roadways, rail lines and buried utilities. Requires off-gas capture and may increase indoor air exposure.	No
	Six Phase Soil Heating	Removal of strippable contaminants using heat, recovery of condensate at surface.	Stray electrical current may impact neighboring rail lines and buried utilities. Limited to accessible areas, requires capture and treatment of extracted vapors.	No
	Soil Flushing	Removal of leachable contaminants using surfactants. Leachate is recovered at the surface.	Access limited by buildings, roadways, rail lines and buried utilities. Technology may not be effective due to PCBs limited solubility in non-organic solvents.	No
	Pneumatic Fracturing	Pretreatment of in-place soils to enhance performance of other *in situ* processes.	Not needed because native soil permeable. Pneumatic injection of sand may cause ground movement beneath existing structures and utilities.	No

Table 2-7 - Physical/Chemical Screening Criteria of Remedial Technologies for PCB-Impacted Near-Surface Soil

General Response Action	Remedial Technology	Description	Screening Comments	Technology Retained
In situ Treatment of Soils (continued)	Chemical Treatment	Injection of chemicals for *in situ* treatment of contaminants (e.g., oxidation/reduction, pH adjustment).	Has been used for the treatment of PCBs at Battery Tech Superfund Site. Along with PCBs, various VOCs were also treated (EPA 2003).	Yes
	Electro-Kinetic	Direct current used to cause contaminants to migrate to electrodes where they are treated.	PCBs are not ionized and will not migrate in an electric field.	No
Excavation and On-Site Treatment of Soil	Mechanical Screening	Segregate coarse-grain soil from contaminated soil as pretreatment for treatment/disposal.	Restricted to excavatable soils only. Has been demonstrated effective at Kaiser for concentrating PCBs in soil. Screening removes cobbles which make up about 20 percent of the soil matrix.	Yes
	Ex situ Bioremediation	Enhance biodegradation by processing soils in an aboveground bioreactor.	Restricted to excavatable soils only. Slurry bioreactors with co-metabolites and specially adapted organisms have been used for PCB treatment.	Yes
	Solvent Extraction	Extract organics into solvent, with subsequent recovery of organics.	Restricted to excavatable soils only. Large volume of soil and low concentration of COCs present make soil/solvent contact difficult.	No
	Dehalogenation	Chemical dehalogenation through reaction of reagent with soil in aboveground reactor.	Restricted to excavatable soils only. APEG treatment has been successfully field tested with PCB-impacted soils.	Yes
	High Temperature Thermal Desorption	Rotary dryer (indirect or direct fired), Thermal screw (indirect heating) (FRTR 2009b).	Restricted to excavatable soils only. XTRAX^{TM} process has been used for PCB treatment with high removal efficiency.	Yes
	Low Temperature Thermal Desorption	Rotary dryer (indirect or direct fired), Thermal screw (indirect heating) (FRTR 2009b).	Restricted to excavatable soils only. Due to relatively low operating temperatures, not an effective technology for PCBs due to low volatility.	No

Table 2-7 - Physical/Chemical Screening Criteria of Remedial Technologies for PCB-Impacted Near-Surface Soil

General Response Action	Remedial Technology	Description	Screening Comments	Technology Retained
Excavation and On-Site Treatment of Soil (continued)	Pyrolysis	Rotary kiln, fluidized bed furnace, molten salt destruction.	Restricted to excavatable soils only. Limited performance data for PCBs. By-products of incomplete combustion (dioxins and furans) are toxic.	No
	Incineration	Heat soils to above 1600°F to combust organic contaminants.	Restricted to excavatable soils only. By-products of incomplete combustion (dioxins and furans) are toxic.	No
	Soil Washing	Removal of leachable contaminants using water and surfactants in an aboveground reactor.	Restricted to excavatable soils only. Technology may not be effective due to PCBs limited solubility.	No
	Chemical Treatment	Chemical oxidation or reduction to convert contaminants to less toxic compounds.	Restricted to excavatable soils only. Technology may not be effective with PCBs, since PCBs are relatively stable and non-reactive compounds.	No
	Solvated Electron Treatment (SET)	Ammonia mixed with anhydrous calcium or sodium.	Restricted to excavatable soils only. Technology poses many health and safety concerns due to reagents and highly exothermic reaction.	No
	Solidification/ Stabilization	Add reagents that will physically/chemically bind contaminants in place and minimize mobility.	Treatment typically used for inorganic impacted soils. May be difficult to bind PCBs to non-organic matrix.	No
On-Site Treatment of Extracted Soil Vapor	Condensation	Condensation of PCBs from air using refrigeration.	May be an effective technology for PCBs, however due to low volatility, soil vapor extraction technologies generally not effective for removal of PCBs.	No

Table 2-7 - Physical/Chemical Screening Criteria of Remedial Technologies for PCB-Impacted Near-Surface Soil

General Response Action	Remedial Technology	Description	Screening Comments	Technology Retained
On-Site Treatment of Extracted Soil Vapor (continued)	Adsorption	Removal of adsorbable compound using canister in series, may require disposal.	Demonstrated effective for SVOCs, however due to low volatility, soil vapor extraction technologies generally not effective for removal of PCBs.	No
	Thermal Oxidation	Vapor heated above 1,400°F to oxidize organics; requires emission controls.	Limited effectiveness with PCBs. Due to low volatility, soil vapor extraction technologies generally not effective for removal of PCBs and by-products of incomplete combustion (dioxins and furans) are toxic.	No
	Catalytic Oxidation	Vapor heated up to 800°F to oxidize organics, requires HCI controls.	Destruction of halogenated compounds requires special catalysts, special materials or construction, and due to low volatility, soil vapor extraction technologies generally not effective for removal of PCBs and by-products of incomplete combustion (dioxin, furan) are toxic.	No
	Advanced Oxidation	Vapor is passed through catalyst while exposed to high intensity UV light or ozone.	Target group are non-halogenated VOCs and SVOCs. Due to low volatility, soil vapor extraction technologies generally not effective for removal of PCBs and by-products of incomplete combustion (dioxin, furan) are toxic.	No
	Biofiltration	Gases are passed through a soil bed where contaminants are sorbed and degraded.	Limited effectiveness with PCBs. due to low volatility, soil vapor extraction technologies generally not effective for removal of PCBs. By-products (dioxin, furan) are toxic.	No
Excavation and Off-Site Treatment/ Disposal of Soil	Landfill	Off-site disposal of excavated soils at an RCRA- or TSCA-permitted landfill or solid waste (industrial) landfill depending on soil characteristics.	Restricted to excavatable soils only. Excavation may be limited due to access for construction equipment and treatment facility.	Yes

Table 2-7 - Physical/Chemical Screening Criteria of Remedial Technologies for PCB-Impacted Near-Surface Soil

General Response Action	Remedial Technology	Description	Screening Comments	Technology Retained
Excavation and Off-Site Treatment/ Disposal of Soil (continued)	Off-Site Incineration	Off-site treatment of excavated soil in an incinerator.	Restricted to excavatable soils only. Excavation may be limited due to access for construction equipment and treatment facility. By-products of incomplete combustion (dioxin, furan) are toxic.	Yes
	Re-Use Facility	Off-site treatment of excavated soil at a treatment or recycling facility.	Restricted to excavatable soils only. Excavation may be limited due to access for construction equipment and treatment facility. PCB-impacted soil will not be accepted for use in asphalt. Per TSCA, off-site treatment is an option only for non-soil waste.	No

Table 2-8a - Implementability of Monitoring for VOC-Impacted Near-Surface Soil

	Process Options for Monitoring
Attribute	**Protection, Performance, and Confirmational Monitoring**
Can it be constructed?	Yes, the site is suitable for collecting soil samples for compliance monitoring.
Will it work?	Yes
Will this be acceptable to regulatory agencies?	Yes, Ecology approval of a Sampling Plan may be required.
Is technology available?	Yes
Is process option accepted?	Yes

Note:

Table 2-8b - Implementability of Institutional Controls for VOC-Impacted Near-Surface Soil

	Process Options for Institutional Controls	
Attribute	**Access Restrictions**	**Best Management Practices (BMPs)**
Can it be constructed?	The facility is currently restricted from public access. Additional physical barriers or administrative restrictions can be constructed or implemented. Design and construction will take < 1 year.	Some measures are already in place. Additional non-administrative BMPs can be constructed. Design and construction will take < 1 year.
Will it work?	Access restrictions will prevent direct contact and provide additional protection for worker health and safety.	BMPs have been shown to effectively reduce contaminant loading into the environment with proper storage and leak protection.
Will this be acceptable to regulatory agencies?	Yes	Yes
Is technology available?	Yes	Yes
Is process option accepted?	Yes	Yes

Table 2-8c - Implementability of Capping VOC-Impacted Near-Surface Soil

	Process Options for Capping					
Attribute	**Soil**	**Clay Cap**	**Asphalt**	**Concrete**	**Synthetic Liner**	**Multilayer Cap (soil + synthetic liner)**
Can it be constructed?	Yes, conditions outside of existing buildings suitable for construction. The subgrade below the cap may need to be strengthened to support the cap and the anticipated future uses of the capped surface.	Yes, conditions outside of existing buildings suitable for construction. The subgrade below the cap may need to be strengthened to support the cap and the anticipated future uses of the capped surface.	Yes, conditions outside of existing buildings suitable for construction. The subgrade below the cap may need to be strengthened to support the cap and the anticipated future uses of the capped surface.	Yes, conditions outside of existing buildings suitable for construction. The subgrade below the cap may need to be strengthened to support the cap and the anticipated future uses of the capped surface.	Yes, conditions outside of existing buildings suitable for construction. The subgrade below the cap may need to be strengthened to support the cap and the anticipated future uses of the capped surface. May have limited effect since liner must be sealed around penetrating objects (e.g., wells, buried utilities).	Yes, conditions outside of existing buildings suitable for construction. The subgrade below the cap may need to be strengthened to support the cap and the anticipated future uses of the capped surface. May have limited effect since liner must be sealed around penetrating objects (e.g., wells, buried utilities).

Table 2-8c - Implementability of Capping VOC-Impacted Near-Surface Soil

	Process Options for Capping					
Attribute	**Soil**	**Clay Cap**	**Asphalt**	**Concrete**	**Synthetic Liner**	**Multilayer Cap (soil + synthetic liner)**
Will it work?	No, because it would be damaged by the heavy industrial site use and will not effectively limit infiltration and volatilization.	No, because it would be damaged by the heavy industrial site use.	Yes, will immediately prevent stormwater infiltration, protect personnel from dermal contact and inhalation exposure, and will withstand site use demands.	Yes, will immediately prevent stormwater infiltration, protect personnel from dermal contact and inhalation exposure, and will withstand site use demands.	No, because it would be damaged by the heavy industrial site use and UV radiation.	Yes, will immediately prevent stormwater infiltration, protect personnel from dermal contact and inhalation exposure provided the upper layer can withstand site use demands. Currently installed at the Hoffman tank site at Kaiser Site.
Will this be acceptable to regulatory agencies?	No	Yes	Yes	Yes	Yes	Yes
Is technology available?	Yes	Yes	Yes	Yes	Yes	Yes
Is process option accepted?	No	No	Yes	Yes	No	Yes

Table 2-8d - Implementability of *In Situ* Bioremediation for VOC-Impacted Near-Surface Soil

	Process Options for *In situ* Bioremediation		
Attribute	**Bioventing (injecting and/or withdrawing air in vadose zone)**	**Enhanced Bioremediation**	**Phytoremediation**
Can it be constructed?	Yes, site is amenable to constructing and operating support equipment though access may be limited in some areas by infrastructure. Can be combined with SVE. Design, construction, and startup will take approximately 1 year.	Yes, site is amenable to constructing and operating support equipment though access may be limited in some areas by infrastructure. Design, construction, and startup will take approximately 1 year. This technology includes the circulation of water-based solutions to stimulate microbes and/or the injection of Oxygen Release Compounds (ORC) or electron donor compounds.	Yes, conditions outside of existing buildings suitable for construction. Existing paving in some areas would have to be removed. Design, construction, and startup will take approximately 1 year.
Will it work?	Uncertain. Extremely low soil moisture content (summer) and colder temperatures (winter) will limit biodegradation rates.	Ineffective for soil in the top 20 feet of the site due to the following: porous sands and gravels will not confine circulating or injected fluids to the near-surface area of interest; ORC and electron donor inputs require saturated soils to work; and very low VOC concentrations and low organic content of soils at this site make contact with treatment inputs difficult.	No, plant matter would be damaged by the heavy industrial site use. Additionally Kaiser maintains the soil in the mill areas with annual applications of herbicides to make the soil sterile (zero plant growth outside of landscaped areas to limit maintenance and prevent brush fires).
Will this be acceptable to regulatory agencies?	Yes	Yes	Yes
Is technology available?	Yes	Yes	Yes
Is process option accepted?	No	No	No

Table 2-8e - Implementability of Monitored Natural Attenuation for VOC-Impacted Near-Surface Soil

	Process Options for Monitored Natural Attenuation
Attribute	**Monitored Natural Attenuation**
Can it be constructed?	Yes, site is suitable for using existing monitoring wells and constructing new monitoring wells for collecting groundwater samples and measuring water levels. Less than one year is needed to design and construct any additional wells needed. Institutional controls are required to prevent direct contact.
Will it work?	Site data indicates natural attenuation of VOCs is actively occurring as they have been infrequently detected in groundwater and are not COCs in the groundwater.
Will this be acceptable to regulatory agencies?	Ecology approval of a Compliance Monitoring Plan will be required.
Is technology available?	Yes
Is process option accepted?	Yes, but may not be capable of reaching cleanup levels at POC in a reasonable time frame without using other technologies.

Table 2-8f - Implementability of Soil Vapor Extraction for VOC-Impacted Near-Surface Soil

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	Process Options for Soil Vapor Extraction (SVE)	
Attribute	**Horizontal Vents**	**Vertical Vents**
Can it be constructed?	Constructing horizontal wells can be difficult due to site soil conditions. The near-surface soils consists of approximately 30% cobbles; this could make it difficult to drill and install an extended run of pipe (e.g. 100 feet or more). Extracted vapors may need to be treated on site. Design and construction will take < 1 year. Could be installed beneath buildings using directional drilling.	Most source areas suitable for constructing additional vertical wells and required equipment. Extracted vapors may need to be treated on site. Design and construction will take < 1 year.
Will it work?	SVE is an EPA presumptive remedy for VOCs in soils. SVE has been shown to be an effective means for removing VOCs from vadose zone soil.	SVE is an EPA presumptive remedy for VOCs in soils. SVE has been shown to be an effective means for removing VOCs from vadose zone soil.
Will this be acceptable to regulatory agencies?	Yes	Yes
Is technology available?	Yes	Yes
Is process option accepted?	No	Yes

Table 2-8g - Implementability of *In Situ* Chemical Treatment for VOC-Impacted Near-Surface Soil

	Process Options for *In situ* Chemical Treatment
Attribute	**Oxidation**
Can it be constructed?	Yes, site is amenable to constructing and operating support equipment though access may be limited in some areas by infrastructure. Design, construction, and startup will take approximately 1 year.
Will it work?	Ineffective for soil in the top 20 feet of the site as the porous sands and gravels will not confine injected fluids to the near-surface area of interest and the very low VOC concentrations and low organic carbon present in soil at this site make contact with and subsequent reaction with treatment inputs difficult. Off-gases will be generated and must be collected and potentially treated to meet regulatory requirements.
Will this be acceptable to regulatory agencies?	Yes
Is technology available?	Yes
Is process option accepted?	No

Table 2-8h - Implementability of Adsorption of Vapors Extracted from Soil for VOC-Impacted Near-Surface Soil

	Process Options for Adsorption of Vapors Extracted from Soil
Attribute	**Granular Activated Carbon (GAC)**
Can it be constructed?	Most source areas suitable for constructing required equipment. Design and construction will take < 1 year.
Will it work?	Yes, known to be effective until contaminants reach a 20% mass loading on the carbon substrate. Would be used after vapor extraction technology has removed the VOCs from the source areas.
Will this be acceptable to regulatory agencies?	Yes
Is technology available?	Yes
Is process option accepted?	Yes

Table 2-8i - Implementability of Thermal and Catalytic Oxidation of Vapors Extracted from Soil for VOC-Impacted Near-Surface Soil

	Process Options for Thermal and Catalytic Oxidation of Vapors Extracted from Soil			
Attribute	**Direct Flame Thermal Oxidizers**	**Flameless Thermal Oxidizers**	**Catalytic Oxidizers**	**Hybrid Thermal/Catalytic Oxidizer**
Can it be constructed?	Most source areas suitable for constructing and equipment required. Design and construction will take < 1 year.	Most source areas suitable for constructing and equipment required. Design and construction will take < 1 year.	Most source areas suitable for constructing and equipment required. Design and construction will take < 1 year.	Most source areas suitable for constructing and equipment required. Design and construction will take < 1 year.
Will it work?	Generally applicable for high VOC concentrations at low flow rates. VOC concentrations very low at this site and effectiveness may be limited.	Yes, technology is best suited for low VOC concentration off gas streams at high flow rates. Will require greater fuel input as VOC concentrations drop over time.	Yes, technology is suited for high and low flows for low concentration off gas streams. High initial VOC concentrations may thermally degrade the catalyst if combustion temperatures are too high. This technology treats a large range of flow rates and concentrations.	Technology is suited for treating high VOC concentration off gas streams in thermal mode (early stages of soil vapor extraction) and then can operate in the lower energy input cat-ox mode at lower VOC concentration streams later in the soil vapor extraction treatment as concentrations decrease with time. VOC concentrations very low at this site making the thermal mode unnecessary.
Will this be acceptable to regulatory agencies?	Yes	Yes	Yes	Yes
Is technology available?	Yes	Yes	Yes	Yes
Is process option accepted?	No, rejected due to greater flexibility of Catalytic Oxidizers.	No, rejected due to greater flexibility of Catalytic Oxidizers.	Yes; Catalytic Oxidizers are effective over a wide range of influent flow rates.	No

Table 2-8j - Implementability of Advanced Oxidation of Vapors Extracted from Soil for VOC-Impacted Near-Surface Soil

	Process Options for Advanced Oxidation of Vapors Extracted from Soil	
Attribute	**UV Light**	**Photocatalytic Destruction**
Can it be constructed?	Yes, design and construction will take < 1 year.	Yes, but many units would be required to handle vapor stream. Design and construction will take < 1 year.
Will it work?	Complete conversion of an organic contaminant to CO_2, H_2O, etc., is not probable under UV light. May require follow on treatment.	Individual units work at relatively low flow rates. Consequently, many units would be needed.
Will this be acceptable to regulatory agencies?	Uncertain	Yes, if pilot scale tests demonstrated effectiveness and practicality.
Is technology available?	Uncertain	Units are available for bench-scale applications (e.g., < 100 cfm)
Is process option accepted?	No	Yes

Table 2-8k - Implementability of Biofiltration of Vapors Extracted from Soil for VOC-Impacted Near-Surface Soil

	Process Options for Biofiltration of Vapors Extracted from Soil
Attribute	**Biofiltration**
Can it be constructed?	Yes, design and construction will take < 1 year.
Will it work?	Unlikely. Kaiser has a wide variety of VOCs with different properties. Effectiveness is dependent on the solubility of the different VOCs among several other variables. Finding one unit to treat the variety of VOCs present is unlikely.
Will this be acceptable to regulatory agencies?	Uncertain
Is technology available?	Yes
Is process option accepted?	No

Table 2-9a - Reliability of Monitoring for VOC-Impacted Near-Surface Soil

	Process Options for Monitoring
Attribute	**Protection, Performance, and Confirmational Monitoring**
Has this process option been used at the scale required for Kaiser?	Yes, this option is commonly used at many sites of similar scale.
Are operation and maintenance requirements infrequent and straightforward?	Yes.
Has this process option been proven effective under COC and site conditions similar to those at Kaiser?	Yes, this option has been accepted at many sites across the country having similar COCs and site conditions, and has been in place at Kaiser for many years.
Is process option accepted?	Yes

Table 2-9b - Reliability of Institutional Controls for VOC-Impacted Near-Surface Soil

	Process Options for Institutional Controls	
Attribute	**Access and Use Restrictions**	**Best Management Practices (BMPs)**
Has this process option been used at the scale required for Kaiser?	Yes, access and use restrictions have been implemented for sites the size of Kaiser. Kaiser facility has secured entrance.	Yes, BMPs have been implemented for sites the size of Kaiser and are currently being used at the site.
Are operation and maintenance requirements infrequent and straightforward?	Yes, this is conventional technology. Skilled labor and materials for access and use restrictions are readily available.	Yes, this is conventional technology. Skilled labor and materials for BMPs are readily available. Some BMPs are already in place.
Has this process option been proven effective under COC and site conditions similar to those at Kaiser?	Yes.	Yes.
Is process option accepted?	Yes	Yes

Table 2-9c - Reliability of Capping VOC-Impacted Near-Surface Soil

	Process Options for Capping		
Attribute	**Low Permeability Asphalt**	**Low Permeability Concrete**	**Multilayer (soil + synthetic liner)**
Has this process option been used at the scale required for Kaiser?	Yes, conventional technology at this scale.	Yes, conventional technology at this scale.	Yes, conventional technology at this scale.
Are operation and maintenance requirements infrequent and straightforward?	Yes, materials and skilled workers readily available. Less resistant to abrasion than concrete and requires more maintenance. Although surface can be sealed for increased performance, it is still less resistant to abrasion than concrete.	Yes, materials and skilled workers readily available. More resistant to abrasion than asphalt. Surface can be sealed for increased performance.	Yes, materials and stilled workers readily available but liner requires more skill, time, and special materials to repair than asphalt or concrete. More resistant to abrasion than asphalt. Surface can be sealed for improved performance characteristics.
Has this process option been proven effective under COC and site conditions similar to those at Kaiser?	Yes, used successfully at many sites.	Yes, used successfully at many sites.	Yes, used successfully at many sites, including the Hoffman Tank Area at Kaiser.
Is process option accepted?	Yes	Yes	Yes

Table 2-9d - Reliability of Monitored Natural Attenuation for VOC-Impacted Near-Surface Soil

	Process Options for Monitored Natural Attenuation
Attribute	**Monitored Natural Attenuation**
Has this process option been used at the scale required for Kaiser?	Yes, this option is commonly used at many sites of similar scale. Past remedial actions at Kaiser have reduced the amount of VOCs in the soil, and facility-wide source control measures have eliminated inputs of VOC into the soil. Kaiser has been monitoring the natural degradation of VOCs and SVOCs at the site for many years.
Are operation and maintenance requirements infrequent and straightforward?	Yes, operation and maintenance work are mostly related to maintaining groundwater monitoring wells so that they can be sampled at regular intervals to track the progress of natural attenuation processes at the site.
Has this process option been proven effective under COC and site conditions similar to those at Kaiser?	Yes, this option has been accepted at many sites across the country having similar COCs and site conditions, and has been in place at Kaiser for many years.
Is process option accepted?	Yes

Table 2-9e - Reliability of Soil Vapor Extraction for VOC-Impacted Near-Surface Soil

		Process Options for Soil Vapor Extraction (SVE)
Attribute		**Vertical Vents**
Has this process option been used at the scale required for Kaiser?		Yes, the AOCs at Kaiser for VOCs are not very large. SVE systems have been constructed for larger scale operations than would be expected here.
Are operation and maintenance requirements infrequent and straightforward?		Yes, this is conventional technology. Skilled labor and materials for vacuum systems are readily available.
Has this process option been proven effective under COC and site conditions similar to those at Kaiser?		Yes, SVE systems have been successful in remediating VOC impacted soil at sites with similar soil conditions (i.e., coarse, permeable sands and gravel with low moisture content in the vadose zone). In addition, this technology is a USEPA Presumptive Remedy for vadose zone VOCs.
Is process option accepted?		Yes

Table 2-9f - Reliability of Adsorption of Vapors Extracted from Soil for VOC-Impacted Near-Surface Soil

	Process Options for Adsorption of Vapors Extracted from Soil
Attribute	**Granular Activated Carbon (GAC)**
Has this process option been used at the scale required for Kaiser?	Yes, this option is commonly used to treat off gases generated by SVE systems at many sites of similar scale.
Are operation and maintenance requirements infrequent and straightforward?	Very straightforward. Maintenance frequency depends on contaminant concentration and size of carbon tanks. With the low VOC concentrations at this site carbon bed replacement should be minimized. This option generates contaminated carbon that must be treated off site upon carbon bed replacement.
Has this process option been proven effective under COC and site conditions similar to those at Kaiser?	Yes, used at many sites when mass loading of the VOCs collected by the carbon does not require frequent replacement of carbon.
Is process option accepted?	Yes

Table 2-9g - Reliability of Thermal and Catalytic Oxidation of Vapors Extracted from Soil for VOC-Impacted Near-Surface Soil

	Process Options for Thermal and Catalytic Oxidation of Vapors Extracted from Soil		
Attribute	**Direct Flame**	**Flameless Thermal Oxidizers**	**Catalytic Oxidizers**
Has this process option been used at the scale required for Kaiser?	Yes, this option is commonly used at many sites of similar scale used in conjunction with SVE.	Yes, this option is commonly used at many sites of similar scale used in conjunction with SVE.	Yes, this option is commonly used at many sites of similar scale used in conjunction with SVE.
Are operation and maintenance requirements infrequent and straightforward?	Straightforward. Kaiser personnel can be trained to perform operation and routine maintenance. Additional safety requirements for operation and maintenance due to materials and skilled labor for non-routine maintenance are readily available.	Straightforward. Kaiser personnel can be trained to perform operation and routine maintenance. Additional safety requirements for operation and maintenance due to materials and skilled labor for non-routine maintenance are readily available.	Straightforward. Kaiser personnel can be trained to perform operation and routine maintenance. Materials and skilled labor for non-routine maintenance are readily available.
Has this process option been proven effective under COC and site conditions similar to those at Kaiser?	Yes, documented high VOC destruction efficiencies for similar COCs at higher loadings than the loadings expected from the Kaiser AOCs.	Yes, documented high VOC destruction efficiencies for similar COCs at higher loadings than the loadings expected from the Kaiser AOCs.	Yes, documented high VOC destruction efficiencies for similar COCs at higher loadings than the loadings expected from the Kaiser AOCs.
Is process option accepted?	Yes	Yes	Yes

Table 2-9h - Reliability of Process Options for Advanced Oxidation of Vapors Extracted from Near-Surface Soil

	Process Options for Advanced Oxidation of Vapors Extracted from Soil
Attribute	**Photocatalytic Destruction**
Has this process option been used at the scale required for Kaiser?	No, emerging technology, still in research and development phase.
Are operation and maintenance requirements infrequent and straightforward?	Pilot testing required to determine destruction and removal efficiency for the variety of VOCs and operating and design parameters for scale up.
Has this process option been proven effective under COC and site conditions similar to those at Kaiser?	No, still in development.
Is process option accepted?	No. Other proven technologies are readily available and commercially proven to treat VOC vapors from an SVE system.

Table 2-10 - Summary of Technology Screening Process: VOCs in Near Surface Soils

			Screening Outcome		
General Response Action (a)	**Remedial Technology (a)**	**Process Options (a)**	**Physical/Chemical (b)**	**Implementability (c)**	**Reliability (d)**
Monitoring	**Monitoring**	**Protection, Performance, and Confirmational**	**Retained**	**Retained**	**Retained**
Institutional Controls	**Access and Use Restrictions**	**Fences, Signs, Deed Restrictions**	**Retained**	**Retained**	**Retained**
	Best Management Practices	**Spill prevention, leak detection, double-walled pipes**	**Retained**	**Retained**	**Retained**
Containment	**Capping**	Soil	Retained	Eliminated	--
		Clay	Retained	Eliminated	--
		Asphalt	**Retained**	**Retained**	**Retained**
		Concrete	**Retained**	**Retained**	**Retained**
		Synthetic	Retained	Eliminated	--
		Multi-layer	**Retained**	**Retained**	**Retained**
	Landfill Cap Enhancements	Run-on and run off controls, vegetative cover	Eliminated	--	--
	Solidification/ Stabilization	Cement- and lime-based processes, microencapsulation, sorption	Eliminated	--	--
***In situ* Soils Treatment**	Vitrification	Combined with soil vapor extraction	Eliminated	--	--
	In Situ Bioremediation	Bioventing	Retained	Eliminated	--
		Enhanced Bioremediation	Retained	Eliminated	--
		Phytoremediation	Retained	Eliminated	--
	Monitored Natural Attenuation	**Monitor natural processes**	**Retained**	**Retained**	**Retained**
	Soil Vapor Extraction (SVE)	Horizontal vents	Retained	Eliminated	--
		Vertical Vents	**Retained**	**Retained**	**Retained**
	Steam Injection	Combined with soil vapor extraction	Eliminated	--	--
	Six Phase Soil Heating	Combined with soil vapor extraction	Eliminated	--	--
	Soil Flushing	Water, surfactants, solvents	Eliminated	--	--
	Pneumatic Fracturing	Pressurized air or steam	Eliminated	--	--

Table 2-10 - Summary of Technology Screening Process: VOCs in Near Surface Soils

			Screening Outcome		
General Response Action (a)	**Remedial Technology (a)**	**Process Options (a)**	**Physical/Chemical (b)**	**Implementability (c)**	**Reliability (d)**
***In situ* Soils Treatment - cont'd**	Chemical Treatment	Oxidation, reduction, pH adjustment	Retained	Eliminated	--
	Electro-Kinetic	Enhanced with surfactants and reagents	Eliminated	--	--
Excavation and On-Site Soils Treatment	Mechanical Screening	Dry, wet sieving	Eliminated	--	--
	Ex Situ Bioremediation	Landfarming	Eliminated	--	--
		Biopiles	Eliminated	--	--
		Slurry bioreactor	Eliminated	--	--
	Solvent Extraction	“BEST Process,” Critical fluid extraction	Eliminated	--	--
	Dehalogenation	APEG Process, BCD Process	Eliminated	--	--
	Thermal Desorption	Rotary dryer (indirect or direct fired), Thermal screw (indirect heating)	Eliminated	--	--
	Pyrolysis	Rotary kiln, fluidized bed furnace, molten salt destruction	Eliminated	--	--
	Incineration	Rotary kiln, fluidized bed	Eliminated	--	--
	Soil Washing	Water, surfactants, thermally enhanced	Eliminated	--	--
	Chemical Treatment	Hydrogen peroxide, potassium permanganate	Eliminated	--	--
	Solvated Electron Treatment (SET)	Ammonia mixed with anhydrous calcium or sodium	Eliminated	--	--
	Solidification/ Stabilization	Cement- and lime-based processes, microencapsulation, sorption	Eliminated	--	--

Table 2-10 - Summary of Technology Screening Process: VOCs in Near Surface Soils

			Screening Outcome		
General Response Action (a)	**Remedial Technology (a)**	**Process Options (a)**	**Physical/Chemical (b)**	**Implementability (c)**	**Reliability (d)**
On-Site Treatment of Extracted Soil Vapor	Condensation	Refrigerated condenser	Eliminated	--	--
	Adsorption	**Granular activated carbon**	**Retained**	**Retained**	**Retained**
	Thermal and Catalytic Oxidation	Direct flame thermal	Retained	Eliminated	--
		Flameless thermal	Retained	Eliminated	--
		Catalytic Oxidizers	**Retained**	**Retained**	**Retained**
		Hybrid Thermal/Catalytic	Retained	Eliminated	--
	Advanced Oxidation	UV light	Retained	Eliminated	--
		Photocatalytic	Retained	Retained	Eliminated
	Biofiltration	Bioreactor, soil pile	Retained	Eliminated	--
Excavation and Off-Site Treatment/ Disposal of Soil	Landfill	Chemwaste Landfill, Washington; Roosevelt Regional Landfill, Oregon	Eliminated	--	--
	Re-Use Facility	Asphalt incorporation, thermal desorption, cement incorporation	Eliminated	--	--
	Off-Site Incineration	Rotary kiln, liquid injection, fluidized bed, infrared incinerators	Eliminated	--	--

Notes:

Bolded Technologies Retained for further evaluation in the FS.

(a) Taken from FS TM Table 2-2

(b) Taken from FS TM Table 2-5

(c) Taken from FS TM Table 2-8a - 2-8k

(d) Taken from FS TM Table 2-9a - 2-9h

Table 2-11a - Implementability of Selected Technologies for SVOC-Impacted Near-Surface Soil

Technology	**Process Options**	**Can it be Implemented?**[1]
Monitoring	Protection, performance, and confirmational monitoring	Yes
Access and Use Restrictions	Fencing, signs, deed restrictions.	Yes
Best Management Practices	Spill prevention, leak detection, double walled pipes, proper storage of chemicals and solvents.	Yes
Cap	Soil Cap	No
Cap	Clay Cap	No
Cap	Low Permeable Asphalt Cap	Yes
Cap	Low Permeable Concrete Cap	Yes
Cap	Synthetic Liner	No
Cap	Multilayer Cap (soil + synthetic liner)	Yes
In situ Bioremediation	Bioventing (injecting and/or withdrawing air in vadose zone)	No
In situ Bioremediation	Enhanced Bioremediation	No
In situ Bioremediation	Phytoremediation	No
Monitored Natural Attenuation	Monitored Natural Attenuation	Yes
Chemical Treatment	Oxidation	No

Note:

1) The reasons for implementability for SVOCs are similar to VOCs as presented in Tables 2-8a through 2-8e and Table 2-8g. Refer to the evaluations in these tables.

Table 2-11b - Implementability of Mechanical Screening of Excavated SVOC-Impacted Near-Surface Soil

	Process Options for Mechanical Screening of Excavated SVOC-Impacted Soils
Attribute	**Mechanical Screening**
Can it be constructed?	Yes, this technology has been successfully used at this site in the past.
Will it work?	Yes. Has been demonstrated effective at Kaiser for concentrating SVOC COCs in soil for disposal. Screening removes large cobble which make up 20 percent of the soil matrix.
Will this be acceptable to regulatory agencies?	Yes
Is technology available?	Yes
Is process option accepted?	Yes

Table 2-11c - Implementability of *Ex Situ* Bioremediation of Excavated SVOC-Impacted Near-Surface Soil

	Process Options for *Ex situ* Bioremediation of Excavated SVOC-Impacted Soils		
Attribute	**Landfarming**	**Biopiles**	**Slurry Phase**
Can it be constructed?	Yes, site is amenable to constructing and operating support equipment. Large open spaces available to the west and south of the Mill for landfarming. <1 year for design, construction, and startup.	Yes, site is amenable to constructing and operating support equipment. Large open spaces available to the west and south of the Mill to create biopiles. <1 year for design, construction, and startup.	Yes, site is amenable to constructing and operating support equipment. <1 year for design, construction, and startup.
Will it work?	Has been demonstrated effective in biodegrading SVOCs. Requires bench scale testing. Mechanical screening will reduce the amount of impacted soil to landfarm. Temperature extremes and dry summers in this location may lengthen treatment time frame and restrict operations during certain months. May require pretreatment of soil prior to excavation if VOCs present. Requires runoff controls.	Has been demonstrated effective in biodegrading TPH. Effectiveness may vary for some SVOCs. Requires bench scale testing. Mechanical screening will reduce the amount of impacted soil to biopile. May require pretreatment of soil prior to excavation if VOCs present. Requires runoff controls.	Has been demonstrated effective in treating SVOCs. Requires bench scale testing. Mechanical screening of soil necessary prior to introduction into bioreactor. May require pretreatment of soil prior to excavation if VOCs present. Requires dewatering of soil after treatment and collection and treatment of water.
Will this be acceptable to regulatory agencies?	Yes, if pilot scale tests demonstrate effectiveness and practicality.	Yes, if pilot scale tests demonstrate effectiveness and practicality.	Yes, if pilot scale tests demonstrate effectiveness and practicality.
Is technology available?	Yes	Yes	Yes
Is process option accepted?	Yes	Yes	Yes

Table 2-11d - Implementability of *Ex Situ* On-Site Thermal Treatment of Excavated SVOC-Impacted Near-Surface Soil

	Process Options for *Ex situ* On-Site Thermal Treatment of Excavated SVOC-Impacted Soils		
Attribute	**Thermal Desorption**	**Pyrolysis**	**Incineration**
Can it be constructed?	Yes, site is amenable to constructing and operating support equipment. <1 year for design, construction, and startup.	Yes, site is amenable to constructing and operating support equipment. <1 year for design, construction, and startup.	Yes, site is amenable to constructing and operating support equipment. <1 year for design, construction, and startup.
Will it work?	Yes, proven technology and an EPA presumptive remedy for SVOCs. Has been demonstrated effective in treating SVOCs. Treatability study should be conducted to find required temperature ranges for contaminant separation. Dioxins/furans may form if PCBs are present in the feed material. Mechanical screening will be required. Off-gas will require capture and treatment via carbon adsorber or thermal/catalytic oxidizer. Cannot separate non-volatile metals from the contaminated soil, if present. May provoke public opposition.	Emerging technology for remedial use. Treatability study should be conducted to find required temperature ranges for contaminant separation/destruction. Requires less than 1% soil moisture prior to treatment (typically not an issue at Kaiser during summer months). Mechanical screening will be required. Off-gas and particulates in the off-gas will require capture and treatment. May provoke public opposition.	Yes, proven technology and an EPA presumptive remedy for SVOCs. Has been demonstrated effective in treating SVOCs. Treatability study should be conducted to find required temperature ranges for contaminate destruction. Dioxins/furans may form if PCBs are present in the feed material. Mechanical screening will be required. Off-gas and particulates will require capture and treatment. May provoke public opposition.
Will this be acceptable to regulatory agencies?	Uncertain, will need to demonstrate effectiveness and meet applicable air pollution regulations.	Uncertain, will need to demonstrate effectiveness and meet applicable air pollution regulations.	Very unlikely, will need to demonstrate effectiveness and meet applicable air pollution regulations.
Is technology available?	Yes	Yes	Yes, but limited
Is process option accepted?	Yes	Yes	No

Table 2-11e - Implementability of *Ex Situ* On-Site Treatment of Excavated SVOC-Impacted Near-Surface Soil

Sheet 1 of 1

	Process Options for *Ex situ* Treatment of Excavated SVOC-Impacted Soils	
Attribute	**Soil Washing**	**Chemical Treatment**
Can it be constructed?	Yes, site is amenable to constructing and operating support equipment. <1 year for design, construction, and startup.	Yes, site is amenable to constructing and operating support equipment. <1 year for design, construction, and startup.
Will it work?	Unlikely, contaminated soils at Kaiser contain mixtures of COCs, which will require evaluation of washing solution(s) that will remove all COCs. Large volume of soil with low native organic content; contacting soil COCs w/ solvent, disposal of spent solvent(s). Will create performance hurdles. Mechanical screening will be required. On-site treatment of wastewater from washing may be possible at Kaiser's IWT plant. Waste solvents may require additional processing before they can be reused or disposed of.	Unlikely, soil with mixtures of COCs will require evaluation of oxidizing agents (or combination of agents) and doses that will fully oxidize all COCs. Mechanical screening will be required. On-site treatment of wastewater from chemical reactor may be possible at Kaiser's IWT plant. Off-gas from oxidation processes will likely require treatment, create refractory compounds, and may create wastewater that must be treated.
Will this be acceptable to regulatory agencies?	Yes, if pilot scale tests demonstrated effectiveness and practicality.	Yes, if pilot scale tests demonstrated effectiveness and practicality.
Is technology available?	Uncertain	Yes
Is process option accepted?	No	No

Table 2-11f - Implementability of Off-Site Disposal/Destruction of Excavated SVOC-Impacted Near-Surface Soil

	Process Options for Off-Site Disposal/Destruction of Excavated Soil	
Attribute	**Disposal at Licensed Landfill**	**Destruction at Licensed Incinerator**
Can it be constructed?	Yes, site is amenable to constructing and operating support equipment. <1 year for design, construction, and startup.	Yes, site is amenable to constructing and operating support equipment. <1 year for design, construction, and startup.
Will it work?	Yes, this technology has been used with success at Kaiser for past disposal of SVOC COC-impacted soil.	Yes, incineration is an EPA presumptive remedy for SVOCs. By-products of incomplete combustion (dioxin, furan) are possible if PCBs are present in the material.
Will this be acceptable to regulatory agencies?	Yes	Yes – at approved facilities.
Is technology available?	Yes	Yes
Is process option accepted?	Yes	Yes

Table 2-12a - Reliability of Selected Technologies for SVOC-Impacted Near-Surface Soil

Technology	Process Options	Is it reliable?[1]
Monitoring	Protection, performance, and confirmational monitoring	Yes
Access and Use Restrictions	Fencing, signs, deed restrictions.	Yes
Best Management Practices	Spill prevention, leak detection, double walled pipes, proper storage of chemicals and solvents.	Yes
Capping	Low Permeability Asphalt Cap	Yes
Capping	Low Permeability Concrete Cap	Yes
Capping	Multilayer (synthetic liner + soil)	Yes
Monitored Natural Attenuation	Monitored Natural Attenuation	Yes

Note:

1) The evaluations of reliability given in this table for SVOCs are the same as those for VOCs for reasons similar to those given, in Tables 2-9a through 2-9d. Refer to the evaluations in those tables.

Table 2-12b - Reliability of Mechanical Screening of Excavated SVOC-Impacted Near-Surface Soil

	Process Options for Mechanical Screening of Excavated SVOC-Impacted Soils
Attribute	**Mechanical Screening**
Has this process option been used at the scale required for Kaiser?	Yes, Kaiser successfully screened approximately 30,000 cubic yards of impacted soil during 2008 to concentrate COCs in soil for disposal. Screening removes large cobbles that make up 20 percent of the soil matrix at the Kaiser site.
Are operation and maintenance requirements infrequent and straightforward?	Requires a minimum of two operators to transport unscreened material to the screening plant and screen and segregate materials. An existing screening plant at the site occupies an approximate 400-foot by 100-foot area underlain by a 60-mil reinforced HDPE liner that is located near the field constructed tanks area of the plant. The screening plant was used by Kaiser to remove cobbles during the 2008 operations associated with the off-site disposal of impacted soils at the site. The perimeter of this area is bermed for stormwater runoff control. Dust suppression may be necessary during dry and windy conditions.
Has this process option been proven effective under COC and site conditions similar to those at Kaiser?	Yes
Is process option accepted?	Yes

Table 2-12c - Reliability of *Ex Situ* Bioremediation of Excavated SVOC-Impacted Near-Surface Soil

	Process Options for *Ex situ* Bioremediation of Excavated SVOC-Impacted Soils		
Attribute	**Landfarming**	**Biopiles**	**Slurry Phase**
Has this process option been used at the scale required for Kaiser?	Yes, large scale landfarming operations (>10,000 cubic yards of soil) have been used to treat impacted soil at a scale comparable to Kaiser.	Yes, large scale biopile operations (>10,000 cubic yards of soil) have been used to treat impacted soil at a scale comparable to Kaiser.	No, large scale slurry phase operations have technically been *in situ* processes treating impoundment sludge sediments where the impoundment was surrounded by a cutoff wall utilizing the impoundment's low permeability underlayment for containment.
Are operation and maintenance requirements infrequent and straightforward?	Will requires several operators to till the soil and run the water irrigation, collection, and treatment system. Soil testing (e.g., *ex situ* COC concentrations from various excavatable areas, TOC, BOD) and bench scale/treatability testing will provide design criteria as well as the expected time frame necessary for meeting CULs.	Will requires several operators to mix and till the soil, run the irrigation/nutrient addition system, aeration system, and the water collection and treatment system. O&M requirements for an aeration system (vacuum or positive pressure) are less straightforward for biopiles than landfarming where the soil is tilled for aeration. Soil testing (e.g., ex-situ COC concentrations from various excavatable areas, TOC, BOD) and bench scale/treatability testing will provide design criteria as well as the expected timeframe necessary for meeting CULs.	No. Reactor operation more labor intensive and technically challenging than other *ex situ* bioremediation processes. Successful operation requires control of air/oxygen flow (aerobic process only), nutrient addition, and slurry pH, among other variables. Will require a treatment train to handle spent non-recyclable leachate and dewater from soil post reactor residence. Bench scale/treatability testing will provide design criteria as well as the expected reactor residence time necessary for meeting CULs.

Table 2-12c - Reliability of *Ex Situ* Bioremediation of Excavated SVOC-Impacted Near-Surface Soil

	Process Options for *Ex situ* Bioremediation of Excavated SVOC-Impacted Soils		
Attribute	**Landfarming**	**Biopiles**	**Slurry Phase**
Has this process option been proven effective under COC and site conditions similar to those at Kaiser?	Yes, proven effective for TPH compounds at several cleanup sites. Soil conditions varied from clays to windblown sands at the landfarming sites examined for technology evaluation purposes. Expect that the loose, mechanically screened sand present at Kaiser would be amenable to landfarming provided that there is sufficient microbial activity that degrades petroleum.	Yes, proven effective for TPH and PAH compounds at several cleanup sites. Biopile bioremediation technology is basically landfarming with the addition of nutrients and aeration to further stimulate microbial activity in degrading contaminants.	Several *ex situ* demonstration projects have proven this technology effective for TPH and PAH compounds. Technology is not proven at the scale likely required at Kaiser.
Is process option accepted?	Yes	No	No

Table 2-12d - Reliability of *Ex Situ* On-Site Thermal Treatment of Excavated SVOC-Impacted Near-Surface Soil

	Process Options for *Ex situ* On-Site Thermal Treatment of Excavated SVOC-Impacted Soils	
Attribute	**Thermal Desorption**	**Pyrolysis**
Has this process option been used at the scale required for Kaiser?	Yes, large scale on-site thermal desorption operations have been used to treat impacted soil at a scale comparable to Kaiser. Typically used in conjunction with oxidation or carbon adsorption for off-gas treatments.	No, on-site pyrolysis has been used at a number of demonstration projects but not at the scale required at Kaiser.
Are operation and maintenance requirements infrequent and straightforward?	Requires skilled technicians to operate the thermal desorption unit, off-gas treatment unit, scrubber, and ancillary equipment. Maintenance is related to unit cleanout, refractory check, conveyor, maintenance, and filter/oxidizer/scrubber maintenance. Maintenance requirements dependent on the type of units used. Will require treatment of wet scrubber liquids if used. Soil and air stream testing will be determined by regulatory authorities. A treatability study will provide necessary design criteria.	Requires skilled technicians to operate the kiln/furnace, off-gas treatment unit, scrubber, and ancillary equipment. Maintenance would be similar to thermal desorption units. Kiln/furnace ash may require stabilization. Will require treatment of wet scrubber liquids if used. Soil and air stream testing will be determined by regulatory authorities. A treatability study will provide necessary design criteria.
Has this process option been proven effective under COC and site conditions similar to those at Kaiser?	Yes, proven effective in separating TPH and PAH compounds from soil at several cleanup sites. Technology was used to effectively treat approximately 82,000 tons of TPH- and PAH-impacted soil at a Superfund site close to Kaiser (North Market Street site in Spokane – thermal desorption followed by thermal oxidation for off-gas treatment).	No, technology has been proven effective in demonstration projects mainly targeting PCBs and dioxins, though it has also proven effective in treating SVOC also in the feedstock. It has not been demonstrated at the scale required at Kaiser.
Is process option accepted?	Yes	No, rejected due to other available proven *ex situ* thermal processes.

Table 2-12e - Reliability of Off-Site Disposal/Destruction of Excavated SVOC-Impacted Near-Surface Soil

	Process Options for Excavation and Off-Site Disposal/Destruction of Excavated Soil	
Attribute	**Excavation and Disposal at Licensed Landfill**	**Excavation and Off-Site Incineration**
Has this process option been used at the scale required for Kaiser?	Yes, excavation of site soil at industrial facilities is a routine activity. Kaiser has ample land area to temporarily store excavated soils prior to its disposal at a Subtitle D Landfill (assuming the COPCs present in the soil meet the landfill's waste acceptance criteria).	Yes, excavation of site soil at industrial facilities is a routine activity. Incineration if a presumptive remedy for the treatment of SVOC-impacted soils.
Are operation and maintenance requirements infrequent and straightforward?	Yes, excavation, confirmation sampling, transportation, disposal, and backfilling are straightforward. Maintenance is mostly limited to the construction and transportation equipment. Operations in the area of existing facility infrastructure (i.e., utilities, railroad lines) may be problematic.	Yes, excavation, confirmation sampling, transportation, disposal, and backfilling are straightforward. Maintenance during excavation work is limited to the construction and transportation equipment. Operations in the area of existing facility infrastructure (i.e., utilities, railroad lines) may be problematic. Operation and maintenance of incineration equipment is very complex. Ash generated by incineration may need to be stabilized.
Has this process option been proven effective under COC and site conditions similar to those at Kaiser?	Yes, numerous removal actions conducted at Kaiser have successfully excavated impacted soil and shipped to a landfill for disposal.	Yes, off-site incineration is a conventional remediation method and a presumptive remedy for SVOC-impacted soils. A limited number of incineration facilities are permitted to operate. The nearest to Kaiser is in Aragonite, Utah.
Is process option accepted?	Yes	Yes

Table 2-13 - Summary of Technology Screening Process: SVOCs in Near Surface Soils

			Screening Outcome		
General Response Action (a)	**Remedial Technology (a)**	**Process Options (a)**	**Physical/Chemical (b)**	**Implementability (c)**	**Reliability (d)**
Monitoring	**Monitoring**	**Protection, Performance, and Confirmational**	**Retained**	**Retained**	**Retained**
Institutional Controls	**Access and Use Restrictions**	**Fences, Signs, Deed Restrictions**	**Retained**	**Retained**	**Retained**
	Best Management Practices	**Spill prevention, leak detection, double-walled pipes**	**Retained**	**Retained**	**Retained**
Containment	**Capping**	Soil	Retained	Eliminated	--
		Clay	Retained	Eliminated	--
		Asphalt	**Retained**	**Retained**	**Retained**
		Concrete	**Retained**	**Retained**	**Retained**
		Synthetic	Retained	Eliminated	--
		Multi-layer	**Retained**	**Retained**	**Retained**
	Landfill Cap Enhancements	Run-on and run off controls, vegetative cover	Eliminated	--	--
	Solidification/ Stabilization	Cement- and lime-based processes, microencapsulation, sorption	Eliminated	--	--
***In situ* Soils Treatment**	Vitrification	Combined with soil vapor extraction	Eliminated	--	--
	In Situ Bioremediation	Bioventing	Retained	Eliminated	--
		Enhanced Bioremediation	Retained	Eliminated	--
		Phytoremediation	Retained	Eliminated	--
	Monitored Natural Attenuation	**Monitor natural processes**	**Retained**	**Retained**	**Retained**
	Soil Vapor Extraction (SVE)	Horizontal vents	Eliminated	--	--
		Vertical Vents	Eliminated	--	--
	Steam Injection	Combined with soil vapor extraction	Eliminated	--	--
	Six Phase Soil Heating	Combined with soil vapor extraction	Eliminated	--	--

Table 2-13 - Summary of Technology Screening Process: SVOCs in Near Surface Soils

			Screening Outcome		
General Response Action (a)	**Remedial Technology (a)**	**Process Options (a)**	**Physical/Chemical (b)**	**Implementability (c)**	**Reliability (d)**
***In situ* Soils Treatment - cont'd**	Soil Flushing	Water, surfactants, solvents	Eliminated	--	--
	Pneumatic Fracturing	Pressurized air or steam	Eliminated	--	--
	Chemical Treatment	Oxidation, reduction, pH adjustment	Retained	Eliminated	--
	Electro-Kinetic	Enhanced with surfactants and reagents	Eliminated	--	--
Excavation and On-Site Soils Treatment	**Mechanical Screening**	**Dry, wet sieving**	**Retained**	**Retained**	**Retained**
	***Ex Situ* Bioremediation**	**Landfarming**	**Retained**	**Retained**	**Retained**
		Biopiles	Retained	Retained	Eliminated
		Slurry bioreactor	Retained	Retained	Eliminated
	Solvent Extraction	“BEST Process,” Critical fluid extraction	Eliminated	--	--
	Dehalogenation	APEG Process, BCD Process	Eliminated	--	--
	Thermal Desorption	**Rotary dryer (indirect or direct fired), Thermal screw (indirect heating)**	**Retained**	**Retained**	**Retained**
	Pyrolysis	Rotary kiln, fluidized bed furnace, molten salt destruction	Retained	Retained	Eliminated
	Incineration	Rotary kiln, fluidized bed	Retained	Eliminated	--
	Soil Washing	Water, surfactants, thermally enhanced	Retained	Eliminated	--
	Chemical Treatment	Hydrogen peroxide, potassium permanganate	Retained	Eliminated	--
	Solvated Electron Treatment (SET)	Ammonia mixed with anhydrous calcium or sodium	Eliminated	--	--
	Solidification/Stabilization	Cement- and lime-based processes, microencapsulation, sorption	Eliminated	--	--

Table 2-13 - Summary of Technology Screening Process: SVOCs in Near Surface Soils

			Screening Outcome		
General Response Action (a)	**Remedial Technology (a)**	**Process Options (a)**	**Physical/Chemical (b)**	**Implementability (c)**	**Reliability (d)**
On-Site Treatment of Extracted Soil Vapor (e)	Condensation	Refrigerated condenser	Eliminated	--	--
	Adsorption	**Granular activated carbon**	**Retained**	**Retained**	**Retained (5)**
	Thermal and Catalytic Oxidation	Direct flame thermal	Retained	Eliminated	--
		Flameless thermal	Retained	Eliminated	--
		Catalytic Oxidizers	**Retained**	**Retained**	**Retained (5)**
		Hybrid Thermal/Catalytic	Retained	Eliminated	--
	Advanced Oxidation	UV light	Retained	Eliminated	--
		Photocatalytic	Retained	Retained	Eliminated
	Biofiltration	Bioreactor, soil pile	Retained	Eliminated	--
Excavation and Off-SiteTreatment/Disposal of Soil	**Landfill**	**Chemwaste Landfill, Washington; Roosevelt Regional Landfill, Oregon**	**Retained**	**Retained**	**Retained**
	Off-Site Incineration	**Rotary kiln, fluidized bed**	**Retained**	**Retained**	**Retained**
	Re-Use Facility	Asphalt incorporation, thermal desorption, cement incorporation	Eliminated	--	--

Notes:

Bolded Technologies Retained for further evaluation in the FS.

(a) Taken from FS TM Table 2-2

(b) Taken from FS TM Table 2-6

(c) Taken from FS TM Table 2-11a - 2-11f

(d) Taken from FS TM Table 2-12a - 2-12e

(e) Technologies eliminated for treatment of extracted soil vapor, evaluated if off-gas treatment is required for on-site *ex situ* thermal processes.

Table 2-14a - Implementability of Selected Technologies for PCB-Impacted Near-Surface Soil

Technology	**Process Options**	**Can it be implemented?** [1]
Monitoring	Protection, performance, and confirmational monitoring	Yes
Access and Use Restrictions	Fencing, signs, deed restrictions.	Yes
Best Management Practices	Spill prevention, leak detection, double walled pipes, proper storage of chemicals and solvents.	Yes
Cap	Soil Cap	No
Cap	Clay Cap	No
Cap	Low Permeability Asphalt Cap	Yes
Cap	High Permeability Asphalt Cap	Yes
Cap	Synthetic Liner	No
Cap	Multilayer (soil and synthetic liner)	Yes
Monitored Natural Attenuation	Monitored Natural Attenuation	Yes
Chemical Treatment	Oxidation	No
Mechanical Screening	Mechanical Screening	Yes [2]

Note:

1) The reasons for implementability for PCBs are similar to VOCs as presented in Tables 2-8a through 2-8c, Table 2-8e, and Table 2-8g except where noted. Refer to the evaluations in those tables.
2) The reasons for implementability for PCBs are similar to SVOCs as present in Table 2-11b. Refer to the evaluations in that table.

Table 2-14b - Implementability of *Ex Situ* Bioremediation of Excavated PCB-Impacted Near-Surface Soil

	Process Options for *Ex situ* Bioremediation of Excavated PCB-Impacted Soils
Attribute	**Slurry Phase Bioreactor**
Can it be constructed?	Yes. Limited amounts of PCB-impacted soil can be excavated because of existing structures, active site use, and underground/overhead utilities. Space will be needed for screening soil (upstream of reactor), reactor and possible dewatering equipment. Staff will be needed for operations and maintenance (O&M) of *ex situ* process equipment.
Will it work?	Yes. Slurry phase bioreactors containing cometabolites and specially adapted microorganisms and sequential anaerobic/aerobic bioreactors have been used for PCB treatment. Soil is screened and crushed to remove cobbles and stones and then enters a reactor where water and oxygen are added to make a slurry. Other necessary amendments such as nutrients and microorganisms are also added in the reactor. Since the addition of water is part of the treatment process, the relatively dry soils in the upper 20 feet should not pose a problem. Treatability studies may be required. Off-gas may be toxic (dioxins, furans).
Will this be acceptable to regulatory agencies?	Uncertain, will need to demonstrate effectiveness and meet applicable air pollution regulations.
Is technology available?	Yes
Is process option accepted?	Yes

Table 2-14c - Implementability of On-Site Dehalogenation of Excavated PCB-Impacted Near-Surface Soil

	Process Options for On-Site Dehalogenation of Excavated PCB-Impacted Soils	
Attribute	**Base Catalyzed Decomposition (BCD)**	**Alkaline Polyethylene Glycol (APEG) Dehalogenation**
Can it be constructed?	Yes. Limited amounts of PCB-impacted soil can be excavated because of existing structures, active site use, and underground/overhead utilities. Space will be needed for BCD process equipment and staff will be needed for system O&M.	Yes. Limited amounts of PCB-impacted soil can be excavated because of existing structures, active site use, and underground/overhead utilities. Space will be needed for APEG process equipment and staff will be needed for system O&M.
Will it work?	Yes. Soils are screened to remove larger materials and then enter a reactor where sodium bicarbonate is added and heated. Heating decomposes and volatilizes contaminants. The off-gas is captured, condensed, and treated through a series of steps including treatment of particulates, air, and water. Since soils are heated, the low moisture content of surface soils at the facility is advantageous. High clay and moisture content make treatment more difficult and raise costs. Surface soils at the site have low clay and moisture content.	Yes. Soils are screened to remove larger materials then enter a reactor where reagent (APEG) is added. After the reactor the slurry is treated to recover reagent and dewater soils. Wastewater will need treatment and off-gas may need treatment depending on concentrations of contaminants. High clay and moisture content make treatment more difficult and raise costs. Surface soils at the site have low clay and moisture content APEG dehalogenation has been used in field tests for PCB-impacted soils.
Will this be acceptable to regulatory agencies?	Uncertain, will need to demonstrate effectiveness and meet applicable air pollution regulations. TSCA-approved treatment.	Uncertain, will need to demonstrate effectiveness and meet applicable air pollution regulations. TSCA-approved treatment. Field testing at other Superfund sites has been successful.
Is technology available?	Yes	Yes
Is process option accepted?	Yes	Yes

Table 2-14d - Implementability of *Ex Situ* On-Site Thermal Treatment for Excavated PCB-Impacted Near-Surface Soil

	Process Options for *Ex situ* On-Site Thermal Treatment for Excavated PCB-Impacted Soils
Attribute	**High Temperature Thermal Desorption**
Can it be constructed?	Yes. Limited amounts of PCB-impacted soil can be excavated because of existing structures, active site use, and underground/overhead utilities. Room will be needed for thermal desorber and off gas treatment process and associated auxiliary equipment. Staff will be needed to perform O&M on process equipment.
Will it work?	Yes. An externally fired rotary dryer indirectly heats soils to 320° to 560°C (600° to 1,000°F). Contaminants are volatilized into an inert carrier gas stream which is treated downstream to remove or recover the contaminants. Since soils are heated, the low moisture content of surface soils at the site is advantageous for this process. The XTRAX™ Thermal Desorption System is a process using indirect heated desorption followed by a high-energy scrubber gas treatment, which successfully removed >99% of PCBs from contaminated soil. Treatability studies may be required. Off gas may be toxic due to presence of dioxins, furans. May provoke public opposition.
Will this be acceptable to regulatory agencies?	Uncertain, will need to demonstrate effectiveness and meets applicable air pollution regulations.
Is technology available?	Yes
Is process option accepted?	Yes

Table 2-14e - Implementability of Off-Site Disposal/Destruction of PCB-Impacted Near-Surface Soil

	Process Options for Off-Site Disposal/Destruction of Excavated Soil	
Attribute	**Disposal at Licensed Landfill**	**Off-Site Incineration**
Can it be constructed?	Only limited amounts of PCB-impacted soil can be excavated due to existing structures, active site use, and underground/overhead utilities.	Only limited amounts of PCB-impacted soil can be excavated due to existing structures, active site use, and underground/overhead utilities.
Will it work?	Yes, excavation and landfill disposal is conventional technology for contaminated soil. Typically method of disposal for PCB-impacted soils excavated at the facility. Soils >50 ppm will have to be sent to a hazardous waste facility (Chemwaste in Oregon).	Yes, incineration protocols are available for PCB-contaminated soils. By-products of incomplete combustion (dioxin, furan) are toxic.
Will this be acceptable to regulatory agencies?	Yes – at approved facilities.	Yes – at approved facilities.
Is technology available?	Yes	Yes
Is process option accepted?	Yes	Yes

Table 2-15a - Reliability of Selected Technologies for PCB-Impacted Near-Surface Soil

Technology	Process Options	Is it reliable?[1]
Monitoring	Protection, performance, and confirmational monitoring	Yes
Access and Use Restrictions	Fencing, signs, deed restrictions.	Yes
Best Management Practices	Spill prevention, leak detection, double walled pipes, proper storage of chemicals and solvents.	Yes
Capping	Low Permeability Asphalt Cap	Yes
Capping	Low Permeability Concrete Cap	Yes
Capping	Multilayer (synthetic liner + soil)	Yes
Monitored Natural Attenuation	Monitored Natural Attenuation	Yes
Mechanical Screening	Mechanical Screening	Yes [2]

Note:

1) The evaluations of reliability given in this table for PCBs are the same as those for VOCs for reasons similar to those given in Tables 2-9a through 2-9d, except where noted. Refer to the evaluations in those tables.
2) The evaluations of reliability given in this table for PCBs are the same as those for SVOCs for reasons similar to those given in Tables 2-12b. Refer to the evaluations in that table.

Table 2-15b - Reliability of *Ex Situ* Bioremediation for PCB-Impacted Near-Surface Soil

	Process Options for *Ex situ* Bioremediation of PCB-impacted soils
Attribute	**Slurry Phase Bioreactor**
Has this process option been used at the scale required for Kaiser?	No. It appears bioremediation of PCBs is in testing phases. Laboratory tests have been performed using aerobic bioreactors and it was determined that PCB degradation was successful with bioaugmentation (Di Toro et al. 2006). Microorganisms have been shown to degrade PCBs under anaerobic conditions; however, it is usually congener specific, and for most chlorinated biphenyls, it is slow. (Pieper and Seegar 2008, CLU-IN 2009).
Are operation and maintenance requirements infrequent and straightforward?	Yes. Mobile treatment units that are quickly moved into and out of the site are available. Process will require at least periodic operations and maintenance (O&M) support to ensure equipment runs properly and necessary oxygen, water and other additions are being made. Vessels are designed with various process controls so that temperature, mixing, and nutrient additions can be manipulated to achieve maximum efficiency. Treated soil will need to be sampled to make sure clean up criteria is being met. Off gas may be toxic due to the presence of furans and dioxins and will need to be monitored.
Has this process option been proven effective under COC and site conditions similar to those at Kaiser?	No. Slurry phase lab-scale aerobic bioreactors have been used for PCB treatment (Di Toro et al. 2006), and there has been success with anaerobic degradation of PCBs (Pieper and Seegar 2008). Full-scale tests have not been completed. Extensive lab- and pilot-scale tests would be needed to demonstrate effectiveness at Kaiser, where PCB concentrations in near-surface soil are generally very low.
Is process option accepted?	No

Table 2-15c - Reliability of BCD Dehalogenation of Excavated PCB-Impacted Near-Surface Soil

	Process Options Excavation and On-Site Treatment of PCB-impacted soil
Attribute	**BCD Dehalogenation**
Has this process option been used at the scale required for Kaiser?	Yes. BCD was used with anaerobic thermal desorption for remediation of PCB Superfund site (Smith's Farm) where 21,000 cy were treated (EPA 2003).
Are operation and maintenance requirements infrequent and straightforward?	No. In this process, sodium bicarbonate is added to impacted soils and heated in a reactor. The off-gas is captured, condensed and treated through a series of steps including treatment of particulates, air and water. The off-gas treatment system involves a number of pieces of equipment, some of which are sophisticated (reactor, carbon beds). This process will likely require continuous operation and maintenance staff. Besides clean soils, there are additional output streams from the off-gas treatment system that will most likely need monitoring including treated wastewater, air, and sludge. The concentration of PCBs in soil at Kaiser is generally less than 1 mg/kg. The complex O&M requirements of this process are judged to be inappropriate for soils with this low concentration of PCBs.
Has this process option been proven effective under COC and site conditions similar to those at Kaiser?	No. This is a TSCA-approved technology for the treatment of PCBs. In combination with anaerobic thermal desorption, BCD dehogenation was used at the Smith's Farm Superfund site to reduce PCB concentrations from 3 to 25 ppm to 300-500 ppb in contaminated soils (EPA 2003). As mentioned above, concentration of PCBs in soil at Kaiser is generally less than 1 mg/kg. Extensive lab- and pilot-scale tests would be needed to demonstrate effectiveness at Kaiser, where PCB concentrations in near surface soil are generally very low.
Is process option accepted?	No

Table 2-15d - Reliability of APEG Dehalogenation of Excavated PCB-Impacted Near-Surface Soil

	Process Options Excavation and On-Site Treatment of PCB-impacted soil
Attribute	**APEG Dehalogenation**
Has this process option been used at the scale required for Kaiser?	Yes. The APEG process was selected for cleanup of PCB-contaminated soils at three Superfund sites: Wide Beach in Erie County, New York (September 1985); Re-Solve in Massachusetts (September 1987); and Sol Lynn in Texas (March 1988). (FRTR 2009c, CPEO 2009). The APEG process was used with anaerobic thermal desorption at Wide Beach to treat 30,000 cy of PCB-impacted soil (EPA 2003).
Are operation and maintenance requirements infrequent and straightforward?	No. In this process, the reagent (alkaline polyethylene glycol) is added to impacted soils and heated in a reactor. The off gas is captured, condensed and treated. Treated soils go through a separation/washer processes to recover and recycle reagent and dewater soils. Wastewater that is recovered will need to be treated, which may include processes such as chemical oxidation, biodegradation, carbon adsorption, or precipitation. Besides treated soils, the additional output streams (off-gas, wastewater) will most likely require monitoring. This process will likely require continuous operation and maintenance staff. The concentration of PCBs in soils at Kaiser is generally less than 1 mg/kg. The complex O&M requirements of this process are judged to be inappropriate for soils with this low concentration of PCBs.
Has this process option been proven effective under COC and site conditions similar to those at Kaiser?	No. This is a TSCA-approved technology for the treatment of PCBs. Glycolate process has been used to successfully treat contaminant concentrations of PCBs from less than 2 ppm to reportedly as high as 45,000 ppm (CPEO 2009, FRTR 2009c). In combination with anaerobic thermal desorption, APEG dehogenation was used at the Wide Beach Superfund site to reduce PCB concentrations from up to 5,300 ppm to 2 ppm in contaminated soils (EPA 2003). As mentioned above, concentration of PCBs in soil at Kaiser is generally less than 1 mg/kg. Extensive lab- and pilot-scale tests would be needed to demonstrate effectiveness at Kaiser, where PCB concentrations in near surface soil are generally very low.
Is process option accepted?	No

Table 2-15e - Reliability of *Ex Situ* On-Site Thermal Treatment of Excavated PCB-Impacted Near-Surface Soil

Sheet 1 of 1

	Process Options for *Ex situ* On-Site Thermal Treatment of Excavated PCB-Impacted Soils
Attribute	**High Temperature Thermal Desorption**
Has this process option been used at the scale required for Kaiser?	Yes. Alternative to incineration (CLU-IN 2009). *Ex situ* thermal desorption has been used at various Superfund sites for treatment of PCB-impacted soils (EPA 2003).
Are operation and maintenance requirements infrequent and straightforward?	No. In this process, impacted soils are heated to 320° to 560°C (600° to 1,000°F). Contaminants are volatilized into an inert carrier gas stream which is treated downstream to remove particulates and contaminants. Particulates are removed by conventional particulate removal equipment and contaminants are removed through condensation followed by carbon adsorption, or they are destroyed in a secondary combustion chamber or a catalytic oxidizer. Heating of PCB-contaminated soils may cause degradation and production of toxic compounds (dioxins, furans). Operation to reduce the generation of dioxin/furans is required. Off-gas treatment to assure destruction of dioxin/furans is needed. Treated wastewater and soils will also need to be monitored. This process will likely require continuous operation and maintenance staff. The concentration of PCBs in soil at Kaiser is generally less than 1 mg/kg. The complex O&M requirements of this process are judged to be inappropriate for soils with this low concentration of PCBs. On-site treatment of off-gases that may contain dioxins and furans would create complex permitting issues.
Has this process option been proven effective under COC and site conditions similar to those at Kaiser?	No. *Ex situ* thermal desorption has been used to treat PCB-impacted soils at various Superfund sites (EPA 2003). The XTRAX™ Thermal Desorption System is a process that has successfully removed more than 99 percent of PCB from contaminated soil (FRTR 2009c). Extensive lab- and pilot-scale tests would be needed to demonstrate effectiveness at Kaiser, where PCB concentrations in near surface soil are generally very low.
Is process option accepted?	No

Table 2-15f - Reliability of Off-Site Landfill Disposal of Excavated PCB-Impacted Near-Surface Soil

	Process Options Excavation and Off-Site Treatment of PCB-impacted soil
Attribute	**Landfill Disposal**
Has this process option been used at the scale required for Kaiser?	Excavation of site soil at industrial facilities is a routine activity. A large quantity of soil (refer to Section 2.6) with PCB concentrations above screening levels will be generated at Kaiser. Kaiser has ample land area to temporarily store excavated soils prior to its disposal at a Subtitle D Landfill (assuming the PCBs and other COPCs present in the soil meet the landfill's waste acceptance criteria).
Are operation and maintenance requirements infrequent and straightforward?	Yes, excavation, confirmation sampling, transportation, disposal and backfilling are straightforward. Maintenance is mostly limited to the construction and transportation equipment. Operations in the area of existing facility infrastructure (i.e., utilities, railroad lines) may be problematic.
Has this process option been proven effective under COC and site conditions similar to those at Kaiser?	Landfill disposal of PCB-impacted soils at Kaiser has been used in the past. Much of the soil at Kaiser will contain less than 1 mg/kg of PCBs. The low concentrations of PCBs in these soils do not require disposal under TSCA. It is expected that the mixture of PCBs and other COPCs will require disposal at a Subtitle D Landfill. The nearest Subtitle D Landfill to the Kaiser site that will accept PCBs at any concentration is located in Roosevelt, WA.
Is process option accepted?	Yes

Table 2-15g - Reliability of Off-Site Destruction of Excavated PCB-Impacted Near-Surface Soil

	Process Options Excavation and Off-Site Treatment of PCB-impacted soil
Attribute	**Off-Site Incineration**
Has this process option been used at the scale required for Kaiser?	Yes. Conventional treatment for PCB-impacted soils.
Are operation and maintenance requirements infrequent and straightforward?	Yes. Excavation, confirmation sampling, transportation, disposal and backfilling are straightforward. Maintenance during excavation work is limited to the construction and transportation equipment. Operations in the area of existing facility infrastructure (i.e., utilities, railroad lines) may be problematic. Operation to reduce the generation of dioxin/furans is required. Off-gas treatment to assure destruction of dioxin/furans is needed. Ash generated by incineration may need to be stabilized.
Has this process option been proven effective under COC and site conditions similar to those at Kaiser?	Yes. Off-Site incineration is a conventional remediation method for PCB-impacted soils. Note that tipping costs for incineration facilities may be two to three times more than tipping costs at landfill facilities. A limited number of PCBs incineration facilities are permitted to operate. The nearest licensed facility is located in Aragonite, Utah.
Is process option accepted?	Yes.

Table 2-16 - Summary of Technology Screening Process: PCBs in Near Surface Soils

			Screening Outcome		
General Response Action (a)	**Remedial Technology (a)**	**Process Options (a)**	**Physical/Chemical (b)**	**Implementability (c)**	**Reliability (d)**
Monitoring	**Monitoring**	**Protection, Performance, and Confirmational**	**Retained**	**Retained**	**Retained**
Institutional Controls	**Access and Use Restrictions**	**Fences, Signs, Deed Restrictions**	**Retained**	**Retained**	**Retained**
	Best Management Practices	**Spill prevention, leak detection, double-walled pipes**	**Retained**	**Retained**	**Retained**
Containment	**Capping**	Soil	Retained	Eliminated	--
		Clay	Retained	Eliminated	--
		Asphalt	**Retained**	**Retained**	**Retained**
		Concrete	**Retained**	**Retained**	**Retained**
		Synthetic	Retained	Eliminated	--
		Multi-layer	**Retained**	**Retained**	**Retained**
	Landfill Cap Enhancements	Run-on and run off controls, vegetative cover	Eliminated	--	--
	Solidification/ Stabilization	Cement- and lime-based processes, microencapsulation, sorption	Eliminated	--	--
***In situ* Soils Treatment**	Vitrification	Combined with soil vapor extraction	Eliminated	--	--
	In Situ Bioremediation	Bioventing	Eliminated	--	--
		Enhanced Bioremediation	Eliminated	--	--
		Phytoremediation	Eliminated	--	--
	Monitored Natural Attenuation	**Monitor natural processes**	**Retained**	**Retained**	**Retained**
	Soil Vapor Extraction (SVE)	Horizontal vents	Eliminated	--	--
		Vertical Vents	Eliminated	--	--
	Steam Injection	Combined with soil vapor extraction	Eliminated	--	--
	Six Phase Soil Heating	Combined with soil vapor extraction	Eliminated	--	--
	Soil Flushing	Water, surfactants, solvents	Eliminated	--	--
	Pneumatic Fracturing	Pressurized air or steam	Eliminated	--	--

Table 2-16 - Summary of Technology Screening Process: PCBs in Near Surface Soils

			Screening Outcome		
General Response Action (a)	**Remedial Technology (a)**	**Process Options (a)**	**Physical/Chemical (b)**	**Implementability (c)**	**Reliability (d)**
***In situ* Soils Treatment - cont'd**	Chemical Treatment	Oxidation, reduction, pH adjustment	Retained	Eliminated	--
	Electro-Kinetic	Enhanced with surfactants and reagents	Eliminated	--	--
Excavation and On-Site Soils Treatment	**Mechanical Screening**	**Dry sieving**	**Retained**	**Retained**	**Retained**
	Ex Situ Bioremediation	Landfarming	Eliminated	--	--
		Biopiles	Eliminated	--	--
		Slurry bioreactor	Retained	Retained	Eliminated
	Solvent Extraction	“BEST Process,” Critical fluid extraction	Eliminated	--	--
	Dehalogenation	APEG Process	Retained	Retained	Eliminated
		BCD Process	Retained	Retained	Eliminated
	High Temperature Thermal Desorption	Rotary dryer (indirect or direct fired), Thermal screw (indirect heating)	Retained	Retained	Eliminated
	Low Temperature Thermal Desorption	Rotary dryer (indirect or direct fired), Thermal screw (indirect heating)	Eliminated	--	--
	Pyrolysis	Rotary kiln, fluidized bed furnace, molten salt destruction	Eliminated	--	--
	Incineration	Rotary kiln, fluidized bed	Eliminated	--	--
	Soil Washing	Water, surfactants, thermally enhanced	Eliminated	--	--
	Chemical Treatment	Hydrogen peroxide, potassium permanganate	Eliminated	--	--
	Solvated Electron Treatment (SET)	Ammonia mixed with anhydrous calcium or sodium	Eliminated	--	--
	Solidification/Stabilization	Cement- and lime-based processes, microencapsulation, sorption	Eliminated	--	--

Table 2-16 - Summary of Technology Screening Process: PCBs in Near Surface Soils

			Screening Outcome		
General Response Action (a)	**Remedial Technology (a)**	**Process Options (a)**	**Physical/Chemical (b)**	**Implementability (c)**	**Reliability (d)**
On-Site Treatment of Extracted Soil Vapor	Condensation	Refrigerated condenser	Eliminated	--	--
	Adsorption	Granular activated carbon, other adsorbents, regenerative systems	Eliminated	--	--
	Thermal and Catalytic Oxidation	Direct flame thermal	Eliminated	--	--
		Flameless thermal	Eliminated	--	--
		Catalytic Oxidizers	Eliminated	--	--
		Hybrid Thermal/Catalytic	Eliminated	--	--
	Advanced Oxidation	UV light	Eliminated	--	--
		Photocatalytic	Eliminated	--	--
	Biofiltration	Bioreactor, soil pile	Eliminated	--	--
Excavation and Off-SiteTreatment/Disposal of Soil	**Landfill**	**Chemwaste Landfill, Washington; Roosevelt Regional Landfill, Oregon**	**Retained**	**Retained**	**Retained**
	Off-Site Incineration	**Rotary kiln, fluidized bed incinerators**	**Retained**	**Retained**	**Retained**
	Re-Use Facility	Asphalt incorporation, thermal desorption, cement incorporation	Eliminated	--	--

Notes:

Bolded Technologies Retained for further evaluation in the FS.

(a) Taken from FS TM Table 2-2

(b) Taken from FS TM Table 2-7

(c) Taken from FS TM Table 2-14a - 2-14e

(d) Taken from FS TM Table 2-15a - 2-15g

(e) Technologies eliminated for treatment of extracted soil vapor, evaluated if off-gas treatment is required for on-site ex situ thermal processes.

Table 2-17 - Location, Concentration, of COCs in Near-Surface Soil in the AOCs at the Kaiser Facility

General Area	Subsites	COC(s)	Sample Number(s)	Depth (feet) [a]	Calculated Concentration (mg/kg)[b]	Final Soil RI Figures and Tables	Comments
ORB Area	**Man-Made Depression - West**	Diesel	B-22/S-1	0-4.5	5,000	Section 2.2.4, Table 2-1, Figure 2-3 to 2-5	One sample in the 2.5 to 4 foot interval exceeded the SL. Samples were below the SL at the 5 foot and suceeding intervals. Assumed the impact zone extended from ground surface to half the distance beetween 4 and 5 feet bgs.
		Heavy Oil	B-22/S-1,B-22/S-2,B-22/S-3,B-22/S-4,B-22/S-5, B-25/S-1,B-25/S-4	0-20	7,571	Section 2.2.4, Table 2-1, Figure 2-3 to 2-5	Seven samples collected at varying depths up to 19 feet below grade exceed SL. Assumed concentration applies to all soil in the 0-20 foot horizion in this AOC. Impacts may extend below 20 feet based on B-25
	Man-Made Depression - East and Small	Diesel	B-14/S-2	0-7	5,700	Section 2.2.4, Tables 2-1, Figure 2-3 to 2-5	One sample up to 6.5 feet exceeded SL. Assumed concentration applies to all soil in the 0 to 7 foot bgs soil horizon in this AOC (approximately half the distance from 6.5 feet (dirty) to 7.5 feet (clean)).
		Heavy Oil	05ORTP-6, B-14/S-2	0-7	7,050	Section 2.2.4, Tables 2-1 and 2-3, Figure 2-3 to 2-5	Two samples at varying depths up to 6.5 feet that exceeded SL. Assumed average concentration applies to all soil in the 0 to 7 foot bgs soil horizon in this AOC (approximatley half the distance from 6.5 feet (dirty) to 7.5 feet (clean)).
	Man-Made Depression - East	Lead	05ORTP-4	0-20	1,280	Section 2.2.2, Table 2-3, Figure 2-3 to 2-5	One sample exceed SL at 5 to 5.5 foot interval. No data available above 5 feet bgs, so assume impacts start at GS. No data available deeper than 05ORTP-4 so assume vertical extent to 20 feet.
	Man-Made Depression - Small	cPAH	05ORTP-100	0-20	0.73	Section 2.2.2, Table 2-3, Figure 2-3 & 2-5	Field duplicate collected at 05ORTP-6, used higher of two concentrations. Concentration based on TEQ Equivalent value. No data available above 5 feet bgs, so assume impacts start at GS. No data available deeper than 05ORTP-6 so assume vertical extent to 20 feet. Impacts may exceed 20 feet bgs.
		Stoddard	05ORTP-6	0-20	360	Section 2.2.4, Table 2-1, Figure 2-3 to 2-5	One sample exceeded SL at 5 to 5.5 foot interval. No data available above 5 feet bgs, so assume impacts start at GS. No data available deeper than 05ORTP-6 so assume vertical extent to 20 feet.
	G1 Transfer Line	Heavy Oil	NA	NA	NA	Section 2.3.2, Table 2-6, Figure 2-6	Impacts handled under ORB Area
		Kensol	NA	NA	NA	Section 2.3.2, Table 2-6, Figure 2-6	Impacts handled under ORB Area
		Stoddard	Location #1 (G-1)	0-20	330	Section 2.3.2, Table 2-6, Figure 2-6	No associated sampling deeper than Location #1 (G-1). Assume soil horizon starts at top of sampling interval for Location #1 (G-1) to 20 feet. Impact may extent past 20 feet.
	G2 Transfer Lines	Heavy Oil	TL-BS-2	18-20	2,100	Section 2.4.2, Table 2-9, Figure 2-8	Localized area. Nearby sample locations were below SL. Assume soil horizon starts at sample depth of TL-BS-2 and extends to 20 feet. Deepest nearby samples are at 20.5 feet and do not exceed SL.
		Heavy Oil	TL-BS-3	18-20	6,500	Section 2.4.2, Table 2-9, Figure 2-8	Localized area. Nearby samples locations were below SL. Assume soil horizon starts at sample depth of TL-BS-3 and extends to 20 feet. Deepest nearby samples are at 20.5 feet and do not exceed SL.
	G3 Transfer Lines	Diesel	TL-3	8-20	4,100	Section 2.5.2, Table 2-14, Figure 2-6	Area localized. No samples nearby deeper than 8 feet (depth of TL-4). Assume depth of contamination of 20 feet. May extend further.
		Heavy Oil	TL-3	8-20	6,900	Section 2.5.2, Table 2-14, Figure 2-6	Area localized. No samples nearby deeper than 8 feet (depth of TL-4). Assume depth of contamination of 20 feet. May extend further.
	1980 Fuel Oil Spill	NA	NA	NA	NA	Section 2.6, tables 2-18, 2-20	No SL exceedances.

Table 2-17 - Location, Concentration, of COCs in Near-Surface Soil in the AOCs at the Kaiser Facility

General Area	Subsites	COC(s)	Sample Number(s)	Depth (feet) ^{a}	Calculated Concentration (mg/kg)^b	Final Soil RI Figures and Tables	Comments
ORB Area (Continued)	**Oil Reclaimation Building**	Diesel	B-7/S-1, B-7/S-2, B-7/S-3, B-13/S-1, B-13/S-2, B-13/S-3, HL-MW-21S-5', HL-MW-21S-10', TL-1, TL-2, B-12/S-1, B-12/S-2, B-12/S-3, B-15/S-1, B-15/S-2, B-15/S-3, B-19/S-1, B-19/S-2, B-19/S-3, Location #1 (G-1), Location #1 (G-1) CS	0-9.5	2,800	Section 2.7.2, Table 2-21, Figure 2-10 to 2-14 Section 2.2.4, Table 2-1, Figure 2-3 to 2-5	Eight samples at varying depths up to 9 feet exceed SL. Assumed average concentration applies to all soil in the 0 to 9.5 foot bgs soil horizon in this AOC (half the distance from 9 feet (dirty) to 10 feet (clean)). The AOC slightly overlaps with area excavated during SPCC upgrades in 2008. The excavated area was considered negligible compared to the total AOC for diesel.
		Heavy Oil	B-1/S-4, B-1/S-7, B-2/S-6, B-2/S-7, B-3/S-6, B-3/S-7, B-6/S-4, B-6/S-5, B-7/S-1, B-7/S-2, B-7/S-3, B-7/S-4, B-7/S-5, B-7/S-6, B-8/S-1, B-8/S-2, B-8/S-4, B-8/S-5, B-8/S-6, B-9/S-1, B-9/S-2, B-9/S-3, B-9/S-4, B-9/S-5, B-9/S-6, B-10/S-1, B-10/S-2, B-10/S-3, B-10/S-4, B-10/S-5, B-10/S-7, B-12/S-1, B-12/S-2, B-12/S-3, B-12/S-4, B-13/S-1, B-13/S-2, B-13/S-3, B-13/S-4, B-13/S-5, B-13/S-6, B-15/S-1, B-15/S-2, B-15/S-3, B-15/S-5, B-18/S-1, B-18/S-2, B-18/S-5, B-18/S-6,B-19/S-1, B-19/S-2, B-19/S-3, B-19/S-4, B-19/S-5, HL-MW-20S/S-3, OR-SB-31/S-1, OR-SB-31/S-2, S-1, S-2, S-3, S-4, S-5, S-6, S-7, S-8, S-9, HL-MW-21S-10', HL-MW-21S-5', TL-1, TL-2, Location #1 (G-1), Location #1 (G-1) CS,	0-20	5,743	Section 2.7.2, Tables 2-21 to 2-23, Figure 2-10 to 2-14 Section 2.2.4, Table 2-1, Figure 2-3 to 2-5 Section 2.3.2, Table 2-6, Figure 2-6	Twenty-eight samples at varying depths up to 19 feet exceed SL. Impacts may extend below 20 feet. Assumed average concentration applies to all the soil in the 0 to 20 foot bgs soil horizon in this AOC. Total volume has been decreased by estimated volume of soil excavated during SPCC upgrades in 2008. Estimated volume of soil excavated during SPCC upgrades was calculated and equal to 580,000 cubic feet (approximately). Values used to calculate this volume are from Figures 2-12 and 2-13 of the Final Soil RI.
		Gasoline	S-3, S-8	0-20	240	Section 2.7.2, Table 2-22, Figure 2-10	Two samples at varying depths up to 18 feet below ground surface exceed SL. No information below 18 feet. Assumed average concentration applies to the 0 to 20 foot soil horizon in this AOC.
Former Rail Car Unloading Area	**RCU Area (SE corner)**	Diesel	TP2-S1	0-2.5	3,600	Section 3.2.4, 3.2.5, Table 3-1, Figure 3-2, 3-3	Assume diesel, heavy oil and cPAH hits in samples TP-2 and TP-2A are related to each other and associated with petroleum hydrocarbons. Assume vertical extent starts at GS and extends to midway point between 1 foot (dirty) and 4 feet (clean) based on TP-2. Lateral Area based on Final Soil RI.
		Heavy Oil	TP2-S1 and TP2A -S1	0-2.5	6,350	Section 3.2.4, 3.2.5, Table 3-1, Figure 3-2, 3-3	Assume diesel, heavy oil and cPAH hits in samples TP-2 and TP-2A are related to each other and associated with petroleum hydrocarbons. Assume vertical extent starts at GS and extends to midway point between 1 foot (dirty) and 4 feet (clean) based on TP-2. Lateral Area based on Final Soil RI.
		cPAH	TP2A -S1	0-2.5	0.78	Section 3.2.4, 3.2.5, Table 3-1, Figure 3-2, 3-3	Assume diesel, heavy oil and cPAH hits in samples TP-2 and TP-2A are related to each other and associated with petroleum hydrocarbons. Assume vertical extent starts at GS and extends to midway point between 1 foot (dirty) and 4 feet (clean) based on TP-2. Lateral Area based on Final Soil RI.
	RCU Area (S end)	Diesel	RCU-TP-FL-SW-1, RCU-TP-FL-SW-2, TP-11-Bottom	0-3	2,480	Section 3.2.4, 3-4, Figure 3-2, 3-3	RCU-TP-FL-SW-2 exceeds SL. Assume vertical extents start at GS and extend to midpoint between RCU-TP-FL-SW-2 and RCU-TP-FL-B-1 (4 feet). RCU-TP-FL-B-1 below SL. Lateral Area based on Final Soil RI .
		Heavy Oil	RCU-TP-FL-SW-1, RCU-TP-FL-SW-2, TP-11-Bottom	0-3	3,780	Section 3.2.4, 3-4, Figure 3-2, 3-3	RCU-TP-FL-SW-2 exceeds SL. Assume vertical extents start at GS and extend to midpoint between TP-11-Bottom and RCU-TP-FL-B-1 (4 feet). RCU-TP-FL-B-1 below SL. Lateral Area based on Final Soil RI.

Table 2-17 - Location, Concentration, of COCs in Near-Surface Soil in the AOCs at the Kaiser Facility

General Area	Subsites	COC(s)	Sample Number(s)	Depth (feet) [a]	Calculated Concentration (mg/kg)[b]	Final Soil RI Figures and Tables	Comments
Former Rail Car Unloading Area (Continued)	**RCU Area (N end)**	Diesel	RU1-S3	15.25-20	2,700	Section 3.2.5, Tables 3-1, 3-4 Figure 3-2, 3-3	Localized area. SL exceedences in boring RU-1 from 17.5 to 44 feet bgs. Sample from RU-1 from 12.5-13 was clean, split half the distance from clean to dirty. Lateral area based on Final Soil RI.
		cPAH	TP9-S1	0-2.25	1.19	Section 3.2.5, Table 3-1, Figure 3-2, 3-3	Localized area. Assume presence of hydrocarbons indicate presence of cPAH. Assume vertical extent starts at GS and extends to midpoint between TP9-S1 and TP9-S2 (3.5 to 4.5 feet). TP9-S2 was not analyzed for cPAHs, but nondetect for petroleum hydrocarbons.
	100,000 gallon Fuel Oil Spill	NA	NA	NA	NA	Section 3.3, Figure 3-2	No SL exceedances
Cold Mill Finishing Areas	**Cold Mill Transfer Lines**	Kensol	NA	NA	NA	Section 4.2.2, Table 4-1, Figure 4-3	Impacts handled under Oil House Area: Tank Farm Kensol Spill
	Transformer Yard Area	NA	NA	NA	NA	Section 4.3, Figure 4-4, Table 4-6	No SL exceedances
	CCPL Cell 4	cPAH	CCPL-C4	10-20	0.49	Section 4.4.2, Table 4-10, Figure 4-5	Excavation took place after removal of equipment, tank and concrete pad. All cells measured for Cr, this is the only cell that had full suite of analysis. Assume vertical extents start at sample depth of CCPL-4 and extend to 20 feet. Impacts may be deeper.
	Chromium Transfer Lines	Total Chromium	TL-7	8-20	5,350	Section 4.5.2, Table 4-16, Figure 4-7	1990/91 Excavation limited in south due to building foundation constraint. Chromium-impacted soils were ID and remain in place (Hart Crowser 2012b).
	Cold Mill Electrical Grounding Pit	Diesel	G-Pit-A, G-Pit-B	3-20	645,000	Section 4.6.2, Tabel 4-19, Figure 4-2	Unable to determine depth of impact because of access limitations. Assume vertical extent starts at depth of grounding pit (3 feet) and goes to 20 feet but impacts may be deeper. Concentration based on material collected in area (samples G-Pit-A and G-Pit-B). Area is based on diameter of grounding pit (2.5 feet).
		Heavy Oil	G-Pit-A, G-Pit-B	3-20	36,150	Section 4.6.2, Tabel 4-19, Figure 4-2	Unable to determine depth of impact because of access limitations. Assume vertical extent starts at depth of grounding pit (3 feet) and goes to 20 feet but impacts may be deeper. Concentration based on material collected in area (samples G-Pit-A and G-Pit-B). Area is based on diameter of grounding pit (2.5 feet).
	Coater Line Tank Area	NA	NA	NA	NA	Section 4.7.2, Table 4-21, Figure 4-2	No SL exceedances
Oil House Area	**Oil House UST**	NA	NA	NA	NA	Section 5.2, Table 5-1, 5-2, Figure 5-2, 5-3	No SL exceedances
	20,000 gal gas tank	Gasoline	GT-D	18-20	1,700	Section 5.4.2, Table 5-6, Figure 5-4	One sample collected at 18 feet exceeded SL. The excavation above this sample collected at 18 feet was backfilled with clean fill. Assumed that this concentration applies to soil excavated in the 18 to 20 foot soil horizon in this AOC.
	Tank Farm Kensol Spill Area	TPH (418.1)	TF#3 Bottom, CM-EX-S1	9-20	7,050	Section 5.7, Table 5-14, Figure 5 8, Section 4.2.2, Table 4-1, Figure 4-3	Two samples collected at 9 and 12 feet exceeded SL. Previous excavation parallel and below transfer lines by sample CM-EX-S1. No nearby samples deeper than 9 feet. Assume impacts start at CM-EX-S1 sample depth and extend to 20 feet. Impacts may be deeper than 20 feet. The excavation above TF#3 (12 feet) was backfilled with clean fill. Assumed that this concentration applies to soil excavated in the 9 to 20 foot soil horizon in this AOC.
	500-Gal. Diesel UST Area	NA	NA	NA	NA	Section 5.3, Table 5-5	No SL exceedances
	8 Tanks Area	Kensol	1-SW (15), 2-NW (15), 2-SW (15), 5 SW (15), EW (15), OH-SB-1-S1 (9-10)	15-20	6,380	Section 5.5, Table 5-9, 5-10, Figure 5-5	Three distinct areas represented by 5 samples. All samples collected at 15 feet and exceeded SL. The excavation above this sample was backfilled with clean fill. Assumed that this average concentration applies to soil in the 15 to 20 foot soil horizon in this AOC.

Table 2-17 - Location, Concentration, of COCs in Near-Surface Soil in the AOCs at the Kaiser Facility

General Area	Subsites	COC(s)	Sample Number(s)	Depth (feet) [a]	Calculated Concentration (mg/kg)[b]	Final Soil RI Figures and Tables	Comments
Oil House Area (Continued)	**Oil House Drum Storage and French Drain Area**	PCBs	SA-1/S-1, SA-1/S-2, SA-1/S-3, SA-2/S-1, SA-2/S-2, SA-2/S-3, SA-5/S-1, SA-5/S-2, SA-5/S-3, SA-6/S-1, SA-6/S-2, SA-6/S-3 Plus nine bottom of excavation composite samples shown on Figure 5-6 of the RI.	6-20	356	Section 5.6, Table 5-12, Figure 5-6 5-7	Samples collected at varying depths between approximately 6 and 20 feet bgs that exceeded SL. The excavation in this area extended to approximately 6 feet bgs and was backfilled with clean fill. Assumed that this average concentration applies to soil excavated in the 6 to 20 foot soil horizon in this AOC.
		TPH (418.1)	SA-1/S-1	6-12.5	2,700	Section 5.6, Table 5-12, Figure 5-6 5-7	One sample collected at 10 feet exceeded SL, sample SA-1/S-2 collected at 15 feet bgs below SL. Assumed that this concentration applied to soil from the base of excavation at 6 feet bgs to half the distance between 10 and 15 feet, 12.5 feet bgs.
Waste Water Treatment Area	**FCT Area**	Arsenic	FCT-TP-2 Bottom, FCT-TP-400, FCT-TP-5 Bottom, FCT-TP-6 Bottom, FCT-TP-7 Bottom, FCT-TP-9 Bottom, FCT-TP-10 Bottom, FCT-TP-12 Bottom, FCT-TP-13 Bottom	0-20	16	Section 6.2, Tables 6-1, 6-5, 6-6, Figures 6-2, 6-3	Five samples collected at depths 6 to 11 feet bgs exceeded SL. All samples were collected at the bottom of the test pits. No samples were taken below test pits. Assumed that the average concentration applies to all the soil in the 0 to 20 foot bgs horizon in this AOC.
		TPH (418.1)	WW-SB-5/S-1	0-15	3,400	Section 6.2, Tables 6-1, 6-5, 6-6, Figures 6-2, 6-3	One sample collected at 5-7 foot interval exceeded SL. Next sample from this boring was below SL at 23 feet bgs. Went half the distance from 7 feet to 23 feet bgs to define the lower bounds of impact zone (15 feet bgs). Assumed that this concentration applies to all soil in the 0 to 15 foot BGS soil horizon in this AOC.
		Diesel	FCT-TP-6-S1, FCT-TP-6-S2, FCT-TP-9-S1	0-7	5,033	Section 6.2, Table 6-6, Figures 6-2, 6-3	Three samples collected at varying depths up to 6.5 feet that exceeded SL. Assumed that this average concentration applies to all soil in the 0 to 7 foot bgs soil horizon in this AOC (approximate half the distance from 6.5 feet (dirty) to 8 feet (clean)).
		Heavy oil	FCT-SB-2-S3, FCT-TP-6-S1, FCT-TP-6-S2	0-7	3,033	Section 6.2, Tables 6-1, 6-5, 6-6, Figures 6-2, 6-3	Three samples collected at varying depths up to 6.5 feet that exceeded SL. Assumed that this average concentration applies to all soil in the 0 to 7 foot bgs soil horizon in this AOC (approximate half the distance from 6.5 feet (dirty) to 8 feet (clean)). Sample FCT-SB-S3 is assumed to be at the surface following excavations.
	Hoffman Tank Area	Arsenic	HTE6	0-15	12	Section 6.3, Table 6-7, 6-8, Figures 6-4 to 6-6	Assumed that HTE6 was collected at approximately 10 feet bgs. Sample HTE4 collected at 20 feet bgs was below the SL for arsenic. Went half the distance between 10 and 20 feet to define the arsenic impact zone from 0 to 15 feet bgs.
		TPH (418.1)	HTE5, HTE6, HTE7	10-20	6,720	Section 6.3, Table 6-7, 6-8, Figures 6-4 to 6-6	Three samples collected at assumed depths 10 feet below current grade that exceeded SL. Assumed that average concentration applies to all soil excavated from AOC at depths of 10 feet bgs to 20 bgs. Approximately 10 feet clean fill overlies sample locations.
	H2S Scrubber Building	Diesel	WW-T-O-SCRUB-COMP (EPH)	7-20	12,382	Section 6.4, Tables 6-9, 6-10, Figure 6-7	One sample collected at 7 feet exceeded SL. Top 7 feet backfilled with clean soil. Assumed that this concentration applies to all soil from 7 feet to 20 foot horizon in this AOC. No samples collected below this depth. Diesel and heavy oil concentrations estimated from EPH data (WW-T-O-Scrub-Comp).
		Heavy Oil	WW-T-O-SCRUB-COMP (EPH)	7-20	18,300	Section 6.4, Tables 6-9, 6-10, Figure 6-7	One sample collected at 7 feet exceeded SL. Top 7 feet backfilled with clean soil. Assumed that this concentration applies to all soil from 7 feet to 20 foot horizon in this AOC. No samples collected below this depth. Diesel and heavy oil concentrations estimated from EPH data (WW-T-O-Scrub-Comp).

Table 2-17 - Location, Concentration, of COCs in Near-Surface Soil in the AOCs at the Kaiser Facility

General Area	**Subsites**	**COC(s)**	**Sample Number(s)**	**Depth (feet)** [a]	**Calculated Concentration (mg/kg)**[b]	**Final Soil RI Figures and Tables**	**Comments**
Waste Water Treatment Area (Continued)		Arsenic	HT-SB-1-S2	7-20	20	Section 6.4, Tables 6-9, 6-10, Figure 6-7	One sample collected in the 19-20 foot depth interval exceeded the SL. The top 7 feet of this AOC has been backfilled with clean fill. Assumed that the impact zone extends from 7 to 20 feet bgs.
Truck Shop Area	**Truck Shop Areas**	Heavy oil	TSMW-1S/S-3, TSMW-1S/S-4	13-20	5,100	Section 7, Table 7-3, Figure 7-2	Two samples collected in the 15-20 foot depth interval exceeded the SL. Samples at the 5 and 10 foot intervals were below SLs. Assumed that the average concentration applies to the 7 feet between the tank bottom at 13 feet and 20 feet in this AOC.
		Stoddard	TSMW-1S/S-3	13-20	700	Section 7, Table 7-3, Figure 7-2	One sample collected at 15 feet exceeded the SL. Samples dirrectly above and below this location were not tested for TPH-Gx. Assumed this sample concentration applies to the 7 feet between the tank bottom at 13 feet and 20 feet in this AOC.
Discharge Ravines Areas	**West Ravine**	PCBs	WDR-EC1-C1, WDR-EC10-C1, WDR-EC10-C2, WDR-EC10-C3, WDR-EC10-D4, WDR-EC11-C1, WDR-EC11-C2, WDR-EC11-D3, WDR-EC11-D7, WDR-EC12-C1, WDR-EC12-C2, WDR-EC12-D14, WDR-EC12-D15, WDR-EC13-C1, WDR-EC13-C4, WDR-EC13-D1, WDR-EC13-D2, WDR-EC14-C1, WDR-EC14-C2, WDR-EC14-D2, WDR-EC14-D7, WDR-EC15-C2, WDR-EC15-C1, WDR-EC15-C3, WDR-EC15-D19, WDR-EC15-D20, WDR-EC16-D1, WDR-EC16-D2, WDR-EC17-1D, WDR-EC17-C1, WDR-EC17-C2, WDR-EC18-2D, WDR-EC18-C1, WDR-EC18-D1, WDR-EC19-3D, WDR-EC19-C1, WDR-EC19-C2, WDR-EC1-C2, WDR-EC1-D1, WDR-EC1-D2, WDR-EC2-C1, WDR-EC20-C1, WDR-EC20-C2, WDR-EC20-D1, WDR-EC21-C1, WDR-EC21-C2, WDR-EC21-D1, WDR-EC22-C1, WDR-EC22-D1, WDR-EC23-D1, WDR-EC2-C2, WDR-EC2-C3, WDR-EC2-D13, WDR-EC2-D17, WDR-EC3-C1, WDR-EC3-C2, WDR-EC3-C3, WDR-EC3-C4, WDR-EC3-D1, WDR-EC3-D2, WDR-EC4-C1, WDR-EC4-C2, WDR-EC4-C3, WDR-EC4-C4, WDR-EC4-D1, WDR-EC4-D6, WDR-EC5-C3, WDR-EC5-C1, WDR-EC5-C2, WDR-EC5-C4, WDR-EC5-C5, WDR-EC5-D4, WDR-EC7-C1, WDR-EC7-C2, WDR-EC7-C3, WDR-EC7-D1, WDR-EC8-C1, WDR-EC8-C2, WDR-EC8-D1, WDR-EC8-D2, WDR-EC9-C1, WDR-EC9-C2, WDR-EC9-C3, WDR-EC9-D1	Varies - assumed to be an approximate 3 foot horizon of impacted soil below the base of the 2007 excavation.	6.5	Section 8.2, Table 8-2, Figures 8-2 to 8-17.	Only 15 of the greater than 90 verification samples in this AOC were below the SL following the 2007 Interim Action. Based on the observed decrease in PCB soil concentration with depth during the WDR Interim Action, it was assumed that if an additional 3 feet of excavation was possible that the SL would be met. Assumed that the average concentration from all verification samples applies to the 3 foot soil horizon at the base of Interim Action excavation in this AOC.
	South Ravine	PCBs	SDR-SS-1 thru SDR-SS-5, SDR-SS-7, SDR-SS-8, SDR-SS1-PH2-2-S3, SDR-SS1-PH2-3-S1, SDR-SS1-PH2-3-S2, SDR-SS1-PH2-3-S3, SDR-SS1-PH2-4-S1, SDR-SS1-PH2-4-S2, SDR-SS1-PH2-4-S3, SDR-SS7-PH2-1-S1, SDR-SS7-PH2-1-S2, SDR-SS7-PH2-1-S3, SDR-SS7-PH2-2-S1, SDR-SS7-PH2-2-S2, SDR-SS7-PH2-2-S3, SDR-SS7-PH2-3-S1, SDR-SS7-PH2-3-S2, SDR-SS7-PH2-3-S3	0-3	4	Section 8.3, Tables 8-4 to 8-6, Figures 8-18 to 8-20.	Eleven samples out of 39 collected along the SDR at depths up to 2.5 feet exceeded the SL. Assumed the average concentration of samples withing the AOC applies to the top 3 feet of soil in this AOC.
	South Ravine	Heavy oil	SDR-SS1-PH2-3-S1	0-0.75	13,000	Section 8.3, Tables 8-4 to 8-6, Figures 8-18 to 8-20.	One sample collected at the 0-0.5 foot depth interval exceeded the SL. Samples were below SL at the 1 foot and succeeding interval. Assumed the impact zone extended from the ground surface to half the distance between 0.5 and 1.0 foot BGS.

Table 2-17 - Location, Concentration, of COCs in Near-Surface Soil in the AOCs at the Kaiser Facility

General Area	Subsites	COC(s)	Sample Number(s)	Depth (feet) [a]	Calculated Concentration (mg/kg)[b]	Final Soil RI Figures and Tables	Comments
Remelt/Casting Areas	**DC1 Area East Excavation**	PCBs	B-2	8-12	0.8	Section 9-2, Table 9-2, Figure 9-3	One sample collected at approximately 8 feet exceeded SL. Top 8 feet backfilled with clean soil following removal and sampling. Assumed that the concentration applies to all soil from 8 feet to 20 feet in the AOC. No samples collected below this depth.
	DC1 Area West Excavation	PCBs	S-2, B-3	5-20	0.5	Section 9-2, Table 9-2, Figure 9-3	Two samples collected at approximately 5 feet exceeded SL. Top 5 feet backfilled with clean soil. Assumed that average concentration applies to all soil from 5 feet to 20 feet in the AOC. No samples collected below this depth.
	DC4 Area	PCBs	TB-5 to TB-8, DC#4-N, DC#4-S	5-20	8	Section 9-2, Table 9-6, Figure 9-4	Six samples collected at approximately 5 feet exceeded SL. Top 5 feet backfilled with clean soil. Assumed that average concentration applies to all soil from 5 feet to 20 feet in the AOC. No samples collected below this depth.
	Remelt Area Wells/Borings - RM-MW-8S	PCBs	RM-MW-8S-S3	13-18	0.6	Section 9.2, Tables 9-1, 9-5, Figure 9-1	Sample RM-MW-8S-S3 exceeded SL at 15-16.2 feet BGS. Below SL at 10-11.5 feet and 20-21 feet BGS. Went half the distance between exceedance sample and clean samples above and below to define impact area of 13 to 18 feet BGS.
	Remelt Area Wells/Borings - RM-MW-9S	PCBs	RM-MW-9S-S3, RM-MW-9S S-4	13-20	76.0	Section 9.2, Tables 9-1, 9-5, Figure 9-1	Sample RM-MW-9S-S3 (15-16.5 feet) and RM-MW-9S S-4 (20-21 feet) exceed SL. Sample at 10-11.5 feet below SL. Went half the distance to the clean sample to define the impacted area of 13 to 20 feet BGS.
	Remelt Area Wells/Borings - RM-F4-SB	PCBs	RM-F4-SB-1 S-1, RM-F4-SB-1 S-2, RM-F4-SB-1 S-3, RM-F4-SB-1 S-4	0-20	13.6	Section 9.2, Tables 9-1, 9-5, Figure 9-1	Sample RM-F4-SB-1 S-1 (4-5 feet) through RM-F4-SB-1 S-4 (20-21.5 feet) exceed the SL. Considered the top 20 feet to be impacted at the average concentrations of the four shallow samples.
	Remelt Area Wells/Borings - INDBG-SB-1	PCBs	INDBG-SB-1 S-2	3-10	0.4	Section 9.2, Tables 9-1, 9-5, Figure 9-1	Sample INDBG-SB-1 S-2 (5-5.3 feet) exceeded the SL. Samples at 0-1.5 feet and 15-15.4 feet BGS were below the SL. Went half the distance between SL exceedances and clean samples to define the impact zone of 3 to 10 feet BGS in this AOC.
		Heavy Oil	INDBG-SB-1 S-1, INDBG-SB-1 S-2, INDBG-SB-1 S-3	0-20	4,733	Section 9.2, Tables 9-1, 9-5, Figure 9-1	Samples INDBG-SB-1 S-1 and Sample INDBG-SB-1 S-3 exceeded the SL. Considered the upper 20 feet to be impacted at the average concentration of the 3 samples.
	Hotline Area Wells/Borings- HL-DW-SB-2	Heavy Oil	HL-DW-SB-2/S-1	0-14.5	4,400	Section 9.2, Tables 9-1, 9-3, 9-7, Figure 9-1	One sample collected at 7-10 foot depth interval exceeded the SL. Sample HL-DW-SB-2/S-2 at the 19-22 foot interval was below SL. Assumed that the HL-DW-SB-2/S-1 sample concentration applies to the top 14.5 feet (half the distance between 10 and 19 feet BGS) in this AOC.

Notes

[a] Only the upper 20 feet was evaluated in this section as this depth was considered excavatable with commonly available equipment.

[b] Concentration represents the average concentration of COCs if more than one sample is included in each AOC. One half of the reporting limit was used in averaging calculations if non-detect samples were present in the AOC.

Table 2-18 - Distribution of COCs in Near-Surface Soils in the General Operating Areas of the Kaiser Site

General Area	Subsites	Rough Order of Magnitude Mass of COCs in pounds								
		Gasoline or Stoddard	cPAHs	TPH (a)	Diesel or Kensol	Heavy Oil	PCBs	Arsenic	Lead	Chromium
ORB	Man-Made Depressions	300	1		7,000	29,000			7000	
	G1 Transfer Line	700								
	G2 Transfer Lines					190				
	G3 Transfer Lines				21,000	36,000				
	1980 Fuel Oil Spill									
	ORB	220			51000	79000				
RCU	RCU Area		4		16,000	17,000				
	100,000 gallon Fuel Oil Spill									
Cold Mill Area	Cold Mill Transfer Lines									
	Tranformer Yard Area									
	CCPL Cell 4		1							
	Cold Mill Electrical Grounding Pit				5,600	310				
	Chromium Transfer Lines									2600
	Former Coater Tank									
Oil House Area	500-Gallon Diesel Underground Storage Tank									
	20,000-Gallon Leaded Gasoline UST	70								
	Tank Farm Kensol Spill Area			28000						
	Eight USTs Excavation				1,400					
	Oil House Drum Storage/French Drain			950			2,200			
Wastewater Treatment Area	Field-Constructed Tanks			7800	9,400	5,700		300		
	Hoffman Tank Excavation			28000				20		
	Hydrogen Sulfide Scrubber Building				1,600	2,300		10		
Truck Shop Tank Area	Truck Shop Tank Area	440				3,200				
Discharge Ravines	West Discharge Ravine						13			
	South Discharge Ravine					1,400	11			
Remelt/Casting Areas	DC-1 Furnace Area Excavations						2.0E-02			
	DC-4 Furnace Vent Trench						1			
	Remelt/Hot Line Area					60,000	250			
Total		1,700	6	65,000	113,000	230,000	2,500	330	7,000	2,600
Percentage of Total		0.40	1.3E-03	15.40	26.77	54.48	0.59	0.08	1.66	0.62

Notes

a - TPH represents mass of total petroleum hydrocarbons calculated based on concentrations provided by analysis TPH 418. This analysis does not provide information on the composition of the hydrocarbon mixture. This method was used during the initial site characterizations conducted in the late 1980s and early 1990s. At that time, it was the only petroleum hydrocarbon analysis accepted by the regulatory agencies (Final Soil RI).

Subsites with no COCs are shaded.

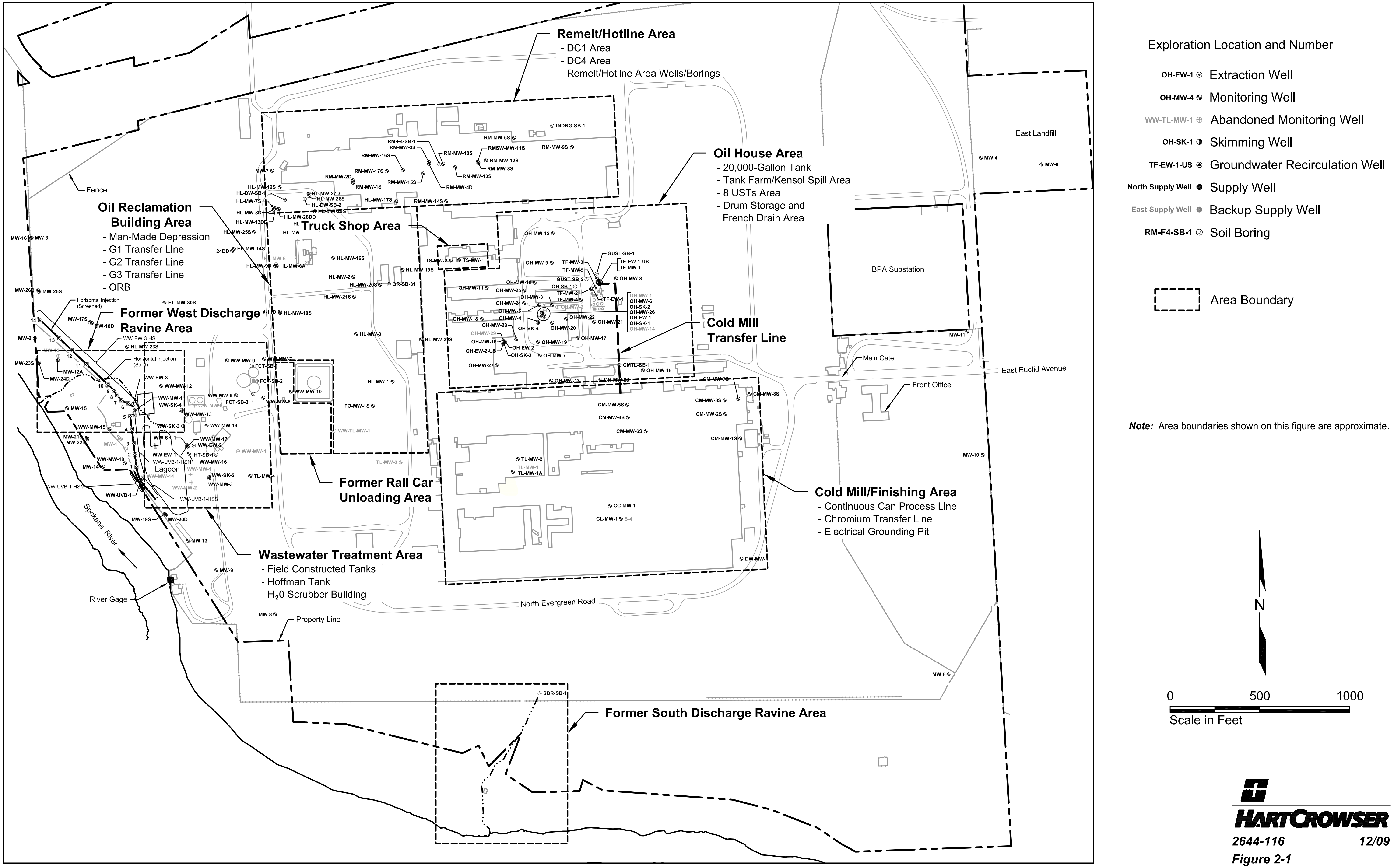
Table 2-19 - Technology-Based Remedial Alternatives: COC Group Matrix - Near-Surface Soils

Alternative	Description	Contaminants of Concern (COC) Group			
		VOCs	SVOCs	PCBs	Pb/Cr
A1	Institutional Controls & Monitoring & MNA	X	X	X	X
A2	Institutional Controls & Monitoring & MNA & Containment	X	X	X	X
A3	A2 & Soil Vapor Extraction plus off-gas treatment	X			
A4a	A1 & Excavation & Off Site Disposal (a)		X	X	X
A4b	A2 & Excavation & Off Site Disposal (b)		X	X	X
A5a	A1 or A2 & Excavation & On Site Biotreatment (c)		X		
A5b	A1 or A2 & Excavation & On Site Thermal Desorption (c)		X		
A6	A1 or A2 & Excavation & Off Site Incineration (c)		X	X	

Notes:
Selected Alternatives can be used individually or in combination depending on COCs in AOC. See Section 2.7.2 for more detail.
(a) For AOCs where no COCs at concentrations greater than SLs will remain at depths greater than 20 feet.
(b) For AOCs where one or more COCs at concentrations greater than SLs will remain at depths greater than 20 feet.

(c) A1 will be added to Alternative for AOCs where no COCs at concentrations greater than SLs will remain at depths greater than 20 feet. A2 will be added to Alternative for AOCs where one or more COC at concentrations greater than SLs will remain at depths greater than 20 feet.

Near-Surface Soil (< 20 Feet) Areas of Interest



Note: Area boundaries shown on this figure are approximate.

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Figure 2-1

Technology Screening Approach

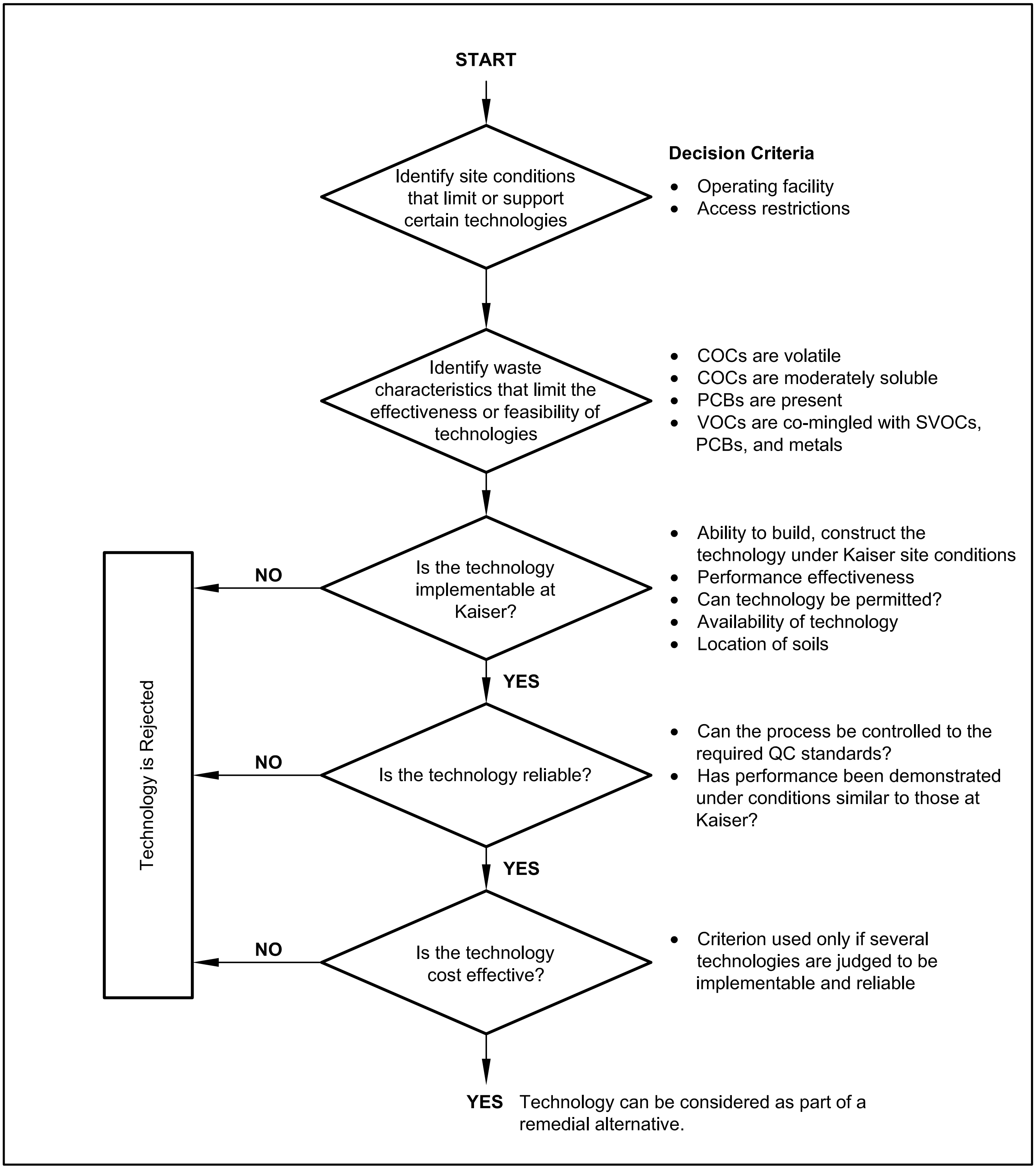

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Figure 2-2

Man-Made Depressions

Near-Surface Soil Screening - Diesel, Heavy Oil, Stoddard, cPAHs, and Lead

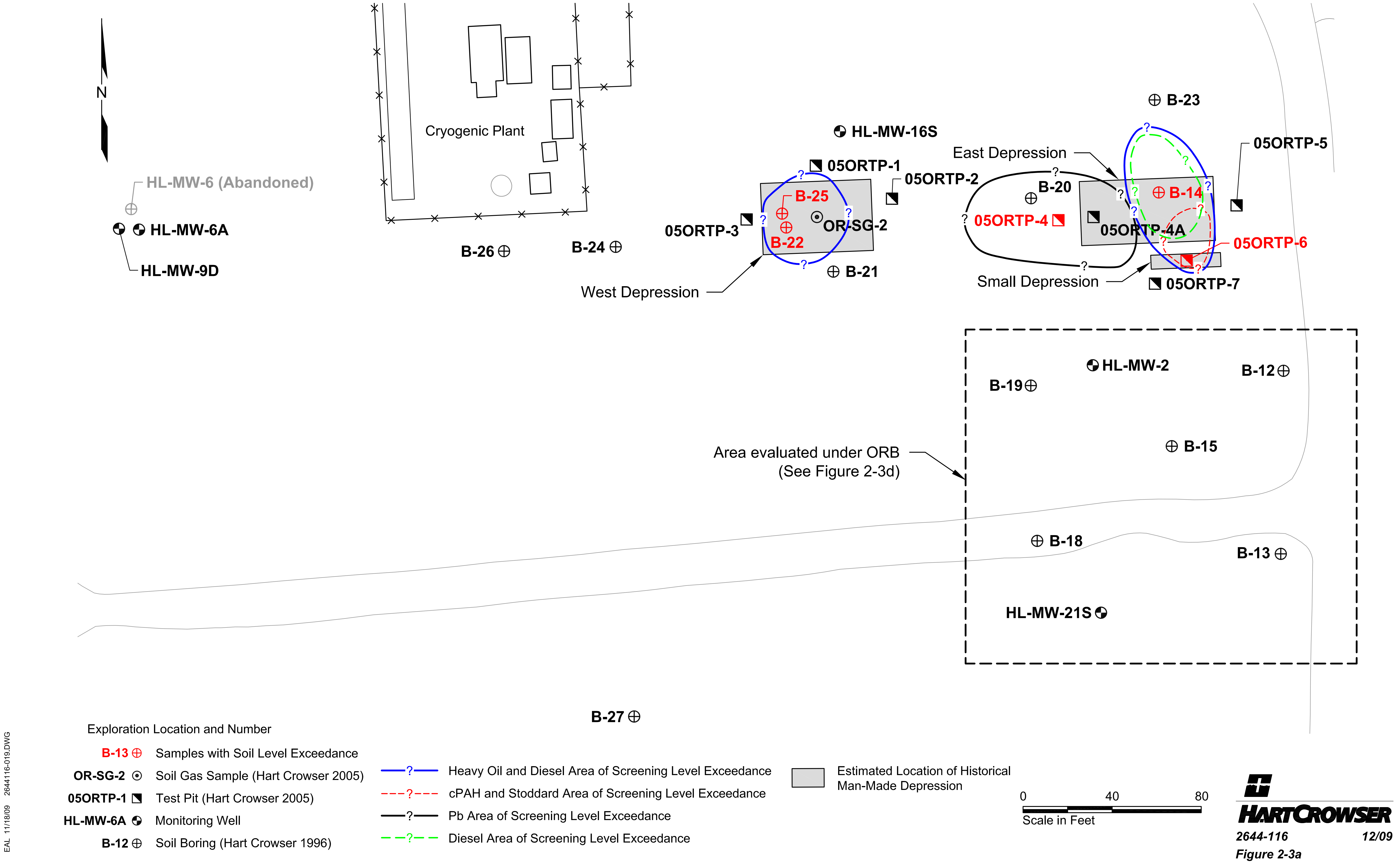

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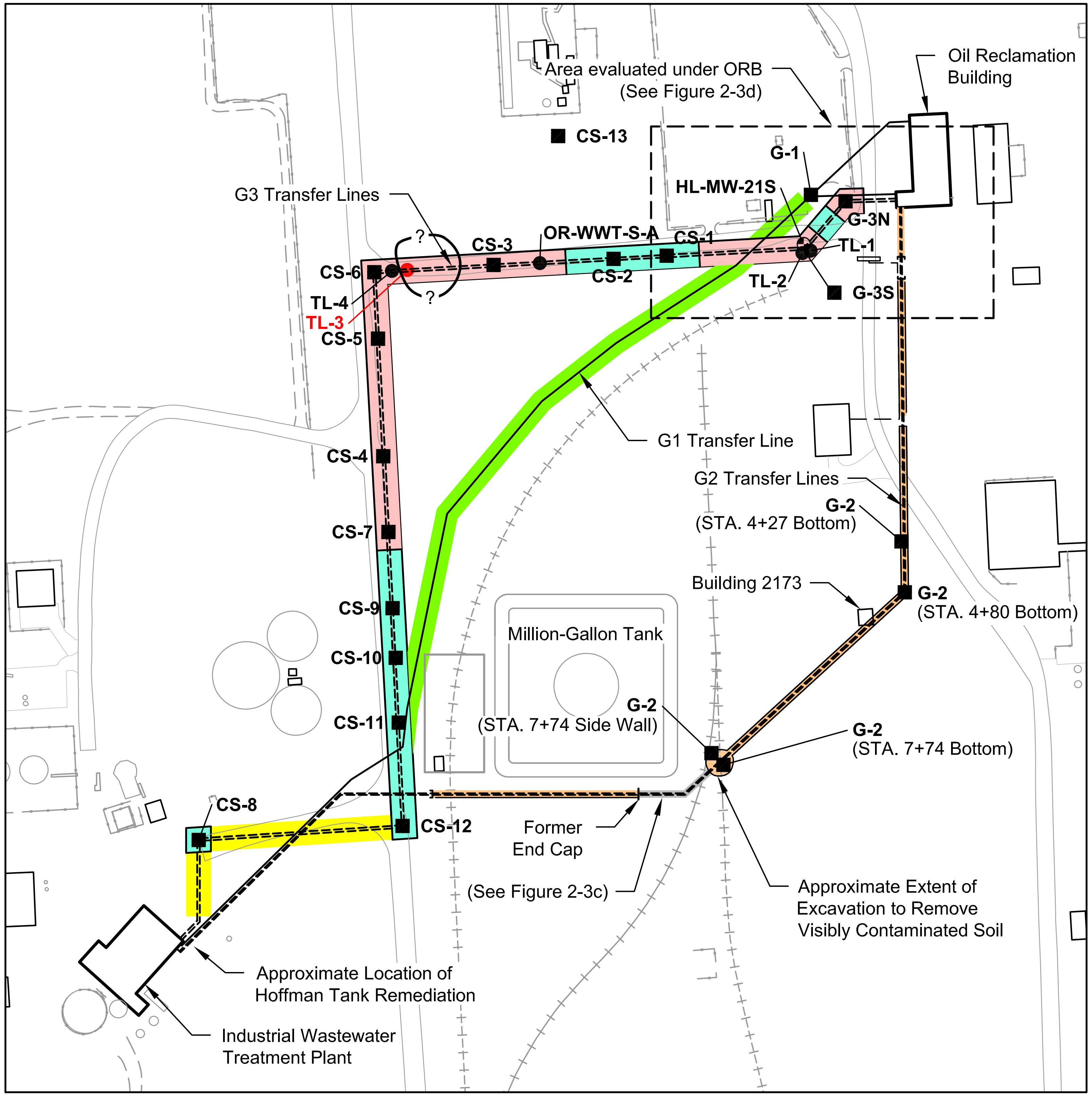
Figure 2-3a

G1, G2, and G3 Transfer Lines and Exploration Map

Near-Surface Soil Screening - Diesel and Heavy Oil



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This figure was originally produced in color. Reproduction in black and white may result in a loss of information.

Excavation Limits

🟥	Previous Study (April/May 2004)
🟦	Phase I Study (November 2006)
🟧	G2 Lines Excavated and Removed (2007)
⬜	G2 Lines Previously Removed (1998)

Soil Sample Location and Number

TL-1 ●	Previous Study (April/May 2004)
CS-1 ■	Phase I Study (November 2006)
TL-2 ●	Samples with SL Exceedances

Pressure or Helium Test Segment

🟩	G1 Line
🟨	G3 Lines

HL-MW-21S ⊕	Existing Monitoring Well Location and Number
]	End Cap (Typical)
—?—	Diesel and Heavy Oil Area of Screening Level Exceedance

N

0 150 300
Scale in Feet

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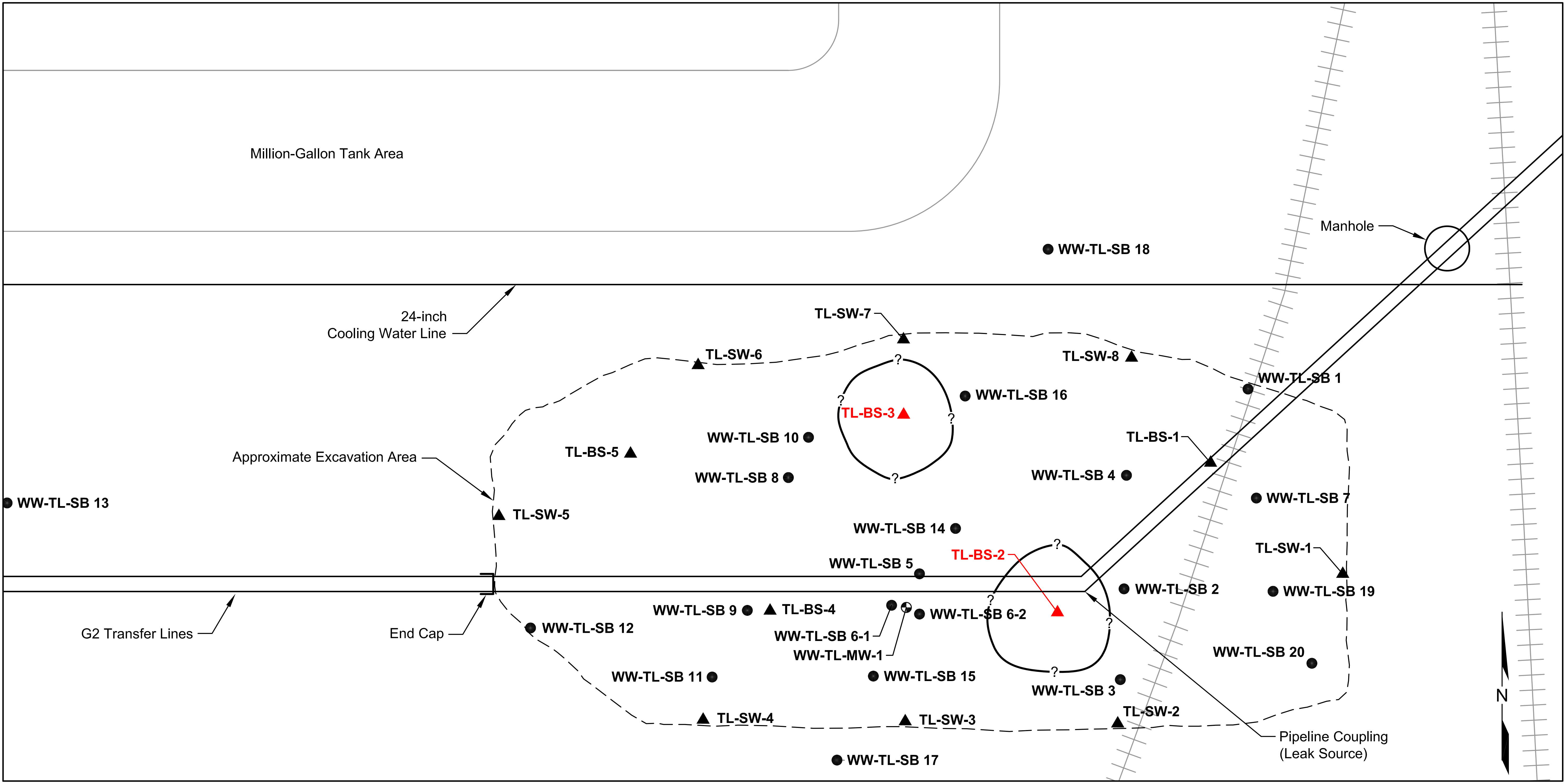
Figure 2-3b

G2 Transfer Lines 1998 Line Break

Near-Surface Soil Screening - Heavy Oil



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Exploration Location and Number

▲ TL-SW-1	Soil Sampling Location with Screening Level Exceedance
▲ TL-SW-1	Verification Soil Sampling
● WW-TL-SB 11	Boring
◐ WW-TL-MW-1	Monitoring Well (Decommissioned)
——?——	Heavy Oil Area of SL Exceedance

0 10 20
Scale in Feet

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Figure 2-3c

Oil Reclamation Building

Near-Surface Soil Screening - Diesel, Heavy Oil, and Gasoline

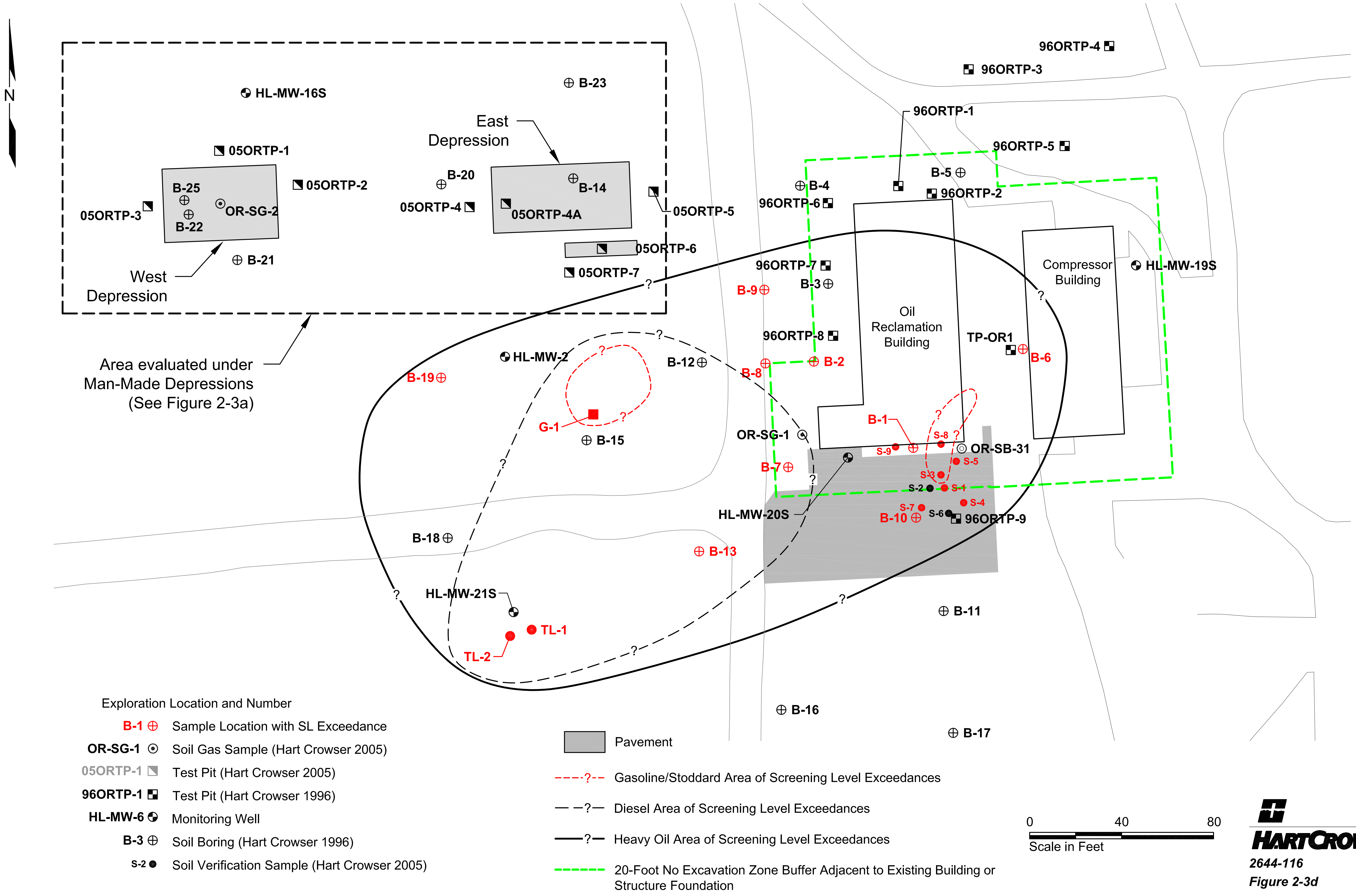

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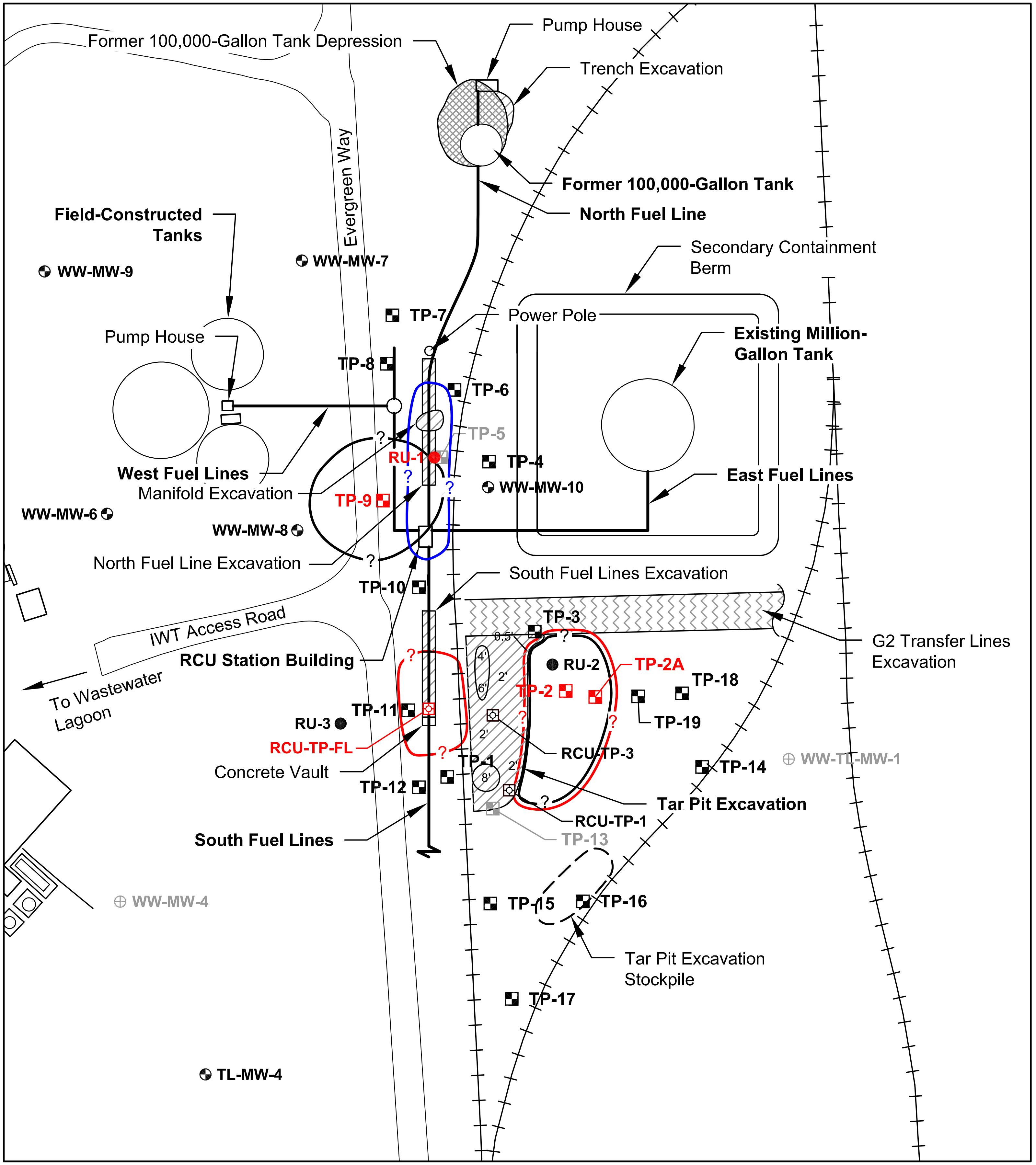
Figure 2-3d

Rail Car Unloading (RCU) Area

Near-Surface Soil Screening - Diesel, Heavy Oil, and cPAHs



Exploration Location and Number

RCU-TP-1	⊠	Phase II RI Test Pit
WW-MW-8	⊕	Monitoring Well
RU-3	●	1996 Soil Boring
TP-12	▣	1996 Test Pit (Shaded Test Pit Excavated)
	2'	Depth of Tar Pit Excavation in Feet
	━━━	Fuel Line
	▩	Existing Excavation
	▦	Phase I Excavation
	▨	Phase II Excavation
	—?—	Diesel and Heavy Oil Area of Screening Level Exceedances
	—?—	cPAHs Area of Screening Level Exceedances
	—?—	Diesel Area of Screening Level Exceedances

Notes:

1. Soil from TP-11 and TP-17 were not submitted for chemical analysis.
2. Soil representative of test pit TP-5 and TP-13 were removed during subsequent excavation.
3. Locations of features not shown on original site base map are approximate.
4. Samples RCU-SP and FO-SP were collected from tar pit excavation stockpile.

N

0 100 200
Scale in Feet

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Figure 2-4

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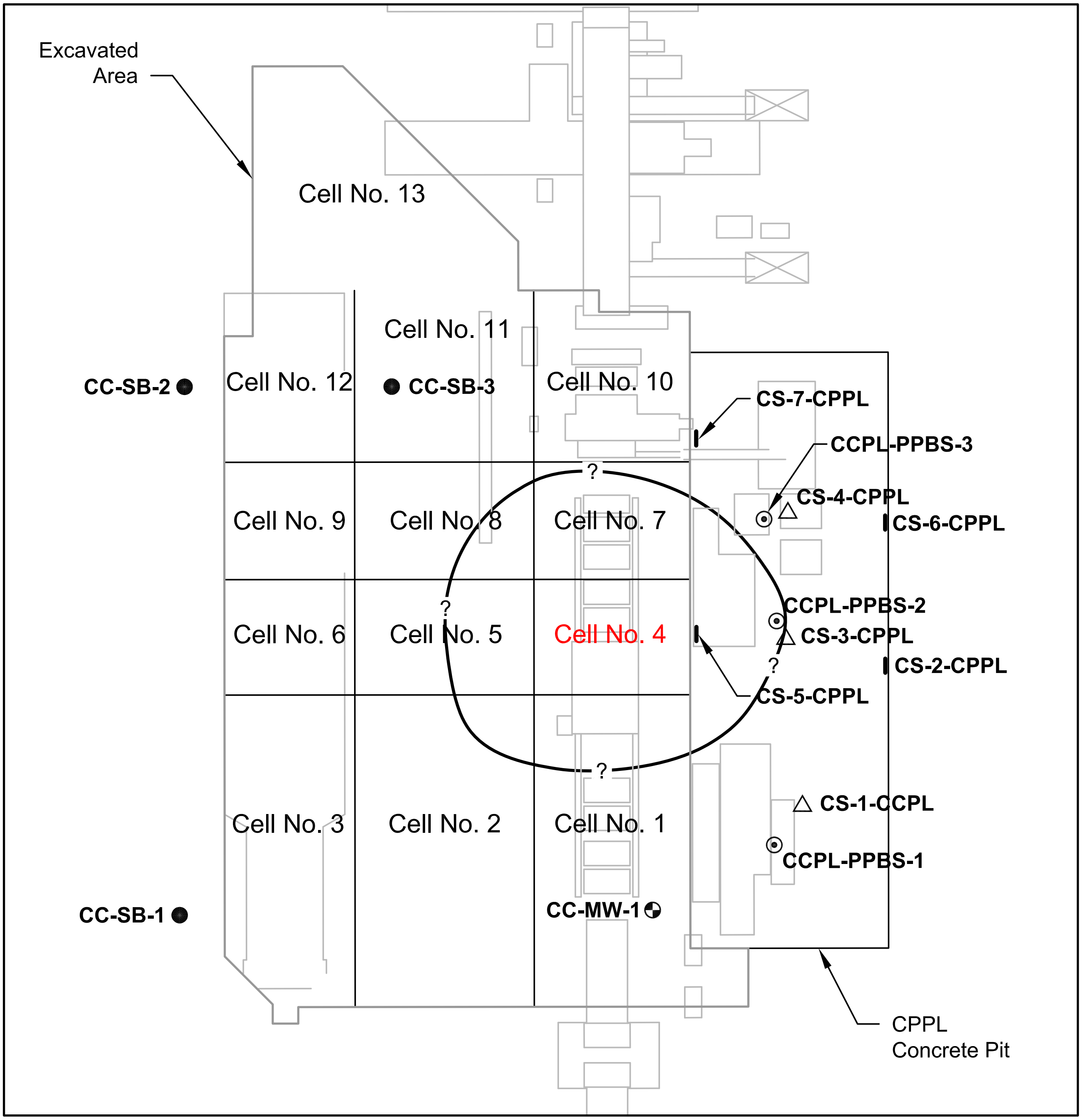
Cold Mill Continuous Can Process Line

Near-Surface Soil Screening - cPAHs



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Exploration Location and Number

Cell No. 4	Soil Sample with Screening Level Exceedance
CC-MW-1 ⊕	Monitoring Well
CC-SB-1 ●	Soil Boring
CCPL-PPBS-1 ⊙	Soil Sample (beneath Process Pit)
CS-1-CPPL △	Floor Concrete Sample
CS-7-CPPL ❙	Wall Concrete Sample
——?——	cPAH Area of Screening Level Exceedance

N

0 20 40

Scale in Feet

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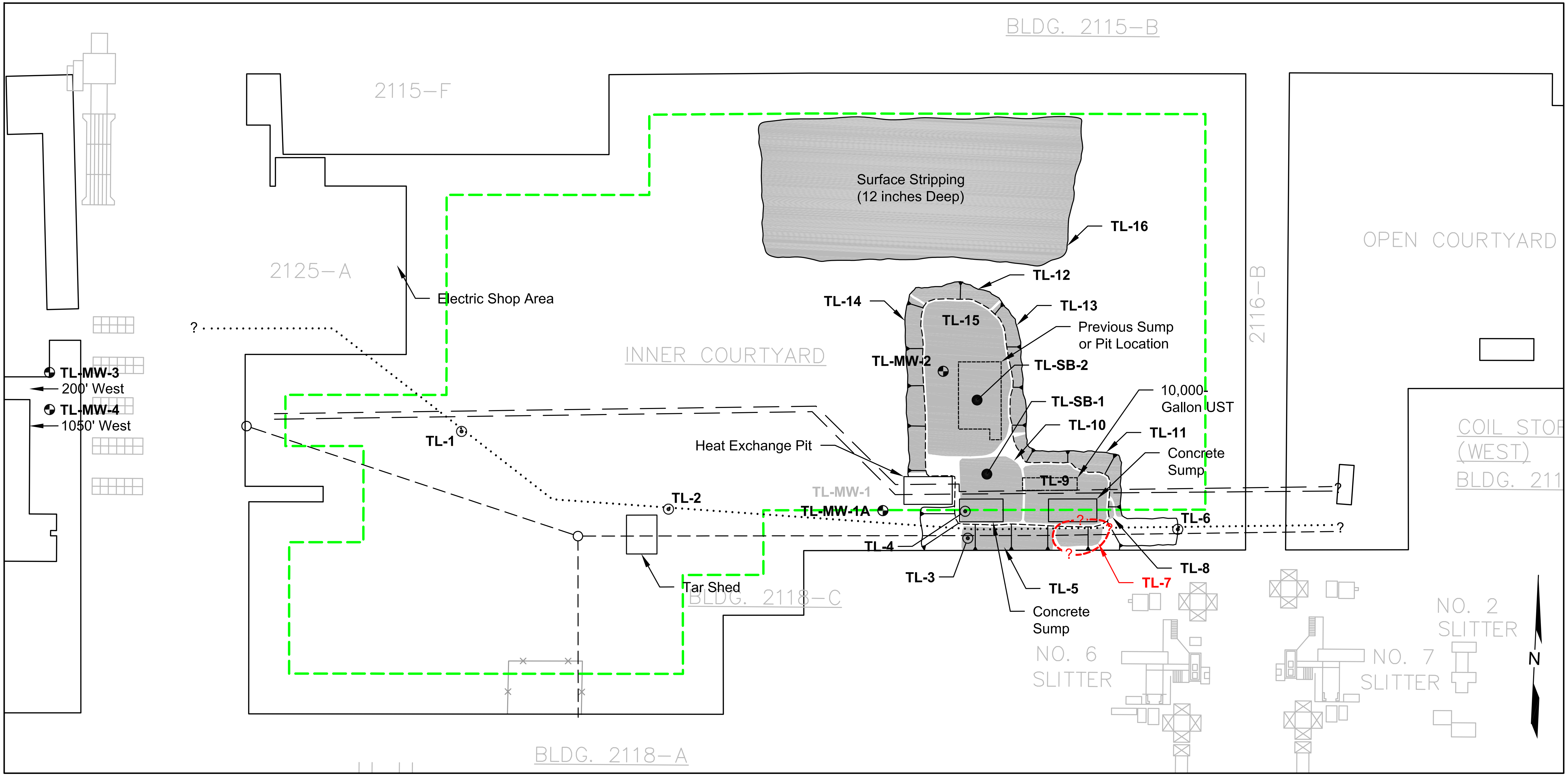
Figure 2-5a

Chromium Transfer Line

Near-Surface Soil Screening - Chromium



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Exploration Location and Number

TL-7 Soil Sampling Location with SL Exceedance

TL-MW-2 ◐ Monitoring Well (October 16, 1980)

TL-SB-2 ● Soil Boring (October 16, 1980)

TL-6 ⦿ Discrete Soil Sample

TL-15 Composite Soil Sample

· · · ⦿ · · · Manhole

· · · · · · · · Chromium Transfer Line

— — Existing Gravity Lines for Phosphate-Bearing Waste

— — — Storm Sewer Line

- - · ? · - - Chromium Area of SL Exceedance

- - - - - - 20-Foot No Excavation Zone Buffer Adjacent to Existing Building or Structure Foundation

Note: Gray shading denotes area of excavation.

0 50 100
Scale in Feet

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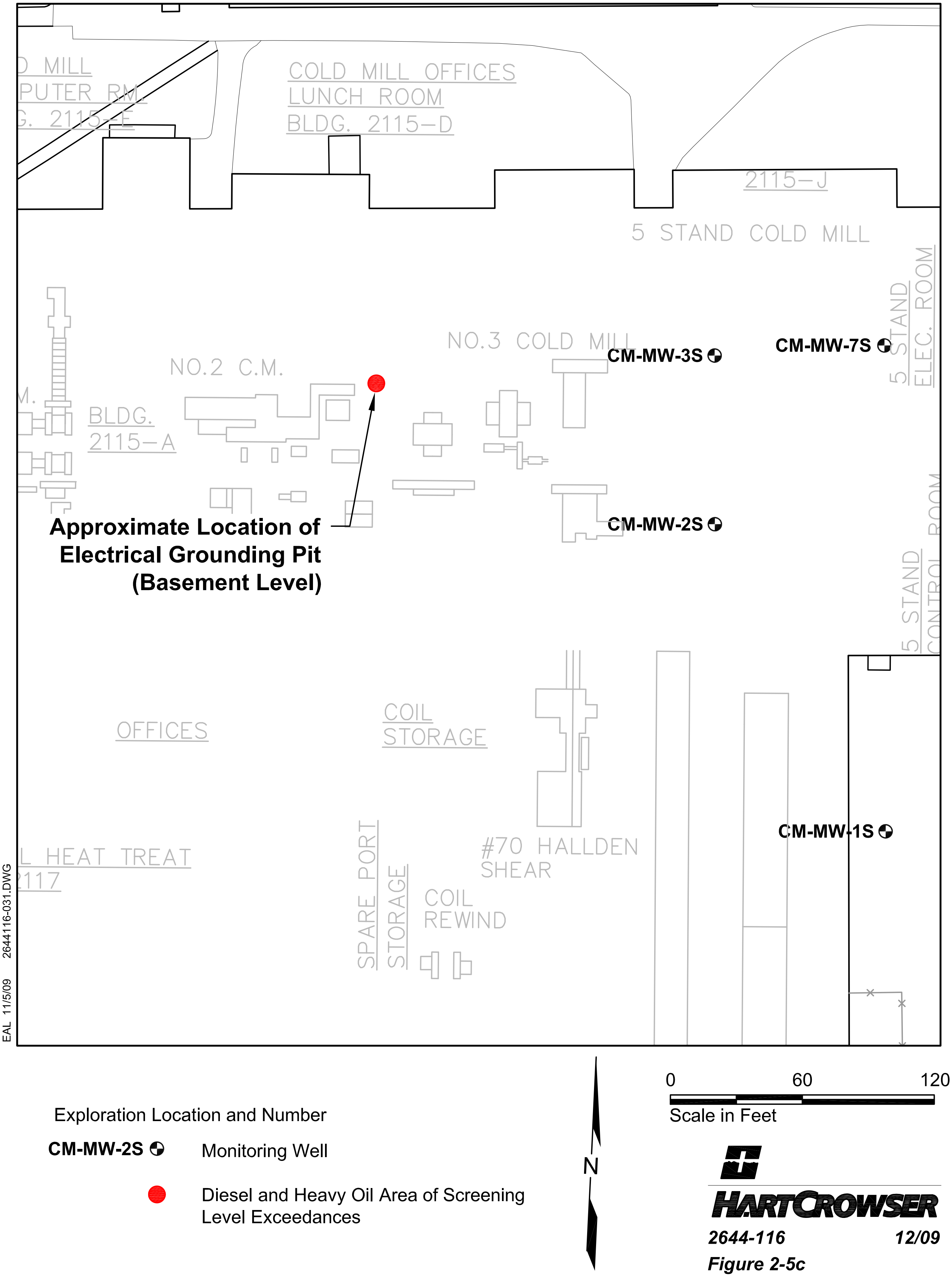
Figure 2-5b

Cold Mill Electrical Grounding Pit

Near-Surface Soil Screening - Diesel and Heavy Oil



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Exploration Location and Number

CM-MW-2S ◐ Monitoring Well

● Diesel and Heavy Oil Area of Screening Level Exceedances

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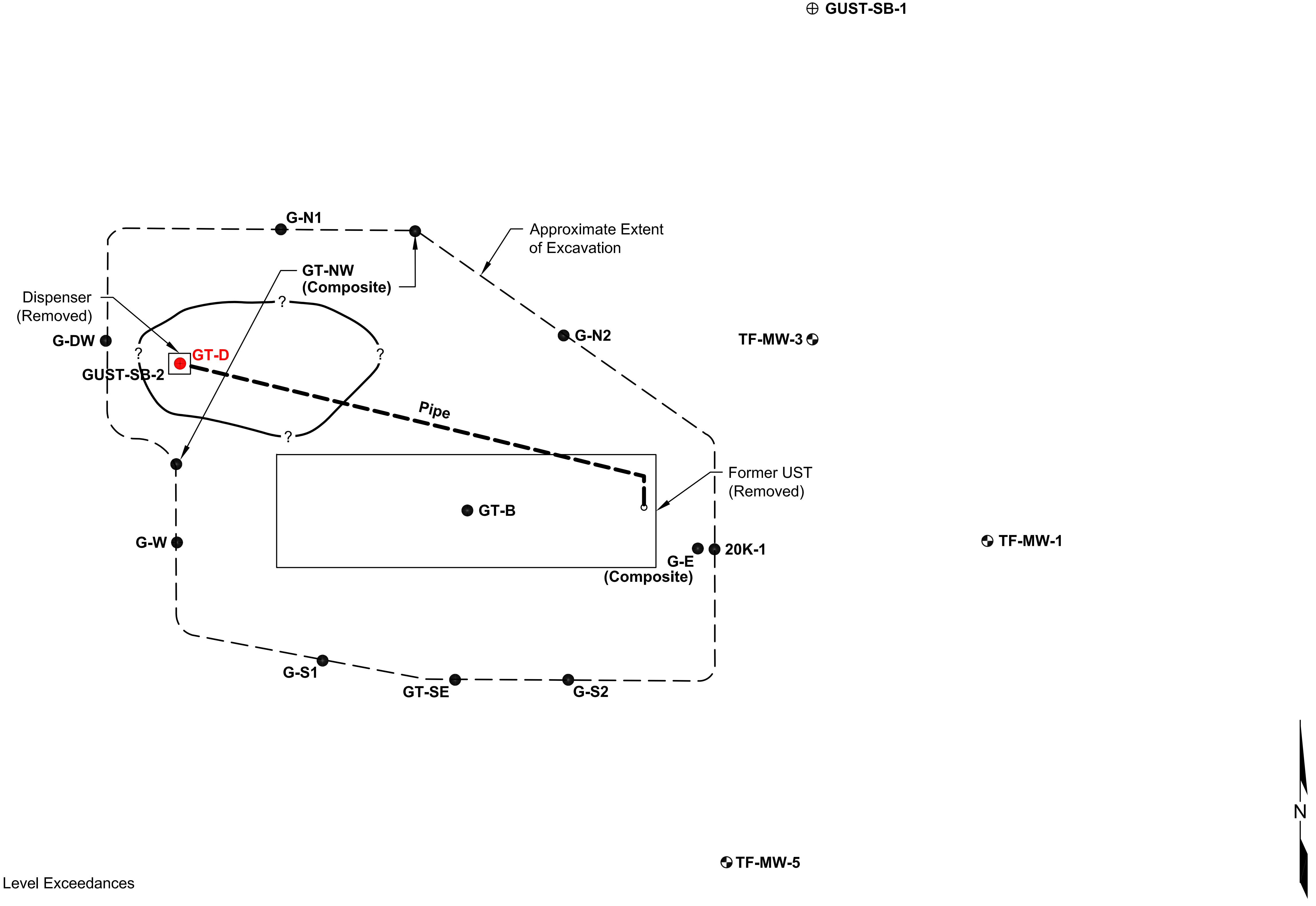
Figure 2-5c

20,000-Gallon Leaded Gasoline UST Excavation

Near-Surface Soil Screening - Gasoline



Exploration Location and Number

GT-D ●	Sample with Screening Level Exceedances
G-S1 ●	Soil Verification Sample
TF-MW-3 ◍	Existing Well
GUST-SB-1 ⊕	Soil Boring
—?—	Gasoline Area of Screening Level Exceedance

0 10 20
Scale in Feet

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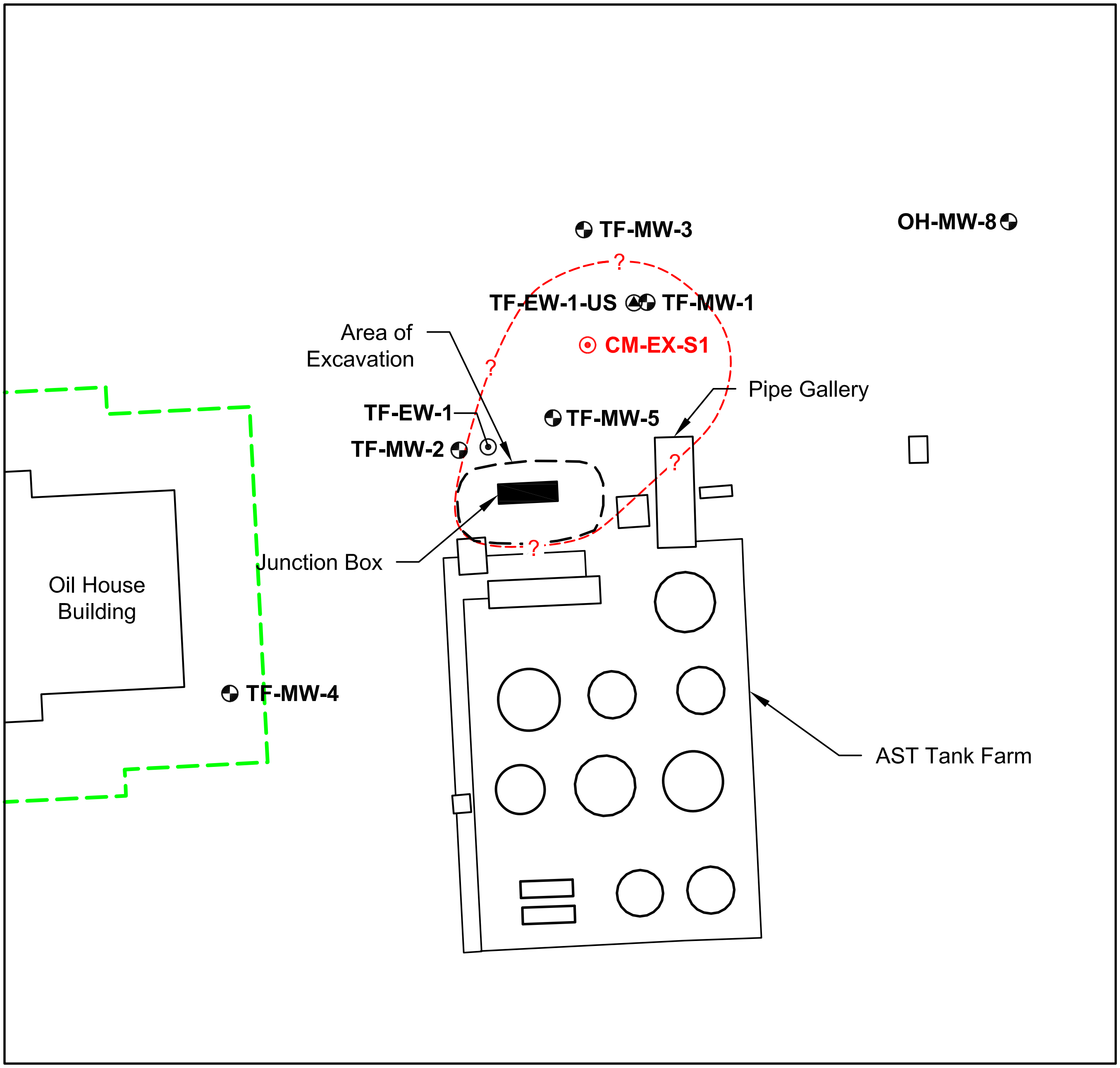
Figure 2-6a

Tank Farm Kensol Spill Area

Near-Surface Soil Screening - TPH



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Exploration Location and Number

TF-EW-1 ⦿ Extraction Well

TF-MW-4 ◕ Monitoring Well

TF-EW-1-US ◭ Groundwater Recirculation Well

CM-EX-S1 ⦿ Sample with Screening Level Exceedance

○ Above-ground Storage Tank

---?--- TPH Area of Screening Level Exceedance

— — — 20-Foot No Excavation Zone Buffer Adjacent to Existing Building or Structure Foundation

N

0 40 80

Scale in Feet

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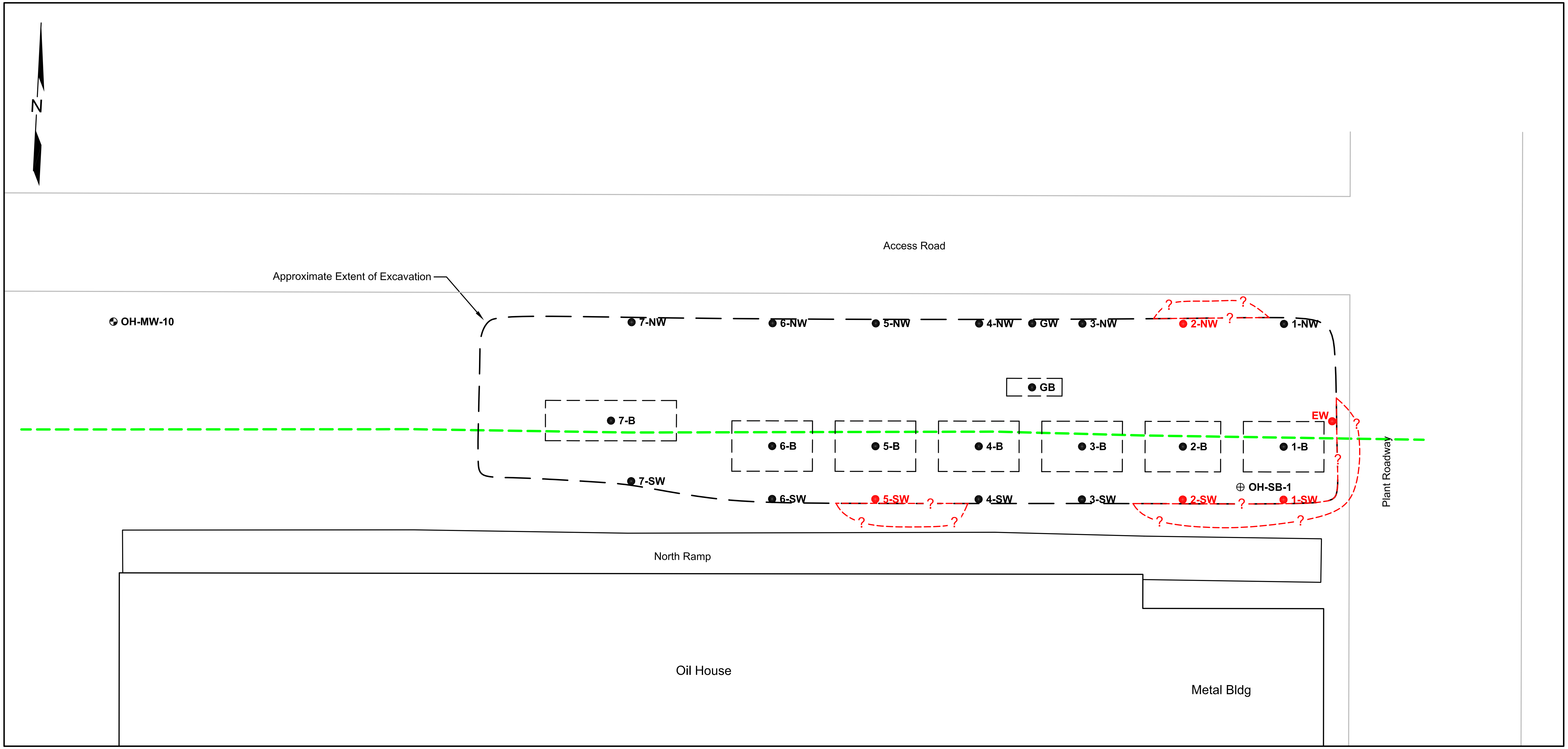
Figure 2-6b

Eight USTs Excavation

Near-Surface Soil Screening - Kensol



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Exploration Location and Number

5-SW ● Sample Location with Screening Level Exceedance

OH-MW-10 ◍ Monitoring Well

6-SW ● Soil Verification Sample

OH-SB-1 ⊕ Soil Boring

⬚ Former UST

- - - ? - - - Kensol Area of Screening Level Exceedance

— — — — 20-Foot No Excavation Zone Buffer Adjacent to Existing Building or Structure Foundation

0 20 40
Scale in Feet

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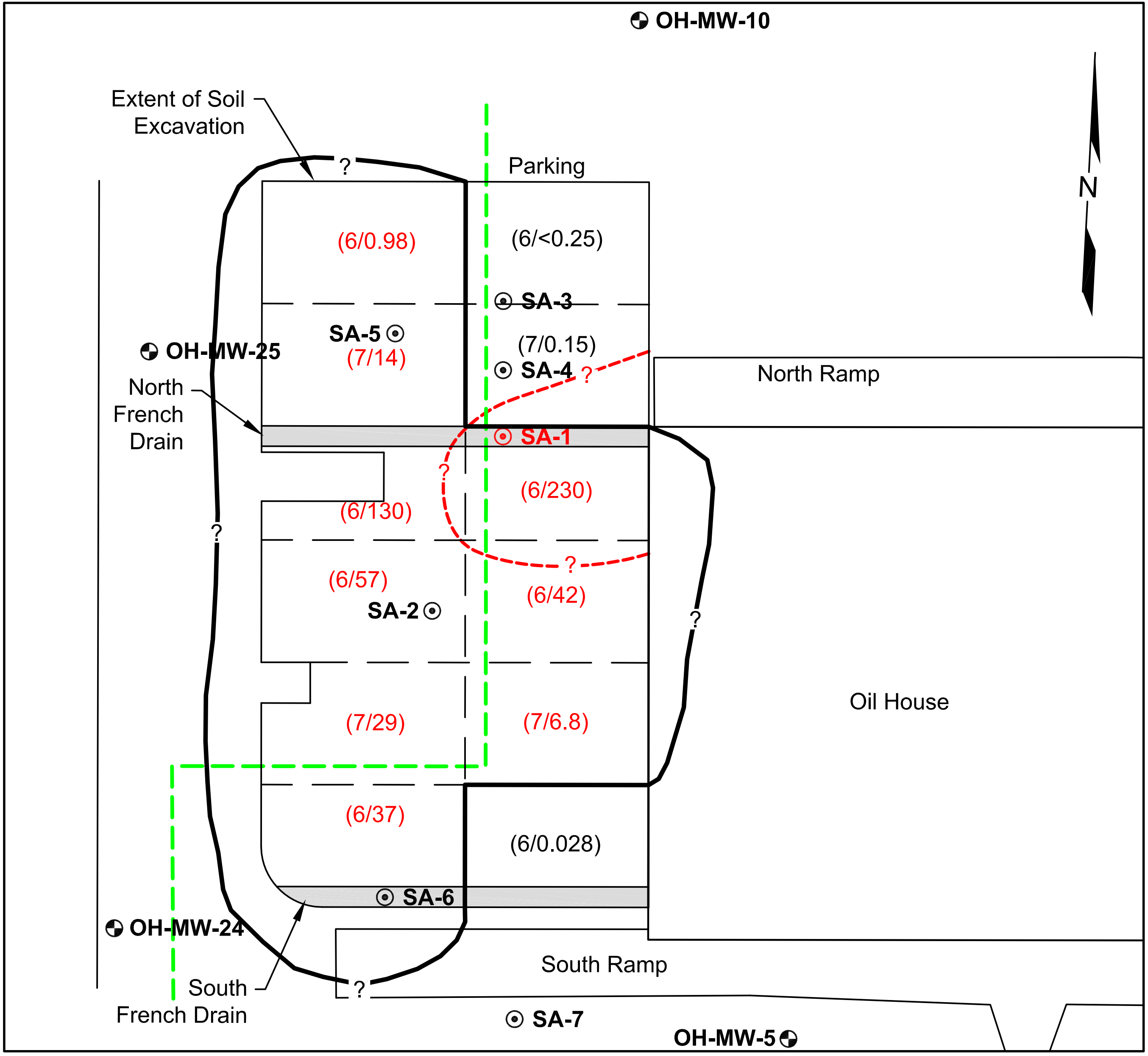
Figure 2-6c

Oil House Drum Storage and French Drain Area

Near-Surface Soil Screening - PCBs and TPH



EAL 11/5/09 2644116-017.DWG

Exploration Location and Number

SA-1 ⊙	Sample Location with Screening Level Exceedance
SA-2 ⊙	Storage Area Soil Boring
OH-MW-4 ⊕	Soil Boring and 4-inch Monitoring Well
— — —	Zones for Composite Sampling of Excavation Floor
(6/<0.25)	Depth of Excavation in Feet/Composited PCB Concentration in mg/kg
——?——	PCB Area of Screening Level Exceedance
- - - -?- - - -	TPH Area of Screening Level Exceedance
— — — —	20-Foot No Excavation Zone Buffer Adjacent to Existing Building or Structure Foundation

0 20 40

Scale in Feet

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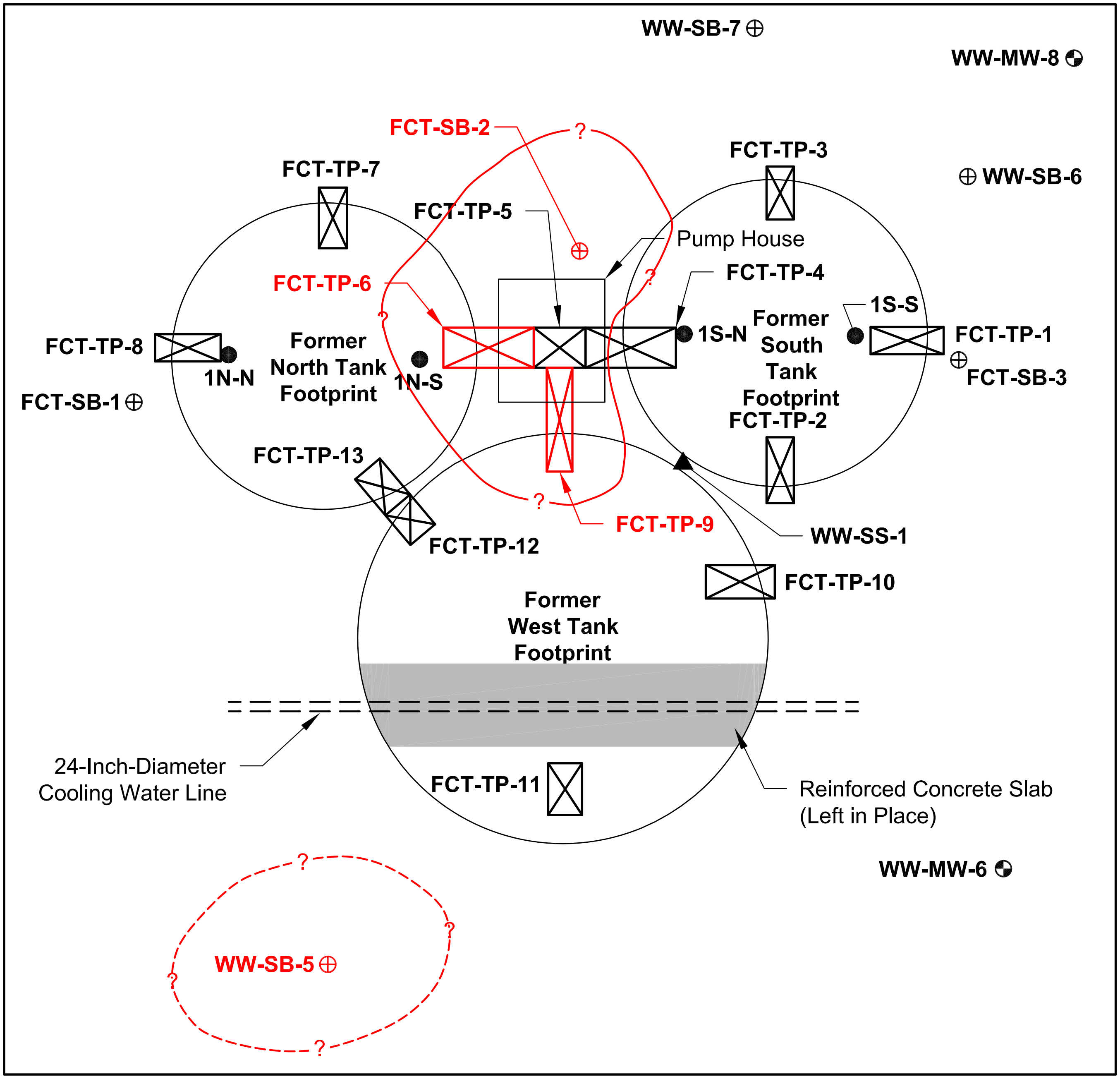
Figure 2-6d

Field-Constructed Tanks

Near-Surface Soil Screening - Diesel, Heavy Oil, and TPH



EAL 11/5/09 2644116-015.DWG

Exploration Location and Number

FCT-TP-1 ☒	Test Pit
FCT-SB-1 ⊕	Soil Boring
WW-MW-6 ◕	Monitoring Well
WW-SS-1 ▲	Surface Soil Sample
1S-N ●	Near-Surface Soil Sample
WW-SB-5 ⊕	Sample Location with Screening Level Exceedance
—?—	Diesel and Heavy Oil Area of Screening Level Exceedance
---?---	TPH Area of Screening Level Exceedance

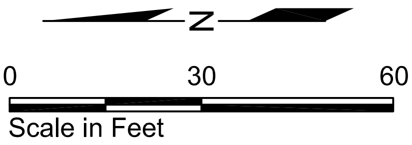


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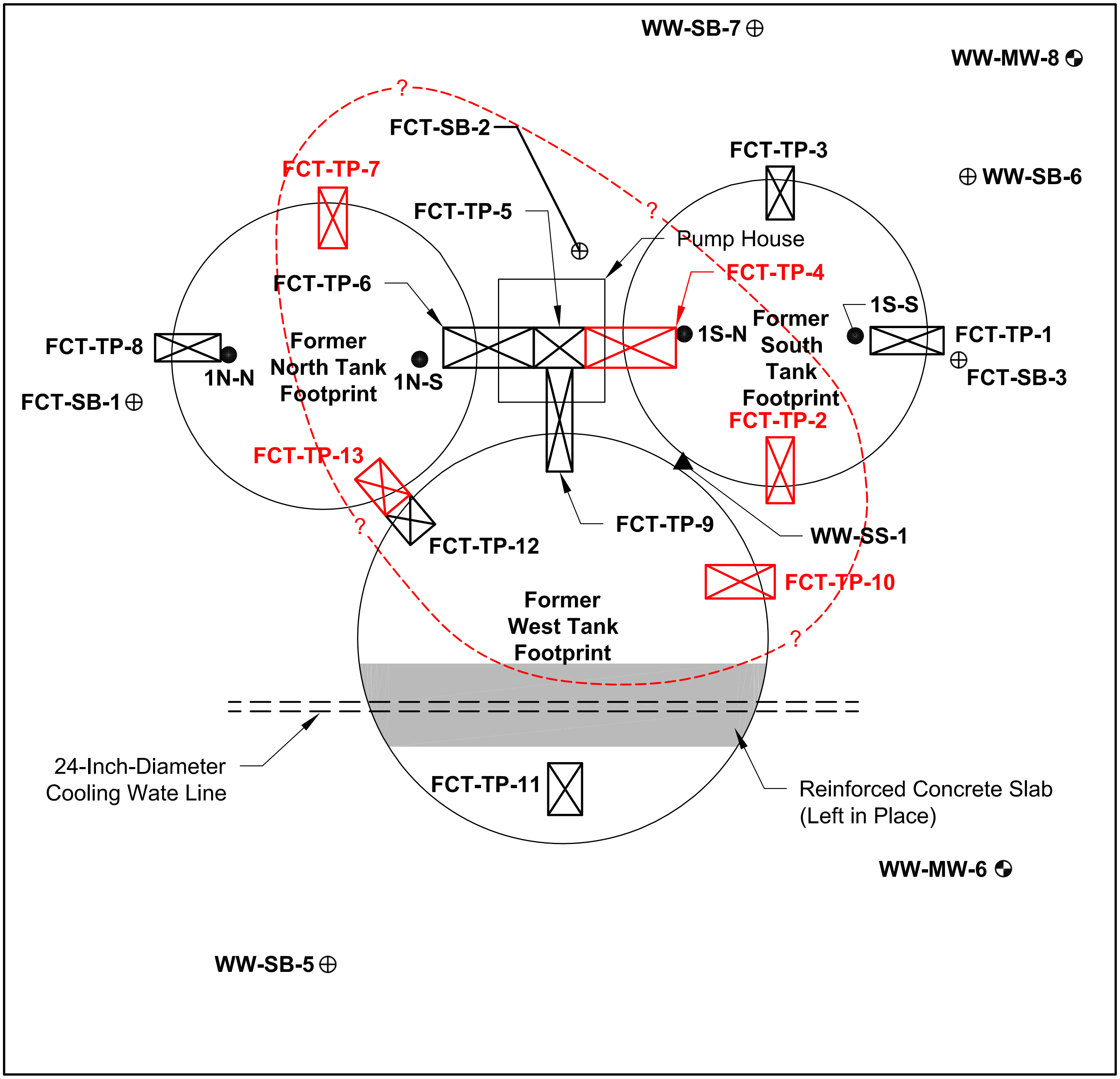
Figure 2-7a

Field-Constructed Tanks

Near-Surface Soil Screening - Arsenic



EAL 11/5/09 2644116-068.DWG

Exploration Location and Number

FCT-TP-1 ☒	Test Pit
FCT-SB-1 ⊕	Soil Boring
WW-MW-6 ◒	Monitoring Well
WW-SS-1 ▲	Surface Soil Sample
1S-N ●	Near-Surface Soil Sample
FCT-TP-10 ☒	Sample Location with Screening Level Exceedance
---?---	Arsenic Area of Screening Level Exceedance

N

0 30 60

Scale in Feet

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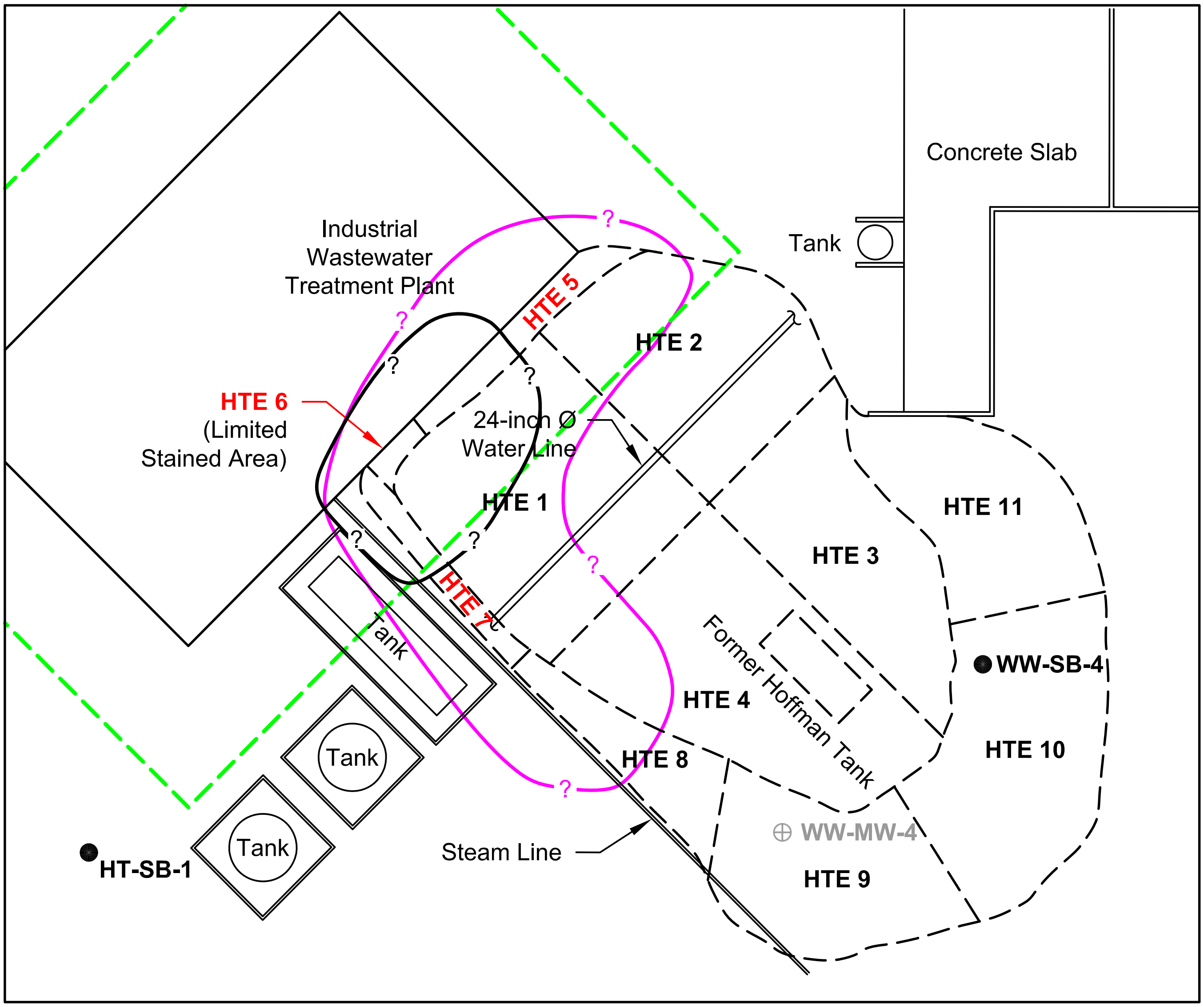
Figure 2-7b

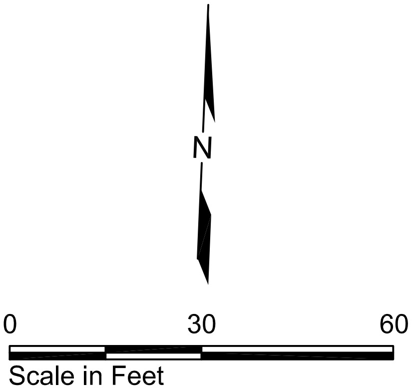
Hoffman Tank Excavation

Near-Surface Soil Screening - Arsenic and TPH



Exploration Location and Number

HTE 9	Sample Location wtih SL Exceedance
● **HT-SB-1**	Soil Boring
⊕ **WW-MW-4**	Monitoring Well (Abandoned)
HTE 9	Composite Soil Sample
— — —	Approximate Limits of Soil Excavation
—?—	Arsenic Area of Screening Level Exceedance
—?—	TPH Area of Screening Level Exceedance
— — —	20-Foot No Excavation Zone Buffer Adjacent to Existing Building or Structure Foundation



EAL 11/5/09 2644116-005.DWG

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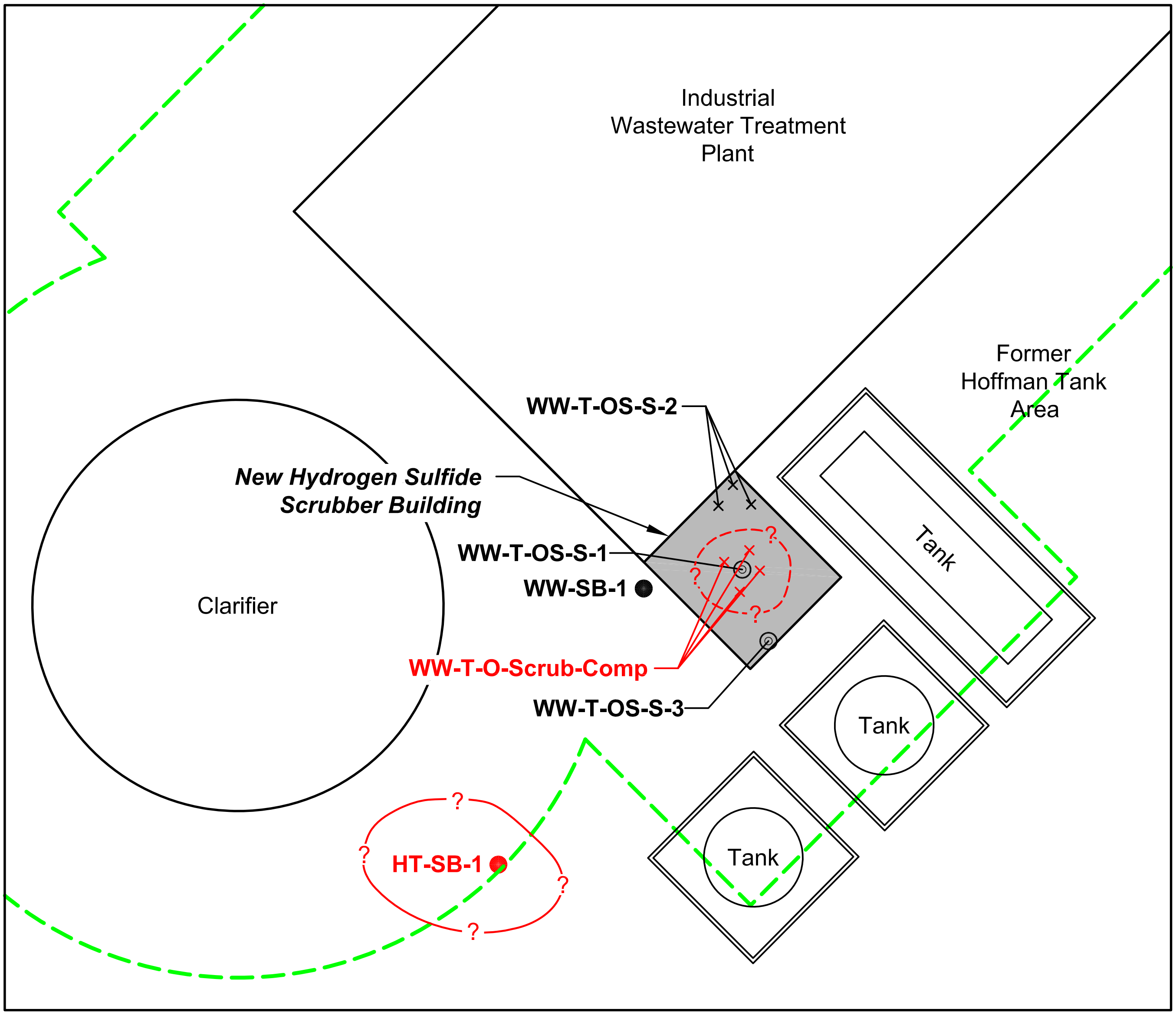
Figure 2-7c

Hydrogen Sulfide Scrubber Building

Near-Surface Soil Screening - Diesel, Heavy Oil, and Arsenic



2644116-006.DWG

EAL 11/5/09

Exploration Location and Number

Source: Base map prepared from Jeddeloh, Hays, Inc. titled "General Plant Lites," dated December 11, 1998.

WW-T-OS-S-3 ◎ Discrete Soil Sample

WW-T-OS-S-2 × Composite Soil Sample

WW-SB-1 ● Soil Boring

HT-SB-1 ● Sample Location with Screening Level Exceedance

▨ Excavated Area

——?—— Arsenic Area of Screening Level Exceedance

- - - - -?- - - - - Diesel and Heavy Oil Area of Screening Level Exceedance

— — — — 20-Foot No Excavation Zone Buffer Adjacent to Existing Building or Structure Foundation

N

0 20 40

Scale in Feet

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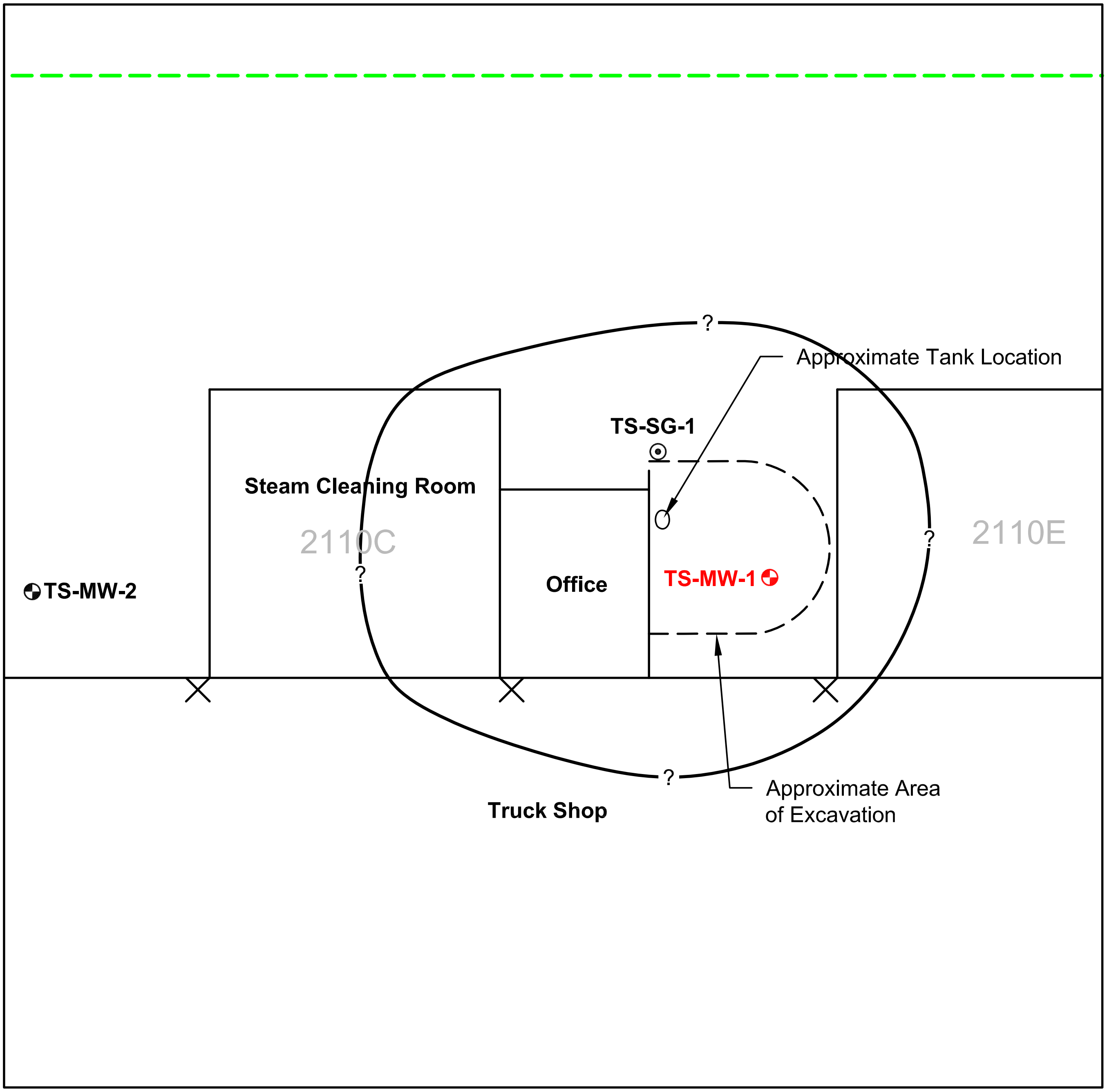
Figure 2-7d

Truck Shop Tank Area

Near-Surface Soil Screening - Heavy Oil and Stoddard Solvent



EAL 11/05/09 2644116-004.DWG

Exploration Location and Number

TS-MW-1 ◒ Sample Location with Screening Level Exceedance

TS-MW-2 ◒ Monitoring Well

TS-SG-1 ⊙ Soil Gas Probe

—?— Heavy Oil and Stoddard Solvent Area of Screening Level Exceedance

– – – 20-Foot No Excavation Zone Buffer Adjacent to Existing Building or Structure Foundation

N

0 10 20

Scale in Feet

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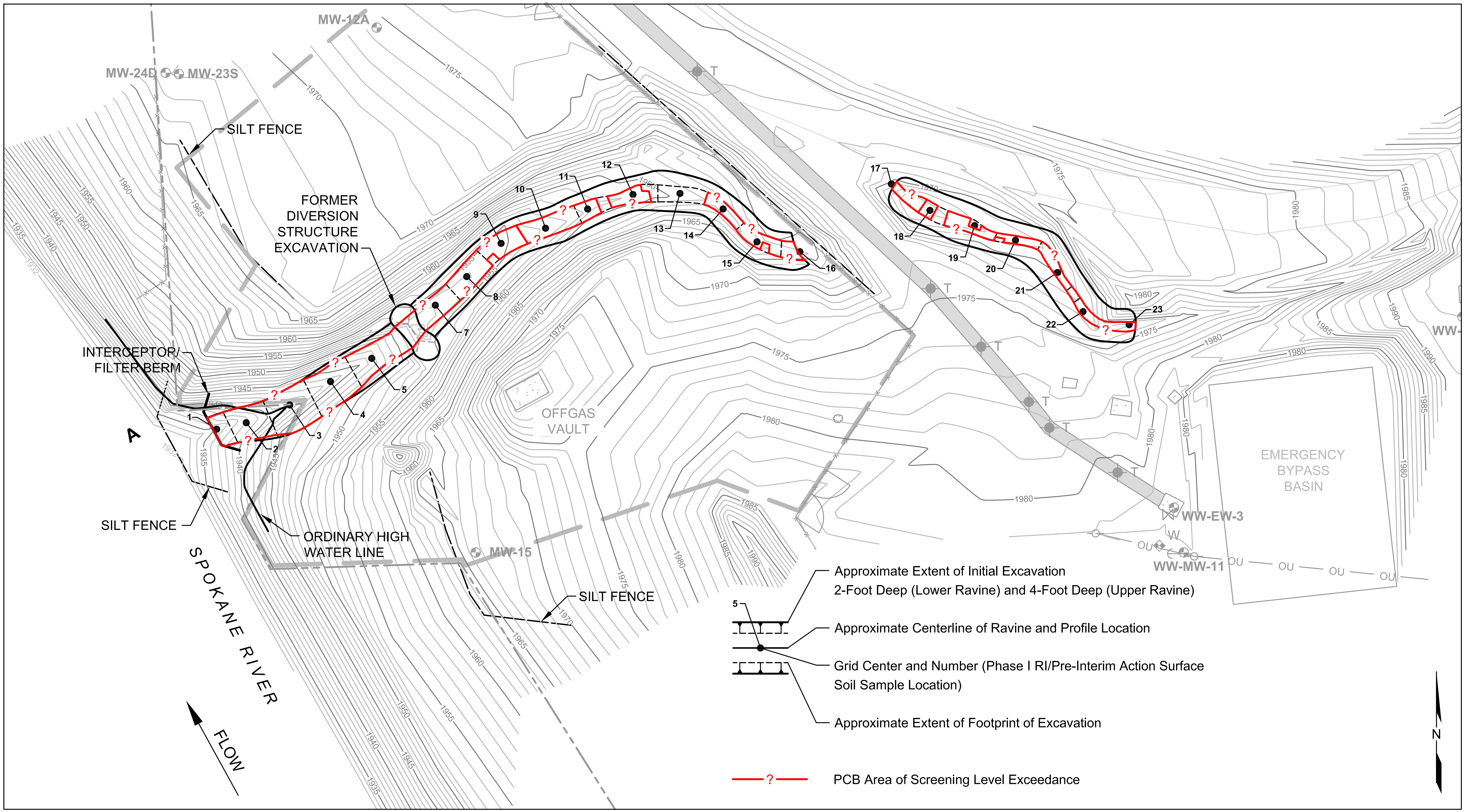
Figure 2-8

Former West Discharge Ravine

Near-Surface Soil Screening - PCBs



0 50 100
Scale in Feet

EAL 11/5/09 2644116-010.DWG

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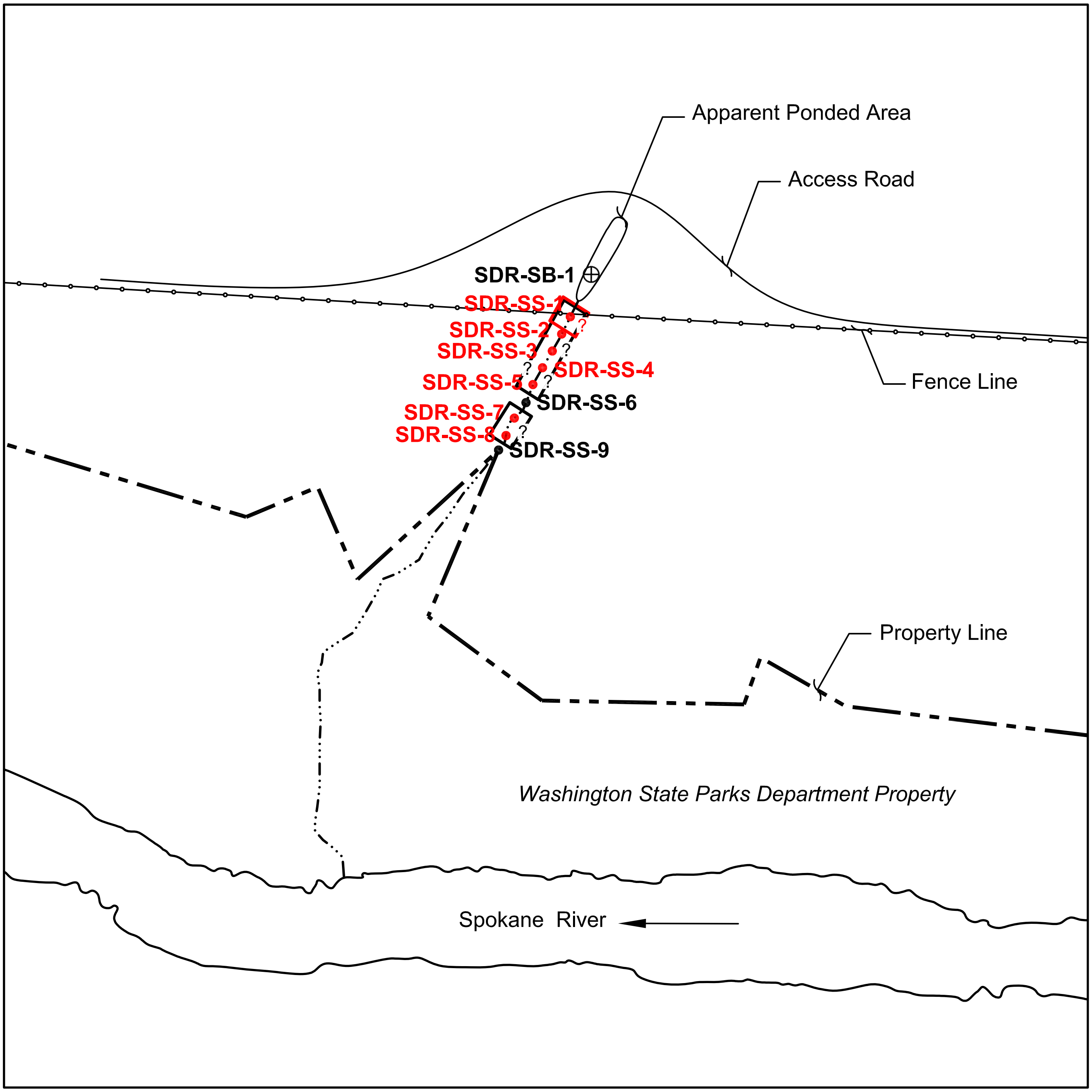
2644-116 12/09

Figure 2-9a

Former South Discharge Ravine

Near-Surface Soil Screening - Heavy Oil and PCBs



EAL 11/05/09 2644116-018.dwg

Exploration Location and Number

SDR-SB-1 ⊕	Boring
SDR-SS-6 ●	Surface Soil Sample
SDR-SS-1 ●	Sample Location with Screening Level Exceedance
—?—	Heavy Oil Area of Screening Level Exceedance
—?—	PCB Area of Screening Level Level Exceedance

0 200 400

Scale in Feet

N

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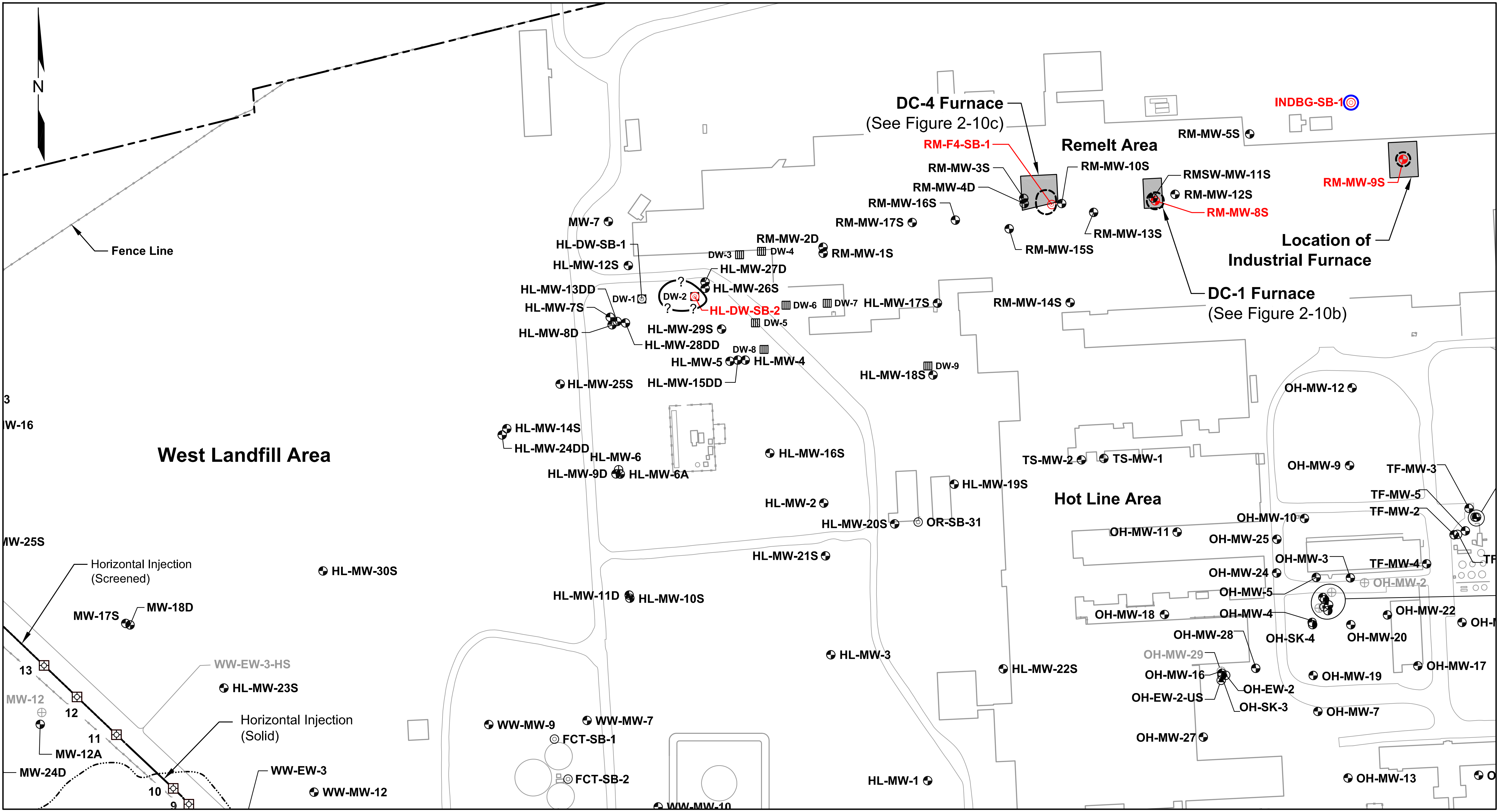
Figure 2-9b

Remelt/Hot Line Area Index Map

Near-Surface Soil Screening - Heavy Oil and PCBs



Exploration Location and Number

OH-EW-1 ⊙ Extraction Well

OH-MW-4 ⊕ Monitoring Well

WW-TL-MW-1 ⊕ Abandoned Monitoring Well

OH-SK-1 ◑ Skimming Well

TF-EW-1-US ⊛ Groundwater Recirculation Well

North Supply Well ● Supply Well

East Supply Well ● Backup Supply Well

RM-F4-SB-1 ◎ Soil Boring

DW-1 ▥ Dry Well

---?--- PCB Area of Screening Level Exceedance

—?— Heavy Oil Area of Screening Level Exceedance

—?— PCB and Heavy Oil Area of Screening Level Exceedance

INDBG-SB-1 ◎ Sample Location with Screening Level Exceedance

Note: Post-2003 RI/FS explorations shown in red.

0 200 400

Scale in Feet

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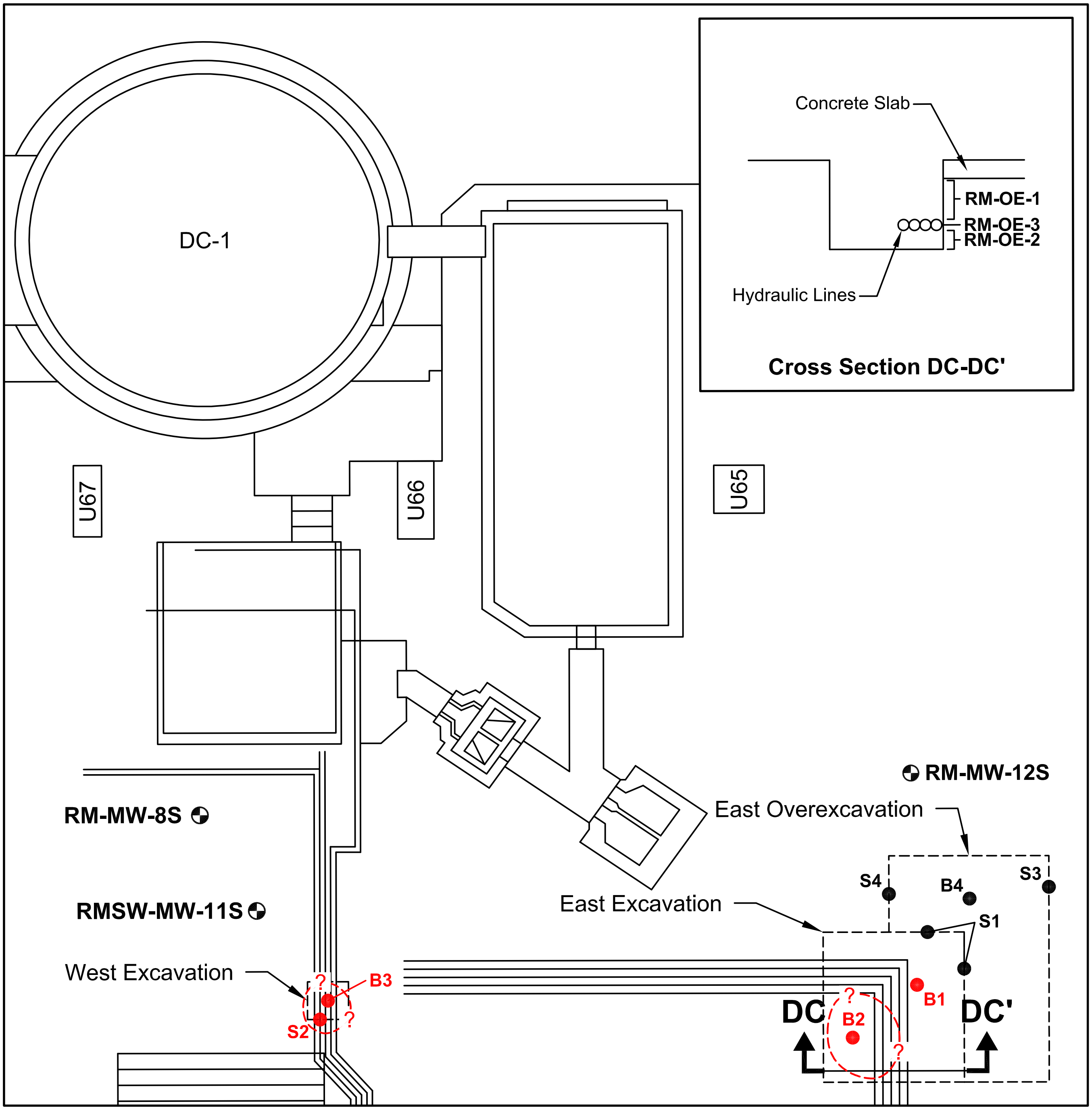
Figure 2-10a

EAL 11/5/09 2644116-027.DWG

DC-1 Furnace Area

Near-Surface Soil Screening - PCBs



EAL 11/5/09 2644116-007.DWG

Exploration Location and Number

B1 ● Sample with Screening Level Exceedance

S1 ● Soil Sample

RM-MW-8S ⊕ Monitoring Well

DC DC' Cross Section Location and Designation

----?---- PCB Area of Screening Level Exceedance

Note: Samples WT1 through WT6 collected in West Excavation prior to overexcavation.

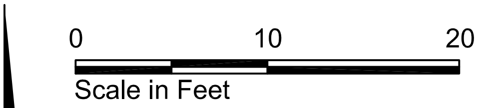


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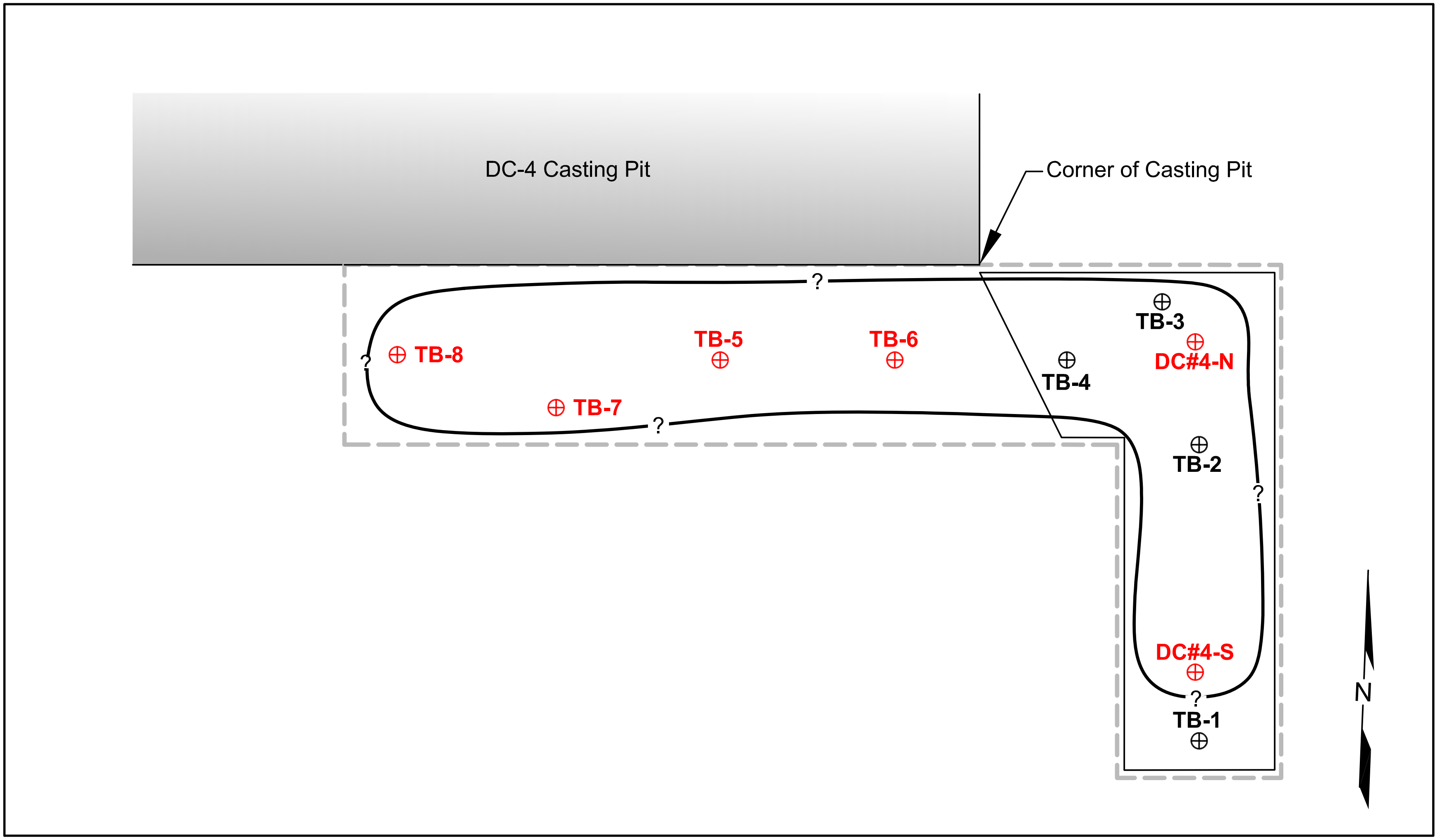
Figure 2-10b

DC-4 Furnace Vent Trench
Near-Surface Soil Screening - PCBs



EAL 11/5/09 2644116-008.DWG

Source: Base map prepared from field drawings completed 06/19/06.

Note: Samples DC#4-N and DC#4-S collected following overexcavation.

Exploration Location and Number

▭ (dashed)	Approximate Trench Limits
▭	Overexcavation Area
⊕ **TB-1**	Soil Verification Sample
⊕ **TB-5**	Sample Location with Screening Level Exceedance
—?—	PCB Area of Screening Level Exceedance

0 3 6
Scale in Feet

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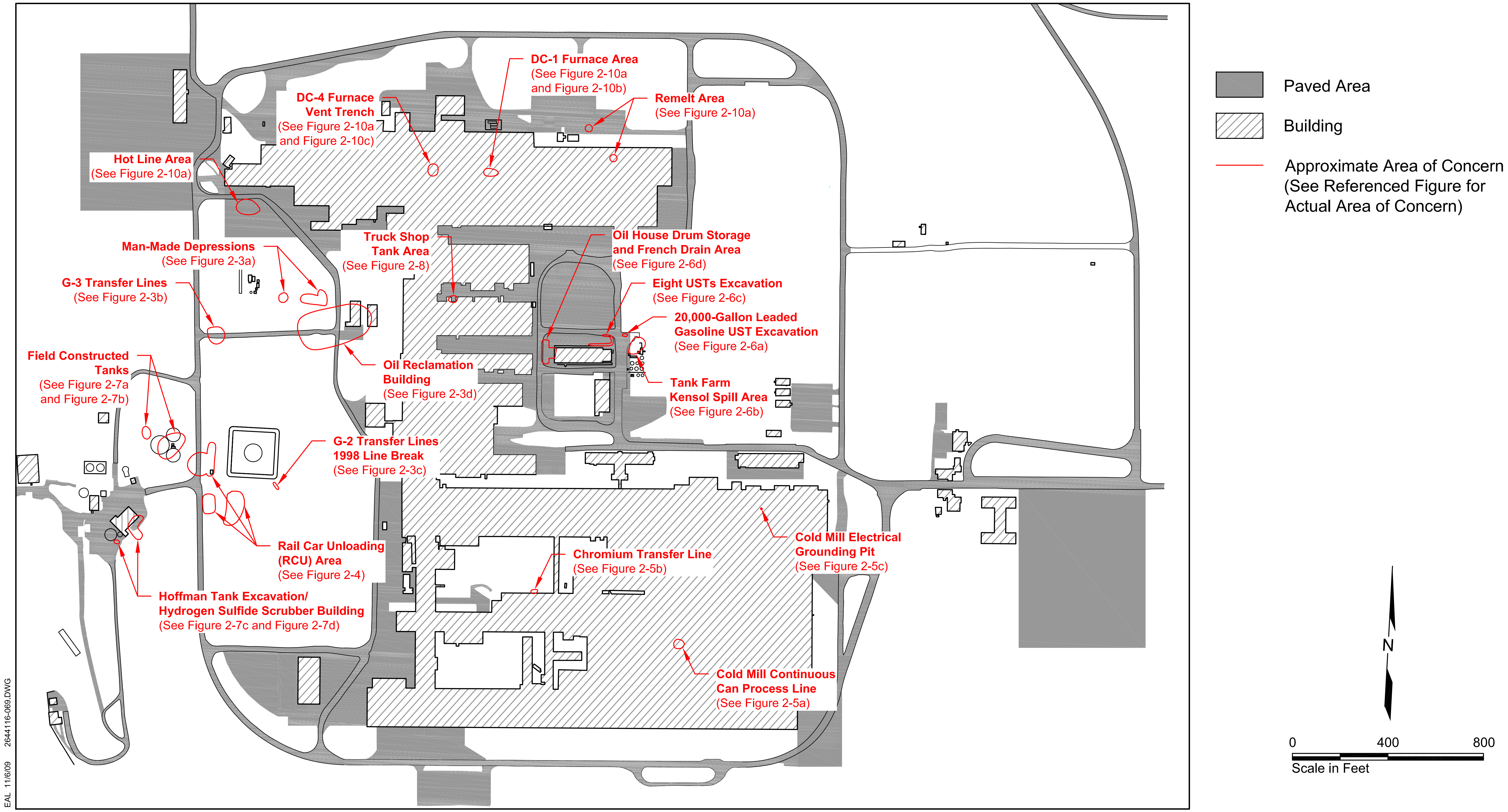
2644-116 ***12/09***
Figure 2-10c

AOC Locations within Paved Area



EAL 11/6/09 2644116-069.DWG

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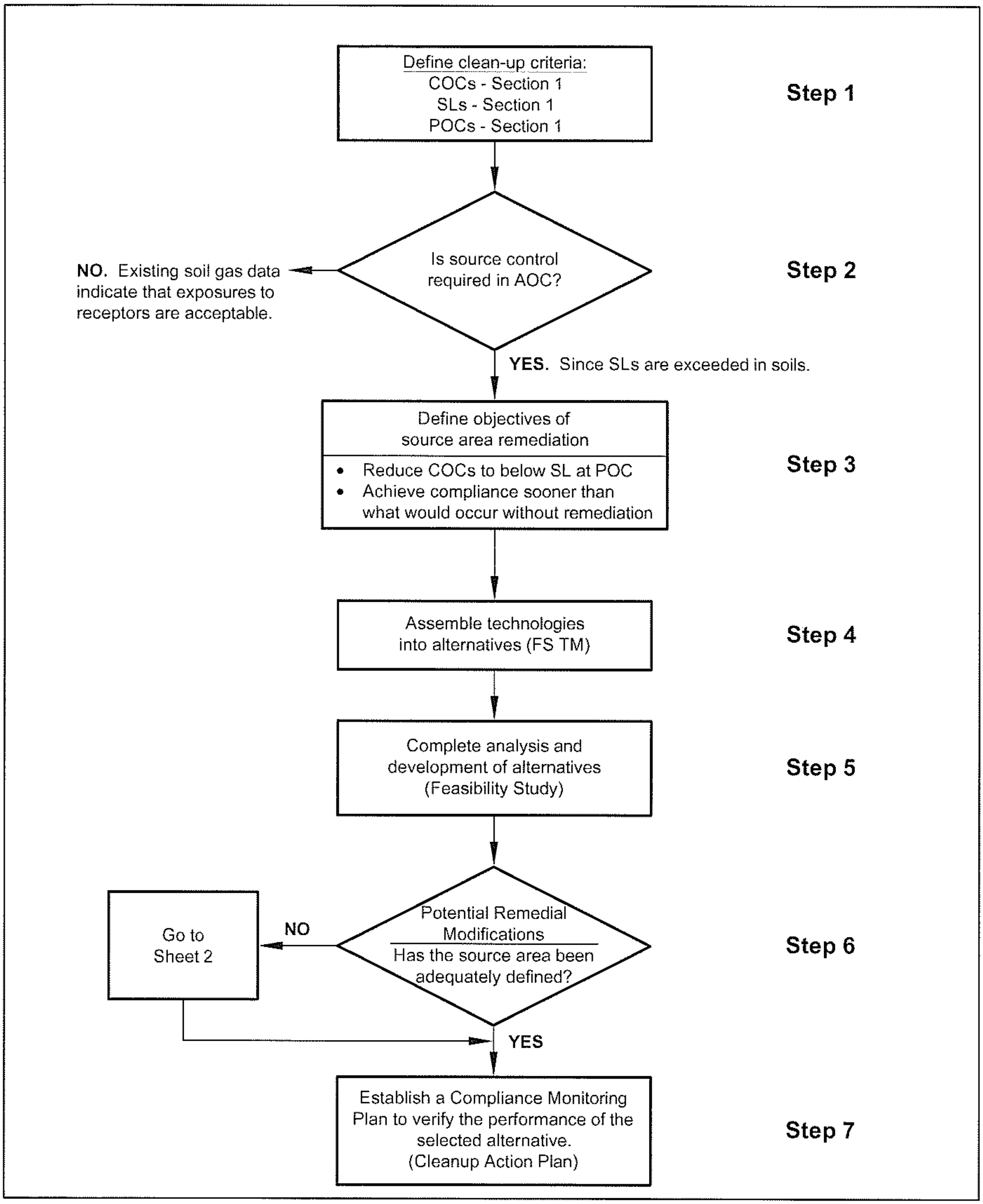
2644-116 12/09
Figure 2-11

Development of Remedial Alternatives for Near-Surface Soil



EAL 03/1/10 2644120-001.DWG

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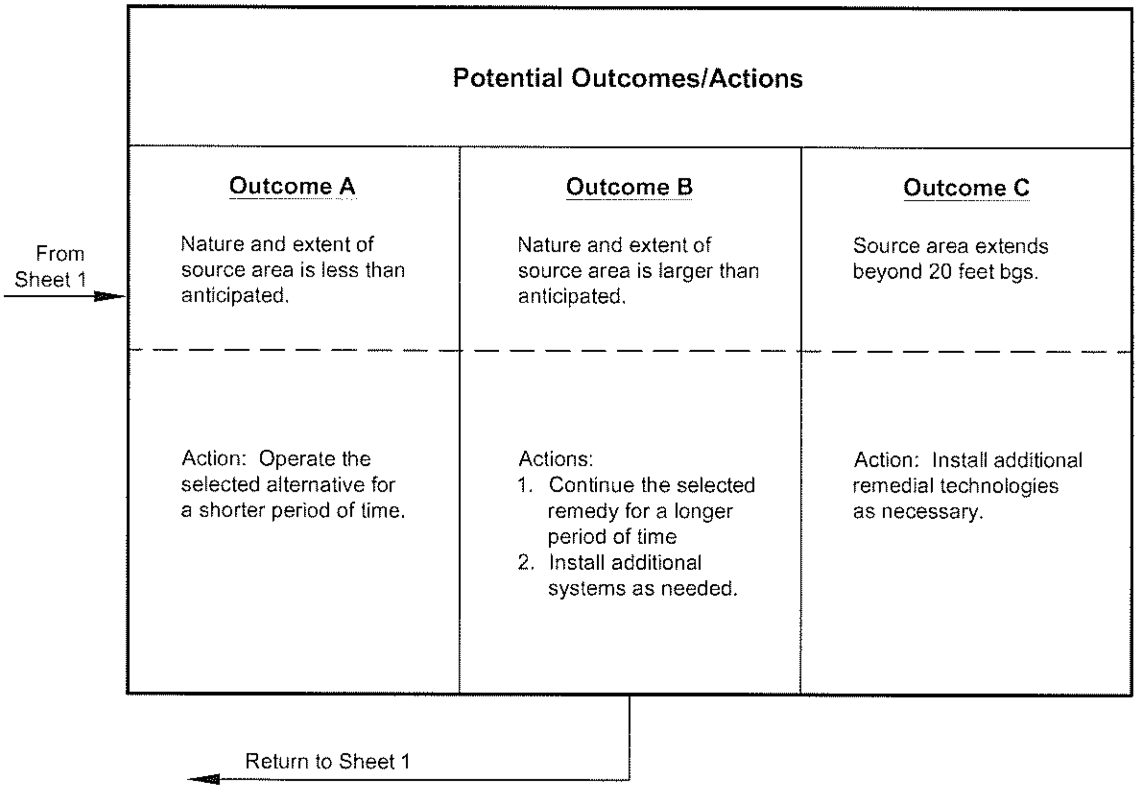
Figure 2-12 *(1 of 2)*

Development of Remedial Alternatives for Near-Surface Soil



Potential Outcomes/Actions		
Outcome A	**Outcome B**	**Outcome C**
Nature and extent of source area is less than anticipated.	Nature and extent of source area is larger than anticipated.	Source area extends beyond 20 feet bgs.
Action: Operate the selected alternative for a shorter period of time.	Actions: 1. Continue the selected remedy for a longer period of time 2. Install additional systems as needed.	Action: Install additional remedial technologies as necessary.

EAL 03/1/10 2644120-002.DWG

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TABLES

CONTENTS (Continued)

TABLES (Continued)

FIGURES

CONTENTS (Continued)

FIGURES (Continued)

3.0 CONTROL OF CONTAMINANTS OF CONCERN IN DEEP VADOSE ZONE SOILS

This FSTM evaluates the potential application of remedial technologies to address environmental issues in deep vadose zone soils throughout the 512 acre Kaiser Facility. Deep vadose zone soils are those soils that are located from 20 feet bgs to the top of the water table. As discussed in Section 1 of the Final Soil RI (Hart Crowser 2012b), three water table levels were assumed for the site based on April 2007 groundwater data: 68 feet bgs in the mill area (Oil Reclamation Building, Rail Car Unloading, Cold Mill/Finishing, Oil House, Truck Shop, and the Remelt/Hot Line areas), 55 feet bgs in the Wastewater Treatment area, and 33 feet bgs in the West Discharge Ravine area near the river wells and borings. Consistent with our approach in Sections 1 and 2, the discussion that follows divides the site into eight general operating areas.

This section of the FSTM focuses on the areas of the site where the concentration of COPCs in deep vadose zone soil was shown to exceed SLs. The general operating areas and applicable subsites that contain COPCs at concentrations above SLs in the deep vadose zone soils are listed in Table 3-1**.**

Because the interval of interest starts at 20 feet bgs, nearly all the data used in this section to evaluate the deep vadose zone soil was obtained during the installation of monitoring wells or soil borings. Base of excavation samples collected during the removals of the eight USTs in the Oil House area and the Hoffman Tank in the Wastewater area are the rare exceptions to this. Due to the nature of the soils at the Facility—gravel, cobbles, and coarse sands with very low organic matter—most soil contamination has been found in immediate source areas (i.e., at the base of former tanks/transfer lines) and in the smear zone at the groundwater interface. The estimated quantities of COCs in deep vadose zone soils is discussed in Section 3.5. Petroleum hydrocarbons in the diesel- and heavy oil-range (including TPH associated with PCBs in hydraulic oil) are estimated to compose about 98 percent of the estimated quantity of COCs in deep vadose zone soils, while PCBs are estimated to compose about 1.9 percent . Following removal of the sources of COCs in the soil from past releases, COCs at concentrations greater than residual soil saturation levels would naturally tend to flow downward toward the water table as the site soil offers relatively little resistance to this downward migration.

During past soil boring and monitoring well installations at the Facility, soil in the deep vadose zone was generally chemically analyzed only when reasonably representative samples could be obtained and there was evidence of the presence of COPCs such as visual indication, odors, or organic vapor analyzer evidence. This was particularly true of early environmental work at Kaiser in the late 1980s and early to mid 1990s where soil from numerous borings/wells was not chemically tested until the water table and the oil smear zone was reached. For these reasons fewer soil samples were collected from the deep vadose zone than from the near-surface (Section 2) or smear zone (Section 4) soil intervals. Results from nearly 850 samples were used in the Section 2 evaluation of the top twenty feet of soil across the site. The evaluation of deep vadose zone soil (up to a 48-foot depth interval in the mill area) discussed in this Section is based on a review of approximately 300 samples.

This section evaluates technologies that could be applicable to COCs in deep vadose zone (from 20 feet bgs to the top of the water table) soils. Section 3 is organized as follows:

- Section 3.1 – Potential Remediation Technologies for VOCs in Deep Vadose Zone Soils
- Section 3.2 – Potential Remediation Technologies for SVOCs in Deep Vadose Zone Soils
- Section 3.3 – Potential Remediation Technologies for PCBs in Deep Vadose Zone Soils
- Section 3.4 –Screening Technologies for Remediating Deep Vadose Zone Soils
- Section 3.5 – Description of Areas of Concern for Deep Vadose Zone Soils
- Section 3.6 – Development of Remedial Alternatives

COPCs in soils at the Facility were identified in Section 1.1. Screening levels (SLs) were then established for the COPCs in each medium (e.g., soil, groundwater) by developing risk-based SLs (RBSLs) following MTCA requirements, by consideration of site-specific conditions such as land use, and by comparison of the risk-based MTCA SLs with other chemical-specific applicable or relevant and appropriate requirements (ARARs). COPCs that exceed SLs are considered to be Constituents of Concern (COCs). The COCs identified for deep vadose zone soils in Section 1.2.2 fall into the following categories:

- Volatile Organic Compounds (VOCs)
- Semivolatile Organic Compounds (SVOCs)

- Total Polychlorinated Biphenyls (PCBs)

- Metals (arsenic, lead, iron, and manganese)

VOCs

Past investigations have identified two locations that contain VOC concentrations above SLs in the deep vadose zone soil. The two locations identified with VOC exceedances are the Oil House area at the Kensol spill and French Drain areas. For both the Kensol spill and French drain areas, the VOC of concern in deep vadose zone soil is Stoddard/mineral spirit range petroleum hydrocarbons. For the purposes of the FSTM technology evaluation, light-end TPH compounds in the gasoline range (e.g., gasoline and Stoddard solvent/ mineral spirits) are evaluated against technologies pertaining to VOCs.

SVOCs

For the purposes of this FSTM, SVOCs are considered to include carcinogenic polycyclic aromatic hydrocarbon (cPAHs) and TPH in the diesel- and heavy oil-ranges that have been identified as COCs.

TPH concentrations in soil have been evaluated at Kaiser for over 20 years. Several different TPH-containing products were used at the Facility, ranging from gasoline to heavy oils. The composition of the various TPH-containing products present at the site varies widely and is directly related to the associated toxicity and mobility of TPH compounds through the soil. By far, the majority of TPH compounds found in impacted soil at Kaiser were in the diesel- and heavy oil-range and at least one TPH compound has been identified in soil at every investigation site at Kaiser. Due to their similar physical properties diesel- and heavy oil-range TPH compounds (e.g., Kensol, diesel, heavy oil, Bunker C) are evaluated by technologies pertaining to SVOCs in the remedial technology evaluation presented in Section 3.2 of this FSTM.

Diesel and heavy oil were found in deep vadose zone soils in the ORB (Man-Made Depressions), Oil House (French Drain), Truck Shop, and in some Hot Line wells and borings. Diesel fuel oil measured by the NWTPH-HCID or 418.1 Methods was found in deep vadose soils in the RCU, Eastern Cold Mill/Finishing area, Oil House (Kensol Spill, Oil House Tank) and Waste Water Treatment (Hoffman Tank area) areas. Kensol was the only SVOC-range TPH found in the Oil House (Kensol spill, eight tanks, and French Drain areas) area. No cPAH compounds were detected in deep vadose zone soil at the site in exceedance of SLs.

Polychlorinated Biphenyls (PCBs)

Soil testing conducted at Kaiser since the late 1980s has included analysis for the various Aroclors that were commonly used prior to their being banned from manufacturing in the United States in the 1970s.

The areas identified with PCBs exceedances in deep vadose zone soils include the Remelt/Casting Area, the Wastewater Treatment area (Hoffman Tank), and the Oil House French Drain area (Figure 2-1).

Metals

Chromium is present at a concentration above its SL in a small area in the inner courtyard of the Cold Mill/Finishing area (refer to Appendix C). This area was previously excavated to remove contaminants. The remaining chromium appears to be located below the excavation.

Arsenic is present at concentrations above its SL in four locations within the Oil House area (Oil House Tank area and Eight UST area), the Wastewater Treatment area (H_2S Scrubber Building area) and the Remelt/Hot Line area (refer to Appendix C). The arsenic AOC in the Oil House Tank area is co-located or adjacent to an SVOC AOC. The arsenic AOCs in the H_2S Scrubber Building and Remelt/Hot Line areas are small in size, isolated from other AOCs, and were established based upon results from one sample location.

Cadmium was excluded as a COC since it has no on-site source and was judged to be a background constituent. There is no known source of cadmium at the Kaiser Facility and there were only a few soil samples with minor exceedances to the background ranges (Ecology 1994) for the Spokane Area and SL, which is based on the fixed parameter, three-phase model in the MTCA - (see Section 1.2.2 for more detail).

Iron and manganese were considered by the Final Groundwater RI as presenting secondary (aesthetic) effects to groundwater. The manganese concentrations measured in site soils were within the natural background concentration range of this element in the Spokane area. Site soil samples were not analyzed for iron. Contaminant-specific technologies to remediate the relatively small and isolated (from one another) AOCs where chromium and arsenic are present at concentrations above SLs are not discussed in this FSTM. It was judged that the remediation of the isolated chromium AOC and the arsenic AOCs would be accomplished by many of the technologies used to remediate the SVOCs in deep vadose soil (Section 3.4.2.4). A separate discussion of the application of these technologies to these small isolated AOCs was considered to be unnecessary.

Summary

This feasibility study focuses on remedial alternatives that will effectively treat VOCs, SVOCs (diesel and heavy oil), and PCBs. The areas of the site where potential COCs within these groups can be found are cited above and listed in Table 3-1.

The technologies that may be appropriate for remediating VOCs in deep vadose soils are discussed in Section 3.1; the technologies that may be appropriate for remediating SVOCs in soils are discussed in Section 3.2; and finally, technologies for remediating PCBs in deep vadose soils are discussed in Section 3.3.

The approach used to screen the technologies identified in Sections 3.1 to 3.3 and the screening of these technologies is discussed in Section 3.4.

3.1 POTENTIAL REMEDIATION TECHNOLOGIES FOR VOCS IN DEEP VADOSE ZONE SOILS

VOCs in soil have been successfully remediated at many sites. Different technologies have been used to contain, treat, and destroy these contaminants. The use of these technologies to remediate VOCs in soil has been well documented.

This documentation has been compiled to identify technologies and screening tools. The Federal Remediation Technologies Roundtable (FRTR) publishes a "Remediation Technologies Screening Matrix and Reference Guide" (FRTR 2009a). The EPA Technology Innovation Office operates a Hazardous Waste Cleanup Information (CLU-IN) Web site that compiles information on a wide array of remediation technologies (CLU-IN 2009).

The Center for Public Environmental Oversight (CPEO) is an organization that promotes and facilitates public participation in the oversight of environmental activities, including but not limited to the remediation of federal facilities, private Superfund sites, and brownfields. CPEO's Technology Tree Matrix is a tool for identifying technologies to characterize and clean up hazardous waste sites (CPOE 2009), and the EPA Annual Status Report (ASR) Remediation Database – Update 2003 documents status and achievements of treatment technologies and Superfund sites (EPA 2003).

These sources and others were used to develop the list of potential technologies for remediating VOC and SVOC COCs present in site soils. The technologies listed in Table 3-2 contain the technologies recommended by the FRTR, CLU-IN, CPEO and the technologies identified by the ASR database as having been used at CERCLA sites, as well as other technologies used by Hart Crowser to successfully remediate source area soil at this and other sites. The monitoring and institutional controls general response actions are also included in Table 3-2.

Excavation-based technologies with on- or off-site treatment of excavated soils were excluded from Table 3-2 because it was judged inappropriate to consider excavation as a means to access soils that are found from 20 feet bgs to the top of the smear zone, typically 55 to 68 feet bgs. *In situ* treatment technologies were judged to be appropriate for soils in this depth interval. Some of these technologies contain additional components to treat vapors extracted from the soil matrix and other off-gases created by the use of the technology.

Treatment technologies contained in Table 3-2 are described in Appendix A.

3.2 POTENTIAL REMEDIATION TECHNOLOGIES FOR SVOCs IN DEEP VADOSE ZONE SOILS

The remediation of SVOCS in deep vadose zone soil has been evaluated and the available technologies have been assembled into the following general response actions: institutional controls, containment, and *in situ* treatment. In addition, on-site treatment of vapor extracted from soil or of off-gases created by the *in situ* treatment process is also deemed appropriate. All of these technologies are presented in Table 3-2 and described in Appendix A.

Some of the technologies described in Appendix A are presumptive remedies for SVOCs. Presumptive remedies are preferred treatment technologies for common categories of sites. The EPA selects presumptive remedies to streamline site characterization and speed up the selection of cleanup actions. EPA has identified several presumptive remedies for compounds typically found at wood treating facilities (EPA 1995a), some of which are also common to Kaiser including diesel, heavy oil, and cPAHs. The presumptive remedies that may be applicable for SVOC-impacted deep vadose zone soil at Kaiser include *in situ* bioremediation, *in situ* thermal desorption, *in situ* incineration (ISV), and *in situ* immobilization. These technologies were discussed in Sections 2.2.1 to 2.2.3.

The SVOCs present in deep vadose zone soil at the site consist primarily of diesel- and heavy oil-range hydrocarbons. Diesel- and heavy oil-range hydrocarbons are mixtures of straight chain and cyclic alkanes and aromatic compounds including cPAHs. Diesel- and heavy oil-range hydrocarbons have also been successfully treated by the presumptive remedies (*in situ* bioremediation, *in situ* thermal desorption, and *in situ* incineration [ISV]) discussed in Section 2.2. Immobilization technologies are more suited to inorganic contaminants and will not be considered for SVOC-impacted soil that does not also contain arsenic, manganese or iron at concentrations that exceed potential SLs at Kaiser.

Heavy oil-range hydrocarbons were found in deep vadose zone soils in the ORB (Man-Made Depressions), Oil House (French Drain), Truck Shop, and in Hot Line wells and borings. Diesel fuel oil measured by the Ecology NWTPH-HCID or 418.1 Methods was found in deep vadose zone soils in the RCU and Eastern Cold Mill/Finishing area, Oil House (Kensol Spill, Oil House Tank) and Wastewater Treatment (Hoffman Tank) operating areas. Kensol was only found in the Oil House (Kensol spill, eight USTs, and French Drain areas) area.

3.3 POTENTIAL REMEDIATION TECHNOLOGIES FOR PCB COMPOUNDS IN DEEP VADOSE ZONE SOILS

The remediation of PCBs in soil has been evaluated and the available technologies have been assembled into the following general response actions: institutional controls, containment, and *in situ* treatment. In addition, there is the on-site treatment of vapor extracted from soil and for off-gas created from the chemical treatment of soil. All of these technologies are presented in Table 3-2 and described in Appendix A except for chlorine scrubbers. Specifically, *in situ* vitrification, *in situ* chemical treatment, *in situ* stabilization/solidification, *in situ* bioremediation, and *in situ* thermal treatment have been tested or used in the *in situ* treatment of PCBs.

Chlorine gas is a potential PCB degradation product from remediation treatment technologies such as chemical oxidation or bioremediation. A chlorine scrubber is a conventional technology for chlorine gas removal. The scrubber is a bed of packed material into which contaminated off-gas flows upward while a solution that absorbs the chlorine flows downward. A solution of sodium hydroxide is commonly used in a chlorine scrubber

The areas identified with PCBs exceedances in deep vadose zone soils include the Remelt/Casting Area, the Wastewater Treatment area (Hoffman Tank), and the Oil House French Drain area (Figure 2-1).

The EPA ASR database identifies 10 CERCLA sites where *in situ* processes are specified in RODs for treating soils containing PCBs. Seven stabilization/ solidification, one ISV, one chemical oxidation, and one bioremediation site are identified.

Solidification/Stabilization Sites

Solidification and stabilization (S/S) has been used for the treatment of PCB-impacted soils (EPA 2000). Generally, most S/S technologies do not destroy organics and pesticides, except vitrification which destroys most organic contaminants (FRTR 2009a). Concentrations that have been treated range as high as 6100 mg/kg down to 10 mg/kg. Depths have ranged from shallow soils to depths of 19 feet. Soil types include clay, till and oily sludge (EPA 2003, EPA 1988, EPA 2009).

One project where S/S was used successfully was the Chemical Control recycling facility in Elizabeth, New Jersey. This site is near a body of water and contains clay and silty soils. Concentrations of Aroclor 1254 ranged from 40 to 973 mg/kg while the concentration of Aroclor 1260 ranged up to 6000 mg/kg. After S/S treatment, groundwater at the site shows no indication of PCBs. Cement was used to encapsulate waste. Depth of contamination was 15 feet. Treatment operations started in August 1993 and ended in December of that year. Total cost of remediation action was approximately $7 million and 25,000 cubic yards were treated.

Solidification/Stabilization was also used at the South 8th Street Landfill site in West Memphis, Arkansas. Here, a corrosive, oily sludge pit was treated. Besides PCBs, the sludge contained lead and cPAHs. A total of 19,376 cubic yards of oily sludge and 22,372 cubic yards of ancillary soil were treated. Depths of soils and sludge ranged from 12 to 18 feet.

In Situ Vitrification

ISV was developed to treat near-surface soils at Department of Energy facilities that contained radionuclides, and where it was judged that the application of more conventional *ex situ* processes would expose workers to unacceptable health risks. ISV was proposed for use at the Oak Ridge National Laboratory to treat PCBs in several holding ponds.

ISV was used in the 1990s at a General Electric (GE) owned site with PCB contamination, located in eastern Washington. GE owned and operated a transformer service shop from 1961 to 1980. Oils containing PCBs and TPH were released to soil during service operations (Ecology 2009). PCBs were also found in groundwater.

Ecology's 1993 Cleanup Action Plan (CAP), prepared in accordance with the MTCA, established ISV as the preferred method to treat all site soil. However, after an ISV demonstration test in 1994, Ecology modified the remedy and consent decree in an Explanation of Significant Differences (Ecology 1996) to allow off-site disposal of soil bearing low concentrations of PCBs because of the substantial and disproportionate costs associated with the treatment of low-concentration PCB soils. Soil (2,500 tons) bearing high concentrations of PCBs (greater than 50 mg/kg), which otherwise would have been incinerated under TSCA rules, were vitrified on site in late 1996.

In Situ Bioremediation

In situ bioremediation was used for the treatment of sludge and soils in a lagoon impacted with PCBs and other SVOCs at the French Limited Petroleum Refinery in Crosby, Texas. The system was equipped with aeration, pure oxygen addition, pH control, and nutrient addition to oxidize the organic contaminants. PCBs and halogenated compounds were biodegraded through aerobic cometabolic oxidation by indigenous microorganisms. The system operated for approximately two years. Approximately 70,000 cubic yards of soil was treated and 230,000 cubic yards of sludge. Concentrations of PCBs treated ranged up to 616 mg/kg. After treatment concentrations of PCBs were reported to be less than 5 mg/kg. The total costs associated with cleanup were $26 million.

In Situ Chemical Treatment

At the Battery Tech Superfund site (in Lexington, North Carolina) soils to a depth of 8 feet bgs were impacted by PCBs and a number of VOCs. Soil types ranged from silty clays to clayey silts. A mixture of hydrogen peroxide, sodium persulfate, iron II catalyst, and sodium permanganate was used for treatment. Design was completed in 2002 and treatment is currently underway. Soil remedial goals were set at 144 mg/kg for PCBs (for the protection of groundwater) (EPA 1999d, EPA 2003). These technologies are summarized in Table3-2.

3.4 SCREENING TECHNOLOGIES FOR REMEDIATING DEEP VADOSE ZONE SOILS

The technologies identified in Sections 3.1 to 3.3 are screened using the approach summarized in Section 2.4. The physical aspects of the Kaiser Facility, the chemical properties of COCs, and the properties of the deep vadose zone soil in the AOCs are identified and used to eliminate certain technologies from further consideration in Section 3.4.1.

The technologies that were judged to be potentially appropriate for the physical and chemical features of the AOCs are evaluated for implementability and reliability (if implementable) in Section 3.4.2. Many technologies judged reliable for treating individual COCs (Stoddard solvent, diesel, heavy oil, cPAHs or PCBs) in soil also were judged reliable for treating other COCs. These common technologies are identified in Section 3.4.2.4. These common technologies will form the core of the remedial alternatives developed in Section 3.5.

3.4.1 Site-Specific Technical Constraints for Technologies

The physical and chemical features of the Facility influence the selection of the remedial technologies identified in Sections 3.1 to 3.3. There are three groups of physical factors that influence proper selection of a remedial technology: (1) factors associated with the active use of the facility, (2) factors limiting access to contaminated soil, and (3) site-specific geologic and hydrologic conditions promoting or prohibiting the applicability of certain remedial technologies. These physical factors were discussed in Section 2.5.1 and summarized in Table 2-3. The factors that constrained the use of near-surface soil treatment technologies will also constrain the use of technologies appropriate for deep vadose zone soils.

In addition to these physical factors, various chemical attributes of the COCs influence the selection of a remedial alternative. A summary of these chemical properties was provided in Section 2.5.1 and summarized in Table 2.4 (Physical/Chemical Properties of COPCs).

The site-specific physical and chemical factors present at the Kaiser site are used to screen the technologies described in Sections 3.1 to 3.3 to identify the set of available technologies that are potentially applicable to VOCs (Table 3-3), SVOCs (Table 3-4), and PCBs (Table 3-5). These potentially applicable technologies are evaluated further in Section 3.4.2.

3.4.2 Screening of Remedial Technologies for COCs in the AOCs

This section evaluates those technologies not rejected on the basis of the site-specific physical/chemical constraints (summarized in Tables 3-3, 3-4, and 3-5) for implementability and reliability in this Section. Cost-effectiveness is not assessed as part of this FSTM. Cost-effectiveness will be used to further screen the implementable and reliable technologies identified by the FSTM (where appropriate) as part of the overall feasibility study for the Kaiser Facility.

3.4.2.1 Technologies for Remediating VOCs in Deep Vadose Zone Soil

Technologies and the associated process options for remediating VOC-contaminated soil in the AOCs that were not rejected on the basis of site-specific constraints are evaluated for implementability in Tables 3-6a and 3-6b. Table 3-6a summarizes our implementability evaluation for technologies that were previously presented in Section 2 in addressing near surface soil. Each table provides information to justify why a process option should be accepted or rejected for the Kaiser Facility. These tables indicate that the following process options for remediating VOCs in deep vadose zone soils are judged to be implementable at the Kaiser Facility.

Technology	Process Option Accepted
Monitoring	Protection, Performance, Confirmation
Institutional Controls	Access and Use Restrictions, BMPs
Capping	Asphalt, Concrete, Multilayer
Monitored Natural Attenuation	Monitored Natural Attenuation
Soil Vapor Extraction (SVE)	Vertical Vents
SVE Off-Gas Treatment Technologies	
Adsorption Technology	Granular Activated Carbon
Thermal Oxidation	Catalytic Oxidizer
Advanced Oxidation	Photocatalytic Oxidation

The technologies and associated process options judged to be implementable are evaluated for reliability in Tables 3-7a through 3-7b. Table 3-7a summarizes our reliability evaluation for technologies that were previously presented in Section 2 for addressing near-surface soil. Photocatalytic oxidation was rejected on the basis of reliability, as shown in Table 2-9h, since this process option is still in the development stage and has not been successfully operated at full scale in a physical and chemical setting similar to that at the Kaiser Facility.

The remaining process options are combined in various ways to create the feasible remedial alternatives discussed below. Table 3-8 summarizes the technology screening process and identifies the technologies and process options judged to be appropriate for the treatment of VOC contaminated deep vadose zone soil at the Kaiser Facility.

3.4.2.2 Technologies for Remediating SVOCs in Deep Vadose Zone Soil

Technologies and the associated process options for remediating SVOC-contaminated soil in the AOCs are evaluated for implementability in Tables 3-9a through 3-9b. Each table identifies the information used to justify why each process option should be accepted or rejected. These tables indicate that the following process options for remediating SVOCs in near-surface soils are judged to be implementable at the Kaiser Facility.

Technology	Process Option Accepted
Monitoring	Protection, Performance, Confirmation
Institutional Controls	Access and Use Restrictions, BMPs
Capping	Asphalt, Concrete, Multilayer
Monitored Natural Attenuation	Monitored Natural Attenuation
In Situ Bioremediation	Bioventing, Enhanced Bioremediation
In Situ Chemical Treatment	Oxidation
Off-Gas Treatment Technologies (if required)	
Adsorption	Activated Carbon
Thermal Oxidation	Catalytic Oxidizer
Advanced Oxidation	Photocatalytic Oxidation

The technologies and associated process options judged to be implementable are evaluated for reliability in Tables 3-10a through 3-10c. Each table identifies the information used to justify why each process option should be accepted or rejected. Photocatalytic oxidation was rejected on the basis of reliability (refer to Table 2-9h) since this process option is still in the development stage and has not been successfully operated at full scale in a physical and chemical setting similar to that at the Kaiser Facility. Bioventing was also rejected on the basis of reliability (refer to Table 3-10b) since SVOCs have low vapor pressures which would reduce the effectiveness of this technology.

Table 3-11 summarizes the technology screening process and identifies the technologies and process options judged to be implementable and reliable for the treatment of SVOC-contaminated soil in the deep vadose zone at the Kaiser Facility.

3.4.2.3 Technologies for Remediating PCBs in Deep Vadose Zone Soil

Technologies and the associated process options for remediating PCB-contaminated soil in the AOCs are evaluated for implementability in Tables 3-12a through 3-12c. Each table provides information to justify why each process option should be accepted or rejected. These tables indicate that the following process options for remediating PCBs in deep vadose zone soils are judged to be implementable at the Kaiser Facility.

Technology	Process Option Accepted
Monitoring	Protection, Performance, Confirmation
Institutional Controls	Access and Use Restrictions, BMPs
Capping	Asphalt, Concrete, Multilayer
Containment	Stabilization/Solidification
Monitored Natural Attenuation	Monitored Natural Attenuation
In Situ Bioremediation	Bioventing, Enhanced Bioremediation
In Situ Chemical Treatment	Oxidation
Solidification/Stabilization	Cement- and Lime-Based Processes, Microencapsulation, Sorption
Off-gas Treatment Technologies (if required)	
Adsorption	Activated Carbon
Thermal Treatment	Catalytic Oxidizer
Advanced Oxidation	Photocatalytic Oxidation
Chlorine Capture	Chlorine Scrubber

The technologies and associated process options judged to be implementable are evaluated for reliability in Tables 3-13a through 3-13c. The *in situ* bioremediation, *in situ* chemical treatment, and solidification/stabilization technologies were rejected on the basis of reliability, as described in Tables 3-13a through 3-13c. These rejected options were judged to be complex operations with limited demonstrated success at large-scale industrial facilities similar to Kaiser, where the soils are very porous and the concentration of PCBs is very low. Photocatalytic oxidation was rejected on the basis of reliability (refer to table 2-9h) since this process option is still in the development stage and has not been successfully operated at full scale in a physical and chemical setting similar to that at the Kaiser Facility.

Table 3-14 summarizes the technology screening process and identifies the technologies and process options judged to be appropriate for the treatment of PCB-contaminated deep vadose zone soil at the Kaiser Facility. Institutional controls, monitoring, monitored natural attenuation, and capping were the technologies selected for the treatment of PCBs present alone (e.g., Remelt/Hot Line area) in deep vadose zone soils due to the very low concentrations of PCBs that were present in the soil. *In situ* bioremediation (enhanced bioremediation) and *in situ* chemical treatment (oxidation) are judged to be potentially applicable technologies when PCBs are co-located with SVOCs in vadose zone soils (e.g., Oil House area).

3.4.2.4 Remediation Technologies Common for VOCs, SVOCs, PCBs, and Metals

The areas identified with VOC exceedances in deep vadose zone soils are associated with Stoddard solvent and are located in the Oil House area (Figure 2-1). There is no direct evidence that these VOCs are causing exceedances of screening criteria in the breathing spaces of site workers.

The technologies accepted for the remediation of VOCs in near-surface soils are listed in Table 3-8, and include capping, institutional controls, monitored natural attenuation, and SVE with thermal treatment or adsorption of VOCs in the extracted soil vapor.

Four general response actions judged acceptable for VOCs also were judged acceptable for one or more of the other COCs. The common response actions include:

- Monitoring (confirmation, performance, protection) – VOCs, SVOCs, PCBs, and metals;

- Institutional Controls – VOCs, SVOCs, PCBs, and metals;

- Capping (asphalt, concrete, multi-layer)- VOCs, SVOCs, PCBs and metals; and

- Monitored Natural Attenuation – VOCs, SVOCs and PCBs.

There were additional common response actions for diesel, heavy oil, and PCBs that are co-located in vadose zone soils. These response actions include:

- *In Situ* Treatment (bioremediation, chemical treatment).

3.5 DESCRIPTION OF AREAS OF CONCERN FOR DEEP VADOSE ZONE SOILS

The AOCs for deep vadose zone soils at the Kaiser Facility are those areas that contain COCs at concentrations above potential SLs that have been established for the site. The COCs for vadose zone soils include VOCs, SVOCs, PCBs, arsenic, and chromium. The remedial objectives for these AOCs are summarized in terms of COCs, SLs, and POCs in Section 1.

This FSTM has divided the Kaiser Facility into eight general operating areas (refer to Table 3-1). The locations of the AOCs within each general operating area are depicted on Figures 3-1 to 3-7 as follows:

Figure 3-1: ORB Area

Figure 3-2: Rail Car Unloading Area

Figures 3-3a to 3-3b: Cold Mill/Finishing Area

Figures 3-4a to 3-4d: Oil House Area

Figures 3-5a to 3-5b: Wastewater Treatment Area

Figure 3-6: Truck Shop Area

Figure 3-7: Remelt/Hot Line Areas

The AOCs depicted on Figures 3-1 to 3-7 were developed by using a "half the distance" rule (as defined below) to define a boundary between sample locations that are known to contain COPCs at concentrations above potential SLs and sample locations where COPCs are known to be present at concentrations below potential SLs.

The next step in defining the AOCs was to estimate the vertical extent of the area of SL exceedance. The upper and lower soil depth intervals evaluated in this Section were 20 feet bgs to the water table: 68 feet bgs in the mill area, 55 feet bgs in the Wastewater Treatment Area, and 33 feet bgs for near river borings/wells respectively. Data from adjacent sampling locations and data from above and below the horizon of interest in the same boring were evaluated to estimate the vertical extent of contamination in each boring. In cases where a clean sample was located above or below a contaminated deep vadose zone sample, half of the vertical distance between the clean and dirty sample locations was used to estimate of the depth of contamination.

Once the horizontal and vertical extent of each AOC was estimated, an average concentration was calculated for each COC. Several AOCs had soil boring data through the deep vadose zone where analytical data indicated clean soil was interspersed vertically with contaminated soil. For example, boring SA-6 from the French Drain/Drum Storage area was sampled through the deep vadose zone at 5-foot intervals (Hart Crowser 2012b, Table 5-12). PCBs were detected above the SL at 20, 25, 30, 45, 50, 60, 65, and 70 feet bgs. Samples collected at 35, 40, and 55 feet bgs had detections of PCBs below the SL. For cases such as this, the average concentration calculated included the samples that were both above and below the SL. In the event that clean samples, vertically bracketed by contaminated samples, were found in a deep vadose zone boring, then 1/2 of the reporting limit was used in the calculation of the average COC concentration for that AOC.

This approach to calculating the average concentration of the COC represents an overestimate of the concentration that is actually present at a sample location for a number of reasons. The soil matrix at Kaiser consists mostly of gravel and cobbles (Hart Crowser 2012b). The soil samples collected initially also consisted of mostly gravel. The COCs in the sample were associated with the sand and organic material (if any) that was present in the sample. The gravel and cobble portion of the sample was not sent to the lab for analysis since cobbles would not fit in the sample jar and gravel would have to be pulverized in the lab prior to analysis. As a result, the concentration of COCs reported by the lab is an overestimate of the actual *in situ* concentration of the contaminant. Nonetheless, the lab values were reported in the Final Soil and Groundwater RIs (Hart Crowser 2012b, 2012a) since they represent a conservative estimate of the actual concentration of the COC present at the site, and contribute to a conservative approach to estimating risks to human health and the environment posed by the COC.

In many instances, the vadose zone soil data was collected 10 to 20 years ago as part of site characterization work. The result of this work often included the removal of contaminated near-surface soils (source area) that were located in the vicinity of or directly above the vadose zone sample. Petroleum contamination is known to degrade over time if left in place. Many vadose zone soil samples are from a location that is regularly flushed by rainwater. The combination of the removal of the source area, the likely natural degradation of contaminants over time, and the result of the rainfall flushing action over time, likely have reduced the original concentration in the vadose zone soils. The quantity of this reduction can not be precisely estimated.

There are numerous paved areas located throughout the Kaiser Facility. These paved areas are depicted on Figure 3-8 in relation to the AOCs at the site described in Appendix C.

The specific COCs that are present in each AOC, and the sampling location where the COC was identified, are shown on Figures 3-1 to 3-7 and are listed in Table 3-15.

The available sampling data (Hart Crowser 2012b), together with the AOCs depicted on Figures 3-1 to 3-7 were used to compute an estimate of the total mass of contaminants contained in deep vadose zone soil in the soil AOCs. These estimates are presented in Table 3-16.

The COC loadings listed in Table 3-16 are allotted to the AOCs within the eight general operating areas of the site that contained that COC. The calculation assumptions used to develop these estimates are summarized in Appendix C and in Table C-1, the spreadsheet used to perform the loading calculations. The soil samples used to calculate the loadings were collected by various investigators over an extended period of time. Nonetheless, it was judged that the information in Tables 3-15, 3-16, and C-1 provide useful insights into the relative distribution of COCs at the site.

The total mass of contaminants above SLs in deep vadose zone soil at the site is approximately 615 thousand pounds (310 tons). Approximately 97.8 percent of this contamination has been reported to be heavier TPHs (diesel, heavy oil, and Kensol). VOCs (Stoddard solvent) compose approximately 1,500 pounds of the total mass (about 0.2 percent), PCBs compose approximately 11,400 pounds (about 1.9 percent) of the total mass of contaminants, and metals (arsenic and chromium) compose approximately 370 pounds (about 0.6 percent).

The heavier TPHs are found within six of the seven general operating areas where contaminants were found in deep vadose zone soil, shown in Tables 3-15 and 3-16. VOCs (Stoddard solvent) are found in the Oil House area. PCBs are found primarily in the ORB (French Drain Area), Remelt/Hot Line and Wastewater Treatment (Hoffman Tank) areas. In most instances the VOCs and PCBs were found in AOCs that also contained SVOCs. Arsenic is found in the Oil House area (Oil House Tank area and Eight UST area), the Wastewater Treatment area (Hydrogen Sulfide Scrubber Building area), and the Remelt/Hot

Line area. The comingling of the COC groups will impact the evaluation and selection of remedial alternatives that is provided in Section 3.7.

The information contained on Figures 3-1 through 3-7 and Tables 3-15, 3-16 and C-1 is summarized for each COC in Appendix C:

- Section C.1 – VOCs;
- Section C.2 – Diesel and Heavy Oil; and
- Section C.3 – PCBs.

3.6 DEVELOPMENT OF REMEDIAL ALTERNATIVES

The technologies and process options that are potentially applicable to the remediation of the deep vadose zone soils in the AOCs at the Kaiser Facility are identified in Section 3.4. These technologies and process options were initially screened to account for site-specific technical constraints and for the chemical properties of the COCs in Section 3.4.1. The technologies and process options judged to be implementable and reliable for the remediation of soils in the AOCs are assembled into remediation alternatives in this Section. The basis for developing alternatives follows the logic shown on Figure 2-12 and was described in Section 2.7.1.

3.6.1 Remedial Alternatives for Deep Vadose Zone Soil

MTCA requires that a reasonable number of alternatives shall be evaluated taking into account the characteristics and complexity of the facility, including current site conditions and physical constraints (WAC 173-340-350[8][c][i][B]). These factors were discussed in Section 2.5.1.

The technology-based remedial alternatives developed in this section range from Alternative A1 (institutional controls, monitoring, and monitored natural attenuation) to the most practical permanent cleanup alternative (A5) for areas that contain SVOCs, and for PCBs that are co-mingled with SVOCs, which includes institutional controls, monitoring, monitored natural attenuation, containment, and *in situ* treatment options. The individual COCs that are addressed by each of the Alternatives, A1 through A5, are summarized in Table 3-17.

Alternatives A1 and A2

Alternative A1, which consists of institutional controls, and monitoring, monitored natural attenuation, is included since many viable remedies at the Kaiser Facility will contain these elements. Alternative A2 comprises containment, institutional controls, monitoring, and monitored natural attenuation. It adds the additional protection of containment to Alternative A1. Alternatives A1 and A2 are common for all the COC groups (VOCs, SVOCs, PCBs, and metals). Alternative A2 is considered to be the most practical permanent cleanup alternative for AOCs that contain metals at concentrations above SLs.

Alternative A3

Alternative A3 adds *in situ* treatment (SVE plus off-gas treatment) to Alternative A2 in AOCs (e.g., Oil House area) that contain VOC COCs (e.g., Stoddard solvent) in deep vadose zone soils at concentrations above SLs. Alternative A3 is considered to be the most practical permanent cleanup alternative for AOCs that contain VOC COCs at concentrations above SLs.

Alternatives A4a and A4b

In situ bioremediation (enhanced bioremediation), containment, institutional controls, monitoring, and monitored natural attenuation are included as Alternative A4a for those AOCs (ORB Man-Made Depressions, Oil House French Drain area, Truck Shop, Hot Line Wells and borings) where SVOCs are present, and for those locations where SVOCs are co-located with PCBs (Oil House French Drain area, Wastewater Treatment – Hoffman Tank area).

Alternative A4b substitutes *in situ* chemical treatment (oxidation) for *in situ* bioremediation in Alternative A4a.

Alternative A5

Alternative A5 includes containment, institutional controls, monitoring, and monitored natural attenuation for those AOCs in the Remelt/Casting areas where PCBs are not co-located with SVOCs in deep vadose zone soils. Alternative A5 is considered to be the most practical permanent cleanup alternative for those AOCs where PCBs are not co-located with PCBs.

Applicability and Combination of Multiple Alternatives

Evaluation of the various alternatives may show that multiple alternatives are applicable for an individual COC. Similarly, if there is more than one type of COC in an AOC, it is possible that a single or a combination of alternatives could be considered. For instance, technology-based Alternatives A1, A2, and A4a or A4b could be used individually or in combination to address SVOCs in deep vadose zone soils. As a further example, one AOC in the ORB operating area (refer to Figure 3-4b) contains both VOCs and SVOCs in deep vadose zone soils at concentrations exceeding SLs. The VOC AOCs are contained within a larger SVOC AOC. In this example, technology-based Alternatives A1,A2, or A3 could be used alone or in combination to remediate the VOC-impacted areas, while Alternatives A1, A2, A4a, or A4b could be used alone or in combination to remediate the overall SVOC AOC, including the VOC impacted areas (if VOCs are co-mingled with SVOCs).

The overall feasibility study will evaluate the technology-based remedial alternatives described above to assess whether or not, or to what extent, the alternatives meet the minimum requirements for cleanup action under MTCA (WAC-173-340-360[2]). One outcome of this evaluation will be to identify the most appropriate alternative(s) for each COC. It is expected that alternatives A1 and A2 will be carried forward for each COC group. For SVOCs, it is expected that the evaluation will differentiate among alternatives A4a and 4b and identify the most appropriate alternative. Similarly, it is expected that the overall feasibility study will identify the most appropriate alternative among the potentially applicable alternatives for PCBs (A1, A2, A4a, A4b, and A5) and for metals (A1 and A2). The most appropriate alternative(s) for each COC group will then be bundled to create the proposed area-based remedy for each of the AOCs identified for deep vadose zone soils, as described above for an AOC in the Oil House operating area.

Compliance Monitoring

Monitoring is needed to assure compliance with cleanup levels, to assess the performance of a remediation technology as it is operating, and to measure the continued effectiveness over time of permanent features added to the site (e.g., capping). Monitoring is an integral element of Alternatives A1 through A5. A comprehensive monitoring program consists of protection monitoring, performance monitoring, and confirmational monitoring. The comprehensive monitoring program is based on an adaptive monitoring and management strategy that is described in Section 2.7.3

Table 3-1 - Kaiser General Operating Areas and Deep Vadose Zone Soil COCs Identified for Each Site

General Operating Area	Sites Located within Operating Area	COCs Identified in Vadose Soil
Oil Reclamation Building and Surrounding Area	Man-Made Depressions	Heavy Oil
	G1 Transfer Line	None
	G2 Transfer Lines	None
	G3 Transfer Lines	None
	1980 Fuel Oil Spill	None
	Oil Reclamation Building	None
Former Rail Car Unloading Area	Rail Car Unloading	Diesel
	100,000 Gallon Fuel Oil AST	None
Cold Mill/Finishing Area	Eastern Cold Mill/Finishing Area	Diesel
	Cold Mill Transfer Lines	None
	Transformer Yard	None
	Continuous Can Process Line	None
	Chromium Transfer Line	Hexavalent Chromium
	Cold Mill Electrical Grounding Pit	None
	Former Coater Line Tank	None
Oil House Area	Oil House UST	Diesel/Heavy Oil[a], Arsenic
	20,000-Gallon Gasoline UST	None
	Tank Farm Kensol Spill	Stoddard solvent, Kensol, Diesel/Heavy Oil[a]
	500-Gallon Diesel UST	None
	Eight USTs	Kensol, Arsenic
	Drum Storage and French Drain	PCBs, Stoddard solvent, Kensol, Heavy Oil
Wastewater Treatment Area	Field-Constructed Tanks	None
	Hoffman Tank	PCBs, Diesel/Heavy Oil[a]
	Hydrogen Sulfide Scrubber Building	Arsenic
Truck Shop Area	Truck Shop	Heavy Oil
Former Discharge Ravine Areas	West Discharge Ravine	None
	South Discharge Ravine	None
Remelt/Hotline Area	Remelt/Hotline Area wells and borings	PCBs, Heavy Oil, Arsenic
	DC4 Area	None
	DC1 Area	None

Notes

[a] Diesel/Heavy Oil indicates that some of the TPH data from this location was obtained via EPA Method 418.1 which reports soil concentrations as "Total TPH." Therefore individual TPH compounds cannot be distinguished. Based on data from nearby sites and past history of these sites, it was assumed that the TPH present was in the diesel to heavy oil range.

Shaded subsites contain COC.

Table 3-2 - Preliminary Identification of Remedial Technologies for Deep Vadose Zone Soil

General Response Action	**Remedial Technology**	**Process Options**	**Description**
Monitoring	Monitoring	Protection, performance, and confirmational.	Provide for protection, performance, and confirmational monitoring.
Institutional Controls	Access and Use Restrictions	Fencing, signs, deed restrictions.	Physical and administrative measures to prevent access or exposure to contaminated soil.
	Best Management Practices	Spill prevention, leak detection, double walled pipes, proper storage of chemicals and solvents.	Some measures currently in place. QA/QC Plan must continue to be enforced.
Containment	Capping	Soil, clay, asphalt, concrete, synthetic liner, or multi-layer cap.	Placement of a cap or soil cover to minimize infiltration and prevent direct contact.
	Landfill Cap Enhancements	Run-on and run-off controls, vegetative cover.	Designed to reduce or eliminate contaminant migration by controlling and channeling runoff.
	Solidification/ Stabilization	Cement- and lime-based processes, microencapsulation, sorption.	Add reagents to physically/chemically bind contaminants in-place and minimize migration.
In situ Soils Treatment	*In situ* Bioremediation	Bioventing, enhanced bioremediation, phytoremediation.	Enhance biodegradation through modification of subsurface environmental conditions.
	Monitored Natural Attenuation	Monitor natural processes.	Naturally occurring processes in soil and groundwater which reduce mass, toxicity, mobility, volume or concentration; processes include biodegradation, dispersion, dilution, adsorption and volatilization.
	Soil Vapor Extraction (SVE)	Horizontal vents, vertical vents.	Removal of volatile contaminants through vacuum extraction in the vadose zone.
	Steam Injection	Combined with soil vapor extraction.	Removal of strippable contaminants using steam and recovery of condensate at surface.
	Six Phase Soil Heating	Combined with soil vapor extraction.	Removal of strippable contaminants using resistive heating and recovery of vapors and condensate at surface.

Table 3-2 - Preliminary Identification of Remedial Technologies for Deep Vadose Zone Soil

General Response Action	Remedial Technology	Process Options	Description
In situ Soils Treatment (continued)	Soil Flushing	Water, surfactants, solvents.	Removal of leachable contaminants using surfactants and recovery of leachate at surface.
	Pneumatic Fracturing	Pressurized air or steam.	Pretreatment of in-place soils to enhance performance of other *in situ* processes.
	Chemical Treatment	Oxidation, reduction, pH adjustment.	Injection of chemicals for *in situ* treatment of contaminants.
	Electro-Kinetic	Enhanced with surfactants and reagents.	Low intensity direct electric current is applied to electrodes placed across area of contaminated soil. Ionized contaminants migrate to electrodes. Will work in low-permeability soil materials.
	Vitrification	Combined with soil vapor extraction.	Use high energy to melt soil in-place and vaporize VOC and SVOC COCs.
On-Site Treatment of Extracted Soil Vapor	Condensation	Refrigerated condenser.	Condensation of VOCs from air using refrigeration.
	Adsorption	Granular activated carbon.	Removal of adsorbable compounds using canisters in series.
	Thermal Oxidation	Direct flame, flameless oxidizers.	Vapor heated above 1,400°F to oxidize organics; will require HCI controls.
	Catalytic Oxidation	Various catalysts, fixed or fluidized beds.	Vapor heated up to 800°F to oxidize organics; will require HCI controls.
	Advanced Oxidation	UV light, photocatalytic.	Vapor passed through catalyst while exposed to high-intensity UV light and/or ozone.
	Biofiltration	Bioreactor, soil pile.	Gases are passed through a soil bed where contaminants are sorbed and degraded.
	Off-Gas Scrubber	Chlorine Scrubber.	Calcium or sodium-based reagents are used to remove chlorine from off-gas generated by some *in situ* PCB treatment processes.

Table 3-3 - Physical/Chemical Screening Criteria of Remedial Technologies for VOC-Impacted Deep Vadose Zone Soil

General Response Action	Remedial Technology	Description	Screening Comments	Technology Retained
Monitoring	Monitoring	Provide for protection, performance, and confirmational monitoring. Soil samples will be collected to test for compliance with cleanup levels.	Required by MTCA as part of threshold requirements. Access to surrounding properties may also be required.	Yes
Institutional Controls	Access and Use Restrictions	Provide physical barriers and/or administrative restrictions to prevent direct contact.	The facility is currently restricted from public access. Evaluate additional controls for the protection of site workers.	Yes
	Best Management Practices	Spill prevention, leak detection, double walled pipes, proper storage of chemicals and solvents.	Measures are currently in place. QA/QC Plan must continue to be enforced.	Yes
Containment	Capping	Placement of a cap or soil cover to minimize infiltration and prevent direct contact.	Potentially effective for reducing volatilization of VOCs, reduces leaching to groundwater from impacted soils. Stormwater is currently managed in some paved areas. Evaluate additional stormwater controls for areas of proposed new capping. Evaluate AOCs currently covered by paving or buildings for protectiveness.	Yes
	Landfill Cap Enhancements	Run-on and run-off controls, vegetative cover.	Plant matter would be damaged by the heavy industrial site use. Additionally, Kaiser maintains the soil in the mill areas with annual applications of herbicides to make the soil sterile (zero plant growth outside of landscaped areas to limit maintenance and prevent brush fires).	No

Table 3-3 - Physical/Chemical Screening Criteria of Remedial Technologies for VOC-Impacted Deep Vadose Zone Soil

General Response Action	Remedial Technology	Description	Screening Comments	Technology Retained
Containment (continued)	Solidification/ Stabilization	Add reagents that will physically/chemically bind contaminants in place and minimize mobility.	Difficult access for construction in many areas. VOCs usually not reactive with inorganic stabilization/solidification agents. Low concentrations of VOCs would make contact with chemical reagents difficult. Highly porous site soils would make it difficult to control chemical application in deep vadose zone soil matrix. If solidification agents entered smear zone, groundwater flow could be impacted.	No
In situ Treatment of Soils	*In situ* Bioremediation	Enhance biodegradation through modification of subsurface environmental conditions.	Technology has been demonstrated to be effective in remediating soil impacted by VOCs	Yes
	Monitored Natural Attenuation	Naturally occurring processes in soil and groundwater that reduce mass, toxicity, mobility, volume or concentration of contaminants. Includes biodegradation, dispersion, dilution, adsorption and volatilization.	VOCs are known to naturally degrade in the soil environment.	Yes
	Soil Vapor Extraction (SVE)	Removal of volatile contaminants by extracting soil vapor with a vacuum pump. Extracted vapor is treated.	Proven effective for VOC removal from vadose soils only. Will reduce/control ambient and indoor air risks in addition to recovering volatiles for treatment. Limited access for subsurface installations due to presence of buildings and traffic . EPA presumptive remedy for VOCs in soil.	Yes
	Steam Injection	Removal of strippable contaminants using steam, recovery of condensate at surface.	Access limited by infrastructure and buried utilities. Requires off-gas capture and may increase indoor air exposure. Highly porous site soils would make it difficult to apply and capture steam in deep vadose zone soil matrix.	No

Table 3-3 - Physical/Chemical Screening Criteria of Remedial Technologies for VOC-Impacted Deep Vadose Zone Soil

General Response Action	**Remedial Technology**	**Description**	**Screening Comments**	**Technology Retained**
In situ Treatment of Soils (continued)	Six Phase Soil Heating	Removal of strippable contaminants using heat, recovery of condensate at surface.	Due to congested infrastructure and safety concerns with stray electrical current use is prohibited by Kaiser. Limited to accessible areas, requires capture and treatment of extracted vapors.	No
	Soil Flushing	Removal of leachable contaminants using surfactants. Leachate is recovered at the surface.	Access to impacted soils limited by infrastructure. Saturation of vadose soil would occur near and beneath buildings and roadways and may create potential for settlements. Potential for contaminants to spread in highly porous substrate if application and recapture of solvents is ineffective.	No
	Pneumatic Fracturing	Pretreatment of in-place soils to enhance performance of other *in situ* processes.	Not needed because of highly permeable nature of native soil.	No
	Chemical Treatment	Injection of chemicals for *in situ* treatment of contaminants (e.g., oxidation/reduction, pH adjustment).	Demonstrated effective for VOCs. Highly porous nature of soil will enhance lateral distribution of treatment fluids from each injection location. The congested infrastructure will limit injection locations in areas of concern.	Yes
	Electro-Kinetic Treatment	Direct current used to cause contaminants to migrate to electrodes where they are treated.	VOCs are not ionized and will not migrate in an electric field.	No

Table 3-3 - Physical/Chemical Screening Criteria of Remedial Technologies for VOC-Impacted Deep Vadose Zone Soil

General Response Action	Remedial Technology	Description	Screening Comments	Technology Retained
In situ Treatment of Soils (continued)	Vitrification	Use high energy to melt soil in place and minimize migration.	Stray current and heat may impact infrastructure; would likely volatilize versus immobilize most VOC COCs; requires off-gas capture/treatment. To vitrify the deep vadose soil zone horizon (20 to 68 feet) would require access to very large source(s) of electrical power. Usually not employed at depth below 20 feet bgs.	No
On-Site Treatment of Extracted Soil Vapor	Condensation	Condensation of VOCs from air using refrigeration.	Not effective for low concentrations of solvent vapors (<10,000 ppm); not demonstrated effective for petroleum hydrocarbons.	No
	Adsorption	Removal of adsorbable compound using canister in series, may require disposal (e.g., activated carbon).	Demonstrated effective for petroleum hydrocarbons.	Yes
	Thermal Oxidation	Vapor heated above 1,400°F to oxidize organics; requires emission controls (e.g., direct flame, flameless).	Demonstrated effective for VOCs.	Yes
	Catalytic Oxidation	Vapor heated up to 800°F to oxidize organics, requires HCI controls.	Potentially effective for VOCs at this site.	Yes
	Advanced Oxidation	Vapor is passed through catalyst while exposed to high intensity UV light or ozone.	Potentially effective for VOCs at this site.	Yes
	Biofiltration	Gases are passed through a soil bed where contaminants are sorbed and degraded by bacteria in soil.	Potentially effective for VOCs at this site.	Yes

Table 3-4 - Physical/Chemical Screening Criteria of Remedial Technologies for SVOC-Impacted Deep Vadose Zone Soil

General Response Action	Remedial Technology	Description	Screening Comments	Technology Retained
Monitoring	Monitoring	Provide for protection, performance, and confirmational monitoring. Soil samples will be collected to test for compliance with cleanup levels.	Required by MTCA as part of threshold requirements. Access to surrounding properties may also be required.	Yes
Institutional Controls	Access and Use Restrictions	Provide physical barriers and/or administrative restrictions to prevent direct contact.	The facility is currently restricted from public access. Evaluate additional controls for the protection of site workers.	Yes
	Best Management Practices	Spill prevention, leak detection, double walled pipes, proper storage of chemicals and solvents.	Measures are currently in place. QA/QC Plan must continue to be enforced.	Yes
Containment	Capping	Placement of a cap or soil cover to minimize infiltration and prevent direct contact.	Reduces leaching to GW by impacted soils. Stormwater is currently managed in some paved areas. Evaluate additional stormwater controls for areas of proposed new capping. Evaluate AOCs currently covered by paving or buildings for protectiveness.	Yes
	Landfill Cap Enhancements	Run-off and run-on controls, vegetative cover.	Vegetative cover is not practical in most industrial areas of the facility. Additionally, Kaiser maintains the soil in the mill areas with annual applications of herbicides to make the soil sterile (zero plant growth outside of landscaped areas to limit maintenance and prevent brush fires).	No
	Solidification/ Stabilization	Add reagents that will physically/chemically bind contaminants in place and minimize mobility.	Potentially effective for some SVOCs. Limited to accessible areas; restricted by structures, roadways and buried utilities. If solidification agents entered smear zone, groundwater flow could be impacted. Will be difficult to apply and recover reagents in porous soils throughout the depth interval. Off-gas capture and treatment will be required.	No

Table 3-4 - Physical/Chemical Screening Criteria of Remedial Technologies for SVOC-Impacted Deep Vadose Zone Soil Sheet 2 of 4

General Response Action	**Remedial Technology**	**Description**	**Screening Comments**	**Technology Retained**
In situ Treatment of Soils	*In situ* Bioremediation	Enhance biodegradation through modification of subsurface environmental conditions. Bioventing involves injecting or withdrawing air in vadose zone.	Technology has been demonstrated to be effective in remediating soil impacted by SVOCs. May not be able to use technology for impacted soils at deeper depths. Pilot scale tests required.	Yes
	Monitored Natural Attenuation	Naturally occurring processes in soil and groundwater that reduce mass, toxicity, mobility, volume or concentration of contaminants. Includes biodegradation, dispersion, dilution, adsorption and volatilization.	SVOCs are known to naturally degrade in the soil environment.	Yes
	Soil Vapor Extraction (SVE)	Removal of volatile contaminants by extracting soil vapor with a vacuum pump. Assumed that extracted vapor treatment is part of this remedial technology.	Not effective for SVOCs because vapor pressure and Henry's Law constant are too low.	No
	Steam Injection	Removal of strippable contaminants using steam, recovery of condensate at surface.	Access limited by infrastructure, buried utilities. Requires off-gas capture and may increase indoor air exposure. Highly porous site soils would make it difficult to apply and capture steam in deep vadose zone soil matrix.	No
	Six Phase Soil Heating	Removal of strippable contaminants using heat, recovery of condensate at surface.	Due to congested infrastructure and safety concerns with stray electrical current, use is prohibited. Limited to accessible areas, requires capture and treatment of extracted vapors. Large source of electrical power needed to heat large volume of vadose zone in soil in AOC.	No

Table 3-4 - Physical/Chemical Screening Criteria of Remedial Technologies for SVOC-Impacted Deep Vadose Zone Soil Sheet 3 of 4

General Response Action	Remedial Technology	Description	Screening Comments	Technology Retained
In situ Treatment of Soils (continued)	Soil Flushing	Removal of leachable contaminants using surfactants. Leachate is recovered at the surface.	Access to impacted soils limited by infrastructure. Saturation of vadose zone soil would occur near and beneath buildings and roadways and may create potential for settlement. Potential for contaminants to spread in highly porous substrate if capture is ineffective.	No
	Pneumatic Fracturing	Pretreatment of in-place soils to enhance performance of other *in situ* processes.	Not needed because of highly permeable nature of native soil.	No
	Chemical Treatment	Injection of chemicals for *in situ* treatment of contaminants (e.g., Oxidation/reduction, pH adjustment).	Fenton's Reagent has been demonstrated effective for SVOCs. COCs such as diesel/heavy oil are more likely to be in liquid phase attached to soil particles and therefore available for contact with treatment chemical. Highly porous nature of soil will enhance lateral distribution of treatment fluids from each injection location. The congested infrastructure will limit injection locations in some areas of concern. Off-gases that are created may need to be treated. Potential for exothermic (explosive) reactions to occur.	Yes
	Electro-Kinetic Treatment	Direct current used to cause contaminants to migrate to electrodes where they are treated.	SVOCs are not ionized and will not migrate in an electric field.	No
	Vitrification	Use high energy to melt soil in place and minimize migration.	Stray current and heat may impact infrastructure; requires off-gas capture. To vitrify the deep vadose zone soil horizon (20 to 68 feet) would require access to very large sources of electrical power. Use typically limited to soils above 20 feet bgs.	No

Table 3-4 - Physical/Chemical Screening Criteria of Remedial Technologies for SVOC-Impacted Deep Vadose Zone Soil

General Response Action	Remedial Technology	Description	Screening Comments	Technology Retained
On-Site Treatment of Extracted Soil Vapor/Off-gas	Condensation	Condensation of VOCs from air using refrigeration.	Not effective for low concentrations of SVOC vapors (<10,000 ppm); not demonstrated effective for petroleum hydrocarbons.	No
	Adsorption	Removal of adsorbable compound using canister in series, may require disposal (e.g., activated carbon).	Potentially effective for SVOC degradation products.	Yes
	Thermal Oxidation	Vapor heated above 1,400°F to oxidize organics; requires emission controls (e.g., direct flame, flameless).	Potentially effective for SVOC degradation products.	Yes
	Catalytic Oxidation	Vapor heated up to 800°F to oxidize organics, requires HCI controls.	Potentially effective for SVOC degradation products.	Yes
	Advanced Oxidation	Vapor is passed through catalyst while exposed to high intensity UV light or ozone.	Potentially effective for SVOC degradation products.	Yes
	Biofiltration	Gases are passed through a soil bed where contaminants are sorbed and degraded by bacteria in soil.	Potentially effective for SVOC degradation products.	Yes

Table 3-5 - Physical/Chemical Screening Criteria of Remedial Technologies for PCB-Impacted Deep Vadose Zone Soil

General Response Action	Remedial Technology	Description	Screening Comments	Technology Retained
Monitoring	Monitoring	Provide for protection, performance, and confirmational monitoring. Soil samples will be collected to test for compliance with cleanup levels.	Required by MTCA as part of threshold requirements. Access to surrounding properties may also be required.	Yes
Institutional Controls	Access and Use Restrictions	Provide physical barriers and/or administrative restrictions to prevent direct contact.	Must follow TSCA institutional control requirements. Kaiser facility property already restricted.	Yes
	Best Management Practices	Spill prevention, leak detection, double walled pipes, proper storage of chemicals and solvents.	Measures are currently in place. QA/QC Plan must continue to be enforced.	Yes
Containment	Capping	Placement of a cap or soil cover to minimize infiltration and prevent direct contact.	Potentially effective for reducing physical contact with PCBs. Reduces leaching to GW by impacted soils. Stormwater is currently managed in some paved areas. Evaluate additional stormwater controls for areas of proposed new capping. Evaluate AOCs currently covered by paving or buildings for protectiveness. Must follow TSCA capping requirements.	Yes
	Landfill Cap Enhancements	Run-on and runoff controls, vegetative cover.	Plant matter would be damaged by the heavy industrial site use. Additionally, Kaiser maintains the soil in the mill areas with annual applications of herbicides to make the soil sterile (zero plant growth outside of landscaped areas to limit maintenance and prevent brush fires).	No
	Solidification/ Stabilization	Add reagents that will physically/chemically bind contaminants in place and minimize mobility.	Potentially effective for PCBs. Limited to accessible areas; restricted by structures, roadways and buried utilities. Has been used at several Superfund sites (EPA 2003).	Yes

Table 3-5 - Physical/Chemical Screening Criteria of Remedial Technologies for PCB-Impacted Deep Vadose Zone Soil

General Response Action	**Remedial Technology**	**Description**	**Screening Comments**	**Technology Retained**
In situ Treatment of Soils	*In situ* Bioremediation	Enhance biodegradation through modification of subsurface environmental conditions.	Limited effectiveness with PCBs. Aerated lagoon was used to treat PCB impacted sludge at French Limited Superfund Site. Other contaminants treated were VOCs and SVOCs (EPA 2003). Most often used to treat PAHs, non halogenated SVOCs and BTEX.	Yes
	Monitored Natural Attenuation	Naturally occurring processes in soil and groundwater that reduce mass, toxicity, mobility, volume or concentration of contaminants. Includes biodegradation, dispersion, dilution, adsorption and volatilization.	Available evidence shows limited natural biological decomposition of PCBs.	Yes
	Soil Vapor Extraction (SVE)	Removal of volatile contaminants by extracting soil vapor with a vacuum pump.	Access may be limited for subsurface installations due to presence of buildings, railroads, and traffic. As standalone treatment method, not effective for PCBs due to their low vapor pressure.	No
	Steam Injection	Removal of strippable contaminants using steam, recovery of condensate at surface.	Access may be limited by buildings, roadways, rail lines and buried utilities. Requires off-gas capture and may increase indoor air exposure. Highly porous site soils would make it difficult to apply and capture steam in deep vadose zone soil matrix.	No

Table 3-5 - Physical/Chemical Screening Criteria of Remedial Technologies for PCB-Impacted Deep Vadose Zone Soil

General Response Action	Remedial Technology	Description	Screening Comments	Technology Retained
In situ Treatment of Soils (continued)	Six Phase Soil Heating	Removal of strippable contaminants using heat, recovery of condensate at surface.	Stray electrical current may impact neighboring rail lines and buried utilities near Kaiser. Limited to accessible areas, requires capture and treatment of extracted vapors. To heat the large volume of deep vadose soil (20 to 68 feet) would require access to very large sources of electrical power.	No
	Soil Flushing	Removal of leachable contaminants using surfactants. Leachate is recovered at the surface.	Access limited by buildings, roadways, rail lines and buried utilities. Technology may not be effective due to PCBs limited solubility in non-organic solvents.	No
	Pneumatic Fracturing	Pretreatment of in place soils to enhance performance of other *in situ* processes.	Not needed because native soil permeable. Pneumatic injection of sand may cause ground movement beneath existing structures and utilities.	No
	Chemical Treatment	Injection of chemicals for *in situ* treatment of contaminants (e.g., oxidation/reduction, pH adjustment).	Has been used for the treatment of PCBs at Battery Tech Superfund Site. Along with PCBs, various VOCs were also treated (EPA 2003).	Yes
	Electro-Kinetic Treatment	Direct current used to cause contaminants to migrate to electrodes where they are treated.	PCBs are not ionized and will not migrate in an electric field.	No
	Vitrification	Use high energy to melt soil in place and minimize migration.	Stray current and heat may impact rail lines and buried utilities; requires off-gas capture; off-gas may be toxic (dioxin and furans); potential for settlement due to volume changes. Technology has been used at Superfund sites (GE site in Eastern Washington and Oak Ridge Reservation in Tennessee) for treatment of PCB-impacted soil (EPA 2003). Use typically confined to soil depths above 20 feet bgs.	No

Table 3-5 - Physical/Chemical Screening Criteria of Remedial Technologies for PCB-Impacted Deep Vadose Zone Soil

General Response Action	Remedial Technology	Description	Screening Comments	Technology Retained
On-Site Treatment of Extracted Soil Vapor/Off-gas	Adsorption	Removal of adsorbable compound using canister in series, may require disposal.	Demonstrated effective for SVOC and organic PCB degradation products.	Yes
	Thermal Oxidation	Vapor heated above 1,400°F to oxidize organics; requires emission controls (e.g., direct flame, flameless).	Demonstrated effective for SVOC and organic PCB degradation products.	Yes
	Catalytic Oxidation	Vapor heated up to 800°F to oxidize organics, requires HCI controls.	Demonstrated effective for SVOC and organic PCB degradation products.	Yes
	Advanced Oxidation	Vapor is passed through catalyst while exposed to high intensity UV light or ozone.	Demonstrated effective for SVOC and organic PCB degradation products.	Yes
	Biofiltration	Gases are passed through a soil bed where contaminants are sorbed and degraded by bacteria in soil.	Demonstrated effective for SVOC and organic PCB degradation product.	Yes
	Chlorine Scrubber	Gases pass through a packed bed where chlorine is absorbed into a liquid (such as water or NaOH solution) typically flowing counter current to gas.	Standard technology to treat PCB degradation products in off-gas from some *in situ* PCB treatment processes.	Yes

Table 3-6a - Implementability of Selected Technologies for VOC-Impacted Deep Vadose Zone Soil

Technology	**Process Options**	**Can it be Implemented?**[1]
Monitoring	Protection, Performance, and Confirmational Monitoring	Yes
Access and Use Restrictions	Fencing, signs, deed restrictions.	Yes
Best Management Practices	Spill Prevention, leak detection, double walled pipes, proper storage of chemicals and solvents.	Yes
Capping	Soil Cap	No
Capping	Clay Cap	No
Capping	Low Permeable Asphalt Cap	Yes
Capping	Low Permeable Concrete Cap	Yes
Capping	Synthetic Liner	No
Capping	Multilayer Cap (soil + synthetic liner)	Yes
In situ Bioremediation	Bioventing (injecting and/or withdrawing air in vadose zone)	No
In situ Bioremediation	Enhanced Bioremediation	No
In situ Bioremediation	Phytoremediation	No
Monitored Natural Attenuation	Monitored Natural Attenuation	Yes
Soil Vapor Extraction	Vertical Vents	Yes
Soil Vapor Extraction	Horizontal Vents	No
Adsorption	Activated Carbon	Yes
Thermal and Catalytic Oxidation	Direct Flame, Flameless, Hybrid Thermal/Catalytic	No
Thermal and Catalytic Oxidation	Catalytic Oxidizers	Yes
Advanced Oxidation	UV light	No
Advanced Oxidation	Photocatalytic destruction	Yes
Biofiltration	Biofiltration	No

Note:

1) The reasons why each process option was judged to be implementable for VOCs in deep vadose zone soils are similar to the reasons the process option was judged to be implementable for VOCs in near-surface soils as presented in Tables 2-8a through 2-8f and Tables 2-8h through 2-8k. Refer to the evaluations in these tables.

Table 3-6b - Implementability of *In Situ* Chemical Treatment for VOC-Impacted Deep Vadose Soil

	Process Options for *In situ* Chemical Treatment
Attribute	**Oxidation**
Can it be constructed?	Yes, site is amenable to constructing and operating support equipment though access may be limited in some areas by infrastructure. Design, construction, and startup will take approximately 1 year.
Will it work?	Uncertain, effective for TPH and non-chlorinated VOCs. Extremely low soil moisture content (summer) and colder temperatures (winter) and relatively low concentration of Stoddard solvent in the Oil house area will make effective contact between the chemical agent and the VOCs difficult.
Will this be acceptable to regulatory agencies?	Yes
Is technology available?	Yes
Is process option accepted?	Yes

Table 3-7a - Reliability of Selected Technologies for VOC-Impacted Deep Vadose Zone Soil

Technology	Process Options	Is it reliable?[1]
Monitoring	Protection, Performance, and Confirmational	Yes
Access and Use Restrictions	Fencing, signs, deed restrictions.	Yes
Best Management Practices	Spill Prevention, leak detection, double walled pipes, proper storage of chemicals and solvents.	Yes
Capping	Low Permeability Asphalt Cap	Yes
Capping	Low Permeability Concrete Cap	Yes
Capping	Multilayer (soil + synthetic liner)	Yes
Monitored Natural Attenuation	Monitored Natural Attenuation	Yes
Soil Vapor Extraction	Vertical Vents	Yes
Adsorption	Activated Carbon	Yes
Thermal and Catalytic Oxidation	Catalytic Oxidizers	Yes
Advanced Oxidation	Photocatalytic Destruction	Yes

Note:

1) The evaluations of reliability given in this table for VOCs are the same as those for VOCs in near-surface soils for reasons similar to those given in Tables 2-9a through 2-9h. Refer to the evaluations in those tables.

Table 3-7b - Reliability of *In Situ* Chemical Treatment of VOC-Impacted Deep Vadose Zone Soil

	Process Options for *In situ* Chemical Treatment of VOC-Impacted Deep Vadose Zone Soils
Attribute	**Oxidation**
Has this process option been used at the scale required for Kaiser?	Yes. Chemical treatment of near-surface vadose zone soils has been completed at other large-scale industrial facilities. Liquid treatment chemicals could be distributed throughout the porous deep vadose zone soil matrix.
Are operation and maintenance requirements infrequent and straightforward?	No. System includes aboveground chemical storage, chemical injection wells, off-gas collection wells, and an off-gas treatment system.
Has this process option been proven effective under waste and site conditions similar to those at Kaiser?	No. Porous sands and gravels will not confine injected fluids to the deep vadose zone area of interest and the relatively low VOC concentrations and low organic carbon present in soil at this site make contact with and subsequent reaction with treatment inputs difficult. Off-gases will be generated and must be collected and potentially treated to meet regulatory requirements.
Is process option accepted?	No

Table 3-8 - Summary of Technology Screening Process: VOCs in Deep Vadose Zone Soils

			Screening Outcome		
General Response Action (a)	Remedial Technology (a)	Process Options (a)	Physical/Chemical (b)	Implementability (c)	Reliability (d)
Monitoring	**Monitoring**	**Protection, Performance, and Confirmational**	**Retained**	**Retained**	**Retained**
Institutional Controls	**Access and Use Restrictions**	**Fences, Signs, Deed Restrictions**	**Retained**	**Retained**	**Retained**
	Best Management Practices	**Spill prevention, leak detection, double walled pipes**	**Retained**	**Retained**	**Retained**
Containment	**Capping**	Soil	Retained	Eliminated	--
		Clay	Retained	Eliminated	--
		Asphalt	**Retained**	**Retained**	**Retained**
		Concrete	**Retained**	**Retained**	**Retained**
		Synthetic	Retained	Eliminated	--
		Multi-layer (soil + synthetic liner)	**Retained**	**Retained**	**Retained**
	Landfill Cap Enhancements	Run-on and run-off controls, vegetative cover	Eliminated	--	--
	Solidification/ Stabilization	Cement- and lime-based processes, microencapsulation, sorption	Eliminated	--	--
***In Situ* Soils Treatment**	Vitrification	Combined with soil vapor extraction	Eliminated	--	--
	In Situ Bioremediation	Bioventing	Retained	Eliminated	--
		Enhanced Bioremediation	Retained	Eliminated	--
		Phytoremediation	Retained	Eliminated	--
	Monitored Natural Attenuation	**Monitor natural processes**	**Retained**	**Retained**	**Retained**
	Soil Vapor Extraction (SVE)	Horizontal vents	Retained	Eliminated	--
		Vertical Vents	**Retained**	**Retained**	**Retained**
	Steam Injection	Combined with soil vapor extraction	Eliminated	--	--
	Six Phase Soil Heating	Combined with soil vapor extraction	Eliminated	--	--
	Soil Flushing	Water, surfactants, solvents	Eliminated	--	--
	Pneumatic Fracturing	Pressurized air or steam	Eliminated	--	--
	Chemical Treatment	Oxidation, reduction, pH adjustment	Retained	Retained	Eliminated
	Electro-Kinetic	Enhanced with surfactants and reagents	Eliminated	--	--
On-Site Treatment of Extracted Soil Vapor	Condensation	Refrigerated condenser	Eliminated	--	--
	Adsorption	**Granular activated carbon**	**Retained**	**Retained**	**Retained**
	Thermal and Catalytic Oxidation	Direct flame Thermal	Retained	Eliminated	--
		Flameless Thermal	Retained	Eliminated	--
		Catalytic Oxidizers	**Retained**	**Retained**	**Retained**
		Hybrid Thermal/Catalytic	Retained	Eliminated	--
	Advanced Oxidation	UV light	Retained	Eliminated	--
		Photocatalytic	Retained	Retained	Eliminated
	Biofiltration	Bioreactor, soil pile	Retained	Eliminated	--

Notes:
Bolded Technologies Retained for further evaluation in the FS.
(a) Taken from FSTM Table 3-2
(b) Taken from FSTM Table 3-3
(c) Taken from FSTM Table 3-6a - 3-6b
(d) Taken from FSTM Table 3-7a - 3-7b

Table 3-9a - Implementability of Selected Technologies for SVOC-Impacted Deep Vadose Zone Soil

Technology	**Process Options**	**Can it be Implemented?**[1]
Monitoring	Performance, Protection, Confirmational	Yes
Access and Use Restrictions	Fencing, signs, deed restrictions.	Yes
Best Management Practices	Spill Prevention, leak detection, double walled pipes, proper storage of chemicals and solvents.	Yes
Capping	Soil Cap	No
Capping	Clay Cap	No
Capping	Low Permeable Asphalt Cap	Yes
Capping	Low Permeable Concrete Cap	Yes
Capping	Synthetic Liner	No
Capping	Multilayer Cap (soil + synthetic liner)	Yes
In situ Bioremediation	Phytoremediation	No
Monitored Natural Attenuation	Monitored Natural Attenuation	Yes
Chemical Treatment	Oxidation	Yes[2]
Adsorption	Activated Carbon	Yes[3]
Thermal and Catalytic Oxidation	Direct Flame, Flameless, Hybrid Thermal/Catalytic	No
Thermal and Catalytic Oxidation	Catalytic Oxidizers	Yes[3]
Advanced Oxidation	UV light	No
Advanced Oxidation	Photocatalytic destruction	Yes[3]
Biofiltration	Biofiltration	No

Note:

1) The reasons for implementability for SVOCs in deep vadose zone soils are similar to the reasons provided for VOCs in shallow soils as presented in Tables 2-8a through 2-8e and Tables 2-8h through 2-8k except where noted. Refer to the evaluations in these tables.
2) The reasons for implementability for SVOCs in deep vadose zone soils are similar to the reasons provided for VOCs in deep vadose zone soils as presented in Table 3-6b.
3) If needed to treat off-gas from *in situ* bioremediation or *in situ* chemical treatment processes.

Table 3-9b - Implementability of *In Situ* Bioremediation for SVOC-Impacted Deep Vadose Zone Soil

	Process Options for *In Situ* Bioremediation	
Attribute	**Bioventing (injecting and/or withdrawing air in vadose zone)**	**Enhanced Bioremediation**
Can it be constructed?	Yes, site is amenable to constructing and operating support equipment though access may be limited in some areas by infrastructure. Design, construction, and startup will take approximately 1 year.	Yes, site is amenable to constructing and operating support equipment though access may be limited in some areas by infrastructure. Design, construction, and startup will take approximately 1 year. This technology includes the circulation of water-based solutions to stimulate microbes and/or the injection of Oxygen Release Compounds (ORC) or electron donor compounds.
Will it work?	Uncertain, effective for TPH and non-chlorinated VOCs. Extremely low soil moisture content (summer) and colder temperatures (winter) will limit biodegradation.	Effectiveness may be limited due to the following: porous sands and gravels will not confine circulating or injected fluids to the area of interest; ORC and electron donor inputs require saturated soils to work; and low organic content of soils at this site make contact with treatment inputs difficult.
Will this be acceptable to regulatory agencies?	Yes	Unknown
Is technology available?	Yes	Yes
Is process option accepted?	Yes	Yes

Table 3-10a - Reliability of Selected Technologies for SVOC-Impacted Deep Vadose Zone Soil

Technology	Process Options	Is it reliable?[1]
Monitoring	Protection, Performance, and Confirmational	Yes
Access and Use Restrictions	Fencing, signs, deed restrictions.	Yes
Best Management Practices	Spill Prevention, leak detection, double walled pipes, proper storage of chemicals and solvents.	Yes
Cap	Low Permeability Asphalt Cap	Yes
Cap	Low Permeability Concrete Cap	Yes
Cap	Multilayer (synthetic liner + soil)	Yes
Monitored Natural Attenuation	Monitored Natural Attenuation	Yes
Adsorption	Activated Carbon	Yes[2]
Thermal and Catalytic Oxidation	Catalytic Oxidizers	Yes[2]
Advanced Oxidation	Photocatalytic destruction	No

Note:

1. The evaluations of reliability given in this table for SVOCs are the same as those for VOCs for reasons similar to those given in Tables 2-9a through 2-9d and 2-9f through 2-9h. Refer to the evaluations in those tables.
2. If off-gas treatment is needed by an *in situ* treatment process.

Table 3-10b - Reliability of *In Situ* Bioremediation of SVOC-Impacted Deep Vadose Zone Soil

	Process Options for *In situ* Bioremediation of SVOC-Impacted Deep Vadose Zone Soils	
Attribute	**Bioventing**	**Enhanced Bioremediation**
Has this process option been used at the scale required for Kaiser?	Yes. Bioventing is a conventional process normally employed to collect SVOCs from subsurface soils.	Yes. Site is amenable to constructing and operating support equipment necessary to use this process option at Kaiser.
Are operation and maintenance requirements infrequent and straightforward?	Yes. Bioventing is a conventional technology. No chemicals are used. Off-gas collection and treatment may be needed.	No. Continuous monitoring of the addition of ORC or other additives will be required. Migration of additives from treatment area must be controlled. Off-gas must be treated.
Has this process option been proven effective under waste and site conditions similar to those at Kaiser?	No. The low vapor pressure of many TPH-D/HO compounds will reduce the effectiveness of this technology. Extremely low soil moisture content (summer) and colder temperatures (winter) will limit biodegradation.	Unclear.
Is process option accepted?	No	Yes

Table 3-10c - Reliability of *In Situ* Chemical Treatment of SVOC-Impacted Deep Vadose Zone Soil

	Process Options for *In situ* Chemical Treatment of SVOC-Impacted Deep Vadose Zone Soils
Attribute	**Oxidation**
Has this process option been used at the scale required for Kaiser?	Yes. Site is amenable to constructing and operating support equipment necessary to use this process option at Kaiser.
Are operation and maintenance requirements infrequent and straightforward?	No. Continuous monitoring of the addition additives will be required. Migration of additives from treatment area must be controlled. Potential for exothermic reactions to create bursts of off-gas. Off-gas must be treated.
Has this process option been proven effective under waste and site conditions similar to those at Kaiser?	Unclear.
Is process option accepted?	Yes

Table 3-11 - Summary of Technology Screening Process: SVOCs in Deep Vadose Zone Soils

			Screening Outcome		
General Response Action (a)	**Remedial Technology (a)**	**Process Options (a)**	**Physical/Chemical (b)**	**Implementability (c)**	**Reliability (d)**
Monitoring	**Monitoring**	**Protection, Performance, and Confirmational**	**Retained**	**Retained**	**Retained**
Institutional Controls	**Access and Use Restrictions**	**Fences, Signs, Deed Restrictions**	**Retained**	**Retained**	**Retained**
	Best Management Practices	**Spill prevention, leak detection, double walled pipes**	**Retained**	**Retained**	**Retained**
Containment	**Capping**	Soil	Retained	Eliminated	--
		Clay	Retained	Eliminated	--
		Asphalt	**Retained**	**Retained**	**Retained**
		Concrete	**Retained**	**Retained**	**Retained**
		Synthetic	Retained	Eliminated	--
		Multi-layer (soil + synthetic liner)	**Retained**	**Retained**	**Retained**
	Landfill Cap Enhancements	Run-on and run-off controls, vegetative cover	Eliminated	--	--
	Solidification/ Stabilization	Cement- and lime-based processes, microencapsulation, sorption	Eliminated	--	--
***In Situ* Soils Treatment**	Vitrification	Combined with soil vapor extraction	Eliminated	--	--
	In Situ Bioremediation	Bioventing	Retained	Retained	Eliminated
		Enhanced Bioremediation	**Retained**	**Retained**	**Retained**
	Monitored Natural Attenuation	**Monitor natural processes**	**Retained**	**Retained**	**Retained**
	Soil Vapor Extraction (SVE)	Horizontal vents	Eliminated	--	--
		Vertical Vents	Eliminated	--	--
	Steam Injection	Combined with soil vapor extraction	Eliminated	--	--
	Six Phase Soil Heating	Combined with soil vapor extraction	Eliminated	--	--
	Soil Flushing	Water, surfactants, solvents	Eliminated	--	--
	Pneumatic Fracturing	Pressurized air or steam	Eliminated	--	--
	Chemical Treatment	**Oxidation, reduction, pH adjustment**	**Retained**	**Retained**	**Retained**
	Electro-Kinetic	Enhanced with surfactants and reagents	Eliminated	--	--
On-Site Treatment of Extracted Soil Vapor (e)	Condensation	Refrigerated condenser	Eliminated	--	--
	Adsorption	**Granular activated carbon**	**Retained**	**Retained**	**Retained**
	Thermal and Catalytic Oxidation	Direct flame Thermal	Retained	Eliminated	--
		Flameless Thermal	Retained	Eliminated	--
		Catalytic Oxidizers	**Retained**	**Retained**	**Retained**
		Hybrid Thermal/Catalytic	Retained	Eliminated	--
	Advanced Oxidation	UV light	Retained	Eliminated	--
		Photocatalytic	Retained	Retained	Eliminated
	Biofiltration	Bioreactor, soil pile	Retained	Eliminated	--

Notes:
Bolded Technologies Retained for further evaluation in the FS.
(a) Taken from FSTM Table 3-2
(b) Taken from FSTM Table 3-4
(c) Taken from FSTM Table 3-9a - 3-9b
(d) Taken from FSTM Table 3-10a - 3-10b
(e) If need to treat off-gas from in situ treatment processes.

Table 3-12a - Implementability of Selected Technologies for PCB-Impacted Deep Vadose Zone Soil

Sheet 1 of 1

Technology	Process Options	Can it be Implemented?[1]
Monitoring	Protection, Performance, and Confirmational	Yes
Access and Use Restrictions	Fencing, signs, deed restrictions.	Yes
Best Management Practices	Spill Prevention, leak detection, double walled pipes, proper storage of chemicals and solvents.	Yes
Capping	Soil Cap	No
Capping	Clay Cap	No
Capping	Low Permeable Asphalt Cap	Yes
Capping	Low Permeable Concrete Cap	Yes
Capping	Synthetic Liner	No
Capping	Multilayer Cap (soil + synthetic liner)	Yes
In situ Bioremediation	Bioventing (injecting and/or withdrawing air in vadose zone)	Yes[2]
In situ Bioremediation	Enhanced Bioremediation	Yes[2]
In situ Bioremediation	Phytoremediation	No
Monitored Natural Attenuation	Monitored Natural Attenuation	Yes
In situ Chemical Treatment	Oxidation	Yes[3]
Adsorption	Activated Carbon	Yes[4]
Thermal and Catalytic Oxidation	Direct Flame, Flameless, Hybrid Thermal/Catalytic Oxidizer	No
Thermal and Catalytic Oxidation	Catalytic Oxidizers	Yes[4]
Advanced Oxidation	UV Light	No
Advanced Oxidation	Photocatalytic destruction	Yes[4]
Biofiltration	Biofiltration	No

Note:

1) The reasons for implementability for PCBs in deep vadose zone soils are similar to the reasons provided for VOCs in shallow soils as presented in Tables 2-8a through 2-8e and Tables 2-8h through 2-8k except where noted. Refer to the evaluations in these tables.
2) The reasons for implementability of this process option for PCBs in deep vadose zone soils are similar to the reasons provided for SVOCs in deep vadose zone soils as presented in Table 3-9b.
3) The reasons for implementability of this process option for PCBs in deep vadose zone soils are similar to the reasons provided for VOCs in deep vadose zone soils as presented in Table 3-6b.
4) If needed to treat off-gas from *in situ* treatment processes.

Table 3-12b - Implementability of Stabilization/Solidification for PCB-Impacted Deep Vadose Zone Soil

	Process Options for Stabilization/Solidification
Attribute	**Addition of reagents to physically/chemically bind PCBs in deep vadose zone soil matrix**
Can it be constructed?	Yes, site is amenable to constructing and operating support equipment though access may be limited in some areas by infrastructure. Design, construction, and startup will take approximately 1 year. Has been used at the Chemical Control (New Jersey) and the South 8th Street Landfill (Arkansas) and other CERCLA sites (EPA 2003).
Will it work?	Uncertain. A very large mass of stabilized vadose zone soil would have to be created. The stabilized mass will alter the path of any water that reaches it through infiltration or via groundwater flow (if the stabilized mass reaches the water table). Surface capping would mitigate this outcome. Assuring the correct mixing of cement or other stabilization compound(s) with the soil matrix would be difficult.
Will this be acceptable to regulatory agencies?	Unknown
Is technology available?	Yes
Is process option accepted?	Yes

Table 3-12c – Implementability of Scrubbers to Remove Chlorine from Off-gas of *In situ* Processes for PCB-Impacted Deep Vadose Soil

	Process Options for Off-gas Treatment
Attribute	**Chlorine Scrubbers**
Can it be constructed?	Yes, chlorine scrubbers are routinely used to remove chlorine from off-gas streams. A packed bed or spray chamber is used to contact the off-gas with a liquid stream that usually contains sodium or calcium compounds that will react with the chlorine in the off-gas to from a precipitate that is eventually removed from the recirculating liquid stream.
Will it work?	Yes
Will this be acceptable to regulatory agencies?	Yes
Is technology available?	Yes
Is process option accepted?	Yes

Table 3-13a - Reliability of Selected Technologies for PCB-Impacted Deep Vadose Zone Soil

Technology	**Process Options**	**Is it reliable?**[1]
Monitoring	Protection, Performance, and Confirmational	Yes
Access and Use Restrictions	Fencing, signs, deed restrictions.	Yes
Best Management Practices	Spill Prevention, leak detection, double walled pipes, proper storage of chemicals and solvents.	Yes
Capping	Low Permeable Asphalt Cap	Yes
Capping	Low Permeable Concrete Cap	Yes
Capping	Multilayer Cap (soil + synthetic liner)	Yes
In situ Bioremediation	Bioventing (injecting and/or withdrawing air in vadose zone)	No[2]
Monitored Natural Attenuation	Monitored Natural Attenuation	Yes
In situ Chemical Treatment	Oxidation	No[3]
Adsorption	Activated Carbon	Yes[4]
Thermal and Catalytic Oxidation	Catalytic Oxidizers	Yes[4]
Advanced Oxidation	Photocatalytic Destruction	No

Note:

1) The evaluations of reliability provided in this Table for PCBs in deep vadose zone soils are similar to the evaluations provided for VOCs in shallow soils as presented in Tables 2-9a through 2-9d and Tables 2-9f through 2-9h except where noted. Refer to the evaluations in these tables.
2) The evaluation of reliability listed in the Table for the treatment of PCBs in deep vadose zone soils are similar to the reasons provided for SVOCs in deep vadose zone soils as presented in Table 3-10b.
3) The evaluation of reliability listed in the Table for the treatment of PCBs in deep vadose zone soils are similar to the reasons provided for VOCs in deep vadose zone soils as presented in Table 3-7b.
4) Technology maybe applied to off-gas from *in situ* processes used to remediate PCBs that are co-located with SVOCs.

Table 3-13b - Reliability of Stabilization/Solidification of PCB-Impacted Deep Vadose Zone Soil

	Process Options for Stabilization/Solidification of PCB-Impacted Deep Vadose Zone Soils
Attribute	**Application of cement-like additives to the deep vadose soil matrix**
Has this process option been used at the scale required for Kaiser?	Yes. Stabilization/solidification has been used at used at the Chemical Control (New Jersey) and the South 8th Street Landfill (Arkansas) ,and is proposed for use at Ludlow Sand and Gravel (New York), Midco I and Midco II (Indiana), Mobray Engineering (Alabama), and Whitehouse Oil Pits (Florida) CERCLA sites (EPA 2003).
Are operation and maintenance requirements infrequent and straightforward?	No. Stabilization/solidification requires the intimate mixing of cement-like reagents with the soil mixture. A reagent slurry must be injected into the soil and completely mix with the existing soil matrix. Assuring that the reagents and the soil matrix are completely mixed in the 20 feet bgs to the top of the smear zone (about 65 feet bgs) will be difficult and may not be possible, given the very porous nature of the site soils.
Has this process option been proven effective under waste and site conditions similar to those at Kaiser?	No. Stabilization/solidification of soils is usually applied *ex situ* to soils that have been excavated. This careful allocation of cement-like agents assures the complete mixing of the reagents with the soil matrix. The CERCLA sites listed above contained a mixture of PCBs and other SVOCs and VOCs in the soil matrix. The PCB concentrations were much higher than those found in the deep vadose zone at Kaiser. The depth of application of the *in situ* processes at the Chemical Control (New Jersey) and the South 8th Street Landfill sites were 15 to 17 feet bgs.
Is process option accepted?	No

Table 3-13c - Reliability of *In Situ* Bioremediation of PCB-Impacted Deep Vadose Zone Soil

	Process Options for *In situ* Bioremediation of PCB-Impacted Deep Vadose Zone Soils
Attribute	**Enhanced Bioremediation**
Has this process option been used at the scale required for Kaiser?	Yes. Site is amenable to constructing and operating support equipment necessary to use this process option at Kaiser.
Are operation and maintenance requirements infrequent and straightforward?	No. Continuous monitoring of the addition of ORC or other additives will be required. Migration of additives from treatment area must be controlled. Off-gas must be treated.
Has this process option been proven effective under waste and site conditions similar to those at Kaiser?	Unlikely. The PCB concentrations in vadose zone soil are very low. Assuming contact between ORC and PCB contaminated soil will be very difficult.
Is process option accepted?	No.

Table 3-13d - Reliability of Scrubbers to Remove Chlorine from Off-gas of *In Situ* Processes for PCB-Impacted Deep Vadose Zone Soil

	Process Options for Off-Gas Treatment
Attribute	**Chlorine Scrubbers**
Has this process option been used at the scale required for Kaiser?	Yes, chlorine scrubbers are a conventional means to remove chlorine from an off-gas stream. A packed bed or spray chamber is used to contact the off-gas with a liquid stream that usually contains sodium or calcium compounds that will react with the chlorine in the off-gas to from a precipitate that is eventually removed from the recirculating liquid stream.
Are operation and maintenance requirements infrequent and straightforward?	No. The recirculating liquid stream involves the maintenance of pumps, fittings and valves. The scrubber will add an additional layer of complexity to the operation of the *in situ* process. The calcium or sodium compounds formed in the scrubber may cause a reduction of the pH in the recirculation system. This pH may need to be adjusted regularly. The calcium or sodium compounds formed in the scrubber system will have to be removed from the system regularly. A solid-liquid treatment system is used to accomplish this goal (adding another layer of complexity).
Has this process option been proven effective under waste and site conditions similar to those at Kaiser?	Yes. Chlorine scrubbers are a conventional means to remove chlorine from an off-gas stream.
Is process option accepted?	Yes

Table 3-14 - Summary of Technology Screening Process: PCBs in Deep Vadose Zone Soils

			Screening Outcome		
General Response Action (a)	**Remedial Technology (a)**	**Process Options (a)**	**Physical/Chemical (b)**	**Implementability (c)**	**Reliability (d)**
Monitoring	**Monitoring**	**Protection, Performance, and Confirmational**	**Retained**	**Retained**	**Retained**
Institutional Controls	**Access and Use Restrictions**	**Fences, Signs, Deed Restrictions**	**Retained**	**Retained**	**Retained**
	Best Management Practices	**Spill prevention, leak detection, double walled pipes**	**Retained**	**Retained**	**Retained**
Containment	**Capping**	Soil	Retained	Eliminated	--
		Clay	Retained	Eliminated	--
		Asphalt	**Retained**	**Retained**	**Retained**
		Concrete	**Retained**	**Retained**	**Retained**
		Synthetic	Retained	Eliminated	--
		Multi-layer (soil + synthetic)	**Retained**	**Retained**	**Retained**
	Landfill Cap Enhancements	Run-on and run-off controls, vegetative cover	Eliminated	--	--
	Solidification/ Stabilization	Cement- and lime-based processes, microencapsulation, sorption	Retained	Retained	Eliminated
***In Situ* Soils Treatment**	Vitrification	Combined with soil vapor extraction	Eliminated	--	--
	In Situ Bioremediation	Bioventing	Retained	Retained	Eliminated
		Enhanced Bioremediation	Retained	Retained	Eliminated
		Phytoremediation	Retained	Eliminated	--
	Monitored Natural Attenuation	**Monitor natural processes**	**Retained**	**Retained**	**Retained**
	Soil Vapor Extraction (SVE)	Horizontal vents	Eliminated	--	--
		Vertical Vents	Eliminated	**--**	**--**
	Steam Injection	Combined with soil vapor extraction	Eliminated	--	--
	Six Phase Soil Heating	Combined with soil vapor extraction	Eliminated	--	--
	Soil Flushing	Water, surfactants, solvents	Eliminated	--	--
	Pneumatic Fracturing	Pressurized air or steam	Eliminated	--	--
	Chemical Treatment	Oxidation, reduction, pH adjustment	Retained	Retained	Eliminated
	Electro-Kinetic	Enhanced with surfactants and reagents	Eliminated	--	--
On-Site Treatment of Extracted Soil Vapor (e)	**Adsorption**	**Granular activated carbon**	**Retained**	**Retained**	**Retained**
	Thermal and Catalytic Oxidation	Direct flame Thermal	Retained	Eliminated	--
		Flameless Thermal	Retained	Eliminated	--
		Catalytic Oxidizers	**Retained**	**Retained**	**Retained**
		Hybrid Thermal/Catalytic	Retained	Eliminated	--
	Advanced Oxidation	UV light	Retained	Eliminated	--
		Photocatalytic	Retained	Retained	Eliminated
	Biofiltration	Bioreactor, soil pile	Retained	Eliminated	--
	Chlorine Scrubber	**Chlorine Scrubbers**	**Retained**	**Retained**	**Retained**

Notes:

Bolded Technologies Retained for further evaluation in the FS.

(a) Taken from FSTM Table 3-2

(b) Taken from FSTM Table 3-5

(c) Taken from FSTM Table 3-12a - 3-12c

(d) Taken from FSTM Table 3-13a - 3-13d

(e) If needed to treat off-gas from in situ treatment processes.

Table 3-15 - Location, Concentration, of COCs in Deep Vadose Zone Soil in the AOCs at the Kaiser Facility

Sheet 1 of 3

General Location	Process Unit	COC(s)	Sample Number(s)	Depth (feet)[a]	Concentration (mg/kg)[b]	2012 RI Reference Figures and Tables	Comments
ORB Area	**Man-Made Depression Areas**	Heavy Oil	B-25/S-5, B-25/ S-7, B-25/S-9, B-25/S-11	20 to 68	4,880	Section 2.2, Table 2-1, Figure 2-3 to 2-5	Exceeds SL at 20 feet to 69 feet. No data available below 69 feet. Vertically, started extent of impact at 20 feet bgs and terminated at transition to saturated soil (68 feet). Note that for shallow soils (<20 feet bgs), assumed vertical extent is in entire upper 20 feet. This is the only boring in or close to the West Depression that extends below 20 feet. Assumed lateral extent of contamination is same as near-surface soils in west depression.
	G1 Transfer Line	NA	NA	NA	NA	Section 2.3, Table 2-6, Figure 2-6	No SL exceedances
	G2 Transfer Lines	NA	NA	NA	NA	Section 2.4, Table 2-9, Figure 2-8	No SL exceedances
	G3 Transfer Lines	NA	NA	NA	NA	Section 2.5, Table 2-15, Figure 2-6	No SL exceedances
	1980 Fuel Oil Spill	NA	NA	NA	NA	Section 2.6, tables 2-18, 2-20	No SL exceedances
	Oil Reclamation Building	NA	NA	NA	NA	Section 2.7, Table 2-21, Figure 2-10 to 2-14	No SL exceedances
Rail Car Unloading Area	**RCU Area**	Diesel	RU1-S4, RU1-S5, RU1-S7, RU1-S8	20 to 68	4,300	Section 3.2, Table 3-1, Figure 3-2	Exceeds SL at 17.5 feet. No data deeper than RU1-S8. Vertically, started extent of impact at 20 feet bgs (since examining vadose zone) and terminated at transition to saturated soil (68 feet). Note that for shallow soils (<20 feet bgs), assumed vertical extent from 17.5 to 20 feet bgs. Nearby borings WW-MW-8 and -10 have data in saturated zone with detections and exceedance for petroleum hydrocarbon. Assumed localized lateral area of concern around RU-1 (identical to near-surface soils).
	100,000 gallon Fuel Oil Spill	NA	NA	NA	NA	Section 3.3, Figure 3-2	No SL exceedances
Cold Mill/Finishing Areas	**Cold Mill/Finishing Areas**	Diesel	CM-MW-7S-S1, CM-MW-7S-S2	20 to 68	8,300	Section 4.3, Figure 4-2, Hart Crowser Soil Database	Assume vertical extent from 20 to 68 feet. Sample at 20 feet exceeded SL. Sample from 50 to 51 feet and below water table (70 to 73 feet) also exceed SL. For lateral extent assumed 30 feet radius circle around CM-MW-7S due to lack of data in the area.
	Cold Mill Transfer Lines	NA	NA	NA	NA	Section 4.2, Table 4-1, 4-2 Figure 4-3	No SL exceedances
	Transformer Yard Area	NA	NA	NA	NA	Section 4.3, Figure 4-4, Table 4-6	No SL exceedances
	Continuous Can Process Line (CCPL)	NA	NA	NA	NA	Section 4.4, Tables 4-7 to 4-12, Figure 4-5, 4-6	No SL exceedances
	Chromium Transfer Lines	Hexavalent Chromium	TL-SB-1/S6 (dup of TL-SB-1/S5)	22.5 to 68	24	Section 4.5, Table 4-14, Figure 4-7	Below SL at 21 feet. No data available below 26 feet. For upper boundary went half the distance to clean sample and terminated at transition to saturated soil (68 feet). For lateral extent assumed circle with radius equal to half of the distance between TL-SB-1 and TL-SB-2. TL-SB-2 samples collected from 19 to 24 feet bgs were below screening level.
	Cold Mill Electrical Grounding Pit	NA	NA	NA	NA	Section 4.6, Table 4-19, Figure 4-2	No SL exceedances
	Former Coater Line Tank	NA	NA	NA	NA	Section 4.7, Table 4-20, 4-21, Figure 4-2	No SL exceedances

Table 3-15 - Location, Concentration, of COCs in Deep Vadose Zone Soil in the AOCs at the Kaiser Facility

General Location	Process Unit	COC(s)	Sample Number(s)	Depth (feet)[a]	Concentration (mg/kg)[b]	2012 RI Reference Figures and Tables	Comments
Oil House Area	**Oil House Tank Area**	TPH (418.1)	OH-SB-2-S8	41.5-68	4,000	Section 5.2, Table 5-1, Figure 5-2, 5-3	Only sample collected in this AOC with vadose soil exceeding SLs. Only one sample collected from OH-SB-2. Considered the adjacent sample OH-SB-3/S-5 collected at 23-25 feet (below SL for TPH) to represent the upper bounds to this impacted zone. Went half the distance to 25 feet on the upper end and assumed impacts extend to the transition depth of 68 feet.
		Arsenic	OH-SB-3/S-5	20-68	11	Section 5.2, Table 5-1, Figure 5-2, 5-3	Sample exceeded in near-surface, assume upper bound begins at 20 feet bgs. No data available below OH-SB-3/S-5 (23 to 25 feet), so assumed vertical extent terminates at water table (68 feet). Assumed localized areal impact.
	20,000 gal gas tank	NA	NA	NA	NA	Section 5.4.2, Table 5-6, Figure 5-4	No SL exceedances
	Tank Farm Kensol Spill Area	Kensol	TF-MW-1-S10, TF-MW-1-S11, TF-MW-4-S6, TF-MW-5-S6	41-68	14,925	Section 5.7, Table 5-15, Figure 5 8	Samples at 26 feet (TF-MW-4 only) below SL, samples at 56 and 66 feet exceeded SLs. Went half the distance between 26 and 56 feet to define the upper bounds of impacted zone. Assumed the impacted zone extended to 68 feet.
		Stoddard	TF-MW-1-S10, TF-MW-1-S11	41-68	260	Section 5.7, Table 5-15, Figure 5 8	Samples at 26 feet (TF-MW-4 only) below SL, samples at 56 and 66 feet exceeded SLs. Went half the distance between 26 and 56 feet to define the upper bounds of impacted zone. Assumed the impacted zone extended to 68 feet.
		Stoddard	TF-MW-4-S6	41-68	150	Section 5.7, Table 5-15, Figure 5 8	Samples at 26 feet (TF-MW-4 only) below SL, samples at 56 and 66 feet exceeded SLs. Went half the distance between 26 and 56 feet to define the upper bounds of impacted zone. Assumed the impacted zone extended to 68 feet.
	500-Gal. Diesel UST Area	NA	NA	NA	NA	Section 5.3, Table 5-5	No SL exceedances
	8 Tanks Area	Kensol	1-B, 2-B, 3-B	32-68	28,700	Section 5.5, Table 5-9, 5-10, Figure 5-5	Only samples collected in the vadose zone, considered the 32-68 foot zone to be impacted.
		Kensol	5-B, 6-B, 7-B	32-68	3,100	Section 5.5, Table 5-9, 5-10, Figure 5-6	Only samples collected in the vadose zone, considered the 32-68 foot zone to be impacted.
		Arsenic	2-B, 4-B	32-68	12	Section 5.5, Table 5-9, 5-10, Figure 5-5	Two distinct areas. Only samples collected in the vadose zone, considered the 32-68 foot zone to be impacted.
	Drum Storage and French Drain Area	PCBs	SA-1/S-5, SA-1/S-6, SA-1/S-8, SA-1/S-9, SA-1/S-12	20-68	0.49	Section 5.6, Table 5-12, Figure 5-6 5-7	Exceeds SL at 20 feet and at 65 feet with several exceedances in between. Assumed the entire vadose zone is impacted.
		PCBs	SA-6/S-4, SA-6/S-5c, SA-6/S-8, SA-6/S-9, SA-6/S-11, SA-6/S-12	20-68	79	Section 5.6, Table 5-12, Figure 5-6 5-7	Exceeds SL at 20 feet and exceeds SL at 70 feet with several exceedances in between. Assumed the entire vadose zone is impacted.
		Kensol	SA-6/S-12	62.5-68	7,400	Section 5.6, Table 5-12, Figure 5-6 5-7	Below SL at 60 feet and exceeds SL at 70 feet. Went half the distance to the clean sample and terminated area of concern at transition to saturated soil (68 feet).
		Stoddard	SA-6/S-12	62.5-68	230	Section 5.6, Table 5-12, Figure 5-6 5-7	Below SL at 60 feet and exceeds SL at 70 feet. Went half the distance to the clean sample and terminated area of concern at transition to saturated soil (68 feet).
		Heavy oil	SA-6/S-4	22.5-27.5	2,800	Section 5.6, Table 5-12, Figure 5-6 5-7	Below SL at 20 feet and 30 feet. Went half the distance to clean samples.

Table 3-15 - Location, Concentration, of COCs in Deep Vadose Zone Soil in the AOCs at the Kaiser Facility

General Location	Process Unit	COC(s)	Sample Number(s)	Depth (feet)[a]	Concentration (mg/kg)[b]	2012 RI Reference Figures and Tables	Comments
Wastewater Treatment Area	**FCT Area**	NA	NA	NA	NA	Section 6.2, Table 6-1, Figure 6-2	No SL exceedances
	Hoffman Tank Area	TPH (418.1)	WW-MW-4/S-5	35-55	2,800	Section 6.3, Table 6-7, 6-8, Figures 6-4 to 6-6	Only sample between 20 feet and 55 feet BGS (assumed water table in Wastewater area). Assumed upper 35 feet of soil in this vicinity is clean backfill.
		PCBs	HTE-4	35-55	0.52	Section 6.3, Table 6-7, 6-8, Figures 6-4 to 6-6	Only sample between 20 feet and 55 feet BGS (assumed water table in Wastewater area). Assumed upper 35 feet of soil in this vicinity is clean backfill.
	H2S Scrubber Building	Arsenic	HT-SB-1-S4	20-49	12	Section. 6.4, Tables 6-9, 6-10, Figure 6-7	Sample in near-surface exceeds SL at 19-20 feet bgs. Sample collected at 59 feet bgs below screening level. Vertical extent went from 20 to half the distance to the clean sample. Assumed localized lateral area of concern around sample (identical to near-surface soils).
Truck Shop Area	**Truck Shop**	Heavy oil	TSMW-1S/S-5	20-27.5	2,300	Section 7, Table 7-3, Figure 7-2	Exceeds SL at 20 feet, below SL at 30 feet. Considered 20 to 27.5 foot zone greater than SL, went half the distance between dirty sample at 25 feet and clean sample at 30 feet.
Discharge Ravines Areas	**West Ravine**	NA	NA	NA	NA	Section. 8.2, Table 8-2, Figures 8-2 to 8-17	No SL exceedances
	South Ravine	NA	NA	NA	NA	Section. 8.3, Tables 8-4 to 8-6, Figures 8-	No SL exceedances
Remelt/Casting Areas	**DC1 Area East Excavation**	NA	NA	NA	NA	Section. 9-2, Table 9-2, Figure 9-3	No SL exceedances
	DC1 Area West Excavation	NA	NA	NA	NA	Section. 9-2, Table 9-2, Figure 9-3	No SL exceedances
	Remelt Area Wells/Borings	PCBs	RM-MW-8S S-6, RM-MW-8S S-7, RM-MW-8S S-8, RM-MW-8S S-9, RMSW-MW-11S-S3, RMSW-MW-11S-S4, RMSW-MW-11S-S5, RMSW-MW-11S-S6, RMSW-MW-11S-S7, RMSW-MW-11S-S8, RMSW-MW-11S-S9	22.5-68	351	Section 9.2, Tables 9-1, 9-5, Figure 9-1	Samples below SL at 20 feet in both borings, greater than SL at 70 feet in RMSW-MW-11. Assumed impacted zone extends from half the distance to clean soil (22.5 feet) to the saturated soil interface at 68 feet.
		PCBs	RM-MW-9S S-5, RM-MW-9S S-6, RM-MW-9S S-7, RM-MW-9S S-8, RM-MW-9S S-9, RM-MW-9S S-10	20-68	553	Section 9.2, Tables 9-1, 9-5, Figure 9-1	Samples at 20 feet and 75 feet BGS exceed SL. Assumed the entire vadose zone exceeds SL.
		PCBs	RM-F4-SB-1 S-6, RM-F4-SB-1 S-8	27.5-50.5	1	Section 9.2, Tables 9-1, 9-5, Figure 9-1	Samples at 25 feet and 60 feet below SL. Went half the distance to clean samples.
		Arsenic	HL-MW-24DD-S4, HL-MW-30S 40'	30-56	11	Section 9.2, Tables 9-1, 9-3, 9-7, Figure 9-1	Two distinct areas. Scattered arsenic data for vadose zone soils. Assumed a 30-foot radius around each sample location. Samples were below the SL at 69 and 70 feet. Assumes upper bound to be half the distance from the sample to the top of the vadose zone (20 ft). Assumed lower bound to be half the distance from the samples to the clean sample.
		Heavy Oil	HL-DW-SB-2/S-6	55.5-68	3,500	Section 9.2, Tables 9-1, 9-3, 9-7, Figure 9-1	Samples at 52 feet and 79 feet below SL. Went half the distance to clean samples which extended into the saturated zone. Terminated the lower depths of this impacted zone at the saturated zone transition (68 feet).

Notes

[a] Seasonal high water tables were determined in Section 1 of the Final Soil RI (Hart Crowser 2012b) based on April 2007 groundwater monitoring data and are as follows: Mill Area - 68 feet BGS, Wastewater Area - 55 feet BGS, near river area - 33 feet BGS.

[b] Concentration represents the average concentration of COCs if more than one sample exceeded CULs in each AOC. One half of the reporting limit was used in averaging calculations if non-detect samples were present in the AOC.

NA= not applicable, no screening level exceedances in area. Field shaded for ease of reading.

Table 3-16 - Distribution of COCs in Deep Vadose Zone Soil in the General Operating Areas of the Kaiser Facility

General Area	Subsites	Rough Order of Magnitude Mass of COCs in pounds							
		Stoddard solvent	cPAHs	TPH[a]	Diesel or Kensol	Heavy Oil	PCBs	Arsenic	Chromuim
ORB	Man-Made Depressions					30,000			
	G1 Transfer Line								
	G2 Transfer Lines								
	G3 Transfer Lines								
	1980 Fuel Oil Spill								
	Oil Reclamation Building								
RCU	RCU Area				96,000				
	100,000 gallon Fuel Oil Spill								
Cold Mill/Finishing Area	Eastern Cold Mill/Finishing Area				117,000				
	Cold Mill Transfer Lines								
	Tranformer Yard Area								
	CCPL Cell 4								
	Cold Mill Electrical Grounding Pit								
	Chromium Transfer Lines								150
	Former Coater Tank								
Oil House Area	500-Gallon Diesel Underground Storage Tank								
	20,000-Gallon Leaded Gasoline UST								
	Oil House Tank Area			13,800				17	
	Tank Farm Kensol Spill Area	1,455			230,000				
	Eight USTs Excavation				70,600			19	
	Oil House Drum Storage/French Drain	90			2,900	1,000	271		
Wastewater Treatment Area	Field-Constructed Tanks								
	Hoffman Tank Excavation			14,000			5		
	Hydrogen Sulfide Scrubber Building							11	
Truck Shop Tank Area	Truck Shop Tank Area					1,500			
Discharge Ravines	WDR								
	SDR								
Remelt/Casting Areas	DC-1 Furnace Area East Excavation								
	DC-4 Furnace Vent Trench								
	Remelt/Hot Line Area					22,000	11,103	173	
Total		1,500	0	27,800	517,000	54,500	11,400	219	150
Percentage of Total		0.24%	0.00%	4.54%	84.40%	8.90%	1.86%	0.04%	0.02%

Notes

a - TPH represents mass of total petroleum hydrocarbons calculated based on concentrations provided by analysis TPH 418. This analysis does not provide information on the composition of the hydrocarbon mixture. This method was used during the initial site characterizations conducted in the late 1980s and early 1990s. At that time, it was the only petroleum hydrocarbon analysis accepted by the regulatory agencies (Final Soil RI).

Subsites with no COCs are shaded.

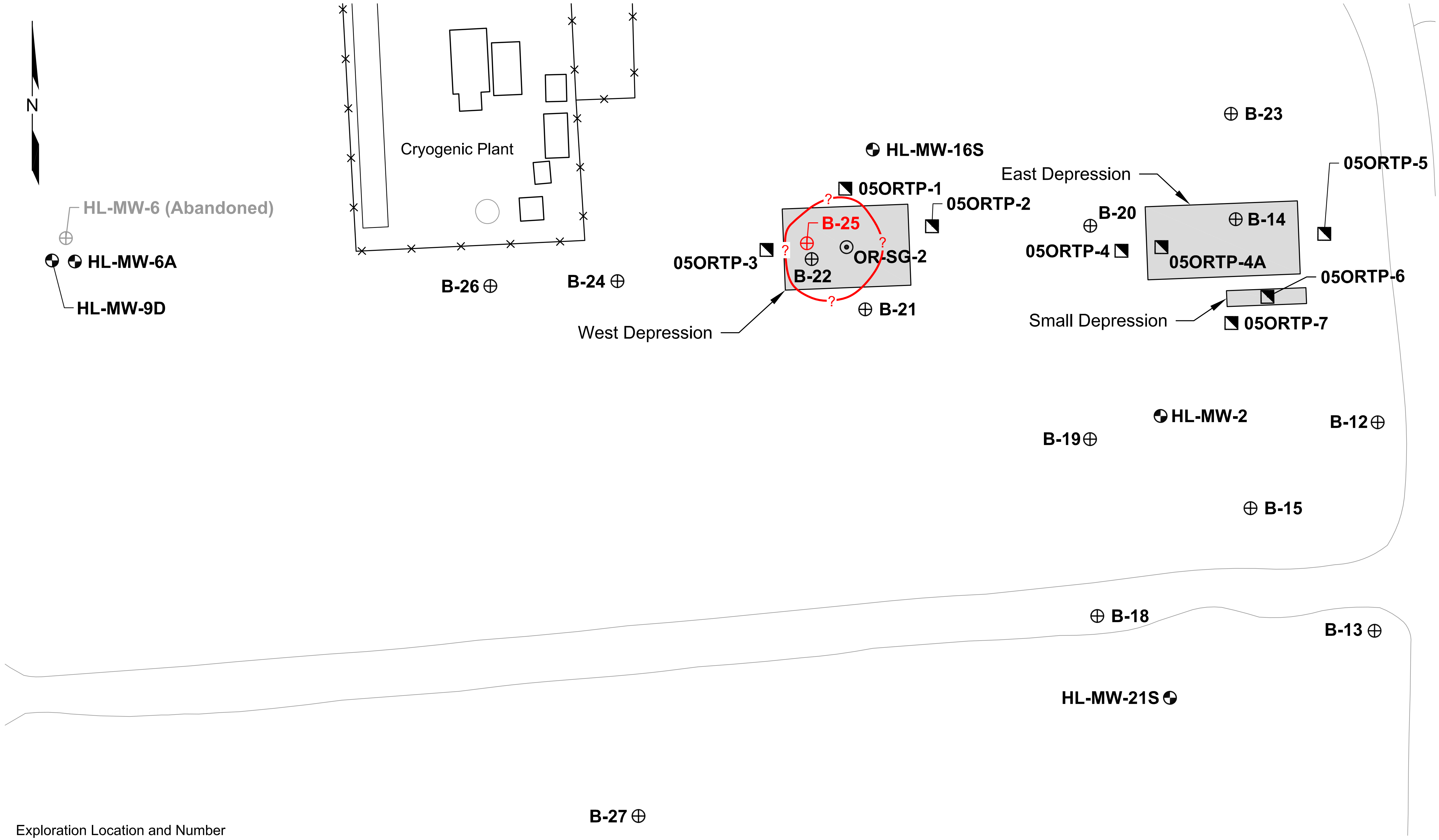
Table 3-17 - Technology-Based Remedial Alternatives: COC Group Matrix - Deep Vadose Zone Soils

		Contaminants of Concern			
Alternative	Description	VOCs	SVOCs	PCBs	Metals
A1	Institutional Controls & Monitoring & MNA	X	X	X	X
A2	Institutional Controls & Monitoring & MNA & Capping	X	X	X	X
A3	Soil Vapor Extraction plus off-gas treatment & A2	X			
A4a	*In situ* Bioremediation & A3 (2)		X	X	
A4b	*In situ* Chemical Oxidation & A3 (2)		X	X	
A5	A2 (1)			X	

Notes:
Selected Alternatives can be used individually or in combinationdepending on COCs in AOD. See Section 2.7.2 for more detail.
(1) For areas where PCBs are not comingled with SVOCs.
(2) For areas where PCBs are comingled with SVOCs.

Man-Made Depressions

Deep Vadose Zone Soil Screening - Heavy Oil



Exploration Location and Number

B-25 ⊕	Samples with Screening Level Exceedance
OR-SG-2 ⊙	Soil Gas Sample (Hart Crowser 2005)
05ORTP-1 ◪	Test Pit (Hart Crowser 2005)
HL-MW-6A ◐	Monitoring Well
B-12 ⊕	Soil Boring (Hart Crowser 1996)

—?— Heavy Oil Area of Screening Level Exceedance

▨ Estimated Location of Historical Man-Made Depression

0 40 80
Scale in Feet

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Figure 3-1

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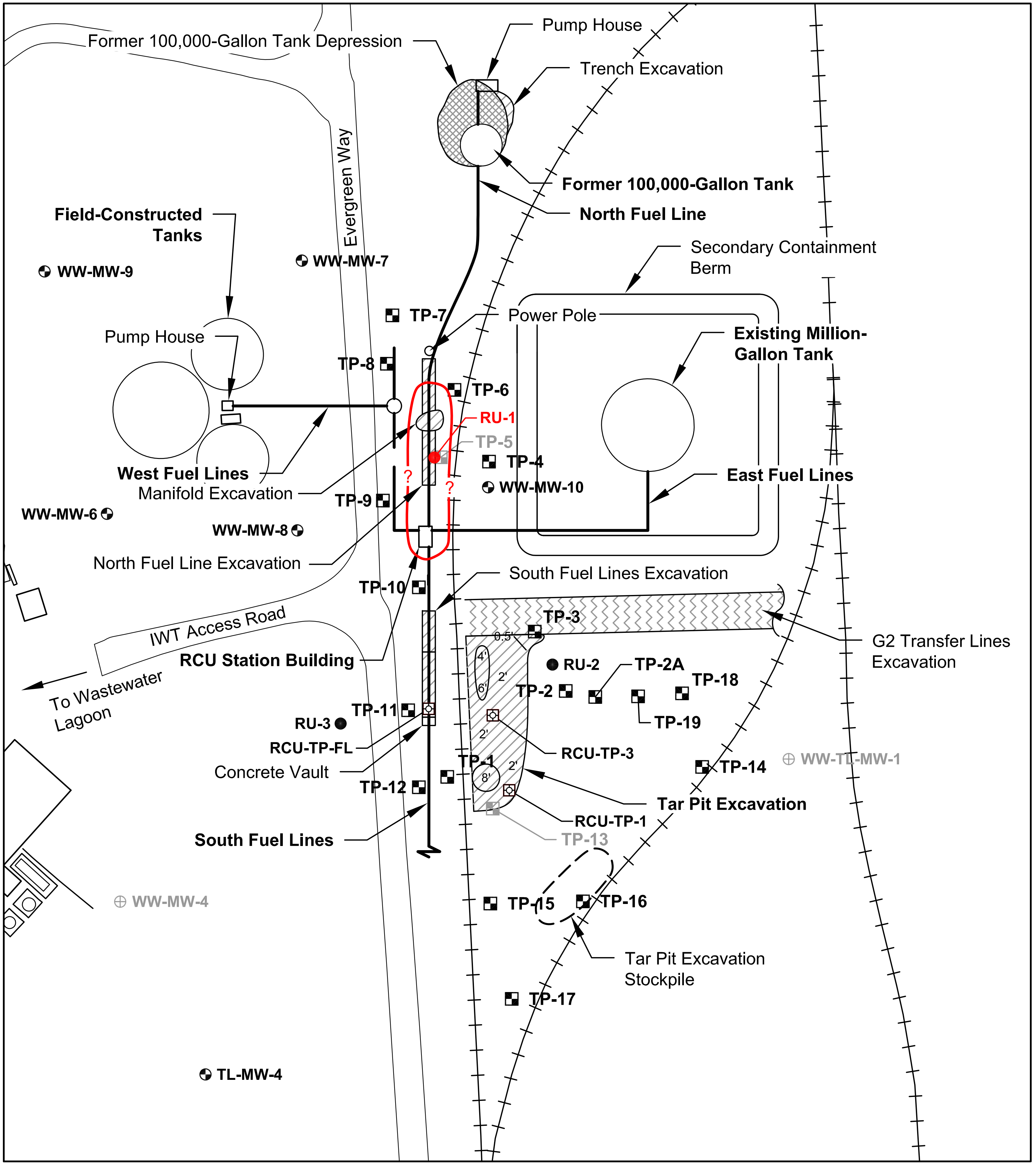
Rail Car Unloading (RCU) Area

Deep Vadose Zone Soil Screening - Diesel



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Exploration Location and Number

RCU-TP-1 ⊠	Phase II RI Test Pit
WW-MW-8 ⊕	Monitoring Well
RU-3 ●	1996 Soil Boring
TP-12 ◪	1996 Test Pit (Shaded Test Pit Excavated)
2'	Depth of Tar Pit Excavation in Feet
RU-1 ●	Soil Sampling Location with Screening Level Exceedance
—	Fuel Line
▦	Existing Excavation
▧	Phase I Excavation
▨	Phase II Excavation
—?—	Diesel Area of Screening Level Exceedances

Notes:

1. Soil from TP-11 and TP-17 were not submitted for chemical analysis.
2. Soil representative of test pit TP-5 and TP-13 were removed during subsequent excavation.
3. Locations of features not shown on original site base map are approximate.
4. Samples RCU-SP and FO-SP were collected from tar pit excavation stockpile.

N

0 100 200

Scale in Feet

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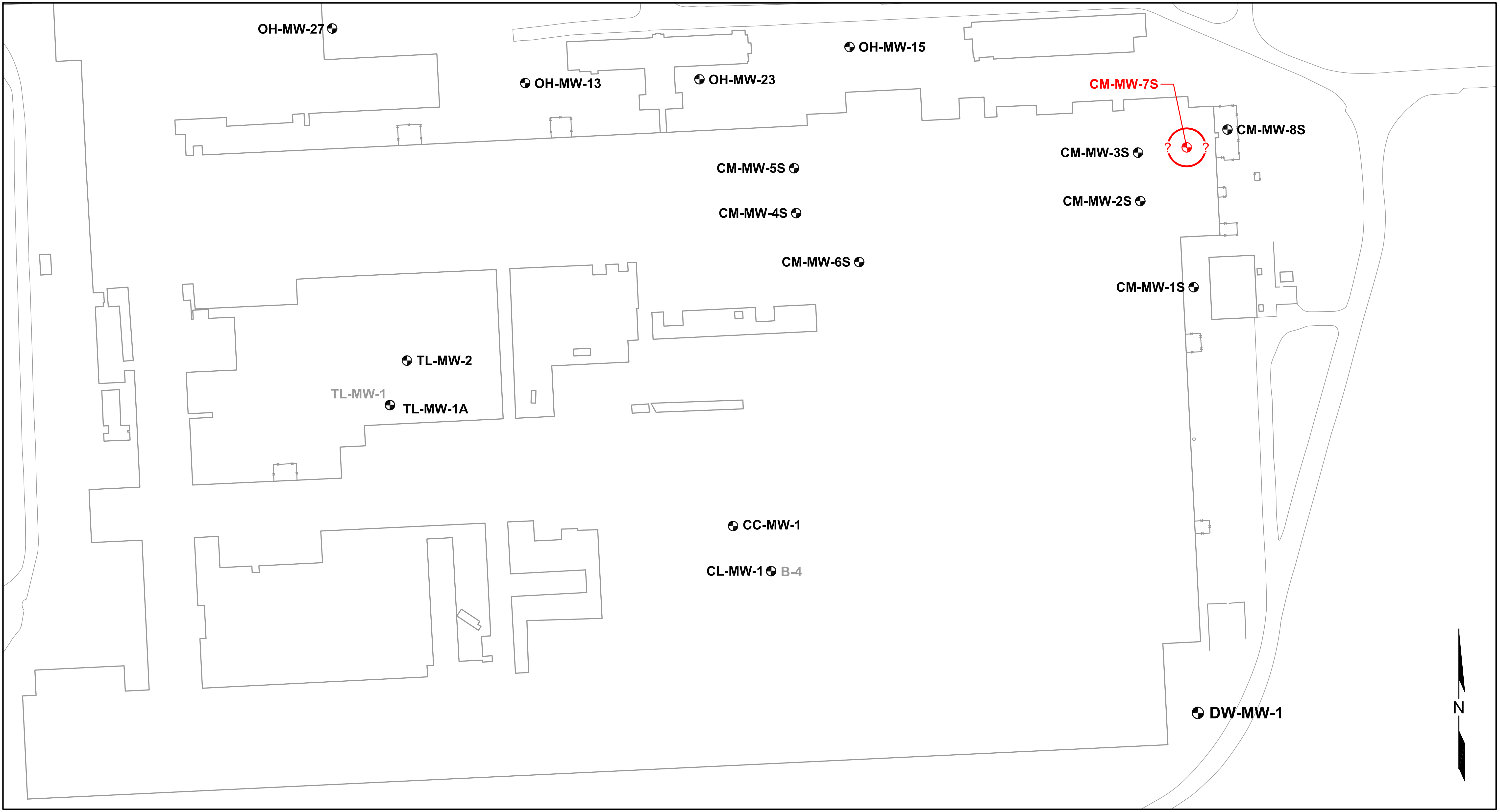
Figure 3-2

Eastern Cold Mill/Finishing Area
Deep Vadose Zone Soil Screening - Diesel



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Exploration Location and Number

CM-MW-6S ◐ Monitoring Well

TL-MW-1 ⊕ Abandoned Monitoring Well

? —— Diesel Area of Screening Level Exceedance

CM-MW-2S ◐ Sample Location with Screening Level Exceedance

0 150 300
Scale in Feet

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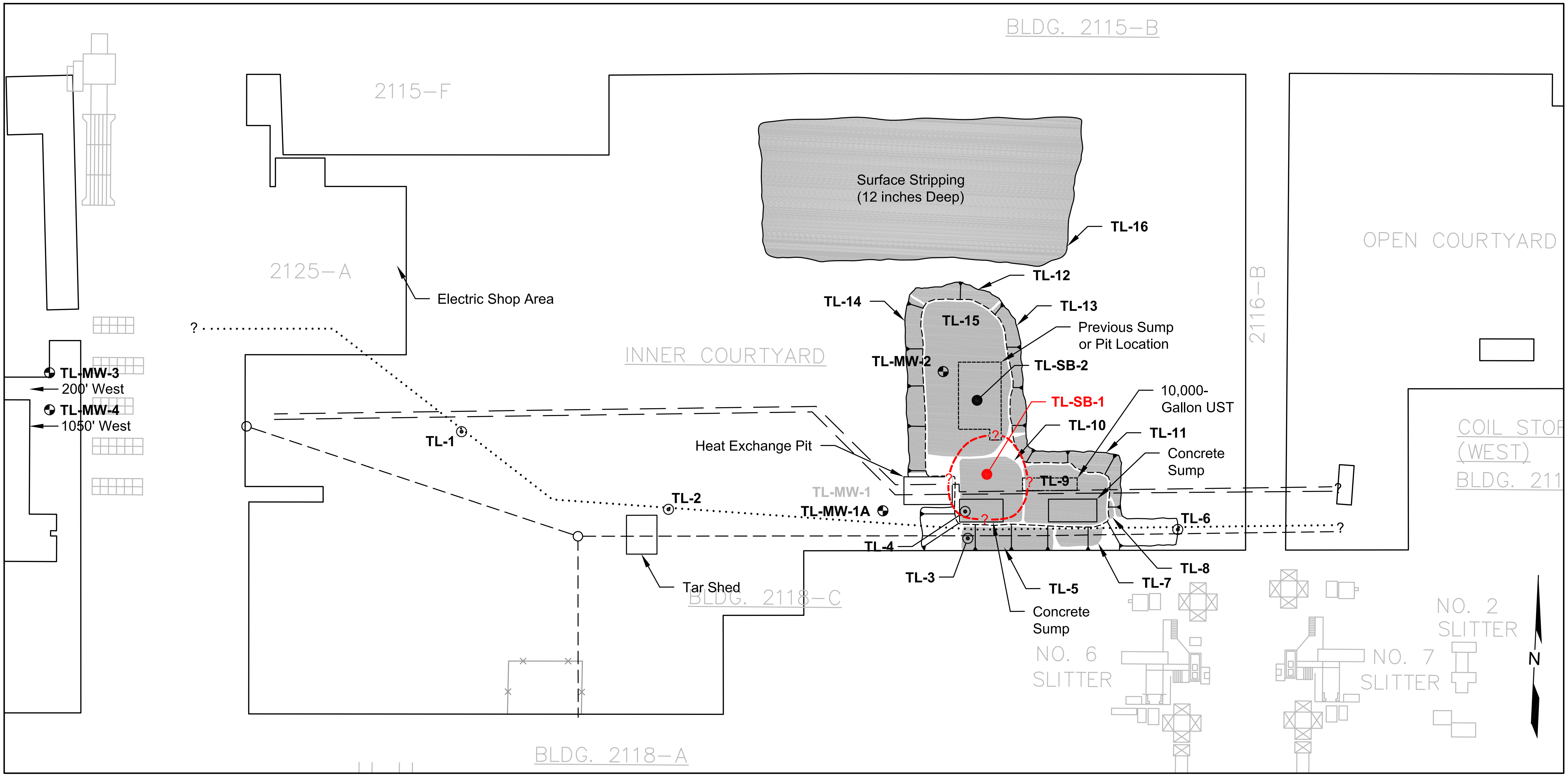
Figure 3-3a

Chromium Transfer Line

Deep Vadose Zone Soil Screening - Chromium



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TL-SB-1 Soil Sampling Location with Screening Level Exceedance

TL-MW-2 ◐ Monitoring Well Location and Number (October 16, 1980)

TL-SB-2 ● Soil Boring Location and Number (October 16, 1980)

TL-6 ⊙ Discrete Soil Sample Location and Number

TL-15 Composite Soil Sample Location and Number

···⊙··· Manhole

········ Chromium Transfer Line

— — Existing Gravity Lines for Phosphate-Bearing Waste

— — — Storm Sewer Line

--?-- Chromium Area of Screening Level Exceedance

Note: Gray shading denotes area of excavation.

0 50 100
Scale in Feet

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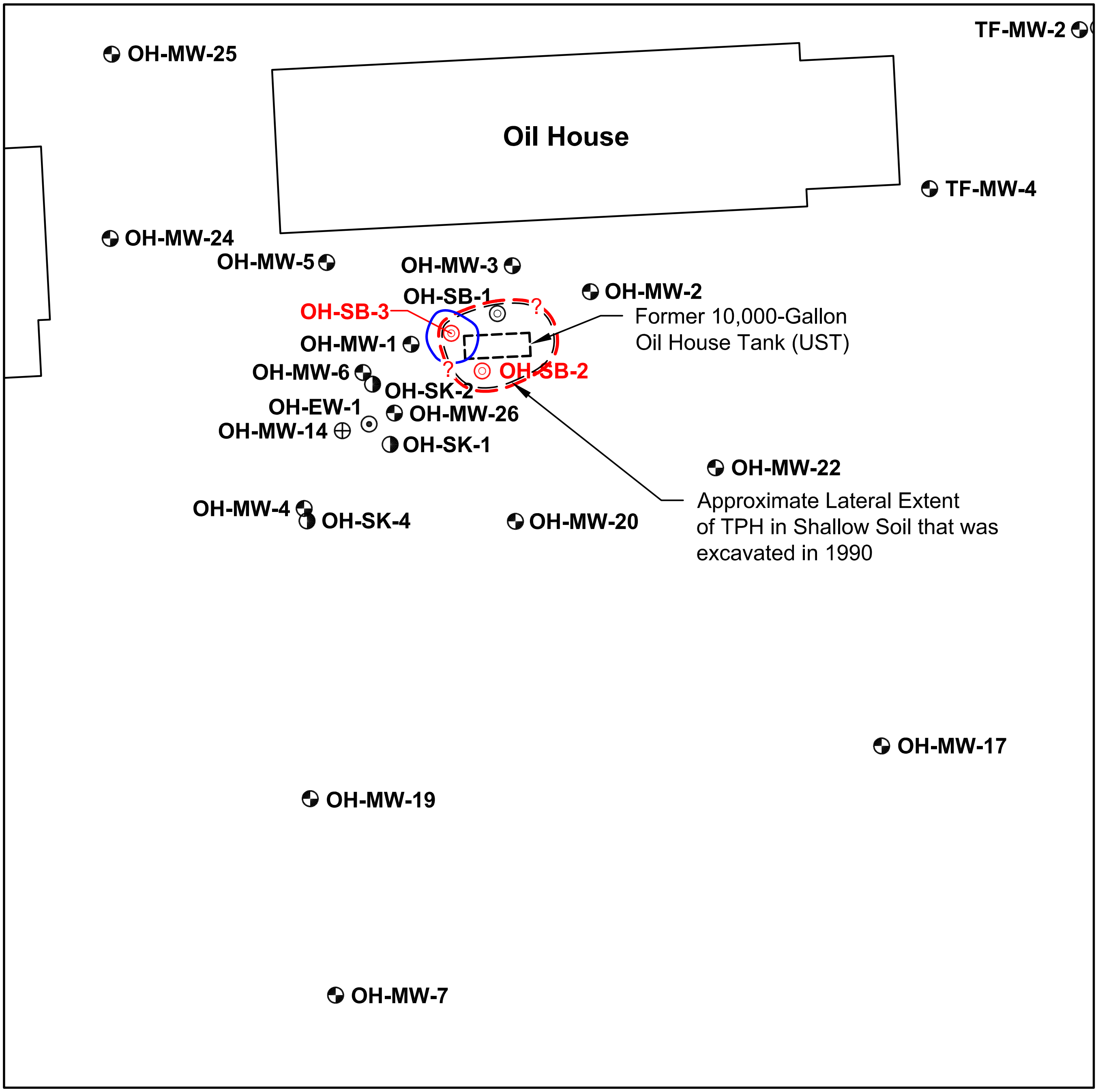
Figure 3-3b

Oil House Tank Area

Deep Vadose Zone Soil Screening - TPH and Arsenic



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Exploration Location and Number

OH-SB-2	◎	Samples with Screening Level Exceedance
OH-EW-1	⊙	Extraction Well
OH-MW-4	⊕	Monitoring Well
OH-SK-1	◑	Skimming Well
OH-SB-1	◎	Soil Boring
— —?— —		TPH Area of Screening Level Exceedance
——?——		Arsenic Area of Screening Level Exceedance

N

0 60 120

Scale in Feet

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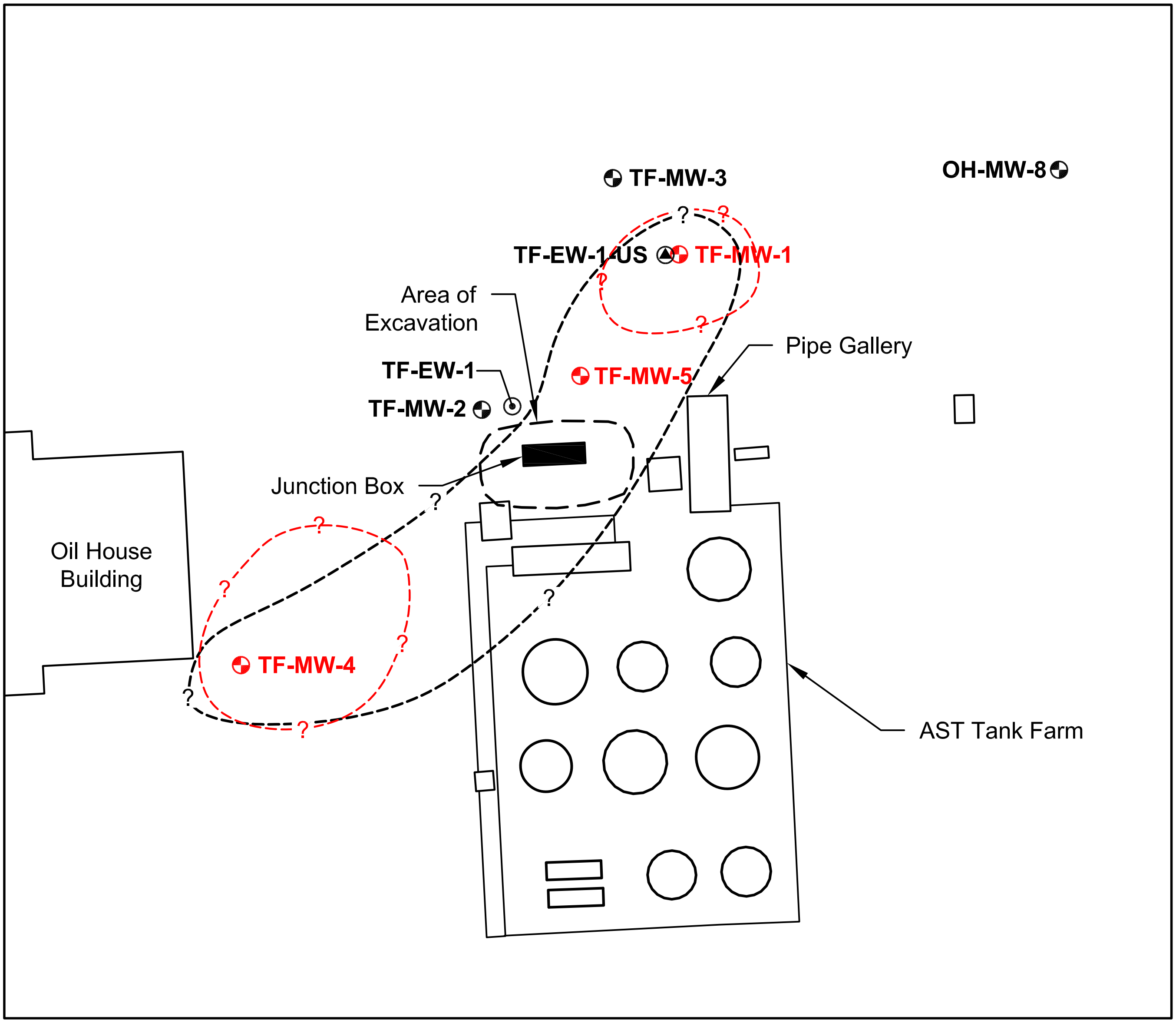
Figure 3-4a

Tank Farm Kensol Spill Area

Deep Vadose Zone Soil Screening - Stoddard Solvent and Kensol



EAL 11/10/09 2644116-037.DWG

Exploration Location and Number

TF-EW-1	⊙	Extraction Well
TF-MW-4	◐	Monitoring Well
TF-EW-1-US	◬	Groundwater Recirculation Well
TF-MW-1	◐	Samples with Screening Level Exceedance
	○	Above-ground Storage Tank
	– –?– –	Kensol Area of Screening Level Exceedance
	---?---	Stoddard Solvent Area of Screening Level Exceedance

N

0 40 80
Scale in Feet

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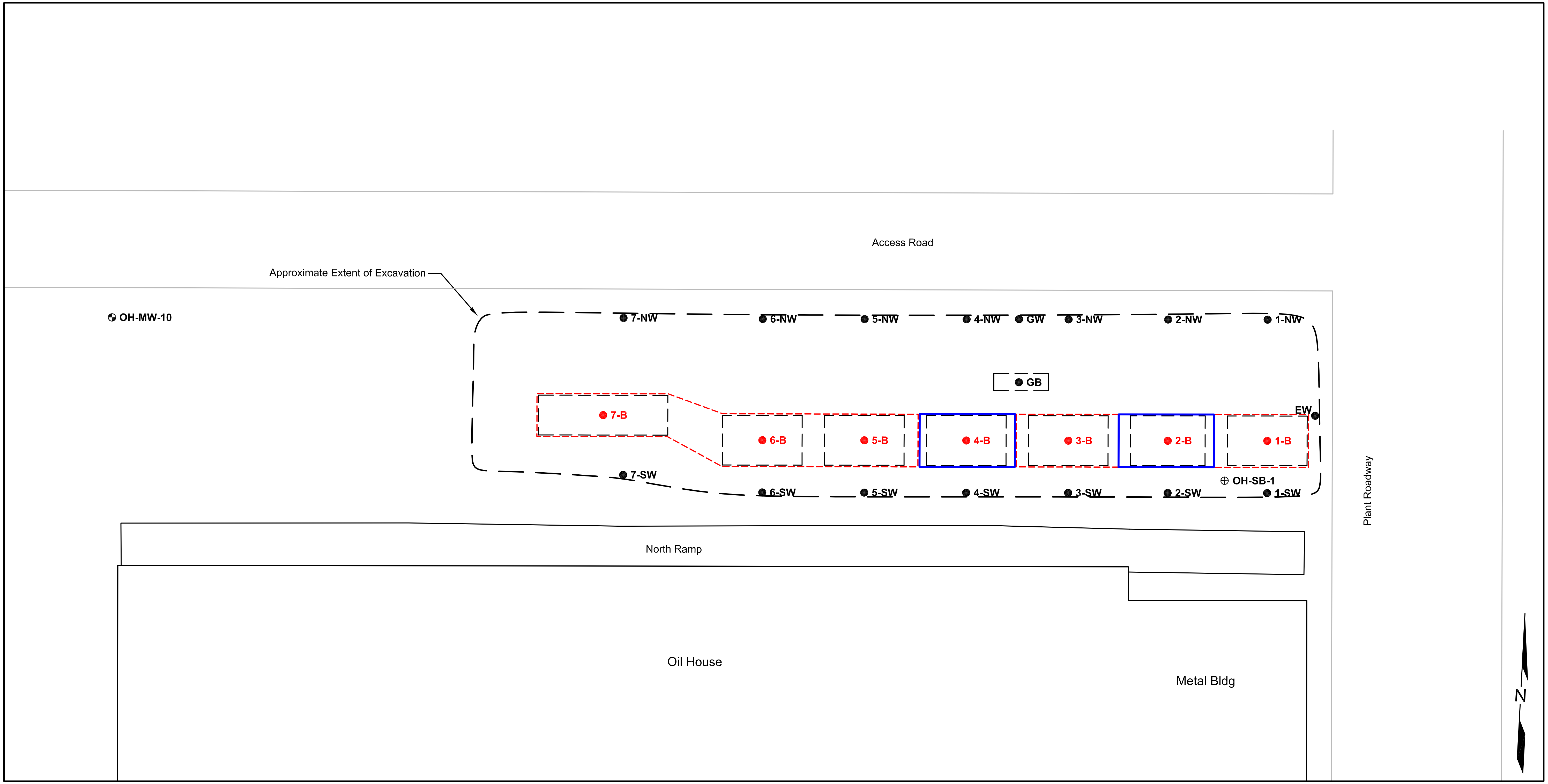
Figure 3-4b

Eight USTs Excavation

Deep Vadose Zone Soil Screening - Kensol and Arsenic



EAL 11/10/09 2644116-040.DWG

7-B ● Sample Location with Sceening Level Exceedance

OH-MW-10 ◐ Monitoring Well Location and Number

6-SW ● Soil Verification Sample Location and Number

OH-SB-1 ⊕ Soil Boring Location and Number

┌ ─ ┐ Former UST

- - - ? - - - Kensol Area of Screening Level Exceedance

—?— Arsenic Area of Screening Level Exceedance

0 20 40

Scale in Feet

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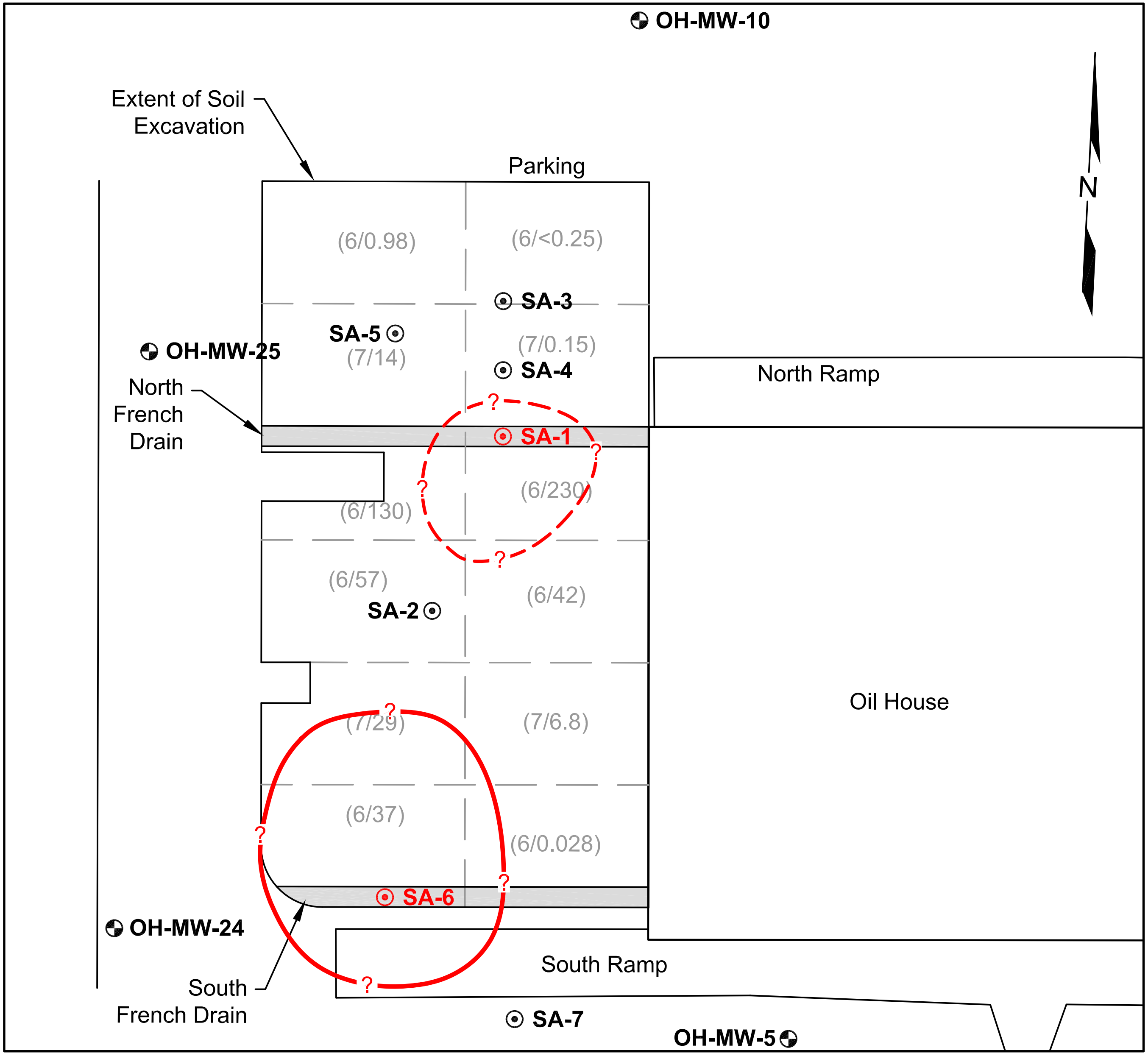
Figure 3-4c

Oil House Drum Storage and French Drain Area

Deep Vadose Zone Soil Screening - Stoddard Solvent, Kensol, Heavy Oil, and PCBs



EAL 11/18/09 2644116-041.DWG

Monitoring Location and Number

SA-1 ⦿ Sample Location with Screening Level Exceedance

SA-2 ⦿ Storage Area Soil Boring Location and Number

OH-MW-4 ◕ Soil Boring and 4-inch Monitoring Well Location and Number

— — — Zones for Composite Sampling of Excavation Floor

(6/<0.25) Depth of Excavation in Feet/Composited PCB Concentration in mg/kg

——?—— PCB, Stoddard Solvent, Kensol, and Heavy Oil Areas of Screening Level Exceedance

0 20 40

Scale in Feet

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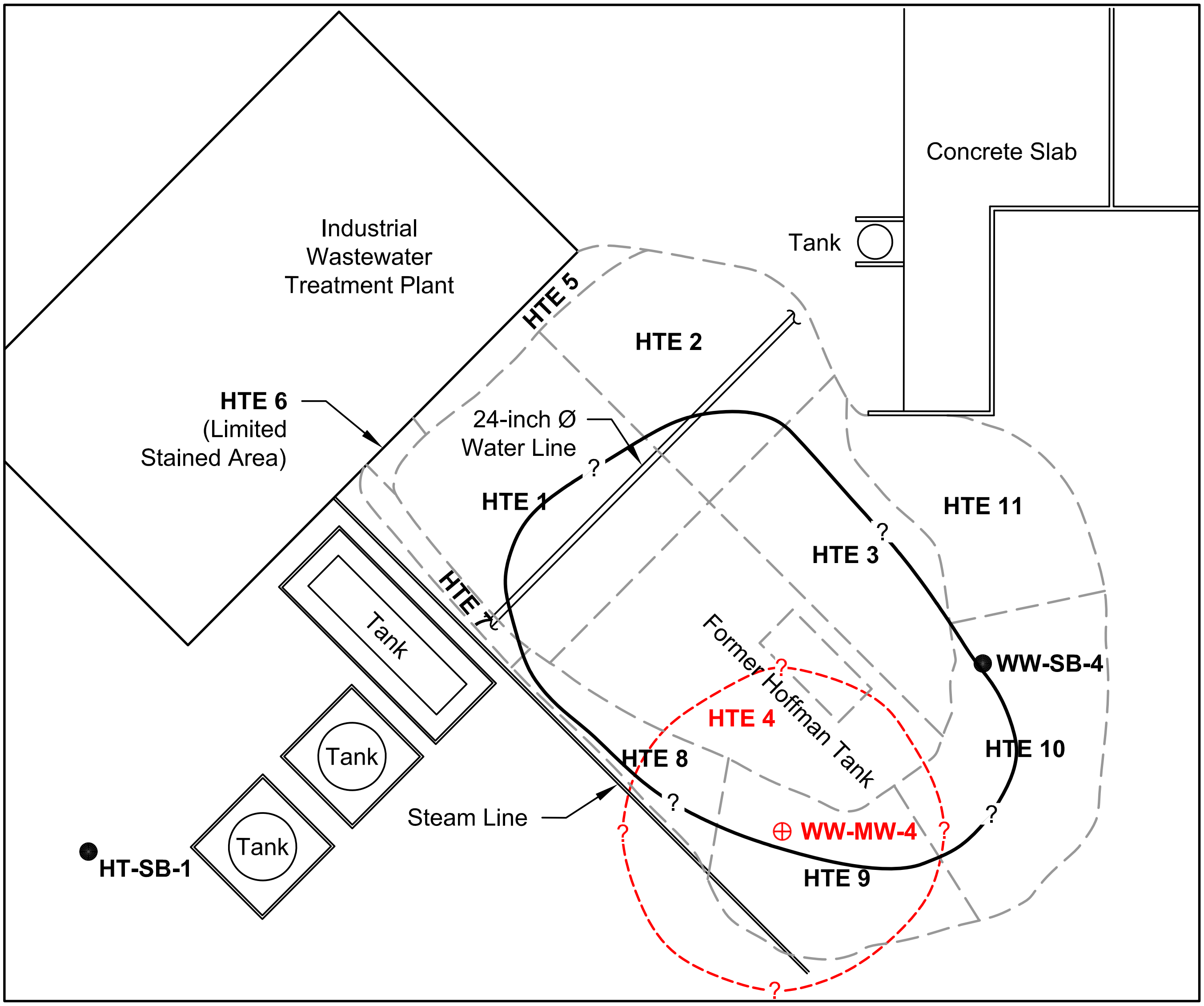
Figure 3-4d

Hoffman Tank Excavation

Deep Vadose Zone Soil Screening - TPH and PCBs



EAL 11/10/09 2644116-042.DWG

Exploration Location and Number

HTE 4	Sample Location wtih Screening Level Exceedance
● **HT-SB-1**	Soil Boring
⊕ **WW-MW-4**	Monitoring Well (Abandoned)
HTE 9	Composite Soil Sample
— — —	Approximate Limits of Soil Excavation
—?—	PCB Area of Screening Level Exceedance
– –·?·– –	TPH Area of Screening Level Exceedance

N

0 30 60

Scale in Feet

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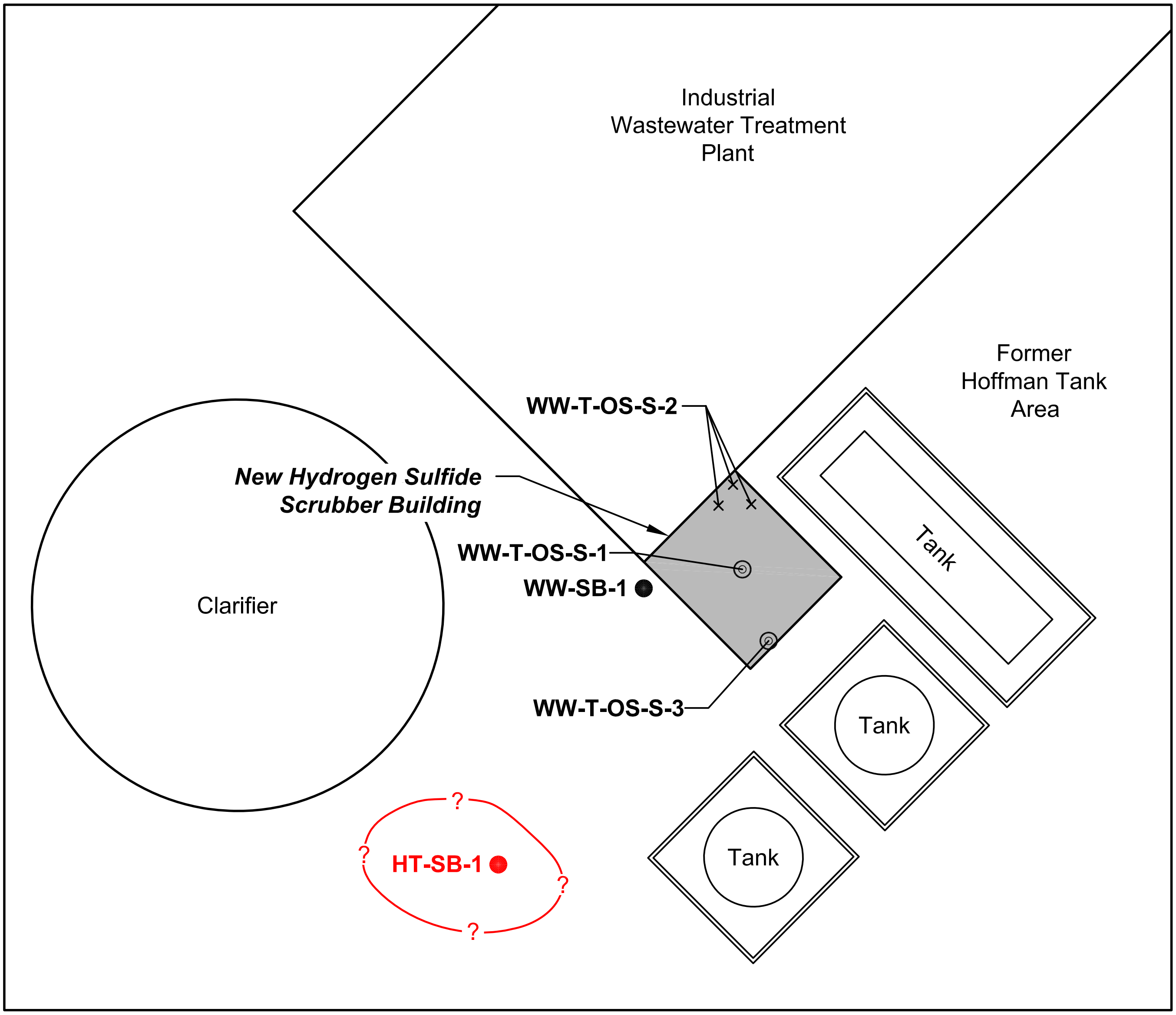
Figure 3-5a

Hydrogen Sulfide Scrubber Building

Near-Surface Soil Screening - Arsenic



EAL 11/10/09 2644116-071.DWG

Source: Base map prepared from Jeddeloh, Hays, Inc. titled "General Plant Lites," dated December 11, 1998.

Exploration Location and Number

WW-T-OS-S-3 ◎	Discrete Soil Sample
WW-T-OS-S-2 ×	Composite Soil Sample
WW-SB-1 ●	Soil Boring
HT-SB-1 ●	Sample Location with Screening Level Exceedance
▨	Excavated Area
——— ? ———	Arsenic Area of Screening Level Exceedance

N

0 20 40

Scale in Feet

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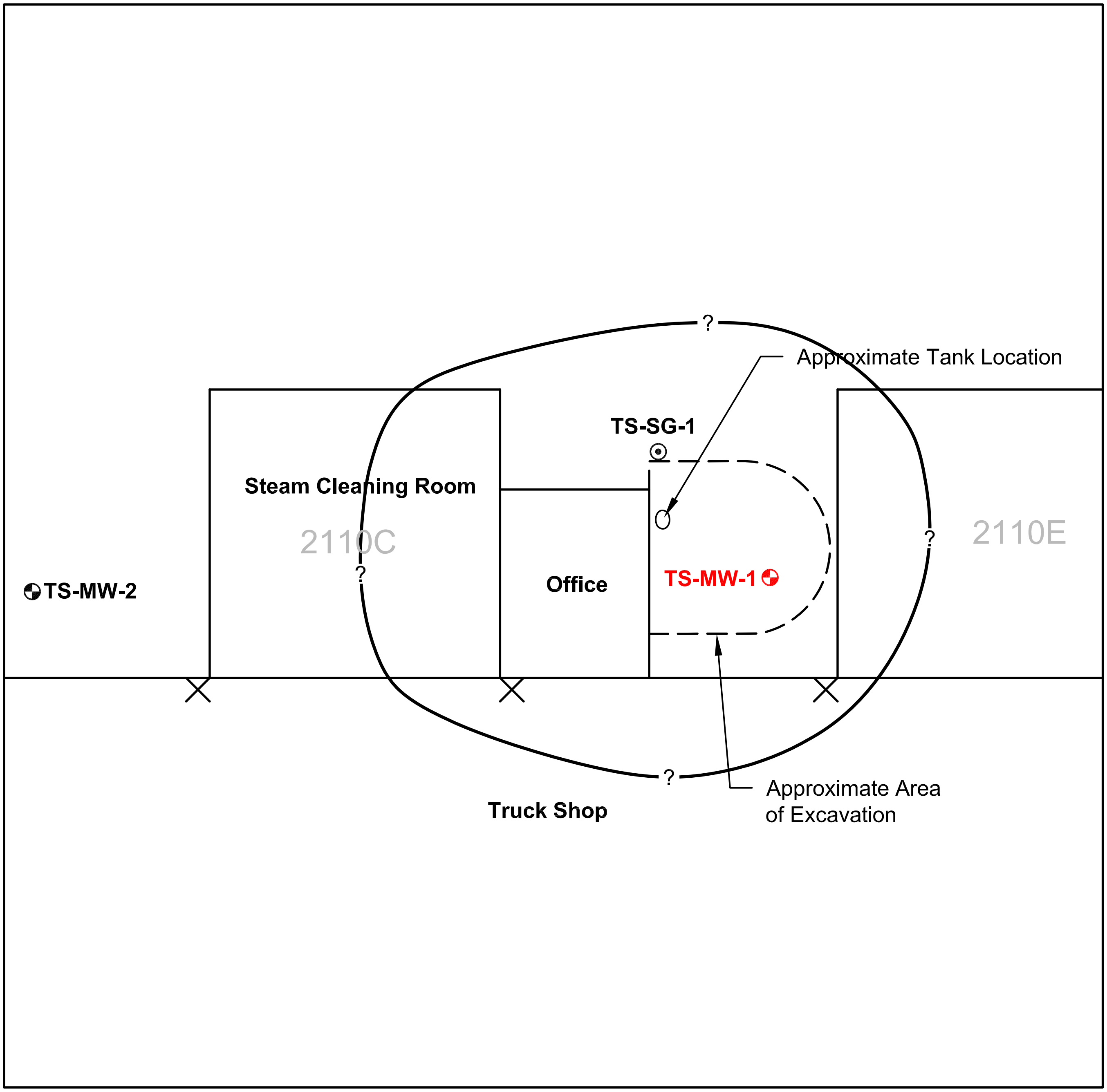
Figure 3-5b

Truck Shop Tank Area

Deep Vadose Zone Soil Screening - Heavy Oil



EAL 11/10/09 2644116-038.DWG

Exploration Location and Number

TS-MW-1 ⊕ Sample Location with Screening Level Exceedance

TS-MW-2 ⊕ Monitoring Well

TS-SG-1 ⊙ Soil Gas Probe

—?— Heavy Oil Area of Screening Level Exceedance

N

0 10 20

Scale in Feet

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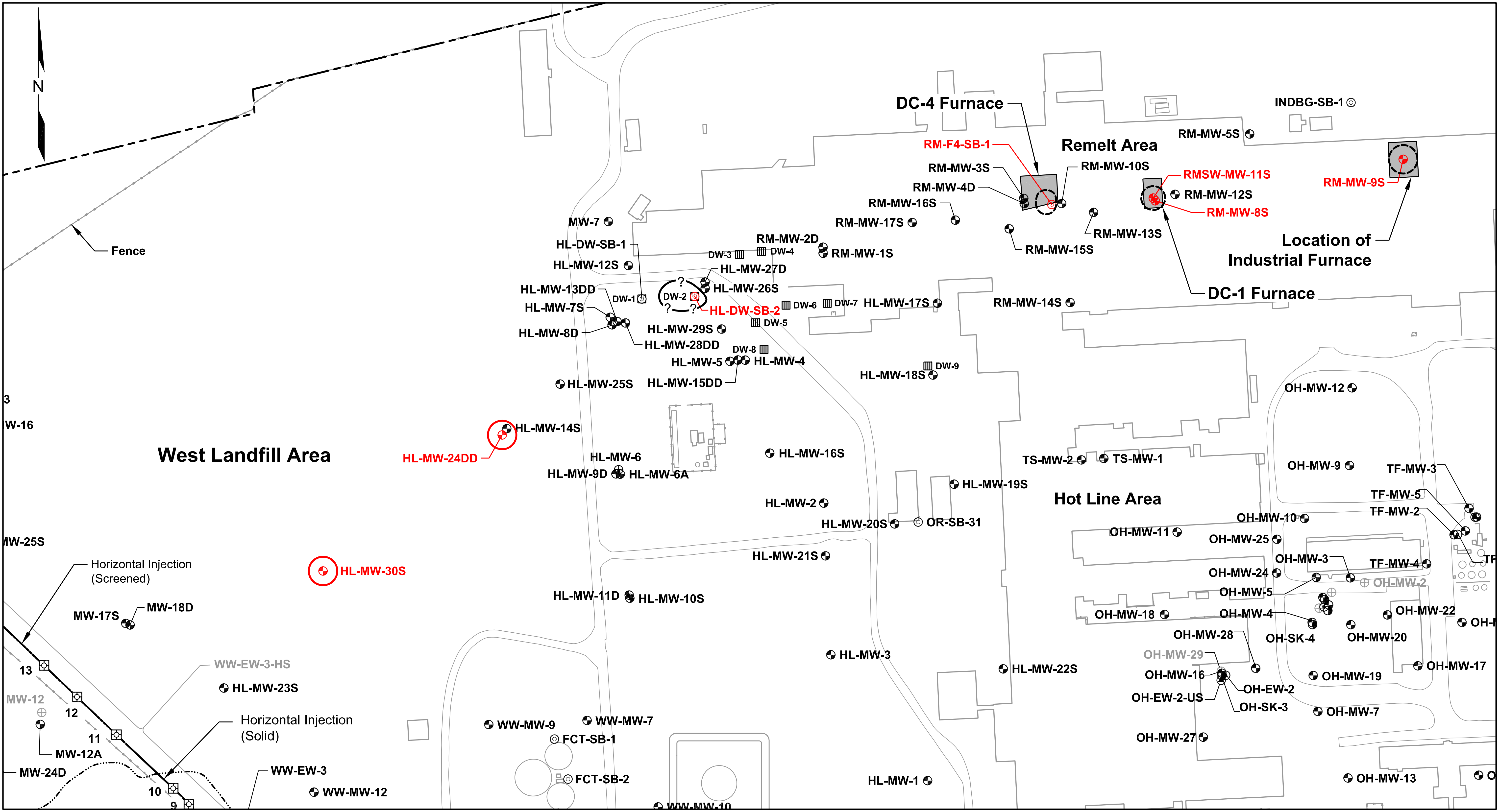
Figure 3-6

Remelt/Hot Line Area Index Map

Deep Vadose Zone Soil Screening - TPH, PCBs, and Arsenic



Exploration Location and Number

OH-EW-1 ⦿ Extraction Well

OH-MW-4 ⊕ Monitoring Well

WW-TL-MW-1 ⊕ Abandoned Monitoring Well

OH-SK-1 ◑ Skimming Well

TF-EW-1-US ⊕ Groundwater Recirculation Well

North Supply Well ● Supply Well

East Supply Well ● Backup Supply Well

RM-F4-SB-1 ◎ Soil Boring

DW-1 ▥ Dry Well

---?--- PCB Area of Screening Level Exceedance

——?—— TPH Area of Screening Level Exceedance

——?—— Arsenic Area of Screening Level Exceedance

RM-MW-9S ◎ Sample Location with Screening Level Exceedance

0 200 400

Scale in Feet

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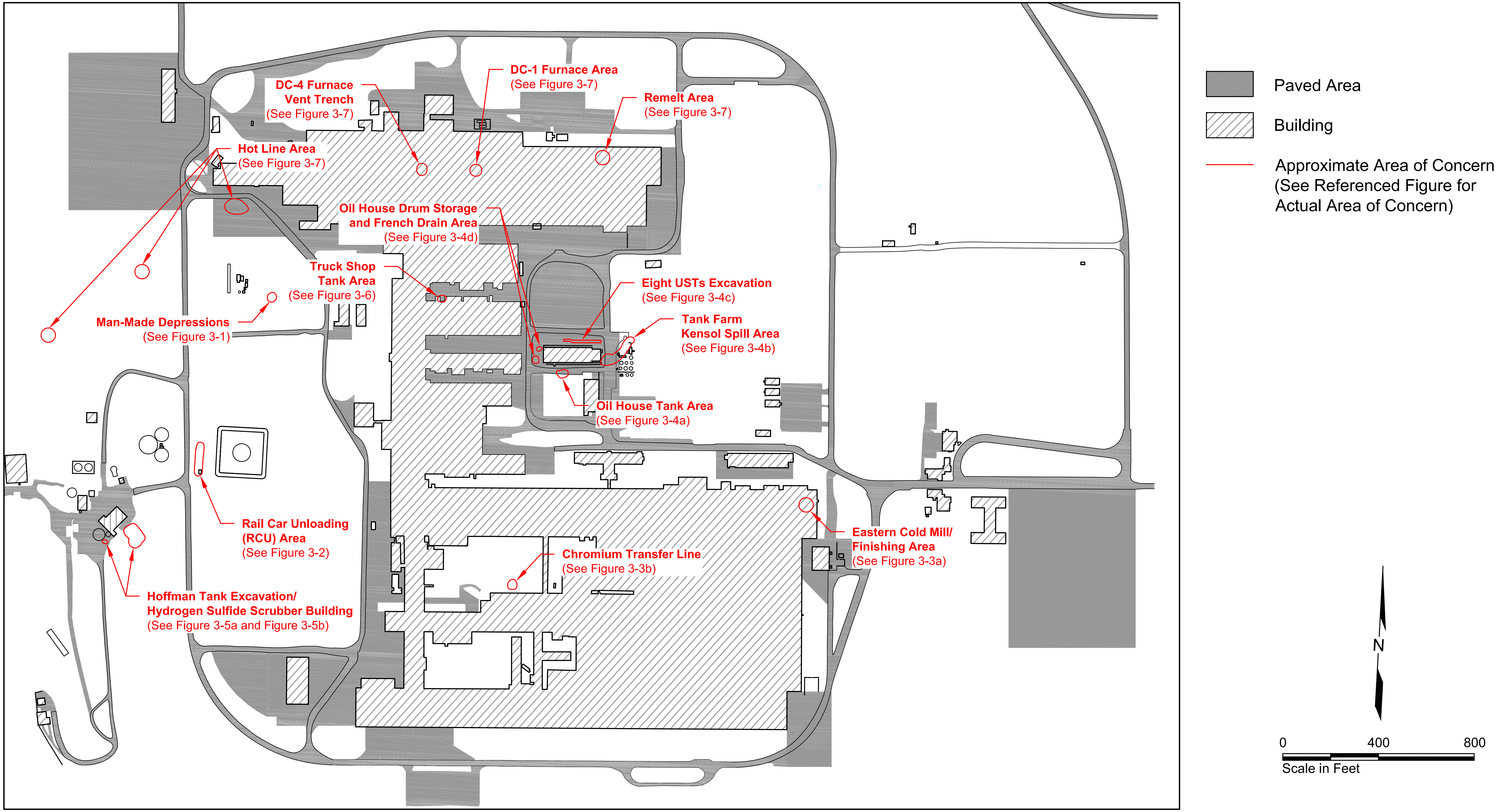
Figure 3-7

EAL 11/10/09 2644116-043.DWG

Deep Vadose AOC Locations within Paved Areas



EAL 11/11/09 2644116-072.DWG

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Figure 3-8

CONTENTS

TABLES

CONTENTS (Continued)

TABLES (Continued)

FIGURES

CONTENTS (Continued)

FIGURES (Continued)

4.0 CONTROL OF CONTAMINANTS OF CONCERN IN SMEAR ZONE SOILS

This Section of the FSTM evaluates the potential application of remedial technologies to address environmental issues in smear zone soils throughout the 512-acre Kaiser Facility.

Smear zone soils are those soils that are located adjacent to the water table. As discussed in Section 1 of the Final Groundwater RI (Hart Crowser 2012a), three water table levels were assumed for the site based on April 2007 groundwater data, which represents the seasonal high groundwater table: 68 feet bgs in the mill area (Oil Reclamation, Rail Car Unloading, Cold Mill, Oil House, Truck Shop, and the Remelt/Hot Line areas), 55 feet bgs in the Wastewater Treatment area, and 33 feet bgs in the West Discharge Ravine area near river wells and borings. These groundwater elevations are representative of the elevations present in spring 2007.

The Final Groundwater RI (Hart Crowser 2012a) discusses groundwater levels in Section 4.2.2. Water levels are strongly influenced by winter and spring precipitation recharge and Spokane river stage. Historical water level data is plotted in Figures 4-10 and 4-11of the Final Groundwater RI. The historical annual range of water levels at a given location on the site is approximately 10 feet. The water levels measured in the spring of 2007 were on the higher end of the historical range of measured values. Thus, most of the smear zone soil data discussed in this Section was collected from approximately 68 to 78 feet bgs in the mill area, from approximately 55 to 65 feet bgs in the Wastewater Treatment area of the Facility, and from about 33 to 43 feet near the Spokane River.

This section of the FSTM focuses on the areas of the site where the concentration of COPCs in smear zone soil was shown to exceed SLs for saturated soil. The general operating areas and applicable subsites that contain COCs in the smear zone soils and those areas that do not contain COCs are listed in Table 4-1**.**

As the interval of interest starts at the uppermost water level, the soil data used in this Section to evaluate the smear zone soil was obtained during the installation of monitoring wells or soil borings.

The predominant COCs at Kaiser are petroleum hydrocarbons in the diesel- and heavy oil-range, or COCs associated with TPH, such as PCBs. Following removal of the sources of COCs in the soil from past releases, COCs at concentrations greater than residual soil saturation levels would naturally tend to flow towards the water table as permeable site soil offers very little resistance to this downward migration.

During past soil boring/monitoring well installations at Kaiser, soil in the smear zone was generally chemically analyzed only when there was evidence of the presence of COPCs, by field observations and/or organic vapor analyzer evidence. This was particularly true of early environmental evaluation work at Kaiser in the late 1980s and early to mid 1990s where soil from numerous borings/wells was not chemically tested until the water table and the smear zone was reached.

For these reasons fewer soil samples were collected from the smear zone at the site than from the near-surface (Section 2) soil interval. Results from nearly 850 samples were used in the Section 2 evaluation of the top twenty feet of soil across the site. The evaluation of deep vadose zone soil discussed in Section 3 was based on a review of approximately 300 samples. This smear zone evaluation is also based upon a review of approximately 300 samples.

This section evaluates technologies that could be applicable to COCs in smear zone soils. Section 4 is organized as follows:

- Section 4.1 – Potential Remediation Technologies for VOCs in Smear Zone Soil;
- Section 4.2 – Potential Remediation Technologies for SVOCs in Smear Zone Soil;
- Section 4.3 – Potential Remediation Technologies for PCBs in Smear Zone Soil;
- Section 4.4 –Screening Technologies for Remediating Smear Zone Soil;
- Section 4.5 – Description of Areas of Concern for Smear Zone Soil; and
- Section 4.6 – Development of Remedial Alternatives.

COPCs in soils on the Kaiser Facility were identified in Section 1.1. Screening levels (SLs) were then established for the COPCs in each medium (e.g., soil, groundwater) by developing risk-based SLs (RBSLs) following MTCA requirements, by consideration of site-specific conditions such as land use, and by comparison of the RBSLs with other chemical-specific applicable or relevant and appropriate requirements (ARARs). COPCs that are present at concentrations that exceed SLs may be considered to be Constituents of Concern (COCs). The COCs identified for smear zone soils in Section 1.2.2 fall under the following groupings:

- Volatile Organic Compounds (VOCs);
- Semivolatile Organic Compounds (SVOCs);

- Total Polychlorinated Biphenyls (PCBs);
- Metals (arsenic, lead, iron and manganese).

VOCs

Past investigations have identified two locations that contain VOCs in the smear zone soil above SLs. For the purposes of the FSTM, light-end TPH compounds in the gasoline range (e.g., gasoline and Stoddard solvent/mineral spirits) will be evaluated against technologies pertaining to VOCs.

VOC exceedances in the smear zone are in the Oil House area. Two distinct subsites are present; one in the vicinity of the Kensol spill, and another located near the French Drain area and extending to the southeast. For both the Kensol spill and French drain areas the VOC of concern in smear zone soil is Stoddard solvent/mineral spirit-range petroleum hydrocarbons. These VOCs are co-located with SVOC (diesel, Kensol, and heavy oil) and PCB COCs. Free phase product is also located in a portion of the VOC AOC for smear zone soils (refer to Section 4.5.2). Some of this free phase product may contain Stoddard solvent since the concentration of Stoddard solvent (average concentration of 1395 mg/kg) exceeds the MTCA default value for residual saturation of gasoline range hydrocarbons (1000 mg/kg).

SVOCs

For the purposes of this FSTM and remediation technology evaluations, SVOCs are considered to include carcinogenic Polycyclic Aromatic Hydrocarbon (cPAHs) and TPH in the diesel- and heavy oil-ranges that have been identified as COCs.

TPH concentrations in soil have been evaluated at Kaiser for over 20 years. Several different TPH-containing products were used across the Facility, ranging from gasoline to heavy oils. The composition of the various TPH-containing products present at the site varies widely and is directly related to the associated toxicity and mobility of TPH compounds in the soil. By far, the majority of TPH compounds found in impacted soil at Kaiser are in the diesel- and heavy oil-range and at least one TPH compound has been identified at every investigation site at Kaiser. Due to their similar physical properties, diesel- and heavy oil-range TPH compounds (e.g., Kensol, diesel, heavy oil, Bunker C) will be evaluated by technologies pertaining to SVOCs in the remedial technology evaluation presented in Section 4.2.

Diesel and heavy oil were found in smear zone soils in the ORB area, the Oil House area, the Cold Mill Finishing area, the Wastewater Treatment area, and in a single Remelt area well. TPH data used in the smear zone soil evaluation was obtained by four different analytical methods; Ecology Methods NWTPH-Dx and NWTPH-HCID, and EPA Methods 8015 Modified and 418.1. EPA Method 418.1, used in the late 1980s and early 1990s, is the only TPH method used at Kaiser that cannot differentiate individual TPH compounds and results are reported as "Total TPH." EPA Method 418.1 smear zone data from the ORB, Oil House, and Wastewater Treatment areas were evaluated in this Section. Based on data collected from nearby borings using the other three TPH methods, the Method 418.1 Total TPH values were assigned to either diesel or heavy oil results in statistical calculations to avoid double counting of TPH exceedances.

Kensol, a diesel-range oil, was found in several Oil House and Wastewater Treatment operating area borings at levels exceeding SLs. Kensol data was assigned to diesel-range TPH for the purposes of statistical calculations. With the exception of the single Remelt boring heavy oil exceedance, smear zone diesel/heavy oil exceedances were found in areas where the historic plumes of free phase product were located (Hart Crowser 2012a, Figure 5-9).

cPAHs were found within the smear zone in one location in the southeast corner of the ORB building at concentrations exceeding saturated soil SLs. This area is currently part of the ORB unloading area and is under a pavement surface.

Polychlorinated Biphenyls (PCBs)

Soil testing at Kaiser conducted since the late 1980s has included analysis for the various Aroclors that were commonly used by industry prior to their banning in the United States in the 1970s.

The areas at Kaiser identified with PCBs exceedances in smear zone soils include the Cold Mill, Oil House, and Remelt/Casting areas (Figure 2-1). The PCBs in the Cold Mill and Oil House areas were found in locations where the historic plume of free phase product was located (Hart Crowser 2012a, Figure 5-9), while the PCBs in the Remelt/Casting area do not appear to be associated with a historic petroleum plume.

Metals

Arsenic is present at concentrations near the SL at two locations within the Oil House area in the smear zone soil. The arsenic AOCs are co-located with SVOCs.

Cadmium was excluded as a COC since it has no on-site source and was judged to be a background constituent (refer to the discussion in Section 1.2.2). Iron and manganese were considered (in the Final Groundwater RI) as presenting secondary (aesthetic) effects to groundwater. The manganese concentrations measured in site soils were within the natural background concentration range of this element in the Spokane area. Site soil samples were not analyzed for iron.

Contaminant-specific technologies to remediate the relatively small and isolated (from one another) AOCs where arsenic is present at concentrations above SLs are not discussed in this FSTM. The arsenic AOCs are co-located with a SVOC AOC in the Oil House area. The remediation of the arsenic AOCs is judged to be incidental to the remediation of the SVOC AOCs. Some of the technologies used to remediate the SVOC AOC (e.g. Institutional Controls, Monitoring, Monitored Natural Attenuation, Capping) will also be used to remediate the arsenic AOCs.

Summary

This FSTM focuses on remedial alternatives that will effectively treat VOCs, SVOCs (diesel and heavy oil and cPAHs) and PCBs. The areas of the site where COCs within these groups can be found are cited above and listed in Table 4-1.

The technologies that may be appropriate for remediating VOCs in smear zone soil are discussed in Section 4.1; the technologies that are judged to be most appropriate for remediating SVOCs in smear zone soil are discussed in Section 4.2; and finally, technologies judged to be most appropriate for remediating PCBs in smear zone soil are discussed in Section 4.3.

The approach used to screen the technologies identified in Sections 4.1 to 4.3 and the screening of these technologies is discussed in Section 4.4.

4.1 POTENTIAL REMEDIATION TECHNOLOGIES FOR VOCS IN SMEAR ZONE SOILS

VOCs in vadose zone and saturated soil have been successfully remediated at many sites. Different technologies have been used to contain, treat, and destroy these contaminants. The use of these technologies to remediate VOCs in soil has been well documented.

This documentation has been compiled to create technology identification and screening tools. The Federal Remediation Technologies Roundtable (FRTR) publishes a "Remediation Technologies Screening Matrix and Reference Guide (FRTR 2009a). The EPA Technology Innovation Office operates a Hazardous Waste Cleanup Information (CLU-IN) Web site that compiles information on a wide array of remediation technologies (CLU-IN 2009). The Center for Public Environmental Oversight (CPEO) is an organization that promotes and facilitates public participation in the oversight of environmental activities, including but not limited to the remediation of federal facilities, private Superfund sites, and Brownfields. CPEO's Technology Tree Matrix is a tool for identifying technologies to characterize and clean up hazardous waste sites (CPOE 2009), and the EPA Annual Status Report (ASR) Remediation Database – Update 2003, documents status and achievements of treatment technologies and Superfund sites (EPA 2003).

These sources and others were used to develop the list of potential technologies for remediating VOC COCs. Technologies applicable to these COCs in the smear zone soils are similar to the technologies listed for deep vadose zone soils listed in Table 3-2. The technologies listed in Table 3-2 contain the technologies recommended by the FRTR, CLU-IN, CPOE and the technologies identified by the ASR database as having been used at CERCLA sites, as well as other technologies used by Hart Crowser to successfully remediate source area soil at this and other sites. The Monitoring and Institutional Controls technologies are also included in this table.

Excavation-based technologies (with on- or off-site treatment of excavated soils) are not considered potential remediation technologies for smear zone soils since it is judged inappropriate to consider excavation as a means of access to soils that are found in the smear zone (typically 55 to 88 feet bgs). *In situ* treatment technologies were judged to be appropriate for soils in this depth interval. Some of these technologies contain additional components to treat vapors extracted from the soil matrix and other off-gases created by the use of the technology.

All of the VOC treatment technologies contained in Table 3-2 are described in Appendix A.

4.2 POTENTIAL REMEDIATION TECHNOLOGIES FOR SVOCs IN SMEAR ZONE SOILS

Nonaqueous phase liquids (NAPLs) are substances that are present in soil, groundwater or surface water as a free phase liquid not dissolved in water. The term includes both light NAPL (LNAPL) and dense NAPL (DNAPL). SVOCs like diesel and heavy oil are considered LNAPLs since they will float on the surface of groundwater. VOCs like TCE are considered DNAPLs since they will tend to sink to the bottom of a groundwater pool.

Free phase product is defined as an NAPL that is present in the soil, bedrock groundwater or surface water as a distinct layer (WAC 173-340-200). One of the characteristics of free phase product as defined by MTCA is that it is capable of migrating, independent of the direction of flow of groundwater and surface water. Thus, free phase product is an observable condition which either is or is not present at a given location.

SVOCs in smear zone soils can be present at concentrations below residual saturation values or be present as free phase product. Residual saturation is the concentration of a substance in the soil at equilibrium conditions. At concentrations above residual saturation, the NAPL will continue to migrate due to gravimetric and capillary forces and may eventually reach groundwater, provided a sufficient amount of NAPL has been released (WAC 173-340-747(10)(b). Residual saturation is often represented as the ratio of the volume of NAPL divided by the volume of voids in the soil column. Typical residual saturation values for SVOCs can vary widely depending upon the properties (e.g., soil porosity, total organic carbon) of the soil column. Residual saturation values can be determined empirically for a site (WAC 173-340-747(10)(c) or a default value can be used (WAC173-340-747(10)(d)(i)). The default value for diesel and heavy oil is 2000 mg/kg. This value can provide an indication of the concentration of diesel and heavy oil remaining in the soil column necessary to cause the diesel and heavy oil to migrate downward to the water table.

The Final Groundwater RI (Hart Crowser 2012a, Table 5-5) identified those areas of the site where free phase product has been observed historically, and the relatively small number of locations where free phase product is still observed (e.g., the Oil House area and the Wastewater Treatment area). The areal extent of the free phase product plumes observed in 2008 was estimated to total approximately 15,000 square feet in the Oil House area and 72,000 square feet in the Wastewater Treatment area (Hart Crowser 2012a, Table 5-6, Figure 5-12).

The remediation of SVOCS (Diesel- and heavy oil-range petroleum and cPAHs) in smear zone soil (when the SVOCs are not present as free phase product) has been evaluated thoroughly and the available technologies have been assembled into the following general response actions: monitoring, institutional controls, containment, and *in situ* treatment. In addition, there is the on-site treatment of vapor extracted from soil or of off-gases created by the *in situ* treatment process. All of these technologies are presented on Table 3-2 and described in Appendix A.

Some of the technologies described in Appendix A are presumptive remedies for SVOCs. Presumptive remedies are preferred treatment technologies for common categories of sites. The EPA selects presumptive remedies to streamline site characterization and speed up the selection of cleanup actions. EPA has identified several presumptive remedies for sites containing SVOCs (EPA 1995a).

The presumptive remedies that may be applicable for SVOC impacted smear zone soil at Kaiser include *in situ* bioremediation, *in situ* thermal desorption, *in situ* incineration (ISV), and *in situ* immobilization. These technologies are discussed in Appendix A.

The SVOCs present in smear zone soil at the Kaiser Facility consist primarily of diesel- and heavy oil-range hydrocarbons. Diesel- and heavy oil-range hydrocarbons are mixtures of straight chain and cyclic alkanes and aromatic compounds including PAHs. Diesel- and heavy oil-range hydrocarbons have also been successfully treated by the presumptive remedies (*in situ* bioremediation, *in situ* thermal desorption, and *in situ* incineration) discussed in Section 2.2. Immobilization technologies are more suited to inorganic contaminants and will not be considered for SVOC-impacted soil that does not also contain arsenic, manganese, or iron at concentrations that exceed SLs at Kaiser.

Technologies applicable to SVOCs in the smear zone soil are similar to the technologies listed as applicable to deep vadose zone soils as listed in Table 3-2. Table 4-2 presents additional remedial technologies for smear zone soils, applicable to enhanced SVOC recovery from soils and free phase product recovery.

Only technologies that remove free phase product without extracting groundwater are considered in the discussion contained in this Section. For the purpose of the evaluation of free phase product removal in this section of the FSTM we are not considering the current groundwater extraction system. Groundwater extraction technologies are discussed in Section 5 and 6 of this FSTM. The extraction of free phase product and groundwater together is discussed in Section 5. These enhanced SVOC and free phase product extraction technologies will be assessed to determine if they can be successfully deployed to remove free phase product from the Oil House and Wastewater Treatment areas of the site.

4.2.1 SVOC Removal from Smear Zone Soils

Thermal treatment or soil flushing can be used to enhance recovery of residual product from smear zone soils. These technologies are typically used in conjunction with free phase product recovery technologies such as pneumatic pumps and skimming belts.

In situ thermal treatment involves the application of heat to subsurface contaminants to change their physical properties in order to enhance mobility. Heat is applied to subsurface contaminants through delivery of heated fluids (e.g., steam, hot air, or hot water) or by passing electromagnetic energy (e.g., electrical current or electromagnetic radiation in the radio frequency range) into the subsurface. Soil flushing is an *in situ* process that floods contaminated soil with a solution that moves the contaminants to an area from which they are removed. These technologies are described in Appendix A, and presented in Table 4-2 as applicable to the removal of SVOCs from smear zone soils.

4.2.2 Free Phase Product Removal/Skimming Systems

Skimming systems collect free phase product with little or no recovery of water. In general this approach involves using skimming devices to remove product floating on the water table in excavations, gravel-filled trenches, and wells. Free phase product removal using skimming equipment is applicable in settings where long-term hydraulic control of the dissolved hydrocarbon plume is not required, although skimming equipment has been used successfully along with pumping wells at Kaiser in Oil House and Wastewater Treatment areas. In most settings, skimmer operations will not control the liquid hydrocarbon plume (EPA 1996g).

Diesel and heavy oil was found in smear zone soils in the ORB area (Man Made Depressions), Oil House area (Kensol), the Cold Mill Finishing area, the Wastewater Treatment area, and in Hot Line wells and borings. Diesel fuel oil measured by the NWTPH-HCID or 481.1 methods was found in smear zone soils in the ORB, Oil House, and Wastewater Treatment operating areas. Kensol was only found in the Oil House and Wastewater Treatment operating areas. The diesel and heavy oil was usually found in areas where the historic plume of free phase product was located (Hart Crowser 2012a, Figure 5-9).

cPAHs were found in the smear zone soil in one location in the southeast corner of the ORB. This area is part of the ORB unloading area and is currently under a pavement surface.

Mechanical Skimmers

Mechanical skimming systems rely on pumps (either surface mounted or within the well) or other motors to actively extract free phase product from the subsurface. The more common forms of mechanical skimming systems are floating skimmers (large and small), pneumatic pumps and belt skimmers.

Large floating skimmers can remove product at a fairly high rate (up to 5 gpm) if the free phase product thickness is deep. Each skimmer has a large hydrophobic screen that allows only product into the pump body. These skimmers are generally limited to shallow applications (less than 20 feet) and may require a well or sump 24 inches in diameter or greater.

Small float systems require 4-inch or larger wells for operation. They are limited to depths of 30 feet or less. This type of skimmer typically uses a floating screen inlet to capture the product and is contained in a pump device or bailer. A variation on floating skimmers employs a floating (or depth-controlled) intake equipped with conductivity sensors that activate surface-mounted pumps when liquid hydrocarbons have accumulated to a sufficient thickness.

Pneumatic skimming systems may have a top intake that allows skimming of fluids from the liquid hydrocarbon/water interface or they may have a density-sensitive float valve that permits the passing of water before the valve seats.

Belt skimmers use a continuous loop of hydrocarbon-absorbing material that slowly cycles down into and out of the well, soaking up product as it moves through the water surface. These skimmers are simple mechanical systems that can operate in 4-inch or larger wells, but they are perhaps best suited for skimming sumps (EPA 1996g).

As part of the Kaiser groundwater Interim Remedial Measure (IRM) belt skimmers have been effectively operating in the Oil House and Wastewater areas since 1993. The details associated with the groundwater IRM are discussed in further detail in Section 5 of this FSTM.

Passive Skimmers

Passive skimming systems do not actively pump free phase product; instead they slowly accumulate it over time. Filter canisters and absorbent bailers are the two basic forms of passive skimmers. Filter canisters are lowered into 2-inch or greater diameter wells so that they contact the layer of free phase product floating on top of the water surface. The filter is constructed of a hydrophobic material which allows only free phase product to enter. Gravity causes the liquid hydrocarbons to trickle through the filter and then flow into the bottom of the canister where the product is stored. Canisters can store between 0.5 and 2 gallons of free phase product. The product can be removed automatically by a suction pump or manually by pulling up and emptying the canister.

Absorbent bailers are simple skimming devices which are suspended in the well across the surface of the free phase product layer. Absorbent material placed in the bailer removes product from the water surface and must be periodically removed and disposed of (EPA 1996g).

4.3 POTENTIAL REMEDIATION TECHNOLOGIES FOR PCBS IN SMEAR ZONE SOILS

The remediation of PCBs in saturated soil has been evaluated thoroughly and the available technologies have been assembled into the following general response actions: monitoring, institutional controls, containment, and *in situ* treatment. In addition, there is the on-site treatment of vapor extracted from soil and for off-gases created as a result of the chemical treatment of soil. All of these technologies are described in Appendix A. Specifically, *in situ* vitrification, *in situ* chemical treatment, *in situ* stabilization/solidification, *in situ* bioremediation and *in situ* thermal treatment have been tested or used in the *in situ* treatment of PCBs.

The EPA ASR database identifies 10 CERCLA sites where *in situ* processes are specified in RODs for treating soils containing PCBs. Seven stabilization/ solidification, one ISV, one chemical oxidation and one bioremediation site are identified. The maximum treatment depth reported was 17 feet bgs. These technologies were discussed in Section 3.3 of this FSTM. These general response actions and their associated technologies for remediation of PCBs in smear zone soils are similar to the general response actions and technologies applicable to deep vadose zone soils and are discussed in Section 3.3 and summarized in Table 3-2.

The areas at Kaiser identified with PCBs exceedances in smear zone soils include the Remelt/Casting area and the Oil House area (Figure 2-1). The PCBs in the Oil House area were found in locations where the historic plume of free phase product was located (Hart Crowser 2012a, Figure 5-9), while the PCBs in the Remelt/Casting area do not appear to be associated with historic petroleum plumes.

TSCA Requirements for Institutional Controls, Capping and Offsite Disposal

For lower PCB soil concentrations where on-site treatment of soils may not be appropriate, soils may remain in place or be disposed of off site. In these cases, PCB regulations in Title 40 of the Code of Federal Regulations at Part 761 (40 CFR Part 761) formed under the Toxic Substances and Control Act of 1976 (TSCA) will serve as an ARAR. Specifically, 40 CFR Part 761 will serve as an ARAR for parts of the site where PCB concentrations are greater than TSCA SLs. TSCA SLs depend on how contaminated property will be used (occupancy) and what type of media contaminated.

Since most smear zone soil at Kaiser contains less than 1 mg/kg of PCB, no additional treatment or containment of this soil would be required by TSCA. The smear zone soil does not contain PCBs at concentrations above the soil SL for the protection of human health (Oil House area) RBSL criteria (Pioneer 2012), but does contain PCBs that exceed the saturated soil SL for the protection of groundwater at several areas of the site. This subject is discussed in more detail in Section 2.3.

The PCBs found in the in the Cold Mill and Oil House areas at the Kaiser Facility were co-located with dissolved or free phase petroleum product. The PCBs in these areas may have been mobilized downward through unsaturated soils from source areas to the water table. Once at the water table, PCBs appear to be co-mingled with the petroleum hydrocarbon groundwater plume. There was no dissolved or free phase petroleum found in the smear zone in the Remelt area. The PCBs present in the smear zone and groundwater in this area are likely dissolved in groundwater or adsorbed to mobile soil colloids that are migrating with groundwater (Hart Crowser 2012a, Section 6.3).

4.4 SCREENING TECHNOLOGIES FOR REMEDIATING SMEAR ZONE SOILS

The technologies identified in Section 4.1 to 4.3 are screened using the approach summarized in Sections 2.4. The physical aspects of the Kaiser facility, the chemical properties of COCs and the properties of the smear zone soil in the AOCs are identified and used to eliminate certain technologies from further consideration in Section 4.4.1.

The technologies that are judged to be potentially appropriate for the physical and chemical features of the Kaiser AOCs are evaluated for implementability and reliability (if implementable) in Section 4.4.2. Many technologies judged reliable for treating individual COCs (Stoddard solvent, diesel, heavy oil, cPAHs or PCBs) in smear zone soil also were judged reliable for treating other COCs. These common technologies are identified in Section 4.4.2.4. These common technologies will form the core of the remedial alternatives developed in Section 4.6.

4.4.1 Site-Specific Technical Constraints for Technologies

The physical and chemical features of the Kaiser Facility significantly influence the selection of the remedial technologies identified in Sections 4.1 through 4.3. There are three groups of physical factors that influence proper selection of a remedial technology: 1) factors associated with the active use of the facility, 2) factors limiting access to contaminated soil, and 3) site-specific geologic and hydrologic conditions promoting or prohibiting the applicability of certain remedial technologies. These physical factors are discussed in Section 2.5.1 and summarized in Table 2-3. The factors that constrained the use of near surface and vadose zone soil treatment technologies will also constrain the use of technologies appropriate for smear zone soils.

In addition to these physical factors, various chemical attributes of the COCs influence the selection of a remedial alternative. A summary of these chemical properties is provided in Section 2.5.1 and summarized in Table 2-4 (Physical/Chemical Properties of COPCs). In addition, smear zone soils will be intermittently saturated by groundwater. The soil treatment technologies discussed in this Section would be applied when the groundwater level is low and expected to remain at that level for the duration of treatment.

The outcome of the physical and chemical screening of these comparable technologies is presented in Tables 4-3 (VOCs), 4-4 (SVOCs), and 4-5 (PCBs). Additional physical and chemical screening criteria for enhanced SVOC removal and free phase product recovery are presented in Table 4-6. All of these potentially applicable technologies are evaluated further in Section 4.4.2.

4.4.2 Screening of Remedial Technologies for COCs in the AOCs

This section evaluates those technologies not rejected on the basis of the site-specific physical/chemical constraints (summarized in Tables 4-3, 4-4, 4-5, and 4-6) for implementability or reliability using the step-wise approach shown on Figure 2.2 and described in Section 2.5.2. Cost-effectiveness was not assessed as part of this FSTM. Cost-effectiveness will be used to further screen the implementable and reliable technologies identified by the FSTM (where appropriate) as part of the overall feasibility study for the Kaiser Facility.

4.4.2.1 Technologies for Remediating VOCs in Smear Zone Soil

Technologies and the associated process options for remediating VOC-contaminated soil in the AOCs are evaluated for implementability in Tables 4-7a to 4-7b. Table 4-7a summarizes our implementability evaluation for technologies that were previously presented in Section 2 in addressing near-surface soil. Each table provides information to justify why each process option should be accepted or rejected for the Kaiser Facility. These tables indicate that the following process options for remediating VOCs in Smear Zone soils are judged to be implementable at the Kaiser Facility.

Technology	Process Option Accepted
Monitoring	Protection, Performance, Confirmational
Institutional Controls	Access and Use Restrictions, BMPs
Capping	Asphalt, Concrete, Multilayer
Monitored Natural Attenuation	Monitored Natural Attenuation
Soil Vapor Extraction (SVE)	Vertical Vents
Bioremediation	Enhanced Bioremediation
SVE Off-Gas Treatment Technologies	
Adsorption Technology	Granular Activated Carbon
Thermal Oxidation	Catalytic Oxidizers
Advanced Oxidation	Photocatalytic Oxidation

The technologies and associated process options judged to be implementable are evaluated for reliability in Tables 4-8a through 4-8b. Table 4-8a summarizes our reliability evaluation for technologies that were previously presented in Section 2 in addressing near-surface soil. Photocatalytic oxidation was rejected on the basis of reliability (refer to Table 2-9h) since this process option is still in the development stage and has not been successfully operated at full-scale in a physical and chemical setting similar to that at the Kaiser Facility.

In situ bioremediation (enhanced bioremediation) was rejected for reliability since this technology has not been demonstrated under the COC (low VOC concentration) and site conditions (very porous soils) present at the Kaiser Facility (Refer to Table 4-8b). The remaining process options are combined in various ways to create the feasible remedial alternatives discussed in Section 4.6. Table 4-9 summarizes the technology screening process and the technologies and process options judged to be appropriate for the treatment of VOC contaminated smear zone soil at the Kaiser Facility.

4.4.2.2 Technologies for Remediating SVOCs in Smear Zone Soil

Technologies and the associated process options for remediating smear zone SVOC contaminated soil in the AOCs are evaluated for implementability in Tables 4-10a, 4-10b, and 4-16a through 4-16c. Table 4-10a summarizes our implementability evaluation for technologies that were previously presented in Sections 2 and 3 in addressing near-surface soil. Each table provides information to justify why each process option should be accepted or rejected for the Kaiser Facility. These tables indicate that the following process options for remediating SVOCs in near surface soils are judged to be implementable for smear zone soil at the Kaiser Facility.

Technology	Process Option Accepted
Monitoring	Protection, Performance, Confirmational
Institutional Controls	Access and Use Restrictions, BMPs
Capping	Asphalt, Concrete, Multilayer
In situ Bioremediation	Enhanced Bioremediation
Monitored Natural Attenuation	Monitored Natural Attenuation
In situ Chemical Treatment	Oxidation
Enhanced SVOC Removal	
Hot Air Injection	Injection Wells, Extraction Wells
Off-Gas Treatment Technologies	
Adsorption Technology	Granular Activated Carbon
Thermal Oxidation	Catalytic Oxidizers
Advanced Oxidation	Photocatalytic Oxidation
Free Phase Product Removal Technologies (with out groundwater extraction)	
Mechanical Skimmers	Floating Skimmer, Pneumatic Pump, Skimmers Belt
Passive Skimmers	Filter Canister, Absorbent Bailer

The technologies and associated process options judged to be implementable are evaluated for reliability in Tables 4-11a through 4-11c and Tables 4-17a through 4-17c. Photocatalytic oxidation was rejected on the basis of reliability (refer to Table 2-9h) since this process option is still in the development stage and has not been successfully operated at full-scale in a physical and chemical setting similar to that at the Kaiser Facility. Hot air injection was rejected on the basis of reliability because it has had limited success in the field (refer to Table 4-17a). Floating skimmers and pneumatic pump mechanical skimmers and passive skimmers were rejected (Tables 4-17b and 4-17c) because skimmer belts have been shown to be an effective means of removing FPP from groundwater at the Kaiser Facility.

Table 4-12 (smear zone soils) and 4-18 (free phase product removal) summarize the technology screening process and the technologies and process options judged to be appropriate for the treatment of diesel, heavy oil and cPAH contaminated smear zone soil at the Kaiser Facility. Note that the enhanced SVOC removal technologies evaluated in Table 4-18 are those technologies assessed for their ability to improve the accumulation of free phase petroleum and thereby enhance recovery using a free phase product recovery system.

4.4.2.3 Technologies for Remediating PCBs in Smear Zone Soil

Technologies and the associated process options for remediating PCB contaminated soil in the AOCs are evaluated for implementability in Tables 4-13a through 4-13c. Each table provides information to justify why each process option should be accepted for further consideration or rejected for the Kaiser Facility. These tables indicate that the following process options for remediating PCBs in smear zone soils are judged to be potentially implementable at the Kaiser Facility.

Technology	Process Option Accepted
Monitoring	Protection, Performance, Confirmational
Institutional Controls	Access and Use Restrictions, BMPs
Capping	Asphalt, Concrete, Multilayer
Monitored Natural Attenuation	Monitored Natural Attenuation
Containment	Stabilization/Solidification
***In situ* Treatment Technologies (where PCBs and SVOCs are co-located)**	
Bioremediation	Enhanced Bioremediation
Chemical Treatment	Oxidation

Off-gas Treatment Technologies (if needed by *in situ* treatment process)

Adsorption	Granular Activated Carbon
Thermal Oxidation	Catalytic Oxidizers,
Advanced Oxidation	Photocatalytic Oxidation
Chlorine Removal	Chlorine Scrubbers

In situ bioremediation (Enhanced bioremediation) and *in situ* chemical treatment were accepted for implementability for the treatment of smear zone soils that contain PCBs co-located with SVOCs (e.g., Oil House area, Wastewater Treatment area). These *in situ* processes were rejected for implementability for locations at Kaiser where PCBs were present alone due to the relatively low concentration of PCBs and the depth of the smear zone (e.g., Remelt/Hot Line area). No full-scale successful applications of the technologies for dilute PCB concentrations at depths of 33 to 78 feet bgs were identified.

The technologies and associated process options judged to be potentially implementable are evaluated for reliability in Tables 4-14a through c. Photocatalytic oxidation was rejected on the basis of reliability since this process option is still in the development stage and has not been successfully operated at full-scale in a physical and chemical setting similar to that at the Kaiser Facility (refer to Table 2-9h). *In situ s*tabilization/solidification was rejected because it has not been used *in situ* at a site similar to Kaiser and because it is typically used as an *ex situ* technology (refer to Table 3-13b)

Table 4-15 summarizes the technology screening process and the technologies and process options judged to be potentially appropriate for the treatment of PCB-contaminated soil at the Kaiser Facility.

4.4.2.4 Remediation Technologies Common for VOCs, SVOCs PCBs, and Metals

The areas identified with VOC exceedances in smear zone soils are associated with Stoddard solvent and are located in the Oil House area (Figure 4-3b). There is no direct evidence that these VOCs are causing exceedances of screening criteria in the breathing spaces of site workers.

The technologies accepted for the remediation of VOCs in smear zone soils were listed in Table 4-9, and included capping, institutional controls, monitored natural attenuation, and SVE (with thermal treatment or adsorption of VOCs in the extracted soil vapor.)

Four general response actions judged acceptable for VOCs also were judged potentially acceptable for one or more of the other COCs. The common response actions include:

- Monitoring (protection, performance, confirmational) – VOCs, SVOCs, PCBs, and metals;
- Institutional Controls – VOCs, SVOCs, PCBs, and metals;
- Capping (asphalt, concrete, Multi-layer) – VOCs, SVOCs, PCBs, and metals;
- Monitored Natural Attenuation – VOCs, SVOCs, and PCBs.

There were additional common response actions for SVOCs and PCBs that were co-located:

- *In situ* Bioremediation (enhanced bioremediation); and
- *In situ* Chemical Treatment (oxidation).

There was an additional common response action for SVOCs and PCBs that were co-located with free phase product. This response action was:

- Mechanical Skimmers (skimmers belt).

4.5 DESCRIPTION OF AREAS OF CONCERN FOR SMEAR ZONE SOILS

The AOCs for smear zone soils at the Kaiser Facility are those areas that contain COCs (refer to Table 1-2) at concentrations above SLs that have been established for the site. The remedial objectives for these AOCs are summarized in terms of COCs, SLs and POCs in Section 1. The MTCA specifies that free phase product must be removed to the maximum extent practicable from groundwater using normally accepted engineering practices (WAC 173-340-450(4), WAC 173-340-360(2)(c)(ii)(A)). Free phase product was present in the Oil House and Wastewater Treatment areas of the Facility in 2008 (Hart Crowser 2012b). Thus free phase product was added to the list of COCs for smear zone soils.

This FSTM has divided the Kaiser Facility into eight general operating areas (Table 4-1). The location of the AOCs evaluated for smear zone soil SL exceedances are depicted on Figures 4-1 to 4-5 as follows:

- Figure 4-1: ORB/Man-Made Depressions Area
- Figure 4-2: Cold Mill/Finishing Area
- Figures 4-3a- 4-3d: Oil House Area
- Figure 4-4: Wastewater Treatment Area
- Figure 4-5: Remelt/Hot Line Area

The AOCs depicted on Figures 4-1 through 4-5 were developed by using a "half the distance" rule to define a boundary between sample locations that are known to contain COPCs at concentrations above saturated soil SLs and sample locations where COPCs are known to be present at concentrations below saturated soil SLs. As shown in Section 1 and Table 1-2, saturated SL concentrations will generally be one order of magnitude lower than the unsaturated soil SL concentration due to higher leachability of COCs in wetted soils. The "half the distance" rule was also used to define the AOCs for near-surface soils (Section 2) and vadose zone soils (Section 3). The small number of smear zone soil samples and large distances between saturated soil samples in the ORB, Cold Mill/Finishing area, and Wastewater Treatment area likely caused the calculated impacted areas of the AOCs in these locations to overestimate the actual size of the AOCs (when compared to the calculated areas of the AOCs in Sections 1 and 2). This would contribute to an overestimate of the quantity of smear zone COCs present in those AOCs.

The next step in defining the AOCs is to estimate the vertical extent of the area of SL exceedance. Nearly twenty years of groundwater level measurements collected from wells across the site indicates that the average yearly groundwater fluctuation is approximately 10 feet (Hart Crowser 2012a). This observation was used as a starting assumption for defining the smear zone. An analysis of soil data collected below the upper extent of the water table supported an approximate 10-foot-thick smear zone in most AOCs.

With TPH compounds making up nearly 100 percent of smear zone SL exceedances, it was found that the bulk of contamination did reside in an approximate 10- to 12-foot band extending downward from the water table upper limits (68 feet bgs in the Mill areas and 55 feet bgs in the Wastewater Treatment area). For example, in the Oil House area 110 samples have been collected at depths greater than 68 feet bgs and analyzed for TPH compounds since 1989. Out of this data set there are 36 SL exceedances for Kensol and 28 SL exceedances for Stoddard solvent/mineral spirits[1].

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[1] These numbers also include screening level exceedances for Total TPH obtained by EPA Method 418.1. Used of the 418.1 data is further discussed in Appendix D.

Only one sample from this data set, OH-SB-1-S8 collected at 88 to 89 feet bgs, is located outside of an approximate 12-foot zone extending from 68 feet to 80 feet bgs. This trend holds for all other COCs (including PCBs in the Remelt plume area that are not co-located with TPH compounds) and AOCs examined in this Section. The handful of soil samples exceeding saturated soil SLs located below the 10- to 12-foot smear zone are considered outliers to this smear zone analysis but are considered as potential sources of groundwater contaminants, and are discussed in Sections 5 and 6.

In all AOCs the upper limit of the water table was taken as the start of a smear zone AOC with the lower boundary extending ten to twelve feet below the water table. An average concentration was then calculated for each COC that was present in the AOC. If clean samples were located within a smear zone AOC, then either the detected concentration below the SL or 1/2 of the reporting limit for non-detect samples was used in the calculation of the average COC concentration for that AOC. Samples where the collection interval began or ended in a defined AOC smear zone were included in the average calculations. For example, the smear zone in the Oil House area is defined as extending from 68 feet to 80 feet bgs. Therefore sample OH-MW-19/S-4, collected from 79 to 81 feet bgs was included in the average calculation even though the assumed smear zone extends only to 80 feet bgs.

This approach to the calculation of the average concentration of the COC represents an overestimate of the concentration that is actually present at a sample location for a number of reasons. The soil matrix at Kaiser consists mostly of gravel and cobbles (Hart Crowser 2012b). The soil samples collected initially also consisted of mostly gravel. The COCs in the sample were associated with the sand and organic material (if any) that was present in the sample. The gravel and cobble portion of the sample was not sent to the lab for analysis since cobbles would not fit in the sample jar and gravel would have to be pulverized in the lab prior to analysis. As a result, the concentration of COCs reported by the lab is an overestimate of the actual *in situ* concentration of the contaminant. Nonetheless, the lab values were reported in the Final Soil and Groundwater RIs (Hart Crowser 2012b, 2012a) since they represent a conservative estimate of the actual concentration of the COC present at the site, and contribute to a conservative approach to estimating risks to human health and the environment posed by each COC.

In many instances the smear zone soil data was collected 10 to 20 years ago as part of site characterization work. The result of this work often included the removal of contaminated near-surface soils (source area) that were located in the vicinity of or directly above the smear zone sample. Petroleum contamination is known to degrade over time if left in place. Each smear zone sample is from a location where it is regularly flushed by groundwater. The combination of the removal of the source area, the natural degradation of the contaminants over time and the result of the groundwater flushing action over time, likely reduced the original concentration of the smear zone soils. The quantity of this reduction can not be reliably estimated.

There are numerous paved areas located throughout the Kaiser facility. These paved areas are depicted on Figure 4-12 in relation to the smear zone AOCs and free phase product contours.

The specific COCs that are present in each AOC, and the sampling location where the COC is identified, are shown on Figures 4-1 to 4-5 and are listed in Table 4-19.

The available sampling data (Hart Crowser 2012b), together with the AOCs depicted on Figures 4-1 to 4-5, is used to compute an estimate of the total mass of contaminants contained in smear zone soil in the soil AOCs. This estimate is presented in Table 4-21, and provides a rough order of magnitude (ROM) estimate of the contaminant load in smear zone soils. The bands on the ROM estimate for smear zone soils are likely to exceed the nominal +/- 50 percent range identified for the near-surface and vadose zone soils for the reasons listed above. The calculation assumptions used to develop these estimates are summarized in Appendix D and in Table D-1, the spreadsheet used to calculate the loading. The estimate of the total mass of contaminants contained in smear zone soil in the soil AOCs is likely to represent a significant overestimate of the quantities that are actually present at the site in smear zone soils. Nonetheless, it was judged that the information in Tables 4-19, 4-21 and D-1 would provide useful insights into the relative distribution of COCs (e.g., mass of TPH vs. mass of PCBs, quantity of a COC in the Remelt area vs. the Oil House area) at the site.

The COC loadings listed in Table 4-21 are allotted to the AOCs within the five general operating areas of the site that contained that smear zone COCs. The calculation assumptions used to develop this estimate are summarized in Appendix D and in Table D-1, the spreadsheet used to perform the loading calculations. The total mass of contaminants in smear zone soil at the Kaiser Facility is approximately 3.7 million pounds (1,850 tons). Approximately 95 percent of this contamination has been reported to be heavier petroleum (diesel- and heavy oil-range hydrocarbons). VOCs (Stoddard solvent) comprise approximately 180 thousand pounds of the total mass (about 5 percent), and PCBs and arsenic each comprise approximately 60 pounds (about 0.002 percent) of the total mass of contaminants in smear zone soils. Less than 1 pound of cPAHs was estimated to reside in the ORB area based on the one sample that was collected that contained cPAHs at a concentration above the SL.

Figures 4-6 through 4-8 identify the areas at Kaiser with historic free phase petroleum (FPP) product. Figures 4-9 through 4-11 depict the areas with FPP identified during 2008 groundwater monitoring rounds. Comparing Figure 4-6 to Figure 4-9 a significant reduction in the size of the FPP areas can be seen as a result of source control, natural attenuation, and FPP removal measures conducted at Kaiser over the past 20 years.

Using the 2008 groundwater monitoring data (Hart Crowser 2012a), an evaluation of the quantities of FPP currently present in the Oil House and Wastewater AOCs was conducted. Referring to Figure 4-9, four areas with FPP were identified in 2008. Two are in the Oil House area (termed the East and West FPP areas) and two are in the Wastewater area (termed the North and South FPP areas). During 2008 groundwater monitoring rounds, product thickness measures were taken in select wells. Referring to Table 4-20, average FPP thicknesses were calculated for the four FPP areas with the 2008 data. Where a product thickness measurement was non-detect, 1/2 of the oil/water interface probe's detection limit of 0.01 feet (i.e., 0.005 feet) was used in calculating average FPP thickness. In all four FPP areas, average product thickness was less than 1 inch during 2008.

To calculate a volume of FPP present in the four areas containing FPP the average thickness was multiplied by the estimated area (Figures 4-10 and 4-11) and by an effective porosity. An effective porosity of 0.3 as defined in Section 4 of the Final Groundwater RI (Hart Crowser 2012a) was used in the FPP calculations. Product thickness measurements from 2008 and average FPP thicknesses are presented in Table 4-20. Estimates of the volumes of FPP present are provided in the last column in Table 4-21.

The information contained on Figures 4-1 through 4-5, 4-9 through 4-11, and Tables 4-19 through 4-21, and C-1 is summarized for each COC in Appendix D:

- Section D-1 – VOCs
- Section D-2 – Diesel, Heavy oil and cPAHs
- Section D-3 – PCBs

4.6 DEVELOPMENT OF REMEDIAL ALTERNATIVES

The technologies and process options that are potentially applicable to the remediation of the smear zone soils in the AOCs at the Kaiser Facility are identified in Section 4.4. These technologies and process options were initially screened to account for site-specific technical constraints and for the chemical properties of the COCs in Section 4.4.1. The technologies and process options judged to be implementable and reliable for the remediation of soils in the AOCs (refer to Section 4.4.2) are assembled into remediation alternatives in this Section. The basis for developing alternatives follows the logic shown on Figure 2-11 and was described in Section 2.7.

4.6.1 Remedial Alternatives for Smear Zone Soil

MTCA requires that a reasonable number of alternatives shall be evaluated taking into account the characteristics and complexity of the facility, including current site conditions and physical constraints (WAC 173-340-350[8][c][i][B]). These factors were discussed in Section 2.5.1.

The technology-based remedial alternatives developed in this section range from Alternative A1 (monitoring, institutional controls, and monitored natural attenuation [MNA]) to Alternative A6 (monitoring, institutional controls, containment, and *in situ* treatment). The individual COCs that are addressed by each of the alternatives described above are summarized in Table 4-22.

Alternatives A1 and A2

The monitoring, institutional controls, and MNA alternative, Alternative A1, is included since many viable remedies for smear zone soils at the Kaiser Facility will contain these elements. Containment, institutional controls, MNA, and monitoring compose Alternative A2. It adds the additional protection of containment to Alternative A1. Alternatives A1 to A2 are common for all the COC groups (VOCs, SVOCs, PCBs, and metals). Alternatives A1 and A2 are considered to be the most practical permanent cleanup alternatives for metals at concentrations above SLs in smear zone soils.

Alternative A3

Alternative A3 adds *in situ* treatment (SVE plus off-gas treatment) to Alternative A2 in AOCs (e.g., Oil House area) that contain VOC COCs (Stoddard solvent) at concentrations above SLs. Alternative A3 is considered to be the most practical permanent cleanup alternative for the treatment of VOCs in smear zone soils.

Alternative A4

Free phase product removal, containment, institutional controls, MNA, and monitoring are included in Alternative A4 for those AOCs (e.g., Oil House area Wastewater Treatment area) where free phase product is currently present. Alternative A4 is considered to be the most practical permanent cleanup alternative for the removal of free phase product from smear zone soils. Based on implementability, the mechanical belt skimmers would be used for free phase product recovery.

Alternatives A5 and A6

In situ bioremediation, containment, institutional controls, monitoring, and MNA are included under Alternative A5a for those AOCs (ORB area, Cold Mill Finishing area, Oil House area, Wastewater Treatment area, and Remelt/Casting area) where SVOCs (without free phase product) are present.

Alternative A5b substitutes *in situ* chemical treatment for *in situ* bioremediation in Alternative A5a.

Alternative A6a includes *in situ* bioremediation, containment, institutional controls, monitoring, and MNA for those AOCs (Cold Mill Finishing area, Remelt/Casting area, Oil House area) where PCBs are co-located with SVOCs and present in smear zone soils.

Alternative A6b substitutes *in situ* chemical treatment for *in situ* bioremediation in Alternative A6a. Alternative A6 is considered to be the most practical permanent cleanup alternative for AOCs that contain SVOCs alone or mixtures of SVOCs and PCBs in smear zone soils.

Applicability and Combination of Multiple Alternatives

Several technology-based alternatives may be applicable for each individual COC. For instance, technology-based alternatives A1, A2, and A3 could be used individually or in combination to address VOCs in smear zone soils. Similarly, technology-based alternatives A1, A2, A4, and A5a or A5b could be used individually or in combination to address SVOCs in smear zone soils.

If there is more than one type of COC in an AOC, it is possible that a single alternative or a combination of alternatives could be considered. For example, one AOC in the Oil House operating area (refer to Figure 4-3a) contains SVOCs in smear zone soils at concentrations exceeding SLs. This AOC contains within it other smaller AOCs that contain VOCs, PCBs, and arsenic (refer to Figures 4-

3b through 4-3d). In this example, technology-based alternatives A1 or A2 could be used to remediate any of the COC groups in any of these AOCs. Alternative A3 (SVE) could be added for the areas containing VOC AOCs. Alternatives A5a or A5b could be used to remediate the entire SVOC AOC, while alternatives A6a or A6b could be used in those areas where both SVOCs and PCBs were found.

One AOC contains only PCBs at concentrations exceeding SLs (Figure 4-3c around monitoring well OH-MW-16). For this AOC the potential remedial alternatives include alternatives A1 and A2.

The overall feasibility study will evaluate the technology-based remedial alternatives described above to assess whether or not, or to what extent, the alternatives meet the minimum requirements for cleanup action under MTCA (WAC-173-340-360[2]). One outcome of this evaluation will be to identify the most appropriate technology-based alternative(s) for each COC. It is expected that alternatives A1 and A2 will be carried forward for each COC group. For SVOCs it is expected that the evaluation will differentiate among alternatives A5a and A5b and identify the most appropriate alternative. Similarly, it is expected that the overall feasibility study will identify the most appropriate alternative among the potentially applicable alternatives for mixtures of PCBs and SVOCs (A1, A2, A6a and A6b), VOCs (A1, A2 and A3), and for metals (A1 and A2). The most appropriate alternative(s) for each COC group within an AOC will then be bundled to create the proposed area-based remedy for each of the AOCs identified for smear zone soils, as described above for an AOC in the Oil House operating area.

Compliance Monitoring

Monitoring is needed to assure compliance with cleanup levels, to assess the performance of a remediation technology as it is operating, and to measure the continued effectiveness over time of permanent features added to the site (e.g., capping). Monitoring is an integral element of Alternatives A1 through A6. A comprehensive monitoring program consists of protection monitoring, performance monitoring, and confirmational monitoring. The comprehensive monitoring program is based on an adaptive monitoring and management strategy that is described in Section 2.7.3.

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Table 4-1 - Kaiser General Operating Areas and Smear Zone Soil COCs

General Operating Area	COCs Identified in Smear Zone Soil
Oil Reclamation Building and Surrounding Area	Diesel, Heavy Oil[a], cPAH
Rail Car Unloading Area	None
Cold Mill/Finishing Area	Diesel, Heavy Oil, PCBs
Oil House Area	Kensol[a], Stoddard, PCBs, Arsenic
Wastewater Treatment Area	Diesel/Kensol[a]
Truck Shop Area	None
Discharge Ravine Area	None
Remelt/Hotline Area	PCBs, Heavy Oil

Notes:

[a] Indicates that some of the TPH data from this location was obtained via EPA Method 418.1 which reports soil concentrations as "Total TPH." Therefore, individual TPH compounds cannot be distinguished. Based on the predominance of TPH compounds in an AOC, the Total TPH values were assigned to either the diesel/Kensol- or heavy oil-range.

Shaded operating areas do not contain COCs

Table 4-2 - Preliminary Identification of Remedial Technologies for Enhanced SVOC and Free Phase Product Removal in Smear Zone Soil [1]

General Response Action	Remedial Technology	Process Options	Description
Enhanced SVOC Removal	Steam or hot water injection	Combined with soil vapor extraction and/or liquid (product) recovery.	Mobility of free phase product is increased by heating and fluid displacement. Free phase product recovery technologies will need to be used to recover mobilized product. Heating may also produce vapors that will need to be recovered and treated.
	Hot air injection	Combined with soil vapor extraction and/or liquid (product) recovery.	Mobility of free phase product is increased by heating and fluid displacement. Free phase product recovery technologies will need to be used to recover mobilized product. Heating may also produce vapors that will need to be recovered and treated.
	Electrical Resistance Heating	Combined with soil vapor extraction and/or liquid (product) recovery.	Heat is mostly adsorbed by pore water which indirectly heats residual product. Heating increases mobility of free phase product. Free phase product recovery technologies will need to be used to recover mobilized product. Heating may also produce vapors that will need to be recovered and treated.
	Radio Frequency Heating	Combined with soil vapor extraction and/or liquid (product) recovery.	Heat is adsorbed by soil which indirectly heats residual product. Heating increases mobility of free phase product. Recovery wells will need to be used to capture mobilized product. Heating may also produce vapors that will need to be recovered and treated.
	Soil Flushing	Surfactants, cosolvents	Increase mobilization of residual product through chemical addition. Mobilized product and added chemicals need to be recovered.
Free Phase Product Removal	Mechanical Skimmers	Floating skimmers, pneumatic pumps, skimming belts	Skimming systems that rely on pumps (either surface mounted or within the well) or other motors to actively extract free phase product from the subsurface.
	Passive Skimmers	Filter canisters, absorbent bailers	Slowly recover free phase product from well over time.

Note

1) Technologies that apply to VOCs, SVOCs and PCB-impacted smear zone soils are the same that apply to deep vadose zone soils. Refer to Table 3-2.

Table 4-3 - Physical/Chemical Screening Criteria of Remedial Technologies for VOC-Impacted Smear Zone Soil

General Response Action	**Remedial Technology**	**Technology Retained?**[1]
Monitoring	Monitoring	Yes
Institutional Controls	Access and Use Restrictions	Yes
Institutional Controls	Best Management Practices	Yes
Containment	Capping	Yes
Containment	Landfill Cap Enhancements	No
Containment	Vertical Barrier	No
In situ Treatment of Soils	*In situ* Bioremediation	Yes
In situ Treatment of Soils	Monitored Natural Attenuation	Yes
In situ Treatment of Soils	Soil Vapor Extraction (SVE)	Yes
In situ Treatment of Soils	Steam Injection	No
In situ Treatment of Soils	Six Phase Soil Heating	No
In situ Treatment of Soils	Soil Flushing	No
In situ Treatment of Soils	Pneumatic Fracturing	No
In situ Treatment of Soils	Chemical Treatment	Yes
In situ Treatment of Soils	Electro-Kinetic Treatment	No
In situ Treatment of Soils	Solidification/ Stabilization	No
In situ Treatment of Soils	Vitrification	No
On-Site Treatment of Extracted Soil Vapor	Condensation	No
On-Site Treatment of Extracted Soil Vapor	Adsorption	Yes
On-Site Treatment of Extracted Soil Vapor	Thermal Oxidation	Yes
On-Site Treatment of Extracted Soil Vapor	Catalytic Oxidation	Yes
On-Site Treatment of Extracted Soil Vapor	Advanced Oxidation	Yes
On-Site Treatment of Extracted Soil Vapor	Biofiltration	Yes

Note:

1) The reasons for retaining a technology to treat VOCs in smear zone soils based on physical/chemical criteria are the same as the reasons cited for technologies to treat VOCs in deep vadose zone soils as presented in Table 3-3. Refer to the evaluations in that table.

Table 4-4 - Physical/Chemical Screening Criteria of Remedial Technologies for SVOC-Impacted Smear Zone Soil

General Response Action	**Remedial Technology**	**Technology Retained?**^{1}
Monitoring	Monitoring	Yes
Institutional Controls	Access and Use Restrictions	Yes
Institutional Controls	Best Management Practices	Yes
Containment	Capping	Yes
Containment	Landfill Cap Enhancements	No
Containment	Vertical Barrier	No
In situ Treatment of Soils	*In situ* Bioremediation	Yes
In situ Treatment of Soils	Monitored Natural Attenuation	Yes
In situ Treatment of Soils	Soil Vapor Extraction (SVE)	No
In situ Treatment of Soils	Steam Injection	No
In situ Treatment of Soils	Six Phase Soil Heating	No
In situ Treatment of Soils	Soil Flushing	No
In situ Treatment of Soils	Pneumatic Fracturing	No
In situ Treatment of Soils	Chemical Treatment	Yes
In situ Treatment of Soils	Electro-Kinetic Treatment	No
In situ Treatment of Soils	Solidification/ Stabilization	No
In situ Treatment of Soils	Vitrification	No
On-Site Treatment of Extracted Soil Vapor	Condensation	No
On-Site Treatment of Extracted Soil Vapor	Adsorption	Yes^2
On-Site Treatment of Extracted Soil Vapor	Thermal Oxidation	Yes^2
On-Site Treatment of Extracted Soil Vapor	Catalytic Oxidation	Yes^2
On-Site Treatment of Extracted Soil Vapor	Advanced Oxidation	Yes^2
On-Site Treatment of Extracted Soil Vapor	Biofiltration	Yes^2

Note:

1) The reasons for retaining a technology to treat SVOCs in smear zone soils based on physical/chemical criteria also apply to SVOCs in deep vadose zone soils as presented in Tables 3-4. Refer to the evaluations in that table.
2) Technology retained to treat off-gas from chemical treatment.

Table 4-5 - Physical/Chemical Screening Criteria of Remedial Technologies for PCB-Impacted Smear Zone Soil

General Response Action	Remedial Technology	Technology Retained?[1]
Monitoring	Monitoring	Yes
Institutional Controls	Access and Use Restrictions	Yes
Institutional Controls	Best Management Practices	Yes
Containment	Capping	Yes
Containment	Landfill Cap Enhancements	No
Containment	Vertical Barrier	No
In situ Treatment of Soils	*In situ* Bioremediation	Yes
In situ Treatment of Soils	Monitored Natural Attenuation	Yes
In situ Treatment of Soils	Soil Vapor Extraction (SVE)	No
In situ Treatment of Soils	Steam Injection	No
In situ Treatment of Soils	Six Phase Soil Heating	No
In situ Treatment of Soils	Soil Flushing	No
In situ Treatment of Soils	Pneumatic Fracturing	No
In situ Treatment of Soils	Chemical Treatment	Yes
In situ Treatment of Soils	Electro-Kinetic Treatment	No
In situ Treatment of Soils	Solidification/ Stabilization	Yes
In situ Treatment of Soils	Vitrification	No
On-Site Treatment of Extracted Soil Vapor	Adsorption	Yes[2]
On-Site Treatment of Extracted Soil Vapor	Thermal Oxidation	Yes[2]
On-Site Treatment of Extracted Soil Vapor	Catalytic Oxidation	Yes[2]
On-Site Treatment of Extracted Soil Vapor	Advanced Oxidation	Yes[2]
On-Site Treatment of Extracted Soil Vapor	Biofiltration	Yes[2]
On-Site Treatment of Extracted Soil Vapor	Chlorine Scrubber	Yes[2]

Note:

1) The reasons for retaining a technology to treat PCBs in smear zone soils based on physical/chemical criteria are the same as the reasons cited for technologies to treat PCBs in deep vadose zone soils as presented in Tables 3-5. Refer to the evaluations in that table.

2) Technology retained to treat off-gas from chemical treatment.

Table 4-6 - Physical/Chemical Screening Criteria of Remedial Technologies for Enhanced SVOC and Free Phase Product Removal in Smear Zone Soil

General Response Action	Remedial Technology	Description	Screening Comments	Technology Retained
Enhanced SVOC Removal	Steam or hot water injection	Heating enhances free phase product recovery by increasing mobility. Combined with vapor and/or liquid (including product) recovery.	Access limited by infrastructure and buried utilities. If there is volatilization, may require off-gas capture and may increase indoor air exposure. May cause settlement damage to buildings and roadways. Highly porous site soils would make it difficult to apply and capture steam or water in smear zone soil matrix. Water and steam can displace free phase product and potentially move and spread smear zone.	No
	Hot air injection	Heating enhances free phase product recovery by increasing mobility. Combined with vapor and/or liquid (including product) recovery.	Access limited by infrastructure and buried utilities. If there is volatilization, may require off-gas capture and may increase indoor air exposure. Heat capacity of air may limits effectiveness of technology.	Yes
	Electrical Resistance Heating	Residual product is indirectly heated by heating groundwater. Heating increases mobility of free phase product. Combined with vapor and/or liquid (including product) recovery.	Due to congested infrastructure and safety concerns with stray electrical current, use is prohibited by Kaiser. Limited to accessible areas, requires capture and treatment of extracted vapors. Boiling point of water is highest temperature that can be achieved which may limit the effectiveness of this technology.	No
	Radio Frequency Heating	Residual product is indirectly heated by heating soils. Heating increases mobility of free phase product. Combined with vapor and/or liquid (including product) recovery.	Due to congested infrastructure and safety concerns with stray electrical current, use is prohibited by Kaiser. Limited to accessible areas, requires capture and treatment of extracted vapors. Technology limited to unsaturated soil matrix.	No

Table 4-6 - Physical/Chemical Screening Criteria of Remedial Technologies for Enhanced SVOC and Free Phase Product Removal in Smear Zone Soil

General Response Action	Remedial Technology	Description	Screening Comments	Technology Retained
Enhanced SVOC Removal (continued)	Soil Flushing	Surfactants and/or cosolvents combined with liquid (including product) recovery.	Access to impacted soils limited by infrastructure. Potential for contaminants and chemicals to spread if recovery is ineffective.	No
Free Phase Product Removal	Mechanical Skimmers	Mechanical skimming systems rely on pumps (either surface mounted or within the well) or other motors to actively extract free phase product from the subsurface.	Potentially effective for free phase product at this site. Skimming belt currently in use at this site per IRM.	Yes
	Passive Skimmers	Passive skimmers accumulate free phase product from the well over time.	Potentially effective for free phase product at this site.	Yes

Table 4-7a - Implementability of Selected Technologies for VOC-Impacted Smear Zone Soil

Technology	**Process Options**	**Can it be Implemented?**[1]
Monitoring	Protection, Performance, Confirmational	Yes
Access and Use Restrictions	Fencing, signs, deed restrictions.	Yes
Best Management Practices	Spill prevention, leak detection, double-walled pipes, proper storage of chemicals and solvents.	Yes
Capping	Soil Cap	No
Capping	Clay Cap	No
Capping	Low Permeable Asphalt Cap	Yes
Capping	Low Permeable Concrete Cap	Yes
Capping	Synthetic Liner	No
Capping	Multilayer Cap (soil + synthetic liner)	Yes
In situ Bioremediation	Bioventing (injecting and/or withdrawing air in vadose zone)	No
In situ Bioremediation	Phytoremediation	No
Monitored Natural Attenuation	Monitored Natural Attenuation	Yes
Soil Vapor Extraction	Vertical Vents,	Yes
Soil Vapor Extraction	Horizontal Vents	No
In situ Chemical Treatment	Oxidation	No
Adsorption	Activated Carbon	Yes
Thermal and Catalytic Oxidation	Direct Flame, Flameless Hybrid Thermal/Catalytic	No
Thermal and Catalytic Oxidation	Catalytic Oxidizer	Yes
Advanced Oxidation	UV Light	No
Advanced Oxidation	Photocatalytic Destruction	Yes
Biofiltration	Biofiltration	No

Note:

1) The reasons a technology was judged to be implementable for VOCs in smear zone soils are similar to the reasons provided for VOCs in near-surface soils as presented in Tables 2-8a through 2-8k. Refer to the evaluations in these tables.

Table 4-7b - Implementability of *In Situ* Bioremediation for VOC-Impacted Smear Zone Soil

	Process Options for *In situ* Bioremediation
Attribute	**Enhanced Bioremediation**
Can it be constructed?	Yes, site is amenable to constructing and operating support equipment though access may be limited in some areas by infrastructure. Design, construction, and startup will take approximately 1 year. This technology includes the circulation of water-based solutions to stimulate microbes and/or the injection of Oxygen Release Compounds (ORC) or electron donor compounds.
Will it work?	ORC and electron donor inputs require saturated soils to work; low organic content of soils at this site make contact with treatment inputs difficult; treatment is also very difficult in areas of low VOC concentrations.
Will this be acceptable to regulatory agencies?	Yes
Is technology available?	Yes
Is process option accepted?	Yes

Table 4-8a - Reliability of Selected Technologies for VOC-Impacted Smear Zone Soil

Technology	**Process Options**	**Is it reliable?**[1]
Monitoring	Protection, Performance, Confirmational	Yes
Access and Use Restrictions	Fencing, signs, deed restrictions	Yes
Best Management Practices	Spill prevention, leak detection, double-walled pipes, proper storage of chemicals and solvents	Yes
Capping	Low Permeability Asphalt Cap	Yes
Capping	Low Permeability Concrete Cap	Yes
Capping	Multilayer (synthetic liner + soil)	Yes
Monitored Natural Attenuation	Monitored Natural Attenuation	Yes
Soil Vapor Extraction	Vertical Vents	Yes
Adsorption	Activated Carbon	Yes
Thermal and Catalytic Oxidation	Catalytic Oxidizers	Yes
Advanced Oxidation	Photocatalytic Destruction	No

Note:

1) The evaluations of reliability given in this table for VOCs are the same as those provided for VOCs in near-surface soils for reasons provided in Tables 2-9a - 2-9h. Refer to the evaluations in those tables.

Table 4-8b - Reliability of *In Situ* Bioremediation of VOC-Impacted Smear Zone Soil

	Process Options for *In situ* Bioremediation of VOC-Impacted Smear Zone Soils
Attribute	**Enhanced Bioremediation**
Has this process option been used at the scale required for Kaiser?	Yes, enhanced bioremediation is an established process employed to treat VOCs in subsurface soils.
Are operation and maintenance requirements infrequent and straightforward?	Yes. Chemicals may need to be stored on site. Periodic chemical addition is necessary. Off-gas collection and treatment may be needed.
Has this process option been proven effective under COC and site conditions similar to those at Kaiser?	No. Concentrations of Stoddard solvent varies from approximately 1,000-7,000 mg/kg. The presence of free phase product will make treatment more difficult to achieve. Colder temperatures (winter) will limit biodegradation. Porous soils will make the injection of ORC or another additive in the appropriate location difficult.
Is process option accepted?	No

Table 4-9 - Summary of Technology Screening Process: VOCs in Smear Zone Soils

			Screening Outcome		
General Response Action (a)	**Remedial Technology (a)**	**Process Options (a)**	**Physical/Chemical (b)**	**Implementability (c)**	**Reliability (d)**
Monitoring	**Monitoring**	**Protection, Performance, and Confirmational**	**Retained**	**Retained**	**Retained**
Institutional Controls	**Access and Use Restrictions**	**Fences, Signs, Deed Restrictions**	**Retained**	**Retained**	**Retained**
	Best Management Practices	**Spill prevention, leak detection, double-walled pipes**	**Retained**	**Retained**	**Retained**
Containment	**Capping**	Soil	Retained	Eliminated	--
		Clay	Retained	Eliminated	--
		Asphalt	**Retained**	**Retained**	**Retained**
		Concrete	**Retained**	**Retained**	**Retained**
		Synthetic	Retained	Eliminated	--
		Multi-layer (soil + synthetic liner)	**Retained**	**Retained**	**Retained**
	Landfill Cap Enhancements	Run-on and run-off controls, vegetative cover	Eliminated	--	--
	Solidification/ Stabilization	Cement- and lime-based processes, microencapsulation, sorption	Eliminated	--	--
***In situ* Soils Treatment**	Vitrification	Combined with soil vapor extraction	Eliminated	--	--
	In situ Bioremediation	Bioventing	Retained	Eliminated	--
		Enhanced Bioremediation	Retained	Retained	Eliminated
		Phytoremediation	Retained	Eliminated	--
	Monitored Natural Attenuation	**Monitor natural processes**	**Retained**	**Retained**	**Retained**
	Soil Vapor Extraction (SVE)	Horizontal vents	Retained	Eliminated	--
		Vertical Vents	**Retained**	**Retained**	**Retained**
	Steam Injection	Combined with soil vapor extraction	Eliminated	--	--
	Six Phase Soil Heating	Combined with soil vapor extraction	Eliminated	--	--
	Soil Flushing	Water, surfactants, solvents	Eliminated	--	--

Table 4-9 - Summary of Technology Screening Process: VOCs in Smear Zone Soils

			Screening Outcome		
General Response Action (a)	**Remedial Technology (a)**	**Process Options (a)**	**Physical/Chemical (b)**	**Implementability (c)**	**Reliability (d)**
***In situ* Soils Treatment - cont'd**	Pneumatic Fracturing	Pressurized air or steam	Eliminated	--	--
	Chemical Treatment	Oxidation, reduction, pH adjustment	Retained	Retained	Eliminated
	Electro-Kinetic	Enhanced with surfactants and reagents	Eliminated	--	--
On-Site Treatment of Extracted Soil Vapor	Condensation	Refrigerated condenser	Eliminated	--	--
	Adsorption	**Granular activated carbon**	**Retained**	**Retained**	**Retained**
	Thermal and Catalytic Oxidation	Direct flame Thermal	Retained	Eliminated	--
		Flameless Thermal	Retained	Eliminated	--
		Catalytic Oxidizers	**Retained**	**Retained**	**Retained**
		Hybrid Thermal/Catalytic	Retained	Eliminated	--
	Advanced Oxidation	UV light	Retained	Eliminated	--
		Photocatalytic	Retained	Retained	Eliminated
	Biofiltration	Bioreactor, soil pile	Retained	Eliminated	--

Notes:
Bolded Technologies Retained for further evaluation in the FS.
(a) Taken from FSTM Table 3-2
(b) Taken from FSTM Table 4-3
(c) Taken from FSTM Table 4-7a - 4-7b
(d) Taken from FSTM Table 4-8a - 4-8b

Table 4-10a - Implementability of Selected Technologies for SVOC-Impacted Smear Zone Soil

Sheet 1 of 1

Technology	**Process Options**	**Can it be Implemented?**[1]
Monitoring	Protection, Performance, Confirmational	Yes
Access and Use Restrictions	Fencing, signs, deed restrictions.	Yes
Best Management Practices	Spill prevention, leak detection, double-walled pipes, proper storage of chemicals and solvents.	Yes
Capping	Soil Cap	No
Capping	Clay Cap	No
Capping	Low Permeable Asphalt Cap	Yes
Capping	Low Permeable Concrete Cap	Yes
Capping	Synthetic Liner	No
Capping	Multilayer Cap (soil + synthetic liner)	Yes
In situ Bioremediation	Bioventing (injecting and/or withdrawing air in vadose zone)	No
In situ Bioremediation	Phytoremediation	No
Monitored Natural Attenuation	Monitored Natural Attenuation	Yes
In situ Chemical Treatment	Oxidation	Yes[2]
Adsorption	Activated Carbon	Yes[3]
Thermal and Catalytic Oxidation	Direct Flame, Flameless, Hybrid Thermal/Catalytic	
Thermal and Catalytic Oxidation	Catalytic Oxidizers	Yes[3]
Advanced Oxidation	UV Light	No
Advanced Oxidation	Photocatalytic Destruction	Yes[3]
Biofiltration	Biofiltration	No

Note:

1) The reasons for implementability for SVOCs in smear zone soils are similar to the reasons provided for VOCs in near-surface soils as presented in Tables 2-8a through 2-8e and 2-8h through 2-8k, except where noted. Refer to the evaluations in these tables.
2) The reasons for implementability for SVOCs in smear zone soils are similar to the reasons provided for SVOCs in deep vadose zone soils as presented in Table 3-9a.
3) If needed to treat off-gas from *in situ* processes.

Table 4-10b - Implementability of *In Situ* Bioremediation for SVOC-Impacted Smear Zone Soil

	Process Options for *In situ* Bioremediation
Attribute	**Enhanced Bioremediation**
Can it be constructed?	Yes, site is amenable to constructing and operating support equipment though access may be limited in some areas by infrastructure. Design, construction, and startup will take approximately 1 year. This technology includes the circulation of water-based solutions to stimulate microbes and/or the injection of Oxygen Release Compounds (ORC) or electron donor compounds.
Will it work?	ORC and electron donor inputs require saturated soils to work. High concentrations of SVOCs in saturated soil matrix make contact between contaminants and chemical additions likely, thereby encouraging microbial activity. Bioremediation is an EPA presumptive remedy for SVOCs.
Will this be acceptable to regulatory agencies?	Yes, it is a presumptive remedy for SVOCs.
Is technology available?	Yes
Is process option accepted?	Yes

Table 4-11a - Reliability of Selected Technologies for SVOC-Impacted Smear Zone Soil

Technology	**Process Options**	**Is it reliable?[1]**
Monitoring	Protection, Performance, Confirmational	Yes
Access and Use Restrictions	Fencing, signs, deed restrictions	Yes
Best Management Practices	Spill prevention, leak detection, double-walled pipes, proper storage of chemicals and solvents	Yes
Capping	Low Permeability Asphalt Cap	Yes
Capping	Low Permeability Concrete Cap	Yes
Capping	Multilayer (synthetic liner + soil)	Yes
Monitored Natural Attenuation	Monitored Natural Attenuation	Yes
Adsorption	Activated Carbon	Yes[2]
Thermal and Catalytic Oxidation	Catalytic Oxidizers	Yes[2]
Advanced Oxidation	Photocatalytic Destruction	No

Note:

1. The evaluations of reliability given in this table for SVOCs are the same as those provided for VOCs, for reasons summarized in Tables 2-9a through 2-9d and 2-9f through 2-9h. Refer to the evaluations in those tables.
2. If off-gas treatment is needed by an *in situ* treatment process.

Table 4-11b - Reliability of *In Situ* Bioremediation of SVOC-Impacted Smear Zone Soil

	Process Options for *In situ* Bioremediation of SVOC-Impacted Smear Zone Soils
Attribute	**Enhanced Bioremediation**
Has this process option been used at the scale required for Kaiser?	Yes, this option has been used at sites of similar scale.
Are operation and maintenance requirements infrequent and straightforward?	Yes. Enhanced bioremediation is an established technology. This technology includes the circulation of water-based solutions to stimulate microbes and/or the injection of Oxygen Release Compounds (ORC) or electron donor compounds. Degradation of SVOCs may produce off-gas that will need to be treated.
Has this process option been proven effective under COC and site conditions similar to those at Kaiser?	Yes. Enhanced bioremediation is a presumptive remedy for SVOCs. Depending on contaminant concentrations, treatment time may last several years (EPA 1995a).
Is process option accepted?	Yes

Table 4-11c - Reliability of *In Situ* Chemical Treatment of SVOC-Impacted Smear Zone Soil

	Process Options for *In situ* Chemical Treatment
Attribute	**Oxidation**
Has this process option been used at the scale required for Kaiser?	Yes, this option has been used at sites of similar scale.
Are operation and maintenance requirements infrequent and straightforward?	No. System includes aboveground chemical storage, chemical injection wells, off-gas collection wells, and an off-gas treatment system.
Has this process option been proven effective under COC and site conditions similar to those at Kaiser?	Yes. At depth of contamination, wells will most likely have to be used for application of chemicals. Due to porous soil matrix, chemicals will be applied at low pressures to ensure chemicals are applied in areas of concern. Technology involves exothermic reactions and should not be applied to areas with significant product layer (greater than 0.5 feet). Off-gas may be generated and must be collected and potentially treated to meet regulatory requirements.
Is process option accepted?	Yes

Table 4-12 - Summary of Technology Screening Process: SVOCs in Smear Zone Soils

			Screening Outcome		
General Response Action (a)	**Remedial Technology (a)**	**Process Options (a)**	**Physical/Chemical (b)**	**Implementability (c)**	**Reliability (d)**
Monitoring	**Monitoring**	**Protection, Performance, and Confirmational**	**Retained**	**Retained**	**Retained**
Institutional Controls	**Access and Use Restrictions**	**Fences, Signs, Deed Restrictions**	**Retained**	**Retained**	**Retained**
	Best Management Practices	**Spill prevention, leak detection, double walled pipes**	**Retained**	**Retained**	**Retained**
Containment	**Capping**	Soil	Retained	Eliminated	--
		Clay	Retained	Eliminated	--
		Asphalt	**Retained**	**Retained**	**Retained**
		Concrete	**Retained**	**Retained**	**Retained**
		Synthetic	Retained	Eliminated	--
		Multi-layer (soil + synthetic liner)	**Retained**	**Retained**	**Retained**
	Landfill Cap Enhancements	Run-on and run-off controls, vegetative cover	Eliminated	--	--
	Solidification/ Stabilization	Cement- and lime-based processes, microencapsulation, sorption	Eliminated	--	--
***In Situ* Soils Treatment**	Vitrification	Combined with soil vapor extraction	Eliminated	--	--
	In Situ Bioremediation	Bioventing	Retained	Eliminated	--
		Enhanced Bioremediation	**Retained**	**Retained**	**Retained**
		Phytoremediation	Retained	Eliminated	
	Monitored Natural Attenuation	**Monitor natural processes**	**Retained**	**Retained**	**Retained**
	Soil Vapor Extraction (SVE)	Horizontal vents	Eliminated	--	--
		Vertical Vents	Eliminated	--	--
	Steam Injection	Combined with soil vapor extraction	Eliminated	--	--
	Six Phase Soil Heating	Combined with soil vapor extraction	Eliminated	--	--

Table 4-12 - Summary of Technology Screening Process: SVOCs in Smear Zone Soils

			Screening Outcome		
General Response Action (a)	**Remedial Technology (a)**	**Process Options (a)**	**Physical/Chemical (b)**	**Implementability (c)**	**Reliability (d)**
***In Situ* Soils Treatment - cont'd**	Soil Flushing	Water, surfactants, solvents	Eliminated	--	--
	Pneumatic Fracturing	Pressurized air or steam	Eliminated	--	--
	Chemical Treatment	**Oxidation, reduction, pH adjustment**	**Retained**	**Retained**	**Retained**
	Electro-Kinetic	Enhanced with surfactants and reagents	Eliminated	--	--
On-Site Treatment of Extracted Soil Vapor (e)	Condensation	Refrigerated condenser	Eliminated	--	--
	Adsorption	**Granular activated carbon**	**Retained**	**Retained**	**Retained**
	Thermal and Catalytic Oxidation	Direct flame Thermal	Retained	Eliminated	--
		Flameless Thermal	Retained	Eliminated	--
		Catalytic Oxidizers	**Retained**	**Retained**	**Retained**
		Hybrid Thermal/Catalytic	Retained	Eliminated	--
	Advanced Oxidation	UV light	Retained	Eliminated	--
		Photocatalytic	Retained	Retained	Eliminated
	Biofiltration	Bioreactor, soil pile	Retained	Eliminated	--

Notes:

Bolded Technologies Retained for further evaluation in the FS.

(a) Taken from FSTM Table 3-2

(b) Taken from FSTM Table 4-4

(c) Taken from FSTM Table 4-10a - 4-10b

(d) Taken from FSTM Table 4-11a - 4-11b

(e) If need to treat off-gas from in situ treatment processes.

Table 4-13a - Implementability of Selected Technologies for PCB-Impacted Smear Zone Soil

Technology	**Process Options**	**Can it be Implemented?**[1]
Monitoring	Protection, Performance, Confirmational	Yes
Access and Use Restrictions	Fencing, signs, deed restrictions.	Yes
Best Management Practices	Spill prevention, leak detection, double-walled pipes, proper storage of chemicals and solvents.	Yes
Capping	Soil Cap	No
Capping	Clay Cap	No
Capping	Low Permeable Asphalt Cap	Yes
Capping	Low Permeable Concrete Cap	Yes
Capping	Synthetic Liner	No
Capping	Multilayer Cap (soil + synthetic liner)	Yes
In situ Bioremediation	Bioventing (injecting and/or withdrawing air in vadose zone)	No
In situ Bioremediation	Phytoremediation	No
Monitored Natural Attenuation	Monitored Natural Attenuation	Yes
Containment	Stabilization/Solidification	Yes[2]
Adsorption	Activated Carbon	Yes[3]
Thermal and Catalytic Oxidation	Direct Flame, Flameless, Hybrid Thermal/Catalytic	No
Thermal and Catalytic Oxidation	Catalytic Oxidizers	Yes[3]
Advanced Oxidation	UV Light	No
Advanced Oxidation	Photocatalytic Destruction	Yes[3]
Biofiltration	Biofiltration	No
Chlorine Removal	Chlorine Scrubber	Yes [2, 3]

Note:

1) The reasons a technology was judged to be implementable for PCBs in smear zone soils are similar to the reasons the technology was judged to be implementable for VOCs in near-surface soils as presented in Tables 2-8a through 2-8e and 2-8h through 2-8k, except where noted. Refer to the evaluations in these tables.

2) The reasons behind the judgment about implementability for these technologies for PCBs in smear zone soils are similar to the reasons provided for PCBs in deep vadose zone soils as presented in Tables 3-12b and 3-12c. Refer to the evaluations in these tables.

3) If technology is needed to treat off-gas from *in situ* processes.

Table 4-13b - Implementability of *In Situ* Bioremediation for PCB-Impacted Smear Zone Soil

	Process Options for *In situ* Bioremediation
Attribute	**Enhanced Bioremediation**
Can it be constructed?	Yes, site is amenable to constructing and operating support equipment though access may be limited in some areas by infrastructure. Design, construction, and startup will take approximately 1 year. This technology includes the circulation of water-based solutions to stimulate microbes and/or the injection of Oxygen Release Compounds (ORC) or electron donor compounds.
Will it work?	No, not for PCBs alone. Enhanced Bioremediation typically used for PAHs, non-halogenated SVOCs (not including PAHs), and BTEX (FRTR Table 2-4). In general, bioremediation has limited effectiveness with PCBs. *In situ* lagoon was used to treat PCB-impacted sludge at a French Limited Superfund Site. Other contaminants treated were VOCs and SVOCs. May work where PCBs are co-located with higher concentrations of other SVOCs.
Will this be acceptable to regulatory agencies?	Yes
Is technology available?	Yes
Is process option accepted?	No. Not for the treatment of PCBs present (alone) at low concentrations at depths of 45- 78 feet bgs. Yes, for PCBs that are co-located with higher concentrations of SVOCs.

Table 4-13c - Implementability of *In Situ* Chemical Treatment for PCB-Impacted Smear Zone Soil

	Process Options for *In situ* Chemical Treatment
Attribute	**Oxidation**
Can it be constructed?	Yes, site is amenable to constructing and operating support equipment though access may be limited in some areas by infrastructure. Design, construction, and startup will take approximately 1 year.
Will it work?	Yes, however, limited data available showing field application. Has been used for the treatment of PCBs at Battery Tech Superfund Site at shallow soil depths. Along with PCBs, various VOCs were also treated. May work where PCBs are co-located with higher concentrations of other SVOCs.
Will this be acceptable to regulatory agencies?	Yes
Is technology available?	Yes
Is process option accepted?	No. Not for the treatment of PCBs present (alone) at low concentrations at depths of 45- 78 feet bgs. Yes, for PCBs that are co-located with higher concentrations of SVOCs.

Table 4-14a - Reliability of Selected Technologies for PCB-Impacted Smear Zone Soil

Technology	**Process Options**	**Is it reliable?**[1]
Monitoring	Protection, Performance, Confirmational	Yes
Access and Use Restrictions	Fencing, signs, deed restrictions	Yes
Best Management Practices	Spill prevention, leak detection, double-walled pipes, proper storage of chemicals and solvents	Yes
Capping	Low Permeable Asphalt Cap	Yes
Capping	Low Permeable Concrete Cap	Yes
Capping	Multilayer Cap (soil + synthetic liner)	Yes
Monitored Natural Attenuation	Monitored Natural Attenuation	Yes
Adsorption	Activated Carbon	Yes[2]
Thermal and Catalytic Oxidation	Catalytic Oxidizers	Yes[2]
Advanced Oxidation	Photocatalytic Destruction	No
Chlorine Removal	Chlorine Scrubbers	Yes[2,3]

Note:

1) The reliability evaluations provided in this table for PCBs in deep vadose zone soils are similar to the evaluations provided for VOCs in near-surface soils as presented in Tables 2-9a through 2-9d and 2-9f through 2-9h, except where noted. Refer to the evaluations in those tables.
2) If off-gas treatment is required by the *in situ* enhanced bioremediation and/or chemical treatment technologies.
3) The evaluations for reliability provided in this table for these technologies as a means to treat PCBs in smear zone soils are similar to the evaluations provided for technologies designed to treat PCBs in deep vadose zone soils presented in Table 3-13d. Refer to the evaluations in those tables.

Table 4-14b - Reliability of *In Situ* Bioremediation of PCB-Impacted Smear Zone Soil

	Process Options for *In situ* Bioremediation of PCB-Impacted Smear Zone Soils
Attribute	**Enhanced Bioremediation**
Has this process option been used at the scale required for Kaiser?	Yes. Site is amenable to constructing and operating support equipment necessary to use this process option at Kaiser.
Are operation and maintenance requirements infrequent and straightforward?	No. Continuous monitoring of the addition of ORC or other additives will be required. Migration of additives from treatment area must be controlled. Off-gas may need to be collected and treated.
Has this process option been proven effective under COC and site conditions similar to those at Kaiser?	Unknown. The PCB concentrations in smear zone soil at Kaiser are very low. Ensuring effective contact between the ORC or other additive and the PCB-contaminated soil will be very difficult. The additional substrate provided by the SVOCs that are co-located with the PCBs in the Oil House and Wastewater Treatment areas is likely to enhance the potential for bioremediation of the PCBs. Bench- and pilot-scale treatability tests of this technology on Kaiser smear zone soils will be required.
Is process option accepted?	No. Not for the treatment of PCBs present (alone) at low concentrations at depths of 45- 78 feet bgs. Yes, for PCBs that are co-located with higher concentrations of SVOCs.

Table 4-14c - Reliability of *In Situ* Chemical Treatment of PCB-Impacted Smear Zone Soil

Sheet 1 of 1

	Process Options for *In situ* Chemical Treatment of PCB-Impacted Smear Zone Soils
Attribute	**Oxidation**
Has this process option been used at the scale required for Kaiser?	Yes, this option has been used at sites of similar scale.
Are operation and maintenance requirements infrequent and straightforward?	No. System includes aboveground chemical storage, chemical injection wells, off-gas collection wells, and an off-gas treatment system.
Has this process option been proven effective under COC and site conditions similar to those at Kaiser?	Unknown. The PCB concentrations in smear zone soil at Kaiser are very low. Ensuring effective contact between the Fenton's reagent or other oxidant and the PCB-contaminated soil will be very difficult. The presence of SVOCs that are co-located with the PCBs in the Oil House and Wastewater Treatment areas is likely to enhance the potential for the oxidation of the PCBs. Off-gas may be generated and must be collected and potentially treated to meet regulatory requirements. Bench- and pilot-scale treatability tests of this technology on Kaiser smear zone soils will be required.
Is process option accepted?	No. Not for the treatment of PCBs present (alone) at low concentrations at depths of 45- 78 feet bgs. Yes, for PCBs that are co-located with higher concentrations of SVOCs.

Table 4-15 - Summary of Technology Screening Process: PCBs in Smear Zone Soils

			Screening Outcome		
General Response Action (a)	**Remedial Technology (a)**	**Process Options (a)**	**Physical/Chemical (b)**	**Implementability (c)**	**Reliability (d)**
Monitoring	**Monitoring**	**Protection, Performance, and Confirmational**	**Retained**	**Retained**	**Retained**
Institutional Controls	**Access and Use Restrictions**	**Fences, Signs, Deed Restrictions**	**Retained**	**Retained**	**Retained**
	Best Management Practices	**Spill prevention, leak detection, double-walled pipes**	**Retained**	**Retained**	**Retained**
Containment	**Capping**	Soil	Retained	Eliminated	--
		Clay	Retained	Eliminated	--
		Asphalt	**Retained**	**Retained**	**Retained**
		Concrete	**Retained**	**Retained**	**Retained**
		Synthetic	Retained	Eliminated	--
		Multi-layer (soil + synthetic)	**Retained**	**Retained**	**Retained**
	Landfill Cap Enhancements	Run-on and run-off controls, vegetative cover	Eliminated	--	--
	Solidification/ Stabilization	Cement- and lime-based processes, microencapsulation, sorption	Retained	Retained	Eliminated
***In Situ* Soils Treatment**	Vitrification	Combined with soil vapor extraction	Eliminated	--	--
	In Situ Bioremediation	Bioventing	Retained	Eliminated	--
		Enhanced Bioremediation	Retained	Eliminated (f)	--
		Phytoremediation	Retained	Eliminated	--
	Monitored Natural Attenuation	**Monitor natural processes**	**Retained**	**Retained**	**Retained**
	Soil Vapor Extraction (SVE)	Horizontal vents	Eliminated	--	--
		Vertical Vents	Eliminated	--	--
	Steam Injection	Combined with soil vapor extraction	Eliminated	--	--
	Six Phase Soil Heating	Combined with soil vapor extraction	Eliminated	--	--
	Soil Flushing	Water, surfactants, solvents	Eliminated	--	--

Table 4-15 - Summary of Technology Screening Process: PCBs in Smear Zone Soils

			Screening Outcome		
General Response Action (a)	**Remedial Technology (a)**	**Process Options (a)**	**Physical/Chemical (b)**	**Implementability (c)**	**Reliability (d)**
***In Situ* Soils Treatment - cont'd**	Pneumatic Fracturing	Pressurized air or steam	Eliminated	--	--
	Chemical Treatment	Oxidation, reduction, pH adjustment	Retained	Eliminated (f)	--
	Electro-Kinetic	Enhanced with surfactants and reagents	Eliminated	--	--
On-Site Treatment of Extracted Soil Vapor (e)	**Adsorption**	**Granular activated carbon**	**Retained**	**Retained**	**Retained**
	Thermal and Catalytic Oxidation	Direct flame Thermal	Retained	Eliminated	--
		Flameless Thermal	Retained	Eliminated	--
		Catalytic Oxidizers	**Retained**	**Retained**	**Retained**
		Hybrid Thermal/Catalytic	Retained	Eliminated	--
	Advanced Oxidation	UV light	Retained	Eliminated	--
		Photocatalytic	Retained	Retained	Eliminated
	Biofiltration	Bioreactor, soil pile	Retained	Eliminated	--
	Chlorine Scrubber	**Chlorine Scrubbers**	**Retained**	**Retained**	**Retained**

Notes:

Bolded Technologies Retained for further evaluation in the FS.

(a) Taken from FSTM Table 3-2

(b) Taken from FSTM Table 4-5

(c) Taken from FSTM Table 4-13a - 4-13c

(d) Taken from FSTM Table 4-14a - 4-14c

(e) If needed to treat off-gas from in situ treatment processes

(f) Potential treatment technology for AOCs where PCBs are co-located with higher concentrations of other SVOCs

Table 4-16a - Implementability of Hot Air Injection for Enhanced SVOC Removal in Smear Zone Soil

Sheet 1 of 1

	Process Options for Hot Air Injection
Attribute	**Injection Wells, Extraction Wells, Off-Gas Treatment**
Can it be constructed?	Yes, site is amenable to constructing and operating support equipment though access may be limited in some areas by infrastructure. Design, construction, and startup will take approximately 1 year.
Will it work?	Yes, however, technology has shown limited effectiveness in the field due to the low heat capacity of air (EPA 1997a).
Will this be acceptable to regulatory agencies?	Yes
Is technology available?	Yes
Is process option accepted?	Yes

Table 4-16b - Implementability of Mechanical Skimmers for Free Phase Product Removal in Smear Zone Soil

Sheet 1 of 1

	Process Options for Mechanical Skimmers		
Attribute	**Floating Skimmer**	**Pneumatic Pumps**	**Skimming Belt**
Can it be constructed?	Most source areas suitable for constructing the vertical wells and equipment required. Design and construction will take < 1 year.	Most source areas suitable for constructing the vertical wells and equipment required. Design and construction will take < 1 year.	Most source areas suitable for constructing the vertical wells and equipment required. Design and construction will take < 1 year.
Will it work?	Yes. No water produced; skims thin layers; moves with fluctuating groundwater tables. Limited radius of influence; clogging of screen; limited to shallow (less than 30 ft.) applications	Yes. Can be adjusted so very little water is collected. Skims very thin product layers. Limited radius of influence; requires manual adjustments; clogging of screens and intake valves.	Yes. Skimming belt will need to be selected based on free phase product properties. At least 4-inch diameter well will be needed. Skims very thin product layer. Limited capacity, low recovery rates. Technology currently being used on site as part of the IRM that is underway.
Will this be acceptable to regulatory agencies?	Yes.	Yes.	Yes.
Is technology available?	Yes.	Yes.	Yes.
Is process option accepted?	Yes.	Yes.	Yes.

Table 4-16c - Implementability of Passive Skimmers for Free Phase Product Removal in Smear Zone Soil

	Process Options for Passive Skimmers	
Attribute	**Filter Canisters**	**Absorbent Bailer**
Can it be constructed?	Most source areas are suitable for constructing the vertical wells and equipment required. Design and construction will take < 1 year.	Most source areas suitable for constructing the vertical wells and equipment required. Design and construction will take < 1 year.
Will it work?	Yes. Low product recovery. Well required to have 2-inch diameter.	Yes. Low product recovery. Well required to have 2-inch diameter.
Will this be acceptable to regulatory agencies?	Yes.	Yes.
Is technology available?	Yes.	Yes.
Is process option accepted?	Yes.	Yes.

Table 4-17a – Reliability of Hot Air Injection for Enhanced SVOC Removal in Smear Zone Soil

	Process Options for Hot Air Injection
Attribute	**Injection Wells, Extraction Wells, Off-Gas Treatment**
Has this process option been used at the scale required for Kaiser?	No. Technology has been found to enhance product recovery in laboratory studies, however, limited effectiveness in the field due to the low heat capacity of air (EPA 1997a).
Are operation and maintenance requirements infrequent and straightforward?	Yes. This technology is composed of conventional technologies (heat exchangers, blowers, injection and extraction wells, and off-gas treatment system). Skilled labor and materials are readily available.
Has this process option been proven effective under COC and site conditions similar to those at Kaiser?	Yes, however, due to the low heating capacity of air this is only effective for contaminants that can be volatilized. At Kaiser, the majority of free phase product at the site is associated with diesel range hydrocarbons that are readily volatilized.
Is process option accepted?	No. Technology has limited success in the field and may not be able to treat a significant portion of free phase product contamination at Kaiser.

Table 4-17b – Reliability of Mechanical Skimmers for Free Phase Product Removal in Smear Zone Soil

	Process Options for Mechanical Skimmers		
Attribute	**Floating Skimmer**	**Pneumatic Pumps**	**Skimming Belt**
Has this process option been used at the scale required for Kaiser?	Yes. High to moderate product recovery rates. Limited radius of influence.	Yes. Moderate to low product recovery rates. Limited radius of influence.	Yes. Low product recovery rates. Currently in use at Kaiser per IRM.
Are operation and maintenance requirements infrequent and straightforward?	Yes. Screens can become clogged.	Yes. Requires manual adjustments; clogging of screens and intake valves. Pumps are durable.	Yes. Periodically skimmer tank will need to be emptied.
Has this process option been proven effective under COC and site conditions similar to those at Kaiser?	No. Applicable for shallow conditions (30 feet).	Yes.	Yes. Currently in use at Kaiser as part of the IRM that is underway.
Is process option accepted?	No. Skimming belt is preferred since it has been an effective means of free product recovery at the site.	No. Skimming belt is preferred since it has been an effective means of free product recovery at the site.	Yes.

Table 4-17c - Reliability of Passive Skimmers for Free Phase Product Removal in Smear Zone Soil

	Process Options for Passive Skimmers	
Attribute	**Filter Canister**	**Absorbent Bailer**
Has this process option been used at the scale required for Kaiser?	Yes. Low product recovery rates.	Yes. Low product recovery rates.
Are operation and maintenance requirements infrequent and straightforward?	Yes. The product can be removed automatically by a suction pump or manually by pulling up and emptying the canister.	Yes. Requires manual replacement and disposal after saturation.
Has this process option been proven effective under COC and site conditions similar to those at Kaiser?	Yes.	Yes.
Is process option accepted?	No. Skimmer belt is a preferred technology; it has been an effective means of free phase product recovery at the Facility.	No. Skimmer belt is a preferred technology; it has been an effective means of free phase product recovery at the Facility.

Table 4-18 - Summary of Technology Screening Process: Free Phase Product Removal in Smear Zone Soil

			Screening Outcome		
General Response Action (a)	**Remedial Technology (a)**	**Process Options (a)**	**Physical/Chemical (b)**	**Implementability (c)**	**Reliability (d)**
Enhanced SVOC Removal	Steam or hot water injection	Combined with soil vapor extraction and/or liquid (product) recovery.	Eliminated	--	--
	Hot air injection	Combined with soil vapor extraction and/or liquid (product) recovery. Injection Wells, Extraction Wells, Off-Gas Treatment	Retained	Retained	Eliminated
	Electrical Resistance Heating	Combined with soil vapor extraction and/or liquid (product) recovery.	Eliminated	--	--
	Radio Frequency Heating	Combined with soil vapor extraction and/or liquid (product) recovery.	Eliminated	--	--
	Soil Flushing	Surfactants, cosolvents	Eliminated	--	--
Free Phase Product Removal	**Mechanical Skimmers**	Floating Skimmer	Retained	Retained	Eliminated
		Pneumatic Pumps	Retained	Retained	Eliminated
		Belt Skimmers	**Retained**	**Retained**	**Retained**
	Passive Skimmers	Filter Canister	Retained	Retained	Eliminated
		Absorbent Bailer	Retained	Retained	Eliminated

Notes:

Bolded Technologies Retained for further evaluation in the FS.

(a) Taken from FSTM Table 4-2

(b) Taken from FSTM Table 4-6

(c) Taken from FSTM Table 4-16a - 4-16c

(d) Taken from FSTM Table 4-17a - 4-17c

Table 4-19 - Location, Concentration of COCs in Smear Zone Soil in the AOCs at the Kaiser Facility

General Location	Process Unit	COC(s)	Sample Number(s)	Depth (feet)[a]	Calculated Concentration (mg/kg)[b]	2012 RI Reference Figures and Tables	Comments
ORB Area	**Oil Reclaimation Building**	Heavy Oil/TPH 418.1	OR-SB-31 S-7 (80 to 81.5 feet), B-25/S-13 (67.5 to 69 feet), HL-MW-2/S-1 (74-76 feet) (TPH 418.1), HL-MW-2/S-2 (79-81 feet)(TPH 418.1), HL-MW-20S/S1 (75 to 75.8 feet), OR-SB-31/S-6 (70 to 70.4 feet)	68-80	3,938	Section 2.7, Table 2-1, 2-23a, 2-23b, Figure 2-10 to 2-14 & Hart Crowser Soil Database	AOC for TPH 418.1 incorporated into heavy oil AOC on Figure 4-1. Assumed that the heavy oil/TPH smear zone extends from the water table transition at 68 feet BGS and extends to 78 feet BGS (assumed bottom of smear zone).
		Diesel	B-25/S-13 (67.5 to 69 feet)	68-80	4,900	Table 2-1, Figure 2-3 to 5	S-13 was deepest sample from B-25. Area borings did not have detections of diesel above CULs. Terminated the lower extent of diesel impacts at 69 feet. Assumed 68-78 foot smear zone was impacted at this concentration.
		cPAH	OR-SB-31 S-7 (80 to 81.5 feet)	68-80	0.03	Section 2.7, Table 2-23b, Figure 2-10 to 2-14	S-7 was the deepest sample collected in OR-SB-31. S-6, collected at 70 feet BGS did not test for PAHs. Conservatively assumed that impact depth extends from 68 to 78 feet BGS.
Cold Mill Finishing Areas	**Cold Mill**	Diesel	CM-MW-2S-S1 (75-77 feet), CM-MW-3S-S1 (75-77 feet), CM-MW-7S-S3 (70-73 feet)	68-78	5,467	Hart Crowser Soil Database	Impacted at 70 feet BGS in CM-MW-7S-S3, below CUL at 85 feet CUL in CM-MW-2S-S2 and CM-MW-3S-S2. Considered impact zone from water table interface at 68 feet to 78 feet BGS.
		Heavy Oil	CM-MW-2S-S1 (75-77 feet), CM-MW-3S-S1 (75-77 feet)	68-78	2,800	Hart Crowser Soil Database	Below CUL at 70 feet BGS for CM-MW-7S-S3, below CUL at 85 feet BGS for CM-MW-2S-S2. Went half the distance from 75-77 foot impacted sample zone to consider impacted depth interval between 72.5 to 78 feet BGS (assumed bottom of smear zone). Heavy Oil based on residual range organics (RRO).
		PCBs	CM-MW-2S-S1 (75-77 feet)	68-78	0.02	Hart Crowser Soil Database	No "total PCBs" in database - adding listings for Aroclor 1248 and 1254. The 75-77 sample interval was the shallowest sample collected in CM-MW-2S. Sample CM-MW-2S-S-3 collected at 85-87 feet BGS was below CUL. Considered impact zone from 68 to 78 feet BGS.
Oil House Area	**Oil House**	Kensol/TPH (418.1)	OH-MW-1/S-7 (68-70 feet), OH-MW-3/S-2 (68-70 feet), OH-MW-4/S-4 (68-70 feet), OH-MW-5/S-8 (68.5-70.5 feet), OH-MW-7/S-3 (74-76 feet), OH-MW-9/S-2 (74-76 feet), OH-MW-10/S-3 (74-76 feet), OH-MW-13/S-2 (74-76 feet), OH-MW-14/S-1 (74-76 feet), OH-EW-1/S-3 (75 feet), GUST-SB2-S4 (74-75 feet), OH-MW-19/S-3 (74-76 feet), OH-MW-19/S-4 (79-81 feet), OH-MW-20/S-2 (69-71 feet), OH-MW-20/S-3 (74-76 feet), OH-MW-22/S-2 (68-70 feet), OH-MW-22/S-3 (73-75 feet), SA-1/S-13 (70 feet), SA-1/S-14 (75 feet), SA-1/S-15 (80 feet), SA-3/S-13 (70 feet), SA-3/S-14 (75 feet), SA-3/S-15 (80 feet), SA-4/S-13 (70 feet), SA-4/S-14 (75 feet), SA-4/S-15 (80 feet), SA-5/S-13 (70 feet), SA-5/S-14 (75 feet), SA-5/S-15 (80 feet), SA-6/S-13 (70 feet), SA-6/S-14 (75 feet), SA-6/S-15 (80 feet), SA-7/S-14 (70 feet), SA-7/S-15 (75 feet), SA-7/S-16 (80 feet), OH-MW-23/S-2 (68-70 feet), OH-MW-23/S-3 (73-75 feet), OH-MW-23/S-4 (78-80 feet), OH-MW-24/S-13 (68-70 feet), OH-MW-24/S-14 (73-75 feet), OH-MW-24/S-15 (78-80 feet), OH-MW-25/S-15 (73-75 feet), OH-MW-25/S-16 (78-80 feet), GUST-SB-1-S-4 (77 to 80 feet), OH-EW-1/S-4 (80 feet), OH-MW-20/S-4 (79 to 81 feet), OH-MW-22/S-4 (78 to 80 feet), OH-EW-1/S-2 (70 feet), OH-SB-1-S7 (68 to 69 feet), OH-MW-25/S-14 (68 to 70 feet), OH-MW-19/S-2 (69 to 71 feet), OH-MW-13/S-3 (79 to 81 feet), OH-MW-10/S-4 (79 to 81 feet), OH-MW-2/S-7 (68 to 70 feet), OH-MW-6/S-5 (69 to 70.5 feet), OH-MW-9/S-3 (79 to 81 feet), OH-MW-7/S-2 (69.5 to 71.5 feet)	68-80	3,932	Hart Crowser Soil Database, Figure 5-2 to 7	AOC for TPH 418.1 and Kensol data combined. Considered impact zone extends from 68 to 78 feet BGS.
		Stoddard (East)	GUST-SB2-S4 (74-75 feet)	68-80	7,100		
		Stoddard (West)	OH-EW-1/S-3 (75 feet), OH-MW-19/S-3 (74-76 feet), OH-MW-19/S-4 (79-81 feet), OH-MW-20/S-2 (69-71 feet), OH-MW-20/S-3 (74-76 feet), SA-1/S-13 (70 feet), SA-1/S-14 (75 feet), SA-1/S-15 (80 feet), SA-3/S-13 (70 feet), SA-3/S-14 (75 feet), SA-3/S-15 (80 feet), SA-4/S-13 (70 feet), SA-4/S-14 (75 feet), SA4/S-15 (80 feet), SA-5/S-13 (70 feet), SA-5/S-14 (75 feet), SA-5/S-15 (80 feet), SA-6/S-13 (70 feet), SA-6/S-14 (75 feet), SA-6/S-15 (80 feet), SA-7/S-14 (70 feet), SA-7/S-15 (75 feet), SA-7/S-16 (80 feet), OH-MW-24/S-13 (68-70 feet), OH-MW-24/S-14 (73-75 feet), OH-MW-24/S-15 (78-80 feet), OH-MW-25/S-15 (73-75 feet), OH-MW-25/S-16 (78-80 feet), OH-EW-1/S-2 (70 feet), OH-EW-1/S-4 (80 feet), OH-MW-19/S-2 (69 to 71 feet), OH-MW-20/S-4 (79 to 81 feet), OH-MW-25/S-14 (68 to 70 feet)	68-80	1,082	Table 5-7,5-12, Figure 5-2 to 7	Considered impact zone to extend from 68 to 78 feet BGS.
		PCBs	OH-MW-16/S-3 (74-75.5 feet), OH-MW-19/S-3 (74-76 feet), OH-MW-19/S-4 (79-81 feet), OH-MW-20/S-3 (74-76 feet), OH-MW-20/S-4 (79-81 feet), OH-MW-24/S-14 (73-75 feet), OH-MW-24/S-15 (78-80 feet), SA-6/S-13 (70 feet), SA-6/S-14 (75 feet), SA-6/S-15 (80 feet), SA-7/S-14 (70 feet), SA-7/S-15 (75 feet), SA-7/S-16 (80 feet), OH-MW-16/S-4 (79 to 79.5 feet), OH-MW-17/S-3 (74 to 76 feet), OH-MW-17/S-4 (79 to 81 feet), OH-MW-24S/S-13 (68 to 70 feet)	68-80	0.39	Table 5-12, Figure 5-2 to 7	Considered impact zone to extend from 68 to 78 feet BGS.
		Arsenic	OH-MW-2/S-7 (68-70 feet)	68-78	11	Hart Crowser Soil Database	Assumed that the arsenic smear zone extends from the water table transition at 68 feet BGS and extends to 78 feet BGS (assumed bottom of smear zone). For lateral extent assumed 30 feet radius circle around OH-MW-02 due to lack of data in the area.
		Arsenic	OH-MW-4/S-4 (68-70 feet)	68-78	11	Hart Crowser Soil Database	Assumed that the arsenic smear zone extends from the water table transition at 68 feet BGS and extends to 78 feet BGS (assumed bottom of smear zone). For lateral extent assumed 30 feet radius circle around OH-MW-04 due to lack of data in the area.

Table 4-19 - Location, Concentration of COCs in Smear Zone Soil in the AOCs at the Kaiser Facility

General Location	Process Unit	COC(s)	Sample Number(s)	Depth (feet)[a]	Calculated Concentration (mg/kg)[b]	2012 RI Reference Figures and Tables	Comments
Wastewater Treatment Area		Kensol/Diesel/TPH (418.1)	WW-MW-5/S-6 (58.5-60.5 feet), WW-MW-6/S-6 (63-65 feet), WW-MW-9/S-2 (64-66 feet), WW-MW-12/S-8 (61.5-62.5 feet), WW-MW-13/S-4 (58-60 feet), HT-SB-1-S6 (59-60 feet) (Kensol), HT-SB-1-S6 (59-60 feet) (diesel), HT-SB-1-S7 (65 to 66 feet), WW-MW-12/S-6 (56.5 to 58 feet), WW-MW-12/S-7 (59 to 61 feet), WW-MW-13/S-5 (63 to 65 feet), WW-MW-9/S-1 (59 to 61 feet)	55-65	2,079	Sect 5.6, Table 5-12,6-1, Figure 5-6 5-7, 6-2 to 3. Table 6-9a, Figure 6-7	Combined TPH 418.1 data with Kensol and diesel data in this AOC. Considered impact zone to extend from 55 to 65 feet BGS.
Remelt/Casting Areas	**Remelt Area Wells/Borings**	PCBs	RM-MW-1S S-1 (75-80 feet), RM-MW-9S S-11 (75-76.2 feet), RM-F4-SB-1 S-11 (76-76.5 feet), RM-MW-10S S-4 (70.5-71 feet), RMSW-MW-11S-S10 (70 feet), RMSW-MW-11S-S10 (80 feet), RM-MW-14S/S-7 (70-71.5 feet), RM-MW-16S/S-7 (70-70.6 feet), RM-MW-17S/S-7 (70-71.5 feet), RM-MW-17S/S-8 (80-81.5 feet), RM-MW-2D S-1 (75 to 80 feet), RM-MW-3S S5 (75 to 75.9 feet), RM-MW-8S/S-11 (75 to 75.8 feet), RM-MW-12S-S11 (75 feet), RM-MW-13S-S11 (75 feet), RM-MW-14S/S8 (81 to 81.5 feet), RM-MW-15S/S7 (70 to 71.5 feet), RM-MW-15S/S8 (80 to 81.5 feet), RM-MW-16S/S-8 (80 to 81.5 feet)	68-80	0.11	Section 9.2, Tables 9-1, 9-5, Figure 9-1 to 3, 5-2	Assumed impact zone extends from 68 feet BGS to 78 feet BGS.
		Heavy oil	RM-MW-14S/S-7 (70-71.5 feet), RM-MW-14S/S-8 (80 to 81.5 feet)	68-80	4,050	Table 9-5,5-2, Figure 9-2	Considered impact zone to extend from 68 to 78 feet BGS.

Notes

[a] Seasonal high water tables were determined in Section 1 of the Final Soil RI (Hart Crowser 2012b) based on April 2007 groundwater monitoring data and are as follows: Mill Area - 68 feet BGS, Wastewater Area - 55 feet BGS; West Discharge Ravine area - 33 feet BGS.

[b] Concentration represents the average concentration of COCs if more than one sample is in each AOC. One half of the reporting limit was used in averaging calculations if non-detect samples were present in the AOC.

Table 4-20 - Free Phase Petroleum Measurements

Station	FPP Thickness in 2008	
	Product Thickness in Feet	Sample Date
Cold Mill Area		
CM-MW-01S	ND	10/18/2008
Oil Reclamation Building		
HL-MW-20S	ND	10/18/2008
HL-MW-21S	ND	10/18/2008
Oil House Area		
West Oil House FPP Area		
OH-MW-01	--	--
OH-MW-02	--	--
OH-MW-03	ND	10/18/2008
OH-MW-04	0.04	10/18/2008
OH-MW-05	ND	10/18/2008
OH-MW-06	0.06	10/18/2008
OH-MW-10	ND	10/18/2008
OH-MW-16	--	--
OH-MW-18	ND	10/18/2008
OH-MW-20	--	--
OH-MW-23	--	--
OH-MW-24	ND	10/18/2008
OH-MW-28	--	--
OH-SK-01	0.02	10/18/2008
OH-SK-02	0.01	7/22/2008
OH-SK-03	0.09	1/23/2008
OH-SK-04	0.01	1/23/2008
Average FPP Thickness[a]	**0.02**	
East Oil House FPP Area		
TF-MW-01	0.03	10/18/2008
TF-MW-02	0.01	1/23/2008
TF-MW-03	ND	10/18/2008
TF-MW-04	ND	10/18/2008
TF-MW-05	--	--
TF-EW-01	--	--
Average FPP Thickness[a]	**0.0125**	
Wastewater Treatment Area		
South WW Area		
TL-MW-04	ND	10/18/2008
WW-MW-03	0.10	1/23/2008
WW-SK-02	0.09	1/23/2008
Average FPP Thickness[a]	**0.07**	

Table 4-20 - Free Phase Petroleum Measurements

Station	FPP Thickness in 2008	
	Product Thickness in Feet	Sample Date
North WW Area		
WW-MW-04	--	--
WW-MW-06	0.10	7/22/2008
WW-MW-08	ND	10/18/2008
WW-MW-11	ND	10/18/2008
WW-MW-13	0.02	10/18/2008
WW-MW-15	ND	10/18/2008
WW-MW-19	ND	10/18/2008
WW-SK-01	ND	10/18/2008
WW-SK-03	0.06	10/18/2008
WW-SK-04	ND	10/18/2008
Average FPP Thickness[a]	**0.02**	

Notes:

FPP = Free phase petroleum product

ND = Not Detected.

-- = Well no longer exists, destroyed, or not measured in 2008.

[a] FPP thickness detection limit is 0.01 feet. For calculations, 1/2 the detection limit (0.005 feet) was used for ND samples in calculating average FPP thickness.

Table 4-21 - Distribution of COCs in the Smear Zone Soil in the General Operating Areas of the Kaiser Site

General Area	Rough Order of Magnitude Mass of COCs in pounds						Volume of Free Phase Petroleum Product in Gallons
	Stoddard Solvent	cPAHS	Diesel or Kensol[a]	Heavy Oil[a]	PCBs	Arsenic	FPP
ORB		0.10	112,000	290,000			
Cold Mill Area			630,000	160,000	1		
Oil House Area	183,000		1,800,000		20	60	600
Wastewater Treatment Area			500,000				5,000
Remelt/Hot Line Areas				14,000	40		
Total	183,000	0.10	3,042,000	464,000	61	60	5,600
Percentage of Total	4.96%	0.000003%	82.46%	12.58%	0.002%	0.002%	NA

Notes

a - These numbers may be calculated in part with total petroleum hydrocarbon data provided by analysis TPH 418. This analysis does not provide information on the composition of the hydrocarbon mixture. Based on the predominance of TPH compounds in an AOC, the Total TPH values were assigned to either diesel/Kensol or heavy oil data when calculating average concentrations for an AOC.

FPP = Free phase petroleum product

Table 4-22 - Remedial Alternative: COC Group Matrix - Smear Zone Soils

		Contaminants of Concern				
Alternative	Description	VOCs	FPP	SVOCs	PCBs	Metals
A1	Institutional Controls & Monitoring & MNA	X	X	X	X	X
A2	Institutional Controls & Monitoring & MNA & Capping	X	X	X	X	X
A3	Soil Vapor Extraction plus off-gas treatment & A2	X				
A4	Free Phase Product (FPP) Removal & A2		X	X	X	
A5a	*In situ* Bioremediation & A2			X		
A5b	*In situ* Chemical Oxidation & A2			X		
A6a	*In situ* Bioremediation & A2 (1)			X	X	
A6b	*In situ* Chemical Treatment & A2 (1)			X	X	

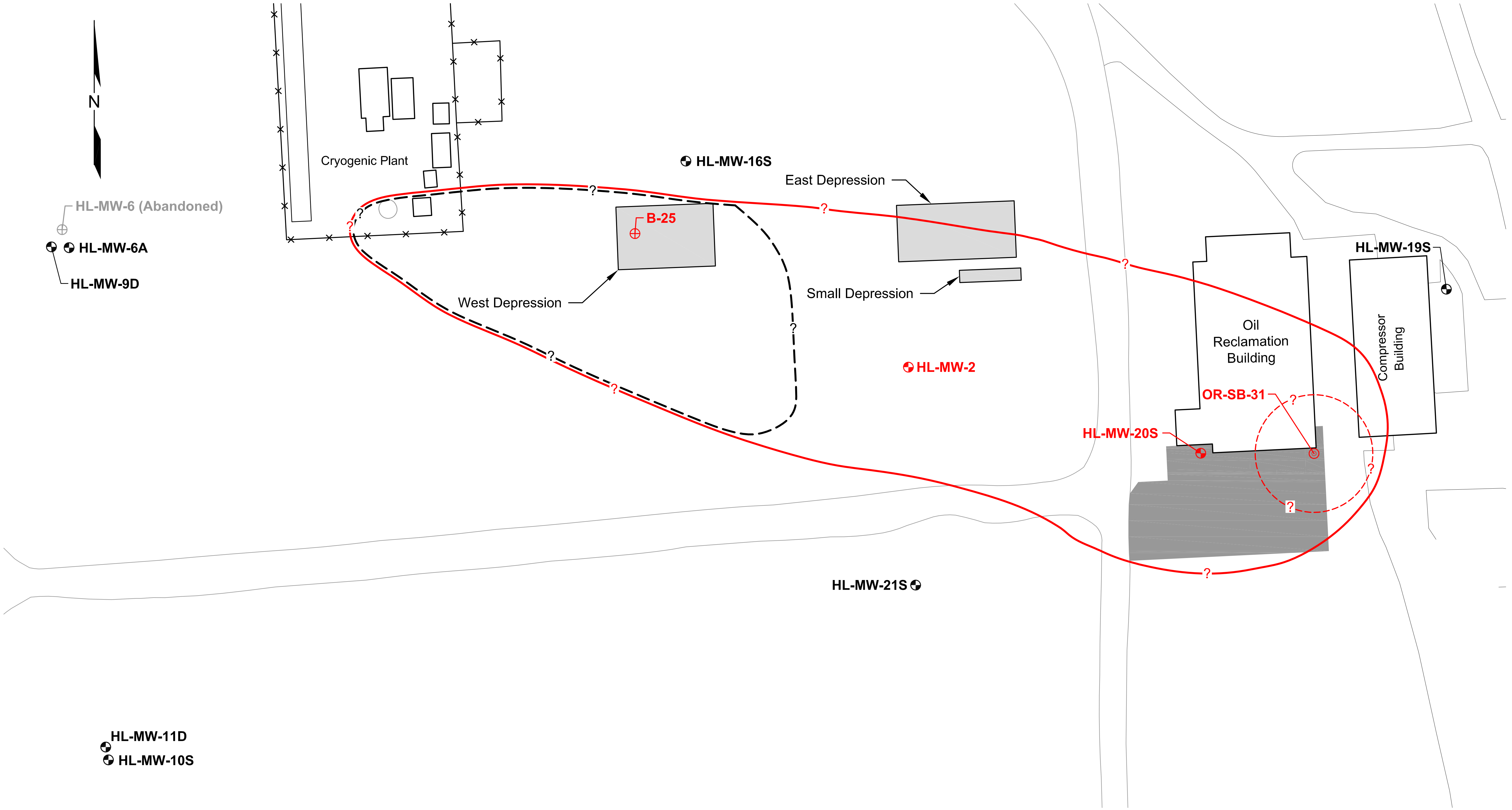
Notes:

(1) Only for locations where PCBs and SVOCs are co-mingled.

(2) Only for locations where FPP is not present.

Oil Reclamation Building/Man-Made Depressions

Smear Zone Soil Screening - Diesel, Heavy Oil, and cPAHs



Exploration Location and Number

B-25 ⊕	Samples with Screening Level Exceedance	—?—	Diesel Area of Screening Level Exceedance	▢	Estimated Location of Historical Man-Made Depression
HL-MW-6A ◒	Monitoring Well	—?—	Heavy Oil Area of Screening Level Exceedance	▨	Pavement
B-25 ⊕	Soil Boring (Hart Crowser 1996)	---?---	cPAH Area of Screening Level Exceedance		

0 50 100
Scale in Feet

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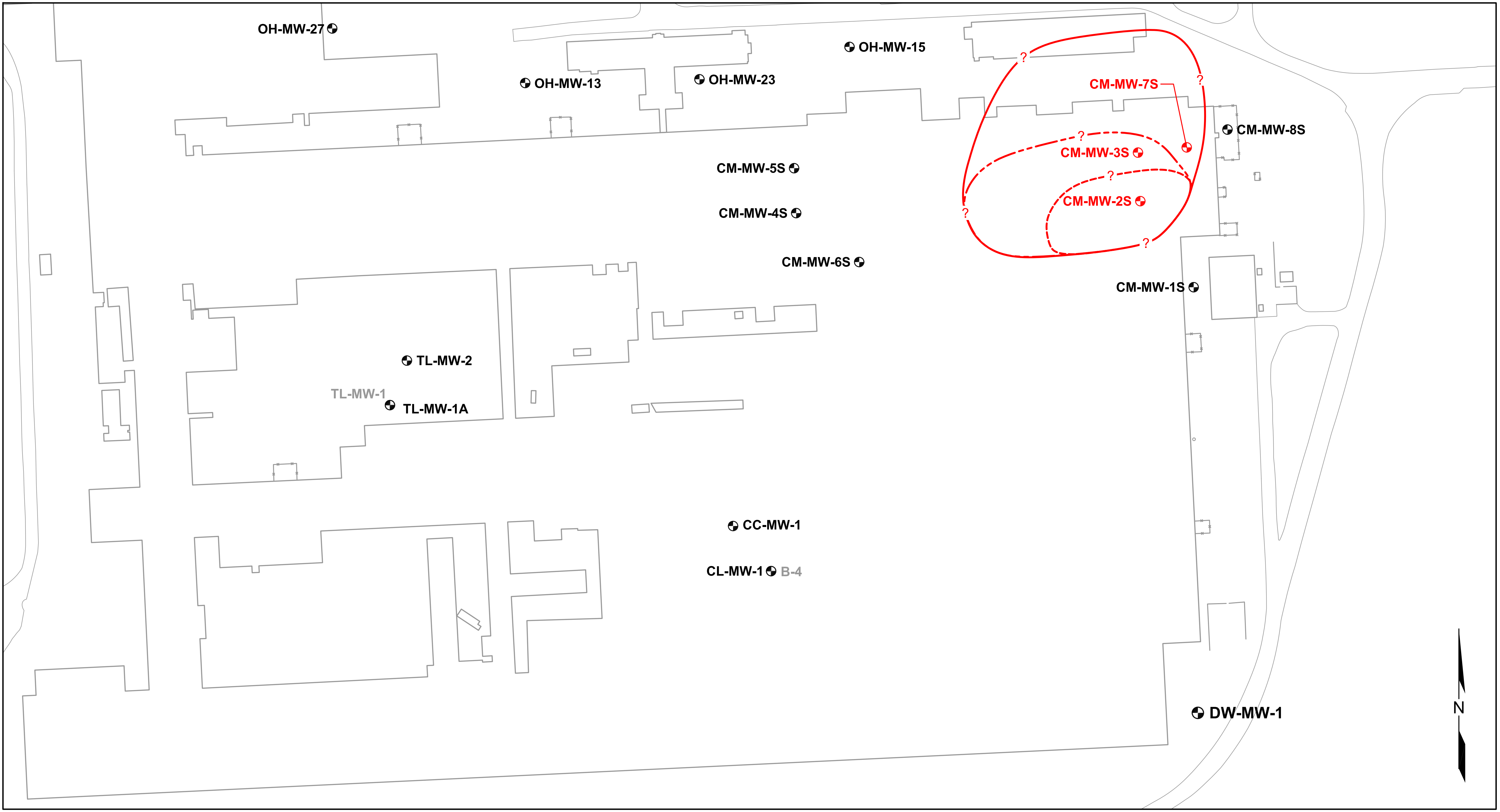
Figure 4-1

EAL 11/23/09 2644116-051.DWG

Cold Mill/Finishing Area

Smear Zone Soil Screening - Diesel, Heavy Oil, and PCBs



EAL 11/17/09 2644116-050.DWG

Exploration Location and Number

CM-MW-6S ⊕ Monitoring Well

TL-MW-1 ⊕ Abandoned Monitoring Well

? - - - - - - PCB Area of Screening Level Exceedance

? ——— Diesel Area of Screening Level Exceedance

? — - — Heavy Oil Area of Screening Level Exceedance

CM-MW-2S ⊕ Sample Location with Screening Level Exceedance

0 150 300

Scale in Feet

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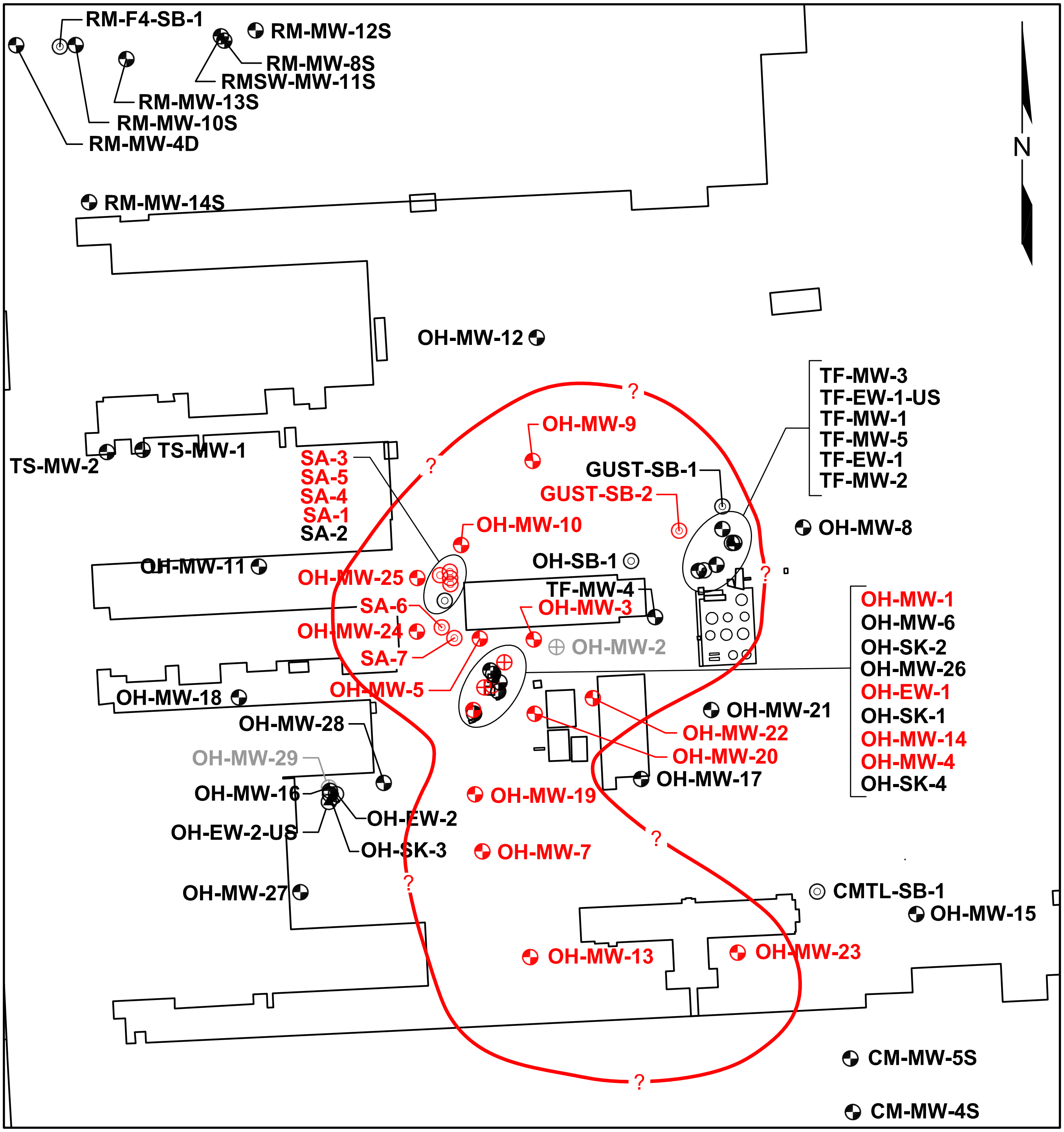
Figure 4-2

Oil House Area Index Map

Smear Zone Soil Screening - Kensol



EAL 11/17/09 2644116-046.DWG

Exploration Location and Number

SA-1 ◎	Samples with Screening Level Exceedance
OH-EW-1 ⊙	Extraction Well
OH-MW-4 ◕	Monitoring Well
OH-MW-29 ⊕	Abandoned Monitoring Well
OH-SK-1 ◑	Skimming Well
TF-EW-1-US ◭	Upper Screen Well
OH-SB-1 ◎	Soil Boring
—— ? ——	Kensol Area of Screening Level Exceedance

0 200 400

Scale in Feet

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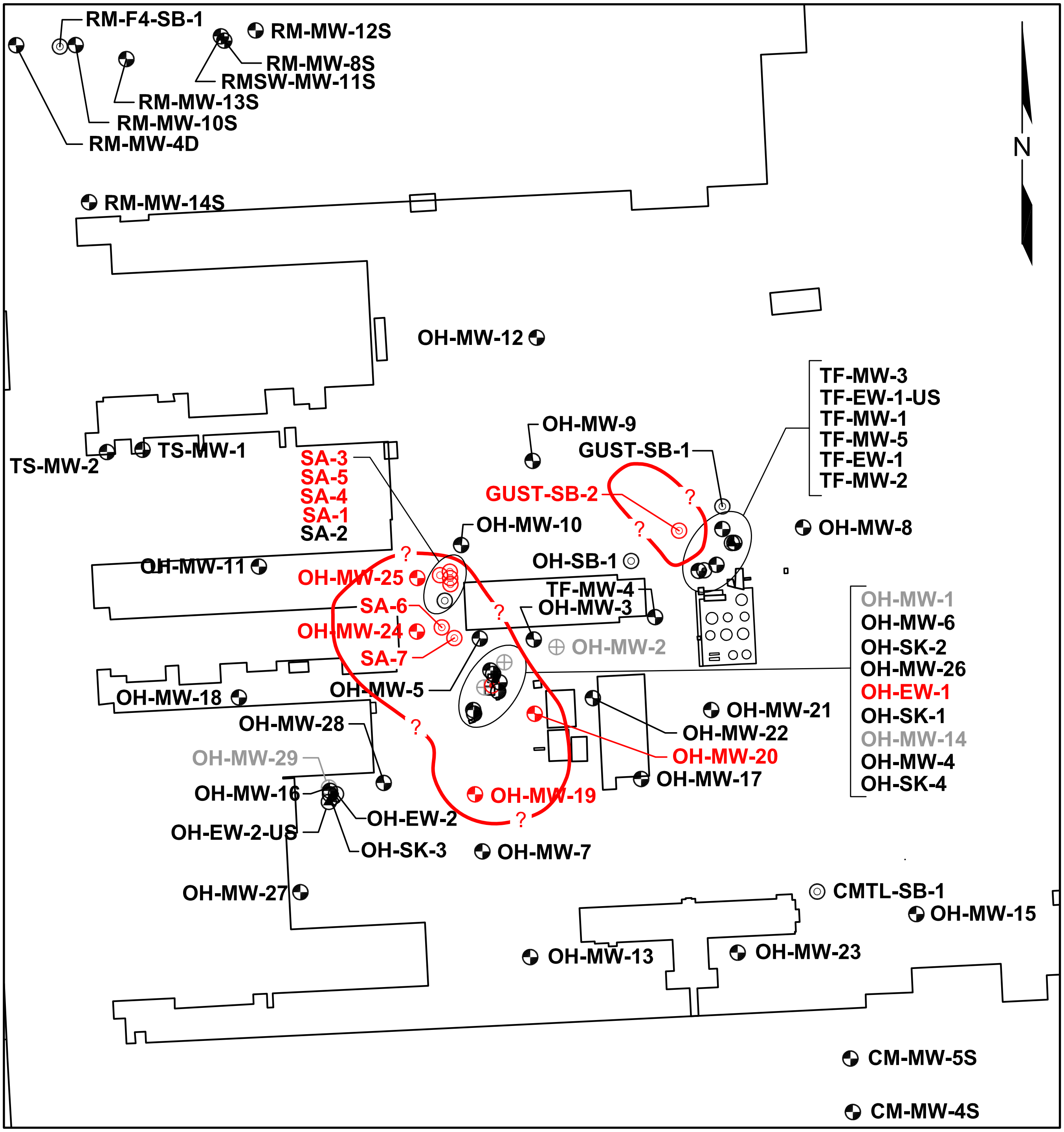
Figure 4-3a

Oil House Area Index Map

Smear Zone Soil Screening - Stoddard Solvent



EAL 11/17/09 2644116-058.DWG

Exploration Location and Number

SA-1	◎	Samples with Screening Level Exceedance
OH-EW-1	⊙	Extraction Well
OH-MW-4	◕	Monitoring Well
OH-MW-29	⊕	Abandoned Monitoring Well
OH-SK-1	◑	Skimming Well
TF-EW-1-US	◭	Upper Screen Well
OH-SB-1	◎	Soil Boring
— ? —		Stoddard Solvent Area of Screening Level Exceedance

0 200 400

Scale in Feet

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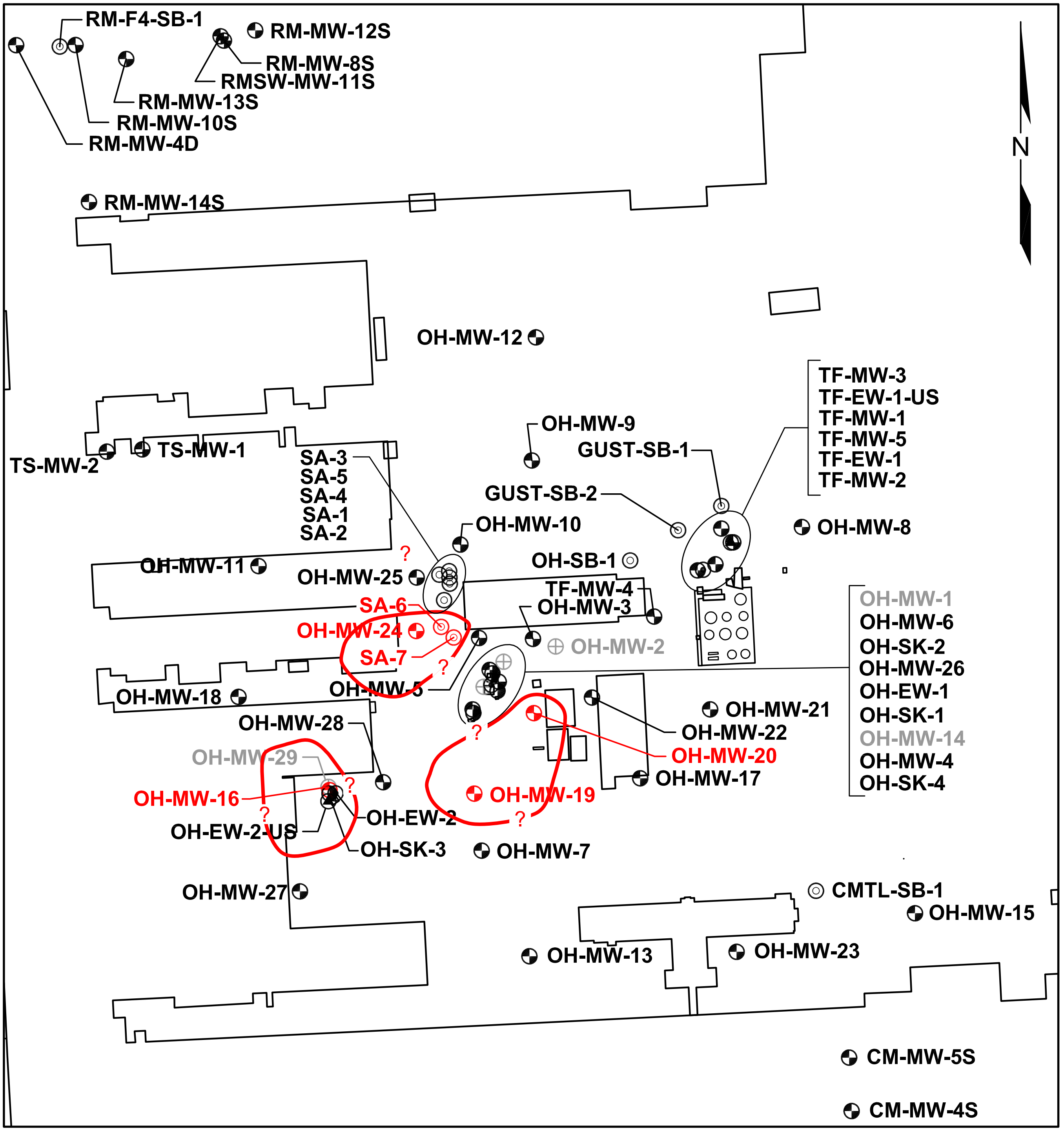
Figure 4-3b

Oil House Area Index Map

Smear Zone Soil Screening - PCBs



EAL 11/17/09 2644116-059.DWG

Exploration Location and Number

SA-1 ◎ Samples with Screening Level Exceedance

OH-EW-1 ⦿ Extraction Well

OH-MW-4 ◕ Monitoring Well

OH-MW-29 ⊕ Abandoned Monitoring Well

OH-SK-1 ◑ Skimming Well

TF-EW-1-US ◭ Upper Screen Well

OH-SB-1 ◎ Soil Boring

—— ? —— PCB Area of Screening Level Exceedance

0 200 400

Scale in Feet

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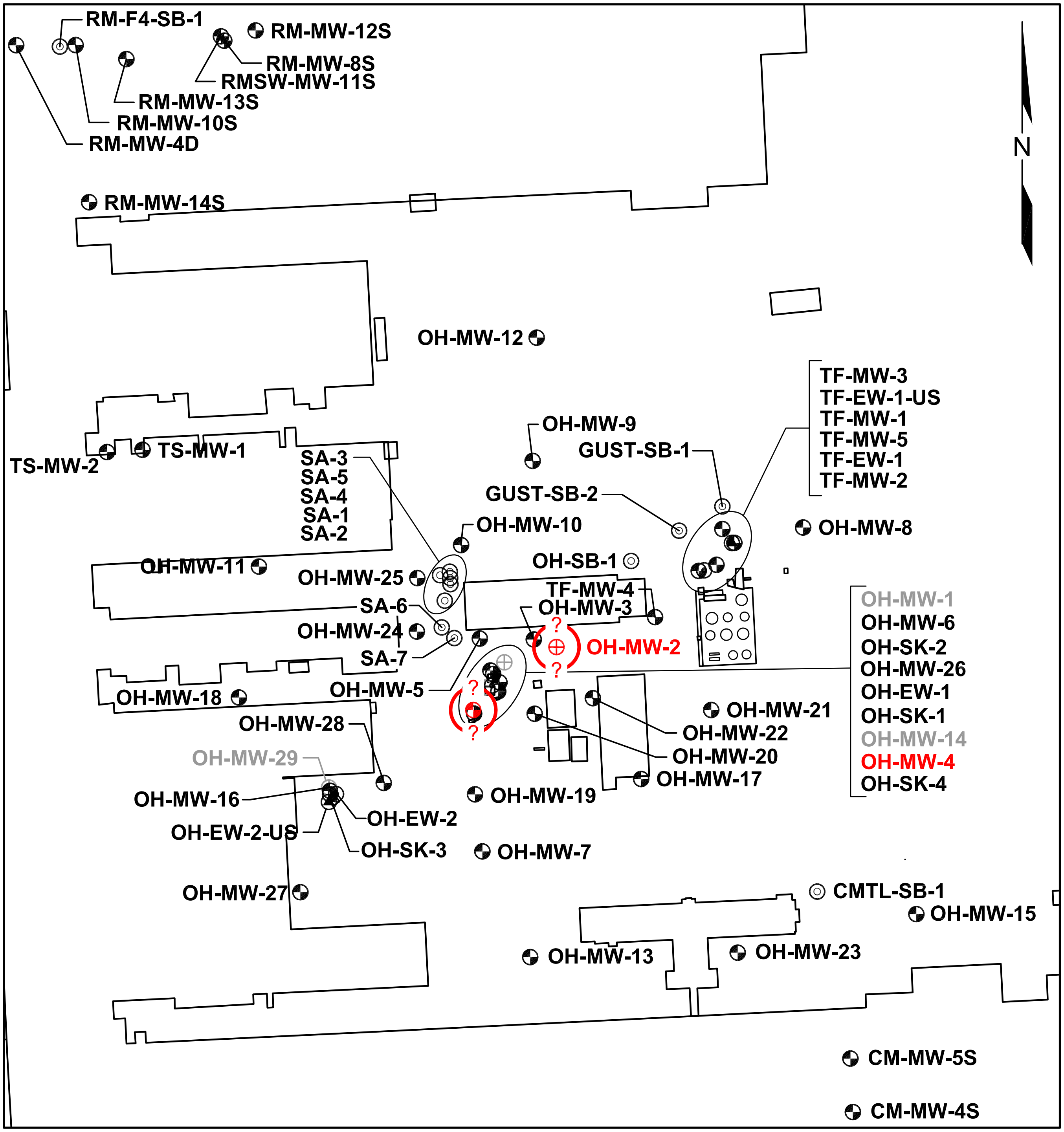
Figure 4-3c

Oil House Area Index Map

Smear Zone Soil Screening - Arsenic



EAL 11/17/09 2644116-073.DWG

Exploration Location and Number

SA-1	◎	Samples with Screening Level Exceedance
OH-EW-1	⊙	Extraction Well
OH-MW-4	◕	Monitoring Well
OH-MW-29	⊕	Abandoned Monitoring Well
OH-SK-1	◑	Skimming Well
TF-EW-1-US	◭	Upper Screen Well
OH-SB-1	◎	Soil Boring
—?—		Arsenic Area of Screening Level Exceedance

0 200 400

Scale in Feet

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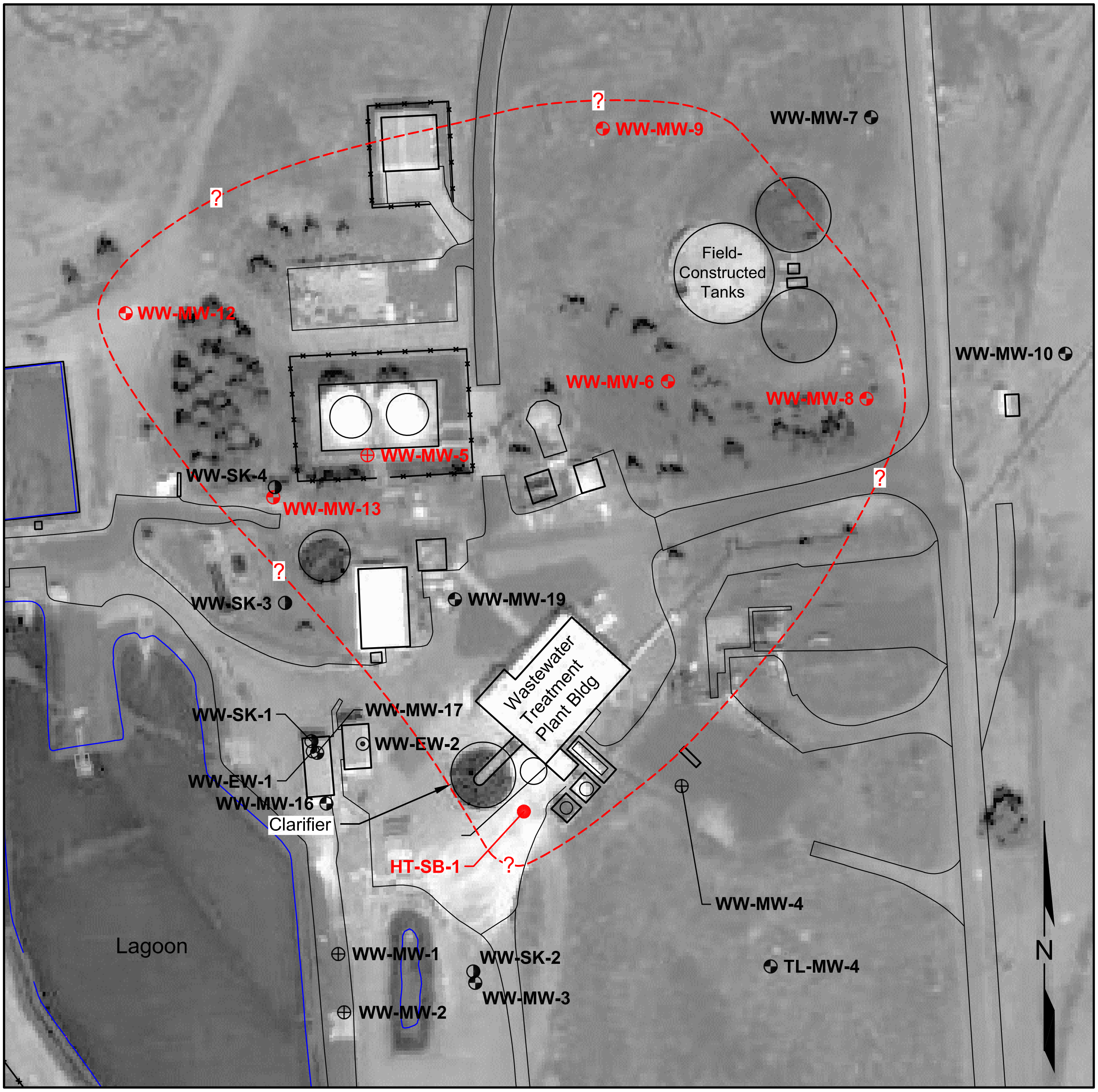
Figure 4-3d

Wastewater Treatment Area

Smear Zone Soil Screening - Kensol/Diesel



EAL 11/19/09 2644116-048.DWG

Source: Base map prepared from Kaiser base map (2008) and imagery from Google Maps, 2008.

Exploration Location and Number

HT-SB-1 ●	Soil Boring
WW-SK-2 ◑	Skimming Well
WW-EW-2 ⊙	Extraction Well
WW-MW-3 ◕	Existing Monitoring Well
WW-MW-2 ⊕	Abandoned Well
WW-MW-12 ◕	Samples with Screening Level Exceedance

? - - - - Kensol/Diesel Area of Screening Level Exceedance

0 120 240

Scale in Feet

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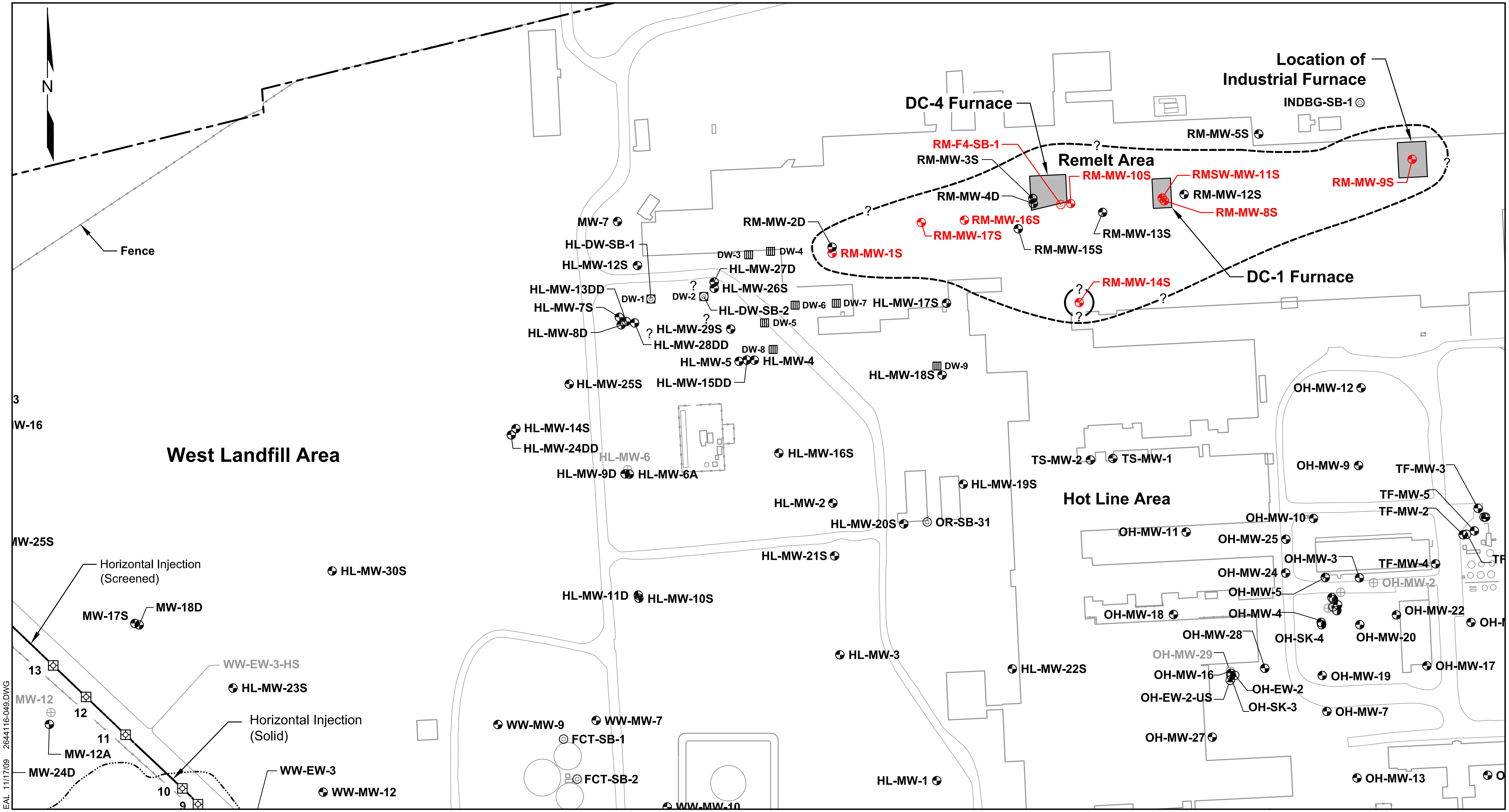
Figure 4-4

Remelt/Hot Line Area

Smear Zone Soil Screening - Heavy Oil and PCBs



Exploration Location and Number

OH-MW-4 ⊕ Monitoring Well

HL-MW-6 ⊕ Abandoned Monitoring Well

RM-F4-SB-1 ◎ Soil Boring

DW-1 ▥ Dry Well

- - - ? - - - PCB Area of Screening Level Exceedance

—— ? —— Heavy Oil Area of Screening Level Exceedance

RM-MW-9S ◎ Sample Location with Screening Level Exceedance

0 200 400

Scale in Feet

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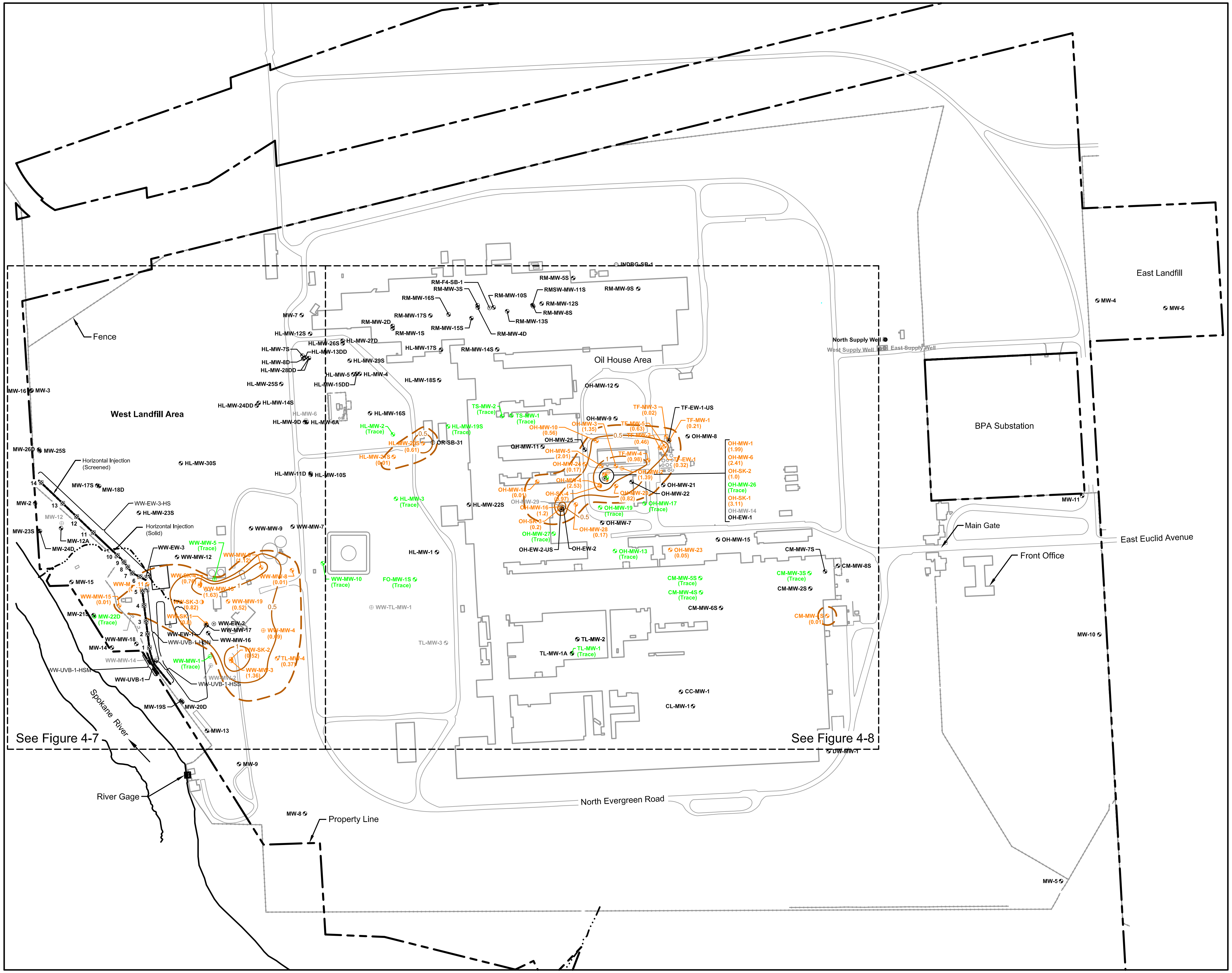
Figure 4-5

Maximum Historical Free Phase Petroleum Thickness Contour Map

1989 to 2008



	Exploration Location and Number
OH-EW-1 ◎	Extraction Well
OH-MW-03 ⊕	Monitoring Well
TL-MW-3 ⊕	Abandoned Monitoring Well
OH-SK-1 ◑	Skimming Well
TF-EW-1-US ⊕	Upper Screen Well
North Supply Well ●	Supply Well
West Supply Well ●	Backup Supply Well
(0.03)	Free Phase Petroleum Thickness in Feet
(Trace)	Free Phase Petroleum Sheen Present
0.5 ———	Maximum Historical Free Phase Petroleum Thickness Contour in Feet
— — —	Inferred Historical Extent of Free Phase Petroleum

N

0 500 1000

Scale in Feet

EAL 09/10/09 2644116-052.DWG

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Figure 4-6

Maximum Historical Free Phase Petroleum Thickness Contour Map

West Area

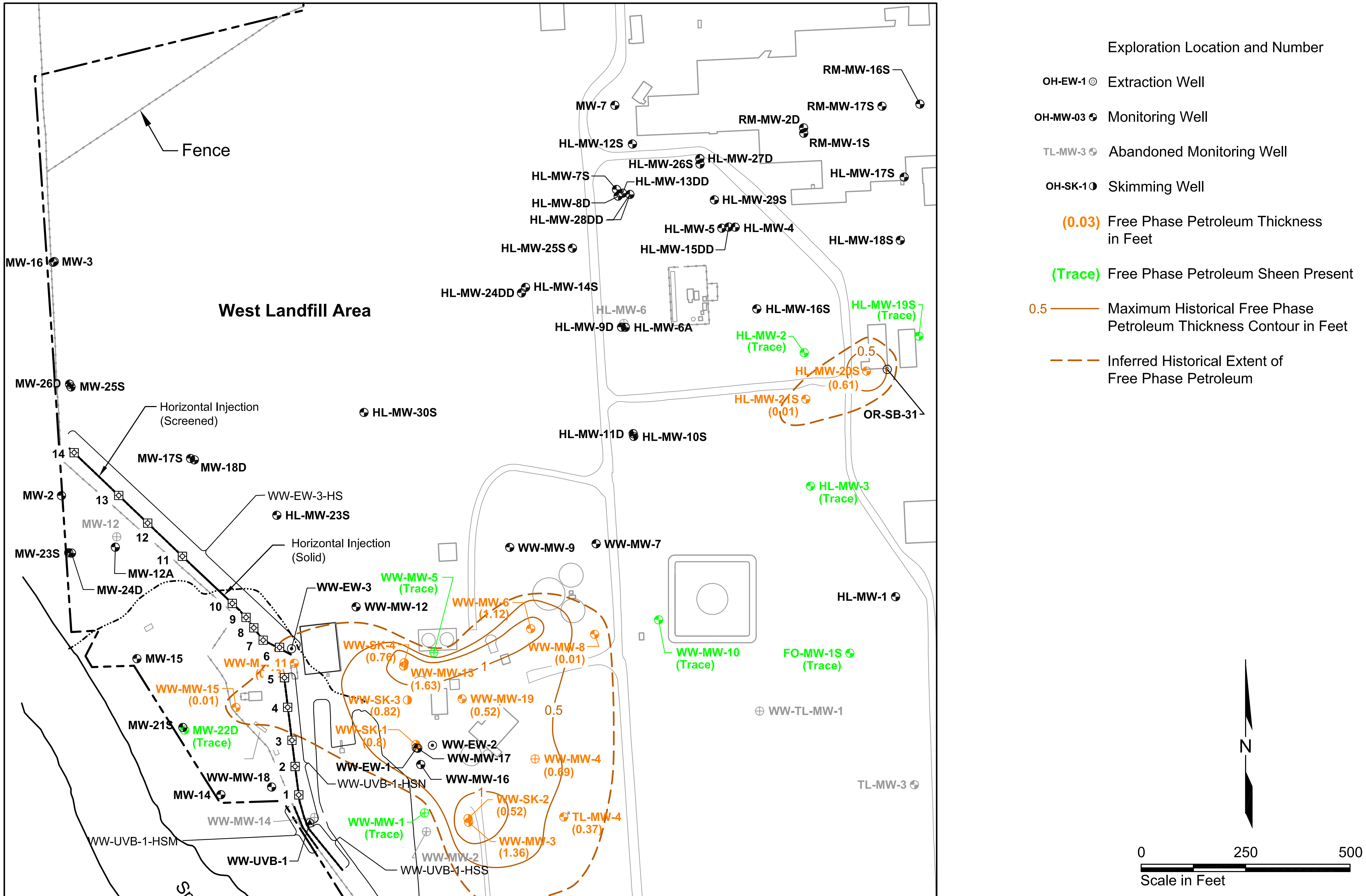

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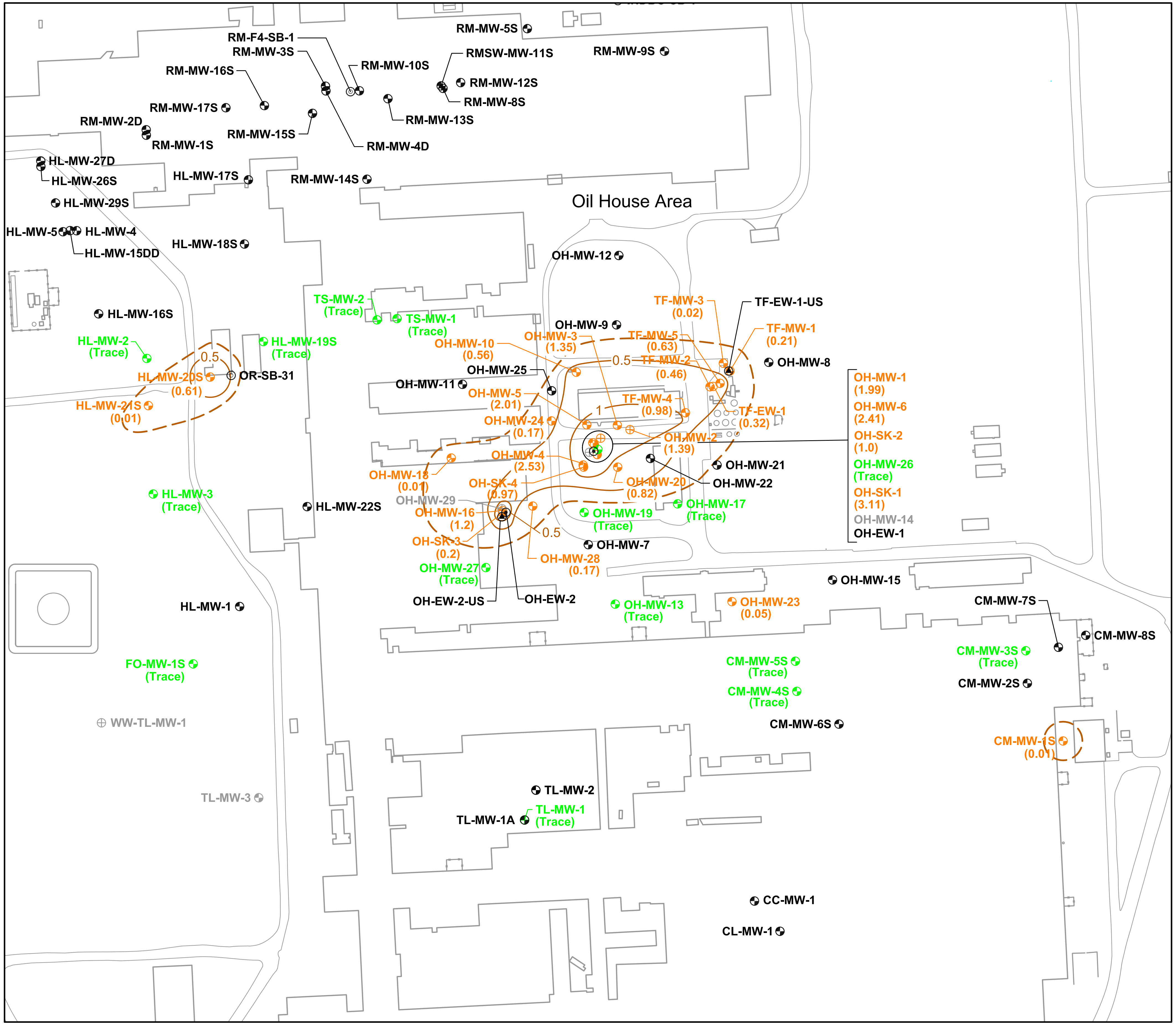
Figure 4-7

EAL 09/10/09 2644116-053.DWG

Maximum Historical Free Phase Petroleum Thickness Contour Map

East Area



Exploration Location and Number

OH-EW-1 ◎	Extraction Well
OH-MW-03 ●	Monitoring Well
TL-MW-3 ●	Abandoned Monitoring Well
OH-SK-1 ◑	Skimming Well
TF-EW-1-US ▲	Upper Screen Well
(0.03)	Free Phase Petroleum Thickness in Feet
(Trace)	Free Phase Petroleum Sheen Present
0.5 ———	Maximum Historical Free Phase Petroleum Thickness Contour in Feet
— — —	Inferred Historical Extent of Free Phase Petroleum

N

0 250 500

Scale in Feet

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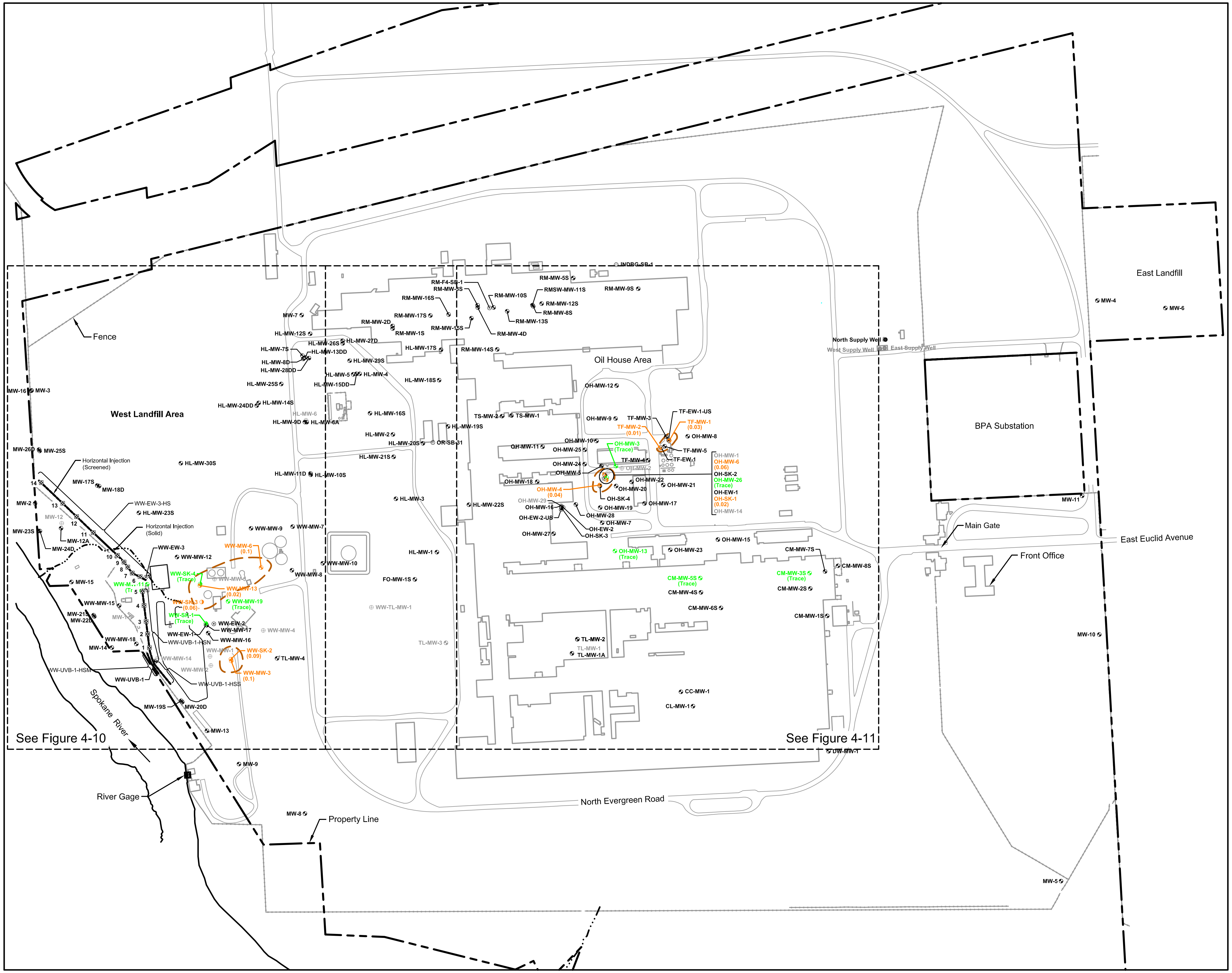
Figure 4-8

EAL 09/10/09 2644116-054.DWG

Free Phase Petroleum Thickness Map

Measured 2008



	Exploration Location and Number
OH-EW-1 ◎	Extraction Well
OH-MW-03	Monitoring Well
TL-MW-3	Abandoned Monitoring Well
OH-SK-1 ◑	Skimming Well
TF-EW-1-US	Upper Screen Well
North Supply Well ●	Supply Well
West Supply Well ●	Backup Supply Well
(0.03)	Free Phase Petroleum Thickness in Feet
(Trace)	Free Phase Petroleum Sheen Present
— — —	Inferred Historical Extent of Free Phase Petroleum

N

0 500 1000

Scale in Feet

EAL 09/10/09 2644116-055.DWG

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Figure 4-9

Free Phase Petroleum Thickness Map

Measured 2008 - West Area

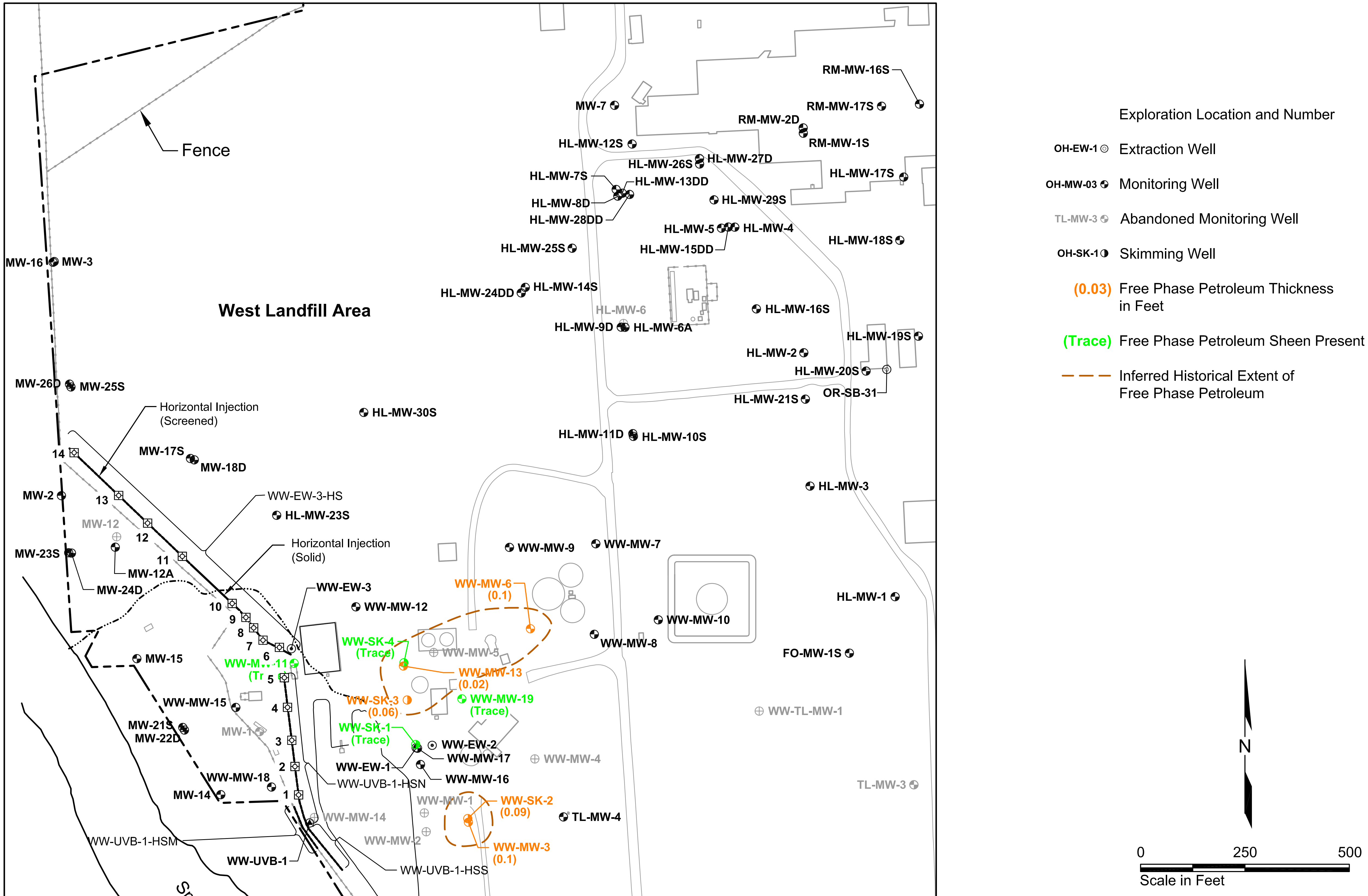

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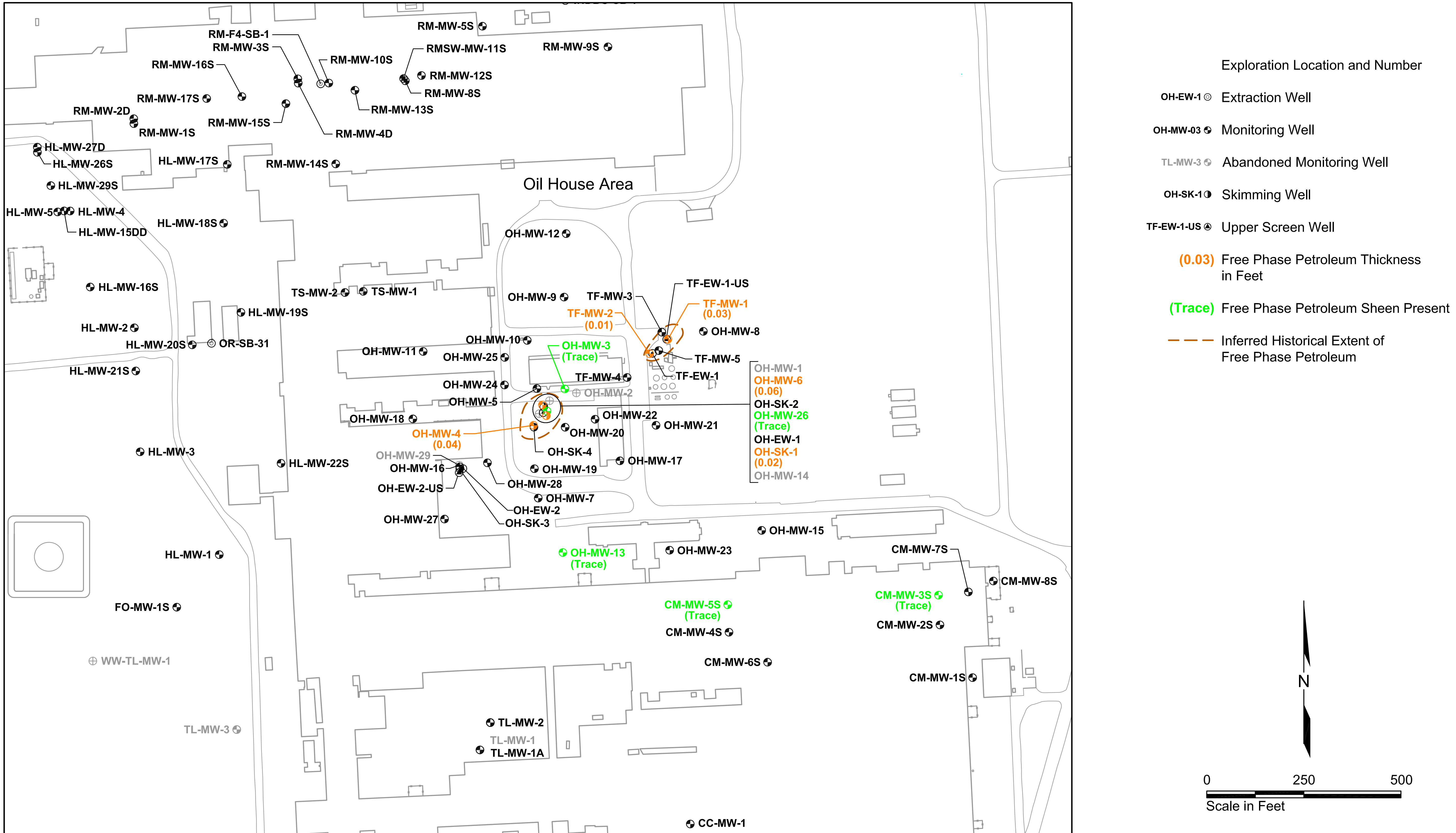
Figure 4-10

EAL 09/10/09 2644116-056.DWG

Free Phase Petroleum Thickness Map

Measured 2008 - East Area



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2644-116 12/09

Figure 4-11

EAL 09/10/09 2644116-057.DWG

Smear Zone AOC Locations within Paved Areas

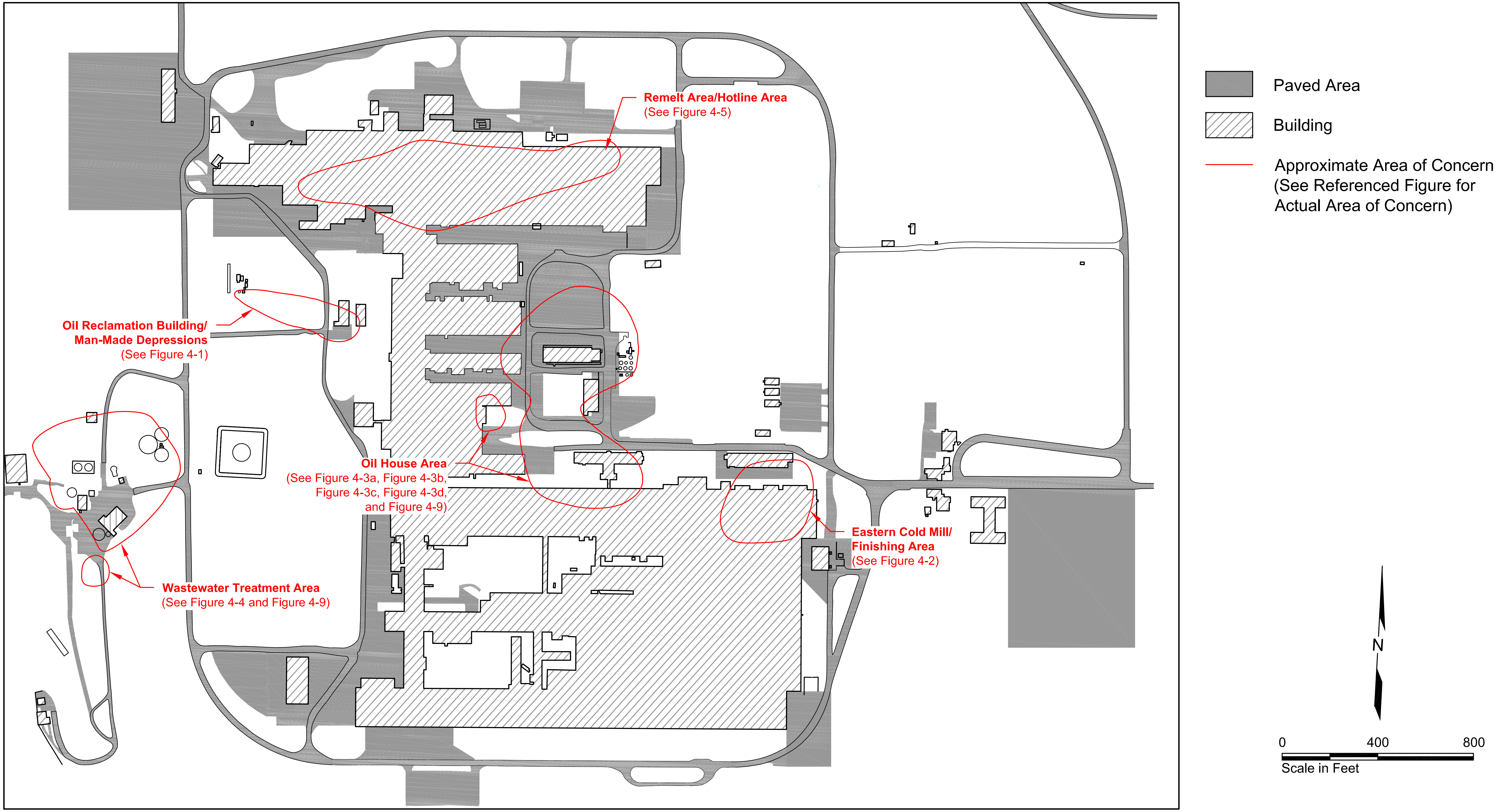

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Figure 4-12

CONTENTS

Page

TABLES

CONTENTS (Continued)

TABLES (Continued)

CONTENTS (Continued)

TABLES (Continued)

FIGURES

5.0 CONTROL OF CONSTITUENTS OF CONCERN IN THE PETROLEUM HYDROCARBON GROUNDWATER PLUMES

Constituents of potential concern (COPCs) in groundwater on the Kaiser Facility were identified in Section 1.3. Screening levels (SLs) were then established for the COPCs following MTCA requirements, by considering site-specific conditions such as groundwater use and by comparison of the risk-based MTCA SLs with other chemical-specific applicable or relevant and appropriate requirements (ARARs). COPCs that are present at concentrations that exceed SLs may be considered to be constituents of concern (COCs). The COCs identified for groundwater in Section 1.3.2 fall under the following groupings:

- Free phase product;
- Semivolatile organic compounds (SVOCs), including diesel and heavy oil-range petroleum hydrocarbons and carcinogenic polycyclic aromatic hydrocarbon (cPAHs);
- Total polychlorinated biphenyls (PCBs); and
- Metals (arsenic, lead, iron, and manganese).

Free Phase Product

Figures 4-6 through 4-8 identify the areas at Kaiser with historic free phase petroleum product (FPP). Figures 4-9 through 4-11 depict the areas with FPP identified during 2008 groundwater monitoring events. Comparing Figure 4-9 to Figure 4-11, a significant reduction in the size of the FPP areas can be seen as a result of source control, FPP removal measures conducted at Kaiser over the past 20 years, and natural degradation processes.

Using the 2008 groundwater monitoring data (Hart Crowser 2012a) an evaluation of the quantities of FPP currently present in the Oil House and Wastewater Treatment AOCs was conducted. In 2008, a total of four areas with FPP were identified in the Oil House and Wastewater Treatment AOCs (Figure 4-9). Two areas in the Oil House area were termed the East and West FPP areas and two areas in the Wastewater Treatment area were termed the North and South FPP areas. During 2008 groundwater monitoring events, product thickness measurements were taken in select wells. Average FPP thicknesses (Table 4-20) were calculated for the four FPP areas with the 2008 data. Where no FPP was measured, 1/2 of the oil/water interface probe’s detection limit (0.005 feet) was used in calculating average FPP thickness. In all four FPP areas, average product thickness was less than 1 inch.

To calculate a volume of FPP present in the four areas the average thickness was multiplied by the estimated area (Figures 4-10 and 4-11) and by an effective porosity. An effective porosity of 0.3 as defined in Section 4 of the Final Groundwater RI (Hart Crowser 2012a) was used in the FPP calculations. Product thickness measurements from 2008 and average FPP thicknesses are presented in Table 4-20. Rough order of magnitude (ROM) estimates of the volume of FPP present in 2008 are provided in Table 4-19. A total of approximately 5,000 gallons of free phase product is estimated to be present. Nearly all of this free phase product is located in the Wastewater Treatment area.

The free phase product removal technologies presented in Section 5 also involve the extraction of groundwater (refer to Section 5.1.4). Free phase product recovery technologies that do not require the removal of groundwater were discussed in Section 4.2 and 4.4. They will not be discussed further in Section 5.

Semivolatile Organic Compounds (SVOCs)

For the purposes of this FSTM and remediation technology evaluations, SVOCs include carcinogenic cPAHs and TPH in the diesel and heavy oil-ranges.

TPH concentrations in groundwater have been evaluated at Kaiser for over 20 years. Several different TPH-containing products were used across the Facility, ranging from gasoline to heavy oils. By far, the majority of TPH compounds found in impacted soil and groundwater at Kaiser are in the diesel- and heavy-oil ranges. Due to their similar physical properties, diesel- and heavy oil-range TPH compounds, including Kensol and Bunker C, are evaluated by technologies pertaining to SVOCs in the remedial technology evaluation presented in Section 5.2.

The inferred location of the petroleum hydrocarbon groundwater plumes measured in 2008 was described in the Final Groundwater RI (Hart Crowser 2012a) in Figures 5-2 (diesel) and 5-4 (heavy oil). The diesel plumes are located in the Oil House, ORB, Cold Mill/Finishing, and Wastewater Treatment areas of the site. The heavy oil plumes are located in the Oil House, Cold Mill/Finishing and Wastewater Treatment areas of the Facility, and generally fall within the footprint of the diesel plumes in these locations.

Groundwater containing cPAHs at concentrations above SLs was found in the Oil House, ORB, Cold Mill/Finishing, Wastewater Treatment, and Hot Line areas of the site as shown on Figure 5-30 in the Final Groundwater RI (Hart Crowser 2012a).

Polychlorinated Biphenyls (PCBs)

Groundwater containing PCBs at concentrations above SLs was found in the Oil House, Wastewater Treatment, and Remelt/Hot Line areas of the Facility as shown on Figures 5-1, 5-4, and 5-6 . Three PCB plumes are present at the site. Two plumes are co-located with the free phase product, diesel, heavy oil, and cPAH constituents that are present in the Oil House and Wastewater Treatment areas. A third PCB plume appears to emanate from the Remelt/Hot Line area.

Metals

The Final Groundwater RI (Hart Crowser 2012a) identified arsenic, iron, and manganese as COPCs in the site groundwater. Arsenic is a known human carcinogen and a very conservative screening level was applied to arsenic detections in the site groundwater. Screening levels for iron and manganese are based on drinking water rules regulating contaminants that may cause cosmetic effects such as skin or tooth discoloration or aesthetic effects such as taste, odor, or color.

Arsenic

As part of the 2008 quarterly groundwater monitoring events, all 102 groundwater samples collected from across the Kaiser Facility were analyzed for arsenic. All arsenic concentrations exceeded the SL of 0.018 µg/L. It is important to note that the screening level for arsenic is based on the Clean Water Act Section 304 Water Quality Criteria for Freshwater Human Health (consumption of water + organisms) and is conservatively low when compared to background conditions in Washington State. MTCA Method A groundwater cleanup level (CUL) for arsenic of 5 µg/L is based on Washington State background levels (two orders of magnitude above the SL).

The Spokane County Water Resources Department has been monitoring groundwater quality, including arsenic concentrations, in the Spokane Valley-Rathdrum Prairie Aquifer since 1977 (Spokane County Water Resources 2009). Two monitoring wells within their aquifer-wide network of 45 wells are located directly up- and cross-gradient of Kaiser. The two wells, designated 6436N01 and 5505D01, are located approximately 1 mile northeast and approximately 2.5 miles east of Kaiser, respectively. The top of the screened interval for well 6436N01 is 104.5 feet bgs and the top of the second interval for well 5505D01 is 87 feet bgs. The sampling pump intakes are generally set at the top of the screened interval.

Analytical results from 2008 monitoring indicate that well 6436N01 had an average total arsenic concentration of 3.1 µg/L with an average total arsenic concentration of 5 µg/L reported in well 5505D01. Well 5505D01 has frequently exceeded the drinking water regulations trigger level of 5 µg/L in past years; therefore, a 10-year trend analysis was performed for the 2008 monitoring report. A summary of ten years of monitoring data from this well shows a range in total arsenic concentrations of 3.1 to 7.3 µg/L with a mean of 5.2 µg/L.

Monitoring well MW-10, located on Kaiser's eastern property boundary and upgradient of the impacted areas of the site, has been sampled 20 times for dissolved arsenic between 1991 and 2008. Concentrations have ranged from 5.6 to 15 µg/L with an average concentration of 8.5 µg/L, suggesting that the area background concentration may be within this range. Kaiser's North Supply Well, also near the eastern property boundary and upgradient of site impact areas, has been sampled twice for total arsenic with an estimated concentration of 4.6 µg/L and a non-detect result with a 5 µg/L reporting limit. Comparisons of samples tested for total and dissolved arsenic samples from select wells across the site have been in general agreement, indicating that arsenic detected in the groundwater is predominately dissolved.

Elevated arsenic concentrations in groundwater at this site have generally been attributed, in part, to area background conditions and the historical petroleum free product in the Wastewater Treatment and Oil House areas that cause reducing conditions and can mobilize naturally occurring arsenic into the groundwater. In 2008, the highest detections of arsenic at the site occurred in the Oil House area with arsenic levels of 59 and 38 µg/L in wells TF-MW-2 and TF-MW-4, respectively. These wells are located in an area with historic and recent detections of FPP (Figures 4-8 and 4-11) and groundwater conditions are shown to be mildly reducing. Field measurements of the oxidation-reduction potential (ORP) collected during 2008 sampling of wells TF-MW-2 and TF-MW-4 show an average ORP of –112 millivolts (mV) between the two wells which corroborates petroleum-induced reducing conditions.

The above reported maximum arsenic detections in TF-MW-2 and TF-MW-4 represent outliers of the site-wide 2008 groundwater data set, with the remaining 50 samples tested for arsenic during 2008 generally an order of magnitude lower in concentration. Eliminating these two data points, arsenic concentrations collected from across the site ranged from 1.8 to 11.4 µg/L with an average concentration of 5.1 µg/L during 2008.

Groundwater sampling and analysis for metals analysis was conducted during initial site investigations between 1989 and 1991 and from 1995 to the present. During the approximately four-year metals testing hiatus from 1991 to 1995, efforts were mainly focused on monitoring for petroleum hydrocarbons and PCBs in the groundwater and removal of FPP in the Oil House area. Between 1994 and 2008, Kaiser has recovered approximately 4,200 gallons of FPP from the groundwater in the Oil House and Wastewater Treatment areas. Removal of FPP in these areas lessens the reducing conditions that will mobilize naturally occurring arsenic into the groundwater.

Comparing the 1989 to 1991 data to the 1995 through 2008 data, a decreasing trend in dissolved arsenic concentrations has been documented. Detections of dissolved arsenic in the 1989 to 1991 data set range from 5 to 93 μg/L with an average concentration of 33 μg/L. During 1995 to 2008, site-wide dissolved arsenic concentrations ranged from 0.8 to 59 μg/L with an average concentration of 4.1 μg/L.[1] The higher sample population in the later data set (86 metals samples collected from 1989–1991 compared to 645 collected from 1995–2008) will tend to dilute high concentration excursions, but a lowering trend can be seen more clearly when comparing the number of high arsenic detections between the two sample sets.

Arsenic concentrations greater than 10 μg/L are considered excursions above the expected background range. Between 1989 and 1991, 25 out of 86 sample analytical results were greater than 10 μg/L for arsenic compared to 11 samples out of 645 in the 1995 to 2008 data set that exceeded 10 μg/L. The highest levels of arsenic in the groundwater have been consistently detected in the Oil House and Wastewater Treatment area petroleum and FPP plumes.

Based on a review of previous site groundwater data and area background arsenic concentrations, it is evident that previous high levels of dissolved arsenic detected in site groundwater samples are related to petroleum plumes located in the Oil House and Wastewater Treatment areas of the site. Arsenic concentrations in the groundwater are expected to be lowered with the continued natural breakdown and/or physical removal of petroleum and the subsequent increase in the redox potential. Technology evaluations for the remediation of COCs in site groundwater will focus on the reduction of dissolved/adsorbed and floating petroleum hydrocarbons in groundwater and smear zone soils rather than directly addressing arsenic.

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[1] Note that non-detect samples were not included in the comparison of these data sets due to the lowering of method reporting limits over time.

Iron and Manganese

Iron and manganese were considered by the Final Groundwater RI (Hart Crowser 2012a) as presenting adverse secondary (aesthetic) effects to groundwater. Drinking water standards set Secondary Maximum Contaminant Levels (SMCLs) for iron and manganese at 300 and 50 µg/L, respectively, and these values were selected as SLs. During 2008, 9 out of 95 groundwater samples exceeded the iron SL and 15 out of 92 samples exceeded the manganese SL. With the exception of a single manganese SL exceedance in MW-23S (located near Kaiser's west property boundary), all SL exceedances for iron and manganese during 2008 were from wells located within petroleum plume groundwater AOCs.

Similar to arsenic, it is expected that the petroleum-induced reducing conditions present in these areas facilitate the mobilization of naturally occurring iron and manganese into the groundwater. Technology evaluations in this section will focus only on the reduction of petroleum in groundwater. These technologies will indirectly lower the concentrations of metals in groundwater by raising the redox potential and lessening reducing conditions.

The Petroleum Hydrocarbon Groundwater Plume

This FSTM focuses on remedial alternatives that will effectively treat SVOCs (diesel, heavy oil, and cPAHs) and PCBs that are co-located in groundwater. The areas of the Facility where COCs within these groups can be found are listed in Table 5-1 and depicted on Figure 5-1. Figure 5-1 is a composite of the data provided in the Final Groundwater RI (Hart Crowser 2012a) and cited above. Section 5 does <u>not</u> address the PCBs that are present in the groundwater plume that appears to originate in the Remelt/Hot Line area. Technologies to address the PCBs in this plume are discussed in Section 6.

Some SVOC and PCB contamination at Kaiser is associated with light non-aqueous phase liquid (LNAPL). As mentioned in Section 4, the areas of the Facility where free phase product has been observed historically and the relatively small number of locations where free phase product is still observed (such as the Oil House and the Wastewater Treatment areas) are discussed in Section 3 of this FSTM. The areal extent of the free phase product plumes observed in 2008 was estimated to total approximately 15,000 square feet in the Oil House area and 72,000 square feet in the Wastewater Treatment area (Hart Crowser 2012a, Table 5-6, Figure 5-12).

Technologies that enhance SVOC removal from smear zone soils and free phase product recovery without groundwater extraction are discussed in Section 4 of this FSTM. In this section, enhanced SVOC removal from groundwater and free phase product recovery are discussed.

Section 5 evaluates technologies that could be applicable to COCs in the petroleum hydrocarbon groundwater plumes. Section 5 is organized as follows:

- Section 5.1 – Potential Remediation Technologies for SVOCs in Groundwater
- Section 5.2 – Potential Remediation Technologies for PCBs in the Petroleum Hydrocarbon Groundwater Plumes
- Section 5.3 –Screening Technologies for Remediating Petroleum Hydrocarbon Groundwater Plumes
- Section 5.4 - Description of Areas of Concern for the Petroleum Hydrocarbon Groundwater Plumes
- Section 5.5 – Development of Remedial Alternatives

5.1 POTENTIAL REMEDIATION TECHNOLOGIES FOR SVOCS IN GROUNDWATER

SVOCs in groundwater have been successfully remediated at many sites. Different technologies have been used to contain, treat, and destroy these contaminants. The use of these technologies to remediate SVOCs in groundwater has been well documented.

This documentation has been compiled to create technology identification and screening tools. The Federal Remediation Technologies Roundtable (FRTR) publishes a Remediation Technologies Screening Matrix and Reference Guide (FRTR 2009a). The EPA Technology Innovation Office operates a Hazardous Waste Cleanup Information (CLU-IN) web site that compiles information on a wide array of remediation technologies (CLU-IN 2009).

The Center for Public Environmental Oversight (CPEO) is an organization that promotes and facilitates public participation in the oversight of environmental activities, including but not limited, to the remediation of federal facilities, private Superfund sites, and Brownfields. CPEO's Technology Tree Matrix is a tool for identifying technologies to characterize and clean up hazardous waste sites (CPEO 2009), and the EPA Annual Status Report (ASR) Remediation Database – Update 2003 that documents status and achievements of treatment technologies and Superfund sites (EPA 2003).

These sources and others were used to develop the list of potential technologies for remediating SVOC COCs. The lists in Tables 5-2a and 5-2c contain the technologies recommended by the FRTR, CLU-IN, CPEO and the technologies identified by the ASR database as having been used at CERCLA sites as well as other technologies to successfully remediate groundwater at other sites. The Monitoring and Institutional Controls Alternative is shown in Table 5-2a.

The response actions suitable for remediating groundwater in the AOC are: monitoring, institutional controls, containment, *in situ* treatment, and extraction including on-site groundwater treatment. These response actions and their remedial technologies are listed in Table 5-2a. The remedial technologies not already described in Appendix A and Sections 2 through 4 are briefly described below.

5.1.1 Containment

A variety of capping, vertical barrier, horizontal barrier, and hydraulic control technologies have been used to contain SVOCs present in groundwater. Caps and vertical barriers are described in Section 2.1. Other technologies are described below.

Horizontal Barriers

Horizontal barriers prevent vertical migration of groundwater contaminants. Horizontal barriers can be constructed by injecting grout into a horizontal slot or by fracturing the soil matrix along the horizontal plane and injecting fluid along the fracture to contain groundwater contaminants (Pearlman 1999). This process can be used to stop, collect, or destroy subsurface contaminants using an impervious barrier or a porous reactive barrier (EPA 1996f). One disadvantage of horizontal barriers is the difficulty of ensuring a continuous barrier (Pearlman 1999).

Hydraulic Control

Hydraulic control can be achieved by groundwater pumping and water injection. Groundwater contaminants can be contained in a specific area by removing groundwater and affecting the flow of contaminants.

Over the past 14 years hydraulic control has been used at the Kaiser facility as part of the Interim Remedial Measure (IRM) (Hart Crowser 2012a). The three basic objectives of the IRM were to:

- Prevent horizontal migration and spreading of free phase petroleum, associated PCBs, and dissolved hydrocarbons identified near the Oil House area (east central part of site) and the Wastewater Treatment area (west central part of site);

- Recover free phase petroleum;

- Enhance biodegradation of dissolved and residual petroleum hydrocarbons in the source areas. This system is further described in Section 5 of the Groundwater RI/FS (Hart Crowser 2003); and

- Increase the ORP to reduce the mobilization of naturally occurring arsenic, iron, and manganese into the groundwater.

The groundwater IRM system consist of three primary components: (1) groundwater extraction wells to depress the water table beneath free phase petroleum accumulations; (2) skimming wells and belt skimmers to extract free phase petroleum; and (3) special deep wells to monitor for potential downward migration of petroleum hydrocarbons or PCBs near the groundwater extraction wells. The paragraphs below provide more details of this system in the Oil House and Wastewater Treatment areas.

Oil House

Operations began in 1993 and were expanded in 2000. Well OH-MW-1 is used for extraction and has been pumping on average 1,000 gallons per minute (gpm) since 1993. Water from this well is used for plant processes. Skimming operations began in 1993 at well OH-SK-2 and in 2000 at well OH-SK-4. Originally, a skimming pump was used in OH-SK-2. Currently, there are skimming belts in both wells (Hart Crowser 2003 and 2012a).

Wastewater Treatment IRM

Operations began in 1993 and were expanded in 2000. Three extraction wells, one recirculation well, four skimmer wells, and one deep monitoring well were installed to enhance product recovery and biodegradation. Currently, two extraction wells (WW-EW-1 and WW-EW-2) and the recirculation well (WW-UVB-1) are operating, with two skimmer wells (WW-SK-1 and WW-SK-4) operating when free phase petroleum is present (Hart Crowser 2003 and 2012a). Originally, wells WW-EW-1 and WW-EW-2 extracted 3,500 gpm of water each, some of which was used for plant processes; the excess water was sent to the plant's wastewater system for treatment prior to discharge. The current combined pumping capacity of the pumps in extraction wells WW-EW-1 and WW-EW-2 is 7,400 gpm and 10,900 gpm, respectively.

The performance of the IRM was evaluated by monitoring groundwater and free phase petroleum levels in observation wells in the Oil House and Wastewater Treatment areas and by computer modeling. The IRM systems were shown to meet project objectives with respect to containment, product recovery, and enhanced biodegradation. Migration and spreading of the contaminant plumes in the Wastewater Treatment and Oil House areas have been eliminated through hydraulic control. The extent and thickness of free phase petroleum has declined over time. Finally, based on conditions at the site in 2003 (Hart Crowser 2003) the IRM has effectively increased dissolved oxygen concentrations in the source areas, which in turn enhances the rate of aerobic biodegradation of residual petroleum hydrocarbons and will reduce the mobilization of naturally occurring metals (Hart Crowser 2012a). The overall feasibility study will further evaluate the performance of the IRM using an updated version of the Kaiser groundwater flow model that reflects current site and IRM conditions.

5.1.2 In Situ Treatment Technologies

In situ groundwater treatment technologies for SVOCs include bioremediation, monitored natural attenuation, dual vacuum extraction (DVE), air sparging, steam injection, passive treatment walls, hydrofracturing, chemical treatment, and in-well air stripping. Monitored natural attenuation, DVE, air sparging, and steam injection are discussed in Appendix A. A brief description of the technologies not already discussed in Appendix A follows.

In Situ Bioremediation

Bioremediation usually requires a mechanism for stimulating and maintaining the activity of microorganisms. This mechanism is often a delivery system for providing one or more of the following: an electron acceptor (oxygen, nitrate), nutrients (nitrogen, phosphorous), and an energy source (carbon).

In a typical *in situ* bioremediation system, groundwater is extracted using one or more wells, and if necessary, is treated to remove residual dissolved constituents. The treated groundwater is then mixed with an electron acceptor, nutrients, and other constituents if needed, and is reinjected upgradient of or within the contaminant source. Infiltration galleries or wells can be used to reinject treated water. In an ideal system, a closed-loop system would be established. All water extracted would be reinjected without treatment and all remediation would occur *in situ*. The system continually recirculates the water until the CULs are achieved.

Short-chain, low-molecular-weight, and more water-soluble constituents are degraded more rapidly and to lower residual levels than are long-chain, high-molecular-weight, less-soluble constituents. Recoverable free phase product should be removed from the subsurface prior to the operation of the *in situ* bioremediation system. This will mitigate a major source of contaminants as well as reduce the smearing or spreading of high concentrations of contaminants (EPA 2004a).

A form of enhanced bioremediation has been used in the Oil House and Wastewater Treatment areas since 2000 (Hart Crowser 2003). Oxygenated groundwater is being used to raise the dissolved oxygen concentration in the upper part of the aquifer in both areas, which increases the rate of aerobic metabolism of naturally occurring bacteria and results in enhanced biodegradation of the residual petroleum hydrocarbons. The pumping of oxygenated groundwater from oxygen-rich deeper zones to oxygen-poor upper zones is accomplished through a combination of vertical and horizontal screens. In the past, extraction wells OH-EW-2 and TF-EW-1 and distribution wells OH-EW-2-US and TF-EW-1-US have been used in the Oil House Area.

Currently, in the Wastewater Treatment area, well WW-UVB-1 extracts water at a rate of 2,400 gpm and distributes it to three horizontal screen segments for enhanced biodegradation. The original enhanced biodegradation system included extraction well WW-EW-3, which distributed water to the upper screen of the same well and to horizontal screen WW-EW-3-HS (Hart Crowser 2003). This extraction well and horizontal screen system was shut down in 2008 to reduce the potential of increasing the vertical distribution of PCBs in the vicinity.

In Situ Chemical Treatment (Oxidation)

Chemical oxidation technologies are predominantly used to address contaminants in source area saturated zones and the capillary fringe. A wide variety of oxidants and application techniques can be used to bring oxidizing agents into contact with subsurface contaminants. Typical oxidants include hydrogen peroxide, potassium or sodium permanganate, and ozone.

As with *in situ* bioremediation systems, groundwater is extracted using one or more wells, and if necessary, is treated to remove residual dissolved constituents. The treated groundwater is then mixed with the oxidant and reinjected upgradient of or within the contaminant source. Chemical oxidation is often used in conjunction with DVE and/or SVE to help alleviate safety issues associated with controlling and recovering off-gas containing VOCs, oxygen, oxidants, and other reaction by-products that can be generated by various chemical oxidants. Chemical oxidation can also provide benefits to the subsequent bioremediation of contaminants (EPA 2004a).

Passive Treatment Walls

Treatment walls are a passive *in situ* treatment alternative that can be used to degrade or immobilize contaminants as groundwater flows through a reactive media (EPA 1995c). A treatment wall ensures that a contaminant plume does not move toward and endanger a sensitive receptor, such as drinking water wells, or discharge into surface waters (EPA 1997d). Natural gradients transport contaminants through the treatment wall where the reactants either degrade, sorb, precipitate, or otherwise remove them (EPA 1997d).

Treatment walls can be installed as permanent, semi-permanent, or replaceable units. They are constructed by excavating a trench across the flow path of the contaminated material and filling it with reactive materials (EPA 1996f). There are currently two basic designs used in full-scale implementation of reactive barriers: (1) the funnel and gate design; and (2) the continuous trench design. Reactants contained in treatment walls include: reactants for degrading volatile organics, chelators for immobilizing metals, nutrients and oxygen to enhance bioremediation, or other agents. Most treatment walls installed to date use zero-valent iron (Fe^{o}) as the reactive media for converting contaminants to non-toxic or immobile species (Kovalik 1999).

Hydrofracturing

Hydrofracturing or hydraulic fracturing is a technology that uses high pressure water to create distinct fractures in low-permeability materials such as over-consolidated clays or sediment. During this process, a slurry of water, sand, and a thick gel is injected into a borehole at high pressure. (Other granular materials such as graphite may be used to create fractures with different properties.) The residual gel biodegrades and the resultant fracture is a highly permeable sand-filled lens that may be as large as 60 feet in diameter. These sand-filled fractures are pathways that facilitate bioremediation, steam injection, contaminant recovery, pumping, or other *in situ* processes. Hydrofracturing has been used to treat VOCs and SVOCs (EPA 1995e).

In-Well Air Stripping

Air is injected into a double screened well, lifting the water in the well and forcing it out the upper screen. Simultaneously, additional water is drawn into the lower screen. Once in the well, some of the VOCs in the contaminated groundwater are converted from the dissolved phase to the vapor phase by the air bubbles. The contaminated air rises in the well to the water surface where vapors are drawn off and treated by a soil vapor extraction system. The circulation of water helps stimulate microbiological activity in the soil by movement of air and contaminants (FRTR 2009b and NFESC 1997).

5.1.3 Groundwater Extraction and On-Site Treatment Technologies

Groundwater contaminated with SVOCs can be extracted and treated on-site to remove the SVOCs. These *ex situ* processes are listed in Table 5-2a.

Some of these technologies are presumptive remedies for *ex situ* treatment of SVOCs in groundwater. They include the use of granular activated carbon, chemical/UV oxidation and aerobic biological reactors (EPA 1996h). These technologies and additional *ex situ* groundwater technologies listed in Table 5-2a that are not described in Section 2 and Appendix A are discussed below.

Granular Activated Carbon

Activated carbon removes contaminants from groundwater by adsorption. The principal form of activated carbon used for groundwater treatment is granular activated carbon (GAC). GAC is an excellent sorbent due to its large surface area, which generally ranges from 500 to 2,000 m^2/g. GAC is applicable to a wide variety of contaminants including halogenated volatile and semivolatile organics, nonhalogenated volatile and semivolatile organics, PCBs, pesticides, dioxins/furans, most organic corrosives, metals, radioactive materials, inorganic cyanides, and certain oxidizers. Activated carbon is a well-developed, widely used technology, with many successful groundwater treatment applications, especially for secondary polishing of effluents from other treatment technologies.

In a GAC treatment system, contaminated groundwater is contacted with a fixed GAC bed in a vessel. Flow direction is generally vertically downward, although an upward flow configuration is also possible. GAC adsorption is a presumptive technology for the *ex situ* treatment of contaminated groundwater (EPA 1996h).

Chemical/UV Oxidation

Chemical oxidation is applicable to both volatile and semivolatile organic compounds and cyanide compounds. Chemical oxidation is potentially applicable to PCBs, dioxins/furans, and metals (oxidation can be used to precipitate metals under certain conditions). Ultraviolet light (UV) can enhance the oxidation of compounds such as PCBs that are resistant to chemical oxidation alone. Commonly used oxidizing agents include: ozone, hydrogen peroxide, hypochlorites, chlorine, and chlorine dioxide. Ozone and hydrogen peroxide are generally preferred for removing organics. UV is often used in conjunction with ozone and/or hydrogen peroxide to promote faster and more complete destruction of organic compounds (reaction rates may be increased by factors of 100 to 1,000).

Complete oxidation decomposes hydrocarbons into carbon dioxide and water, although chlorinated organic compounds also yield chloride ions. If oxidation is incomplete, toxic constituents may remain or intermediate degradation products can be formed that may be toxic. These toxic substances may be removed using GAC as a secondary or polishing treatment step. Chemical oxidation is a proven and effective technology that is carried out in either batch or continuous reactors. Oxidants are generally added to contaminated groundwater in a mixing tank prior to introduction into the reaction vessel (reactor). Chemical/UV oxidation is a presumptive technology for the *ex situ* treatment of contaminated groundwater (EPA 1996h).

Aerobic Biological Reactors

Biological reactors (bioreactors) use microorganisms to degrade organic contaminants in groundwater in *ex situ* reactors. There are two basic types of *ex situ* biological treatment processes: aerobic reactors and anaerobic reactors. Anaerobic treatment processes are not widely used for groundwater treatment. Aerobic reactors are a presumptive technology for *ex situ* treatment of dissolved contaminants in extracted groundwater. Aerobic biological reactors are applicable to a wide variety of halogenated and non-halogenated volatile and semivolatile organics and may be applied to heavy organics, such as PCBs and certain pesticides, and organic and inorganic cyanides, but are generally not as effective for such recalcitrant compounds. Depending on influent concentrations, pre- or post treatment may be required.

There are two general designs for aerobic biological reactors: suspended and attached growth.

In **suspended growth** reactors, microbes are kept suspended in water using mechanical aerators or diffused air systems. These aeration systems also keep the solution well mixed, improving contact between microbes and dissolved contaminants and supplying oxygen to the system. Activated sludge systems are the most common suspended growth bioreactors. Other examples include aerated ponds or lagoons, stabilization ponds (using both algae and bacteria), and sequencing batch reactors.

In **attached growth** reactors, biomass is attached to a solid substrate, such as sand, rock, plastic, activated carbon, or resin. Reactor design is dependent upon the surface area of substrate media available for biomass growth. Examples include trickling filter, rotating biological contactor, fluidized bed, fixed bed, and roughing filter designs (EPA 1996h).

Suspended Solids Removal

Solids removal technologies are used to remove solids from groundwater after it has been extracted. Sedimentation, precipitation, and filtration are processes that can be used to remove solids from water.

Sedimentation is used to separate suspended solids from water by the gravitational settling of particles that are denser than water. A sedimentation tank can be used to remove particles that settle due to gravity. Flocculants and precipitants are chemicals that can be added to hasten the settling rate (Metcalf & Eddy 2003). They alter the physical or chemical state of dissolved and suspended solids and facilitate their removal by sedimentation. Sedimentation can occur due to changes in surface charge, particle aggregation, or polymer formation (Metcalf & Eddy 2003).

Filters are used to physically separate suspended materials from groundwater. Filters can be composed of one or more materials such as sand and anthracite. Typical mechanisms that are used to remove suspended materials within a granular filter include straining, sedimentation or inertial impaction, interception, adhesion, or flocculation (Metcalf & Eddy 2003).

Ion Exchange

Ion exchange is a process in which ions of a given species are displaced from an insoluble exchange material by ions of a different species in the solution being treated. This process can be operated in either batch or continuous mode. In continuous mode, the exchange material is placed in a bed or a packed column, and the water to be treated is passed through it. When the resin capacity is exhausted, the column is backwashed to remove trapped solids and then regenerated. High concentrations of influent-suspended solids can plug ion exchange beds, causing pressure losses and inefficient operation. Typically, some form of chemical treatment and clarification is required prior to ion exchange (Metcalf & Eddy 2003).

Ion exchange is presumptive technology for *ex situ* treatment of dissolved contaminants in extracted groundwater (EPA 1996h).

Membranes

Membrane separation includes the use of porous membranes for the removal of dissolved and colloidal material. Reverse osmosis, ultrafiltration and membrane evaporation are examples of membrane separation processes.

Reverse osmosis is a process in which water is separated from dissolved salts in solution by filtering through a semipermeable membrane at a pressure greater than the osmotic pressure caused by the dissolved salts in the wastewater. Reverse osmosis is able to remove dissolved organics that are less selectively removed by other demineralization techniques.

Ultrafiltration systems are pressure-driven membrane operations that use porous membranes to remove suspended materials. Ultrafiltration is typically used to remove large molecules and requires low driving pressures. The limiting factors of membrane separation are its high cost, the chemical treatment needs of the membrane, and the tendency of the membrane to become clogged (Metcalf & Eddy 2003).

Membrane evaporation uses nonporous organophilic polymer membranes. Contaminated groundwater is heated and passed through membranes composed of the polymer formed into capillary fibers. A vacuum is applied that causes the VOCs to diffuse through the membrane. Contaminant vapor is collected and condensed and treated water is discharged.

Distillation

Distillation is a chemical separation process involving vaporization and condensation that is used to separate components of varying vapor pressures (volatilities) in a liquid or gas stream. The process can be done in single or multiple stages. In a single stage operation, heat is applied to a liquid mixture in a still, causing a portion of the liquid to vaporize. These vapors are subsequently cooled and condensed producing a liquid product called distillate or overhead product. Conversely, the mixture remaining in the still is enriched with the less volatile components. This mixture is called the bottoms product. Multiple stages are used in most commercial distillation operations to obtain better separation of organic components than is possible in a single evaporation and condensation stage (FRTR 2009b).

Freeze Crystallization

Freeze crystallization processes remove purified solvent from solution as frozen crystals. When a solution containing dissolved contaminants is slowly frozen, ice crystals form on the surface, and contaminants are concentrated in the remaining solution. The ice crystals can be separated from the mother liquor, washed and melted to yield a nearly pure water stream. The contaminated waste stream, mother liquor, and any precipitated solids, are generally more amenable to subsequent treatment by conventional destruction and stabilization technologies due to the higher contaminant concentrations (FRTR 2009b).

5.1.4 Free Phase Product Removal

As mentioned above, there are small areas of the Kaiser Facility where free phase product is still observed during late summer and fall (e.g., the Oil House and the Wastewater Treatment areas). Table 4-2 presents remedial technologies for smear zone soils, applicable to enhanced SVOC recovery from soils, and free phase product recovery without groundwater extraction. This section describes enhanced SVOC recovery from groundwater resulting from the depression of the water table, *in situ* free phase product recovery with groundwater extraction (DVE), and *ex situ* free phase product recovery (oil-water separators). These technologies are presented in Table 5-2c.

Water Table Depression

This method of recovery uses groundwater extraction to create a cone of depression so that any free phase product is directed toward pumping wells or trenches within the plume area. Both free phase product and groundwater are extracted during recovery operations. Product recovery systems using water table depression are most applicable when hydraulic control of the hydrocarbon plume is necessary. These systems are used for a wide range of permeability values and geologic media. However, because of the costs associated with the separation and treatment of dissolved hydrocarbons, these systems are better suited for formations of moderate to high permeability (greater than 10^{-4} cm/s). Typically, free phase product recovery with water table depression is used in long-term operations of greater than one year. Typical configurations are single- and dual-pump systems.

In single-pump systems, one pump extracts groundwater and product simultaneously which may emulsify liquid hydrocarbons. As a result, aboveground separation and perhaps other levels of treatment are necessary components of these systems. In dual-pump recovery systems, one pump extracts groundwater to create a cone of depression in the water table and a second pump is used to collect free phase product. This dual-pump system optimizes the cone of depression to achieve maximum product recovery while minimizing smearing and preventing mixing of free phase product with water. By carefully balancing the pumping rates for groundwater and free phase product, emulsification of oil can be minimized or eliminated, which negates the need for oil/water separation (EPA 1996g).

Dual Vacuum Extraction (DVE)

As described in Appendix A, DVE simultaneously extracts both soil vapors and groundwater from the subsurface via groundwater wells. Multi-phase extraction (MPE) refers to refers to removal of three phases—soil vapor, groundwater, and NAPL—from the subsurface.

There are several ways that DVE/MPE technology can be set up. In one type of installation, the set point for vapor extraction is different than the set point for liquid extraction. Another name for this type of set up is Vapor Extraction/ Groundwater Extraction or VE/GE. These systems are designed to expose the smear zone in the capillary fringe by pumping groundwater while simultaneously volatilizing the residual petroleum hydrocarbons in the smear/vadose zone with soil vapor extraction (SVE). VE/GE systems are used after other free phase product recovery methods have removed as much mobile product as feasible (EPA 1996g).

Another setup option for DVE is a single extraction point. The set point may be in the water table to extract groundwater and product or may be set at the air and product interface. If the extraction suction point is located in the latter, the technology is commonly referred to as "bioslurping" (EPA 1996g). Due to the location of the extraction point in bioslurping, there is air circulation which helps bioremediate vadose zone soils. Bioslurping can improve free phase product recovery efficiency without extracting large quantities of groundwater.

Oil-Water Separation

Oil-water separators are used to remove oils and grease from wastewater. Oil may be present as a free phase or as an emulsified oil. The separation of free phase oils occurs by gravity and normally occurs by allowing oils to float to the surface of the water where the oil is skimmed off by mechanical means. Two types of oil-water separation processes are typically used: API separators and dissolved air flotation processes. In dissolved air flotation processes, product can attach to dissolved air bubbles and be brought to the surface. Oil-water emulsions must first be "broken" using chemicals (typically acid) and/or heat to generate free phase oil. The free phase oil can then be removed using skimming techniques (EPA 1997f; Metcalf & Eddy 2003).

5.2 POTENTIAL REMEDIATION TECHNOLOGIES FOR PCBS IN THE PETROLEUM HYDROCARBON GROUNDWATER PLUMES

The remediation of PCBs that are co-located with free phase product and SVOCs (diesel, heavy oil, and cPAHs) in groundwater has been evaluated and the available technologies have been assembled into the following general response actions: monitoring, institutional controls, containment, *in situ* treatment, groundwater extraction and on-site treatment.

These general response actions and their associated technologies for remediation of PCBs in groundwater are similar to the technologies applicable to SVOCs in groundwater and are discussed in Section 5.2 and summarized in Table 5-2a through 5-2c. A technology that is only applicable to PCB remediation is chlorine scrubbing. This technology is evaluated in Table 5-2b. The scrubber is used for the treatment of PCB off-gas. This technology is described in more detail in Section 3.3.

The EPA ASR database identifies 27 CERCLA sites where technologies are specified in RODs for treating groundwater containing PCBs and other contaminants. Five vertical barrier, 1 DVE technology, 21 pump and treat sites were identified. Vertical barrier technologies are judged to be inappropriate at the site because of the depth to groundwater and the lengthy boundary along the Spokane River.

The CERCLA sites where the pump and treat approach was used had other contaminants in the groundwater, such as VOCs in addition to PCBs. At these sites, the *ex situ* treatment plant usually had unit operations to address these other contaminants (i.e., air stripper for VOCs) but added a polishing GAC bed that was installed to remove PCBs. For example, at the Sangamo Weston/Twelve-Mile CERCLA site in South Carolina, the groundwater treatment system designed to treat VOCs and PCBs has an air stripper, filtration, and carbon adsorption equipment. This system treated approximately 155 million gallons of groundwater through 2005. This has resulted in the removal of approximately 1,140 pounds of chlorinated solvents and 12.3 pounds of PCBs, primarily Aroclor 1248. Based on analytical data collected in 2005, it appears that the majority of PCB removal is occurring in the carbon beds (RMT 2006).

Technologies that are designed to solely remediate low concentrations (ppb range) of PCBs in groundwater to achieve the very low PCB SL concentrations established for the Kaiser site could not be found after searching sources mentioned above (CLU-IN, FRTR, ASR, etc.,). However, the F. O'Connor CERCLA site used DVE and passive methods to recover separate phase PCB oil from the water table. From 1992 to 2007, 125 gallons of oil containing PCBs were recovered (EPA 2007). A review of GAC and polymeric adsorption literature did identify some locations where GAC and polymeric adsorption (after significant pre- and post-treatment to remove oil and suspended and colloidal particulates) technologies were able to achieve effluent PCB concentrations that were less than 1 ppb. These technologies are described in Section 6.

At the General Electric site in Spokane, Washington, exposure to and migration of PCB-impacted water was limited by institutional controls and long-term monitoring. In addition, soils in contact with groundwater were grouted in 1996 to decrease their mobility and reduce PCB concentrations in groundwater and a significant volume of these soils were removed, stockpiled, and vitrified on-site that same year (Ecology 2008b).

5.2.1 Location of PCB Plumes

Groundwater containing PCBs at concentrations above SLs was found in the Oil House, Wastewater Treatment, and Remelt/Hot Line areas of the site as shown on Figure 5-8 in the Final Groundwater RI (Hart Crowser 2012a). Three PCB plumes are currently present at the site. Two plumes are co-located with the free phase product, TPH-diesel, TPH-heavy oil, and cPAH constituents that are present in the Oil House and Wastewater Treatment areas. A third PCB plume appears to emanate from the Remelt/Hot Line.

5.3 SCREENING TECHNOLOGIES FOR REMEDIATING PETROLEUM HYDROCARBON GROUNDWATER PLUMES

In this section, the technologies identified in Sections 5.1 and 5.2 are screened using the approach summarized in Section 2.4. The physical aspects of the Kaiser facility, the chemical properties of COCs and the properties of the smear zone soil in the AOCs are identified and used to eliminate certain technologies from further consideration in Section 5.3.1.

The technologies that are judged to be potentially appropriate for the physical and chemical features of the Kaiser AOCs are evaluated for implementability and reliability (if implementable), in Section 5.3.2. Cost-effectiveness was not assessed as part of this FSTM. Cost-effectiveness will be used to further screen the implementable and reliable technologies identified by the FSTM (where appropriate) as part of the overall feasibility study for the Kaiser Facility.

Many technologies judged reliable for treating individual SVOCs (heavy oil, diesel, and cPAHs) also were judged reliable for treating PCBs that are co-located with SVOCs. These common technologies are identified in Section 5.3.2.3 and will form the core of the remedial alternatives developed in Section 5.5.

5.3.1 Site-Specific Technical Constraints for Technologies

The physical and chemical features of the Kaiser Facility influence the selection of the remedial technologies identified in Sections 5.1 to 5.2. There are three groups of physical factors that influence proper selection of a remedial technology: (1) factors associated with the active use of the facility; (2) factors limiting access to contaminated soil; and (3) site-specific geologic and hydrologic conditions promoting or prohibiting the applicability of certain remedial technologies. These physical factors were discussed in Section 2.5.1 and summarized in Table 2-3. The factors that constrain the use of near-surface and deep vadose zone soil treatment technologies also constrain the use of technologies appropriate for treating groundwater.

In addition to these physical factors, various chemical attributes of the AOC COCs influence the selection of a remedial alternative. A summary of these chemical properties was provided in Section 2.5.1.4 and summarized in Table 2-4 (Physical/Chemical Properties of COPCs). The chemical properties of the AOC COCs that will exert the greatest influence on the selection of technologies are discussed below.

SVOCs

In general, diesel and heavy oil are liquid at room temperature and are less dense than water. Petroleum mixtures may contain constituents that have significant solubility in water, but as a whole the mixtures tend to be sparingly soluble. In general, the shorter chain or more polar constituents exhibit greater aqueous solubility, and the longer chain or less polar constituents have lower or negligible solubility. Similarly, petroleum hydrocarbon mixtures contain components with a range of volatilities, as determined by their respective vapor pressures. Generally, the lighter end and less polar components exhibit greater vapor pressures and thus a greater tendency to evaporate.

The petroleum hydrocarbons historically used at the Facility are generally sparingly soluble in groundwater, with maximum dissolved concentrations expected to be less than 10 mg/L (Lu and Polak 1973, Shiu et al. 1990). Observed dissolved hydrocarbon concentrations at Kaiser range from non-detect (at reporting limits as low as 0.1 to 6 mg/L) in samples from wells with no product accumulation or sheen, up to 92 mg/L in wells with sheen reported, and up to 950 mg/L in samples from wells with free phase petroleum accumulations.

It should be noted that the higher concentrations may indicate the likely presence of globules, emulsified oil, or silt with sorbed oil in the sample, which is possibly a consequence of the sampling procedure. This is especially true for samples collected with bailers.

PCBs

PCBs in groundwater are present in the Remelt/Hot Line area, the Oil House area, and the Wastewater Treatment area. The PCBs present in the Oil House and Wastewater Treatment areas are generally thought to be associated with the free phase petroleum in these areas, rather than being dissolved in groundwater (Hart Crowser 2012a). The Oil House and Wastewater Treatment plumes are associated with petroleum hydrocarbons whereas the Remelt/Hot Line plume is notable for the absence of petroleum hydrocarbons.

PCBs, as a group of chemicals, exhibit high thermal stability; strong resistance to oxidation, acids, bases, and other chemical reagents; as well as excellent electrical insulating (dielectric) properties. They generally have low water solubility and vapor pressure and strongly adsorb to organic matter. Properties of individual chlorinated biphenyl congeners are most strongly influenced by their degree of chlorination and molecular weight. Solubility and vapor pressure both decrease with increasing chlorine content. Water solubilities have been reported (Monsanto 1972) for Aroclors 1242 (200 μg/L), 1248 (100 μg/L), 1254 (40 μg/L), and 1260 (25 μg/L) although results are probably biased due to selective dissolution of only the lower molecular weight components in the Aroclor mixtures.

Aroclors are denser than water. While pure chlorinated biphenyls are solids at room temperature, Aroclor mixtures are fluid oils (1221, 1232, 1242, 1248), viscous liquids (1254), or sticky resins (1260 and 1262).

For groundwater, the site-specific physical factors present at the Kaiser Facility used to screen the technologies described in Sections 5.1 to 5.2 are similar to the factors that affected the application of technologies to deep vadose zone soil. These factors were used together with the chemical properties of diesel, heavy oil, and cPAHs to identify the set of available technologies that that are potentially applicable to SVOCs in groundwater. The outcome of the physical/chemical screening of these comparable technologies is presented in Table 5-3 (SVOCs). The physical and chemical screening for PCBs is similar to the screening for SVOCs. The similarities are summarized in Table 5-4a. Table 5-4b presents additional technologies where the physical/chemical screening of groundwater technologies for PCBs differs from the screening of groundwater technologies for SVOCs.

For free phase product recovery involving groundwater or groundwater extraction, technologies and physical and chemical screening criteria are presented in Table 5-5. All of these potentially applicable technologies were evaluated further in Section 5.1.4.

5.3.2 Screening of Remedial Technologies for COCs in the AOCs

This section evaluates those technologies not rejected on the basis of the site-specific physical/chemical constraints (summarized in Tables 5-3, 5-4 and 5-5) for implementability and reliability using the approach shown on Figure 2.2 and described in Section 2.5.2.

5.3.2.1 Technologies for Remediating SVOCs in Groundwater

Technologies and the associated process options for remediating SVOCs in groundwater are evaluated for implementability in Tables 5-6a through 5-6i and Tables 5-12a through 5-12c.

Each table provides information to justify why each process option should be accepted or rejected for the Kaiser Facility. These tables indicate that the following process options for remediating SVOCs in groundwater are judged to be potentially implementable at the Kaiser Facility.

Technology	**Process Option Accepted**
Monitoring	Protection, Performance, Confirmation
Institutional Controls	Access and Use Restrictions, BMPs
Capping	Asphalt, Concrete, Multilayer
Monitored Natural Attenuation	Monitored Natural Attenuation
Hydraulic Containment	Vertical Wells
In Situ Bioremediation	Enhanced Bioremediation
In Situ Chemical Treatment	Chemical Oxidation
***Ex Situ* Treatment Technologies**	
Adsorption	Granular Activated Carbon
Chemical Treatment	Chemical/UV Oxidation
Aerobic Bioremediation	Various - Aeration Basin, Constructed Wetlands, Bioreactors, Trickling Filters

Suspended Solids Removal (as a pre-treatment step)	Precipitation, Sedimentation, Filtration

Off-Gas Treatment Technologies

Adsorption	GAC
Thermal Oxidation	Catalytic Oxidizers
Advanced Oxidation	Photocatalytic Oxidation

Free Phase Product Recovery Technologies

Free Phase Product Removal (With groundwater extraction)	Water Table Depression, DVE/MPE
Free Phase Product Recovery	Oil-Water Separation (API Separator, Dissolved Air Flotation)

The technologies and associated process options judged to be potentially implementable are evaluated for reliability in Tables 5-7a through 5-7i and 5-13a through 5-13c. Advanced oxidation was rejected on the basis of reliability since this process option is still in the development stage and has not been successfully operated at full scale in a physical and chemical setting similar to that at the Kaiser Facility (refer to Table 2-9h).

Tables 5-8 and 5-14 (free phase product) summarize the technology screening process and the technologies and process options judged to be potentially appropriate for the treatment of diesel- and heavy oil-range contaminants in groundwater at the Kaiser Facility.

5.3.2.2 Technologies for Remediating PCBs in the Petroleum Hydrocarbon Plumes

Technologies and the associated process options for remediating PCBs associated with petroleum-contaminated groundwater in the AOCs are evaluated for implementability in Tables 5-9a through 5-9f. Each table provides information to justify why each process option should be accepted for further consideration or rejected for the Kaiser Facility.

These tables indicate that some process options selected as potentially implementable for SVOCs (institutional controls, monitoring, hydraulic containment, and suspended solids removal) are judged to be potentially implementable for PCBs that are co-located with SVOCs in groundwater at the Kaiser Facility.

The technologies and associated process options judged to be potentially implementable are evaluated for reliability in Table 5-10. Advanced oxidation was rejected on the basis of reliability since this process option is still in the development stage and has not been successfully operated at full-scale in a physical and chemical setting similar to that at the Kaiser Facility (refer to Table 2-9h).

Table 5-11 summarizes the technology screening process and the technologies and process options judged to be potentially appropriate for the treatment of PCBs that are co-located with SVOCs in groundwater at the Kaiser Facility.

Section 6 discusses additional technologies that may be applicable to the low concentration, colloidal PCBs that are found in the groundwater plume that originates in the Remelt/Hot Line area of the site.

5.3.2.4 Remediation Technologies Common for Diesel, Heavy Oil, cPAHs, and PCBs

The technologies accepted for further consideration for the remediation of SVOCs and PCBs that are co-located with SVOCs in groundwater are listed in Table 5-8 and 5-14 and include monitoring, institutional controls, monitored natural attenuation, capping, *in situ* treatment (bioremediation and chemical oxidation), and *ex situ* treatment (GAC adsorption, chemical/UV oxidation, aerobic biological treatment).

There were additional common response actions for SVOCs and PCBs that were co-located with free phase product:

- Free phase product removal with groundwater extraction (water table depression and DVE/MPE); and

- Free phase product recovery (API separator, dissolved air floatation).

5.4 DESCRIPTION OF AREAS OF CONCERN FOR THE PETROLEUM HYDROCARBON GROUNDWATER PLUMES

The AOCs for the petroleum groundwater plumes at the Kaiser Facility are those areas that contain COCs (refer to Table 1-2) at concentrations above SLs established for groundwater at the site. These groundwater AOCs are distinguished from the Remelt/Hot Line area PCB groundwater plume that is not associated with petroleum hydrocarbons. The Remelt/Hot Line PCB groundwater plume is evaluated in Section 6.

The remedial objectives for the petroleum groundwater plumes are summarized in terms of COCs, SLs and POCs in Section 1. As discussed in Section 4, FPP was present in the Oil House and Wastewater Treatment areas of the Facility in 2008 (Hart Crowser 2012a). Treatment of areas with FPP is evaluated in Section 4 along with technologies applicable to treating smear zone soils. Several technologies applicable for petroleum impacted groundwater are also applicable in treating FPP impacted areas and are discussed in Section 5.1.5.

This FSTM has divided the petroleum groundwater plume into four general operating areas; Oil House, Oil Reclamation, Cold Mill, and Wastewater Treatment areas. The location of the petroleum groundwater plumes are depicted on Figure 5-1, with the COCs in each of the four AOCs, summarized in Table 5-1. A more detailed summary of recent diesel, heavy oil, cPAH, and PCB groundwater data for each AOC is provided in Figures 5-2 through 5-5:

- Figure 5-2: Diesel/Heavy Oil and Free Phase Petroleum in Groundwater, West Area – 2008;
- Figure 5-3: Diesel/Heavy Oil and Free Phase Petroleum in Groundwater, East Area – 2008;
- Figure 5-4: Total PCB Concentrations Associated with Petroleum in Groundwater, West Area - Most Recently Measured; and
- Figure 5-5: Total PCB Concentrations Associated with Petroleum in Groundwater, East Area - Most Recently Measured.

The boundaries of these AOCs are based on 2008 groundwater monitoring data for the majority of wells and COCs evaluated. In the case of PCB plumes associated with petroleum, the most recent data for a well was used if a particular well was not tested for PCBs in 2008. This was done to provide a more conservative estimate of the areal extent of PCBs in groundwater as several wells in and around the AOCs did not have 2008 data for PCBs. Areas of groundwater petroleum SL exceedances (diesel- and heavy oil-range hydrocarbons) included the smaller plumes of PCB groundwater SL exceedances, and FPP in the Oil House and Wastewater Treatment areas. The groundwater within the petroleum groundwater AOCs is currently being contained at least in part by the IRM discussed in section 5.1.1.

There were also exceedances of SLs for metals and cPAH in these AOCs (Hart Crowser 2012a). Elevated levels of arsenic, manganese, and iron in the groundwater within the petroleum plumes are thought to be associated with the petroleum-induced reducing conditions that mobilize naturally occurring metals in groundwater. SL exceedances of cPAHs are associated with the diesel and heavy oil petroleum. Therefore, the AOCs established in this Section focus on petroleum in groundwater and PCBs associated with the petroleum. Metals and cPAHs are judged to be incidental COCs in the petroleum groundwater plumes that will be remediated in conjunction with the treatment of the petroleum groundwater plumes.

5.4.1 Hydraulic Containment of TPH Groundwater Plume AOCs

Based on soil data, the thickness of the smear zone was shown to be approximately 10 to 12 feet. In establishing the petroleum groundwater plume AOCs (refer to Section 4.5), it was conservatively assumed the top 20 feet of groundwater is impacted by petroleum. With the vertical boundary and the areal extent of the AOCs defined, the next step in evaluating the petroleum groundwater AOCs was to estimate the volumes of groundwater that may require treatment.

To provide this estimate, capture zone analysis was performed to determine the hydraulic containment pumping rates for each of the TPH plumes. This capture zone analysis included the 2003 IRM scenario. The capture zone analysis for each petroleum groundwater plume included the placement of 1 to 3 hypothetical extraction wells. The pumping rates estimated by the capture zone analysis were shown to also contain PCBs, FPP, and incidental COCs within the greater petroleum groundwater plumes. A capture zone in this context is equivalent to the “zone of hydraulic containment.” If a contaminant plume is hydraulically contained, contaminants moving with the groundwater will not spread beyond the capture zone. Detailed modeling using the Kaiser groundwater model and the current IRM configuration and potential adjustments to either augment, or replace the current IRM will be included in the overall feasibility study.

Using the site-specific groundwater model, one or two extraction wells (depending on the size and shape of the plumes) were assigned to the leading edge of each of the four TPH plumes to provide hydraulic containment. Particle tracking was used to evaluate the capture zone of the extractions wells. This simulates simple advective migration of particles through the groundwater flow regime. Clouds of particles corresponding to the footprint of each plume were released at the beginning of the simulation and allowed to migrate toward the extraction wells.

The pumping rate was adjusted until all the particles were captured by the extraction well(s) thus indicating hydraulic containment of an AOC. The result of this analysis indicates that pumping approximately 13 million gallons per day (mgd) would be necessary to hydraulically contain the four TPH plumes depicted on Figure 5-1. Details of the capture zone analysis performed on the petroleum groundwater plume AOCs are presented in greater detail in Appendix

E. The pumping rates to achieve hydraulic containment for each plume are summarized in Tables E-1 and E-7.

Using the 2008 sampling data and the calculated pumping rates for each TPH groundwater plume AOC, an estimate of the mass of COCs contained in the volume from one day of pumping was determined to provide a quantitative comparison of the groundwater impacts in each AOC. Average concentrations for each COC were determined in each of the AOCs using the data from the 2008 quarterly monitoring events with the exception of PCBs, as noted above. All data for each well within an AOC, and the COCs evaluated, was used in calculating the average COC concentration. One half of the reporting limit was used for non-detect samples. These estimated average concentrations are listed in Table 5-15.

The calculation of one day's mass of COCs at hydraulic containment pumping rates assumes that the volume of water pumped from an AOC is impacted by COCs at concentrations represented by the calculated average concentrations of COCs within each AOC. These quantities represent a rough order of magnitude (ROM) estimate of the contaminant load in the TPH groundwater plume AOCs. Nonetheless, it was judged that the information in Tables 5-15, 5-16, and E-8 provide useful insights into the relative distribution of COCs (e.g., mass of TPH vs. mass of PCBs, quantity of a COC in the Wastewater Treatment area vs. the Oil House area, etc.,) in each petroleum groundwater plume.

Using this approach, the total mass of contaminants in the four petroleum groundwater plume AOCs that would be contained in the approximate 13 million gallons pumped per day to maintain hydraulic containment is approximately 3,200 pounds.

Approximately 84 percent of this groundwater contamination is diesel- and heavy oil-range hydrocarbons. PCBs represent the next highest mass fraction of COCs present in the four TPH groundwater plume AOCs with an estimated 350 pounds present in a one-day pumping volume. Arsenic and cPAHs combined make up approximately 150 pounds of the total mass of contaminants in the four TPH groundwater plume AOCs. As detailed below, this figure is considered to significantly overestimate the current amount of PCBs remaining in site groundwater given FPP removal efforts conducted since the mid 1990s.

The AOCs for FPP are described in Section 4 and are shown on Figures 5-1 through 5-3. The metals and cPAHs in the petroleum groundwater plume AOCs are considered incidental COCs, which will be remediated in conjunction with the remediation of the petroleum plumes. Nonetheless, the calculated average concentrations and estimated quantities present in each groundwater AOC are presented in Tables 5-15, 5-16, and E-8.

Section 5.4.3 presents a discussion on the use of the calculated hydraulic containment pumping rates to estimate cleanup times for the petroleum groundwater plume AOCs.

5.4.2 TPH Groundwater Plume Areas of Concern

This section describes the groundwater AOCs associated with petroleum-contaminated groundwater plumes. Diesel- and heavy oil-range hydrocarbons have been identified as COCs in groundwater in four distinct locations: the ORB, Cold Mill/Finishing, Oil House, and Wastewater Treatment areas. Sources of petroleum in the groundwater were discussed in Sections 1 to 4. As with the soil AOCs, petroleum in the diesel- and heavy oil-ranges are the most pervasive COCs in the groundwater on this site (refer to Table 5-16), making up approximately 84 percent of the COC loading in the petroleum hydrocarbon groundwater plumes.

The AOCs depicted on Figures 5-1 through 5-5 were developed by using a “half the distance” rule to define a boundary between monitoring wells with COPCs at concentrations above SLs and wells where COPCs are known to be present at concentrations below SLs. The petroleum groundwater plume AOCs differ from the 2008 inferred extents of COCs presented in the Final Groundwater RI (Hart Crowser 2012a) in that the petroleum groundwater plume AOCs were drawn to combine both diesel- and heavy oil-range exceedances into one area.

The main focus in addressing these areas is to examine technologies to address petroleum and PCBs associated with petroleum in the groundwater in the several distinct plumes across the site. As discussed above, cPAHs and metals are considered incidental COCs in petroleum AOCs in that groundwater concentrations of these COCs would be expected to be either directly or indirectly lowered below SLs with the removal of the petroleum.

Elevated cPAHs in the groundwater at Kaiser are a result of the presence of heavier range petroleum hydrocarbons and the treatment of this petroleum in the smear zone soil and groundwater would directly reduce the concentration of cPAHs. Elevated concentrations of dissolved metals in the petroleum groundwater plume AOCs are related to the reducing conditions created by the presence of hydrocarbons in the groundwater and the smear zone. Metals concentrations in groundwater are expected to be indirectly lowered with the continued natural breakdown or physical removal of petroleum and the subsequent increase in the redox potential.

With the extremely low SL for arsenic, 0.018 µg/L, only one groundwater sample out of 110 samples collected, is below the arsenic SL criteria across the Kaiser site during 2008 sampling. There are also scattered SL exceedances for iron and manganese in wells located in the ORB, Cold Mill, and Oil House petroleum groundwater plume AOCs during 2008. Four groundwater samples collected in the Oil House and one sample in the Cold Mill petroleum groundwater plume AOCs exceeded the cPAH SL of 0.0028 µg/L during 2008 quarterly monitoring. There were no cPAH SL exceedances in the ORB or Wastewater petroleum groundwater plume AOCs during 2008.

Under the above assumptions, and following an examination of current groundwater data, AOCs were not defined for metals or cPAHs within the greater petroleum groundwater plume AOCs. Nonetheless, cPAHs and metals COCs were carried forward in mass estimate calculations as detailed in Tables 5-15 and 5-16.

The following subsections describe how the diesel and heavy oil groundwater plume AOCs shown on Figures 5-1 though 5-5 were defined. More comprehensive descriptions of all AOCs examined in the FSTM are provided in the Final Groundwater RI (Hart Crowser 2012a).

5.4.2.1 Oil Reclamation Building (ORB) Area Petroleum Groundwater Plume AOC

The petroleum groundwater plume AOC in the ORB area is based on monitoring results from two wells, HL-MW-2 and HL-MW-20S, which had diesel and heavy oil exceedances in groundwater during the 2008 sampling round. PCBs were not detected in these wells during 2008, with the exception of one estimated detection (J flagged) in HL-MW-2 during January 2008. Therefore, the groundwater in the ORB area is not considered to be an AOC for PCBs associated with petroleum products. Free phase petroleum was also not detected in the ORB area during 2008.

The highest levels of petroleum were detected during the October 2008 monitoring round when the water table is typically at its lowest elevation for the year. Nearby wells were non-detect for diesel and heavy oil during 2008. The area of the ORB petroleum plume is estimated to be 33,000 square feet (Figure 5-2) requiring an estimated pumping rate of 1.5 mgd to hydraulically contain the plume. Based on 2008 data, the average concentrations of diesel and heavy oil in this AOC were 3 mg/L and 4.5 mg/L, respectively. Assuming that these average diesel and heavy oil concentrations were representative of a one-day hydraulic containment pumping volume of 1.5 million gallons, the total mass of TPH contained in this volume would be approximately 90 pounds.

5.4.2.2 Cold Mill Petroleum Groundwater Plume AOC

The Cold Mill petroleum groundwater plume AOC is defined by elevated diesel- and heavy oil-range hydrocarbons in four wells in the east end of the Cold Mill (Figure 5-3) during the 2008 monitoring events. Trace FPP was detected in well CM-MW-03S during 2008 monitoring. Heavy oil was detected in a single sample from CM-MW-03S at a concentration of 3 mg/L collected during October 2008 but was non-detect in the other three wells within this AOC during 2008. The average heavy oil concentration for this AOC (including half the reporting limit for non-detect samples) is 0.6 mg/L. Though the average heavy oil concentration is below the SL of 0.8 mg/L, this AOC was retained to account for the elevated concentrations detected in CM-MW-03S. Diesel range hydrocarbons, identified as Kensol oil, were detected in wells CM-MW-01S, CM-MW-02S, CM-MW-03S, and CM-MW-07S during April and October monitoring round with an average concentration of 2.6 mg/L.

As shown on Figure 5-5 of the Final Groundwater RI (Hart Crowser 2012a), PCBs have been detected in four Cold Mill wells during initial groundwater monitoring in this area at low estimated (J flagged) concentrations. Specifically, four out of 101 samples collected in Cold Mill wells since 2004, had estimated detections ranging from 4.3 to 17 ng/L. The most recent detection of PCBs in a Cold Mill area well was from CM-MW-8S in October 2006 with an estimated concentration of 4.8 ng/L. This well has been sampled 4 times since this estimated detection with all results non-detect for PCBs. Similarly, a CM-MW-6S sample collected in July 2006 had an estimated detection of 6.3 ng/L; 5 samples collected since then have been non-detect for PCBs. Samples from CM-MW-2S and CM-MW-3S have not contained detectable concentrations of PCBs since 2004 with 11 non-detect samples collected from both wells since that time. Moreover PCBs have never been detected in downgradient protection wells MW-8 (17 years of data), MW-9 (17 years of data), and MW-13 (10 years of data). Based on these data PCBs are not considered to be a COC in Cold Mill area groundwater.

The area of the Cold Mill TPH plume is estimated to be 101,000 square feet (Figure 5-3) requiring an estimated pumping rate of 2.3 mgd to hydraulically contain the plume. Assuming that the average diesel concentration and heavy oil concentrations are representative of a one day hydraulic containment pumping volume of 2.3 mgd, the total mass of TPH contained in this volume would be approximately 60 pounds.

5.4.2.3 Oil House Petroleum Groundwater Plume AOC

At an estimated 12 acres, the Oil House petroleum groundwater AOC is the largest hydrocarbon plume on the site, and encompasses the majority of the soil petroleum smear zone AOC discussed in Section 4 and shown on Figure 4-3a. During 2008 there were twelve exceedances of the diesel range SL of 0.5 mg/L with all samples reported as Kensol. Concentrations of Kensol ranged from 0.54 mg/L in OH-MW-13 to 610 mg/L in TF-MW-01. The average Kensol concentration in the Oil House TPH groundwater plume AOC is 63 mg/L. The highest Kensol concentrations in the Oil House AOC were in the vicinity of the Tank Farm, and are co-located with an area of FPP (Figure 5-3).

To hydraulically contain the approximate 12-acre Oil House petroleum plume, an estimated 4.9 mgd pumping rate would be required. Assuming that the average Kensol concentration is representative of a one-day hydraulic containment pumping volume, the total mass of petroleum contained in this volume would be approximately 2,500 pounds of Kensol.

Within the greater Oil House petroleum plume AOC is an apparent plume of elevated PCBs in the groundwater with an estimated area of 1.3 acres (Figure 5-5). The majority of the data shown on Figure 5-5, and used to calculate an average PCB concentration for this plume, was not collected during the 2008 monitoring events but rather represents the most recent data for wells within the AOC. Some of the data used in calculating the average concentration dates back to 1991 and includes some very high concentrations of PCBs collected from wells which historically had the highest levels of FPP (see Figure 5-9 from the Final Groundwater RI [Hart Crowser 2012a]) as hydrophobic PCBs will tend to accumulate in the floating hydrocarbon plumes. Use of this data represents a very conservative approach.

Ongoing remediation efforts since the 1990s have focused on the reduction of the FPP plume in the Oil House area and therefore many of the wells shown on Figure 5-5 with reported PCB detections have not been tested for PCBs since the early to mid 1990s. Using the most recent data for Oil House area wells, the calculated average PCB concentration for this AOC is 36 mg/L. It is expected that with the ongoing FPP removal efforts and the noted reduction in the size of FPP plume during the past twenty years, that the calculated average PCB concentration (36 mg/L) for this AOC is judged to represent a significant overestimate of the current concentration of PCBs in the area.

To hydraulically contain the approximate 1.3 acre Oil House PCB plume, an estimated 935,000 gallons per day (gpd) pumping rate would be required. Assuming that the average PCB concentration of 36 mg/L is representative of a one-day hydraulic containment pumping volume, the total mass of PCBs contained in this volume would be approximately 270 pounds. Again, the calculated average concentration based on most recent data is likely several orders of magnitude above actual current conditions due to the ongoing removal of FPP in this area. The only current data (2008) used in calculating the average Oil House PCB plume concentration was from wells OH-MW-24 and OH-MW-26 which had an average concentration of 1.1 µg/L. Applying this concentration to the estimated pumping rate would result in a one-day removal of 0.008 pound or 3.6 grams of PCBs. The Oil House PCB AOC is contained within the greater petroleum groundwater plume AOC discussed above and remediation efforts may focus on the larger petroleum impacted area.

The monitoring data, including well numbers and dates of sample collection, used in the calculation of average concentrations in the AOC, is presented in Table 5-15.

5.4.2.4 Wastewater Treatment Area Petroleum Groundwater Plume AOC

With an estimated area of 11 acres (Figure 5-2), the Wastewater Treatment area petroleum groundwater plume AOC is the second largest TPH groundwater plume on this site. This AOC covers the Industrial Wastewater Treatment (IWT) plant area and is similar in size to the petroleum smear zone soil AOC discussed in Section 4 and shown on Figure 4-4. However, the groundwater AOC also extends to the west to encompass the heavy oil exceedance in well WW-MW-18 during October 2008.

This large AOC is based on four exceedances of diesel and heavy oil groundwater SLs during 2008 in wells spread over a rather large geographical area which encompasses the IWT plant. The southern boundary of this AOC is conservatively based on detections of free phase petroleum in wells WW-SK-2 and WW-MW-3 as these wells were not tested for diesel and heavy oil during 2008.

Hydraulic containment of this petroleum plume would require an estimated pumping rate of 4.2 mgd. Based on 2008 data the average concentration of diesel and heavy oil are 2.3 mg/L and 0.60 mg/L respectively. Assuming that these concentrations would be representative of a one day pumping volume, the total mass of petroleum products contained in this volume would be approximately 100 pounds.

An apparent plume of elevated PCBs in the groundwater is present within the greater Wastewater Treatment area petroleum plume AOC (Figure 5-4). Only one of the four samples (WW-MW-8 from October 2008 with a concentration of 0.0063 μg/L) that define this AOC, and used to calculate the average PCB concentration for this plume, is representative of current conditions within the AOC. The remaining data used in calculating the average PCB concentration are representative of conditions prior to FPP removal efforts in the Wastewater Treatment area. The highest detections of PCBs presented on Figure 5-4 are from samples collected from wells WW-MW-6 and WW-MW-13 in 1991. These wells historically had some of the highest levels of FPP in the Wastewater Treatment area (see Figure 5-9 from the Final Groundwater RI [Hart Crowser 2012a]) and have not been tested for PCBs since 1991.

Using the most recent data for the Wastewater Treatment area wells, the calculated average PCB concentration for this AOC is 6.2 mg/L. The calculated average PCB concentration for this AOC is judged to represent a significant overestimate of the current concentration of PCBs in the area as the FPP plume in the Wastewater Treatment area has been reduced considerably over the past twenty years (Hart Crowser 2012a).

To hydraulically contain the approximate 2.5 acre Wastewater Treatment area PCB plume, an estimated 1.65 mgd pumping rate would be required. Assuming that the average PCB concentration of 6.2 mg/L is representative of a one day hydraulic containment pumping volume, the total mass of PCBs contained in this volume would be approximately 82 pounds. Similar to the Oil House PCB plume, this removal mass may significantly overestimate the amount of PCBs currently remaining in this AOC. Applying the current (October 2008) concentration of 0.0063 μg/L from WW-MW-8 to this AOC, would result in a one-day pumping removal of 0.04 mg of PCBs.

5.4.3 Estimated Cleanup Times for the Petroleum Groundwater Plume AOCs

The time required to meet the groundwater cleanup goals is estimated using the number of pore volumes of groundwater that must be pumped from the contaminated zone to attain cleanup concentrations. One pore volume equals the total amount of water stored within a particular petroleum groundwater AOC. The mixed reactor or batch flush model (Brusseau 1996; EPA 1988c; National Research Council 1994) was used to estimate how many times the contaminated aquifer has to be flushed to meet the cleanup goals.

The batch flush model uses several simplifying assumptions to estimate cleanup times. The model assumes that the sorption/desorption process is the only treatment process that is underway, that the process is linear and that the reaction is virtually instantaneous. The batch flush model assumes a simple adsorption of contaminant between the soil and water phases in the aquifer, and that incoming water, free of contaminant, mixes completely within the aquifer in a time interval that is very small relative to the hydraulic residence time. The batch flush model further assumes that there are no continuing sources of contamination such as NAPL in the unsaturated zone.

In general, the cleanup time estimates generated using the batch flush model should be considered to be the minimum time required for a sorption/desorption process to meet cleanup objectives because the model does not account for the effect of heterogeneities, the presence of FPP, the nonlinear sorption processes, and the production of leachate from the original source of contamination. Other petroleum remediation processes such as natural attenuation, enhanced bioremediation or chemical treatment (oxidation, reduction pH adjustment) would tend to reduce the restoration time frame significantly below the estimate provided by this model.

The calculations were run in two ways by fixing particular variables: (1) estimate pumping rates to achieve cleanup of the TPH plumes assuming a 30-year treatment period of aquifer flushing; and (2) estimate the number of years to achieve cleanup from aquifer flushing, assuming the minimum pumping rates for hydraulic containment.

Oil House Plume

The footprint of the Oil House plume is 5.2 x 10^5 ft^2 The pumping rate to hydraulically contain the Oil House plume is estimated to be nearly 3,400 gpm. The estimated pumping rate to achieve cleanup of the Oil House plume within 30 years is 451,000 gpm. The estimated time to cleanup, assuming the pumping rate required for hydraulic containment, is 25,000 years.

Wastewater Treatment Area Plume

The footprint of the Wastewater Treatment area plume is 4.7 x 10^5 ft^2 The pumping rate to hydraulically contain the Wastewater plume is estimated to be 2,900 gpm. The estimated pumping rate to achieve cleanup of the Wastewater plume within 30 years is 59,000 gpm. The estimated time to cleanup, assuming the pumping rate required for hydraulic containment, is 3,650 years.

Cold Mill Plume

The footprint of the Cold Mill plume is 1 x 10^5 ft^2 The pumping rate to hydraulically contain the Cold Mill plume is estimated to be 1,600 gpm. The estimated pumping rate to achieve cleanup of the Cold Mill plume within 30 years is 23,700 gpm. The estimated time to cleanup, assuming the pumping rate required for hydraulic containment, is 6,800 years.

Oil Reclamation Building Plume

The footprint of the ORB plume is 3.3×10^4 ft^2. The pumping rate to hydraulically contain the ORB plume is estimated to be 1,040 gpm. The estimated pumping rate to achieve cleanup of the ORB plume within 30 years is 5,100 gpm. The estimated time to cleanup, assuming the pumping rate required for hydraulic containment, is 4,600 years.

The estimated time to cleanup for all AOCs is very long (centuries), and the pumping rates needed to contain the plumes in the AOCs are very high. This result provides an indication that remediation of the petroleum plumes may require significant investment in equipment, operating costs and time.

Appendix E contains a complete discussion of the batch flush model and the assumptions used and built into the model.

5.4.4 Industrial Wastewater Treatment (IWT) Plant

Kaiser operates both a sewage treatment facility (average flow of 40,000 GPD) and an IWT plant. The IWT plant is designed to remove oil, metals, and other organic contaminants from process waters that are collected in the ORB. Once the oil and other contaminants are removed, the remaining water is filtered and conveyed to the wastewater lagoon for eventual discharge to the Spokane River. The IWT plant, or modifications of the current IWT plant processes, may play a role in the treatment of any extracted groundwater that is ultimately treated at the site. A process flow diagram of the IWT plant is shown on Figure 5-6.

5.4.4.1 Oil Reclamation Building

The ORB acts as the main collection area for spent rolling coolants (emulsified oils) and other oily wastewater piped from various areas of the mill. Spent coolants and waste oil streams are collected in several tanks located in this building.

5.4.4.2 Cooker Circuit

Wastewater is transferred from the ORB to the IWT plant via an aboveground pipeline. The wastewater is preheated through a heat exchanger prior to entering the cooker. In the cooker, live steam and sulfuric acid are used to heat the oil-water emulsion to break up the emulsion.

The heated, broken emulsion passes through the tube side of the heat exchanger to preheat incoming wastewater feed prior to entering a parallel set of oil-water separators. The oil phase from the separators is transferred to the coagulator for further oil-water separation. The oil from the coagulator is transferred to the recovered oil tank and can be reprocessed to remove more water and improve oil quality. The water phases from the oil-water separators and the coagulator are transferred to the process pits.

5.4.4.3 Wastewater Processing

The four process pits are operated in series to provide process surge capacity/flow equalization and to provide additional oil separation. Wastewater is transferred from the process pits to the neutralization tank where lime is added for pH control and to precipitate metals. From the neutralization tank, wastewater flows into the clarifier where precipitated metals settle. Clarifier scum is returned to the process pits and underflow solids are processed by a vacuum drum filter. Sludge is conveyed to a roll-off container for off-site disposal and the water phase is returned to the clarifier. The clarifier overflow is filtered through a bank of sand bed filters. Filter backwash is transferred back to the process pits. Treated wastewater from the sand filters flows to the lagoon.

5.4.4.4 The Lagoon System

The lagoon has a capacity of 5.6 million gallons. The lagoon receives treated water from the sand bed filters, effluent from the sewage treatment plant, contact and non-contact cooling water, stormwater collected from the mill area, and backwash from the black walnut shell filter (BWSF) system. The purpose of the lagoon is to provide surge capacity and additional solids settlement. Effluent from the lagoon is conveyed to the BWSF where suspended solids and remaining dissolved organic contaminants are removed.

5.4.4.5 Black Walnut Shell Filter (BWSF) System

As the final polishing step, wastewater from the lagoon is pumped through the BWSF system. Filter backwash from this system is transferred to the backwash tank. After being held for 100 minutes, all but 5,000 gallons from the backwash tank's mid-level is transferred back to the lagoon. The settled material and any floating material are transferred back to the process pits for additional treatment.

5.4.4.6 Operations

Filtered water from the BWSF system, after being combined with groundwater from an active groundwater remediation activity (WW-EW-2) is discharged to the

Spokane River under Kaiser's National Pollutant Discharge Elimination System (NPDES) permit. WW-EW-2 is part of the existing IRM and is currently used to provide hydraulic containment in the IWT plant area. During 2008, 7.3 mgd was pumped from this well to maintain hydraulic containment.

The long-term average flow through the Industrial Wastewater Treatment System is approximately 70,000 gallons per day based on 12-hour operating days (96 gpm). The highest monthly average flow through the Industrial Wastewater Treatment System is approximately 98,000 gallons per day based on 12-hour operating day (136 gpm). The rated capacity of the IWT plant, with a 24-hour operating day, is approximately 200,000 GPD and is mainly limited by the size of the clarifier.

Kaiser's NPDES permit authorizing the discharge to the Spokane River has effluent limits. It does not place a volume restriction on this discharge but amended Agreed Order 2868 limits the volume that goes through the trace oil filters.

The current IWT plant capacity of about 96 to 136 gpm (0.14 to 0.2 mgd) is approximately 65 to 100 times less than the pumping rate that would be needed to hydraulically contain the petroleum plume groundwater AOCs described above.

The potentially very large pumping rates that a petroleum groundwater treatment system could require (13 mgd), when combined with Kaiser's current groundwater withdrawal, would exceed Kaiser's existing water rights under its current groundwater permit. Under the current groundwater permit, Kaiser is authorized to withdraw 20 million gallons of water per day from the Spokane Valley-Rathdrum Prairie aquifer. Currently, Kaiser is withdrawing about 3 mgd from the river and 13 mgd from the aquifer in support of plant operations and ongoing remediation efforts.

5.5 DEVELOPMENT OF REMEDIAL ALTERNATIVES

The technologies and process options that are potentially applicable to the remediation of the groundwater in the AOCs at the Kaiser Facility are identified in Section 5.2. These technologies and process options were initially screened to account for site-specific technical constraints and for the chemical properties of the COCs in Section 5.3.1. The technologies and process options judged to be potentially implementable and reliable for the remediation of petroleum contaminated groundwater in the AOCs (refer to Section 5.3.2) are assembled into remediation alternatives in this Section. The basis for developing alternatives follows the logic shown on Figure 2-11 and was described in Section 2.7.

5.5.1 Remedial Alternatives for Petroleum Contaminated Groundwater

MTCA requires that a reasonable number of alternatives shall be evaluated taking into account the characteristics and complexity of the facility, including current site conditions and physical constraints (WAC 173-340-350[8][c][i][B]). These factors are discussed in Section 2.5.1.

The technology-based remedial alternatives developed in this section range from Alternative A1 (institutional controls, monitored natural attenuation [MNA], and monitoring) to Alternative A5 (free phase product removal, containment, institutional controls, monitoring, and MNA). The individual COCs that are addressed by each of the alternatives described above are summarized in Table 5-17.

Alternatives A1 and A2

Alternative A1 (institutional controls, MNA, and monitoring) is included since many viable remedies at the Kaiser Facility will contain these elements. Alternative A2 consists of containment (hydraulic, capping), institutional controls, MNA, and monitoring. It adds the additional protection of containment to Alternative A1. Alternatives A1 and A2 are common for all the COC groups (SVOCs, PCBs, and metals). Alternative A2 is considered to be the most practical permanent treatment method for the arsenic, iron, and manganese that are present in the petroleum groundwater plumes. The presence of petroleum in the plumes creates reducing conditions that mobilize the arsenic, iron, and manganese (refer to Section 5.0). The concentration of these metals in the plumes is expected to be reduced as the petroleum COCs are treated by Alternatives A3, A4, and A5.

Alternatives A3 and A4

Alternative A3 adds *in situ* treatment (bioremediation, chemical oxidation) to Alternative A2. The overall feasibility study will identify the appropriate *in situ* treatment technology (e.g., bioremediation or chemical oxidation).

Alternative A4 substitutes *ex situ* treatment (e.g., oil-water separation, suspended solids removal, chemical/UV oxidation, aerobic biological reactors, GAC) for *in situ* treatment of groundwater. The overall feasibility study will identify the most appropriate oil-water separation technology and suspended solids removal technologies. These technologies are likely to be required as pre-treatment of groundwater and FPP extracted from the plume. The overall feasibility study will also identify the appropriate *ex situ* aerobic biological treatment technology (e.g., aerobic bioreactors, fixed film reactors). The overall feasibility study will then identify whether *ex situ* oxidation (chemical/UV oxidation) or aerobic biological treatment is the appropriate *ex situ* treatment technology.

Alternative A4 is considered to be the most practical permanent cleanup alternative for the SVOCs and PCBs that are mixed with SVOCs in the petroleum groundwater plumes.

Alternative A5

Alternative A5 includes free phase product removal, containment, institutional controls, monitoring, and MNA as an addition to Alternatives A3 and A4 for those AOCs (Oil House area, Wastewater Treatment area) where free phase product is currently present. Alternative A5 is considered to be the most practical permanent cleanup alternative for the removal of FPP from the petroleum groundwater plumes.

Applicability and Combination of Multiple Alternatives

Several technology-based alternatives may be applicable for each individual COC. For instance, technology-based alternatives A1, A2, A3, or A 4 could be used individually to remediate the petroleum groundwater plumes. Similarly, a combination of technology-based alternatives A1, A2, or A4 could be used to address SVOCs and/or PCBs that are co-mingled with SVOCs, in the petroleum groundwater plumes. Alternative A5 would be added to Alternatives A1 to A4 for those AOCs where FPP was also present and could be extracted.

The overall feasibility study will evaluate the technology-based remedial alternatives described above to assess whether or not, or to what extent, the alternatives meet the minimum requirements for cleanup action under MTCA (WAC-173-340-360[2]). One outcome of this evaluation will be to identify the most appropriate technology-based alternative(s) for each COC. It is expected that alternatives A1 and A2 will be carried forward for each COC group (SVOCs, PCBs, metals), and that alternative A5 will be carried forward for AOCs that contain FPP along with SVOCs and PCBs. Additionally, it is Kaiser's desire to use the existing IRM infrastructure to the extent possible during implementation of the selected remedial alternative. The current baseline IRM and potential modifications to the IRM will be evaluated during the overall feasibility study.

For SVOCs and mixtures of SVOCs and PCBs, it is expected that the evaluation in the overall feasibility study will differentiate among alternatives A3 and A4 and identify the most appropriate alternative. Similarly, it is expected that the overall feasibility study will identify the most appropriate alternative among the potentially applicable alternatives for metals (A1 and A2). The most appropriate alternative(s) for each COC group within an AOC will then be bundled to create the proposed area-based remedy for each of the AOCs identified for the petroleum groundwater plumes.

Compliance Monitoring

Monitoring is needed to assure compliance with cleanup levels, to assess the performance of a remediation technology as it is operating, and to measure the continued effectiveness over time of permanent features added to the site (e.g., capping). Monitoring is an integral element of Alternatives A1 through A5. A comprehensive monitoring program consists of protection monitoring, performance monitoring, and confirmational monitoring. The comprehensive monitoring program is based on an adaptive monitoring and management strategy that is described in Section 2.7.3.

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Table 5-1 - Operating Areas and COCs Associated with Petroleum Hydrocarbons in Groundwate

General Operating Area	COCs Associated with Petroleum Plumes Identified in Groundwater
Oil Reclamation Building and Surrounding Area	Diesel, Heavy Oil, cPAH, Arsenic, Manganese, Iron
Rail Car Unloading Area	None
Cold Mill/Finishing Area	Kensol, Heavy Oil, cPAH, Arsenic, Manganese, Iron
Oil House Area	Kensol, cPAH, PCBs, Arsenic, Manganese, Iron
Wastewater Treatment Area	Diesel, Kensol, Heavy Oil, cPAH, PCBs, Arsenic, Manganese, Iron
Truck Shop Area	None
Discharge Ravine Area	None
Remelt/Hotline Area	None

Note:
Areas without COCs are shaded.

Table 5-2a - Preliminary Identification of Remedial Technologies for SVOC-Impacted Groundwater

General Response Action	Remedial Technology	Process Options	Description
Monitoring	Monitoring	Protection, performance, and confirmational	Provide for protection, performance, and confirmational monitoring. Groundwater samples will be collected to test for compliance with cleanup levels.
Institutional Controls	Access and Use Restrictions	Fencing, deed restrictions, restrictive covenant	Physical and administrative measures to prevent access or exposure to contaminated water.
	Alternative Water Supply	Connect to distribution system, new supply well	Provide an alternate supply of drinking water.
	Best Management Practices (BMPs)	Spill prevention, cleanup procedures, secondary containment, etc.	Practices designed to protect surroundings from environmental hazards that may occur at the Kaiser facility.
Containment	Caps	Clay cap, asphalt, concrete, synthetic liner, multi-layer cap	Placement of a cap to minimize infiltration and contaminant migration.
	Vertical Barriers	Slurry wall, grout curtain, sheet piling	Placement of vertical, low-permeability barriers to minimize contaminant migration.
	Horizontal Barriers	Block displacement, grout injection	Placement of subsurface, low-permeability barriers to minimize contaminant migration.
	Hydraulic Containment	Extraction wells/trenches	Modify the groundwater gradient to minimize off-site migration of contaminants.
In Situ Treatment of Groundwater	*In situ* Bioremediation	Enhanced bioremediation, phytoremediation	Enhance biodegradation through modification of subsurface environmental conditions. Enhanced biodegradation refers to additions to the groundwater such as nutrients, electron donors or microbiological populations.
	Monitored Natural Attenuation	Monitored Natural Attenuation	Naturally occurring processes in soil and groundwater which reduce mass, toxicity, mobility, volume or concentration and include biodegradation, dispersion, dilution, adsorption and volatilization.
	Air Sparging	Horizontal, vertical wells	Removal of volatile contaminants through air injection, recovery of vapor at the surface.

Table 5-2a - Preliminary Identification of Remedial Technologies for SVOC-Impacted Groundwater

General Response Action	**Remedial Technology**	**Process Options**	**Description**
In situ Treatment of Groundwater (continued)	Passive Treatment Walls	Various innovative processes	Install reaction wall across flow path using porous media and a metal catalyst.
	Hydrofracturing	Variety of fluids and pumping schedules	Improve permeability using standard oilfield stimulation practices.
	Chemical Treatment	Oxidation, reduction, pH adjustment	Injection of chemicals for *in situ* treatment of contaminants.
	In-Well Air Stripping	Vertical wells	In-well air stripping technology used to vaporize volatile components and enhance bioremediation in soils by circulation of air-enriched water.
Extraction and On-Site Treatment of Groundwater	Aerobic *Ex situ* Bioremediation	Biological treatment of groundwater in aboveground bioreactor. Various COC and site-specific processes	Biological treatment of groundwater in aboveground bioreactor. Bioreactors include aeration basins, constructed wetlands, bioreactors, trickling filters).
	Air Stripping	Packed tower, diffused aeration, tray aeration, spray aeration	Removal of volatile contaminants through volatilization in aboveground reactor.
	Adsorption	Granular activated carbon, regenerative, other media	Removal of adsorbable contaminants by passing water through adsorbent.
	Suspended Solids Removal	Precipitation, sedimentation, filtration	Physical/chemical treatment for the removal of suspended solids.
	Ion Exchange	Cationic, anionic	Removal of exchangeable ions by passing water through a resin bed.
	Membranes	Reverse osmosis, ultrafiltration, membrane prevaporation	Porous membranes used to remove dissolved or colloidal material.
	Distillation	One stage, multistage	Single or multi-stage system where heat is applied and contaminants are separated due to differences in vapor pressures.
	Freeze Crystallization	Freeze Crystallization	Extracted groundwater is slowly frozen, forming ice crystals that are separated from solution.
	Chemical/UV Oxidation	Oxidation through chemical addition and/or UV light	Oxidation through addition of chemicals or UV light or combination of two techniques. Addition of chemical oxidant may require pH adjustment

Table 5-2a - Preliminary Identification of Remedial Technologies for SVOC-Impacted Groundwater

General Response Action	Remedial Technology	Process Options	Description
Extraction and On-Site Treatment of Groundwater (continued)	Adsorption	Granular activated carbon, other adsorbents, regenerative systems	Removal of adsorbable compounds using canisters in series.
On-Site Treatment of Extracted Soil Vapor	Thermal Oxidation	Direct Flame, Flameless	Vapor heated above 1,400°F to oxidize organics; will require HCI controls.
	Catalytic Oxidation	Various catalysts, fixed or fluidized beds	Vapor heated up to 800°F to oxidize organics; will require HCI controls.
	Advanced Oxidation	UV light, ozonation	Vapor passed through catalyst while exposed to high-intensity UV light and/or ozone.
	Biofiltration	Bioreactor, soil pile	Gases are passed through a soil bed where contaminants are sorbed and degraded.

Table 5-2b - Preliminary Identification of Additional Remedial Technologies for PCBs Contained in the Petroleum Groundwater Plumes

General Response Action	Remedial Technology	Process Options	Description
On-Site Treatment of Extracted Soil Vapor	Chlorine Capture	Chlorine Scrubber	Calcium or sodium-based reagents are used to remove chlorine from off-gas generated by some *in situ* PCB-treatment processes.

Table 5-2c - Preliminary Identification of Remedial Technologies for Free Phase Product Recovery from Groundwater

General Response Action	Remedial Technology	Process Options	Description
In situ Free Phase Product Recovery	Dual Vacuum Extraction (DVE)	VE/GE[1], single vacuum pump, bioslurping	Removal of groundwater, free pahse product, and/or soil vapor by extraction and/or pumping surface treatment on-site.
	Free Product Recovery With Water Table Depression	One pump, two pump recovery system	Cone of depression is created by pumping groundwater, drawing product into well or trench. NAPL and groundwater are recovered via one- or two-pump recovery system.
Ex situ Free Phase Product Recovery	Oil-Water (Free Product) separation	API separator, dissolved air flotation, gravity	Physical treatment for the removal of free-phase oils from extracted groundwater.

1) VE/GE stands for Vapor Extraction/Groundwater Extraction (EPA 1996g).

Table 5-3 - Physical/Chemical Screening Criteria of Remedial Technologies for SVOC-Impacted Groundwater

General Response Action	Technology	Description	Screening Comments	Technology Retained
Monitoring	Monitoring	Provide for protection, performance, and confirmational monitoring. Groundwater samples will be collected to test for compliance with cleanup levels.	Required by MTCA as part of threshold requirements. Access to surrounding properties maybe required.	Yes
Institutional Controls	Access and Use Restrictions	Physical and administrative measures to prevent access or exposure to contaminated water.	Kaiser property already restricted. Off-property restrictions, if needed, may require permission of property owner. Administrative measure (deed restriction) will be required.	Yes
	Alternative Water Supply	Provide an alternate supply of drinking water.	Impacted aquifer is a current drinking water source. Drinking water is currently obtained from wells upgradient of industrial facilities.	No
	Best Management Practices (BMPs)	Practices designed to protect surroundings from environmental hazards that may occur at the Kaiser facility.	BMPs currently in place at Kaiser such as spill prevention, cleanup procedures and secondary containment. Additional BMPs may be required.	Yes
Containment	Capping	Placement of a cap to minimize infiltration and contaminant migration.	Potentially effective for reducing groundwater mounding (where infiltration occurs) and contaminant spreading, and for reducing leaching from vadose zone soil into groundwater. Requires run-on and run-off management and control measures.	Yes
	Vertical Barriers	Placement of vertical, low-permeability barriers to minimize contaminant migration.	Most effective for shallow impacts, not at depth of 45 to 75 feet bgs that would be needed at Kaiser. Limited access for construction due to traffic, buildings, roads, railroads and utilities.	No

Table 5-3 - Physical/Chemical Screening Criteria of Remedial Technologies for SVOC-Impacted Groundwater

General Response Action	**Technology**	**Description**	**Screening Comments**	**Technology Retained**
Containment (continued)	Horizontal Barriers	Placement of subsurface, low-permeability barriers to minimize contaminant migration.	Barrier would have to be effective over very long horizontal distance.	No
	Hydraulic Containment	Modify the groundwater gradient to minimize off-site migration of contaminants.	Potentially effective for protection of Spokane River. Useful in conjunction with DVE and for free phase product removal and recovery. Since 1993, extraction wells have been used in the Oil House and Wastewater Treatment areas for plume containment per IRM.	Yes
In situ Treatment of Groundwater	*In situ* Bioremediation	Enhance biodegradation through modification of subsurface environmental conditions.	Demonstrated effective for SVOCs at similar sites under similar conditions. Per IRM, recirculation of oxygen-rich groundwater to upper horizon of aquifer has been used at Kaiser to enhance subsurface bioremediation in the Oil House and Wastewater Treatment areas (Kaiser 2003).	Yes
	Monitored Natural Attenuation	Naturally-occurring processes in soil and groundwater which reduce mass, toxicity, mobility, volume or concentration and include biodegradation, dispersion, dilution, adsorption and volatilization.	SVOCs are known to naturally degrade in the groundwater environment.	Yes
	Air Sparging	Removal of volatile contaminants through air injection, recovery of air at the surface.	Not effective for SVOCs due to low vapor pressures of compounds.	No

Table 5-3 - Physical/Chemical Screening Criteria of Remedial Technologies for SVOC-Impacted Groundwater

General Response Action	Technology	Description	Screening Comments	Technology Retained
In situ Treatment of Groundwater (continued)	Passive Treatment Walls	Install reaction wall across flow path using porous media and a metal catalyst.	Limited available area for construction, buried utilities interfere with installation options. The walls would have to cover very large horizontal distances.	No
	Hydrofracturing	Improve permeability using standard oilfield stimulation practices.	Site soil is porous and does not require improvement.	No
	Chemical Treatment	Injection of chemicals for *in situ* treatment of contaminants.	Fenton's Reagent and other oxidants have been demonstrated effective for SVOCs. Potential for exothermic (explosive) reactions to occur.	Yes
	In-Well Air Stripping	In-well air stripping technology used to vaporize volatile components.	Not effective for SVOCs due to low vapor pressures of compounds but may enhance biodegradation in soils by circulation of air-enriched water. (For details on enhanced biodegradation see *in situ* bioremediation).	No
Extraction and On-Site Treatment of Groundwater	Aerobic *Ex situ* Bioremediation	Biological treatment of groundwater in aboveground bioreactor. Various COC and site-specific processes.	Aerobic bioreactors are an EPA presumptive remedy for extracted groundwater. Reactors are typically used to treat SVOCs (EPA 1996h).	Yes
	Air Stripping	Removal of volatile contaminants through volatilization in aboveground reactor.	Due to low volatility, not effective for semivolatiles.	No
	Adsorption	Removal of adsorbable contaminants by passing groundwater through adsorbent.	Requires periodic carbon reactivation at off-site facility.	Yes
	Suspended Solids Removal	Physical/chemical treatment for the removal of suspended solids.	Potentially effective as a pre-treatment option, minimal space required, conventional technology. Some PCB contamination is associated with colloids.	Yes
	Ion Exchange	Removal of exchangeable ions by passing water through a resin bed.	Not effective for organic compounds.	No

Table 5-3 - Physical/Chemical Screening Criteria of Remedial Technologies for SVOC-Impacted Groundwater

General Response Action	Technology	Description	Screening Comments	Technology Retained
Extraction and On-Site Treatment of Groundwater (continued)	Membranes	Porous membranes used to remove dissolved or colloidal material.	High potential for fouling due to presence of oil material and metals (i.e., iron and manganese). Extensive pretreatment is required for this technology.	No
	Distillation	Contaminants are separated by different boiling points. Heat is applied.	Significant differences in vapor pressure between water and SVOCs may make technology applicable. Due to relatively low concentrations of SVOCs, may not be effective technology.	No
	Freeze Crystallization	Contaminants are separated by different freezing points. Water is slowly frozen.	Significant differences in melting points between water and SVOCs may make technology applicable. Due to relatively low concentrations of SVOCs, may not be effective technology.	No
	Chemical/UV Oxidation Treatment	Oxidation through chemical addition and/or UV light.	Effective for SVOCs; requires space for chemical storage and for extracted groundwater treatment equipment/ facilities.	Yes
On-Site Treatment of Extracted Soil Vapor	Adsorption	Removal of adsorbable compound using canister in series may require disposal.	Potentially effective for SVOC degradation products.	Yes
	Thermal Oxidation	Vapor heated above 1,400 °F to oxidize organics; requires emission controls.	Potentially effective for SVOC degradation products.	Yes
	Catalytic Oxidation	Vapor heated up to 800 °F to oxidize organics, requires HCI controls.	Potentially effective for SVOC degradation products.	Yes
	Advanced Oxidation	Vapor is passed through catalyst while exposed to high intensity UV light or ozone.	Potentially effective for SVOC degradation products.	Yes
	Biofiltration	Gases are passed through a soil bed where contaminants are sorbed and degraded.	Potentially effective for SVOC degradation products.	Yes

Table 5-4a - Physical/Chemical Screening Criteria of Remedial Technologies for PCBs Contained in the Petroleum Groundwater Plumes

Sheet 1 of 2

General Response Action	Remedial Technology	Technology Retained[1]
Monitoring	Monitoring	Yes
Institutional Controls	Access and Use Restrictions	Yes
Institutional Controls	Alternative Water Supply	No
Institutional Controls	Best Management Practices (BMPs)	Yes
Containment	Capping	Yes
Containment	Vertical Barriers	No
Containment	Horizontal Barriers	No
Containment	Hydraulic Containment	Yes
In situ Treatment of Groundwater	Monitored Natural Attenuation	Yes
in situ Treatment of Groundwater	Air Sparging	No
In situ Treatment of Groundwater	Passive Treatment Walls	No
In situ Treatment of Groundwater	Hydrofracturing	No
In situ Treatment of Groundwater	Chemical Treatment	Yes
In situ Treatment of Groundwater	In-Well Air Stripping	No
Extraction and On-Site Treatment of Groundwater	Air Stripping	No
Extraction and On-Site Treatment of Groundwater	Adsorption	Yes
Extraction and On-Site Treatment of Groundwater	Suspended Solids Removal	Yes
Extraction and On-Site Treatment of Groundwater	Ion Exchange	No
Extraction and On-Site Treatment of Groundwater	Membranes	No
Extraction and On-Site Treatment of Groundwater	Distillation	No
Extraction and On-Site Treatment of Groundwater	Freeze Crystallization	No
Extraction and On-Site Treatment of Groundwater	Chemical/UV Oxidation	Yes
On-Site Treatment of Extracted Soil Vapor[2]	Adsorption	Yes
On-Site Treatment of Extracted Soil Vapor[2]	Thermal Oxidation	Yes
On-Site Treatment of Extracted Soil Vapor[2]	Catalytic Oxidation	Yes
On-Site Treatment of Extracted Soil Vapor[2]	Advanced Oxidation	Yes
On-Site Treatment of Extracted Soil Vapor[2]	Biofiltration	Yes
On-Site Treatment of Extracted Soil Vapor[2]	Chlorine Scrubber	Yes[3]

Notes:

Table 5-4a - Physical/Chemical Screening Criteria of Remedial Technologies for PCBs Contained in the Petroleum Groundwater Plumes

1) The reasons for retaining a technology to treat PCBs in groundwater based on physical/chemical criteria also apply to SVOCs in groundwater as presented in Table 5-3 unless otherwise noted. Refer to the evaluations in that table.

2) If off-gas treatment is needed by *in situ* treatment process.

3) The reasons for retaining a technology to treat PCBs in groundwater based on physical/chemical criteria also apply to PCBs in deep vadose zone soils as presented in Table 3-5. Refer to the evaluations in that table.

Table 5-4b – Physical/Chemical Screening Criteria of Additional Remedial Technologies for PCBs Contained in the Petroleum Groundwater Plumes

General Response Action	**Remedial Technology**	**Description**	**Screening Comments**	**Technology Retained**
In situ Treatment of Groundwater	*In situ* Bioremediation	Enhance biodegradation through modification of subsurface environmental conditions.	PCBs are not prone to biodegradation. Laboratory studies have been done showing biodegradation success; however, limited evidence showing success in the field. Less chlorinated PCBs are more reactive (Ravi). PCBs coexist with hydrocarbons which may help maintain biomass and allow degradation of PCBs. The SVOCs that are co-located with PCBs will provide additional biomass, which will enhance the bioremediation of the dilute concentrations of PCBs that are present in the groundwater.	Yes
Extraction and On-Site Treatment of Groundwater	Aerobic *Ex situ* Bioremediation	Biological treatment of groundwater in aboveground bioreactor. Various COC and site-specific processes.	Aerobic bioreactors are an EPA presumptive remedy for extracted groundwater. Reactors are typically used to treat SVOCs (EPA 1996h). PCBs are not prone to biodegradation. Laboratory studies have been done showing biodegration success; however, limited evidence showing success in the field. Less chlorinated PCBs are more reactive (Ravi). PCBs coexist with hydrocarbons which may help maintain biomass and allow degradation of PCBs. The SVOCs that are co-located with PCBs will provide additional biomass, which will enhance the bioremediation of the dilute concentrations of PCBs that are present in the groundwater.	Yes

Table 5-5 - Physical/Chemical Screening Criteria of Remedial Technologies for Free Phase Product Recovery from Groundwater

Sheet 1 of 1

General Response Action	Remedial Technology	Description	Screening Comments	Technology Retained
In situ Free Phase Product Recovery	Dual Vacuum Extraction (DVE)	Removal of groundwater, free phase product and soil vapor by extraction or pumping (under vacuum), surface treatment on-site.	Used to remove free phase product (if present) from water table. Somewhat effective at removing dissolved SVOCs since contaminated groundwater is extracted, however, groundwater will need to be treated prior to any discharge. Access for well installation restricted by buildings, railroads, traffic and utilities.	Yes
	Free Phase Product Recovery With Water Table Depression	Cone of depression is created by pumping groundwater, drawing product into well or trench. NAPL and groundwater are recovered via one- or two-pump recovery system.	Technology well suited for permeable soil matrix at the site.	Yes
Ex situ Free Product Recovery	Oil-Water (Free Phase Product) separation	Physical treatment for the removal of free phase oils from extracted groundwater.	SVOCs and PCBs co-mingled in free phase product.	Yes

Table 5-6a - Implementability of Remedial Technologies for SVOC-Impacted Groundwater

Technology	**Process Options**	**Can it be Implemented?**[1]
Monitoring	Protection, performance, and confirmational	Yes
Access and Use Restrictions	Fencing, deed restrictions, restrictive covenant	Yes
Best Management Practices (BMPs)	Spill prevention, cleanup procedures, secondary containment, etc.	Yes
Capping	Soil Cap	No
Capping	Clay Cap	No
Capping	Low Permeable Asphalt Cap	Yes
Capping	Low Permeable Concrete Cap	Yes
Capping	Synthetic Liner	No
Capping	Multilayer Cap (soil+ synthetic liner)	Yes
Adsorption (Extracted Vapor)	Activated Carbon	Yes[2]
Thermal and Catalytic Oxidation (Extracted Vapor)	Direct Flame, Flameless,Hybrid Thermal/Catalytic	No
Thermal and Catalytic Oxidation (Extracted Vapor)	Catalytic Oxidation	Yes[2]
Advanced Oxidation (Extracted Vapor)	UV Light	Yes[2]
Advanced Oxidation (Extracted Vapor)	Photocatalytic Destruction	No
Biofiltration (Extracted Vapor)	Bioreactor/Soil Pile	No

Notes:

1) The reasons for implementability for SVOCs in groundwater are similar to the reasons provided for VOCs in shallow soils as presented in Tables 2-8a through 2-8d and 2-8h through 2-8k. Refer to the evaluations in those Section 2 tables.

2) If off-gas treatment is needed by SVOC treatment process. For *in situ* treatment technologies, soil vapor extraction system may be needed.

Table 5-6b - Implementability of Hydraulic Containment for SVOC-Impacted Groundwater

	Process Options for Hydraulic Containment	
Attribute	**Extraction Wells**	**Trenches**
Can it be constructed?	Yes, can be designed and constructed in <1 year.	Depth to groundwater is 45 to 75 feet bgs.
Will it work?	Yes. Has been proven effective at Kaiser. Refer to Section 2.5 of the Final Groundwater RI (Hart Crowser 2012a) and Section 5 of the 2003 Kaiser Groundwater RI/FS (Hart Crowser 2003). A pumping test is needed to determine the pumping rate for containment. Extracted water would have to be treated on site and disposed of off site. Water treatment will create waste streams that also have to be disposed of. Hydraulic containment will lower the water table and leave contaminated soil in the vadose zone where it will recontaminate groundwater after the pumps are turned off.	No. Cannot be constructed given the depth of the water table at the Kaiser Site.
Will this be acceptable to regulatory agencies?	Probably. Depends on pumping rates. Would require NPDES permit, since the public treatment facility is unlikely to permit high discharge rates, especially for a period of time likely to be decades long. Kaiser has NPDES permit for discharge of process and stormwater. They also have a permit for their own sewage treatment plant.	Yes
Is technology available?	Yes	Yes
Is process option accepted?	Yes, however, extracted water may need treatment before reinjection or discharge.	No

Table 5-6c - Implementability of *In Situ* Bioremediation for SVOC-Impacted Groundwater

	Process Options for *In Situ* Bioremediation	
Attribute	**Enhanced Bioremediation**	**Phytoremediation**
Can it be constructed?	Yes, site is amenable to constructing and operating support equipment though access may be limited in some areas by infrastructure. Design, construction, and startup will take approximately 1 year. This technology includes the circulation of water-based solutions (i.e., nutrients) to stimulate microbes and/or the injection of Oxygen Release Compounds (ORC) or other electron acceptor compounds or bioaugmentation.	Yes, <1 year required.
Will it work?	ORC and electron donor inputs require water to work. High concentrations of SVOCs in saturated soil matrix make contact between contaminants and chemical additions likely, thereby encouraging microbial activity. Per IRM, recirculation of oxygen-rich groundwater to upper horizon of aquifer has been used at Kaiser to enhance subsurface bioremediation in the Oil House and Wastewater Treatment areas (Hart Crowser 2003).	No, plant root system will not reach impacted groundwater. Additionally, plant matter would be damaged by the heavy industrial site use. Kaiser maintains the soil in the mill areas with annual applications of herbicides to make the soil sterile (zero plant growth outside of landscaped areas to limit maintenance and prevent brush fires).
Will this be acceptable to regulatory agencies?	Yes	Yes
Is technology available?	Yes	Yes
Is process option accepted?	Yes	No

Table 5-6d - Implementability of Monitored Natural Attenuation for SVOC-Impacted Groundwater

	Process Options for Monitored Natural Attenuation
Attribute	**Monitored Natural Attenuation**
Can it be constructed?	Yes, site is suitable for using existing monitoring wells and constructing new monitoring wells for collecting groundwater samples and measuring water levels. Less than one year is required to design and to construct any additional wells needed. Institutional controls required.
Will it work?	Site data indicate natural attenuation is occurring *in situ*. Currently not effective at destroying all SVOC compounds. Requires a much longer time period than active remediation technologies. Some active remediation processes may alter *in situ* conditions such that natural attenuation at the site becomes less efficient.
Will this be acceptable to regulatory agencies?	Ecology approval of a Compliance Monitoring Plan will be required.
Is technology available?	Yes
Is process option accepted?	Yes, but this option will be relied upon only after source area concentrations are reduced to residual levels.

Table 5-6e - Implementability of *In Situ* Chemical Treatment for SVOC-Impacted Groundwater

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	Process Options for *In situ* Chemical Treatment
Attribute	**Oxidation, Reduction, pH adjustment**
Can it be constructed?	Yes, it can be constructed but many injection, extraction, and monitoring wells are needed to maintain and validate proper operation. Design, construction, and startup will take approximately 1 year.
Will it work?	Yes, effective for TPH. Also, oxidant may react with non-target compounds hindering treatment of area of concern. Multiple injection events are likely. Potential for exothermic (explosive) reactions to occur (EPA 2004a).
Will this be acceptable to regulatory agencies?	Yes
Is technology available?	Yes
Is process option accepted?	Yes

Table 5-6f - Implementability of Aerobic *Ex Situ* Bioremediation for SVOC-Impacted Groundwater

	Process Options for Aerobic *Ex situ* Bioremediation
Attribute	**Biological treatment of groundwater in aboveground bioreactor.**
Can it be constructed?	Yes. Extensive footprints are required for the large tanks that are used to treat large volumes of groundwater and groundwater with high contaminant concentrations. Treatments require large tanks for sufficient residence time for biologic processes to be effective.
Will it work?	Yes. Aerobic *ex situ* bioremediation is a presumptive remedy for SVOCs in groundwater. Treatability assessment is required. Concentrations and extent of SVOCs may make this technology impractical.
Will this be acceptable to regulatory agencies?	Yes.
Is technology available?	Yes, but significant assessment is required to optimize design.
Is process option accepted?	Yes

Table 5-6g - Implementability of Adsorption for SVOC-Impacted Groundwater

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Attribute	Process Options for Adsorption from Extracted Groundwater	
	Granular Activated Carbon (GAC)	**Other Adsorbents**
Can it be constructed?	Most source areas suitable for construction and equipment required. Readily designed and constructed <1 year.	Other forms of carbon and polymer resins can be readily installed on site in <1 year.
Will it work?	Yes, presumptive treatment for extracted groundwater containing many different organic compounds. For areas with higher contaminant concentrations may not be able to use GAC as single step treatment. For flowrates 3 gpm (or less) GAC is a cost effective, single-step treatment (EPA 1996h).	Maybe, Pilot or process application test required.
Will this be acceptable to regulatory agencies?	Yes	Maybe
Is technology available?	Yes	Maybe, this option is only at pilot scale stage of development with limited full-scale applications.
Is process option accepted?	Yes	No

Table 5-6h - Implementability of Suspended Solids Removal in SVOC-Impacted Groundwater

Attribute	Process Options for Suspended Solids Removal in SVOC-Impacted Groundwater
	Physical/chemical treatment for the removal of suspended solids
Can it be constructed?	Yes, site is amenable to constructing and operating support equipment though access may be limited in some areas by infrastructure. Sedimentation tanks, if needed, may have large footprints depending on influent characteristics (concentration, flow rate, etc.,). Design, construction, and startup will take approximately 1 year.
Will it work?	Yes, however, not as a sole remedy. Removal of suspended solids will likely decrease concentrations of SVOCs but not to cleanup levels. More likely, removal of suspended solids will be needed for pre- or post treatment of other remediation technologies (i.e., removal of suspended solids to prevent fouling in GAC vessel). Unit operations used for solids removal will depend on size and concentration of suspended solids and flow rate that needs to be treated.
Will this be acceptable to regulatory agencies?	Yes
Is technology available?	Yes
Is process option accepted?	Yes

Table 5-6i - Implementability of On-Site Chemical/UV Oxidation for SVOC-Impacted Groundwater

	Process Options for Chemical/UV Oxidation of Extracted Groundwater
Attribute	**Oxidation by chemical addition and/or UV light**
Can it be constructed?	Yes, site is amenable to constructing and operating support equipment though access may be limited in some areas by infrastructure. Design, construction, and startup will take approximately 1 year.
Will it work?	Presumptive remedy for *ex situ* treatment of groundwater. Incomplete reactions may leave toxic by-products; carbon polishing step may be necessary and treatability studies will be required (EPA 1996h). Depending on contaminant concentrations, large quantities of oxidant may be needed. Off-gas may be produced that needs treatment.
Will this be acceptable to regulatory agencies?	Yes
Is technology available?	Yes
Is process option accepted?	Yes

Table 5-7a - Reliability of Selected Technologies for SVOC-Impacted Groundwater

Technology	**Process Options**	**Is it reliable?[1]**
Monitoring	Protection, performance, and confirmational	Yes
Access and Use Restrictions	Fencing, deed restrictions, restrictive covenant	Yes
Best Management Practices (BMPs)	Spill prevention, cleanup procedures, secondary containment, etc.,	Yes
Capping	Low Permeability Asphalt Cap	Yes
Capping	Low Permeability Concrete Cap	Yes
Capping	Multilayer (soil + synthetic liner)	Yes
Adsorption (Extracted Vapor)	Activated Carbon	Yes[2]
Thermal and Catalytic Oxidation (Extracted Vapor)	Catalytic Oxidation	Yes[2]
Advanced Oxidation (Extracted Vapor)	UV Light/Ozonation	No

Notes:

1) The evaluations of reliability given in this table for SVOCs in groundwater are similar to the evaluation of reliability for VOCs in soils as given in Tables 2-9a through 2-9c and Tables 2-9f through 2-9h. Refer to the evaluations in those Section 2 tables.

2) If off-gas treatment is needed by a SVOC treatment process.

Table 5-7b - Reliability of Hydraulic Containment of SVOC-Impacted Groundwater

	Process Options for Hydraulic Containment of SVOC-Impacted Groundwater
Attribute	**Extraction Wells**
Has this process option been used at the scale required for Kaiser?	Yes, currently containment extraction wells are operating in Oil House and Wastewater Treatment areas per IRM. Groundwater is used as plant process water or discharged at NPDES discharge point. See 2003 Groundwater RI/FS (Hart Crowser 2003) and 2012 Final Groundwater RI (Hart Crowser 2012a) for more details.
Are operation and maintenance requirements infrequent and straightforward?	Yes. Water quality monitoring may be required for plant process water and will be required at discharge point for NPDES permit.
Has this process option been proven effective under COC and site conditions similar to those at Kaiser?	Yes. Per 2012 Final Groundwater RI, the IRM systems were shown to meet project objectives with respect to containment, product recovery, and enhanced biodegradation. Migration and spreading of the contaminant plumes in the Wastewater and Oil House areas have been significantly reduced through hydraulic control (Hart Crowser 2012a).
Is process option accepted?	Yes

Table 5-7c - Reliability of *In Situ* Bioremediation of SVOC-Impacted Groundwater

	Process Options for *In situ* Bioremediation of SVOC-Impacted Groundwater
Attribute	**Enhanced Bioremediation**
Has this process option been used at the scale required for Kaiser?	Yes, enhanced bioremediation is an established process employed to treat SVOCs in subsurface soils and groundwater.
Are operation and maintenance requirements infrequent and straightforward?	Yes. Chemicals may need to be stored on site. Periodic chemical addition may be necessary. Off-gas collection and treatment may be needed.
Has this process option been proven effective under COC and site conditions similar to those at Kaiser?	No. High concentrations of SVOCs (where present) and the presence of free product will make treatment more difficult to achieve. Colder temperatures in winter will limit biodegradation. Porous soils will make the injection of ORC or another additive in the appropriate location difficult. Per IRM, recirculation of oxygen-rich groundwater to upper horizon of aquifer has been used at Kaiser to enhance subsurface bioremediation in the Oil House and Wastewater Treatment areas (Hart Crowser 2003).
Is process option accepted?	Yes

Table 5-7d - Reliability of Monitored Natural Attenuation for SVOC-Impacted Groundwater

	Process Options for Monitored Natural Attenuation
Attribute	**Monitored Natural Attenuation**
Has this process option been used at the scale required for Kaiser?	Yes, this option is commonly used at many sites of similar scale. Source control must first be performed to reduce the concentration of COCs.
Are operation and maintenance requirements infrequent and straightforward?	Yes, operations and maintenance are mostly related to water monitoring.
Has this process option been proven effective under COC and site conditions similar to those at Kaiser?	Yes, this option has been accepted as many sites across the country having similar SVOCs and site conditions.
Is process option accepted?	Yes, but after source control has reduced concentrations to low levels.

Table 5-7e - Reliability of *In Situ* Chemical Treatment for SVOC-Impacted Groundwater

	Process Options for *In situ* Chemical Treatment of Groundwater
Attribute	**Addition of chemical oxidant or reducer, may need pH adjustment**
Has this process option been used at the scale required for Kaiser?	Yes, hydrogen peroxide has been used to treat groundwater in volumes consistent with those anticipated in the source areas.
Are operation and maintenance requirements infrequent and straightforward?	No. Common oxidant for petroleum sites is Fenton's Reagent which is very reactive and, besides reacting with contaminants, it may react with carbonates and other organic material. Also, decomposition is an exothermic reaction that elevates temperatures, produces steam and oxygen and may create an explosive atmosphere; therefore, addition of reagent will have to be carefully monitored. Production of off-gas may need extraction and treatment. Will need to store and handle chemicals on site. Adjustment of pH may be required to create ferrous iron required to produce hydroxyl radical. Oxidation can cause iron fouling of wells, which will require maintenance. Multiple injection events will likely be needed (EPA 2004a).
Has this process option been proven effective under COC and site conditions similar to those at Kaiser?	Yes, Per OSWER (Office of Solid Waste and Emergency Response) guidance document for cleanup alternatives for UST (underground storage tank) sites, chemical oxidation has been used for the remediation of petroleum contaminated sites (EPA 2004).
Is process option accepted?	Yes

Table 5-7f - Reliability of Aerobic *Ex Situ* Bioremediation of SVOC-Impacted Groundwater

	Process Options for *Ex situ* Bioremediation of SVOC-Impacted Groundwater
Attribute	**Biological treatment of groundwater in aboveground bioreactor**
Has this process option been used at the scale required for Kaiser?	Yes, *ex situ* aerobic bioremediation is an established process employed to treat SVOCs in groundwater.
Are operation and maintenance requirements infrequent and straightforward?	No. Startup times vary depending how long it takes microorganisms to become acclimated. Pre-treatment will be needed to remove free phase product and compounds toxic to microorganisms such as heavy metals. Due to colder winter temperatures, treatment system may need to be enclosed and heated to maintain biological activity. Depending on effectiveness of biological treatment, carbon polishing unit may be needed. The system may be equipped with settling tanks to remove sludge. Filtration units may be needed to remove suspended solids. Off-gas collection and treatment may be needed for SVOCs degradation byproducts. Residual biosludge that is created may need periodic removal and disposal.
Has this process option been proven effective under COC and site conditions similar to those at Kaiser?	Yes. High concentrations of SVOCs in some locations may make it more difficult to achieve low SVOC effluent concentration. Low concentrations in other locations make it difficult to sustain microorganisms and nutrient addition may be needed. Treatability studies will be required. Presumptive remedy for *ex situ* treatment of SVOC impacted groundwater (EPA 1996h).
Is process option accepted?	Yes.

Table 5-7g - Reliability of Adsorption for SVOC-Impacted Groundwater

Attribute	Process Options for Activated Carbon Adsorption of Extracted Groundwater
	Granular Activated Carbon (GAC)
Has this process option been used at the scale required for Kaiser?	Yes, but GAC typically used for a final polishing step for SVOC removal following removal of the bulk of suspended contaminants (or suspended solids) by another technology.
Are operation and maintenance requirements infrequent and straightforward?	No, prefiltration is required and there is a potential for iron fouling. Carbon beds will require regular O&M (backwashing) and periodic replacement. Spent carbon must be regenerated or disposed of as a hazardous waste.
Has this process option been proven effective under COC and site conditions similar to those at Kaiser?	Yes, GAC polishing is typically a condition of a PTOW discharge permit.
Is process option accepted?	Yes

Table 5-7h - Reliability of Suspended Solids Removal for SVOC-Impacted Groundwater

	Process Options for Suspended Solids Removal in SVOC-impacted groundwater
Attribute	**Physical/chemical treatment for the removal of suspended solids**
Has this process option been used at the scale required for Kaiser?	Yes, this is conventional treatment for suspended solids in water.
Are operation and maintenance requirements infrequent and straightforward?	Yes, depending on treatment method used, (e.g., precipitation, sedimentation, filtration) chemical addition/pH adjustment may be needed.
Has this process option been proven effective under COC and site conditions similar to those at Kaiser?	Yes, however, not as a sole remedy. More likely, removal of suspended solids will be needed for pre- or post treatment of other remediation technologies (i.e., removal of suspended solids to prevent fouling in GAC vessel).
Is process option accepted?	Yes.

Table 5-7i - Reliability of *Ex Situ* Chemical/UV Oxidation for SVOC-Impacted Groundwater

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	Process Options for *Ex situ* Chemical/UV Oxidation of Groundwater
Attribute	**Oxidation by chemical addition and/or UV light**
Has this process option been used at the scale required for Kaiser?	Yes, hydrogen peroxide and other oxidants have been used to treat groundwater in volumes consistent with those anticipated in the source area. The addition of UV light accelerates the oxidation process.
Are operation and maintenance requirements infrequent and straightforward?	Yes. Off-gas may be generated that will need treatment. Incomplete oxidation will leave original contaminants and possibly toxic oxidation products. On-site storage of chemicals. Monitoring of effluent to ensure compliance standards are met.
Has this process option been proven effective under COC and site conditions similar to those at Kaiser?	Yes. Presumptive remedy for *ex situ* treatment of groundwater (EPA 1996h).
Is process option accepted?	Yes

Table 5-8 - Summary of Technology Screening Process: SVOC-Impacted Groundwater

			Screening Outcome		
General Response Action [1]	**Remedial Technology [1]**	**Process Options [1]**	**Physical/Chemical [2]**	**Implementability [3]**	**Reliability [4]**
Monitoring	**Monitoring**	**Protection, Performance, and Confirmational**	**Retained**	**Retained**	**Retained**
Institutional Controls	**Access and Use Restrictions**	**Fences, Signs, Deed Restrictions**	**Retained**	**Retained**	**Retained**
	Alternative Water Supply	Connect to distribution system, new supply well	Eliminated	--	--
	Best Management Practices	**Spill prevention, leak detection, double-walled pipes**	**Retained**	**Retained**	**Retained**
Containment	**Capping**	Soil	Retained	Eliminated	--
		Clay	Retained	Eliminated	--
		Asphalt	**Retained**	**Retained**	**Retained**
		Concrete	**Retained**	**Retained**	**Retained**
		Synthetic	Retained	Eliminated	--
		Multi-layer cap (soil + synthetic)	**Retained**	**Retained**	**Retained**
	Vertical Barriers	Slurry wall, grout curtain, sheet piling	Eliminated	--	--
	Horizontal Barriers	Block displacement, grout injection	Eliminated	--	--
	Hydraulic Containment	**Extraction wells**	**Retained**	**Retained**	**Retained**
		Trenches	Retained	Eliminated	--
***In Situ* Treatment of Groundwater**	***In situ* Bioremediation**	**Enhanced bioremediation**	**Retained**	**Retained**	**Retained**
		Phytoremediation	Retained	Eliminated	--
	Monitored Natural Attenuation	**Monitored Natural Attenuation**	**Retained**	**Retained**	**Retained**
	Air Sparging	Horizontal, vertical wells	Eliminated	--	--
	Passive Treatment Walls	Various innovative processes	Eliminated	--	--
	Hydrofracturing	Variety of fluids and pumping schedules	Eliminated	--	--

Table 5-8 - Summary of Technology Screening Process: SVOC-Impacted Groundwater

			Screening Outcome		
General Response Action [1]	**Remedial Technology [1]**	**Process Options [1]**	**Physical/Chemical [2]**	**Implementability [3]**	**Reliability [4]**
***In Situ* Treatment of Groundwater (continued)**	**Chemical Treatment**	**Oxidation, reduction, pH adjustment**	**Retained**	**Retained**	**Retained**
	In-Well Air Stripping	Vertical wells	Eliminated	--	--
Extraction and On-Site Treatment of Groundwater	**Aerobic *Ex situ* Bioremediation**	**Various, such as aeration basins, constructed wetlands, bioreactors, trickling filters**	**Retained**	**Retained**	**Retained**
	Air Stripping	Packed tower, diffused aeration, tray aeration, spray aeration	Eliminated	--	--
	Adsorption	**Granular activated carbon**	**Retained**	**Retained**	**Retained**
		Other Adsorbents	Retained	Eliminated	--
	Suspended Solids Removal	**Precipitation, sedimentation, filtration**	**Retained**	**Retained**	**Retained [5]**
	Ion Exchange	Cationic, anionic	Eliminated	--	--
	Membranes	Reverse osmosis, ultrafiltration, membrane prevaporation	Eliminated	--	--
	Distillation	One stage, multistage	Eliminated	--	--
	Freeze Crystallization	Freeze Crystallization	Eliminated	--	--
	Chemical/UV Oxidation	**Oxidation through chemical addition and/or UV light**	**Retained**	**Retained**	**Retained**
On-Site Treatment of Extracted Soil Vapor [6]	**Adsorption**	**Granular activated carbon**	**Retained**	**Retained**	**Retained**
	Thermal and Catalytic Oxidation	Direct flame Thermal	Retained	Eliminated	--
		Flameless Thermal	Retained	Eliminated	--
		Catalytic Oxidizers	**Retained**	**Retained**	**Retained**
		Hybrid Thermal/Catalytic	Retained	Eliminated	--
	Advanced Oxidation	UV light	Retained	Eliminated	--
		Photocatalytic	Retained	Retained	Eliminated
	Biofiltration	Bioreactor, soil pile	Retained	Eliminated	--

Table 5-8 - Summary of Technology Screening Process: SVOC-Impacted Groundwater

			Screening Outcome		
General Response Action [1]	**Remedial Technology [1]**	**Process Options [1]**	**Physical/Chemical [2]**	**Implementability [3]**	**Reliability [4]**

Notes:

Bolded Technologies Retained for further evaluation in the FS.

1) Taken from FSTM Table 5-2a
2) Taken from FSTM Table 5-3
3) Taken from FSTM Table 5-6a through 5-6i
4) Taken from FSTM Table 5-7a through 5-7i
5) Not as stand-alone remedy. Used as pre- or post-GAC treatment technology.
6) Subsurface vapor extraction may be required with this technology.

Table 5-9a - Implementability of Selected Technologies for PCBs Contained in the Petroleum Groundwater Plumes

Technology	**Process Options**	**Can it be Implemented?**[1]
Monitoring	Protection, performance, and confirmational	Yes
Access and Use Restrictions	Fencing, deed restrictions, restrictive covenant	Yes
Best Management Practices (BMPs)	Spill prevention, cleanup procedures, secondary containment, etc.	Yes
Capping	Soil Cap	No
Capping	Clay Cap	No
Capping	Low Permeable Asphalt Cap	Yes
Capping	Low Permeable Concrete Cap	Yes
Capping	Synthetic Liner	No
Capping	Multilayer Cap (soil + synthetic liner)	Yes
Hydraulic Containment	Vertical Wells	Yes
Hydraulic Containment	Trenches	No
Bioremediation (*in situ)*	Phytoremediation	No
Monitored Natural Attenuation	Monitored Natural Attenuation	Yes
Adsorption (*ex situ)*	Other Adsorbents	No
Suspended Solids Removal *(ex situ)*	Preciptation, sedimentation, filtration	Yes
Adsorption (extracted vapor)	Granular Activated Carbon	Yes[2]
Thermal and Catalytic Oxidation (Extracted Vapor)	Direct Flame, Flameless, Hybrid Thermal/Catalytic	No
Thermal and Catalytic Oxidation (Extracted Vapor)	Catalytic Oxidation	Yes[2]
Advanced Oxidation (Extracted Vapor)	UV Light	Yes[2]
Advanced Oxidation (Extracted Vapor)	Photocatalytic Yes[2]	No
Biofiltration (Extracted Vapor)	Bioreactor/Soil Pile	No
Chlorine Removal (Extracted Vapor)	Chlorine Scrubber	Yes[2, 3]

Note:

1) The reasons a technology was judged to be implementable for PCBs in groundwater are similar to the reasons the technology was judged to be implementable for SVOCs in groundwater as presented in Tables 5-6a through 5-6i except where noted. Refer to the evaluations in those tables.
2) If off-gas treatment is needed by PCB treatment process.
3) The reasons a technology was judged to be implementable for PCBs in groundwater are similar to the reasons the technology was judged to be implementable for PCBs in deep vadose zone soils as presented in Table 3-12c. Refer to the evaluation in that table.

Table 5-9b - Implementability of *In Situ* Bioremediation for PCBs Contained in the Petroleum Groundwater Plumes

	Process Options for *In situ* Bioremediation
Attribute	**Enhanced Bioremediation**
Can it be constructed?	Yes, site is amenable to constructing and operating support equipment though access may be limited in some areas by infrastructure. Design, construction, and startup will take approximately 1 year. This technology includes the circulation of water-based solutions (i.e., nutrients) to stimulate microbes and/or the injection of Oxygen Release Compounds (ORC) or electron donor compounds or bioaugmentation.
Will it work?	Uncertain. No evidence showing that low concentrations of PCBs alone can be treated by this technology to reduce PCB concentrations to the very low screening level concentrations established for the Kaiser site. However, in diesel and heavy oil groundwater plumes, PCBs coexist with higher concentration SVOCs which may make technology more effective. PCBs that are less chlorinated are more likely to degrade. Treatability studies will be required.
Will this be acceptable to regulatory agencies?	Maybe
Is technology available?	Yes
Is process option accepted?	Yes, but not for the treatment of PCBs alone present at low concentrations at depths of 45–78 feet bgs.

Table 5-9c - Implementability of *In Situ* Chemical Treatment for PCBs Contained in the Petroleum Groundwater Plumes

	Process Options for *In situ* Chemical Treatment
Attribute	**Oxidation, Reduction, pH adjustment**
Can it be constructed?	Yes, it can be constructed but many injection, extraction and monitoring wells are needed to maintain and validate proper operation. Design, construction, and startup will take approximately 1 year.
Will it work?	Maybe. No evidence showing that low concentrations of PCBs can be treated by this technology to reduce PCB concentrations to the very low screening level concentrations established for the Kaiser site (chemical treatment may degrade PCBs where co-located with higher concentrations of other SVOCs). However, in diesel and heavy oil groundwater plumes, PCBs coexist with higher concentration SVOCs which may make technology more effective. Oxidant may react with non-target compounds hindering treatment of area of concern. Multiple injection events are likely. Potential for exothermic (explosive) reactions to occur (EPA 2004). Incomplete reactions may leave toxic compounds; off-gas treatment may be needed. Ozone and sodium persulfate (heat catalyzed) are oxidants that are highly reactive with PCBs (EPA 2006).
Will this be acceptable to regulatory agencies?	Yes
Is technology available?	Yes
Is process option accepted?	Yes, but not for the treatment of PCBs (alone) present at low concentrations at depths of 45 to 78 feet bgs.

Table 5-9d - Implementability of *Ex Situ* Bioremediation for PCBs Contained in the Petroleum Groundwater Plumes

	Process Options for Aerobic *Ex situ* Bioremediation
Attribute	**Biological treatment of groundwater in aboveground bioreactor**
Can it be constructed?	Yes. Extensive footprints are required for the large tanks that are used to treat large volumes of groundwater and groundwater with high contaminant concentrations. Treatments require large tanks for sufficient residence time for biologic processes to be effective.
Will it work?	Yes, for diesel and heavy oil groundwater plumes where PCBs exist with SVOCs at higher concentration that are likely to help maintain biomass population. Not likely where PCB is the sole contaminant since biodegradation of PCBs is relatively slow. No evidence showing that low concentrations of PCBs alone can be treated by this technology to reduce PCB concentrations to the very low screening level concentrations established for the Kaiser site. However, in diesel and heavy oil groundwater plumes, PCBs coexist with higher concentration SVOCs which may make technology more effective. Treatability assessment is required.
Will this be acceptable to regulatory agencies?	Yes.
Is technology available?	Yes, but significant bench- and pilot-scale assessment is required to optimize design.
Is process option accepted?	Yes, but not for the treatment of PCBs (alone) present at low concentrations.

Table 5-9e - Implementability of Adsorption for PCBs Contained in the Petroleum Groundwater Plumes

	Process Options for Adsorption from Extracted Groundwater
Attribute	**Granular Activated Carbon (GAC)**
Can it be constructed?	Most source areas suitable for construction and equipment required. Readily designed and constructed <1 year.
Will it work?	Yes, but GAC typically used for a final polishing step, that is, following removal of the bulk of suspended contaminants (or solids) by another technology. GAC beds were part of the *ex situ* groundwater treatment system for PCB-impacted water at Superfund sites La Salle Electric, Norwood PCBs, Rose Disposal Pit and Sangamo Weston/Twelve-Mile. Note: at these sites, groundwater was also impacted by VOCs and most of the treatment systems included an air stripper (EPA 2004b, EPA 2004c, RMT 2006). For example, at the Sangamo Weston/Twelve-Mile CERCLA site in South Carolina, the groundwater treatment system designed to treat VOCs and PCBs has an air stripper, filtration, and carbon adsorption. From startup to 2005, this system treated approximately 155 million gallons of groundwater. This has resulted in the removal of approximately 1,140 pounds of chlorinated solvents and 12.3 pounds of PCBs. Based on analytical data collected in 2005 it appears the majority of PCB removal is occurring in carbon beds (RMT 2006).
Will this be acceptable to regulatory agencies?	Yes
Is technology available?	Yes
Is process option accepted?	Yes

Table 5-9f - Implementability of On-Site Chemical/UV Oxidation for PCBs Contained in the Petroleum Groundwater Plumes

	Process Options for Chemical/UV Oxidation of Extracted Groundwater
Attribute	**Oxidation by chemical addition and/or UV light**
Can it be constructed?	Yes, site is amenable to constructing and operating support equipment, though access may be limited in some areas by infrastructure. Design, construction, and startup will take approximately 1 year.
Will it work?	Uncertain. No evidence showing that low concentrations of PCBs can be treated by this technology to reduce PCB concentrations to the very low screening level concentrations established for the Kaiser site. However, in diesel/heavy oil-groundwater plumes, PCBs coexist with higher concentration SVOCs which may make technology more effective. Incomplete reactions may leave toxic compounds; carbon polishing step may be required and treatability studies will be required. Off-gas may be produced that needs treatment. Ozone and sodium persulfate (heat catalyzed) are oxidants that are highly reactive with PCBs (EPA 2006).
Will this be acceptable to regulatory agencies?	Yes
Is technology available?	Yes
Is process option accepted?	Yes, but not for PCBs alone that are present at low concentrations.

Table 5-10 - Reliability of Selected Technologies for PCBs Contained in the Petroleum Groundwater Plumes

Technology	**Process Options**	**Is it reliable?**[1]
Monitoring	Protection, performance, and confirmational	Yes
Access and Use Restrictions	Fencing, deed restrictions, restrictive covenant	Yes
Best Management Practices (BMPs)	Spill prevention, cleanup procedures, secondary containment, etc.	Yes
Capping	Low Permeability Asphalt Cap	Yes
Capping	Low Permeability Concrete Cap	Yes
Capping	Multilayer (synthetic liner + soil)	Yes
Hydraulic Containment	Vertical Wells	Yes
In situ Bioremediation	Enhanced Bioremediation	Yes
Monitored Natural Attenuation	Monitored Natural Attenuation	Yes
In situ Chemical Treatment	Oxidation, reduction, pH adjustment	Yes
Aerobic *Ex situ* Bioremedation	Aeration basins, bioreactors, trickling filters	Yes
Ex situ Adsorption	Granular Activated Carbon	Yes
Suspended Solids Removal *(ex situ)*	Precipitation, sedimentation, filtration	Yes
Ex situ Chemical Treatment	Oxidation by chemical addition or UV light	Yes
Adsorption (extracted vapor)	Granular Activated Carbon	Yes[2]
Thermal and Catalytic Oxidation (extracted vapor)	Catalytic Oxidation	Yes[2]
Advanced Oxidation (extracted vapor)	UV Light	No
Chlorine Removal (extracted vapor)	Chlorine Scrubber	Yes[2, 3]

Notes:

1 The reliability evaluations given in this table for PCBs in groundwater are similar to SVOCs in groundwater as given in Tables 5.7a and 5.7i except where noted. Refer to the evaluations in those tables.

2 If off-gas treatment is needed by PCB treatment process.

3 The reasons a technology was judged to be reliable for PCBs in groundwater are similar to the reasons the technology was judged to be reliable for PCBs in deep vadose zone soils as presented in Table 3-13d. Refer to the evaluation in that table.

Table 5-11 - Summary of Technology Screening Process: PCBs Contained in the Petroleum Groundwater Plumes

			Screening Outcome		
General Response Action [1]	Remedial Technology [1]	Process Options [1]	Physical/Chemical [2]	Implementability [3]	Reliability [4]
Monitoring	**Monitoring**	**Protection, Performance, and Confirmational**	**Retained**	**Retained**	**Retained**
Institutional Controls	**Access and Use Restrictions**	**Fences, Signs, Deed Restrictions**	**Retained**	**Retained**	**Retained**
	Alternative Water Supply	Connect to distribution system, new supply well	Eliminated	--	--
	Best Management Practices	**Spill prevention, leak detection, double walled pipes**	**Retained**	**Retained**	**Retained**
Containment	**Capping**	Soil	Retained	Eliminated	--
		Clay	Retained	Eliminated	--
		Asphalt	**Retained**	**Retained**	**Retained**
		Concrete	**Retained**	**Retained**	**Retained**
		Synthetic	Retained	Eliminated	--
		Multi-layer cap (soil + synthetic)	**Retained**	**Retained**	**Retained**
	Vertical Barriers	Slurry wall, grout curtain, sheet piling	Eliminated	--	--
	Horizontal Barriers	Block displacement, grout injection	Eliminated	--	--
	Hydraulic Containment	**Extraction wells**	**Retained**	**Retained**	**Retained**
		Trenches	Retained	Eliminated	--
***In Situ* Treatment of Groundwater**	***In situ* Bioremediation**	**Enhanced bioremediation**	**Retained**	**Retained[5]**	**Retained**
		Phytoremediation	Retained	Eliminated	--
	Monitored Natural Attenuation	**Monitored Natural Attenuation**	**Retained**	**Retained**	**Retained**
	Air Sparging	Horizontal, vertical wells	Eliminated	--	--
	Passive Treatment Walls	Various innovative processes	Eliminated	--	--
	Hydrofracturing	Variety of fluids and pumping schedules	Eliminated	--	--

Table 5-11 - Summary of Technology Screening Process: PCBs Contained in the Petroleum Groundwater Plumes

			Screening Outcome		
General Response Action[1]	**Remedial Technology[1]**	**Process Options[1]**	**Physical/Chemical[2]**	**Implementability[3]**	**Reliability[4]**
***In Situ* Treatment of Groundwater (continued)**	**Chemical Treatment**	**Oxidation, reduction, pH adjustment**	**Retained**	**Retained[5]**	**Retained**
	In-Well Air Stripping	Vertical wells	Eliminated	--	--
Extraction and On-Site Treatment of Groundwater	**Aerobic *Ex situ* Bioremediation**	**Various, such as aeration basins, constructed wetlands, bioreactors, trickling filters**	**Retained**	**Retained[5]**	**Retained**
	Air Stripping	Packed tower, diffused aeration, tray aeration, spray aeration	Eliminated	--	--
	Adsorption	**Granular activated carbon**	**Retained**	**Retained**	**Retained**
		Other Adsorbents	Retained	Eliminated	--
	Suspended Solids Removal	**Precipitation, sedimentation, filtration**	**Retained**	**Retained**	**Retained[6]**
	Ion Exchange	Cationic, anionic	Eliminated	--	--
	Membranes	Reverse osmosis, ultrafiltration, membrane prevaporation	Eliminated	--	--
	Distillation	One stage, multistage	Eliminated	--	--
	Freeze Crystallization	Freeze Crystallization	Eliminated	--	--
	Chemical/UV Oxidation	**Oxidation through chemical addition and/or UV light**	**Retained**	**Retained[5]**	**Retained**
On-Site Treatment of Extracted Soil Vapor[7,8]	**Adsorption**	**Granular activated carbon**	**Retained**	**Retained**	**Retained**
	Thermal and Catalytic Oxidation	Direct flame Thermal	Retained	Eliminated	--
		Flameless Thermal	Retained	Eliminated	--
		Catalytic Oxidizers	**Retained**	**Retained**	**Retained**
	Advanced Oxidation	UV light	Retained	Retained	Eliminated
		Photocatalytic	Retained	Retained	Eliminated
	Biofiltration	Bioreactor, soil pile	Retained	Eliminated	--
	Chlorine Removal	**Chlorine Scrubber**	**Retained**	**Retained**	**Retained**

Table 5-11 - Summary of Technology Screening Process: PCBs Contained in the Petroleum Groundwater Plumes

			Screening Outcome		
General Response Action [1]	**Remedial Technology [1]**	**Process Options [1]**	**Physical/Chemical [2]**	**Implementability [3]**	**Reliability [4]**

Notes:

Bolded Technologies Retained for further evaluation in the FS.

1) Taken from FSTM Table 5-2a through 5-2b
2) Taken from FSTM Table 5-4a through 5-4b
3) Taken from FSTM Table 5-9a through 5-9f
4) Taken from FSTM Table 5-10
5) Retained, but not for the treatment of PCBs (alone) present at low concentrations.
6) Not as stand-alone remedy. Used as pre- or post-GAC treatment technology.
7) If off-gas treatment required by PCB treatment process.
8) Subsurface vapor extraction may be required with this technology.

Table 5-12a - Implementability of Dual Vacuum Extraction (DVE) for Free Phase Product Recovery from Groundwater

	Process Options for Dual Vacuum Extraction (DVE)
Attribute	VE/GE,[1] Single vacuum pump, bioslurping
Can it be constructed?	Yes. Design and construction will require less than 1 year.
Will it work?	DVE has been proven effective for extracting groundwater, soil vapor, and free phase product. Groundwater is extracted with water pumps or vacuum pumps to lower the water table to expose previously saturated soil. Free phase product, if present in the vadose zone within cone of depression (in the previously saturated zone) will be extracted. If water pumps are used, the overall system will be more mechanically complex. However, groundwater pumps may be easier to automate than extraction equipment for controlling groundwater levels. In addition, extraction may require each well to be manually activated. F. O'Connor Superfund Site used DVE to recover separate-phase PCB oil. Note groundwater at this site is contaminated with PCBs and other VOCs (EPA 2007).
Will this be acceptable to regulatory agencies?	Yes
Is technology available?	Yes
Is process option accepted?	Yes

1) VE/GE stands for Vapor Extraction/Groundwater Extraction (EPA 1996g).

Table 5-12b - Implementability of Water Table Depression for Free Phase Product Recovery from Groundwater

	Process Options for Water Table Depression
Attribute	**Single Pump, Dual Pump**
Can it be constructed?	Yes, site is amenable to constructing and operating support equipment though access may be limited in some areas by infrastructure. Design, construction, and startup will take approximately 1 year.
Will it work?	Yes. Drawdown has to be optimized so the sufficient drawdown is achieved without smearing product layer or extracting too much groundwater. Note that turning off technology before product is recovered will cause recontamination. Water table depression is currently being used at Kaiser per IRM. Specifically, water table depression is used to enhance product recovery, however, free phase product is not pumped to the surface, instead skimming belts in nearby wells are used for free phase product collection (see Section 4 for more details on skimming belts).
Will this be acceptable to regulatory agencies?	Yes
Is technology available?	Yes
Is process option accepted?	Yes

Table 5-12c - Implementability of Free Phase Product Recovery from Groundwater

	Process Options for Free Phase Product Separation from Extracted Groundwater	
Attribute	**API Separator**	**Dissolved Air Floatation**
Can it be constructed?	Yes, can be designed and constructed in <1 year.	Yes, can be designed and constructed in <1 year.
Will it work?	Yes	Yes
Will this be acceptable to regulatory agencies?	Yes	Yes
Is technology available?	Yes	Yes
Is process option accepted?	Yes	Yes

Table 5-13a - Reliability of Dual Vacuum Extraction (DVE) for Free Phase Product Recovery from Groundwater

	Process Options for Dual Vacuum Extraction (DVE)
Attribute	VE/GE,[1] single vacuum pump, bioslurping
Has this process option been used at the scale required for Kaiser?	Yes, DVE, along with passive recovery, has been used at the F. O'Connor Superfund site for the recovery of separate phase PCB oil (EPA 2007).
Are operation and maintenance requirements infrequent and straightforward?	No. More maintenance is required for groundwater extraction pumps. However, they are easier to automate than extraction equipment. However, this extraction is more labor-intensive because each well may require manual starting and the overall system operation is difficult to automate. Groundwater and vacuum pump operation and maintenance is conventional technology. If free phase product is extracted with groundwater, an aboveground oil-water separator will be needed.
Has this process option been proven effective under COC and site conditions similar to those at Kaiser?	Yes, DVE has been used at the F. O'Connor Superfund site for the recovery of separate phase PCB oil that was induced into the water table by 1992 pump tests. From 1992 to 2007, approximately 125 gallons of oil was recovered from DVE and passive recovery. In 2007, DVE was discontinued when amounts of oil had decreased to levels that could be recovered passively (EPA 2007).
Is process option accepted?	Yes, will have to be used in conjunction with product recovery technologies (i.e., passive recovery).

1) VE/GE stands for Vapor Extraction/Groundwater Extraction (EPA 1996g).

Table 5-13b - Reliability of Water Table Depression for Free Phase Product Recovery from Groundwater

Attribute	Process Options for Free Phase Product Removal by Water Table Depression
	Single or Dual Pump(s)
Has this process option been used at the scale required for Kaiser?	Yes, this is conventional technology for free phase product recovery and a modification of this method is being used currently at Kaiser per the IRM. Specifically, water table depression is used to enhance product recovery; however, free phase product is not pumped to the surface, instead skimming belts in nearby wells are used for free phase product collection (see Section 4 for more details on skimming belt recovery systems).
Are operation and maintenance requirements infrequent and straightforward?	Yes, depending on process option used (single or dual pump), treatment of extracted groundwater may be needed to recover free phase product.
Has this process option been proven effective under COC and site conditions similar to those at Kaiser?	Yes
Is process option accepted?	Yes

Table 5-13c - Reliability of Free Phase Product Recovery from Groundwater

Sheet 1 of 1

Attribute	Process Options for Free Phase Product Separation of Extracted Groundwater	
	API Separation	**Dissolved air floatation**
Has this process option been used at the scale required for Kaiser?	Yes, this is conventional technology for separating and recovering LNAPL from wastewater streams at the flow rates expected at Kaiser.	Yes this is conventional technology for solids and oil separation from water.
Are operation and maintenance requirements infrequent and straightforward?	Yes, periodic cleaning of tank and free phase product is required. The skilled labor required is locally available.	Yes, periodic cleaning of tank and free phase product is required. The skilled labor required is locally available.
Has this process option been proven effective under COC and site conditions similar to those at Kaiser?	Yes	Yes
Is process option accepted?	Yes	Yes

Table 5-14 - Summary of Technology Screening Process: Free-Phase Product Recovery from Groundwater

			Screening Outcome		
General Response Action [1]	Remedial Technology [1]	Process Options [1]	Physical/Chemical [2]	Implementability [3]	Reliability [4]
***In situ* Free Phase Product Recovery**	**Dual Vacuum Extraction (DVE)**	**VE/GE[5], single vacuum pump, bioslurping**	**Retained**	**Retained**	**Retained**
	Free Product Recovery With Water Table Depression	**One pump, two pump recovery system**	**Retained**	**Retained**	**Retained**
***Ex situ* Free Phase Product Recovery**	**Oil-Water (Free Product) separation**	**API separator**	**Retained**	**Retained**	**Retained**
		Dissolved air flotation	**Retained**	**Retained**	**Retained**

Notes:

Bolded Technologies Retained for further evaluation in the FS.

1) Taken from FSTM Table 5-2c.

2) Taken from FSTM Table 5-5.

3) Taken from FSTM Table 5-12a through 5-12c.

4) Taken from FSTM Table 5-13a through 5-13c.

5) VE/GE stands for Vapor Extraction/Groundwater Extraction (EPA 1996g).

Table 5-15 - Location and Concentration of COCs in Petroleum Contaminated Groundwater

General Location	COC(s)	Sample Number(s)	Calculated Concentration[a]	Units	Comments
ORB Area	Heavy oil	HL-MW-2 (24-Jan-08), HL-MW-2 (22-Apr-08), HL-MW-2 (19-Oct-08), HL-MW-20S (22-Oct-08), HL-MW-20S (20-Apr-08)	5	mg/L	
	Diesel	HL-MW-2 (24-Jan-08), HL-MW-2 (22-Apr-08), HL-MW-2 (19-Oct-08), HL-MW-20S (22-Oct-08), HL-MW-20S (20-Apr-08)	3	mg/L	
	cPAH	HL-MW-2 (24-Jan-08), HL-MW-2 (22-Apr-08), HL-MW-2 (19-Oct-08), HL-MW-20S (22-Oct-08), HL-MW-20S (20-Apr-08)	0.01	μg/L	
	Arsenic	HL-MW-20S (22-Oct-08), HL-MW-20S (20-Apr-08)	2	μg/L	Dissolved
	Manganese	HL-MW-20S (22-Oct-08), HL-MW-20S (20-Apr-08)	190	μg/L	Dissolved
	Iron	HL-MW-20S (22-Oct-08), HL-MW-20S (20-Apr-08)	220	μg/L	Dissolved
Cold Mill/Finishing Areas	Heavy oil	CM-MW-1S (21-Apr-08), CM-MW-1S (19-Oct-08), CM-MW-2S (21-Apr-08), CM-MW-2S (20-Oct-08), CM-MW-3S (21-Apr-08), CM-MW-3S (21-Oct-08), CM-MW-7S (21-Apr-08), CM-MW-7S (20-Oct-08)	0.6	mg/L	
	Kensol	CM-MW-1S (21-Apr-08), CM-MW-1S (19-Oct-08), CM-MW-2S (21-Apr-08), CM-MW-2S (20-Oct-08), CM-MW-3S (21-Apr-08), CM-MW-3S (21-Oct-08), CM-MW-7S (21-Apr-08), CM-MW-7S (20-Oct-08)	3	mg/L	
	cPAH	CM-MW-1S (21-Apr-08), CM-MW-1S (19-Oct-08), CM-MW-2S (21-Apr-08), CM-MW-2S (20-Oct-08), CM-MW-3S (21-Apr-08), CM-MW-3S (21-Oct-08), CM-MW-7S (21-Apr-08), CM-MW-7S (20-Oct-08)	0.01	μg/L	
	Arsenic	CM-MW-1S (21-Apr-08), CM-MW-2S (21-Apr-08), CM-MW-3S (21-Apr-08), CM-MW-7S (21-Apr-08)	4	μg/L	Dissolved
	Manganese	CM-MW-1S (21-Apr-08), CM-MW-2S (21-Apr-08), CM-MW-3S (21-Apr-08), CM-MW-7S (21-Apr-08)	12	μg/L	Dissolved
	Iron	CM-MW-1S (21-Apr-08), CM-MW-2S (21-Apr-08), CM-MW-3S (21-Apr-08), CM-MW-7S (21-Apr-08)	190	μg/L	Dissolved
Oil House Area	Kensol	OH-EW-1 (22-Oct-08), OH-EW-1 (23-Apr-08), OH-MW-10 (22-Oct-08), OH-MW-10 (22-Apr-08), OH-MW-13 (23-Apr-08), OH-MW-13 (23-Oct-08), OH-MW-18 (23-Apr-08), OH-MW-18 (22-Oct-08), OH-MW-24 (23-Oct-08), OH-MW-24 (24-Apr-08), OH-MW-25 (24-Apr-08), OH-MW-25 (23-Oct-08), OH-MW-26 (22-Apr-08), OH-MW-26 (23-Oct-08), TF-MW-1 (21-Oct-08), TF-MW-1 (24-Apr-08), TF-MW-2 (24-Apr-08), TF-MW-2 (21-Oct-08), TF-MW-3 (23-Apr-08), TF-MW-3 (20-Oct-08), TF-MW-4 (20-Oct-08), TF-MW-4 (24-Apr-08)	60	mg/L	
	cPAH	OH-MW-10 (22-Oct-08), OH-MW-10 (22-Apr-08), OH-MW-24 (23-Oct-08), OH-MW-24 (24-Apr-08), OH-MW-25 (24-Apr-08), OH-MW-25 (23-Oct-08), TF-MW-1 (21-Oct-08), TF-MW-1 (24-Apr-08), TF-MW-2 (24-Apr-08), TF-MW-2 (21-Oct-08), TF-MW-4 (20-Oct-08), TF-MW-4 (24-Apr-08)	0.02	μg/L	
	PCBs	OH-MW-4 (6/28/1994), OH-SK-1 (6/28/1994), OH-MW-6 (9/22/1991), OH-MW-16 (11/3/1993), OH-MW-3 (6/23/1994), OH-MW-5 (9/22/1991), OH-MW-26 (23-Oct-08), OH-MW-24 (23-Oct-08), OH-MW-20 (5/14/1992)	36000	μg/L	
	Arsenic	OH-MW-10 (22-Oct-08), OH-MW-10 (22-Apr-08), OH-MW-24 (23-Oct-08), OH-MW-24 (24-Apr-08), OH-MW-25 (24-Apr-08), OH-MW-25 (23-Oct-08), TF-MW-1 (21-Oct-08), TF-MW-1 (24-Apr-08), TF-MW-2 (24-Apr-08), TF-MW-2 (21-Oct-08), TF-MW-4 (20-Oct-08), TF-MW-4 (24-Apr-08)	12	μg/L	Dissolved
	Manganese	OH-MW-10 (22-Oct-08), OH-MW-10 (22-Apr-08), OH-MW-24 (23-Oct-08), OH-MW-24 (24-Apr-08), OH-MW-25 (24-Apr-08), OH-MW-25 (23-Oct-08), TF-MW-1 (21-Oct-08), TF-MW-1 (24-Apr-08), TF-MW-2 (24-Apr-08), TF-MW-2 (21-Oct-08), TF-MW-4 (20-Oct-08), TF-MW-4 (24-Apr-08)	520	μg/L	Dissolved
	Iron	OH-MW-10 (22-Oct-08), OH-MW-10 (22-Apr-08), OH-MW-24 (23-Oct-08), OH-MW-24 (24-Apr-08), OH-MW-25 (24-Apr-08), OH-MW-25 (23-Oct-08), TF-MW-1 (21-Oct-08), TF-MW-1 (24-Apr-08), TF-MW-2 (24-Apr-08), TF-MW-2 (21-Oct-08), TF-MW-4 (20-Oct-08), TF-MW-4 (24-Apr-08)	3100	μg/L	Dissolved
Wastewater Treatment Area	Heavy oil	WW-EW-1 (23-Apr-08), WW-EW-1 (22-Oct-08), WW-EW-2 (24-Apr-08), WW-EW-2 (22-Oct-08), WW-MW-7 (24-Apr-08), WW-MW-7 (23-Oct-08), WW-MW-8 (24-Apr-08), WW-MW-8 (23-Oct-08), WW-MW-15 (24-Apr-08), WW-MW-15 (23-Oct-08), WW-MW-17 (24-Apr-08), WW-MW-17 (23-Oct-08), WW-MW-18 (24-Apr-08), WW-MW-18 (23-Oct-08), MW-14 (23-Apr-08), MW-14 (21-Oct-08), MW-21S (23-Apr-08) MW-21S (23-Oct-08), MW-22D (23-Apr-08), MW-22D (23-Oct-08)	0.6	mg/L	

Table 5-15 - Location and Concentration of COCs in Petroleum Contaminated Groundwater

General Location	COC(s)	Sample Number(s)	Calculated Concentration^a	Units	Comments
	Diesel	WW-EW-1 (23-Apr-08), WW-EW-1 (22-Oct-08), WW-EW-2 (24-Apr-08), WW-EW-2 (22-Oct-08), WW-MW-7 (24-Apr-08), WW-MW-7 (23-Oct-08), WW-MW-8 (24-Apr-08), WW-MW-8 (23-Oct-08), WW-MW-15 (24-Apr-08), WW-MW-15 (23-Oct-08), WW-MW-17 (24-Apr-08), WW-MW-17 (23-Oct-08), WW-MW-18 (24-Apr-08), WW-MW-18 (23-Oct-08), MW-14 (23-Apr-08), MW-14 (21-Oct-08), MW-21S (23-Apr-08) MW-21S (23-Oct-08), MW-22D (23-Apr-08), MW-22D (23-Oct-08)	2	mg/L	
	Kensol	WW-EW-1 (23-Apr-08), WW-EW-1 (22-Oct-08), WW-EW-2 (24-Apr-08), WW-EW-2 (22-Oct-08), WW-MW-7 (24-Apr-08), WW-MW-7 (23-Oct-08), WW-MW-8 (24-Apr-08), WW-MW-8 (23-Oct-08), WW-MW-15 (24-Apr-08), WW-MW-15 (23-Oct-08), WW-MW-17 (24-Apr-08), WW-MW-17 (23-Oct-08), WW-MW-18 (24-Apr-08), WW-MW-18 (23-Oct-08), MW-14 (23-Apr-08), MW-14 (21-Oct-08), MW-21S (23-Apr-08) MW-21S (23-Oct-08), MW-22D (23-Apr-08), MW-22D (23-Oct-08)	0.1	mg/L	
	cPAH	WW-MW-7 (24-Apr-08), WW-MW-8 (24-Apr-08), WW-MW-8 (23-Oct-08), MW-21S (23-Apr-08), MW-21S (23-Oct-08)	0.01	μg/L	
	PCBs	WW-MW-6 (9/21/1991), WW-MW-8 (10/23/2008), WW-MW-11 (4/27/1994), WW-MW-13 (12/4/1991)	6200	μg/L	
	Arsenic	WW-MW-18 (24-Apr-08), WW-MW-18 (23-Oct-08), MW-14 (23-Apr-08), MW-14 (21-Oct-08), MW-21S (23-Apr-08) MW-21S (23-Oct-08), MW-22D (23-Apr-08), MW-22D (23-Oct-08)	4	μg/L	Dissolved
	Manganese	WW-MW-18 (24-Apr-08), WW-MW-18 (23-Oct-08), MW-14 (23-Apr-08), MW-14 (21-Oct-08), MW-21S (23-Apr-08) MW-21S (23-Oct-08), MW-22D (23-Apr-08), MW-22D (23-Oct-08)	1	μg/L	Dissolved
	Iron	WW-MW-18 (24-Apr-08), WW-MW-18 (23-Oct-08), MW-14 (23-Apr-08), MW-14 (21-Oct-08), MW-21S (23-Apr-08) MW-21S (23-Oct-08), MW-22D (23-Apr-08), MW-22D (23-Oct-08)	8	μg/L	Dissolved

Notes

a - Based on four quarters of groundwater monitoring conducted in January, April, July, and October 2008. Concentration represents the average concentration of COCs in each AOC. One half of the reporting limit was used in averaging calculations if non-detect samples were present in the AOC.

Table 5-16 - Distribution of COCs in Petroleum Contaminated Groundwater in the General Operating Areas

General Area	Rough Order of Magnitude Mass of COCs in pounds[a]						
	cPAHS	Diesel or Kensol	Heavy Oil	PCBs	Arsenic	Manganese	Iron
ORB	1.3E-04	3.6E+01	5.4E+01		2.3E-02	2.2E+00	2.7E+00
Cold Mill/Finishing Area	1.0E-04	4.8E+01	1.1E+01		7.9E-02	2.2E-01	3.6E+00
Oil House Area	7.4E-04	2.5E+03		2.7E+02	4.6E-01	2.0E+01	1.2E+02
Wastewater Treatment Area	2.6E-04	8.0E+01	2.0E+01	8.2E+01	1.5E-01	5.0E-02	2.7E-01
Total	1.2E-03	2.6E+03	8.5E+01	3.5E+02	7.1E-01	2.3E+01	1.3E+02
Percentage of Total[b]	0.00004%	81.7%	2.7%	10.9%	0.02%	0.7%	4.0%

Notes

a - The rough order of magnitude quantities shown represent estimated quantities of COCs contained in one day's volume of groundwater at the determined hydraulic containment pumping rates.

b - Percent of the total COC mass removed in one day's volume of groundwater pumping.

Table 5-17 - Remedial Alternative: COC Group Matrix - Petroleum Groundwater Plumes

Alternative	Description	Contaminants of Concern			
		SVOCs	FPP	PCBs	Metals
A1	Institutional Controls & Monitoring & MNA	X	X	X	X
A2	Institutional Controls & Monitoring & MNA & Containment	X	X	X	X
A3	*In situ* Treatment & A2 [1]	X		X [2]	
A4	*Ex situ* Treatment & A2 [3]	X		X [2]	
A5	FPP Removal & A2	X	X	X [2]	

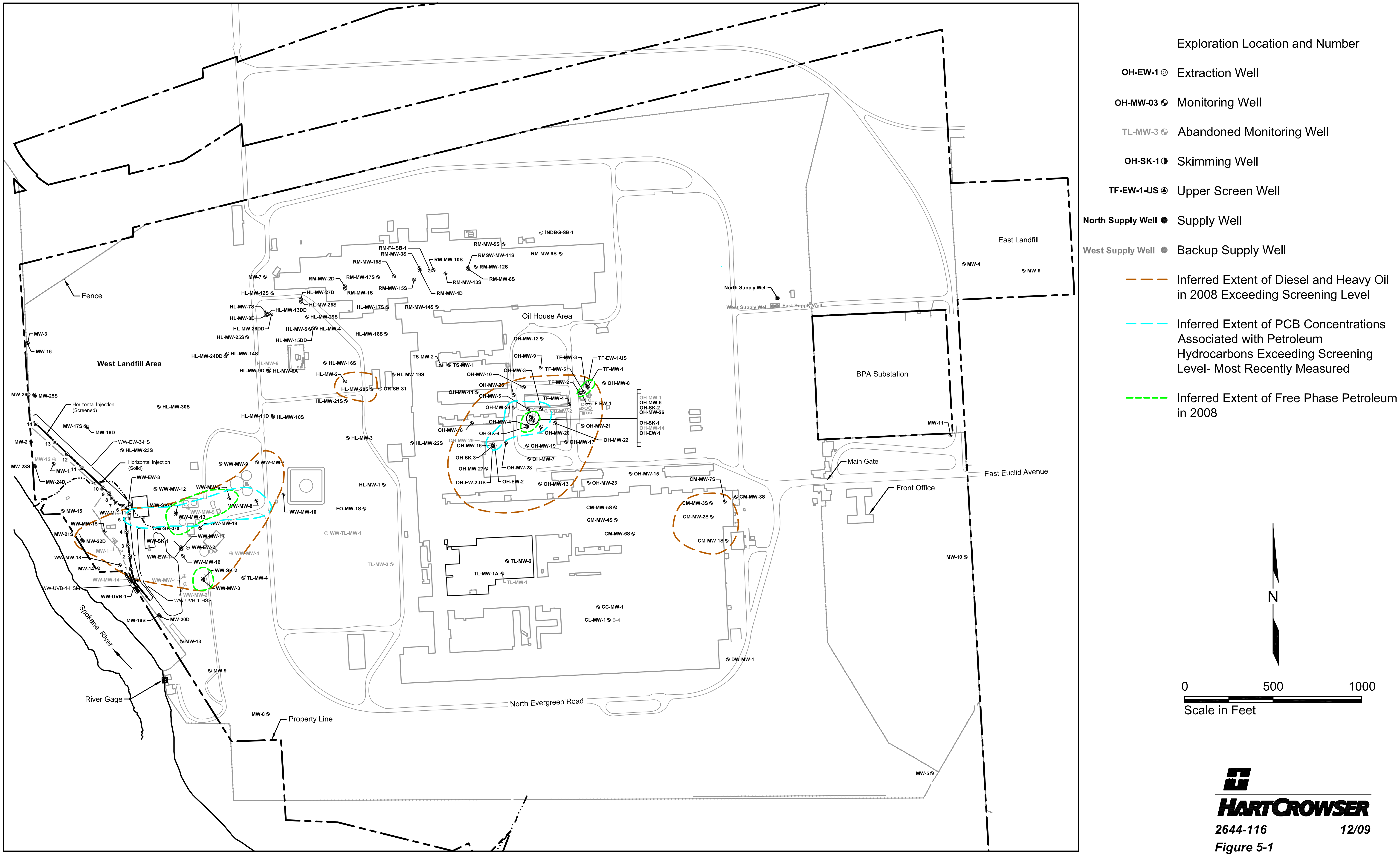
Notes:

1) *In situ* treatment refers to *in situ* bioremediation or chemical oxidation.

2) For areas where PCBs are co-mingled with SVOCs.

3) *Ex situ* treatment may include oil-water separation, suspended solids removal, chemical oxidation (chemical/UV oxidation), aerobic biological treatment, GAC.

Groundwater Areas of Concern Associated with Petroleum Hydrocarbons



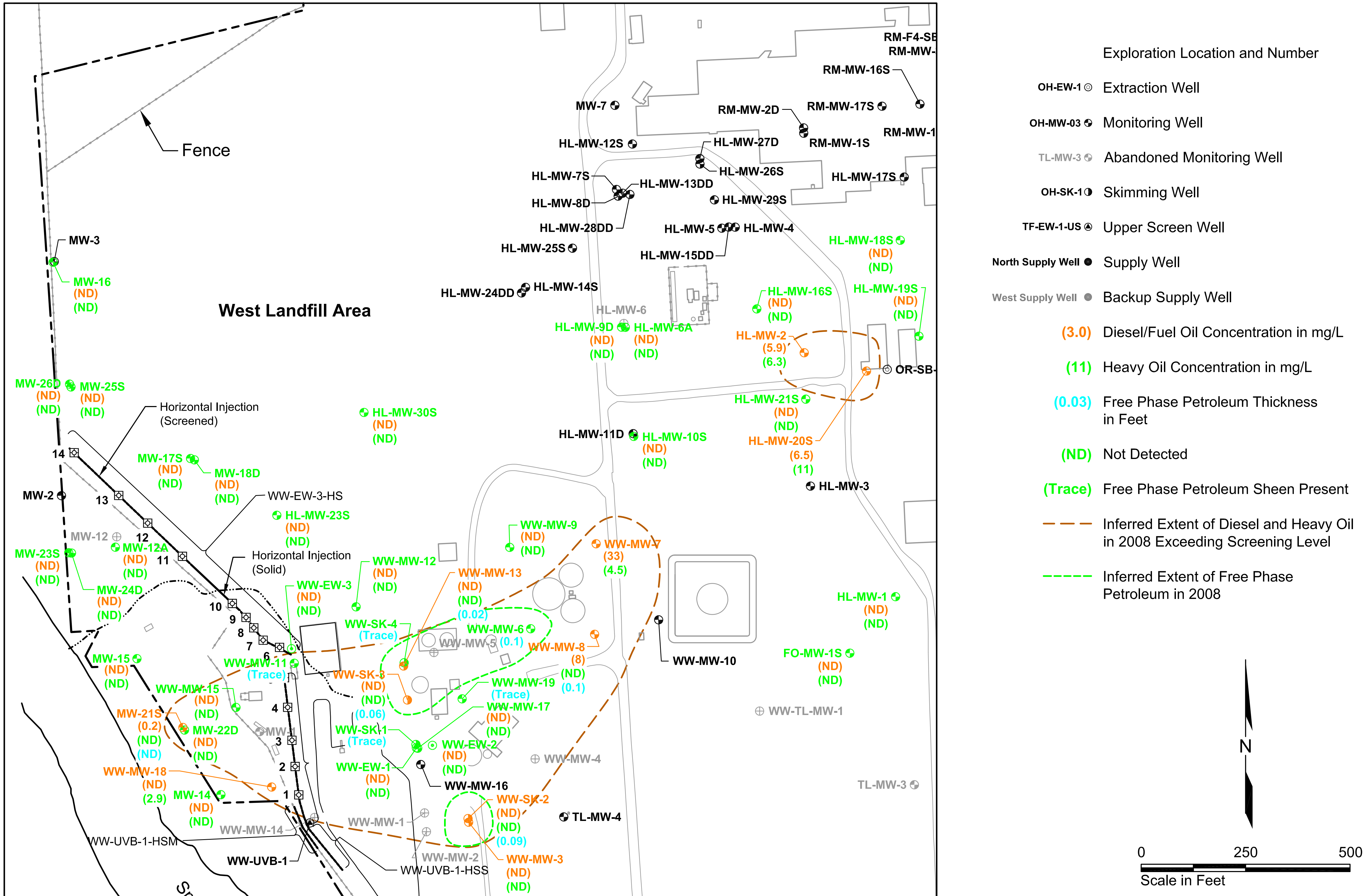
HARTCROWSER

2644-116 12/09

Figure 5-1

Diesel/Heavy Oil and Free Phase Petroleum in Groundwater

West Area - 2008



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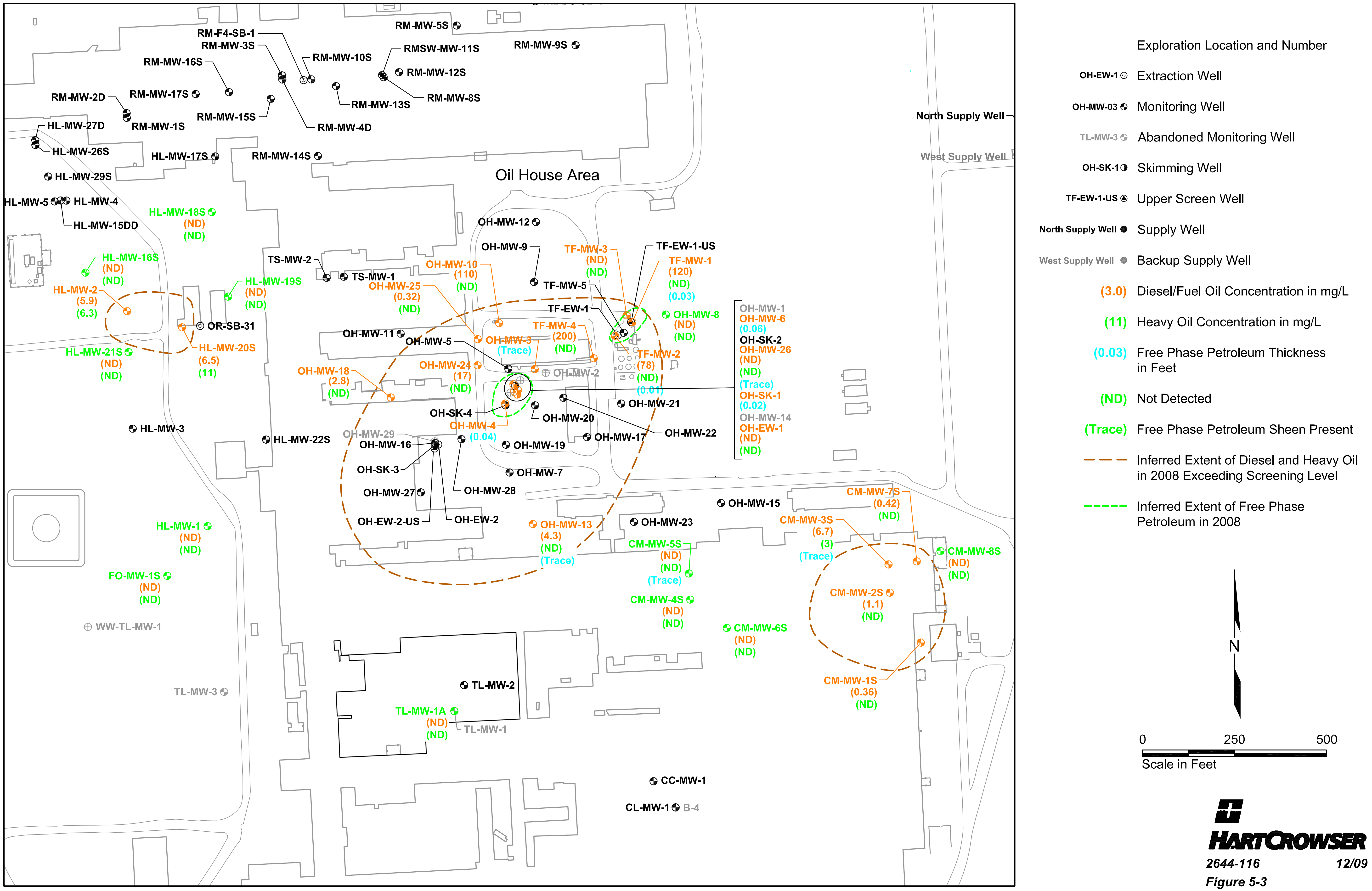
2644-116 *12/09*

Figure 5-2

EAL 12/1/09 2644116-063.DWG

Diesel/Heavy Oil and Free Phase Petroleum in Groundwater
East Area - 2008



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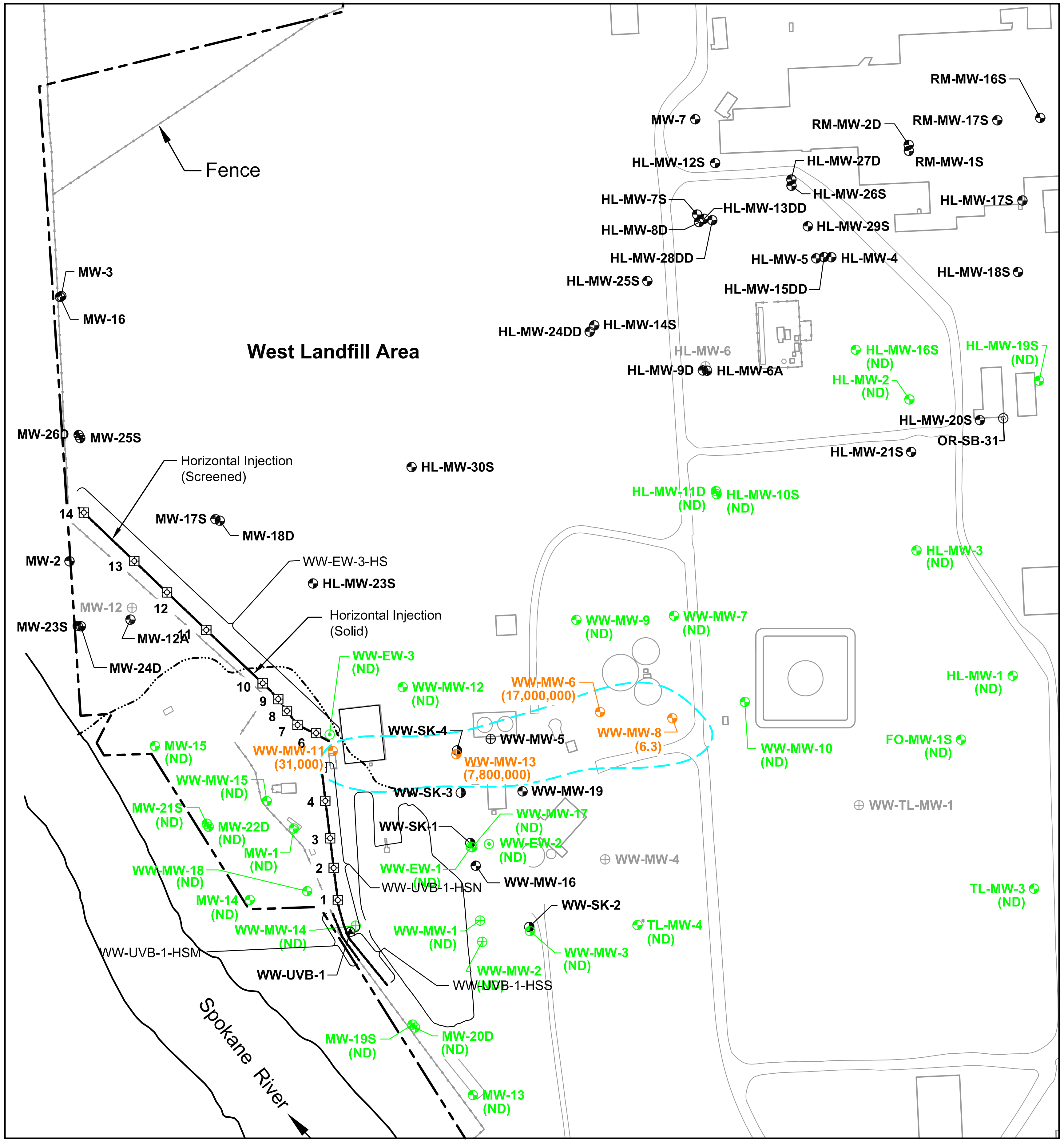
2644-116 12/09

Figure 5-3

EAL 12/1/09 2644116-064.DWG

Total PCB Concentrations Associated with Petroleum in Groundwater

West Area - Most Recently Measured



Exploration Location and Number

OH-EW-1 ◎	Extraction Well
OH-MW-03 ◐	Monitoring Well
TL-MW-3 ◐	Abandoned Monitoring Well
OH-SK-1 ◑	Skimming Well
TF-EW-1-US ◬	Upper Screen Well
North Supply Well ●	Supply Well
West Supply Well ●	Backup Supply Well
(3.0)	Total PCB Concentration in ng/L
J	Estimated Value
P	GC Confirmation Criteria was Exceeded
T	Value is between the MDL and MRL
(ND)	Not Detected
— — —	Inferred Extent of PCB Concentrations Associated with Petroleum Hydrocarbons Exceeding Screening Level. PCB Concentrations are not Dissolved in Groundwater.

Notes:

1. PCBs associated with the Remelt plume will be discussed in Section 6.

N

0 250 500
Scale in Feet

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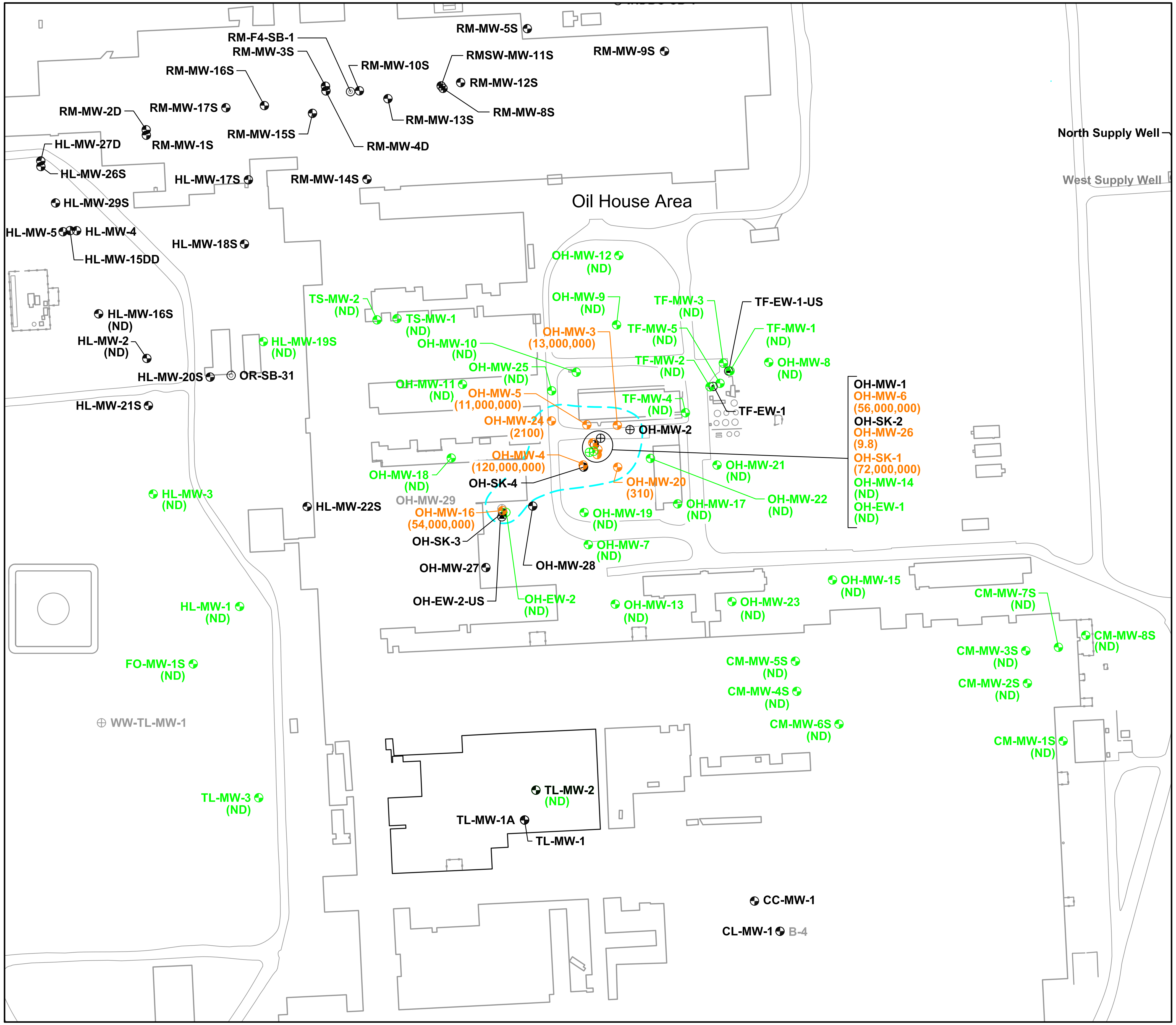
2644-116 *12/09*

Figure 5-4

EAL 12/1/09 2644116-061.DWG

Total PCB Concentrations Associated with Petroleum in Groundwater

East Area - Most Recently Measured



Exploration Location and Number

OH-EW-1 ◎	Extraction Well
OH-MW-03 ●	Monitoring Well
TL-MW-3 ●	Abandoned Monitoring Well
OH-SK-1 ◑	Skimming Well
TF-EW-1-US ◉	Upper Screen Well
North Supply Well ●	Supply Well
West Supply Well ●	Backup Supply Well
(3.0)	Total PCB Concentration in ng/L
J	Estimated Value
P	GC Confirmation Criteria was Exceeded
T	Value is between the MDL and MRL
(ND)	Not Detected
– – –	Inferred Extent of PCB Concentrations Associated with Petroleum Hydrocarbons Exceeding Screening Level. PCB Concentrations are not Dissolved in Groundwater.

Notes:

1. PCBs associated with the Remelt plume will be discussed in Section 6.

N

0 250 500

Scale in Feet

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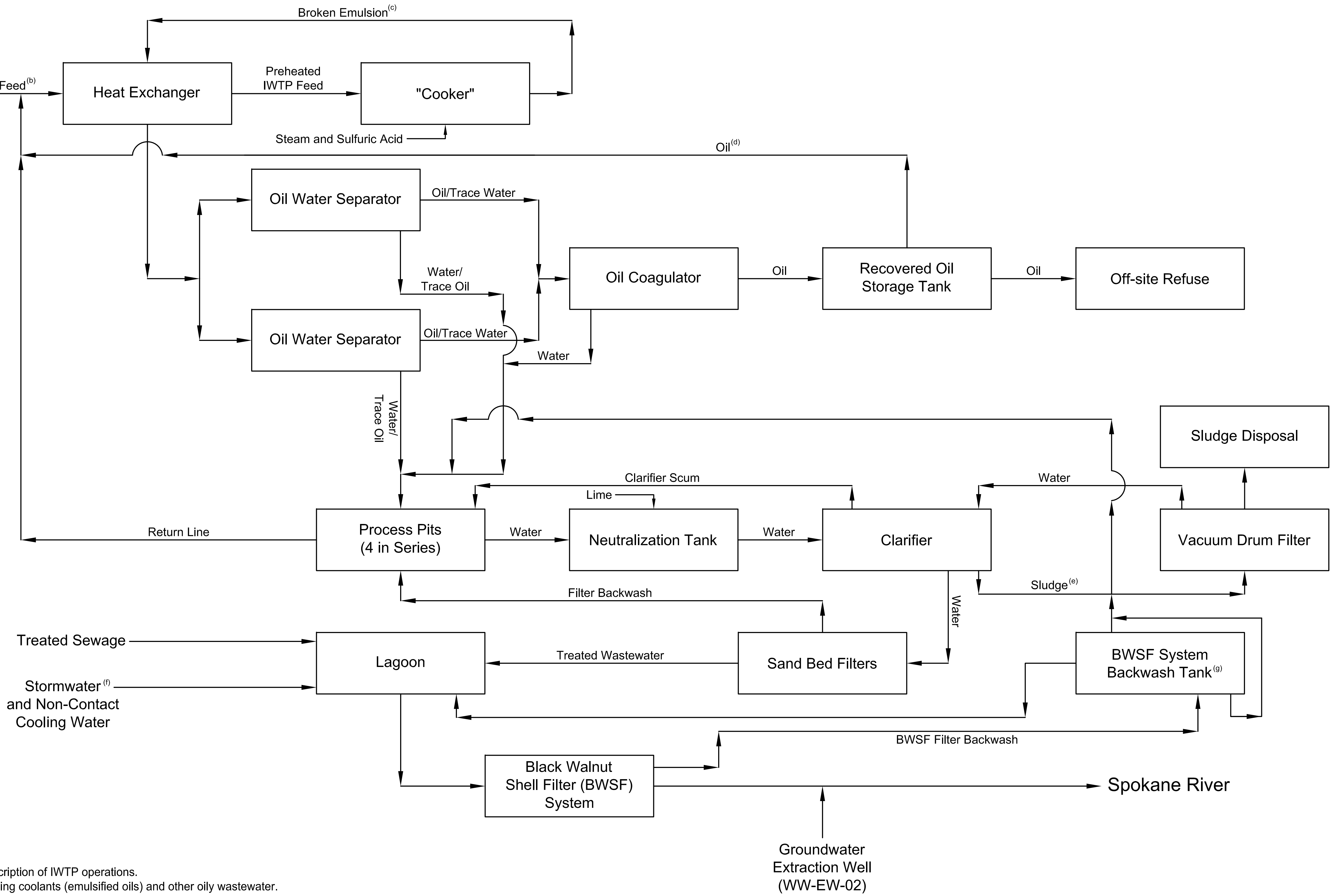
2644-116 ***12/09***

Figure 5-5

EAL 12/1/09 2644116-062.DWG

Industrial Wastewater Treatment Plant (IWTP) Process Flow Diagram (a)



EAL 12/1/09 2644116-066.DWG

Notes:

- a. Refer to Section 5.4.4 for a description of IWTP operations.
- b. IWTP feed consists of spent rolling coolants (emulsified oils) and other oily wastewater.
- c. The heated broken emulsion effluent from the cooker is used to preheat incoming IWTP feed in the heat exchanger.
- d. Oil from the Recovered Oil Storage Tank can be reprocessed to break out more water and improve oil quality.
- e. Clarifier sludge consists of precipitated metals and other settled solids.
- f. Storm runoff from the Mill Buildings and paved areas is conveyed to the Lagoon.
- g. BWSF backwash is held for 100 minutes in the BWSF Backwash Tank. Water from the mid-level of the tank is transferred to the Lagoon. Settled material and floating material is transferred to the process tanks.

CONTENTS

TABLES

CONTENTS (Continued)

TABLES (Continued)

FIGURE

6.0 CONTROL OF CONSTITUENTS OF CONCERN IN THE REMELT/HOT LINE GROUNDWATER PLUME

Constituents of potential concern (COPCs) in groundwater on the Kaiser Facility were identified in Section 1.3. Screening levels (SLs) were then established for the COPCs by following MTCA requirements considering site-specific conditions such as groundwater use, and by comparison of the risk-based MTCA SLs with other chemical-specific applicable or relevant and appropriate requirements (ARARs). COPCs that are present at concentrations that exceed SLs may be considered to be constituents of concern (COCs). The COCs identified for groundwater in Section 1.3.2 fall under the following groupings:

- Free phase petroleum (FPP);
- Semivolatile organic compounds (SVOCs): including diesel and heavy oil-range petroleum hydrocarbons and carcinogenic polycyclic aromatic hydrocarbon (cPAHs);
- Total polychlorinated biphenyls (PCBs); and
- Metals (arsenic, iron, and manganese).

Free Phase Petroleum

Figures 4-6 through 4-8 identify the areas at Kaiser with historic FPP while Figures 4-9 through 4-11 depict the areas with FPP identified during 2008 groundwater monitoring events. Comparing Figure 4-6 to Figure 4-9, a significant reduction in the size of the FPP areas can be seen as a result of source control and FPP removal measures conducted at Kaiser over the past 20 years.

A review of Figures 4-6 to 4-11 reveals that no free phase product has been detected in the Remelt/Hot Line groundwater plume area.

SVOCs

For the purposes of this FSTM and remediation technology evaluations, SVOCs include carcinogenic polycyclic aromatic hydrocarbon (cPAHs) and petroleum hydrocarbons in the diesel- and heavy oil-ranges.

The distribution of diesel and heavy oil in groundwater at the Facility is discussed in Section 5, and shown on Figures 5-1 to 5-5. Diesel and heavy oil hydrocarbons were not detected in the Remelt/Hot Line groundwater plume in 2008.

Remelt Building area wells have not been tested for cPAHs as there are no known sources in this area. Wells downgradient of the Remelt Building have been regularly tested for cPAHs during the past four years. Sporadic estimated (J flagged) concentrations of cPAHs in excess of the SL (2.8 ng/L for TEQ Equivalent) have been detected. During 2008, there were no SL exceedances for cPAHs in wells downgradient of the Remelt building.

The fate and transport properties of cPAHs are similar to that of PCBs. cPAHs have low solubility in water, strongly bind to organic matter, and resist natural degradation processes. Because of the lack of organic carbon content in the aquifer, dissolved and colloidal transport of cPAHs is likely to be important. It is likely that cPAH will be influenced by colloidal transport in a fashion similar to PCBs. As a result, it was judged that the remedial measures selected to treat PCBs in the Remelt/Hot Line groundwater plume would also treat the cPAHs in the plume.

Polychlorinated Biphenyls (PCBs)

Groundwater containing PCBs at concentrations above SLs (0.064 ng/L) were found in the Remelt/Hot Line areas of the site as shown on Figure 5-8 in the Final Groundwater RI (Hart Crowser 2012a). PCBs detected in the Remelt/Hot Line groundwater plume AOC during 2008 ranged from 4.7 (in MW-12A) to 2300 ng/L (in RM-MW-17S), with an AOC-wide average value of about 270 ng/L. The wells sampled for PCBs did not contain diesel or heavy oil compounds or any free phase product. The evaluation of technologies aimed at remediating dissolved and/or colloid-transported PCBs not associated with petroleum in groundwater that flows through the Remelt/Hot Line area towards the Spokane River will be the focus of this section.

Metals

Remelt wells (designated RM-MW-XX on Figure 6-1) have not been tested for metals, as PCBs are the primary focus of monitoring efforts in this area. Wells immediately downgradient of the Remelt building and extending toward the river have been recently tested for metals. All groundwater samples collected within the Remelt/Hot Line PCB Plume AOC and analyzed for arsenic during 2008 (21 total) exceeded the arsenic SL.

Arsenic monitoring results for 2008 from wells within the Remelt/Hot Line PCB plume AOC ranged from 3.6 to 8.9 µg/L with an average concentration of 5.8 µg/L. Oxidation-reduction potential (ORP) measurements collected in the field during groundwater sample collection indicate oxidative conditions are present in the Remelt/Hot Line PCB plume with measurements ranging from -9 mV to 300 mV.

In this oxidative environment, significant mobilization of soil-bound arsenic is not expected. At this site, reducing conditions have been noted only in areas with elevated levels of petroleum hydrocarbons in the groundwater and smear zone soils (e.g., Oil House and Wastewater Treatment areas). Based on a review of recent arsenic data and evaluation of the area's background arsenic concentrations presented in Section 5, arsenic levels in the Remelt/Hot Line PCB plume are considered within the range of expected background concentrations (refer to Section 5). Remediation technologies will not be evaluated specifically for removing arsenic from groundwater. However, arsenic was included in average concentration and mass estimate calculations as detailed in Tables 6-6 and 6-7.

The SLs of 300 µg/L for iron and 50 µg/L for manganese were not exceeded within the Remelt/Hot Line PCB plume during quarterly monitoring events conducted from 2006 through 2008. This was when monitoring of the Hot Line wells (designated HL-MW-XX on Figure 6-1) for metals began in earnest. Therefore, remedial measures to remove iron and manganese from the Remelt/Hot Line plume are not evaluated in Section 6. Iron and manganese are considered by the Final Groundwater RI as presenting secondary (aesthetic) effects to groundwater.

The Remelt/Hot Line Groundwater Plume

This FSTM focuses on remedial alternatives that will effectively treat PCBs that are located in groundwater that flows from the Remelt/Hot Line area towards the Spokane River. This groundwater plume is depicted on Figure 6-1. The PCB concentrations shown on Figure 6-1 are the highest concentration measured in each well during 2008.

Section 6 evaluates technologies that could be applicable to PCBs in the Remelt/Hot Line groundwater plume and is organized as follows:

- Section 6.1 – Potential Remediation Technologies for PCBs in the Remelt/Hot Line Groundwater Plume
- Section 6.2 –Screening Technologies for Remediating the Remelt/Hot Line Groundwater Plume
- Section 6.3 - Description of Areas of Concern for PCBs in the Remelt/Hot Line Groundwater Plume
- Section 6.4 – Development of Remedial Alternatives

6.1 POTENTIAL REMEDIATION TECHNOLOGIES FOR PCBS IN THE REMELT/HOT LINE GROUNDWATER PLUME

The remediation of PCBs that are co-located with free phase product and SVOCs in groundwater are evaluated in Sections 5.1 and 5.2. The available technologies are assembled into the following general response actions: institutional controls, monitoring, containment, *in situ* treatment, groundwater extraction, and on-site treatment.

The general response actions and their associated technologies that are potentially applicable to the remediation of PCBs in the Remelt/Hot Line groundwater plume are similar to the technologies applicable to SVOCs in groundwater and are discussed in Section 5.1 and summarized in Table 5-2. A technology that is only applicable to the treatment of off-gases from some PCB remediation processes is chlorine scrubbing. This technology is evaluated in Table 5-2b. The scrubber is used for the treatment of PCB off-gas. This technology is described in more detail in Section 3.3.

The response actions judged to be potentially applicable for the treatment of PCBs in the Remelt/Hot Line groundwater plume are institutional controls, monitoring, containment, *in situ* treatment, and extraction and on-site treatment of groundwater. These response actions and their remedial technologies are listed in Table 6-1. Containment technologies are discussed in Section 5.1.1. Monitoring and institutional controls are discussed in Section 2. *In situ* treatment technologies judged to be potentially applicable to the Remelt/Hot Line plume (bioremediation, chemical treatment) are discussed in Section 5.1.2. Several potentially applicable groundwater extraction and on-site treatment technologies are discussed in Section 5.1.3, including granular activated carbon (GAC) adsorbers, chemical/UV oxidation, aerobic biological reactors, and suspended solids removal. Refer to Sections 5.1.1 through 5.1.3 for information about these technologies.

Section 6.1.1 discusses the variety of technologies that can be applied to the removal of suspended solids, particularly the colloidal particles that are present in the Remelt/Hot Line plume. The application of GAC adsorbers or powdered activated carbon (PAC) and MYCELX® polymeric adsorbers to the Remelt/Hot Line groundwater plume is discussed in Section 6.1.2.

6.1.1 Pre- and Post-Adsorption Technologies

Suspended solids, oil, grease, and other suspended matter must be removed from groundwater before it is treated by adsorption technologies. Coagulation, flocculation, and pH adjustment are the technologies most often used to aggregate and thus enhance the removal of low concentrations of small-sized suspended and colloidal solids, like those in the Remelt/Hot Line groundwater plume. These technologies are discussed in Section 6.1.1.1.

The removal of low concentrations of small-sized suspended solids is usually carried out in depth filters, surface filters (e.g., cartridge filters), and in membrane filters (microfilters, ultrafilters). These technologies are discussed in Section 6.1.2.

6.1.1.1 Particle Aggregation Technologies

The PCBs in the Remelt/Hot Line plume are thought to be present in soluble and colloidal adsorbed forms (refer to Section 6.2.1). The particle aggregation technologies discussed in this Section will aggregate colloidal particles into larger, more filterable aggregates that will be more readily removed by the filtration technologies discussed in Section 6.1.2.2.

Chemical Coagulation

Coagulation is a process that destabilizes colloidal particles so particle growth can result. Colloidal particles in an aqueous environment will move in an electric field, indicating that these particles carry an electric charge. Most colloids develop a negative charge (Weber 1972). The primary charge on the particles is counterbalanced in the aqueous phase. As a result, an electric double layer exists at every interface between the colloid and water. When two similar colloid particles approach each other the electrostatic interaction between the particles produces a repulsive force that keeps the particles apart. The magnitude of the negative charge on the particle and the resulting repulsive force is a function of the ionic strength and pH of the liquid phase.

Destabilization is achieved by adding coagulant(s) to the incoming stream and rapidly mixing the two together to ensure uniform dispersion of the coagulant. Rapid mixing is accomplished by devices such as vertical impellers, baffles, and pumps. Common coagulants are made of aluminum and iron salts. Chitosan is a cationic coagulant derived from chitin which is found in the exoskeletons of shellfish like shrimp and crabs (Borvickova 2005).

There are two common mechanisms behind coagulation: (1) adsorption of soluble hydrolysis species on the colloid and destabilization; and (2) sweep coagulation where the colloid is entrapped within aluminum hydroxide precipitate. The first mechanism is much faster than the second; however, both occur quickly, generally in less than 10 seconds. With this fast reaction time, in combination with rapid mixing, coagulation addition tanks tend to be small (3 to 10 feet in diameter) with short detention times (1 to 2 minutes) (Corbitt 1989).

Numerous bench-scale tests have compared the effectiveness of different coagulants on PCBs removal. One evaluation comparing aluminum sulfate and ferric chloride using water with low-level PCBs (2.0-2.2 μg/L), found that the percentage of PCBs removed ranged from 10 to 40 percent, and that over a particular dosage rate of aluminum sulfate and ferric chloride, PCB removal did not improve. The study also found that a coagulant aid (Nalco) improved removal rates suggesting that PCB removal was due to coagulation and adsorption (Aly 1986).

Electrochemical Coagulation

Electrocoagulation is an electrochemical method of treating contaminated water whereby sacrificial anodes corrode to release active coagulant precursors, usually aluminum or iron cations, into solution. The electrolytic reactions evolve gas, usually hydrogen bubbles, at the cathode. Depending upon the reactor operating conditions and the contaminant, these bubbles may float a portion of the contaminant to the surface.

Both batch and continuous electrocoagulation equipment is available. Both types of equipment require that oil and grease and larger particulates (10 to 20 μm) be removed before the waste stream enters the unit. Little information is available to allow a reasonable prediction of performance to be made for a particular contaminant in the water to be treated.

The operational state of the electrodes is often the limiting factor in the long-term operation of electrocoagulation equipment. Electrode passivation (formation of an inhibiting layer on the electrode) prevents metal dissolution and electron transfer, and so limits the coagulant addition to the solution (Holt et al. 2005)

Flocculation

Flocculation is a process where particle size increases as a result of particle collisions. There are two types of flocculation: macroflocculation and microflocculation. Macroflocculation refers to aggregation of particles greater than 1 to 2 μm and is caused by larger particles overtaking smaller particles which can be induced by mixing (velocity gradients) and differential settling. Microflocculation refers to formation of floc due to random Brownian motion.

Flocculation typically follows and may overlap destabilization. Gentle or low-energy mixing is employed to allow destabilized particles to come into contract and aggregate. Flocculation is a longer duration process than coagulation and typical residence times in flocculation tanks are 10 to 30 minutes (Corbitt 1989; Metcalf & Eddy 2003).

Flocculants, also referred to as filter aids, are additives used to enhance flocculation. They are used to assist in the filtration of colloids, once the colloids have been destabilized by a coagulant. They can be used to precoat the surface of filter media or in conjunction with feeding suspension as body feed (or "admix"), or a combination of precoat and body feed. Principal types of filter aids include diatomaceous earth (DE), perlite, cellulose, and rice hull ash (RHA). Filter aids provide a surface for destabilized colloids to attach to and form floc (AFS 2009).

pH Adjustment

The colloids present in the Remelt/Hot Line plume range in size from smaller than 0.3 μm to over 25 μm in effective diameter, with about 30 percent of the particles less than 1 μm in size, and 60 percent less than 2 μm in effective diameter (refer to Section 6.2.1). Most of the particles appear to be a form of silicon dioxide (i.e., quartz).

The low ionic strength and low organic content of the Remelt/Hot Line plume is likely to increase the thickness of the electric double layer around the particles. pH adjustment can affect the charge on the colloid particle or the charge on a coagulant or flocculent added to overcome the native repulsive forces that surround the colloidal particles. The direction of pH adjustment (lower or higher), and the magnitude of the adjustment needed to effectively improve coagulation/flocculation is determined on a case-by-case basis during laboratory and bench-scale testing.

pH adjustment also has a role in the adsorption of organic materials. In general, the adsorption of organic material from water is increased with decreasing pH (Weber 1972). This may be one reason that some of the more effective lab-scale tests conducted on Remelt/Hot Line groundwater samples involved a reduction in the pH of the groundwater sample to a pH of 4 before the addition of powdered activated carbon (PAC). A discussion of the lab-scale tests performed on Remelt/Hot Line groundwater samples is presented below in Section 6.1.2.

6.1.1.2 Particle Filtration Technologies

The colloids present in the Remelt/Hot Line plume range in size from smaller than 0.3 μm to over 25 μm in effective diameter, with about 30 percent of the particles less than 1 μm in size, and 60 percent less than 2 μm in effective diameter (refer to Section 6.2.1). This small particle size rules out the efficient use of sedimentation as a means to separate the particles from groundwater. Filtration is the solids-liquid separation approach generally used to remove particles in this size range. Several common filtration technologies, including those used by the providers of GAC and polymeric adsorption media, are discussed below.

Surface Filters

Surface filters typically remove particulate matter greater than approximately 10 to 30 μm in diameter. These filters come in different forms such as bags, cartridges, and disks and can be made of various materials such as metal, cloth, or synthetics. Typically, these filters are replaced once they are exhausted. These filters use a sieving mechanism for solid-liquid separation (Metcalf & Eddy 2003). Cartridge filters are a commonly used surface filter in the wastewater industry and are described in more detail below.

Cartridge Filtration

Cartridge filters are composed of filter units placed in a filter housing. The filter units can have a variety of shapes and be made of filtration material such as metal, cloth, or synthetics. For example, cartridge particulate filters typically used in wastewater treatment are wound cartridges. These cartridges are cylindrical in shape and consist of a core typically made of plastic or metal. As the name implies, string is wound repeatedly around the core to serve as a sieve. The housing unit usually holds a number of these filter units.

The mesh of the filter media can be as fine as a fraction of a micron, thereby allowing the filter to capture even microorganisms like Giardia and Cryptosporidium. Certain bacteria and viruses, however, are able to pass through even some of the finest filters. Cartridge filters can be used to remove contaminants from a wide range of fluids, including water, oil, and air. Filters and housings are rated for different flow rates, temperatures, and pressures. Generally, the finer the mesh of the filtration media, the lower the maximum flow rate. Note that other, more complex filter media are available, including activated carbon, reverse osmosis membranes for ion removal and semi-conductor grade resin cartridges. Some of these technologies are described below (ThomasNet 2009).

Membranes

Membrane filtration is a solid-liquid separation technology that can be used to remove dissolved constituents (typically 0.0001 to 1.0 µm). Mechanisms for separation include sieving and diffusion. Membranes consist of thin skin about 0.20 to 0.25 µm thick made of organic and inorganic material that is attached to a thicker porous structure (approximately 100 µm thick) to provide support. Common membrane materials are cellulose acetate, aromatic polyamides, and polypropylene. Commercial membranes are available as flat sheets, fine hollow fibers or are tubular in form. Membranes can be defined by their porous size, such as microfiltration (0.08 to 2.0 µm), ultrafiltration (0.005 to 0.2 µm), nanofiltration (0.001 to 0.01 µm) and reverse osmosis (0.0001 to 0.001 µm) (Metcalf & Eddy 2003).

Based on the size of colloidal material found at Kaiser, microfiltration and ultrafiltration may be applicable technologies and are discussed further below.

Microfiltration

Microfiltration is a process which removes contaminants from a liquid or a gas by passing it through a microporous membrane. The term microfiltration has been used to describe membrane filters with pore sizes ranging from about 0.1 to 10 µm. The membranes are located on a support structure (usually tubular). Feed water passes through the membrane and is collected in the annular space within the support structure.

Microfilters can operate at low pressures or they can be part of a pressurized system. Low-pressure systems are usually used where the solids loading is low, chemical conditioning is not usually required, and the solids do not tend to clog the filter media rapidly. When the membrane becomes clogged it is replaced. High-pressure systems are used when additional driving force is needed to collect more solids over longer times without clogging, or in systems where a backwash system is used to extend membrane life. Coagulation and flocculation often precedes high-pressure microfilters.

Membranes can be made from a wide variety of materials from spiral wound cotton to trap TSS particles 5 µm and larger, to polyethersulfone (PES) to capture large bacteria and some pathogens 0.2 µm and larger.

Ultrafiltration

Ultrafiltration is very similar to microfiltration. The solid-liquid separation mechanism is sieving. Unlike microfiltration, pore sizes are smaller and range from 0.005 to 0.2 µm. Because of the lower pore sizes, ultrafiltration has to operate at high pressures (around 75 psig) and, therefore, has higher energy requirements than microfiltration (Metcalf & Eddy 2003). Pretreatment steps are similar to those associated with microfiltration.

6.1.2 Adsorption Technologies

GAC, PAC, and polymeric adsorbents have been successfully used to remove low concentrations of PCBs from groundwater. A brief description of the application of these technologies to the Remelt/Hot Line groundwater plume follows.

GAC Adsorption

As mentioned in Section 5.2, the EPA ASR database identifies 27 CERCLA sites where technologies are specified in RODs for treating groundwater containing PCBs and other contaminants. Five vertical barriers, 21 pump-and-treat systems, and 1 DVE technology were identified. The depth to groundwater and the lengthy boundary along the Spokane River at Kaiser are judged to be factors that make the installation of vertical barrier technologies inappropriate. Where pump-and-treat was used, other contaminants in the groundwater such as VOCs were also being treated. The *ex situ* treatment systems usually had unit operations to address these other contaminants (i.e., air stripper for VOCs) but added a polishing GAC bed that was installed to remove PCBs (e.g., the Sangamo Weston/Twelve-Mile CERCLA site in South Carolina). More information about this site can be found in Section 5.2.

Additional evidence of the potential applicability of GAC in removing dilute concentrations of PCBs from groundwater has been identified. Carbtrol, a supplier of activated carbon, has developed isotherms that evaluate the adsorption rate of carbon for different compounds. These isotherms show that PCBs can be adsorbed by activated carbon to produce effluents with PCB concentrations below 1 µg/L. Carbtrol has found that PCBs will attach to colloidal material or carbon fines and pass though a carbon bed without being removed. They have found that pre-filtration of the groundwater (using a basket or cartridge pre-filter) prior to the GAC vessel, and post-filtration with a 1 to 3 µm filter (to catch carbon fines and residual colloidal material) is necessary to reduce PCB levels from the 3 to 15 µg/L range to levels below 0.5 µg/L (Carbtrol 1990).

The New York State Department of Environmental Conservation identifies groundwater extraction and treatment by GAC as a presumptive remedy for the removal of PCBs from groundwater (NYSDEC 2007). Both pre- and post-GAC filtration of groundwater are noted as potentially necessary to achieve improved results.

The effectiveness of GAC technology is impacted by the presence of suspended particles. The presence of colloidal material can affect the performance of the carbon bed and ability for PCBs to adsorb onto the carbon. In a laboratory study where average PCB concentrations were 4.7 μg/L, TSS concentrations were 10 mg/L, and colloidal particles ranged in size from 0.01 to 1.0 μm, breakthrough of PCB and particles in the carbon bed occurred at the same time suggesting that colloidal materials adhere to the bed and PCBs passing through the carbon bed may have been attached to particulate material (Jaradat et al. 2009). Another bench-scale study found the presence of humic acid decreased the adsorption of PCBs onto carbon (Pirbazari 1992).

For this FSTM, a GAC vendor (Calgon) was contacted to identify the type of GAC system that might be applicable to the Remelt/Hot Line plume. According to Calgon, for a hypothetical treatment rate of approximately 1 MGD, two carbon vessels in series would be needed. Each carbon vessel would hold 20,000 lbs of carbon and would be approximately 22 feet in height and 10 feet in diameter. Two vessels in series would ensure saturation of the carbon beds as well as provide minimum recommended contact time (an empty bed contact time of 15 minutes was recommended). To help minimize effects of colloidal material, pretreatment that results in colloidal particles less than 10 μm was recommended as was post treatment with a 0.1 μm filter to capture colloidal material that may pass through the bed with adsorbed PCBs.

PAC Adsorption

Unlike GAC, PAC is generally added directly to other process units, such as raw water intakes, rapid mix basins, clarifiers, and gravity filters. One such setup consists of adding PAC to water that needs to be treated in a contacting basin. After sufficient contact time, PAC is allowed to settle and treated water is removed. The treated water will likely need additional treatment to remove fine carbon particles. Post-treatment may employ technologies such as coagulation or filtration. A common application of PAC in wastewater treatment is the Powdered Activated Carbon Treatment or “PACT” process. In PACT, activated sludge and PAC are combined to allow for biological oxidation and physical adsorption (Metcalf & Eddy 2003, Siemens 2009).

Carbon adsorption through the use of PAC is not a typical full-scale treatment method for PCB removal from groundwater. However, bench-scale tests using PAC can provide an indication of the potential effectiveness of activated carbon in removing PCBs from groundwater.

Bench-Scale PAC Evaluation: Removing PCBs from the Remelt/Hot Line Groundwater Plume

Bench-scale tests were carried out in 2004 and 2005 on groundwater from well HL-MW-5, comparing the effectiveness of PAC and different coagulants/flocculents for PCB removal under various conditions. The highest PCB removal was achieved when the water was acidified to pH 4 and then PAC was added (Hart Crowser 2005a).

Hart Crowser performed a series of laboratory-scale tests to assess whether: (1) Kaiser's existing Industrial Wastewater Treatment (IWT) Plant could be effective in removing PCBs; and (2) evaluate pre- and post-treatment additives that could be used to enhance PCB removal (Hart Crowser 2004, Hart Crowser 2005a). These lab-scale tests evaluated the impacts of various combinations of pH adjustment, coagulants, flocculants, PAC, filtration, and reaction times on the amount of PCB removed from the sample of groundwater. The initial PCB concentration averaged about 105 ng/L.

The most successful lab trials included: (1) the addition of PAC, a 10-hour waiting period, followed by filtration (91 percent removal); (2) the addition of sulfuric acid to achieve a pH of 4, waiting 1 hour, adding PAC, waiting 5 hours, adding a flocculent, waiting another hour and filtering (97 percent removal); (3) pH adjustment to pH 4, wait 1 hour, add PAC, wait 5 hours, add a flocculent, wait 30 minutes, add lime (to pH 7.5) wait 1 hour, and decant (90 percent removal); (4) follow treatment scheme 3 above, then add more PAC, wait about 10 hours, add a flocculent, wait 5 minutes and filter (87 percent removal); and (5) add PAC, wait 5 hours, filter, add PAC to supernatant, wait about 10 hours, add a flocculent, and filter (86 percent removal).

The SL for PCBs is 0.064 ng/L. A removal efficiency of 99.94 percent of the influent PCB concentration used in the lab-scale tests would be needed to achieve this removal efficiency. None of the lab-scale tests achieved this removal efficiency. The long waiting times, the use of PAC and the adjustment of pH will be difficult to achieve at full-scale at Kaiser. The implementability and reliability of these process options is discussed in Section 6.2.2.

Polymeric Adsorption

As discussed above, GAC adsorption is a typical treatment method for PCBs in groundwater, however, polymeric materials are being developed and used in the field for PCB treatment. One example is a product developed by the MYCELX® Company known as HRM (Hydrocarbon Removal Matrix) cartridges. HRM cartridges are polypropylene filter cartridges infused with a special polymer compound that actively bonds to hydrocarbons. The polymer compound, known as MYCELX®, is formed as a synthesis product of natural drying, semi-drying, and non-drying oils with a synthetic polymer. The polymer is infused and cured into a variety of substrates (i.e., filter cartridges and adsorbent materials) so that it is homogeneously dispersed throughout the base material(s). As hydrocarbon compounds come into contact with the polymer, they are dissolved and bonded to, and will not re-disperse or emulsify into water (Abbot 2003).

HRM cartridges have been used for the removal of PCBs, notably at the Carolina Transformer Company (CTC) CERCLA site. Specifically, the HRM filters were part of a treatment train used to treat PCB-impacted water. Surface water and water from dewatering equipment was collected during excavation of PCB-impacted soils from this site.

HRM cartridges were part of a treatment train used to reduce PCB concentrations to 0.5 µg/L or lower. Due to the high turbidity of the water, there was an extensive pretreatment train to reduce or nearly eliminate suspended solids from the water prior to HRM treatment. Pretreatment consisted of flocculation/coagulation tanks, followed by a series of particulate filtration units (cartridge and bag), of different sizes (25-, 15-, 10-, 5- and 2-µm). Pretreatment was required to remove solids and prevent fouling of the HRM cartridges, and prevent PCBs from flushing through HRM filters by attaching to colloidal material. After treatment, the water was held in tanks where it could be sampled before discharge.

At the CTC site, approximately 1.5 million gallons were treated and the treatment system could treat up to 30,000 gallons a day (Abbot 2003; McDonald, C., 301 Environmental, personal communication, 2009).

6.2 SCREENING TECHNOLOGIES FOR REMEDIATING THE REMELT/HOT LINE GROUNDWATER PLUME

The technologies identified in Section 6.1 are screened using the approach summarized in Section 2.4. The physical aspects of the Kaiser Facility, the chemical properties of PCBs, and the properties of the groundwater in the Remelt/Hot Line plume are identified and used to eliminate certain technologies from further consideration in Section 6.2.1.

The technologies that are judged to be potentially appropriate for the physical and chemical features of the Kaiser AOCs are evaluated for implementability and reliability (if implementable) in Section 6.2.2. Cost-effectiveness was not assessed as part of this FSTM. Cost-effectiveness will be used to further screen the implementable and reliable technologies identified by the FSTM (where appropriate) as part of the overall feasibility study for the Kaiser Facility. Remedial alternatives are developed in Section 6.4.

6.2.1 Site-Specific Technical Constraints for Technologies

The physical and chemical features of the Kaiser Facility influence the selection of the remedial technologies identified in Sections 6.1. There are three groups of physical factors that influence proper selection of a remedial technology: (1) factors associated with the active use of the facility; (2) factors limiting access to contaminated groundwater; and (3) site-specific geologic and hydrologic conditions promoting or prohibiting the applicability of certain remedial technologies. These physical factors were discussed in Section 2.5.1 and are summarized in Table 2-3. The factors that constrained the use of near surface and vadose zone soil treatment technologies will also constrain the use of technologies appropriate for treating groundwater.

In addition to these physical factors, the chemical attributes of the PCBs influence the selection of a remedial alternative. A summary of these chemical properties is provided in Section 2.5.1.4 and summarized in Table 2-4 (Physical/Chemical Properties of COCs). Some additional physical/chemical factors that will impact the selection of technologies for the dilute PCB concentrations present in the Remelt/Hot Line groundwater plume are discussed below.

PCBs

PCBs in groundwater are present in the Remelt/Hot Line area. The Remelt/Hot Line plume is notable for the absence of petroleum hydrocarbons.

PCBs, as a class, exhibit high thermal stability; strong resistance to oxidation, acids, bases, and other chemical reagents; as well as excellent electrical insulating (dielectric) properties. They generally have low water solubility and vapor pressure and strongly adsorb to organic matter. Properties of individual chlorinated biphenyl congeners are most strongly influenced by their degree of chlorination and molecular weight. A broader discussion of PCB properties is provided in Section 2.5.1.4.

Low Concentration of PCBs

The concentration of the PCBs present in the Remelt/Hot Line plume is very low and varies from non-detection values up to 2300 ng/L (or 2.3 μg/L). These low concentration values will make it difficult to use *in situ* processes to inject chemical agents (e.g., oxidants) into the groundwater and assure the direct contact of the chemical agent with the PCBs. All of the PCBs must be contacted and oxidized to achieve the very high removal efficiencies needed to reach an effluent SL PCB concentration of 0.064 ng/L. The precise delivery of oxidants *in situ* to groundwater at depths of 55- 85 feet bgs is difficult to achieve. Aboveground treatment processes would provide more opportunity to precisely control the oxidation process.

Presence of Colloids

The PCBs in the Remelt/Hot Line plume are present in a dilute solution and appear to be bound, at least in part, to the colloidal particles present in the plume. Particulates that can move through soil with groundwater must be small enough to move through the soil pore spaces. Colloids are particles in the size range of 10^{-3} to 1 μm**,** which have been shown to move through soil pores in a variety of groundwater systems. Because of their physical and chemical properties, colloids are a special class of matter with properties that lie between those of the dissolved and solid states.

There are many potential sources of colloidal material in groundwater. Colloids are formed in soil when fragments of soil, mineral, or contaminant particles become detached from their parent solid material. They can be carried to the water table when water from precipitation percolates downward through the soil. Colloids will also form as fine precipitates when dissolved minerals in groundwater undergo pH or redox potential changes. Colloids can form as emulsions of small droplets from free phase petroleum or other immiscible liquids. A variety of organic materials can exist as colloids in groundwater such as humic substances and “biocolloids” such as microorganisms (McCarthy and Deguildre 1993; Ryan and Elimelech 1996).

In the low-velocity flow of groundwater, particles larger than 2 μm tend to settle by gravity. Particles smaller than 0.1 μm tend to sorb readily to larger soil particles, becoming retarded or immobilized. Thus, particles in the range of 0.1 to 2 μm are thought to be the most mobile in groundwater. The mean value of the colloidal particles in the Remelt/Hot Line plume is in the 1 to 2 μm range (see below).

Facilitated Transport of PCBs by Colloids

Colloids may be mobilized either by chemical or physical processes. Chemical controls favoring mobilization include changes is solution chemistry such as changes in ionic strength, pH, organic matter, adsorption of ions, and macromolecules that alter surface charge. Physical processes include pumping, sampling, flow velocity, and rapid infiltration.

Colloids have a high surface-area-to-mass ratio due to their very small size, and thus present a large surface area available for transporting sorbed contaminants. For migration of a colloidal particle to occur in an aquifer, the diameter of the migrating colloidal particle must be significantly smaller than the diameter of the soil pore. If this is not the case, the particle is filtered from the migrating liquid.

Constituents of low solubility (like PCBs) can move with groundwater by sorption or occlusion with colloids, resulting in unexpected mobility for otherwise low-solubility materials. When constituents are sorbed to colloids, their transport behavior is determined by the properties of the colloid, not the properties of the sorbed constituent. This facilitated transport of PCBs has been modeled by Hart Crowser (Hart Crowser 2012a, Section 6) and by others (Chatzikosma and Voudrias 2007). One common conclusion of both models is that the concentration of PCBs in a groundwater environment like that at Kaiser will be significantly reduced by removing the colloids from the groundwater plume. This is the reason why pretreatment/filtration technologies are included among the technologies that discussed in Section 6.1.

A groundwater sample from well HL-MW-5 collected in 2004 was subjected to colloidal particle characterization. Analysis indicated a particle grain size ranging from smaller than 0.3 µm to greater than 25 µm in length. The effective diameter of the majority of particles was less than 1.6 µm, indicating that the majority of the particulate matter was in the optimal range for colloidal transport. Most of the particulate material analyzed in the sample appeared to be quartz (Hart Crowser 2004 and 2005a).

Another line of evidence that supports the concept of colloidal transport in the groundwater at the Facility was the results of the treatability batch tests (Hart Crowser 2004 and 2005a). The tests were performed to assess the effectiveness of several water treatment trains to remove trace concentrations of PCBs from groundwater. In samples treated with activated carbon and a flocculent after acidification to pH levels of 6 and 4, respectively, PCB removal efficiencies of greater than 91.5 and 97.2 percent were achieved. This was a significant improvement to the removal efficiency compared to adding activated carbon alone. The apparent improvement of removal efficiency relative to a decrease in pH was thought to be the result of the effect of pH on the surface charge of colloids and adsorbents.

Changes in surface charge affect how colloids and adsorbents react with aqueous species. A decrease in pH could change the affinity of a colloid for adsorbing dissolved PCBs. Additionally, pH affects how colloids interact, with increased particle attraction and flocculation occurring at certain pH levels, thus producing larger particles more easily removed from solution through filtration. A combination of these effects may have produced the significant PCB removal observed in the test scenario.

Based on the available evidence, colloid particles in groundwater at the Facility likely play an important role in facilitating the transport of PCBs in groundwater. As a result, coagulation, flocculation, and pH adjustment are selected as potential particle aggregation technologies in Section 6.1.1.1. Since some of the PCBs are likely attached to colloid particles, the removal of these colloids by filtration will be necessary to achieve the groundwater screening level concentration of 0.064 ng/L for PCBs. Particle filtration technologies are identified in Section 6.1.1.2. The soluble fraction of PCBs will be treated by adsorption processes. The GAC adsorption process is considered to be a presumptive remedy for PCB plumes by the New York Department of Environmental Conservation (NYDEC 2007). The GAC and other adsorption processes are discussed in Section 6.1.2.

The site-specific physical factors present at the Kaiser Facility used to screen the technologies described in Sections 6.1 are similar to the factors that affected the application of technologies to deep vadose zone soil. These factors are used together with the chemical properties of PCBs to identify the set of available technologies that are potentially applicable to PCBs in groundwater. The outcome of the physical/chemical screening of these technologies is presented in Tables 6-2a and 6-2b.

6.2.2 Screening of Remedial Technologies for PCBs in the Remelt/Hot Line Groundwater Plume

This section evaluates those technologies not rejected on the basis of the site-specific physical/chemical constraints (summarized in Tables 6-2a and 6-2b) and for implementability and/or reliability using the approach shown on Figure 2.2 and described in Section 2.5.2. Cost-effectiveness was not assessed as part of this FSTM. Cost-effectiveness will be used to further screen the implementable and reliable technologies identified by the FSTM (where appropriate) as part of the overall feasibility study for the Kaiser Facility.

6.2.2.1 Technologies for Remediating PCBs in the Remelt/Hot Line Groundwater Plume

Technologies and the associated process options for remediating PCBs in the Remelt/Hot Line groundwater are evaluated for implementability in Tables 6-3a through 6-3m.

Each table provides information to justify why each process option should be accepted or rejected for the Kaiser Facility. These tables indicate that the following process options for remediating PCBs in the Remelt/Hot Line groundwater plume are judged to be potentially implementable at the Kaiser Facility.

Technology	Process Option Accepted
Monitoring	Protection, Performance, Confirmational
Institutional Controls	Access and Use Restrictions, BMPs
Capping	Asphalt, Concrete, Multilayer
Monitored Natural Attenuation	Monitored Natural Attenuation
Hydraulic Containment	Vertical Extraction Wells
***Ex Situ* Pre-treatment Technologies**	
Coagulation	Addition of Coagulants (e.g., aluminum or iron salts, organic polymers, chitosan)
Flocculation	Static or Mechanical Mixers or Air Agitation in Tanks or Basins
pH Adjustment	Addition of Acid or Base
Depth Filtration	Mono-medium, Dual-medium, Multimedium
Surface Filtration	Bag, Cartridge or Disk Filter
Membrane Filtration	Microfiltration, Ultrafiltration
***Ex Situ* Treatment Technologies**	
Carbon Adsorption	GAC, PAC
HRM/MYCELX ® Cartridge Filter	HRM/MYCELX ® Cartridge Filter
pH adjustment (if needed)	Addition of Acid or Base

***Ex Situ* Post-treatment Technologies**

Coagulation	Addition of Coagulants (e.g., aluminum or iron salts, organic polymers, chitosan)
Flocculation	Static or Mechanical Mixers or Air Agitation in Tanks or Basins
Depth Filtration	Mono-medium, Dual-medium, Multimedium
Surface Filtration	Bag, Cartridge or Disk Filter
Membrane Filtration	Microfiltration, Ultrafiltration

None of the PCB technologies that are potentially implementable for the Remelt PCB groundwater plume would require off-gas treatment. Thus, the off-gas treatment technologies for PCBs are eliminated in Table 6.2a.

The technologies and associated process options judged to be potentially implementable are evaluated for reliability in Tables 6-4a to 6-4k. PAC was rejected on the basis of reliability since PAC has not been proven effective at full scale installations like the Remelt/Hot Line plume where PCB concentrations are very low, and where the removal efficiencies required are very high (refer to Table 6-4j). Table 6-5 summarizes the screening process and the technologies and process options judged to be potentially appropriate for the treatment of PCB contaminated groundwater in the Remelt/Hot Line plume at the Kaiser Facility. Bench- and pilot-scale tests will be required to identify the appropriate pre-treatment, adsorption (e.g., GAC or HRM/MYCELX ®), and post-treatment process options for the Remelt/Hot Line plume.

6.3 DESCRIPTION OF AREAS OF CONCERN FOR PCBS IN THE REMELT/HOT LINE GROUNDWATER PLUME

This section describes the Remelt/Hot Line PCB groundwater plume AOC. PCB concentrations in groundwater in the Remelt/Hot Line area are encountered in an elongated northeast-southwest trending zone. The PCB plume extends from the apparent source areas in the Remelt area and follows the local groundwater flow direction west southwest towards the river (Figure 6-1). PCB concentrations were detected in 24 wells during 2008: thirteen Hot Line wells, two deep Hot Line wells, eight Remelt wells, and sporadically in well MW-12A.

The maximum detected PCB concentrations from the 2008 quarterly monitoring are shown on Figure 6-1. The highest PCB concentrations within this groundwater PCB plume were measured in the Remelt area at wells RM-MW-13S and RM-MW-17S at concentrations of 1,400 and 2,300 ng/L, respectively. These wells are in the vicinity of an apparent PCB source area. It appears that the PCBs originated from release of hydraulic fluids containing PCBs. PCBs usage at the facility was discontinued in the 1970s. There were some wells sampled for PCBs that showed non-detect results. Where PCBs were detected, the minimum detected PCB concentration during 2008 was from MW-12A with an estimated concentration of 4.7 ng/L. The average PCB concentration in this AOC is 268 ng/L.

Figure 5-20 of the Final Groundwater RI (Hart Crowser 2012a) presents Generalized Subsurface Cross Section D-D′ along the axis of the PCB plume and shows its vertical extent. PCB concentrations in groundwater are concentrated in shallow monitoring wells but are commonly present at depth in two deep monitoring wells (HL-MW-13DD and HL-MW-28DD).

The boundary of the Remelt/Hot Line PCB groundwater plume AOC shown on Figure 6-1 is based on 2008 groundwater monitoring data. The shape of this plume does not differ substantially from the plume boundary shown on Figure 5-5 of the Final Groundwater RI (Hart Crowser 2012a) which details the maximum historic PCB detections in groundwater from 1990 to 2008. The primary differences between the historic plume and the 2008 plume shown on Figure 6-1 include the following:

- A narrowing of the central part of the plume with 2008 non-detects for PCBs in wells HL-MW-2 and HL-MW-16S;
- Truncating the east end of the plume at RM-MW-8S with 2008 non-detects for PCBs in well RM-MW-9S; and
- Extending the west end of the main plume to encompass low level PCB detections in MW-12A near the river.

In its current configuration the Remelt/Hot Line PCB groundwater plume is the largest of the site AOCs, soil or groundwater, with an estimated areal extent of 16 acres. The approximate eastern half of this AOC is in an area of heavy industrial use in and around the Remelt/Hot Line buildings. The western half mainly resides in an undeveloped open field and terminates near the riparian zone along the river.

6.3.1 Hydraulic Containment of the Remelt/Hot Line PCB Groundwater Plume AOC

Similarly to the steps outlined in Section 5.4.1, capture zone analysis was performed to provide an estimate of a hydraulic containment pumping rate for this AOC. The calculated pumping rate will theoretically hydraulically contain the PCBs moving with the groundwater in the AOC to prevent their spread beyond the capture zone. It was assumed that pumping a water volume equating to a twenty foot thick layer of the upper reach of the aquifer over the 16 acre AOC would hydraulically contain PCBs in this plume. It was further assumed that this pumping rate would need to be maintained more or less continuously until such time as the source area stopped contributing PCBs to groundwater at concentrations that are deemed unacceptable.

Two deep monitoring wells (HL-MW-13DD and HL-MW_28DD) have chronic low-level detections of PCBs and the cause of these detections and the transport mechanisms involved are not entirely understood. We believe the most likely transport mechanism is preferred pathways carrying PCB contamination from the upper portion of the aquifer to the deeper zones in the vicinity of these two wells. Implied in the pumping scenario presented in the previous paragraph is the assumption that PCBs entering the aquifer from sources in the Remelt area would be contained in the upper reaches of the aquifer and prevented from migrating to deeper levels, such as wells HL-MW-13DD and HL-MW-28DD. These two wells are the deepest screened monitoring wells in this area with screened intervals of 140 to 150 feet bgs, generally drawing water 40 to 50 feet deeper than the majority of wells in this AOC. The deep detections of PCBs in these wells remain somewhat anomalous. Nearby deep-screened wells HL-MW-15DD and HL-MW-24DD have been non-detect for PCBs during past monitoring events.

Hydraulically containing this large 16-acre plume would require an estimated pumping rate of 8.2 million gallons per day (MGD). Based on 2008 data, the average concentration of PCBs in this AOC is 270 ng/L. Assuming that this concentration would be representative of a one-day pumping volume, the total mass of PCBs contained in this volume would be approximately 8 grams.

In reality, it would probably not be feasible to hydraulically contain this 16-acre area. A more practical approach would be to cut off and hydraulically contain the source area in the Remelt building by installing extraction wells across the east central portion of the plume. One possible configuration would be to install extraction wells in a line trending from northwest to southeast extending from the vicinity of HL-MW-27D to the vicinity of HL-MW-4.

It is expected that the pumping rate to hydraulically contain the source area in this way would require 1/4 to 1/3 of the pumping rate estimated above to contain the entire plume. It should be stressed that the above calculations are intended for technology screening purposes, but they do provide rough order of magnitude (ROM) estimates of COCs present. The results of these calculations likely represent extreme upper bounds of the quantity of water that would have to be treated, but provide an indication of the scale of remediation efforts that may be warranted.

Details of the capture zone analysis performed for the petroleum groundwater plume AOCs are presented in Appendix E. The methods employed in this Appendix would also apply to the capture zone analysis for the Remelt/Hot Line PCB groundwater plume AOC. The mass estimates are summarized in Table 6-7 and details on the mass calculations are provided in Table 6-8.

In Section 5, groundwater pumping rates to achieve site cleanup in a 30-year time frame were calculated for the petroleum plume AOCs using a batch flush model. These calculations were not performed for the Remelt/Hot Line PCB groundwater plume as this model would not apply to colloidal transport of PCBs.

6.4 DEVELOPMENT OF REMEDIAL ALTERNATIVES

The technologies and process options that are potentially applicable to the remediation of the groundwater in the Remelt Hot Line AOC at the Kaiser Facility are identified in Section 6.1. These technologies and process options were initially screened to account for site-specific technical constraints and for the chemical properties of the PCBs in Section 6.2.1. The technologies and process options judged to be potentially implementable and reliable for the remediation of PCB-contaminated groundwater in the AOC (refer to Section 6.2.2) are assembled into remediation alternatives in this Section. The basis for developing alternatives follows the logic shown on Figure 2.11 and was described in Section 2.7.

6.4.1 Remedial Alternatives for PCB Contaminated Groundwater

MTCA requires that a reasonable number of alternatives shall be evaluated taking into account the characteristics and complexity of the facility, including current site conditions and physical constraints (WAC 173-340-350[8][c][i][B]). These factors are discussed in Section 2.5.1.

The remedial alternatives developed in this section range from Alternative A1 (institutional controls, monitored natural attenuation [MNA], and monitoring) to Alternative A3 (containment [hydraulic and capping], institutional controls, MNA, monitoring, and *ex situ* Treatment). Alternative A3 is considered to be the most practical remedial alternative for the PCB-contaminated groundwater plume and will be used as the baseline alternative as Alternatives A1 to A3 are evaluated in the overall feasibility study.

Alternatives A1 and A2

Alternative A1, which consists of institutional controls, MNA, and monitoring is included since many viable remedies at the Kaiser Facility will contain these elements. Containment (hydraulic and capping), institutional controls, MNA, and monitoring compose Alternative A2, which adds to Alternative A1 the additional protection of containment to reduce the possibility that PCBs in groundwater reach the Spokane River.

Alternative A3

Alternative A3 adds *ex situ* treatment processes, including pretreatment (coagulation, pH adjustment, flocculation, and filtration), adsorption (GAC, MYCELX®), and post-treatment (coagulation, pH adjustment [if needed], and flocculation, filtration) to Alternative A2. Bench- and pilot-scale tests will be required to identify the appropriate pretreatment, adsorber, and post-treatment process options for the Remelt/Hot Line PCB plume. This alternative would include pumping of shallow groundwater containing PCBs and this is water would need to be treated. Alternative A3 has been judged to be the most practical permanent cleanup alternative. As described below, the upcoming feasibility study will identify a set of appropriate pre-treatment and post-treatment technology process options.

Applicability and Combination of Multiple Alternatives

Several technology-based alternatives may be applicable to the remediation of the PCB groundwater plume. For instance, technology-based alternatives A1, A2, or A3 could be used individually to remediate the PCB groundwater plume. Alternative A3 adds *ex situ* treatment to Alternative 2.

The overall feasibility study will evaluate the technology-based remedial alternatives described above to assess whether or not, or to what extent, the alternatives meet the minimum requirements for cleanup action under MTCA (WAC-173-340-360[2]). One outcome of this evaluation will be to identify the most appropriate technology-based alternative(s) for the PCB groundwater plume.

It is expected that the overall feasibility study will identify a set of appropriate pre-treatment and post-treatment technology process options, and identify the appropriate adsorbent (e.g., GAC or MYCELX) for Alternative A3.

Bench-scale tests will ultimately be required to confirm that the coagulant, flocculent, and type of filtration device(s) selected by the feasibility study (to remove colloidal and suspended particles) will be effective in pre-treating the influent to, and polishing the effluent from, the adsorber. Bench-scale tests will also be needed to confirm that the adsorbent selected by the feasibility study will be effective in removing soluble PCBs from the PCB groundwater plume, and to define the operating parameters of the adsorption process.

Compliance Monitoring

Monitoring is needed to assure compliance with cleanup levels, to assess the performance of a remediation technology as it is operating, and to measure the continued effectiveness over time of permanent features added to the site (e.g., capping). Monitoring is an integral element of Alternatives A1 through A3. A comprehensive monitoring program consists of protection monitoring, performance monitoring, and confirmational monitoring. The comprehensive monitoring program is based on an adaptive monitoring and management strategy that is described in Section 2.7.3.

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Table 6-1- Preliminary Identification of Remedial Technologies for PCBs in the Remelt/Hot Line Groundwater Plume

General Response Action	Technology	Process Options	Description
Monitoring	Monitoring	Protection, performance, and confirmational	Provide for protection, performance, and confirmational monitoring. Groundwater samples will be collected to test for compliance with cleanup levels.
Institutional Controls	Access and Use Restrictions	Fencing, deed restrictions, restrictive covenant	Physical and administrative measures to prevent access or exposure to contaminated water.
	Alternative Water Supply	Connect to distribution system, new supply well	Provide an alternate supply of drinking water.
	Best Management Practices (BMPs)	Spill prevention, clean up procedures, secondary containment, etc	Practices designed to protect surroundings from environmental hazards that may occur at the Kaiser facility.
Containment	Capping	Clay cap, asphalt, concrete, synthetic liner, multi-layer cap	Placement of a cap to minimize infiltration and contaminant migration.
	Vertical Barriers	Slurry wall, grout curtain, sheet piling	Placement of vertical, low-permeability barriers to minimize contaminant migration.
	Horizontal Barriers	Block displacement, grout injection	Placement of subsurface, low-permeability barriers to minimize contaminant migration.
	Hydraulic Containment	Extraction wells/trenches	Modify the groundwater gradient to minimize off-site migration of contaminants.
In situ Treatment of Groundwater	*In situ* Bioremediation	Enhanced bioremediation, phytoremediation	Enhance biodegradation through modification of subsurface environmental conditions. Enhanced biodegradation refers to the addition of agents to the groundwater such as nutrients, electron donors, or microbiological populations.
	Monitored Natural Attenuation	Monitored Natural Attenuation	Naturally occurring processes in soil and groundwater which reduce mass, toxicity, mobility, volume or concentration of contaminants and include biodegradation, dispersion, dilution, adsorption and volatilization.
	Chemical Treatment	Oxidation, reduction, pH adjustment	Injection of chemicals for *in situ* treatment of contaminants.

Table 6-1- Preliminary Identification of Remedial Technologies for PCBs in the Remelt/Hot Line Groundwater Plume

General Response Action	Technology	Process Options	Description
Extraction and On-Site Treatment of Groundwater	*Aerobic Ex situ* Bioremediation	Biological treatment of groundwater in aboveground bioreactor.	Biological treatment of groundwater in aboveground bioreactor. Bioreactors include aeration basins, constructed wetlands, and trickling filters).
	Chemical Treatment/UV Oxidation	Oxidation through chemical addition and/or UV light	Oxidation through addition of chemicals or UV light or combination of two techniques. Addition of chemical oxidant may require pH adjustment.
Extraction and On-Site Treatment of Groundwater (Particle Aggregation Technologies)	Coagulation	Metal hydroxides. Addition of coagulants (i.e. aluminum or iron salts, organic polymers, chitosan), electrocoagulation	Destabilization of colloid particles by addition of coagulant(s) to cause floc formation.
	Flocculation	Static or mechanical mixers or air agitation in tanks or basins	Aggregation of small particles into larger particles to enhance removal by settling and filtration. Induced by mixing. Effective for colloidal particles 1 or 2 μm or larger in size. Generally follows coagulation.
	pH Adjustment	Addition of acid or base	Addition of acid or base for pH adjustments to assist in filtration of colloids. pH adjustment was used to improve coagulation in bench-scale studies performed on Kaiser groundwater; it has been shown to improve carbon adsorption of PCBs (Hart Crowser 2005a). In practice, sulfuric acid or lime is usually used for pH adjustment.
Extraction and On-Site Treatment of Groundwater (Particle Filtration Technologies)	Floatation	Dissolved Air Floatation, Dispersed Air Floatation	Separation of solid and liquid particles by the use of air. Fine air bubbles attach to surface of particulate matter which increases buoyancy and brings solids to the surface.
	Sedimentation	Sedimentation tanks, Clarifiers, Combination Flocculator-Clarifier	Remove readily settleable solids to reduce TSS.
	Depth Filtration	Mono-medium, dual-medium, multimedium	Filter made of granular or compressible filter material (i.e., sand). Typically used for the removal of particles approximately 1 μm and greater. Depth filters currently in use at the Kaiser industrial wastewater treatment plant are sand bed filters and a black walnut shell filter (See Section 5 for more details on these units).

Table 6-1- Preliminary Identification of Remedial Technologies for PCBs in the Remelt/Hot Line Groundwater Plume

General Response Action	Technology	Process Options	Description
Extraction and On-Site Treatment of Groundwater (Particle Filtration Technologies) (Continued)	Surface Filtration	Cartridge, bag and disk filters	Mechanically sieving particles out of passing groundwater. Made of various materials such as cloth, synthetics and metal. Cloth medium filters have pore size 10 to 30 µm (Metcalf & Eddy 2003), however, cartridge filters with pore size as low as 0.5 µm are available (McMaster Carr 2009).
Extraction and On-Site Treatment of Groundwater (Membrane Filtration Technologies)	Microfiltration	Flat sheets, fine hollow fibers or tubular	Porous membranes used to remove dissolved or colloidal material. Removal of materials from approximately 0.08 to 2 µm (Metcalf & Eddy 2003).
	Ultrafiltration	Flat sheets, fine hollow fibers or tubular	Porous membranes used to remove dissolved or colloidal material. Removal of materials from approximately 0.005 to 0.2 µm (Metcalf & Eddy 2003).
	Nanofiltration	Flat sheets, fine hollow fibers or tubular	Porous membranes used to remove dissolved or colloidal material. Removal of materials from approximately 10^{-3} to 10^{-2} µm (Metcalf & Eddy 2003).
	Reverse Osmosis	Flat sheets, fine hollow fibers or tubular	Porous membranes used to remove dissolved or colloidal material. Removal of materials from approximately 10^{-4} to 10^{-3} µm (Metcalf & Eddy 2003).
	Ion Exchange	Cationic, anionic	Removal of exchangeable ions by passing water through a resin bed.
Extraction and On-Site Treatment of Groundwater (Adsorption Technologies)	HRM/Mycelx ® Filtration	HRM/Mycelx ® Filtration	Removal of PCBs by adsorption onto Mycelx ® filtration material.
	Carbon Adsorption	GAC, PAC	Removal of PCBs by carbon adsorption.
On-Site Treatment of Extracted Soil Vapor	Adsorption	Removal of adsorbable compound using canisters in series, may require disposal	Potentially effective for PCB degradation products that may be produced if PCBs are treated by *in situ* or *ex situ* processes such as bioremediation or chemical treatment.
	Thermal Oxidation	Vapor heated above 1,400 °F to oxidize organics; requires emission controls	Potentially effective for PCB degradation products that may be produced if PCBs are treated by *in situ* or *ex situ* processes such as bioremediation or chemical treatment.
	Catalytic Oxidation	Vapor heated up to 800 °F to oxidize organics, requires HCl controls	Potentially effective for PCB degradation products that may be produced if PCBs are treated by *in situ* or *ex situ* processes such as bioremediation or chemical treatment.
	Advanced Oxidation	Vapor is passed through catalyst while exposed to high intensity UV light or ozone	Potentially effective for PCB degradation products that may be produced if PCBs are treated by *in situ* or *ex situ* processes such as bioremediation or chemical treatment.

Table 6-1- Preliminary Identification of Remedial Technologies for PCBs in the Remelt/Hot Line Groundwater Plume

General Response Action	Technology	Process Options	Description
On-Site Treatment of Extracted Soil Vapor (Continued)	Off-Gas Scrubber	Chlorine Scrubber	Calcium or sodium-based reagents are used to remove chlorine from off-gas generated by some *in situ* or *ex situ* PCB treatment processes such as bioremediation or chemical treatment.

Table 6-2a - Physical/Chemical Screening Criteria of Remedial Technologies for PCBs in Remelt/Hot Line Groundwater Plume

General Response Action	Remedial Technology	Technology Retained[1]
Monitoring	Monitoring	Yes
Institutional Controls	Access and Use Restrictions	Yes
Institutional Controls	Alternative Water Supply	No
Institutional Controls	Best Management Practices (BMPs)	Yes
Containment	Capping	Yes
Containment	Vertical Barriers	No
Containment	Horizontal Barriers	No
Containment	Hydraulic Containment	Yes
In situ Treatment of Groundwater	Monitored Natural Attenuation	Yes
On-Site Treatment of Extracted Soil Vapor[2]	Adsorption	No
On-Site Treatment of Extracted Soil Vapor[2]	Thermal Oxidation	No
On-Site Treatment of Extracted Soil Vapor[2]	Catalytic Oxidation	No
On-Site Treatment of Extracted Soil Vapor[2]	Advanced Oxidation	No
On-Site Treatment of Extracted Soil Vapor[2]	Biofiltration	No
On-Site Treatment of Extracted Soil Vapor[2]	Chlorine Scrubber	No

Note:

1) The reasons for retaining a technology to treat PCBs in groundwater based on physical/chemical criteria also apply to SVOCs in groundwater as presented in Table 5-3 unless otherwise noted. Refer to the evaluations in that table.
2) There are no retained PCB treatment technologies that would require off-gas treatment.

Table 6-2b - Physical/Chemical Screening Criteria of Remedial Technologies for PCB-Impacted Groundwater

General Response Action	Remedial Technology	Description	Screening Comments	Technology Retained
In situ Treatment of Groundwater	*In situ* Bioremediation	Enhance biodegradation through modification of subsurface environmental conditions.	PCBs are not prone to biodegradation. Laboratory studies have been done showing biodegradation success; however, there is limited evidence showing success in the field. Low concentrations of PCBs make biodegradation a less-effective treatment method.	Yes
	Chemical Treatment	Injection of chemicals for *in situ* treatment of contaminants.	Due to very low PCB concentrations and open soil matrix, contact between oxidant and PCB will be difficult to control.	Yes
Extraction and On-Site Treatment of Groundwater	Aerobic *Ex situ* Bioremediation	Biological treatment of groundwater in aboveground bioreactor. Various COC and site-specific processes.	PCBs are not prone to biodegradation. Laboratory studies have been done showing that bioremediation can occur. However, there is limited evidence showing success in the field. Low-level PCB concentrations will make this technology difficult to implement.	Yes
	Chemical Treatment/UV Oxidation	Oxidation through chemical addition and/or UV light	Due to very low PCB concentrations, contact between oxidant and PCB will be difficult to achieve.	Yes
Extraction and On-Site Treatment of Groundwater (Particle Aggregation Technologies)	Coagulation	Destabilization of colloid particles by addition of coagulant(s) to cause floc formation.	Conventional technology for the aggregation of colloidal materials in water. Typically a pretreatment technology, not used for the removal of residual colloid concentration.	Yes
	Flocculation	Aggregation of small particles into larger particles to enhance removal by settling or filtering.	Conventional technology for the removal of suspended solids in water. Typically a pretreatment technology, not used for the removal of residual colloid concentration. Addition of flocculents can be used to improve aggregation.	Yes
	pH adjustment	Addition of acid or base for pH adjustments to assist in filtration of colloids	Lime addition is currently being used at IWT plant for neutralization and metals precipitation, and could also improve the performance of a GAC adsorber (if one were installed at the site).	Yes

Table 6-2b - Physical/Chemical Screening Criteria of Remedial Technologies for PCB-Impacted Groundwater

General Response Action	Remedial Technology	Description	Screening Comments	Technology Retained
Extraction and On-Site Treatment of Groundwater (Particle Filtration Technologies)	Floatation	Separation of solid and liquid particles by the use of air	Usually applied to oil, grease and other solids with specific gravity near 1.0.	No
	Sedimentation	Remove readily settleable solids and floating material to reduce TSS.	The TSS loading in the Remelt/Hot Line plume is low. Not effective for colloidal particles.	No
	Depth Filtration	Filter made of granular or compressible filter material (e.g., sand). Typically used for the removal of particles approximately 10 μm or greater.	Conventional technology to removal residual particles from groundwater. Multi-media filters often used when particle size is in the 1-10 μm range. Depending on water quality, may require pre- and post- treatment.	Yes
	Surface Filtration	Mechanically sieving particles in the 10-30 μm size range out of groundwater.	Conventional technology to removal residual particles from groundwater. Depending on water quality, may require pre- and post-treatment. Cloth medium filters have pore size 10 to 30 μm (Metcalf & Eddy 2003), however, cartridge filters with pore size as low as 0.5 μm are available (McMaster Carr 2009).	Yes
Extraction and On-Site Treatment of Groundwater (Membrane Filtration Technologies)	Microfiltration	Porous membranes used to remove suspended colloidal material. Removal of materials from approximately 0.08 to 2 μm.	Prefiltration of particles greater than 2 μm will be required (e.g., coagulation, flocculation, surface filtration).	Yes
	Ultrafiltration	Porous membranes used to remove dissolved or colloidal material. Removal of materials from approximately 0.005 to 0.2 μm.	Prefiltration of particles greater than 0.2 μm will be required (e.g., coagulation, flocculation, and surface filtration). A potential post-GAC treatment technology.	Yes

Table 6-2b - Physical/Chemical Screening Criteria of Remedial Technologies for PCB-Impacted Groundwater

General Response Action	Remedial Technology	Description	Screening Comments	Technology Retained
Extraction and On-Site Treatment of Groundwater (Membrane Filtration Technologies) (Continued)	Nanofiltration	Porous membranes used to remove dissolved or colloidal material. Removal of materials from approximately 10^{-3} to 10^{-2} μm.	Prefiltration of particles greater than 10^{-2} μm will be required (e.g., coagulation, flocculation, surface filtration, microfiltration) prior to nanofiltration. Membranes subject to fouling.	No
	Reverse Osmosis	Porous membranes used to remove dissolved or colloidal material. Removal of materials from approximately 10^{-4} to 10^{-3} μm.	Due to fouling issues significant pretreatment will be required. Prefiltration of particles greater than 10^{-3} μm will be required (e.g., coagulation, flocculation, surface filtration, microfiltration, ultrafiltration) prior to reverse osmosis.	No
	Ion Exchange	Removal of exchangeable ions by passing water through a resin bed.	Appropriate for dissolve constituents, not for colloidal particles	No
Extraction and On-Site Treatment of Groundwater (Adsorption Technologies)	Carbon Adsorption	Removal of adsorbable contaminants by passing groundwater through adsorbent.	Technology has been proven effective for the removal of colloidal material and PCBs (NYSDEC 2007). To prevent fouling, pretreatment (filtration) is required. Requires periodic carbon reactivation at off-site facility.	Yes
	HRM/Mycelx Filtration	HRM/Mycelx Filtration	Technology has been proven effective for the treatment of PCBs (Abbot 2003). Significant pretreatment is required.	Yes

Table 6-3a - Implementability of Selected Technologies for PCBs in Remelt/Hot Line Groundwater Plume

Sheet 1 of 1

Technology	**Process Options**	**Can it be Implemented?[1]**
Monitoring	Compliance, Performance	Yes
Access Restrictions	Fencing, deed restrictions, restrictive covenant	Yes
Best Management Practices (BMPs)	Spill prevention, clean up procedures, secondary containment, etc.	Yes
Capping	Soil Cap	No
Capping	Clay Cap	No
Capping	Low Permeable Asphalt Cap	Yes
Capping	Low Permeable Concrete Cap	Yes
Capping	Synthetic Liner	No
Capping	Multilayer Cap (soil + synthetic liner)	Yes
Hydraulic Containment	Extraction Wells	Yes
Hydraulic Containment	Trenches	No
Bioremediation (*in situ)*	Phytoremediation	No
Monitored Natural Attenuation	Monitored Natural Attenuation	Yes

Notes:

1) The reasons a technology was judged to be implementable for PCBs in groundwater are similar to the reasons the technology was judged to be implementable for SVOCs in groundwater as presented in Tables 5-6a through 5-6i except where noted. Refer to the evaluations in those tables.

Table 6-3b - Implementability of *In Situ* Bioremediation for PCB-Impacted Groundwater

Sheet 1 of 1

	Process Options for *In situ* Bioremediation
Attribute	**Enhanced Bioremediation**
Can it be constructed?	Yes, site is amenable to constructing and operating support equipment though access may be limited in some areas by infrastructure. Design, construction, and startup will take approximately 1 year. This technology includes the circulation of water-based solutions (i.e., nutrients) to stimulate microbes and/or the injection of Oxygen Release Compounds (ORC) or electron donor compounds or bioaugmentation.
Will it work?	Uncertain. No evidence showing that low concentrations of colloidal and dissolved PCBs can be treated by this technology to reduce PCB concentrations to the very low screening level concentrations established for the Kaiser site. Would be difficult to assure sufficient contact between the additive and the entire groundwater stream, including the colloidal particles. Bioremediation would have to go to completion to reach cleanup levels. Treatability studies will be required.
Will this be acceptable to regulatory agencies?	Maybe
Is technology available?	Yes
Is process option accepted?	No

Table 6-3c - Implementability of *In Situ* Chemical Treatment for PCB-Impacted Groundwater

	Process Options for *In situ* Chemical Treatment
Attribute	**Oxidation, Reduction, pH adjustment**
Can it be constructed?	Yes, it can be constructed but many injection, extraction and monitoring wells are needed to maintain and validate proper operation. Design, construction, and startup will take approximately 1 year.
Will it work?	Uncertain. No evidence showing that low concentrations of PCBs can be treated *in situ* by this technology to reduce PCB concentrations to the very low screening level concentrations established for the Kaiser site. Due to very low PCB concentrations and porous soil matrix, contact between oxidant and PCB on the colloidal particles and dissolved in groundwater will be difficult to control. Would be difficult to assure sufficient contact between the additive and the entire groundwater stream, including the colloidal particles. Chemical treatment will have to go to completion to reach cleanup levels. Also, oxidant may react with non-target compounds hindering treatment of area of concern. Multiple injection events are likely. Incomplete reactions may leave toxic compounds and off-gas treatment will be needed.
Will this be acceptable to regulatory agencies?	Yes
Is technology available?	Yes
Is process option accepted?	No

Table 6-3d - Implementability of *Ex Situ* Bioremediation for PCBs in the Remelt/Hot Line Groundwater Plume

	Process Options for Aerobic *Ex situ* Bioremediation
Attribute	**Biological treatment of groundwater in above-ground bioreactor.**
Can it be constructed?	Yes. Extensive footprints are required for the large tanks that are used to treat large volumes of groundwater. Treatments require large tanks for sufficient residence time for biologic processes to be effective.
Will it work?	Not likely, since biodegradation of PCBs is relatively slow. No evidence showing that low concentrations of colloidal and dissolved PCBs can be treated by this technology to reduce PCB concentrations to the very low screening level concentrations established for the Kaiser site. The addition of oxygen to the extracted groundwater may change the chemistry of the groundwater and result in the creation of additional colloidal or suspended particulates that would need to be filtered out. Treatability assessment is required.
Will this be acceptable to regulatory agencies?	Yes
Is technology available?	Yes, but significant bench- and pilot-scale assessment is required to optimize design.
Is process option accepted?	No

Table 6-3e - Implementability of On Site Chemical/UV Oxidation for PCBs in the Remelt/Hot Line Groundwater Plume

Attribute	Process Options for Chemical/UV Oxidation of Extracted Groundwater
	Oxidation by chemical addition and/or UV light
Can it be constructed?	Yes, site is amenable to constructing and operating support equipment though access may be limited in some areas by infrastructure. Design, construction, and startup will take approximately 1 year.
Will it work?	Uncertain. No evidence showing that low concentrations of dissolved and colloidal PCBs can be treated by this technology to reduce PCB concentrations to the very low screening level concentrations established for the Kaiser site. High-energy mixing will be needed to ensure uniform distribution of oxidant to react with PCBs. Oxidation may result in the formation of additional colloidal and suspended particulates that will need to be filtered out. Incomplete reactions may leave toxic compounds; carbon polishing step may be required and treatability studies will be required. Off-gas may be produced that needs treatment.
Will this be acceptable to regulatory agencies?	Yes
Is technology available?	Yes
Is process option accepted?	No

Table 6-3f - Implementability of Coagulation for PCBs in the Remelt/Hot Line Groundwater Plume

	Process Options for Coagulation
Attribute	**Addition of coagulants (i.e. aluminum or iron salts, organic polymers, chitosan), electrocoagulation**
Can it be constructed?	Yes, can be designed and constructed in <1 year.
Will it work?	Yes. Coagulation is a conventional technology and usually a pretreatment step to enhance flocculation and filtration. Flocculation and filtration typically precedes technologies that are likely to foul due to the presence of suspended solids, such as carbon adsorption. Type and dosing requirements of coagulant will depend on influent water quality (TSS, pH, temperature). Bench scale tests will identify the appropriate coagulant (or series of coagulants) for the Remelt/Hot Line plume.
Will this be acceptable to regulatory agencies?	Yes
Is technology available?	Yes
Is process option accepted?	Yes

Table 6-3g - Implementability of Flocculation for PCBs in the Remelt/Hot Line Groundwater Plume

	Process Options for Flocculation
Attribute	**Static or mechanical mixers or air agitation in tanks or basins**
Can it be constructed?	Yes, can be designed and constructed in <1 year.
Will it work?	Yes. Flocculation is usually a pretreatment to enhance filtration. Filtration typically precedes technologies likely to foul due to presence of suspended solids, such as carbon adsorption. Flocculation is a process that aggregates particles to allow for solids and liquids separation via settling or filtration. Influent water quality (TSS, pH, temperature) will determine if chemical addition is required to enhance flocculation. Bench-scale tests will identify the appropriate flocculent (or series of flocculents) for the Remelt/Hot Line plume.
Will this be acceptable to regulatory agencies?	Yes
Is technology available?	Yes
Is process option accepted?	Yes

Table 6-3h - Implementability of pH Adjustment for PCBs in the Remelt/Hot Line Groundwater Plume

	Process Options for pH adjustment
Attribute	**Addition of acid or base**
Can it be constructed?	Yes, can be designed and constructed in <1 year.
Will it work?	Yes. pH adjustment can be used as a pretreatment to enhance filtration of colloids and the adsorption of PCBs on PAC (Hart Crowser 2005a) or GAC. Filtration typically precedes technologies likely to foul due to presence of suspended solids, such as carbon adsorption. Lime addition is currently being used at Kaiser's IWT plant for neutralization and metals precipitation (see Section 5 for more details). Can be combined with coagulation and/or flocculation.
Will this be acceptable to regulatory agencies?	Yes
Is technology available?	Yes
Is process option accepted?	Yes

Table 6-3i - Implementability of Depth Filtration for PCBs in the Remelt/Hot Line Groundwater Plume

	Process Options for Depth Filtration
Attribute	**Mono-medium, Dual-medium, Multimedium**
Can it be constructed?	Yes, can be designed and constructed in <1 year.
Will it work?	Yes. Conventional technology. Depth filters currently in use at the Kaiser IWT plant are sand bed filters and a black walnut shell filter (See Section 5.4.4 for more details on these units). Size of filter media particles, depth of filter media, type of filter media and the number of filter units necessary depends on parameters such as water quality, influent flow rate, and how well TSS adheres to filter media. Bench-scale tests will identify the appropriate media(s) for the Remelt/Hot Line plume.
Will this be acceptable to regulatory agencies?	Yes
Is technology available?	Yes
Is process option accepted?	Yes, however, this option is best as a pretreatment step for GAC adsorption.

Table 6-3j - Implementability of Surface Filtration for PCBs in the Remelt/Hot Line Groundwater Plume

	Process Options for Surface Filtration
Attribute	**Bag, Cartridge, or Disk Filter**
Can it be constructed?	Yes, can be designed and constructed in <1 year.
Will it work?	Yes. Conventional technology. The type and number of filters used depends on the influent water quality. Bench scale tests are required. Frequently used as final pretreatment step before technologies very sensitive to fouling such as GAC adsorption and membrane technologies.
Will this be acceptable to regulatory agencies?	Yes
Is technology available?	Yes
Is process option accepted?	Yes

Table 6-3k - Implementability of Membrane Filtration for PCBs in the Remelt/Hot Line Groundwater Plume

	Process Options for Membrane Filtration	
Attribute	**Microfiltration (Flat sheets, hollow fibers, rolled tubes)**	**Ultrafiltration (Flat sheets, hollow fibers, rolled tubes)**
Can it be constructed?	Yes, can be designed and constructed in <1 year.	Yes, can be designed and constructed in <1 year.
Will it work?	Yes. Due to fouling issues significant pretreatment will be required. Typical operating range is for particles with diameters from 0.08 – 2.0 μm. Pretreatment may be needed to remove TSS with diameters greater than 2 μm.	Yes. For post-GAC treatment. Due to fouling issues, significant pretreatment will be required. Typical operating range is for particles with diameters from 0.005-0.2 μm. Pretreatment may be needed to remove TSS and colloids with diameters greater than 0.2 μm.
Will this be acceptable to regulatory agencies?	Yes	Yes
Is technology available?	Yes	Yes
Is process option accepted?	Yes	Yes

Table 6-3l- Implementability of Carbon Adsorption for PCBs in the Remelt/Hot Line Groundwater Plume

	Process Options for Carbon Adsorption	
Attribute	**GAC**	**PAC**
Can it be constructed?	Yes, can be designed and constructed in <1 year.	Yes, can be designed and constructed in <1 year.
Will it work?	Yes. Due to the potential for carbon bed fouling, pretreatment will be required. Prefiltration to remove TSS larger than 10 μm is recommended (Calgon 2009). GAC has been used at CERCLA sites to remove low concentrations of PCBs from groundwater. Periodically, carbon will have to be replaced. Depending on concentrations, spent carbon will have to be regenerated or disposed of as hazardous waste.	Yes. Has been shown to successfully remove PCBs in Kaiser bench scale studies (Hart Crowser 2005a). One way to apply PAC is to add it to the water in a contacting basin. After enough time has passed for adsorption, treated water is removed and the PAC is allowed to settle. Since PAC is so fine, coagulation or a post-filtration process may be required to separate residual PAC from treated water.
Will this be acceptable to regulatory agencies?	Yes	Yes
Is technology available?	Yes	Yes
Is process option accepted?	Yes	Yes; however, post treatment will be required.

Table 6-3m - Implementability of HRM/Mycelx® Cartridge Filters for PCBs in the Remelt/Hot Line Groundwater Plume

	Process Options for HRM/Mycelx Cartridge Filters
Attribute	**HRM/Mycelx Cartridge Filters**
Can it be constructed?	Yes, can be designed and constructed in <1 year.
Will it work?	Yes. Due to fouling issues, pretreatment will be required. Besides coagulation and flocculation steps, vendor recommends particle filtration units in series. The first filtration unit is a 25/5-micron dual media bag and the second is 0.35-micron absolute filter. Also, HRM/Mycelx cartridges are set up in series. HRM/Mycelx filters have been used successfully at the Carolina Transformer Company (CTC) CERCLA site (Abbot 2003). Periodically, filters will have to be replaced. Depending on concentration of adsorbed PCBs, filters will have to be disposed of as hazardous waste.
Will this be acceptable to regulatory agencies?	Maybe
Is technology available?	Yes
Is process option accepted?	Yes

Table 6-4a - Reliability of Selected Technologies for PCBs in the Remelt/Hot Line Groundwater Plume

Technology	Process Options	Is it reliable?[1]
Monitoring	Protection, Performance, Confirmational	Yes
Access Restrictions	Fencing, deed restrictions, restrictive covenant	Yes
Best Management Practices (BMPs)	Spill prevention, cleanup procedures, secondary containment, etc.	Yes
Capping	Low Permeability Asphalt Cap	Yes
Capping	Low Permeability Concrete Cap	Yes
Capping	Multilayer (synthetic liner + soil)	Yes
Hydraulic Containment	Extraction Wells	Yes
Monitored Natural Attenuation	Monitored Natural Attenuation	Yes

Note:

1) The evaluations of reliability given in this table for PCBs in groundwater are similar to SVOCs in groundwater as given in Tables 5-7a and 5-7b. Refer to the evaluations in those tables.

Table 6-4b - Reliability of Coagulation for PCBs in the Remelt/Hot Line Groundwater Plume

	Process Options for Coagulation
Attribute	**Addition of coagulants (e.g., aluminum or iron salts, organic polymers, chitosan), electrocoagulation**
Has this process option been used at the scale required for Kaiser?	Yes, but coagulation is usually a pretreatment to enhance filtration. Type of coagulant and type, size, and number of rapid mixing chambers will depend on influent water quality and flow rate.
Are operation and maintenance requirements infrequent and straightforward?	Yes. Moving mechanical equipment such as impellers and feed pumps will require regular O&M. Chemicals will need to be stored and handled on site.
Has this process option been proven effective under COC and site conditions similar to those at Kaiser?	Yes; however, as a preliminary step prior to flocculation and filtration for the removal of colloids and other suspended solids from water.
Is process option accepted?	Yes

Table 6-4c - Reliability of Flocculation for PCBs in the Remelt/Hot Line Groundwater Plume

	Process Options for Flocculation
Attribute	**Static or mechanical mixers or air agitation in tanks or basins**
Has this process option been used at the scale required for Kaiser?	Yes, flocculation is a pretreatment to enhance filtration. Type, size and number of flocculant tanks will depend on influent water quality and flow rate. Flocculents (or filter aids) are added to enhance aggregation of particles.
Are operation and maintenance requirements infrequent and straightforward?	Yes. Moving mechanical equipment such as impellers and feed pumps will require regular O&M. Chemicals will need to be stored and handled on site.
Has this process option been proven effective under COC and site conditions similar to those at Kaiser?	Yes; however, as a preliminary step for the removal of colloids and other suspend solids in water prior to filtration.
Is process option accepted?	Yes

Table 6-4d - Reliability of pH Adjustment for PCBs in the Remelt/Hot Line Groundwater Plume

Attribute	Process Options for pH Adjustment
	Addition of acid or base
Has this process option been used at the scale required for Kaiser?	Yes, pH adjustment can be used as a pretreatment step to enhance filtration. In bench-scale studies performed on Kaiser groundwater, the lowering of pH prior to PAC adsorption was shown to enhance PCB removal (Hart Crowser 2005a). Lime addition is currently used at Kaiser's IWT plant to help with neutralization and metals precipitation (see Section 5.4.4 for more detail).
Are operation and maintenance requirements infrequent and straightforward?	Yes. Moving mechanical equipment such as impellers and feed pumps will require regular O&M. Chemicals will need to be stored and handled on site.
Has this process option been proven effective under COC and site conditions similar to those at Kaiser?	Yes, as a pretreatment step to enhance removal of PCBs and/or colloids in water. Depending on when pH adjustment is made, post treatment steps may include coagulation or flocculation, or carbon adsorption.
Is process option accepted?	Yes

Table 6-4e - Reliability of Depth Filtration for PCBs in the Remelt/Hot Line Groundwater Plume

	Process Options for Depth Filtration
Attribute	**mono-medium, dual-medium, multi-medium**
Has this process option been used at the scale required for Kaiser?	Yes, conventional technology for the removal of particles approximately 1 μm or greater in diameter (Metcalf & Eddy 2003). Sand bed filters and BWS filter are depth filters in use at Kaiser's IWT Plant (see Section 5 for more detail).
Are operation and maintenance requirements infrequent and straightforward?	Yes. Periodically filter will need to be backflushed to remove accumulated solids.
Has this process option been proven effective under COC and site conditions similar to those at Kaiser?	Yes; however, as a pretreatment step for filtration technologies (surface and membrane filtration) designed to remove submicron particulates and/or PCB removal technologies that are sensitive to solids fouling such as carbon adsorption.
Is process option accepted?	Yes; however, best as a pretreatment for GAC.

Table 6-4f - Reliability of Surface Filtration for PCBs in the Remelt/Hot Line Groundwater Plume

	Process Options for Surface Filtration
Attribute	**Bag, cartridge, or disk filter**
Has this process option been used at the scale required for Kaiser?	Yes, conventional technology. Cloth medium filters have pore size of 10 to 30 μm (Metcalf & Eddy 2003). Cartridge filters with pore sizes as low as 0.5 μm are available (McMaster Carr 2009).
Are operation and maintenance requirements infrequent and straightforward?	Yes. Periodically filter units will have to be replaced after exhausted.
Has this process option been proven effective under COC and site conditions similar to those at Kaiser?	Yes; however, as a pretreatment step to filtration technologies (surface and membrane filtration) designed to remove submicron particulates and/or PCB removal technologies that are sensitive to solids fouling such as carbon adsorption.
Is process option accepted?	Yes; however, best as a pretreatment step for GAC.

Table 6-4g - Reliability of Microfiltration for PCBs in the Remelt/Hot Line Groundwater Plume

	Process Options for Microfiltration
Attribute	**Porous membranes for removal of materials from approximately 0.08 to 2 μm in diameter.**
Has this process option been used at the scale required for Kaiser?	Yes
Are operation and maintenance requirements infrequent and straightforward?	Uncertain. Extensive pretreatment needed to prevent fouling; however, system can be automated easily. Membranes will periodically need to be replaced. High-energy process – high pressures are required (15 psi) (Metcalf & Eddy 2003).
Has this process option been proven effective under COC and site conditions similar to those at Kaiser?	Yes; however, extensive pretreatment needed to prevent fouling. Technology can be used as one of final steps before final PCB removal technologies such as carbon adsorption.
Is process option accepted?	Yes

Table 6-4h - Reliability of Ultrafiltration for PCBs in the Remelt/Hot Line Groundwater Plume

	Process Options for Ultrafiltration
Attribute	**Porous membranes for removal of materials from approximately 0.005 to 0.2 μm in diameter**
Has this process option been used at the scale required for Kaiser?	Unknown
Are operation and maintenance requirements infrequent and straightforward?	Uncertain. Extensive pretreatment needed to prevent fouling; however, system can be automated easily. Membranes will periodically need to be replaced. High-energy process – high pressures are required (75 psig) (Metcalf & Eddy 2003).
Has this process option been proven effective under COC and site conditions similar to those at Kaiser?	Yes; however, extensive pretreatment needed to prevent fouling. Technology can be used as one of the final polishing steps after PCB removal technologies such as carbon adsorption.
Is process option accepted?	Yes

Table 6-4i - Reliability of GAC Adsorption for PCBs in the Remelt/Hot Line Groundwater Plume

	Process Options for GAC adsorption
Attribute	**GAC Bed**
Has this process option been used at the scale required for Kaiser?	Yes, but GAC is typically used for a final polishing step, that is, following removal of the bulk of suspended solids, oil, and grease by another technology. For the Remelt/Hot Line groundwater plume, GAC will be one of the final steps for PCB removal after extensive pretreatment for suspended solids removal. Suspended solids in the influent will eventually foul the carbon bed and reduce efficiency. Carbon treatment was used for a pump-and-treat system at the Sangamo Weston/Twelve-Mile CERCLA site. Since 2005, approximately 155 million gallons of groundwater have been treated. This has resulted in the removal of approximately 1,140 pounds of chlorinated solvents and 12.3 pounds of PCBs (EPA 2004b, EPA 2004c, RMT 2006).
Are operation and maintenance requirements infrequent and straightforward?	No. Significant pretreatment will be required to remove suspended and colloidal solids to ensure that the carbon bed does not foul and PCBs are removed. Pretreatment of solids will depend on influent groundwater quality. Calgon representative recommends at least prefiltering of particles below 10 μm in diameter. If colloidal particles do flush out of the carbon bed, post filtration may be required. Periodically, the carbon bed will need to be backflushed to remove accumulated solids. At exhaustion, the carbon bed will have to be disposed of and, depending on concentrations of PCBs, spent carbon may have to be disposed of as hazardous waste.
Has this process option been proven effective under COC and site conditions similar to those at Kaiser?	Yes; however, a pretreatment will be required to prevent solids fouling. If colloidal particles do flush out of the carbon bed, post filtration may be required.
Is process option accepted?	Yes

Table 6-4j - Reliability of PAC Adsorption for PCBs in the Remelt/Hot Line Groundwater Plume

	Process Options for PAC adsorption
Attribute	**PAC**
Has this process option been used at the scale required for Kaiser?	Yes. Proprietary Powdered Activated Carbon Treatment (PACT) is used in wastewater treatment plants. PACT is where activated sludge and PAC are combined so treatment occurs via biological oxidation and adsorption (Metcalf & Eddy 2003).
Are operation and maintenance requirements infrequent and straightforward?	Uncertain. Depending on how PAC is applied, post treatment may be required. For example, if contacting basin is used, PAC will need to be settled out. Used PAC will have to be removed and treated, and treated water will likely contain fine particulates that will need to be removed via filtration (Metcalf & Eddy 2003). Pretreatment will be needed to remove suspended solids and allow adsorption of low-level PCBs.
Has this process option been proven effective under COC and site conditions similar to those at Kaiser?	No. Carbon is known to adsorb PCBs and bench-scale studies performed on well water from HL-MW-5 showed PAC application had high PCB removal efficiencies. PACT increases and improves organics removal, VOC/odor control, color removal, resistance to shock loads, metals removal and sludge/settling thickening. Organics likely to be treated are biodegradable. PCBs have been shown not to readily biodegrade (Metcalf & Eddy 2003, Gallego 2002).
Is process option accepted?	No

Table 6-4k - Reliability of HRM/Mycelx® Cartridge Filters for PCBs in the Remelt/Hot Line Groundwater Plume

	Process Options for HRM/Mycelx ® Cartridge Filters
Attribute	**HRM/Mycelx ® Cartridge Filters**
Has this process option been used at the scale required for Kaiser?	Yes, but as final PCB polishing step; that is, following removal of solids by pretreatment. HRM/Mycelx filters were used at a CERCLA site in North Carolina to achieve 0.5 μg/L.
Are operation and maintenance requirements infrequent and straightforward?	Uncertain. Significant pretreatment will be required to remove suspended or colloidal solids to ensure filters do not foul and PCBs are removed. Pretreatment of solids will depend on influent groundwater quality. If colloidal particles do flush out of the carbon bed, post filtration may be required. Periodically, filters will have to be replaced.
Has this process option been proven effective under COC and site conditions similar to those at Kaiser?	Yes; however, pretreatment will be required to prevent solids fouling of the HRM/Mycelx cartridges. If colloidal particles do flush out of the cartridges, post filtration will be required.
Is process option accepted?	Yes

Table 6-5 - Summary of Technology Screening Process: PCBs in the Remelt/Hot Line Groundwater Plume

			Screening Outcome		
General Response Action [1]	Remedial Technology [1]	Process Options [1]	Physical/Chemical [2]	Implementability [3]	Reliability [4]
Monitoring	**Monitoring**	**Protection, Performance, and Confirmational**	**Retained**	**Retained**	**Retained**
Institutional Controls	**Access and Use Restrictions**	**Fences, Signs, Deed Restrictions**	**Retained**	**Retained**	**Retained**
	Alternative Water Supply	Connect to distribution system, new supply well	Eliminated	--	--
	Best Management Practices	**Spill prevention, leak detection, double-walled pipes**	**Retained**	**Retained**	**Retained**
Containment	**Capping**	Soil	Retained	Eliminated	--
		Clay	Retained	Eliminated	--
		Asphalt	**Retained**	**Retained**	**Retained**
		Concrete	**Retained**	**Retained**	**Retained**
		Synthetic	Retained	Eliminated	--
		Multi-layer cap (soil + synthetic)	**Retained**	**Retained**	**Retained**
	Vertical Barriers	Slurry wall, grout curtain, sheet piling	Eliminated	--	--
	Horizontal Barriers	Block displacement, grout injection	Eliminated	--	--
	Hydraulic Containment	**Vertical extraction wells**	**Retained**	**Retained**	**Retained**
		Trenches	Retained	Eliminated	--
***In situ* Treatment of Groundwater**	*In situ* Bioremediation	Enhanced bioremediation	Retained	Eliminated	--
		Phytoremediation	Retained	Eliminated	--
	Monitored Natural Attenuation	**Monitored Natural Attenuation**	**Retained**	**Retained**	**Retained**
	Chemical Treatment	Oxidation, reduction, pH adjustment	Retained	Eliminated	--

Table 6-5 - Summary of Technology Screening Process: PCBs in the Remelt/Hot Line Groundwater Plume

			Screening Outcome		
General Response Action [1]	Remedial Technology [1]	Process Options [1]	Physical/Chemical [2]	Implementability [3]	Reliability [4]
Extraction and On-Site Treatment of Groundwater	*Aerobic Ex situ* Bioremediation	Biological treatment of groundwater in aboveground bioreactor.	Retained	Eliminated	--
	Chemical Treatment/UV Oxidation	Oxidation through chemical addition and/or UV light	Retained	Eliminated	--
Extraction and On-Site Treatment of Groundwater (Particle Aggregation Technologies)	**Coagulation**	**Addition of coagulants (i.e. aluminum or iron salts, organic polymers, chitosan)**	**Retained**	**Retained**	**Retained**
	Flocculation	**Static or mechanical mixers or air agitation in tanks or basins**	**Retained**	**Retained**	**Retained**
	pH Adjustment	**Addition of acid or base**	**Retained**	**Retained**	**Retained**
Extraction and On-Site Treatment of Groundwater (Particle Filtration Technologies)	Floatation	Dissolved Air Floatation, Dispersed Air Floatation	Eliminated	--	--
	Sedimentation	Sedimentation tanks, Clarifiers, Combination Flocculator-Clarifier	Eliminated	--	--
	Depth Filtration	**Mono-medium, dual-medium, multimedium**	**Retained**	**Retained**	**Retained**
	Surface Filtration	**Cartridge, bag and disk filters**	**Retained**	**Retained**	**Retained**
Extraction and On-Site Treatment of Groundwater (Membrane Filtration Technologies)	**Microfiltration**	**Flat sheets, fine hollow fibers or tubular**	**Retained**	**Retained**	**Retained**
	Ultrafiltration	**Flat sheets, fine hollow fibers or tubular**	**Retained**	**Retained**	**Retained**
	Nanofiltration	Flat sheets, fine hollow fibers or tubular	Eliminated	--	--
	Reverse Osmosis	Flat sheets, fine hollow fibers or tubular	Eliminated	--	--
	Ion Exchange	Cationic, anionic	Eliminated	--	--

Table 6-5 - Summary of Technology Screening Process: PCBs in the Remelt/Hot Line Groundwater Plume

			Screening Outcome		
General Response Action [1]	Remedial Technology [1]	Process Options [1]	Physical/Chemical [2]	Implementability [3]	Reliability [4]
Extraction and On-Site Treatment of Groundwater (Adsorption Technologies)	**HRM/Mycelx ® Cartridge Filters**	**HRM/Mycelx ® Cartridge Filters**	**Retained**	**Retained**	**Retained**
	Carbon Adsorption	**GAC**	**Retained**	**Retained**	**Retained**
		PAC	Retained	Retained	Eliminated

Notes:

Bolded Technologies Retained for further evaluation in the FS.

1) Taken from FSTM Table 6-1.

2) Taken from FSTM Table 6-2a through 6-2b.

3) Taken from FSTM Table 6-3a through 6-3m.

4) Taken from FSTM Table 6-4a through 6-4k.

Table 6-6 - Location and Concentration of Groundwater COCs in the Remelt/Hot Line PCB Plume AOC

General Location	COCs	Sample Numbers	Calculated Concentration[a]	Units
Remelt/Hot Line PCB Plume	PCBs	HL-MW-6A (22-Apr-08), HL-MW-6A (23-Jul-08), HL-MW-6A (19-Oct-08), HL-MW-7S (24-Jan-08), HL-MW-7S (21-Apr-08), HL-MW-7S (23-Jul-08), HL-MW-7S (19-Oct-08), HL-MW-8D (21-Apr-08), HL-MW-8D (19-Oct-08), HL-MW-9D (22-Apr-08), HL-MW-9D (19-Oct-08), HL-MW-13DD (21-Apr-08), HL-MW-13DD (19-Oct-08), HL-MW-14S (25-Jan-08), HL-MW-14S (21-Apr-08), HL-MW-14S (23-Jul-08), HL-MW-14S (24-Oct-08), HL-MW-15DD (22-Apr-08), HL-MW-15DD (20-Oct-08), HL-MW-17S (25-Jan-08), HL-MW-17S (21-Apr-08), HL-MW-17S (23-Jul-08), HL-MW-17S (21-Oct-08), HL-MW-18S (24-Jan-08), HL-MW-18S (21-Apr-08), HL-MW-18S (23-Jul-08), HL-MW-18S (21-Oct-08), HL-MW-24DD (21-Apr-08), HL-MW-24DD (24-Oct-08), HL-MW-25S (25-Jan-08), HL-MW-25S (21-Apr-08), HL-MW-25S (23-Jul-08), HL-MW-25S (19-Oct-08), HL-MW-26S (24-Jan-08), HL-MW-26S (21-Apr-08), HL-MW-26S (23-Jul-08), HL-MW-26S (22-Oct-08), HL-MW-27D (21-Apr-08), HL-MW-27D (21-Oct-08), HL-MW-28DD (24-Jan-08), HL-MW-29S (24-Jan-08), HL-MW-29S (23-Jul-08), HL-MW-30S (25-Jan-08), HL-MW-30S (23-Apr-08), HL-MW-30S (24-Jul-08), HL-MW-30S (19-Oct-08), RM-MW-1S (24-Jan-08), RM-MW-1S (20-Apr-08), RM-MW-1S (24-Jul-08), RM-MW-1S (22-Oct-08), RM-MW-2D (20-Apr-08), RM-MW-2D (22-Oct-08), RM-MW-3S (24-Jan-08), RM-MW-3S (20-Apr-08), RM-MW-3S (23-Jul-08), RM-MW-3S (23-Oct-08), RM-MW-4D (20-Apr-08), RM-MW-4D (23-Oct-08), RM-MW-8S (24-Jan-08), RM-MW-8S (20-Apr-08), RM-MW-8S (22-Jul-08), RM-MW-8S (18-Oct-08), RM-MW-10S (24-Jan-08), RM-MW-10S (20-Apr-08), RM-MW-10S (23-Jul-08), RM-MW-10S (23-Oct-08), RM-MW-13S (24-Jan-08), RM-MW-13S (20-Apr-08), RM-MW-13S (23-Jul-08), RM-MW-13S (23-Oct-08), RM-MW-14S (24-Jan-08), RM-MW-14S (20-Apr-08), RM-MW-14S (24-Jul-08), RM-MW-14S (22-Oct-08), RM-MW-15S (24-Jan-08), RM-MW-15S (20-Apr-08), RM-MW-15S (24-Jul-08), RM-MW-15S (22-Oct-08), RM-MW-16S (24-Jan-08), RM-MW-16S (20-Apr-08), RM-MW-16S (24-Jul-08), RM-MW-16S (22-Oct-08), RM-MW-17S (24-Jan-08), RM-MW-17S (20-Apr-08), RM-MW-17S (24-Jul-08), RM-MW-17S (22-Oct-08)	0.27	µg/L
	Arsenic (Dissolved)	HL-MW-6A (22-Apr-08), HL-MW-24DD (21-Apr-08), HL-MW-24DD (24-Oct-08), HL-MW-25S (21-Apr-08), HL-MW-25S (19-Oct-08), HL-MW-26S (21-Apr-08), HL-MW-26S (22-Oct-08), HL-MW-27D (21-Apr-08), HL-MW-27D (21-Oct-08), HL-MW-28DD (24-Jan-08), HL-MW-28DD (21-Apr-08), HL-MW-28DD (19-Oct-08), HL-MW-29S (24-Jan-08), HL-MW-29S (22-Oct-08), HL-MW-29S (22-Apr-08), HL-MW-30S (25-Jan-08), HL-MW-30S (23-Apr-08), HL-MW-30S (19-Oct-08), MW-12A (24-Apr-08), MW-12A (21-Oct-08)	5.83	µg/L

Notes

a - Based on four quarters of groundwater monitoring conducted in January, April, July, and October 2008. Concentration represents the average concentration of COCs in each AOC. One half of the reporting limit was used in averaging calculations if non-detect samples were present in the AOC.

Table 6-7 - Distribution of COCs in the Remelt/Hot Line PCB Groundwater Plume

General Area	**Rough Order of Magnitude Mass of COCs in pounds**[a]	
	PCBs	**Arsenic**
Remelt/Hot Line	1.8E-02	3.8E-01
Total	1.8E-02	3.8E-01

Notes

a - The rough order of magnitude quantities shown represent estimated quantities of COCs contained in 1 day's volume of groundwater at the determined hydraulic containment pumping rates.

Table 6-8 - Calculation of Rough Order of Magnitude (ROM) Mass of Constituents of Concern (COCs) for the Remelt/Hot Line PCB Plume Area of Concern (AOC)

General Area	COC	Samples/AOC ID	Area (feet^2) of Plume	ROM Hydrualic Containment Pump Rate (GPD)^a	Calculated Concentration^b (mg/L)	ROM Mass of COC in one day of pumping (lbs)
Remelt/Hotline	PCBs	HL-MW-4 (22-Apr-08), HL-MW-4 (20-Oct-08), HL-MW-5 (25-Jan-08), HL-MW-5 (22-Apr-08), HL-MW-5 (23-Jul-08), HL-MW-5 (20-Oct-08), HL-MW-6A (25-Jan-08), HL-MW-6A (22-Apr-08), HL-MW-6A (23-Jul-08), HL-MW-6A (19-Oct-08), HL-MW-7S (24-Jan-08), HL-MW-7S (21-Apr-08), HL-MW-7S (23-Jul-08), HL-MW-7S (19-Oct-08), HL-MW-8D (21-Apr-08), HL-MW-8D (19-Oct-08), HL-MW-9D (22-Apr-08), HL-MW-9D (19-Oct-08), HL-MW-13DD (21-Apr-08), HL-MW-13DD (19-Oct-08), HL-MW-14S (25-Jan-08), HL-MW-14S (21-Apr-08), HL-MW-14S (23-Jul-08), HL-MW-14S (24-Oct-08), HL-MW-15DD (22-Apr-08), HL-MW-15DD (20-Oct-08), HL-MW-17S (25-Jan-08), HL-MW-17S (21-Apr-08), HL-MW-17S (23-Jul-08), HL-MW-17S (21-Oct-08), HL-MW-18S (24-Jan-08), HL-MW-18S (21-Apr-08), HL-MW-18S (23-Jul-08), HL-MW-18S (21-Oct-08), HL-MW-24DD (21-Apr-08), HL-MW-24DD (24-Oct-08), HL-MW-25S (25-Jan-08), HL-MW-25S (21-Apr-08), HL-MW-25S (23-Jul-08), HL-MW-25S (19-Oct-08), HL-MW-26S (24-Jan-08), HL-MW-26S (21-Apr-08), HL-MW-26S (23-Jul-08), HL-MW-26S (22-Oct-08), HL-MW-27D (21-Apr-08), HL-MW-27D (21-Oct-08), HL-MW-28DD (24-Jan-08), HL-MW-28DD (21-Apr-08), HL-MW-28DD (19-Oct-08), HL-MW-29S (24-Jan-08), HL-MW-29S (23-Jul-08), HL-MW-29S (22-Oct-08), HL-MW-30S (25-Jan-08), HL-MW-30S (23-Apr-08), HL-MW-30S (24-Jul-08), HL-MW-30S (19-Oct-08), MW-12A (25-Jan-08), MW-12A (24-Apr-08), MW-12A (23-Jul-08), MW-12A (21-Oct-08), RM-MW-1S (24-Jan-08), RM-MW-1S (20-Apr-08), RM-MW-1S (24-Jul-08), RM-MW-1S (22-Oct-08), RM-MW-2D (20-Apr-08), RM-MW-2D (22-Oct-08), RM-MW-3S (24-Jan-08), RM-MW-3S (20-Apr-08), RM-MW-3S (23-Jul-08), RM-MW-3S (23-Oct-08), RM-MW-4D (20-Apr-08), RM-MW-4D (23-Oct-08), RM-MW-8S (24-Jan-08), RM-MW-8S (20-Apr-08), RM-MW-8S (22-Jul-08), RM-MW-8S (18-Oct-08), RM-MW-10S (24-Jan-08), RM-MW-10S (20-Apr-08), RM-MW-10S (23-Jul-08), RM-MW-10S (23-Oct-08), RM-MW-13S (24-Jan-08), RM-MW-13S (20-Apr-08), RM-MW-13S (23-Jul-08), RM-MW-13S (23-Oct-08), RM-MW-14S (24-Jan-08), RM-MW-14S (20-Apr-08), RM-MW-14S (24-Jul-08), RM-MW-14S (22-Oct-08), RM-MW-15S (24-Jan-08), RM-MW-15S (20-Apr-08), RM-MW-15S (24-Jul-08), RM-MW-15S (22-Oct-08), RM-MW-16S (24-Jan-08), RM-MW-16S (20-Apr-08), RM-MW-16S (24-Jul-08), RM-MW-16S (22-Oct-08), RM-MW-17S (24-Jan-08), RM-MW-17S (20-Apr-08), RM-MW-17S (24-Jul-08), RM-MW-17S (22-Oct-08)	694,600	8,228,000	2.7E-04	1.8E-02
	Arsenic	HL-MW-6A (22-Apr-08), HL-MW-24DD (21-Apr-08), HL-MW-24DD (24-Oct-08), HL-MW-25S (21-Apr-08), HL-MW-25S (19-Oct-08), HL-MW-26S (21-Apr-08), HL-MW-26S (22-Oct-08), HL-MW-27D (21-Apr-08), HL-MW-27D (21-Oct-08), HL-MW-28DD (24-Jan-08), HL-MW-28DD (21-Apr-08), HL-MW-28DD (19-Oct-08), HL-MW-29S (24-Jan-08), HL-MW-29S (22-Oct-08), HL-MW-29S (22-Apr-08), HL-MW-30S (25-Jan-08), HL-MW-30S (23-Apr-08), HL-MW-30S (19-Oct-08), MW-12A (24-Apr-08), MW-12A (21-Oct-08)	694,600	8,228,000	5.8E-03	3.8E-01

Notes

a - The depth of groundwater impacts was conservatively assumed to be 20 feet in each of the AOCs.

b - Based on four quarters of groundwater monitoring conducted in January, April, July, and October 2008. Concentration represents the average concentration of COCs in each AOC. One half of the reporting limit was used in averaging calculations if non-detect sample were present in the AOC.

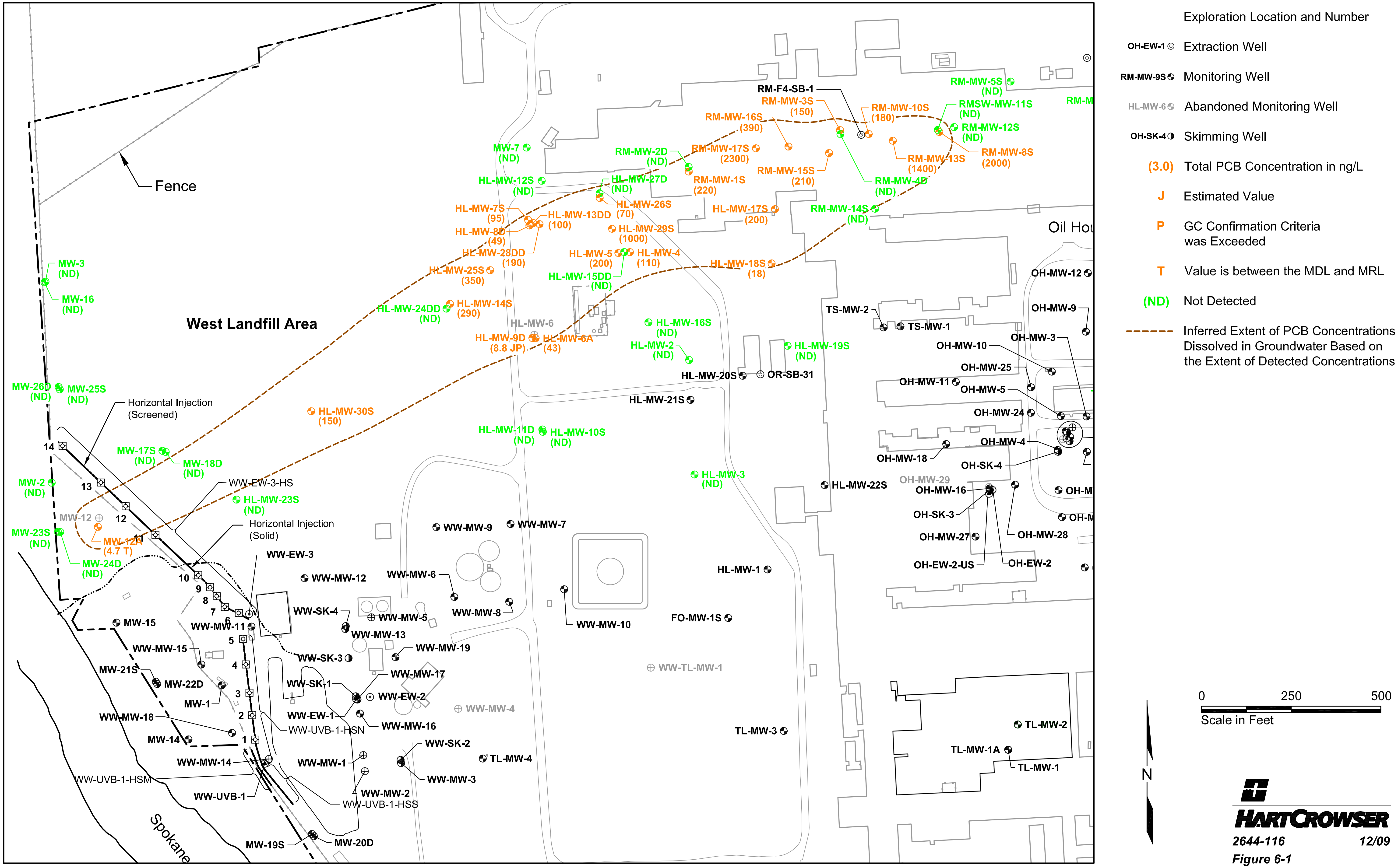
Table 6-9 - Remedial Alternative: COC Group Matrix - PCB Groundwater Plume

Alternative	Description	Contaminants of Concern
		PCBs
A1	Institutional Controls & Monitoring & MNA	X
A2	Institutional Controls & Monitoring & MNA & Containment	X
A3	*Ex situ* Treatment & A2 (1)	X

Notes:

(1) *Ex situ* treatment may include pretreatment (coagulation, pH adjustment, flocculation and filtration), adsorption (GAC, Mycelx®) and post-treatment (coagulation, pH adjustment [if needed], and flocculation, filtration) to Alternative 2.

Remelt/Hotline Dissolved PCBs in Groundwater Screening - 2008



Exploration Location and Number

OH-EW-1 ◎	Extraction Well
RM-MW-9S ⊕	Monitoring Well
HL-MW-6 ⊕	Abandoned Monitoring Well
OH-SK-4 ◑	Skimming Well
(3.0)	Total PCB Concentration in ng/L
J	Estimated Value
P	GC Confirmation Criteria was Exceeded
T	Value is between the MDL and MRL
(ND)	Not Detected
- - - - -	Inferred Extent of PCB Concentrations Dissolved in Groundwater Based on the Extent of Detected Concentrations

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Figure 6-1

EAL 11/4/09 2644116-067.DWG

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APPENDIX A
POTENTIAL REMEDIATION TECHNOLOGIES FOR COCS IN NEAR-SURFACE SOILS

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APPENDIX A
POTENTIAL REMEDIATION TECHNOLOGIES FOR COCS IN NEAR-SURFACE SOILS

A.1 CONTAINMENT TECHNOLOGIES

A variety of capping, vertical barrier, solidification, stabilization, and vitrification technologies have been evaluated for use in treating COCs contained in the soil at Kaiser. A brief description of each technology follows.

Caps

Caps are horizontal barriers used to physically isolate contaminated areas from direct human or ecological contact, and to prevent the infiltration of rainfall and surface water. A wide variety of low permeability capping materials are available. Asphalt, concrete, clay, and multi-layer caps (usually concrete and a synthetic liner) are frequently used to isolate contaminants.

The Hoffman Tank site at Kaiser has an engineered multi-layer cap placed over contaminated soil that could not be safely excavated. The cap consists of a polyvinyl chloride (PVC) liner installed as an impermeable surface over the regraded area. The PVC liner is covered by a 12-inch layer of coarse sand and a top soil layer to protect the liner from abrasion and UV light degradation. A catch basin and stormwater collection system to collect surface water runoff over the membrane and direct it into a catch basin for treatment in the IWT plant was also installed (Hart Crowser 1991b). In addition to the Hoffman Tank cap there are numerous areas on the Kaiser site where shallow-soil impacts have occurred that are currently covered by buildings, concrete, or asphalt that act as a cap. These areas will be evaluated at a later date to determine if the existing cap provides the requisite level of protectiveness as required by WAC 173-340-740(6)(f).

Landfill Cap Enhancements

Landfill cap enhancements are designed to reduce or eliminate contaminant migration. Typical enhancements include runoff channeling and control (with treatment, if necessary) and the installation of a vegetative cover (FRTR 2009c).

Vertical Barriers

Subsurface vertical barriers are used to prevent the horizontal migration of contaminants and to control the flow of groundwater. Vertical barriers can include slurry walls, grout curtains, and sheet pile walls (EPA 1998b).

Slurry walls are the most common type of vertical barrier (Pearlman 1999). These walls are constructed by excavating a vertical trench along the perimeter of the site and filling the trench with low-permeability material (bentonite slurry). Soil-bentonite barriers are the most widely used in the United States. Soil-cement-bentonite and cement-bentonite vertical barriers can also be used as a means of containment (EPA 1998b).

Grout curtains are installed by injecting grout or jet-grouting soil at a site. Grout curtains are advantageous because they can extend into bedrock, but they are more expensive than other techniques (EPA 1998b).

Sheet pile walls are constructed by driving vertical sheets of steel, precast concrete, aluminum, or wood into the soil to form a vertical barrier wall. The sheets are assembled before installation and are driven or vibrated into the ground. Sheet piling is very strong and has successfully been used to contain both soil and water (Pearlman 1999). Continuous sheet pile walls with interlocking joints that lock the sheet piles together are available (EPA 1998b).

Solidification

Solidification is the encapsulation of waste to form a solid material. The process can be accomplished either by a chemical reaction between waste and solidifying reagents or by a mechanical process. Solidification results in the creation of a monolithic block, a clay-like material, a granular particulate, or another solid form (EPA 1999a and 1989). Solidification restricts contaminant migration by vastly decreasing the surface area exposed to leaching and/or by isolating the waste within an impervious capsule (EPA 1997c).

Stabilization

Stabilization chemically reduces the hazard potential of waste by converting the contaminants into less soluble, less mobile, or less toxic forms. This process may change the physical nature or handling characteristics of the waste because the end product may have properties similar to soil (EPA 1999a and 1989). Phosphates, sulfides, carbonates, etc., have been used as stabilizing reagents (EPA 1997c).

Vitrification

Vitrification is designed to treat soil, sludges, and sediment contaminated with organic, inorganic, and radioactive compounds. The process uses electrical current to heat and vitrify the soil in place. Graphite electrodes are inserted into the soil to heat the surrounding area and melt the adjacent soil. Powdered graphite is placed between the electrodes to conduct the current through the soil at temperatures of approximately 3,600°F (Chemical Engineering 1988). Organic contaminants are decomposed into simple gases by the extreme heat. These gases then rise and escape through the molten soil and are collected and treated in an off-gas treatment system (EPA 1995b). Inorganic contaminants are trapped within the molten soil, which then cools and solidifies into a glassy block. This block forms a cap of solidified material that is leach-resistant because of its greatly reduced surface area (Richardson 1995). Vitrification has been tested on a range of VOCs, SVOCs, PCBs, and priority pollutant metals (CPEO 2009).

A.2 *IN SITU* TREATMENT TECHNOLOGIES

A number of *in situ* treatment technologies including *in situ* bioremediation, monitored natural attenuation, soil vapor extraction (SVE), dual vacuum extraction (DVE), air sparging, steam injection, soil heating, soil flushing (alcohol or solvents), pneumatic fracturing, chemical treatment (e.g., oxidation, reduction, pH adjustment), and electrokinetic treatment have been applied to VOCs contained in soil. A brief description of each technology follows.

In Situ Bioremediation

In situ bioremediation is a process by which microorganisms degrade contaminants through use or transformation of the target substances. Bioremediation can take place under either aerobic or anaerobic conditions (EPA 1997e). Bioremediation technologies assist microorganism growth and increase microbial populations by creating optimum environmental conditions. The specific treatment method that is applied to a site is determined by the type of microorganisms present, site conditions, and the target COCs (EPA 1996d). *In situ* biological treatment options include bioventing, biosparging, enhanced bioremediation, Oxygen Release Compound (ORC), electron acceptor additions, and phytoremediation.

Bioventing is a cost-effective approach for removing volatile constituents from the vadose zone (Brown et al. 1999). Bioventing involves the flow of air into soil above the water table to supply oxygen to the subsurface. Bioventing systems deliver air through injection wells placed in the ground where the contamination exists. Also, nutrients may be pumped into the soil to increase the microorganism growth rate (EPA 1996d). Bioventing techniques have been successfully used to remediate soils contaminated with petroleum hydrocarbons and non-chlorinated VOCs (FRTR 2009).

Biosparging is the process by which pressurized air is injected beneath the water table to promote mass transfer of VOCs out of the soil and groundwater and mass transfer of oxygen into the groundwater (Grindstaff 1998). Air is pushed into zones below the water table and into the capillary fringe, which results in *in situ* volatilization and biodegradation of contaminants in both soil and groundwater (Brown et al. 1999). Biosparging is typically used in conjunction with soil vapor extraction (SVE) systems (detailed below). This technology is mainly applicable for VOCs.

Enhanced bioremediation involves the addition of substrates and/or nutrients to the subsurface to increase bacterial growth and degradation rates of COCs (Grindstaff 1998). For instance, nutrients such as nitrogen and phosphorous can be added to the subsurface to increase the growth rate of microorganisms. Variations of enhanced bioremediation techniques have been successful in remediating sites contaminated with VOCs and SVOCs (FRTR 2009c).

ORC is a patented formulation of magnesium peroxide ($Mg0_2$) that is used to slowly release oxygen into the subsurface for aerobic bioremediation. The hydrated product is magnesium hydroxide, $Mg(OH)_2$. The ORC residue may be used as a grout or filler material in the saturated zone. It can be backfilled or injected into direct-push boreholes, or backfilled into augured holes for source area treatment. Generally, the product is able to release oxygen for about 6 months (Cauwenberghe and Roote 1998).

Addition of *electron acceptors* can be used to facilitate biodegradation in cases where anaerobic bacteria exist. Electron acceptor additions typically involve the addition of oxygen because more energy is derived from aerobic respiration than other microbial processes. However, anaerobic bacteria can use nitrate, sulfate, and salts of ferric iron (Fe +3) to degrade organic contaminants (Cauwenberghe and Roote 1998).

Phytoremediation is a bioremediation process that uses various types of plants to remove, transfer, stabilize, and destroy contaminants in soil and sediment. Contaminants may be either organic or inorganic. Contaminants such as metals, volatile organic compounds (VOCs) and semi-volatile organic compounds (SVOCs) may be treated using this process but strongly sorbed contaminants such as polychlorinated biphenyls (PCBs) typically cannot be treated using this method. Phytoremediation is typically limited to lower contaminant concentrations in shallow soil and water horizons; however, the deep root system of trees has allowed remediation to occur at greater depths.

There are a variety of phytoremediation methods including phyto-accumulation (also called phyto-extraction) and hydraulic control. In phyto-accumulation contaminants are sorbed into plant roots and end up in the shoots and leaves of the plant. This remediation method is typically used for metals and success is dependent on the bioavailability of the metal. For lead, bioavailability is low; however, chelating agents have been used to increase plant uptake. Hydraulic control is when trees are used to extract large quantities of groundwater. For example, poplar trees have been used to keep toxic herbicides, pesticides, and fertilizers out of streams and groundwater (CPEO 2009).

The EPA considers bioremediation to be a presumptive remedy for treating soils that contain SVOCs like diesel and cPAHs (EPA 1995a).

Monitored Natural Attenuation

Natural attenuation is the process by which naturally occurring processes degrade or immobilize both organic and inorganic contamination in soil and groundwater (EPA 1996i). The EPA considers natural attenuation to be an acceptable method of treatment if there is a high degree of certainty that the contaminants will degrade before they migrate to a sensitive receptor. Typically, natural attenuation is accompanied by source area treatment or removal. Biodegradation is the preferred treatment mechanism but adsorption, precipitation, dispersion, dilution, transformation, and volatilization are also acceptable alternatives (Brown et al. 1999). Microorganisms are most effective at degrading low to moderate concentrations of contaminants (EPA 1999b). This process is non-invasive and allows the site to continue productive use during cleanup. This method also requires careful study of site conditions and monitoring of contaminant levels (EPA 1996i; Renner 1998).

Monitored Natural Attenuation has been a component of remedies for sites contaminated with most VOCs, SVOCs, and PCBs. It has been more typically applied to sites contaminated with TPH and chlorinated VOCs as these types of compounds are more readily biodegraded by soil microorganisms (CPEO 2009).

Soil Vapor Extraction (SVE)

Soil vapor extraction (SVE) is a process that extracts contaminants from the soil in vapor form. The process involves applying a vacuum through a system of underground wells to enhance volatilization and pull COC vapors to the surface. SVE systems are designed to remove contaminants that volatilize or evaporate easily. SVE is the most frequently selected treatment for VOCs at Superfund sites (EPA 1996e). SVE can be used to remove VOCs and SVOCs from unsaturated soil (FRTR 1998). SVE is considered to be one of the most cost-effective remediation processes for soil contaminated with gasoline, solvents, or other VOCs (Johnson et al. 1990).

In fact, SVE is the preferred presumptive remedy for sites with VOCs present in soil where treatment is necessary (EPA 1993b and 1996a). The EPA Office of Solid Waste and Emergency Response (OSWER) Directive 9355.0-63FS provides a checklist to guide the selection of SVE as a preferred alternative at sites where VOC contaminants are present in soil.

Dual Vacuum Extraction (DVE)

Dual vacuum extraction (DVE) simultaneously extracts both soil vapors and groundwater from the subsurface via groundwater wells. This process effectively combines the use of SVE technology with groundwater extraction to lower the groundwater table and to expose the capillary fringe and smear zone to treatment (Roy 1991). This technology can be used over a wide range of permeabilities if groundwater treatment and disposal can be accomplished cost effectively (Piniewski et al. 1992). This technology provides a rapid and cost-effective treatment method that can be used to remediate the vadose zone, capillary fringe, smear zone, and existing water table impacted by VOCs (Trowbridge and Ott 1991).

Multi-phase extraction technology (MPE) is another term for DVE technology. However, MPE refers to removal of three phases: soil vapor, groundwater, and non-aqueous phase liquid (NAPL). MPE and DVE have been identified as preferred presumptive remedies for sites where VOCs are present in soil and groundwater and treatment is warranted (EPA 1997b). The EPA OSWER Directive 9355.0-68FS provides a checklist to guide the selection of MPE and DVE as preferred alternatives for sites with contaminated soil and groundwater.

Air Sparging

Air sparging is a technology in which air is bubbled through a contaminated aquifer. Air bubbles traverse horizontally and vertically through the soil column, creating an underground stripper that removes contaminants by volatilization. These air bubbles carry the contaminants to a vapor extraction system. Vapor extraction is implemented in conjunction with air sparging to remove the generated vapor-phase contamination. This technology is designed to operate at high flow rates to maintain increased contact between groundwater and soil and strip groundwater by sparging (FRTR 1994). This technology is mainly applicable for VOCs.

Steam Injection

Steam injection is the process by which steam is injected into areas of contamination to volatilize and mobilize the target substances. This process has been used in conjunction with other treatment methods such as SVE and bioremediation (EPA 1995f). Steam injection can be used to recover VOCs and SVOCs in both the liquid and vapor phase. However, injecting steam typically creates areas of residual water saturation. Contaminants with a significant solubility in water may remain at high concentrations in this residual water (EPA 1997a).

Soil Heating

Soil heating or *in situ* thermal treatment is a technology that is used to remove contaminants from soil and groundwater by selectively heating soil and increasing the rate of volatilization and the release of contaminants. Radio frequency (RF) and electrical resistance (alternating current [AC]) heating are effective in expelling organic contaminants from soil in zones rich in clay and with low permeability. The electrical properties of the clay zones have been shown to preferentially capture the RF or AC energy at temperatures greater than or equal to 100°C. This technology is self-limiting because the electrical current will stop flowing as the clay heats and dries (EPA 1995f). This technology has been used to treat VOCs, SVOCs and pesticides. It is typically used in conjunction with SVE technology.

Soil Flushing

Soil flushing is an *in situ* process that floods contaminated soil with a solution that moves the contaminants to an area from which they are removed. The flushing solution can be composed of water or water with additives such as acids, bases, or surfactants (EPA 1995d). The process requires the addition of injection and extraction wells in the contaminated area. This technology is most effective on soil with low silt or clay content where the flow of groundwater is well documented. Contaminants considered amenable to treatment by *in situ* soil flushing include heavy metals, halogenated solvents, aromatics, gasoline and fuel oils, PCBs and chlorinated phenols (EPA 1996c). *In situ* flushing enhances conventional pump and treat technologies by increasing the efficiency of moving groundwater through soil pore spaces, or by accelerating the flushing rate over that of the natural rate (Roote 1997).

Fracturing

Fracturing extends existing fractures and creates a secondary network of fissures and channels. These channels increase the permeability of the subsurface media to liquids and vapors, thus increasing the effectiveness of vapor extraction, biodegradation, and thermal treatment (EPA 1995e). This process is effective for sites where the ground formation is relatively impermeable to airflow. It can be used to increase the radius of influence for a given number of wells and to decrease the time required to remediate a site (EPA 1993a). Technologies commonly used for fracturing are pneumatic fracturing, blast-enhanced fracturing, and Lasagna^{TM} process (FRTR 2009c).

Chemical Treatment

Chemicals can be used to treat soil and groundwater. Chemicals are typically added to oxidize, reduce, or adjust the pH. For soil, chemical treatment technology involves the use of chemical oxidation. *In situ* chemical oxidation delivers chemical oxidants that destroy the contaminants by converting them to innocuous compounds that are commonly found in nature. Hydrogen peroxide (H_20_2), potassium permanganate ($KMn0_4$), ozone (O_3), and dissolved oxygen (O_2) are typical oxidants that are used during this treatment process. The most common field applications use hydrogen peroxide and an iron catalyst to create a hydroxyl free radical called Fenton's Reagent. This hydroxyl free radical is able to oxidize complex organic compounds. *In situ* chemical oxidation is used to treat groundwater and soil for VOCs, SVOCs, PAHs, and PCBs (EPA 1998c). Since this process generates heat which enhances the vaporization of VOCs, it is more effective when coupled with SVE or DVE; a process known "as OxyVac. In addition, hydrogen peroxide can also be a source of oxygen for biodegradation (Yen and Novak 1995).

Chemical applications also are used to control the subsurface environment. Acids or bases can be added to the subsurface to maintain the pH during chemical oxidation treatment. The proper addition of chemicals can adjust the pH to the level where components can be precipitated and removed. This process is a proven technique for removing heavy metals from wastewater (EPA 1997f). In addition, chemicals can also be added to the subsurface to facilitate the co-metabolic degradation by microorganisms (McCarty et al 1998).

Electrokinetic Treatment

Electrokinetic treatment is an *in situ* process involving application of low intensity direct electrical current across electrode pairs implanted in the ground on each side of a contaminated area of soil, causing electro-osmosis, and ion migration. Contaminants migrate toward respective electrodes depending upon their charge. The process may be enhanced through use of surfactants or reagents to increase contaminant removal rates at the electrodes. The process separates and extracts heavy metals, radionuclides, and organic contaminants from saturated or unsaturated soils, sludges, and sediments. The process is especially unique because of its ability to work in low permeability soils as well as high permeability soils. It is applicable to a broad range of organic and inorganic contaminants.

A.3 EXCAVATION AND ON-SITE TREATMENT TECHNOLOGIES

A number of excavation and on-property treatment technologies have been applied to treat VOCs, SVOCs, and PCBs in soil including mechanical screening, bioremediation, SVE, soil flushing (also called soil washing), solvent extraction, dehalogenation, chemical treatment, thermal desorption, and soil heating and incineration technologies. Some of these technologies (i.e., SVE, soil flushing and chemical treatment) are discussed in Section A.2. Bench scale testing would likely be required for the on-site treatment technologies described in this Section to determine if the treated soil can be reused on site or would require off-site disposal. A brief description of the technologies that are not previously described in Section A.2 follows.

Mechanical Screening

Screening technologies use devices to remove coarse solids from soil and groundwater. Screens can be composed of parallel bars, rods or wires, grating, wire mesh, or perforated plates. Screening has been employed numerous times at Kaiser during the processing of contaminated soil in order to remove large cobbles/gravels that typically make up to 30 percent of the site soil (Hart Crowser 2008a). Past screening operations have typically employed a 2-inch screen at Kaiser.

Ex Situ Bioremediation

Ex situ techniques can be faster; easier to control, and used to treat a wider range of contaminants in soil and potentially groundwater than *in situ* techniques. However, they require excavation and treatment of soil before and sometimes after the actual bioremediation step. *Ex situ* bioremediation techniques for soil include slurry-phase and solid phase bioremediation (EPA 1996d).

In slurry-phase bioremediation, contaminated soil is mixed with water and additives in a large tank and mixed to keep microorganisms naturally present in the soil in contact with the contaminants. Nutrients and oxygen can be added to create optimum conditions for degrading the contaminants. After treatment, the water and soil are treated and disposed of. Slurry-phase treatment is fairly rapid.

Solid-phase bioremediation treats soil in aboveground treatment areas equipped with collection systems to prevent contaminants from escaping the treatment. Moisture, heat, nutrients, and oxygen are controlled to optimize conditions for contaminant destruction. Solid-phase treatment requires a lot of space and cleanup requires more time to complete than slurry-phase treatment. Solid-phase process options include landfarming, soil biopiles, and composting.

Both landfarming and biopiles can incorporate liners and leachate collection into the design. The management and optimization of moisture, heat, pH, and nutrients are similar between the two technologies. Contaminated media in landfarming is usually treated in lifts up to 18 inches thick, where biopiles can be up to 20 feet high. Landfarming relies on aeration by the tilling of the soil while biopiles commonly have an air distribution system buried under the soil and use a vacuum or positive pressure to aerate the piles. The operation and maintenance associated with the aeration system for biopiles is more intensive than landfarming (FRTR 2009a).

The EPA considers bioremediation to be a presumptive remedy for treating soils that contain SVOCs like diesel and cPAHs (EPA 1995a)

Solvent Extraction

One method for decontaminating soils is to use the solvent extraction technique. In solvent extraction, an organic solvent is used to remove contaminants such as PCBs and PAHs. This is a non-destructive process. The contaminants are simply concentrated in a form that is separated from the solids.

The Basic Extractive Sludge Treatment (B.E.S.T. ®) process is a technology which extracts and concentrates contaminants such as PCBs and PAHs. The process renders the influent water and soil "clean" and produces a concentrated waste for disposal.

One of the keys of the B.E.S.T.® process is the use of triethylamine as the solvent. The solubility of triethylamine in water is inversely related to temperature. At temperatures around 33°F, triethylamine is almost completely soluble. When the temperature of triethylamine exceeds 130°F the solvent is not soluble and separates from the solution.

The B.E.S.T. ® process takes advantage of this characteristic to extract the contaminants. First, a cold triethylamine-water solution is mixed with contaminated soil to extract the contaminants. Next, the soil and triethylamine-water solution are heated above the solubility limit. The phases separate and nearly all the contaminants are dissolved in the triethylamine, which has separated from the water and the solids. The triethylamine solution is then treated to recover and recycle almost all of the triethylamine and produce a concentrated waste that must be disposed of (EPA 1992).

Dehalogenation

Chemical dehalogenation removes halogens such as chlorine, bromine, iodine, and fluorine from a chemical contaminant, rendering it less hazardous. Chemical dehalogenation is typically achieved through either glycolate dehalogenation or the base-catalyzed decomposition process (BCD). Note that the glycolate process uses alkaline polyethylene glycol (APEG) as a reagent. These processes involve heating and physically mixing the contaminated soil with chemical reagents. Chemical dehalogenation typically treats halogenated aromatic organic contaminants such as PCBs and dioxins. Vapors resulting from the heating process are separated into water and gaseous contaminants by a condenser and the gases are filtered through activated carbon. This technology is limited by high clay or water content, acidity, or high natural organic content of the soil. Because this technology requires soil excavation, there must be sufficient open space at the site to accommodate excavation equipment and the materials that are excavated (EPA 1996b; FRTR 2009c; EPA 2001).

High Temperature Thermal Desorption

High temperature thermal desorption (HTTD) is a commonly used separation process. Contaminated soil, sludge, or other waste is heated from 320° to 560°C so that SVOCs, PAHs, and PCBs are driven off as gases. This process uses heat to separate organics from the soil matrix and allow the volatilized contaminants to be captured or treated by air pollution control equipment. The thermal desorption process is a physical separation technology, not a destruction technology. This process may result in the partial breakdown of compounds and the formation of new compounds. Thermal desorption works best for soil with a high proportion of sand and gravel (Blanchard and Stamnes 1997; EPA 1995b).

The EPA considers high temperature thermal desorption to be a presumptive remedy for the treatment of soils containing SVOCs (EPA 1995a).

Low Temperature Thermal Desorption

Low temperature thermal desorption (LTTD) is a separation process where contaminated soil, sludge, or other waste is heated from 90° to 320°C so that VOCs and hydrocarbon fuels are driven off as gases. LTTD can be used to treat SVOCs at reduced effectiveness (FRTR 2009a). This process uses heat to separate organics from the soil matrix and allow the volatilized contaminants to be captured or treated by air pollution control equipment. The thermal desorption process is a physical separation technology, not a destruction technology. This process may result in the partial breakdown of compounds and the formation of new compounds. Thermal desorption works best for soil with a high proportion of sand and gravel (Blanchard and Stamnes 1997; EPA 1995b).

The EPA considers low temperature thermal desorption to be a presumptive remedy for the treatment of soils containing VOCs (EPA 1993b)

Pyrolysis

In pyrolysis, organic materials are heated and destroyed without the use of oxygen. Pyrolysis typically occurs under pressure and at operating temperatures above 430°C (800°F). By-products of the process include coke and gases such as carbon monoxide, hydrogen, methane, and other hydrocarbons. The pyrolysis gases require further treatment. The off-gases may be treated in a secondary combustion chamber, flared, and partially condensed. Particulate removal equipment such as fabric filters or wet scrubbers are also required. The target contaminants are SVOCs and pesticides (FRTR 2009c).

Incineration

Incineration technology uses controlled flame combustion to volatilize and destroy organic contaminants. Typically, this process involves the use of a burner and combustion chamber to ignite the supplied fuel and combustibles. Incineration can be used to treat soil, sludges, liquids, or gases. The efficiency of this process is determined by the temperature of the combustion chamber, the residence time of the waste material in the chamber, and the turbulent mixing of the material. Sufficient destruction of organic compounds is typically achieved at temperatures between 1,100°F and 1,200°F, and a residence time of 30 to 90 minutes for solid waste. The off-gas from this treatment technology is routed through an air pollution control system (EPA 1998a and EPA 1995g).

The EPA considers incineration to be a presumptive remedy for the treatment of soils containing SVOCs (EPA 1995a) and VOCs (EPA 1993b).

Solvated Electron Treatment (SET)

Solvated electron treatment mixes excavated soil with liquid ammonia in a sealed vessel. Alkaline earth metals such as calcium or sodium are added to the mixture. The combination of ammonia and this type of metal forms free electrons that act as a reducing agent and remove chlorine from organic molecules. After the reaction is complete the soil can go through separation processes to recover and reuse the ammonia. If necessary, soils may need to go through drying pretreatment since ammonia reacts quickly with water, preventing the formation of free electrons. The SET process uses highly reactive compounds and is a highly exothermic process so health, safety, and environment concerns must be properly addressed (CPEO 2009). The SET process has been tested for treating soil contaminated with VOCs, SVOCs, and PCBs (CPEO 2009).

A.4 ON-SITE TREATMENT OF EXTRACTED SOIL VAPOR

Many of the treatment technologies described above are designed to force VOCs from both saturated and unsaturated soils into the vapor phase, followed by the extraction of the vapor. The extracted vapor typically needs to be treated to remove or detoxify the VOCs before the vapor is released to the atmosphere. Condensation, adsorption, thermal oxidation, catalytic oxidation, advanced oxidation, and biofiltration technologies have been used for the treatment of extracted soil vapor. A brief description of the technologies follows.

Condensation

Condensation is a simple vapor-liquid equilibrium process that removes contaminants from extracted soil vapor. This method is typically not used for organic vapors because of the low temperatures needed to condense organic vapors when their concentrations are less than several thousand parts per million (EPA 1995g).

Adsorption

Adsorption is the accumulation of matter at the solute and solid interface (Stumm and Morgan 1996). Substances adsorb when there are forces that attract them from solution to the solid surface (Montgomery 1995). Extracted soil vapor or groundwater is typically treated by adsorption through the use of activated carbon (EPA 1995g). Activated carbon is used to capture chemical molecules within its porous structure while effluent liquid or vapor streams flow through it. Carbon is commonly used as an adsorbent because of its economic feasibility, its extremely high surface area to volume ratio, and its ability to adsorb a wide variety of organic compounds. Carbon adsorption systems are best suited for short-term, low mass flow rate sites (Los Alamos National Laboratory 1996).

Thermal Oxidation

Thermal oxidizers destroy organic vapors by heating them to a high temperature where they are burned in the presence of oxygen to form carbon dioxide and water. Incineration of halogenated VOCs or compounds containing sulfur may require additional control equipment (such as caustic scrubbers) to remove corrosive combustion products (EPA 1997f and 1995g). This technology becomes cost-effective at flow rates greater than approximately 500 cubic feet per minute (cfm) and concentrations greater than approximately 700 parts per million (ppm) (Los Alamos National Laboratory 1996).

Catalytic Oxidation

Catalytic oxidizers operate in a similar manner to thermal oxidizers, but the gas passes through a catalyst bed. The catalyst has the effect of increasing the oxidation reaction rate and enabling conversion at lower reaction temperatures than in thermal incinerator units. Catalysts also allow for smaller incinerator size. Catalysts used for VOC incineration include platinum and palladium. Metal oxides are typically used for gas streams containing chlorinated compounds (EPA 1995g). Catalytic oxidizers are generally less expensive than thermal oxidizers because of their lower capital and operating requirements. This technology becomes cost-effective at flow rates greater than approximately 500 cfm and with contaminant concentrations greater than approximately 700 ppm (Los Alamos National Laboratory 1996).

Advanced Oxidation

Oxidation of organic contaminants in air or water can be achieved by breaking the chemical bonds in the contaminants under the influence of ozone, a peroxide, or UV light. For a process air stream, the products of photo-degradation vary according to the matrix in which the process occurs, but complete conversion of an organic contaminant to CO_2 , H_2O, etc., is not probable (FRTR 2009a).

Extracted water can be treated by oxidation using ozone, peroxide, or ultraviolet (UV) radiation. Ozone can be used for odor control, the removal of organics, and disinfection. The free radicals formed from ozone (HO_2 and HO) have strong oxidizing properties and reaction abilities. Dissolved oxygen concentrations are found to increase with the addition of ozone (Metcalf & Eddy 2003).

Hydrogen peroxide (H_20_2) can be used with an iron catalyst to create a hydroxyl free radical called Fenton's Reagent. This hydroxyl free radical is able to oxidize complex organic compounds. Hydrogen peroxide can be used to treat VOCs, SVOCs, PAHs, and PCBs (EPA 1998c).

UV radiation has been used as a wastewater disinfectant for many years. Low-pressure mercury arc lamps are used to emit UV light. Radiation with a wavelength of approximately 254 nanometers penetrates the cell wall of a microorganism, causing cell death or preventing replication. In addition, environmental compounds can be broken down into more innocuous forms. Limitations of this process occur because the UV light is unable to pass through large distances and turbidity (Metcalf & Eddy 1991).

The presence of dissolved iron in groundwater can interfere with these technologies. *In situ* treatment by chemical oxidation is discussed in Section A.2.

Biofiltration

Industry has used biofiltration for VOC and odor control for a number of years. These industries include the wood products industry, the flavor and fragrance industry, and a number of different solvent-using industries, such as the film processing and screen printing industries. Biofiltration is an air pollution control technology in which VOCs are oxidized into carbon dioxide and water using micro-organisms. Process air is passed through a pre-treatment humidifier to saturate the gas stream before it enters the biofilter. The humidified air then flows through the biofilter where the VOCs are absorbed into an aqueous layer surrounding the filter material. The microorganisms contained in the filter material use the VOCs as their primary carbon source and convert the VOCs to CO_2 and water. This technology has been used for a range of VOCs and SVOCs, though it has been shown to be less effective for halogenated VOCs and SVOCs (CPEO 2009).

A.5 EXCAVATION AND OFF-SITE TREATMENT/DISPOSAL

Three remedial technologies were considered for the excavation and offsite treatment/disposal of soils. The technologies considered included the off-site disposal of excavated soils at an RCRA-permitted landfill (Subtitle C) or solid waste (industrial) landfill (Subtitle D), the off-site incineration of excavated soil, and the off-site treatment of excavated soil at a recycle and re-use facility. Use of a particular off-site treatment technology for Kaiser soil would be contaminant and concentration dependent.

APPENDIX B
DESCRIPTION OF AREAS OF CONCERN FOR NEAR-SURFACE SOILS

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APPENDIX B
DESCRIPTION OF AREAS OF CONCERN FOR NEAR-SURFACE SOILS

B.1 AREAS OF CONCERN FOR NEAR-SURFACE SOILS CONTAMINATED WITH VOCS

There are five sites that are areas of concern (AOC) for VOCs in the near-surface soil zone. These AOCs are located in the following general operating areas of the site (refer to Table 2-18):

- ORB Area (Man-Made Depressions, G1 Transfer Line, and near the ORB)
- Oil House Area (20,000 Gallon Leaded Gasoline UST), and
- Truck Shop Area

The following subsections describe the AOCs for VOCs, and discuss the apparent sources for each VOC. More comprehensive descriptions of all AOCs examined in this FSTM are provided in the Final Soil RI (Hart Crowser 2012b).

Table 2-18 provides a rough order of magnitude (ROM) estimate of quantities of impacted soil and mass of COCs in each AOC for VOCs. Figures 2-3a, 2-3d, 2-6a, and 2-8 show the AOCs across the site, for VOCs. Table B-1 provides the calculation approach and assumptions used to estimate the soil volumes and mass of COCs in each AOC.

ORB AOCs for VOCs

Man-Made Depressions

The Man-Made Depressions area is located on the west-central area of the Facility (Figure 2-1). The development and historical uses of the depressions are unknown. The three depressions include two larger depressions (East and West) and a smaller depression (Small Depression). The depressions are currently filled with a sandy gravel material and surface expressions are not evident. The source of the COCs in this area are unknown but is likely due to past disposal operations. The site consists of bare ground and is currently used as an active contractor staging area for laydown of equipment.

Remedial investigative activities included borings, test pits, and soil gas sampling. A majority of these activities were a part of the 1996 subsurface soil investigation of the ORB and Man-Made Depressions when 10 test pits and 28 hollow-stem auger borings were completed. Borings (B-12 through B-15 and B-18 through B-27) were located in and around the depressions (Figure 2-3a).

Stoddard solvent was detected in the upper six feet of soil in sample 05ORTP-6, and the field duplicate for this sample 05ORTP-100, collected from a test pit excavated in the small depression. For evaluation of these VOCs the higher of the two concentrations from the original sample and the field duplicate was used. Soil sample 05ORTP-6 analytical results indicate that this area also exceeded SLs for heavy oil-range hydrocarbons and cPAHs. The mass of these SVOC COCs is discussed in more detail in section B.2 below.

The estimated boundary of this AOC is depicted on Figure 2-3a and its area is approximately 450 square feet. Sample 05ORTP-6 was collected from the test pit in the 5 to 5.5 foot interval. Deeper soil samples were not collected from this area. Without soil data below this level, the quantity estimate contained in Table B-1 and Table 2.18 assumed, as the most conservative estimate, that the entire top twenty feet of soil in this AOC is impacted with VOCs at the levels represented by soil sample 05ORTP-6. The upper twenty feet of soil in this area equates to a soil volume of approximately 330 cubic yards. The estimated mass of VOCs in this area is approximately 300 pounds of Stoddard solvent.

ORB Area

The ORB houses a partially buried concrete pit divided into nine sections/tanks. Historically, the function of the ORB was to collect, settle and process oil and oily emulsions from plant processes for recycling and partial removal of oils. During this time, contents of the tanks would occasionally overflow onto surrounding soils. This practice is assumed to be the source of VOC, diesel and heavy oil contamination in the ORB area.

The 1996 initial subsurface investigation was conducted to evaluate the nature and extent of oily wastewater releases from the ORB (Hart Crowser 1997). In total, 96 soil samples were collected from 10 test pits (96ORTP-1 through 96ORTP-9 and TP-OR1) and 16 soil borings (B-1 through B-13, B-15 through B-17) advanced around the ORB (Figure 2-3d). Test pit depths ranged from 3 to 8.5 feet bgs and the soil borings were completed to depths between 11.5 and 24 feet bgs.

Additional investigations of the ORB were conducted in 2004 and 2005 to provide information for the design and installation of a new loading and unloading pad at the southern end of the ORB. The investigation work included excavation and stockpiling of about 900 cubic yards of soil from around the location of the new ORB pad, collection of nine soil verification samples on the bottom and side walls of the excavation, installation of soil boring OR-SB-31, and installation and sampling and analysis of groundwater monitoring wells HL-MW-20S and HL-MW-19S (Hart Crowser 2005b). The locations of the boring and monitoring wells are shown on Figure 2-3d.

After soil excavation in the vicinity of the loading/unloading pad was completed to a depth of about 19 feet bgs, nine soil verification samples (S-1 through S-9) were collected from the bottom and side walls of the excavation in January 2005. The nine soil verification samples were analyzed for TPH (NWTPH-HCID) and selected samples were analyzed for NWTPH-Gx, BTEX, PCBs, PAHs, and metals (Hart Crowser 2012b).

Samples S-3 and S-8 had screening level exceedances for gasoline-range hydrocarbons. The vertical extent of contamination was assumed to start at ground surface and extend to 20 feet bgs. The shallowest sample collected in the area (S-3 at 3 feet bgs) was not tested for VOCs, so it was conservatively assumed to exceed SL from the ground surface. The estimated area of concern is 440 square feet and the volume of impacted soil is about 325 cubic yards. The mass of COCs in this area is approximately 220 pounds of gasoline-range hydrocarbons.

G1 Transfer Line

The G1 Transfer Line was a wastewater line between the ORB and IWT. The line was first encountered during excavation and removal of the G3 Transfer Line in 2006. This system had two lines coming from the ORB, which met to form a single line about 100 feet west of the ORB (Figure 2-3c). During this time, the G1 transfer line was also removed where possible. The line was inspected for leaks. A release, resulting from a crack, was observed at the welded joint where both lines met after the G1 Transfer line exited the ORB.

One soil sample Location #1 (G-1) was collected from the pipe bedding material beneath the release point and at the approximate bottom of the pipe (depth of 3 to 8 feet bgs). This sample exceeded SLs for Stoddard solvent.

The area of impact assumed to be associated with sample Location #1 (G-1) is presented on Figure 2-3d and is approximately 960 square feet in size. Based on existing sampling results, the depth of elevated concentrations could not be determined so it was conservatively assumed that impacted soils extend from ground surface to 20 feet bgs, and may also be present below 20 feet. The 20 feet of impacted soil in this AOC equates to a soil volume of approximately 710 cubic yards. Assuming impacted soil in this area is equal to gasoline-hydrocarbon concentration of sample Location #1 (G-1) the approximate mass of gasoline-range hydrocarbons (Stoddard solvent/mineral spirits) is approximately 700 pounds.

Oil House AOCs for VOCs

In the past, there were several UST systems containing volatile hydrocarbons including gasoline and Stoddard solvent located at the Kaiser facility. These systems included a 20,000-gallon tank containing leaded gasoline, two 10,000-gallon tanks containing Stoddard solvent, and a 1,000-gallon gasoline tank. All were located in the Oil House area. All four of these tanks were removed in the early 1990s.

Of the four tanks in the Oil House area, only the 20,000-gallon gasoline UST showed signs of a release from the tank system during decommissioning. Soil sample GT-D, collected below the fuel dispenser at a depth of 18 feet bgs exceeded the SLs for gasoline. No other shallow soil samples collected throughout the Oil House area exceeded SLs for VOCs.

Following removal of the 20,000-gallon gasoline UST and collection of verification samples in 1991, the area was backfilled with clean fill and capped with asphalt. The estimated boundary of this AOC is depicted on Figure 2-6a and is approximately 205 square feet in area. In examining the upper 20 foot soil horizon it is assumed that only the 18- to 20-foot horizon is impacted, because the soil overlying this impacted zone is clean backfill. The 2 feet of impacted soil in this AOC equates to a soil volume of approximately 15 cubic yards.

Excavating in this area to reach the contamination at 18 feet would require the removal of approximately 140 cubic yards of clean backfill. This volume does not account for sloped excavation side walls, which would be necessary to reach impacted soil at this depth and would result in a total volume of soil several times the estimated 140 cubic yards necessary to reach the impacted soil. Assuming that the 2 feet of soil in the 18- to 20-foot soil horizon in this area is at equal concentration with GT-D (1700 mg/kg), the approximate mass of COCs in this area is approximately 70 pounds of gasoline-range hydrocarbons.

It is likely that the contamination associated with the 20,000-gallon gasoline UST is no longer present in the near-surface soil at the levels detected in 1991. Soil boring GUST-SB2 was advanced in the vicinity of the fuel dispenser in 2008 (Hart Crowser 2012b). Levels of petroleum hydrocarbons and BTEX compounds were either non-detect or well below screening levels in samples GUST-SB2-S1 and GUST-SB2-S2 collected at 30 and 51 feet bgs, respectively.

Truck Shop AOCs for VOCs

Near-surface soil in the Truck Shop area is impacted with Stoddard solvent which likely originated from the Truck Shop tank. The tank is an approximately 2,000-gallon concrete septic-type tank with access through a manhole at the surface. The bottom of the tank is estimated to be at approximately 13 feet bgs. During an inspection and cleaning of the tank in 2005, cracks were observed near the bottom of the east wall of the tank (Figure 2-8). Following the 2005 inspection, the tank was taken out of service but remains in place.

The function of the tank was to accumulate and hold wastewater, oil, and cleaning-related material from the Truck Shop area. The tank system was designed to pump fluid using a float-controlled pump, from the Truck Shop area to the ORB. The source of Stoddard solvent in the Truck Shop area soil is likely related to past use of the solvent to clean parts and equipment. Samples of the sludge in the tank collected prior to the 2005 cleaning had Stoddard solvent concentrations as high as 14,000 mg/kg.

During the subsequent investigation of the Truck Shop area, approximately 2.2 cubic yards of soil was removed from the area above the tank. The small excavation was backfilled with clean fill prior to the installation of TS-MW-1, located due south of the tank.

One soil sample (TS-MW-1S/S-3) collected at 15 feet bgs during the installation of TS-MW-1 exceeded the SL for Stoddard solvent with a concentration of 700 mg/kg. No other soil samples collected in the Truck Shop area during the 2005 investigation exceeded SLs for VOCs. Given that the depth of this sample is below the base of the tank, it is assumed that impacts to the soil occurred via the cracks in the base of the tank.

The estimated boundary of this AOC is depicted on Figure 2-8 and is approximately 860 square feet in size. Note that following the criteria of going half the distance to a clean sample places a large portion of this AOC under existing buildings. In examining the upper 20-foot soil horizon in this AOC it is assumed that only the 13- (corresponding to the bottom of the tank) to 20-foot horizon is impacted by past Stoddard solvent releases. The seven feet of impacted soil in this AOC equates to a soil volume of approximately 220 cubic yards.

Excavating in this area to reach the contamination at 13 feet would require the removal of the tank and approximately 400 cubic yards of overburden. This volume does not account for sloped excavation side walls, which would be necessary to reach impacted soil at this depth. Assuming that the 7 feet of impacted soil in the 13- to 20-foot soil horizon in this area is at a concentration of 700 mg/kg (TS-MW-1S/S-3), the approximate mass of Stoddard solvent in this area is 440 pounds.

B.2 AREAS OF CONCERN FOR NEAR-SURFACE SOILS CONTAMINATED WITH SVOCS

SVOCs are considered to include cPAHs and TPH in the diesel- and heavy oil-ranges for the purposes of this FSTM. TPH in the diesel- and heavy oil-ranges are the most pervasive COCs on this site (refer to Table 2-18), contributing more than 95 percent of the COC loading at the site. As such, 23 of the 41 AOCs examined in the FSTM are identified as AOCs for SVOCs in the near-surface soil. These 23 AOCs are found in each of the nine general operating areas of the site. The following subsections describe the AOCs for SVOCs and provide background information on SVOC COCs and their apparent sources. More comprehensive descriptions of all AOCs examined in the FSTM are provided in the Final Soil RI (Hart Crowser 2012b).

Table 2-18 provides the quantities of impacted soil and mass of COCs in each AOC for SVOCs. Figures 2-3 through 2-10 depict the AOCs across the site for SVOCs. Table B-1 includes the calculations used to arrive at the estimates of soil volumes and mass of COCs estimated in this Section.

ORB AOCs for SVOCs

Man-Made Depressions

As described in Section B.1 the Man-Made Depressions are located in the west-central area of the Facility (Figure 2-3a). The nature and historical uses of the depressions are unknown. The three depressions included two larger depressions (East and West) and a smaller depression (Small Depression).

There are individual areas of concern associated with cPAHs, diesel-, and heavy oil-range hydrocarbons in the Man-Made Depressions. These areas were determined by exploration borings and test pits that were part of the 1996 subsurface soil investigation of the ORB and Man-Made Depressions when 10 test pits and 28 hollow-stem auger borings were completed. Borings (B-12 through B-15 and B-18 through B-27) were located in and around the depressions (Figure 2-3a).

In the West Depression, diesel- and heavy-oil impacts were found in samples collected from borings B-22 and B-25. Analytical results from soil boring B-22 indicate diesel-range petroleum hydrocarbons exceeding SLs in the 2.5- to 4-foot sample at 5,000 mg/kg. From 5 to 14.5 feet bgs, diesel-range hydrocarbon concentrations range from 430 to 1,800 mg/kg. Between 2.5 feet and the total depth of the boring at 14 feet, heavy oil-range petroleum hydrocarbons at concentrations between 3,100 and 14,000 mg/kg are present.

The soil sample analytical results from boring B-25 between 10 feet and the total depth of the boring at 69 feet indicate heavy oil-range petroleum hydrocarbons at concentrations between 1,300 and 8,800 mg/kg. Diesel-range petroleum hydrocarbons range from 180 mg/kg to exceeding SLs in the 67.5- to 69-foot depth range, at 4,900 mg/kg. Based on the proximity of these borings to each other and laboratory results it was assumed that the AOC includes both borings. The diesel AOC extends to 4.5 feet bgs while the heavy oil AOC includes the entire shallow soil horizon (upper 20 feet) and may extend further.

The estimated boundary of this AOC is depicted on Figure 2-3a and is approximately 1,220 square feet in size. The volume of diesel-impacted soil is approximately 205 cubic yards and the volume of heavy oil-impacted soil is approximately 905 cubic yards. The mass of diesel is 2,900 pounds and is based on the concentration of B-22/S-1 (5,000mg/kg), the sample with the only diesel screening level exceedance in the AOC in the shallow-soil horizon. The mass of heavy oil is 19,000 pounds based on the average concentration contained in samples from borings B-22 and B-25 in the upper 20 feet.

There is an AOC for heavy oil situated across the East and Small Depressions. This area was estimated based on exceedances in sample 05ORTP-6 and boring B-14. Analytical results from soil boring B-14 indicate heavy oil-range petroleum hydrocarbons exceeding SLs in the 5- to 6.5-foot sample at 9,100 mg/kg. The concentration of heavy oil in test pit sample 05ORTP-6 is 5,000 mg/kg. The test pit sample was collected from 5 to 5.5 feet bgs. Due to the proximity of the samples, depth of contamination and similarity of the COCs, it was assumed that these samples were in the same AOC. The total area of this AOC is estimated to be 1,920 square feet. Based on available information, it was assumed the upper 7 feet of this AOC was impacted which equates to a soil volume of approximately 500 cubic yards. The depth of contamination was assumed to extend to 7 feet based on boring B-14. The estimated mass of heavy oil is 10,000 pounds in this AOC.

In the west depression there is a diesel area of concern based on the screening level exceedance of sample B-14/S-2. The concentration of this sample is 5,700 mg/kg. The lateral extent is localized around B-14 and is based on diesel concentrations and field observations of surrounding samples. The square footage of this area is approximately equal to 1,095 square feet. The vertical extent is 7 feet based on boring B-14. The calculated mass of diesel is 4,500 pounds in 284 cubic yards.

There is also an AOC around sample 05ORTP-6 associated with cPAHs. The total area of this AOC is approximately 450 square feet. The sample was collected 5 to 5.5 feet bgs. There were no other samples collected below this location so it was assumed the vertical extent started at ground surface and extended to 20 bgs. Based on concentrations in sample 05ORTP-100 (the field duplicate of the 05ORTP-6) the mass of cPAHs, using the TEQ Equivalent, is estimated to be approximately one pound.

G2 Transfer Lines

The source of contamination for the G2 Transfer Line was a leak in the line in 1998 when it was still in operation. To determine the nature and extent of the oily emulsion release, an extensive investigation was conducted near the leaking elbow between November 1998 and January 1999 (Hart Crowser 2000). In total, 21 soil borings (WW-TL-SB-1 through WW-TL-SB-5, WW-TL-SB-7 through WW-TL-SB-20, WW-TL-SB-6-1, and WW-TL-SB-6-2) were advanced in the vicinity of the G2 Transfer Lines (Figure 2-3c). Up to three soil samples from each boring were submitted for analysis of TPH (NWTPH-HCID). To evaluate deeper soil and groundwater in this area, in January 1999, a boring (WW-TL-MW-1) was advanced to a depth of 91.5 feet bgs and completed as a monitoring well. Groundwater was encountered at a depth of 73 feet at the time of drilling. Five soil samples were collected between depths of 20 to 66.5 feet bgs and submitted for analysis of TPH (Hart Crowser 2012b, Table 2-7). Petroleum hydrocarbon concentrations from these five samples were below screening levels.

These data indicate that TPH concentrations above screening levels from the oily emulsion release attenuated within the top 18 feet of soil and did not reach the water table. However, although petroleum contamination was not observed in unsaturated soils located just above the water table in boring WW-TL-MW-1 (Hart Crowser 2012b, Table 2-7), a petroleum smear zone was visually identified at the water table. This smear zone is likely associated with historical releases upgradient of the area, rather than the transfer line leak.

In October 1999, and after decommissioning WW-TL-MW-1, Kaiser removed approximately 550 cubic yards of soil from an area approximately 40 by 85 feet with a maximum depth of 18 feet (Hart Crowser 2012b,Table 2-8) . Further excavation in this area was limited by the presence of a high pressure, 24-inch-diameter water supply main and the physical limitations of the excavation equipment. Thirteen soil verification samples and a field duplicate were collected from the excavation bottom (TL-BS-1 through TL-BS-5) and side walls (TL-SW-1 through TL-SW-8) for TPH analysis (Hart Crowser 2012b, Table 2-7).

Sample locations are shown on Figure 2-3c. Heavy oil-range petroleum hydrocarbons exceeding screening levels were identified in samples TL-BS-2 and TL-BS-3 at 2,100 and 6,500 mg/kg, respectively. Two localized areas of concern are estimated based on these exceedances and are shown on Figure 2-3c. Contamination was assumed to extend 20 feet bgs and may extend slightly deeper. The deepest samples from previous borings in the area are at 20.5 feet and do not exceed screening levels (WW-TL-SB 10, WW-TL-SB 8, WW-TL-SB 15). Based on two feet of impacted soil horizon, the total volume of contaminated soil is estimated to total 17 cubic yards, and the mass of heavy oil is calculated to be about 190 pounds.

G3 Transfer Lines

The two G3 Transfer Lines were located in the west-central area of the Facility and were the third generation of wastewater transfer lines connecting the ORB with the IWT (Figure 2-3b). The two lines included an oily emulsion line and an acidified water line. The oily emulsion line consisted of a 4-inch-diameter inner transfer pipe encased in an outer 8-inch-diameter secondary containment line. Similarly, the acidified water line was designed with a 3-inch-diameter inner transfer and 6-inch-diameter outer secondary containment pipe. Soon after installation, leakage from the inner pipe into the outer containment pipe was noted in both lines, particularly with the oily emulsion line. Numerous attempts were made to repair the lines; however, these attempts proved unsuccessful. The G3 Transfer Lines were eventually replaced by a heat-traced aboveground transfer line (the G4 Transfer Line), which became operational in 2005.

In April and May 2004, pressure leak-detection tests were conducted on the emulsion/oil line and the acidified water line. The testing confirmed a lack of integrity on both the inner transfer and outer containment pipe on the emulsion/oil transfer line and the outer containment of the acidified water line. A break in the emulsion/oil line was uncovered at a pipe elbow located approximately 100 feet southwest of the ORB. Another break in the outer containment of the acidified water line was noted about 600 feet southwest of the ORB. Two soil samples were collected at each of these locations. Soil samples TL-1 and TL-2 were collected at the line break closest to the ORB and soil samples TL-3 and TL-4 were collected adjacent to Evergreen Way at a 90-degree bend where the lines turned south (Figure 2-3b).

These four soil samples were analyzed for TPH, metals, PCBs, SVOCs, and VOCs. Analytical results for TL-1, TL-2, and TL-3 indicate diesel-range petroleum hydrocarbons exceed SLs at concentrations of 29,000, 12,000, and 4,100 mg/kg, respectively, and residual-range petroleum hydrocarbons exceed screening levels at concentrations of 33,000, 15,000, and 6,900 mg/kg, respectively.

The G3 Transfer Lines were uncovered, removed, and residual liquid inside sections of the pipes were drained as the sections were removed in November 2006 as part of the Phase I Remedial Investigation (RI). Soil impacted by these releases were immediately excavated and stockpiled for later off-site disposal. Fifteen soil verification samples (CS-1 through CS-13) were collected along the line to assess for potential leaks and two samples (G-3S and G-3N) were collected from the pipe bedding material to represent the assumed worst-case soil conditions (Figure 2-3b). The soil verification samples did not contain detectable petroleum hydrocarbons. Only one soil sample collected along the G3 Transfer Lines (G-3S; pipe bedding material) contained detectable concentrations of heavy oil-range petroleum hydrocarbons at 170 mg/kg (below screening level).

Based on the samples listed above, two localized AOCs associated with samples TL-1, TL-2, and TL-3 were identified. Due to the close proximity to the ORB, the contamination identified in samples TL-1 and TL-2 is addressed in conjunction with the ORB AOC (described below).

The calculated area of the AOC, based on sample TL-3 is estimated as 4,170 square feet. Sample TL-3 was collected at 8 feet bgs. Due to a lack of data in the area around TL-3, contamination was assumed to reach a depth of 20 feet and may extend further. Based on these dimensions, the volume of impacted soil is calculated to be 1,900 cubic yards and the mass of contaminants is estimated to total 21,000 pounds of diesel and 36,000 pounds of heavy oil based on concentrations of these COCs in sample TL-3 (4,100 and 6,900 mg/kg, respectively).

ORB Area

As described in section B.1, contamination in the ORB area is associated with the overflow of oily wastewater to from the building onto the surrounding soil. Additional investigations of the ORB were conducted in 2004 and 2005 to provide information for the design and installation of a new loading and unloading pad at the southern end of the ORB and for the Phase I RI. Borings, test pits, and soil gas sampling have been used in the area including extensive sampling south of the ORB during installation of the unloading/loading pad. Additional explorations were conducted in the area as part of the G1 and G3 Transfer Lines investigations.

Based on sampling, it appears that the impact of heavy oil extends horizontally throughout the area and the shallow soil horizon. Twenty-eight samples at varying depths up to 19 feet bgs exceed the heavy oil SL. Impacts at some locations may extend below 20 feet bgs. The vertical extent of heavy oil impacts is assumed to start at ground surface and extend to 20 feet bgs.

In 2008, a concrete containment trench was installed on the east and west sides of the ORB (see SPCC upgrade in the Final Soil RI (Hart Crowser 2012b) for more detail). As part of installation, soils in the surrounding area were excavated to a depth of about 15 feet. The estimated area of concern is calculated to total approximately 43,500 square feet and is shown on Figure 2-3d. The AOC falls within the footprint of the ORB (or is within 20 feet of these buildings), and the area of excavation for the Spill Prevention, Control, and Countermeasure (SPCC) upgrade, or the paved unloading/loading pad south of the ORB. Some of the AOC overlaps with the footprint of the ORB, or is within 20 feet of it.

The calculated volume of impacted soil takes into account the soil removed during SPCC upgrades. The AOC contains approximately 10,700 cubic yards with an approximately mass of 79,000 pounds of heavy oil.

Diesel impacts were located at six sampling locations east to the ORB. Eight samples at varying depths exceed the diesel SL at varying depths to 9 feet bgs. The vertical extend is assumed to extend from ground surface to 9.5 feet bgs. The AOC is approximately 16,600 square feet in area, and was estimated to contain about 50,500 pounds of diesel. An excavation to 9.5 feet in this area would yield approximately 5,830 cubic yards of soil.

Rail Car Unloading Area AOCs for SVOCs

There are four areas of concern in the RCU area associated with cPAH-, diesel-, and heavy oil-impacted soil. Historically, the RCU area served as an area where fuel oil was delivered by rail tank cars and transported to the plant and storage areas via underground fuel lines.

In the northern portion of the RCU area there are AOCs associated with cPAHs and diesel contamination. These areas were identified based on samples from TP-9 and samples collected from boring RU-1. Based on depth of contamination, it is assumed the volumes of soil are not connected. These samples are associated with 1996 investigative activities in the RCU area; more details can be found in Section 3.2.2 of the Final Soil RI (Hart Crowser 2012b).

Sample TP9-S1 had a cPAH TEQ equivalent exceedance at a concentration of 1.19 mg/kg at a depth of 0.5 feet to 1 foot and a diesel detection below the SL of 500 mg/kg. Sample TP9-S2 collected at 3.5 to 4.5 feet was analyzed for cPAHs, but was non-detect for diesel range hydrocarbons. Assuming that the cPAHs are associated with the hydrocarbons, it is assumed the extent of cPAH impact extends to half the distance to the clean sample (2.25 feet bgs). The estimated area of cPAHs is shown on Figure 2-4 and is estimated to total 8,150 square feet. The volume of cPAH-impacted soil totals 680 cubic yards and the mass of cPAH (based on TEQ equivalent) is approximately 2 pounds.

Soil samples collected at intervals from 17.5 to 44 feet bgs from boring RU-1 had diesel SL exceedances. The 12.5 to 13 feet bgs sample collected from RU-1 did not exceed SLs. The vertical extent of diesel impacts is assumed to be 15.25 to 20 feet bgs. The area around RU-1 is approximately 4,500 square feet. The volume of diesel-impacted soil is approximately 790 cubic yards and the mass of diesel is estimated to be 5,900 pounds. The mass of diesel is based on the concentration of RU1-S3 (2,700 mg/kg).

As part of Phase II activities on the site, test pits and excavation activities were carried out during fuel line investigative activities on April 4, 2008. Test pit RCU-TP-FL was advanced to a final depth of 5 feet bgs (Hart Crowser 2012b, Figure 3-2) along the south fuel line. Since the fuel lines ran along the toe of the rail line embankment, the test pit was limited to prevent undermining the rail line foundation.

The analytical results for side wall sample RCU-TP-FL-SW-2 indicate diesel- and heavy oil-range petroleum hydrocarbons exceed the SLs (Hart Crowser 2012b, Table 3-4). This sample was analyzed for TPH by NWTPH-HCID and NWTPH-Dx, the greater concentration was used to estimate the mass in the AOC. The diesel-range petroleum hydrocarbon concentrations were 7,400 mg/kg by NWTPH-Dx. The heavy oil-range petroleum hydrocarbon concentrations were 9,900 mg/kg by NWTPH-HCID. The other analytical results indicate that constituents were non-detect or detected at concentrations below SLs.

Excavation of the South Fuel Lines started on April 1, 2008, with an underground utility survey. Two 4-inch-diameter fuel lines (supply and return) and a 4-inch-diameter steam line were identified during the survey. After tracing the path followed by the fuel and steam lines, they were uncovered on April 4, 2008, and inspected for potential breaks or leaks. The base of the pipes was estimated at a depth of approximately 3 feet bgs.

A 50-foot section of the South Fuel Line and associated steam line were removed on April 4, 2008. The excavation started in a concrete vault located approximately 130 feet south of the RCU Station Building and continued to the north (Figure 2-4). The vault itself was left in place but the associated valves and other internal pipe infrastructure were removed.

An additional 40 feet of line, extending north from the north end of the April 4 excavation were removed on April 22, 2008. The removal of the RCU South Fuel Line was terminated at this point to prevent undermining the support structure for the G4 Transfer Line. The remaining section of the South Fuel Line located between the G4 Transfer Line support structures and the RCU Station Building was left in place.

No additional soil verification samples other than the test pit samples discussed above were collected along the South Fuel Line excavation. An area of concern was estimated around RCU-TP-FL to reflect the diesel- and heavy-oil range hydrocarbon exceedances in the sample. The area is shown on Figure 2-4 and is estimated to total 3,960 square feet. The vertical extent of impacts was assumed to start at ground surface and extend to the midpoint between RCU-TP-FL-SW-2 and RCU-TP-FL-B-1 (0 to 3 feet bgs). To calculate the mass of diesel in this volume the greater concentration of the NWTPH-Dx and NWTPH-HCID analyses was used. The calculated volume of impacted soil is 440 cubic yards. The mass of diesel is approximately 3,100 pounds, with about 4,700 pounds of heavy oil.

The final RCU AOC is associated with cPAH, diesel, and heavy oil exceedances in an area around TP-2 and TP-2A. Due to the proximity of the samples and nature of the contaminants, it was assumed that these exceedances are related to each other and are in the same area of concern located in the southeast corner of the RCU area.

This area of concern may be associated with an area known as the former Tar Pit. The former Tar Pit area is located south of the Million-Gallon Tank and east of the rail line traveling along the west side of the Million-Gallon Tank (Figure 2-4). The nature and historical uses of the Tar Pit area are unknown. Highly weathered free-phase Bunker C-like product and impacted soil with heavy oil was excavated from the Tar Pit area between April 1 and 3, 2008, and the boundaries of the excavation are shown on Figure 2-4. The Figure also shows the area of concern which is east of the Tar Pit excavation area. The area of this AOC is about 7,515 square feet.

Samples TP-2 and TP-2A were taken from 0.5 to 1 foot of the soil interval. A sample collected in TP-2 at 4 feet bgs was below SLs. It was assumed the depth of contamination was 2.5 feet. The volume of this AOC is calculated to be approximately 700 cubic yards; the mass of diesel and heavy oil is estimated to total approximately 7,000 pounds and 12,000 pounds, respectively; the mass of cPAH is estimated to total 2 pounds.

Cold Mill/Finishing AOCs for SVOCs

Cold Mill Transfer Lines

The Cold Mill Transfer Lines consisted of a four-pipe cluster that ran from the main mill building (Column Gx28) to USTs north of the Oil House. The transfer lines were designed with a containment system with high points that drained to four low points that had collection and inspection points. The Cold Mill Transfer Lines were later truncated when the Oil House USTs were replaced with an above-ground tank farm. The subject transfer line was subsequently replaced by a double-contained set of transfer lines, and the old line was abandoned.

As part of the 2006 amended Work Plan (Ecology 2006), samples were collected from low points along the line. Soil samples from the first three low points (identified as CM-EX-S1, CM-EX-S2, and CM-EX-S3) were submitted for analysis of TPH (NWTPH-HCID; EPA Method 8015 modified, NWTPH-Dx, and NWTPH-Gx), PCBs, SVOCs, VOCs, and metals. The fourth low point (LP-4) located near the Cold Mill Building could not be safely investigated using the backhoe because of underground utilities. This low point was investigated using a hollow-stem auger drill rig. Three samples from boring CMTL-SB-1 were analyzed for TPH (NWTPH-HCID) and PCBs.

Petroleum hydrocarbons were not detected in the low point or soil boring samples except at the LP-1 low point located next to the Tank Farm at a depth of 9 feet below grade. Kensol concentration of this sample (2,100 mg/kg) exceeded the SL. This area was impacted by the January 1991 release of Kensol and is addressed under the Tank Farm Kensol Spill area in the Oil House area.

CCPL Cell 4

An area of concern associated with cPAHs was identified in the Continuous Can Process Line (CCPL) area. Between December 20, 1991, and February 7, 1992, a subcontractor to Kaiser removed the CCPL equipment, tanks, and concrete floor blocks supporting the equipment (Hart Crowser 1992). The work included removal of three ASTs and their associated concrete containment structure, removal of chromium-stained floor blocks and slab, excavating stained soil, and cleaning the concrete walls of the CCPL pit.

After equipment removal and excavation activities were completed in February 1992, thirteen five-point composite surface soil samples (CCPL-C1 through

CCPL-C13) were collected. One sample was collected from each cell of the 13-cell sampling grid established within the excavation, as presented on Figure 4-5 of the Final Soil RI (Hart Crowser 2012b). The surface soil samples were submitted for analysis of total chromium by EPA Method 6010. In addition, the soil sample collected from Cell No. 4 (CCPL-C4) was submitted for analysis of VOCs; SVOCs; Pesticides/PCBs; Priority Pollutant (PP) metals; Total Phenolics; and fuel fingerprinting.

Analytical results for the remaining Cell No. 4 sample indicate screening level exceedances of cPAHs. The estimated cPAH concentration based on the TEQ equivalent for this sample is 0.49 mg/kg. Since this was the only cell that had SVOCs analysis completed, the boundary assumed is relatively conservative and shown on Figure 2-5a. The area of this AOC is estimated to equal 1,375 square feet. The vertical extent of contamination is assumed to run from the bottom of excavation (10 feet bgs) to 20 feet. The volume of contaminated soil in this area is estimated at 510 cubic yards and the mass of cPAHs totals approximately 1 pound.

Electrical Grounding Pit

Impacted soils may be in the electrical grounding pit (EGP) in the Cold Mill Area. The Electrical Grounding Pit (EGP) is located in the basement area of the Cold Rolling Department between Columns G-8 and G-9 (Figure 2-5c). The grounding pit consists of an approximately 2.5-foot-diameter by 3-foot-deep circular manhole into which a grounding rod was driven to provide electrical grounding between plant equipment and the underlying soil.

While performing maintenance activities in March 2004 in the basement adjacent to the No. 2 Cold Mill, Kaiser employees observed the presence of approximately 6 inches of oily water in the bottom of the electrical grounding pit. Kaiser personnel sampled and removed the oily water (G-Pit B) in addition to some underlying soil/sludge (G-Pit-A) observed within the EGP. Due to accessibility issues, soil samples from the surface were not taken at this time, however, sample analytical results from disposed material exceeded diesel and heavy oil SLs.

Based on the diameter of the grounding pit and a soil horizon from 3 to 20 feet, the volume of impacted soils in the area, potentially 3 cubic yards of soil, could be impacted. The concentration of diesel and heavy oil in this volume is based on the average of concentrations of G-Pit-A and G-Pit-B. The mass of diesel-range hydrocarbons is estimated as 5,600 pounds and heavy oil-range hydrocarbons as 310 pounds.

Oil House AOCs for SVOCs

Historically, the Oil House served as the central point where new oils arrived at the Facility for storage and distribution throughout the plant. In addition, the Oil House has also served as a central area for management and storage of used oils within the plant. Oil products stored in the USTs and associated systems located around the Oil House included diesel and gasoline and other process oils such as PCB-containing hydraulic oil, Kensol (an aluminum rolling lubricant), mineral oil, Stoddard solvent, and kerosene.

Three areas in the Oil House area are identified as AOCs for SVOCs in the near-surface soil: the Tank Farm Kensol Spill area, the Eight USTs area, and the Oil House Drum Storage/French Drain area. COCs in these areas include diesel- and heavy oil-range hydrocarbons introduced to the surrounding soils from failed UST systems and past handling practices.

Tank Farm Kensol Spill

In 1991, a release of virgin Kensol, occurred in the Tank Farm area of the Oil House. The Tank Farm is located approximately 120 feet east of the Oil House building in the central area of the Facility and was in the final stages of construction when the leak occurred (Figure 2-6b). Subsequent pressure testing indicated that an underground line travelling from the tank farm and a junction box was not tight. The junction box was located on the north side of the Tank Farm and approximately 5 feet bgs. After failing the test, excavation of impacted soil around the junction box took place in January and February 1991. The excavation was approximately 35 by 20 feet and extended to a depth of 12 feet bgs. Approximately 300 cubic yards of TPH-impacted soil were removed during the excavation.

Confirmation samples were collected following excavation. Only the bottom sample, TF#3 Bottom Composite, exceeded SLs with a TPH concentration of 12,000 mg/kg. No other SVOCs were detected above SLs in the confirmation samples. Following the excavation and sampling, the area was backfilled with clean fill to maintain the integrity of the junction box and a subsurface soil assessment to investigate the vertical extent of the contaminated soil was initiated (Hart Crowser 2012b). Five borings completed as groundwater monitoring wells (TF-MW-1 through TF-MW-5) were advanced to depths ranging from 79.5 to 81 feet bgs during the subsurface investigation conducted in February 1991. There were no near-surface soil SL exceedances in these borings.

Explorations along the Cold Mill Transfer Line determined that TPH exceeding SLs extended to LP-1 (CM-EX-S1). Based on visual observations and sampling results, the TPH AOC extends to at least 20 feet bgs.

The TPH AOC included the SL exceedances in TF#3 and CM-EX-S1 and is approximately 3,500 square feet in area. The AOC is depicted on Figure 2-6b. The area has been excavated and backfilled with clean fill to at least 9 feet bgs. The vertical extent was assumed to be 9 to 20 feet bgs. Excavating in this area to reach the contamination at 12 feet would require the removal of approximately 1,200 cubic yards of clean fill overburden. The volume of impacted soil is estimated to total 1,400 cubic yards, and the mass of Kensol is estimated to be 28,400 pounds.

Eight USTs Area

Eight USTs, located immediately north of the Oil House, were removed in May 1991 (Hart Crowser 2012b). Seven of the tanks were 10,000-gallon USTs, with four of these tanks containing mineral oil, two of the tanks containing Stoddard solvent, and one tank containing kerosene. The eighth tank was a 1,000-gallon tank containing unleaded gasoline. The location of the former USTs area is shown on Figure 2-6c.

The USTs were observed to be in fair to good condition, and no holes were evident during decommissioning. Approximately 7,000 cubic yards of soil were removed from a common excavation where the tanks were formerly located. The extent of the excavation was limited on the south by the foundation of the Oil House and on the north and east by access roads. The maximum depth of the excavation was 32 feet in some areas. During the excavation, field indications of petroleum impacts were noted in soil samples collected from the side walls and bottom of the excavation. The excavation area was backfilled with clean fill and capped with asphalt.

Twenty-four soil verification samples were collected from the final excavation side walls and bottom. These samples were analyzed for TPH (EPA Method 8015 modified). The excavation's bottom samples are not considered in this section due to the depth of collection at greater than 30 feet bgs. Side wall samples were assumed to have been collected at approximately 15 feet bgs.

Kensol was detected in five side wall samples (1-SW, 2-NW, 2-SW, 5-SW, and EW) at concentrations exceeding SLs which ranged from 2,200 to 7,400 mg/kg. With the excavation backfilled with clean fill, the estimated boundaries of the near-surface Kensol Spill areas of exceedance represented by side wall samples are assumed to be discontinuous (Figure 2-6c) and extend into the areas not previously excavated.

The sampling in this area (one sidewall sample in each location along a vertical face greater than 30 feet) does not provide an assessment of the soil condition above each sidewall sample location (at an approximate depth of 15 feet). All bottom samples collected at greater than 30 feet exceeded the SL for TPH so it is likely that the soil in the 15 to 20 foot horizon is similarly impacted in these areas. The excavation above these samples were backfilled with clean fill.

The volume of impacted soil in these three areas equates to a soil volume of approximately 80 cubic yards. Note that excavation of the areas represented by samples 1-SW, 2-SW, 5-SW, and EW is in close proximity to the Oil House foundation. Assuming that the impacted soil equals concentration of the samples exceeding SLs of 6,380 mg/kg, the approximate mass of Kensol in this area is 1,370 pounds.

Oil House Drum Storage/French Drain Area

The former Drum Storage and French Drain area consisted of a 5-inch-think concrete slab-on-grade abutting the west end of the Oil House. The concrete slab was surrounded by asphalt to the north, west, and south. Historically, drums of oil were stored on the concrete pad west of the Oil House. In April 1991, while removing the concrete pad, Kaiser employees discovered that a storm drain at the north end of this oil storage area was actually a French drain that did not discharge to the sewer system. Kaiser employees also discovered what appeared to be a second French drain at the south end of the storage area, that had been covered with concrete.

Past oil-handling activities and the potential for oil to enter the former French drains is the source of TPH to the near-surface soil in the Oil House Drum Storage/French Drain area. Following initial investigations in 1991, the concrete slab and concrete north ramp from the Drum Storage and French Drain area were demolished and removed. Approximately 1,200 tons of soil was removed from under the former Drum Storage/French Drain area, to a depth of 6 to 7 feet bgs. The excavation area was backfilled with imported soil and the French drains were removed in October 1991. An asphalt cap was then installed over a portion of the former Drum Storage and French Drain area.

In November 1991, seven soil borings (SA-1 through SA-7) and two groundwater monitoring wells (OH-MW-24 and OH-MW-25) were completed to a depth of between 75 and 90 feet bgs in this area. Only sample SA-1/S-1 collected at a depth of 10 feet exceeded SLs for TPH in this area. It was noted that TPH concentrations decreased with depth as samples SA-1/S-2 and SA-1/S-3 collected at 15 and 20 feet bgs respectively were below SLs with an order of magnitude decrease in concentration between the 10 foot and 20 foot samples.

The AOC for SVOCs in this area is shown on Figure 2-6d and is approximately 520 square feet in size. With a sample at 15 feet (SA-1/S-2) below the SL, the impact zone is considered to be the 10- to 15-foot soil horizon in this area. This equates to a soil volume of approximately 125 cubic yards. Sample SA-1/S-1 had a TPH concentration of 2,700 mg/kg. Applying this concentration to the 100 cubic yards of assumed impacted soil yields a TPH mass of approximately 950 pounds. Note that this AOC directly abuts the Oil House and excavation in this area to a depth of 15 feet would expose the building foundation.

Wastewater Treatment AOCs for SVOCs

The Wastewater Treatment area is located about 400 feet east of the Spokane River on the western area of the Kaiser Facility just west of Evergreen Way (Figure 2-1). Three areas in the Wastewater Treatment area are identified as AOCs for SVOCs in the near-surface soil: the former Field-Constructed Tanks, the former Hoffman Tank area, and the Hydrogen Sulfide Scrubber Building. The identified SVOC COCs in these areas are diesel- and heavy oil-range hydrocarbons introduced to the surrounding soils from failed tank systems and past handling practices.

Field Constructed Tanks Area

Three FCTs were constructed at Kaiser between 1942 and 1950 to store fuel oil for plant operations. Two concrete 225,000-gallon aboveground storage tanks (ASTs) were constructed in 1942. In 1950, a 588,000-gallon capacity steel AST was constructed abutting the west side of the two existing 225,000-gallon capacity tanks (Figure 2-7a). The two original 225,000-gallon tanks were fitted with a timber deck roof structure covered with composition roof material. The timber deck roof was not designed to seal the tanks but rather protect the contents from the elements. The three-tank system also included a concrete pump house located near the center of the tank configuration used to distribute fuel oil to the plant. Following construction, soil was placed against the side walls of the tanks.

With improved availability of natural gas in the 1970s, use of the tanks for fuel oil storage ceased and the three tanks were eventually emptied. Starting in 1978, the South FCT was used to temporarily store reclaimed oil sent from the oily wastewater separation processes in the Industrial Wastewater Treatment (IWT) Plant. Use of the South FCT for reclaimed oil storage, or for any other purpose, ceased in 1989 at which point the tank was drained of reclaimed oil (Hart Crowser 2008b).

Kaiser demolished the three FCTs in 2008. During demolition, the two eastern 225,000-gallon concrete tanks were noted to be in good condition and there was no evidence of breaches in the concrete floors or walls. Elevated levels of TPH in the soil surrounding the concrete walls were identified during past investigations. Approximately 4,750 cubic yards of impacted soil was removed from the site during demolition. The excavations removed the majority of the soil that was sampled during past FCT investigations with one exception noted below.

Following demolition activities four test pits were advanced in the footprint of each tank and one beneath the former pump house for a total of 13 test pits. Samples from two of the test pits (FCT-TP-6 and FCT-TP-9) exceeded the SLs for heavy oil and diesel. Both of these test pits are located in the vicinity of the former pump house. A third sample in this AOC, FCT-SB-2-S3, also exceeded the SL for heavy oil. This sample was from a pre-demolition boring extending to a depth of approximately 30 feet below pre-demolition grade. The upper samples from this boring (FCT-SB-2-S1 and FCT-SB-2-S2) are assumed to have been excavated and removed and sample FCT-SB-2-S3 collected at 30 feet below pre-demolition grade is assumed to be representative of the surface soil at the base of demolition excavation.

The eastern FCT AOC for diesel and heavy oil is approximately 2,600 square feet in area (Figure 2-7a). Diesel contamination was found to extend to a depth of 6.5 feet bgs in test pit FCT-TP-6 and heavy oil at concentrations above SLs was found to extend to 3 feet bgs in test pits FCT-TP-6 and FCT-TP-9. Samples collected below test pits FCT-TP-6 and FCT-TP-9 had SVOC concentrations below the applicable SLs. The vertical extent was assumed to be 7 feet bgs. Sample FCT-SB-2-S3 also exceeded the SL for heavy oil and is assumed to be representative of near-surface soil, post excavation. The heavy oil and diesel exceedances were averaged to apply concentrations to this AOC in estimating the mass of COCs: heavy oil 5,700 pounds and diesel 9,400 pounds. An excavation to 6.5 feet in this area would yield approximately 670 cubic yards of soil.

A smaller area, located west of the former FCTs, was identified as an AOC for TPH based on one soil sample collected at 5 to 7 feet from soil boring WW-SB-5 in 1989. Sample WW-SB-5/S-1 contained TPH at a concentration of 3,400 mg/kg. The next sample collected below 7 feet (at 23 feet depth) was below SLs. Referring to Figure 2-7a the southern FCT AOC for TPH, is approximately 1,500 square feet in area. Using the “1/2 the distance” rule, we assumed soil in the upper 15 feet of this AOC exceeds SLs at a concentration equal to WW-SB-5/S-1, this area would yield a mass of TPH of approximately 7,800 pounds, and require the excavation of about 825 cubic yards of soil.

Hoffman Tank Area

The former Hoffman Tank was located toward the central area of the IWT plant directly southeast of the IWT building (Figure 2-1). The tank was part of the treatment process of the Facility's industrial wastewater.

The Hoffman Tank was used as a flow-through process tank to filter oily water prior to it entering the IWT plant. In the mid- to late-1980s, the tank was taken off-line and was ultimately removed in 1990. Impacted soils identified during the removal were cleaned up to the maximum extent practicable in an excavation effort in 1991. Composite verification samples were collected from the base of excavation prior to backfilling the area with clean fill and installing an impermeable liner and stormwater collection and treatment system to reduce the potential for residual petroleum contaminants in soil that had to be left in place from migrating to groundwater. Sources of SVOCs in the near-surface soil in this AOC are associated with past operations of the former Hoffman tank.

Samples HTE- 5, HTE-6, and HTE-7 exceeded the SL for TPH with concentrations ranging from 4,400 to 33,000 mg/kg. No other SVOCs exceeded the SLs in this AOC. These samples were collected from the areas directly abutting the IWT building where further excavation was not feasible during the 1990 removal action. This AOC is depicted on Figure 2-7c and is approximately 4,000 square feet in size. Note that a portion of this AOC extends under the IWT building.

The assumed depth of samples HTE- 5, HTE-6, and HTE-7 is 10 feet bgs based on reported excavation depths from 1990. Clean fill was placed above the location of these samples following excavation. Without soil data below these samples, it is conservatively assumed that the 10- to 20-foot soil horizon is similarly impacted as samples HTE- 5, HTE-6, and HTE-7. The 10-foot soil horizon in this AOC equates to a soil volume of approximately 1,500 cubic yards. An equal volume of clean fill lies above the impacted soil in this AOC. Applying the average concentration from these three samples to this soil volume would yield an estimated TPH mass of 28,000 pounds.

Hydrogen Sulfide Scrubber Building

The Hydrogen Sulfide Scrubber Building (H_2S Building) is part of the Wastewater Treatment area (Figure 2-1). The building is located adjacent to the southwest corner of the IWT plant building and was constructed in 1998.

Impacts to the areas were first observed in 1998 while excavating the foundations of the new scrubber building (Hart Crowser 20129b). Based on information collected during subsurface investigations conducted at adjacent locations, the impacted soil appears to have originated from historical releases from the Hoffman Tank. Cleanup activities conducted in this area included further excavation of impacted soils and soil verification sample collection and analysis from the side walls and the bottom of the excavation.

The final excavation was approximately 400 square feet in size (20 by 20 feet) and between 4 and 7 feet in depth. Following overexcavation due to elevated levels of diesel and heavy oil range hydrocarbons in initial verification samples, a final excavation-bottom composite verification sample (WW-T-O-SCRUB-COMP) was collected at 7 feet bgs and analyzed for PAHs, extractable petroleum hydrocarbons (EPH), and volatile petroleum hydrocarbons (VPH). The final dimensions of the excavation area were limited by the proximity of other building structures in the immediate vicinity. Analytical results for this sample indicate that EPH compounds (heavier petroleum fractions) were present at concentrations ranging from 82 to 16,000 mg/kg. This is consistent with the initial samples where only heavy TPH fractions (oil and diesel) were detected. No other SVOCs exceeded applicable SLs in near-surface samples. Following excavation and sampling the area was backfilled with clean fill.

In 2008, as part of Phase II RI activities, one soil boring (HT-SB-1) was advanced approximately 40 feet southwest of the H_2S Scrubber Building. Soil sample analytical results on soil samples collected from this soil boring indicate that evidence of soil contamination are generally at or near the water table and not in the near-surface zone.

The Hydrogen Sulfide Scrubber Building AOC is depicted on Figure 2-7d and is approximately 95 square feet in area. Diesel and heavy oil concentrations were inferred from the sample WW-T-O-SCRUB-COMP EPH data. Detected aromatics and aliphatics carbon in the C12 to C21 range were summed to estimate the diesel concentration. Likewise aromatics and aliphatics in the C21 to C34 range were summed to estimate heavy oil concentration. This may be a conservative estimate as there will be some overlap and double counting of aromatics and aliphatics in the estimated diesel- to heavy oil-transition range.

Without data below sample WW-T-O-SCRUB-COMP, collected at a depth of 7 feet bgs, it was conservatively assumed that this sample is representative of near-surface soil in the 7 to 20 foot horizon. The volume of diesel and heavy oil impacted soil in this AOC is approximately 45 cubic yards overlain by 25 cubic yards of clean fill. The estimated mass of diesel in the impacted soil zone is

1,600 pounds. The mass of heavy oil in this AOC is estimated to be 2,300 pounds. This AOC is located beneath the H_2S building.

Truck Shop AOCs for SVOCs

In addition to detected VOCs in the Truck Shop area as described in Section B.1, heavy oil was also detected at a concentration in excess of the SL in two samples (TS-MW-1S/S-3 and TS-MW-1S/S-4) collected at depths of 15 and 20 feet. Similar to Stoddard solvent SL exceedances, heavy oil was detected below the base of the tank. Samples TS-MW-1S/S-1 and TS-MW-1S/S-2 collected at 5 and 10 feet bgs respectively, were below SLs for heavy oil.

In examining the upper 20-foot soil horizon in this AOC it is judged that only the 13 foot (corresponding to the bottom of the tank) to 20-foot horizon would be impacted by past heavy oil releases. The 7 feet of impacted soil in this AOC (Refer to Figure 2-8) equates to a soil volume of approximately 220 cubic yards. Excavating in this area to reach the contamination at 13 feet would require the removal of the tank and approximately 400 cubic yards of overburden. Assuming that the 7 feet of impacted soil in the 13- to 20-foot soil horizon in this area is represented by the average of the TS-MW-1S/S-3 and TS-MW-1S/S-4 sample results (5100mg/kg), the estimated mass of heavy oil in this AOC is 3,200 pounds.

Former Discharge Ravines AOC for SVOCs

Prior to construction of the IWT Plant in 1973, wastewater discharges from the Trentwood Facility were handled by two discharge ravines located west and south of the plant (Figure 2-1). The wastewater discharged through these ravines was known to contain heavy oil-range hydrocarbons and PCBs. An Interim Action conducted in the Former West Discharge Ravine in 2007 was successful in reducing heavy oil concentrations in the near-surface soil to below the SL.

Former South Discharge Ravine

In support of the Phase I RI soil testing in the former South Discharge Ravine (SDR) included one soil boring, nine surface soil samples, and three test pits. One test pit sample, SDR-SS1-PH2-3-S1, collected in the top six inches of soil, exceeded the SL for heavy oil with a concentration of 13,000 mg/kg. Samples collected directly below this sample were below the heavy oil SL.

The AOC in the SDR associated with heavy oil (Refer to Figure 2-9b) is approximately 1,400 square feet and assumed to extend to a depth of approximately 1 foot. The soil volume is estimated to be 55 cubic yards with a COC mass of 1,400 pounds of heavy oil.

Remelt/Hot Line AOCs for SVOCs

The Remelt/Hot Line area is located about 2000 feet east of the Spokane River on the northern area of the Kaiser Facility just east of Evergreen Way (Figure 2-1). The SVOC COCs identified in the near-surface soil in this area is heavy oil-range hydrocarbons detected in two AOCs associated with drywells located at the northeast and southwest corners of the Remelt building.

The drywell near the northeast corner of the Remelt building receives stormwater from the vicinity of the induction furnace baghouse. In 2005, soil boring INDBG-SB-1 was advanced through the drywell. Samples INDBG-SB-1/S-1 and INDBG-SB-1/S-3 collected at depths intervals of 0 to 1.5 feet and 15 to 15.4 feet respectively, exceeded SLs for heavy oil. The boring was terminated at 15.4 feet bgs. No other petroleum hydrocarbons exceeded SLs in these samples. The source(s) of heavy oil in this AOC is unknown.

The AOC related to heavy oil in the induction furnace baghouse drywell is approximately 2,800 square feet in area as depicted on Figure 2-10a. There were no other near-surface samples collected within a reasonable vicinity of boring INDBG-SB-1. Therefore, the AOC was estimated as a circle centered on the drywell with a radius of 30 feet. This is considered a conservative assumption as significant lateral spreading of heavy oil introduced to the drywell would not be expected in the highly porous soils at this site. With heavy oil detections above the SL at the surface and at 15 feet it is conservatively assumed that the upper 20 foot soil horizon is impacted above the SL. The volume of impacted soil is estimated to be 2,100 cubic yards with a COC mass of 27,700 pounds of heavy oil.

In 2007, a soil boring was advanced through drywell 2 (DW-2) located near the southwest corner of the Remelt building. Heavy oil, at a concentration exceeding the SL, was detected in sample HL-DW-SB-2/S-1 collected at the depth interval of 7 to 10 feet. Sample HL-DW-SB-2/S-2, collected at the depth interval of 19 to 22 feet was non-detect for heavy oil. No other petroleum hydrocarbons were detected in the near-surface samples. Based on these samples the impacted soil zone is assumed to be the upper fourteen and a half feet of soil in DW-2. The source(s) of heavy oil in this drywell is unknown.

The AOC related to heavy oil in DW-2, based on half the distance to nearby clean samples, is approximately 4,900 square feet. The soil in this AOC is estimated to total 2,600 cubic yards with an estimated COC mass of 32,300 pounds of heavy oil.

B.3 AREAS OF CONCERN FOR NEAR-SURFACE SOILS CONTAMINATED WITH PCBS

Six AOCs for PCBs have been identified in this FSTM for near-surface soil. These six sites are located in three general operating areas:

- Oil House Area (Drum Storage/French Drain area);
- Remelt/Hot Line Area (four distinct areas); and
- West and South Discharge Ravines

More comprehensive descriptions of these AOCs are provided in the 2012 Final Soil RI (Hart Crowser 2012b).

Table 2-18 provides the quantities of impacted soil and mass of COCs in each AOC for PCBs. Figures 2-6d, 2-9a, 2-9b, and 2-10a through 2-10c detail the AOCs across the site for PCBs.

Oil House AOC for PCBs

Drum Storage/French Drain Area

Past releases of PCB-containing hydraulic oils to the former French drains discussed in Section B.1 are the source of PCBs to the near-surface soil in this AOC. Most base of excavation composite samples and several of the post excavation soil boring samples, all collected during the 1991 cleanup action, contained PCBs at levels exceeding the SL. Some samples, particularly samples collected adjacent to the north French drain, were several orders of magnitude above the SL for PCBs.

The AOC for PCBs in the French Drain area is shown on Figure 2-6d and is estimated to be 4,200 square feet in size. Though concentrations were observed to decrease with depth in the vadose zone, boring samples collected at 20 feet bgs exceeded the SL. The final depth of excavation in this area in 1991 was between 6 and 7 feet bgs. For this evaluation, it was conservatively assumed that the zone of PCB-impacted soil extends from 6 to 20 feet bgs, resulting in an estimated soil volume of 2,190 cubic yards.

The mass of PCBs in this soil was calculated using the average of PCB concentrations obtained from base of excavation composite samples and soil boring samples collected at depths of 10, 15, and 20 feet. The resulting estimate is 2,200 pounds of PCBs are present in this soil. This mass of PCBs is largely driven by samples SA-1/S-1 and SA-1/S-2 collected adjacent to the north French drain with PCB concentrations of 2,900 and 2,300 mg/kg, respectively. All other samples collected from this area had PCB concentrations one or more orders of magnitude lower than these samples.

Former Discharge Ravines AOC for PCBs

Former West Discharge Ravine

Similar to the South Ravine, the source of PCBs in the West Discharge Ravine (WDR) is associated with past wastewater discharges. The 2007 West Discharge Ravine Interim Action removed approximately 2,500 cubic yards of PCB-impacted material. Though field screening results collected during excavation activities indicated PCBs were still present above SLs, further excavation was not possible due to ravine side slope stability. Over 90 base of excavation verification samples were collected along the length of the WDR in a grid based sampling scheme. Only a select few samples collected are below the SL resulting in a discontinuous AOC (Figure 2-9a) with a total area of 4,900 square feet. Following excavation the ravine was backfilled with clean fill at depths up to 11 feet.

Pothole testing and successive excavations and sampling conducted during the Interim Action indicated a decreasing PCB concentration with depth in most areas. It is assumed that removal of an additional 3 feet of soil in the WDR AOC would be required to meet the SL. This 3-foot impacted soil zone is estimated to equate to a soil volume of 550 cubic yards and is located under several thousand cubic yards of clean fill. Applying the average concentrations of PCBs in the discontinuous AOC would equate to an estimated mass of 13 pounds of PCBs.

Former South Discharge Ravine

Two distinct areas in the South Discharge Ravine (SDR) have been identified as AOCs for PCBs (Figure 2-9b). In support of the Phase I RI, soil testing in the SDR included one soil boring, nine surface soil samples, and three test pits.

The two AOCs are approximately 6,600 square feet in area. The width of the AOCs is assumed to be bounded by the side wall of the ravine. Applying the average concentration to the upper 3 feet of soil in these AOCs results in a soil volume of approximately 740 cubic yards containing an estimated 11 pounds of PCBs.

Remelt/Hot Line AOCs for PCBs

Several distinct areas within the Remelt building have been identified as AOCs for PCBs. Past use of PCB-containing hydraulic oils impacted the underlying soil. Known pathways for PCBs to enter the soil were through the casting pits and floor drains. Extensive sampling of the soil underlying the Remelt building has occurred during the last decade. Additionally, Kaiser has undertaken two removal actions in the Remelt building during the installation or modification of plant equipment that required penetration of the concrete floor and exposed the underlying soil.

Several soil borings (some completed as monitoring wells) have identified PCBs in the near-surface soil. Four soil samples were collected in the top 20 feet of soil during the installation of RM-MW-8S. One sample, RM-MW-8S/S-3, collected at the depth interval of 15 to 16.4 feet exceeded the SL for PCBs. Samples collected at the 5-, 10-, and 20-foot intervals were non-detect for PCBs. Therefore, the zone of PCB-impacted soil in this AOC is assumed to be from 13 to 18 feet. RM-MW-8S was installed directly adjacent to two other monitoring wells (RM-MW-11S and RM-MW-12S). Near-surface soil samples collected during the installation of RM-MW-11S and RM-MW-12S were non-detect for PCBs. This results in a narrow AOC for soil sampled below RM-MW-8S.

The AOC associated with RM-MW-8S is depicted on Figure 2-10a and is estimated to be 1,000 square feet in area. This equates to an estimated soil volume of 190 cubic yards. The mass of PCBs in this AOC was estimated to be 0.3 pounds.

Monitoring well RM-MW-9S (installed down through the center of the Induction Furnace drywell) is one of the more isolated wells inside of the Remelt building in terms of proximity to other wells. It is located in the far eastern portion of the building with over 200 feet to the nearest well (and therefore soil data) inside the building. Two samples collected during the installation of RM-MW-9S at depths of 15 and 20 feet exceeded the SL for PCBs. Samples collected at 5 and 10 feet were non-detect for PCBs. Therefore, the zone of impacted soil in this AOC is considered to be from 13 to 20 feet bgs.

Without soil data reasonably close to RM-MW-9S a circle centered on RM-MW-9S with a radius of 30 feet was used to define this AOC. This results in an area of approximately 2,800 square feet. This is considered a conservative assumption based on the relatively narrow AOCs defined above for RM-F4-SB-1 and RM-MW-8S which were based on comparisons to nearby data. The volume of PCB impacted soil in this AOC was estimated to be 730 cubic yards. The mass of PCBs in this AOC was estimated to be approximately 200 pounds.

Four samples collected from RM-F4-SB-1 in the upper 20 feet (note that sample RM-F4-SB-1/S-4 was collected in the 20 to 21.5 foot interval) exceeded the CUL for PCBs. This boring was installed adjacent to the DC4 furnace and several nearby wells that provided near-surface soil data. All shallow soil samples collected during the installation of the adjacent wells were below the SL for PCBs, which reduced the AOC associated with RM-F4-SB-1.

The AOC associated with RM-F4-SB-1 is depicted on Figure 2-10a and is estimated to be 1,800 square feet in area. With four samples collected from RM-F4-SB-1 ranging in depth of 4 to 20 feet bgs exceeding the PCB SL, it was assumed that the impacted zone is the top 20 feet of soil in this AOC. This equates to an estimated soil volume of 1,320 cubic yards. The mass of PCBs in this AOC was calculated using the average PCB concentration of the four samples, and results in an estimated mass of PCBs of 50 pounds.

Boring INDBG-SB-1 was described in Section B.2. The PCB AOC associated with INDBG-SB-1 is estimated to be 2,800 square feet in area as depicted on Figure 2-10a. There were no other near-surface samples collected within a reasonable vicinity of boring INDBG-SB-1. Therefore the AOC was estimated as a circle centered on the drywell with a radius of 30 feet. One sample collected 5 to 5.3 feet bgs exceeded the SL. Samples above and below this sample were below the SL. The vertical extent was assumed to be 3 to 10 feet bgs. The volume of impacted soil is estimated to be 730 cubic yards with a calculated mass of 1 pound of PCBs.

DC-1 Furnace

In 2005, two excavation pits, termed the east and west excavations, were advanced near the DC-1 Furnace to assess the status of the hydraulic lines and characterize the soil near the hydraulic lines directly below the mill floor.

The East Excavation was located just southeast of the furnace where former hydraulic lines form a 90-degree angle. The West Excavation was located directly south of the furnace. Soil samples were collected from the two excavation pits. Following several rounds of sampling and overexcavation, final verification samples were collected from both excavations and analyzed for PCBs and TPH. Final depths in the east and west excavations were approximately 8 feet and 5 feet, respectively.

Verification samples B-2 in the east excavation, and S-2 and B-3 in the west excavation exceeded the SL for PCBs. Sources of PCBs to near-surface soil in these AOCs are assumed to be related to the former use of PCB-containing hydraulic oil. The AOCs associated with these exceedances are depicted in Figure 2-10b. Following collection of the final verification samples, the areas were backfilled with clean fill and the concrete mill floor was repaired. The east excavation near-surface AOC is assumed to occupy the 8 to 12 foot bgs horizon, the upper 8 feet being clean fill. The west excavation near-surface AOC is assumed to occupy the 5 to 20 foot bgs horizon, the upper 5 feet being clean fill. The total impacted soil volume from the east and west excavations are estimated to be 15 cubic yards with a calculated mass of PCBs of 0.02 pounds.

DC-4 Vent Investigation

In June 2006, Kaiser removed the DC-4 casting pit vent as part of upgrades to restart the furnace and conducted a soil quality investigation under the concrete vent (Figure 2-10c). During the pit vent removal, Kaiser excavated an L-shaped trench approximately 24 feet long and located adjacent to and south of the DC-4 casting pit. The trench was between 3 to 4 feet wide and approximately 5 to 5.5 feet deep. Six of the ten verification samples collected from the base of the excavation exceeded SLs with an average PCB concentration of 8.4 mg/kg. The source of PCBs in this area is assumed to be associated with past use of PCB-containing hydraulic oil. The excavation was backfilled with clean fill and capped with concrete following final sampling.

The AOC (Figure 2-10c) is estimated to be 55 square feet. The zone of impacted soil is assumed to extend from 5 feet to 20 feet bgs. This equates to a soil volume of 30 cubic yards containing an estimated 1 pound of PCBs.

B.4 AREAS OF CONCERN FOR NEAR-SURFACE SOILS CONTAMINATED WITH METALS

Five AOCs for metals (arsenic, lead, chromium) have been identified in this FSTM for near-surface soil. These five sites are located in three general operating areas:

- Wastewater Treatment area (arsenic)
- ORB (lead); and
- Cold Mill/Finishing Area (chromium).

More comprehensive descriptions of these AOCs are provided in the 2012 Final Soil RI (Hart Crowser 2012b).

Table 2-18 provides the quantities of impacted soil and mass of COCs in each AOC for metals. Figures 2-3a, 2-5b, and 2-7b through 2-7d detail the AOCs across the site for PCBs.

Wastewater Treatment AOCs for Metals

The Wastewater Treatment area was described above in Section B.2. All three areas in the Wastewater Treatment area are identified as AOCs for arsenic in the near-surface soil; the former Field-Constructed Tanks, the former Hoffman Tank area, and the Hydrogen Sulfide Scrubber Building.

Field Constructed Tanks Area

As described in Section B.2, three FCTs were constructed at Kaiser between 1942 and 1950 to store fuel oil for plant operations. Kaiser demolished the FCTs in 2008. Approximately 4,750 cubic yards of impacted soil was removed from the site during demolition.

Following demolition activities, four test pits were advanced in the footprint of each tank and one beneath the former pump house for a total of 13 test pits. Samples from five of the test pits (FCT-TP-2, FCT-TP-4, FCT-TP-7, FCT-TP-10 and FCT-TP-13) exceeded the SLs for arsenic (Figure 2.7b).

Referring to Figure 2-7b, the FCT AOC for arsenic is approximately 8,800 square feet in area. Arsenic exceedances were located in the samples collected from the bottom of the test pits and there were no samples collected below. The vertical extent was conservatively assumed to be 0 to 20 feet bgs. The average arsenic concentration in this AOC was use to estimate a mass of 300 pounds of arsenic. An excavation in this area would yield approximately 6,500 cubic yards of soil. This AOC includes the SVOC AOC in the FCT tank area.

Hoffman Tank Area

As described above the former Hoffman Tank was part of the Facility’s industrial wastewater treatment system. The tank was removed in 1990. Impacted soils identified during the removal were cleaned up to the maximum extent practicable in an excavation effort in 1991. Composite verification samples were collected from the base of excavation prior to backfilling the area with clean fill and installing an impermeable liner and stormwater collection and treatment system to reduce the potential for residual petroleum contaminants in soil that had to be left in-place from migrating to groundwater.

Sample HTE-6 exceeded the SL for arsenic with a concentration of 17 mg/kg. This AOC is depicted on Figure 2-7c and is approximately 1,200 square feet in size. The assumed depth is 10 feet below grade based on reported excavation depths from 1990. Clean fill was placed above the location of the sample following excavation. HTE-4, a nearby sample was below the SL at 20 feet bgs. It is assumed that the 0 to 15 foot soil horizon is impacted. The fifteen foot soil horizon in this AOC equates to a soil volume of approximately 680 cubic yards. Applying the concentration from this sample to this soil volume would yield an estimated arsenic mass of 20 pounds. The arsenic AOC is contained within the SVOC AOC.

Hydrogen Sulfide Scrubber Building

The Hydrogen Sulfide Scrubber Building (H_2S Building) is part of the Wastewater Treatment area (Figure 2-1). The building is located adjacent to the southwest corner of the IWT plant building and was constructed in 1998. The H_2S Building is described in Section B.2. An additional soil boring was advanced as part of the Phase II RI to provide additional horizontal and vertical characterization information on the historical releases from the operation of the former Hoffman Tank.

This boring had SL exceedances for arsenic. The top 7 feet of this AOC has been excavated and backfilled with clean fill. The vertical extent of impact is assumed to be from 7 to 20 feet bgs. This soil horizon equates to approximately 290 cubic yards and an estimated arsenic mass of 10 pounds.

ORB AOCs for Metals

Man-Made Depressions

The Man-Made Depressions are described above in Section B.1. Selected soil samples collected from test pits were also analyzed for lead, PCBs, PAHs, and VOCs. Analytical results from these samples indicate that lead was detected at concentrations exceeding screening levels in soil samples from 05ORTP-4. The estimated boundary of this AOC is depicted on Figure 2.3a and its area is approximately 2700 square feet. Samples were collected from a depth of 5 to 5.5 feet, however no other samples were collected below the test pit so it was conservatively assumed that the impacts extended to 20 feet bgs. The estimated mass of lead in this AOC is approximately 7,000 pounds.

Cold Mill/Finishing AOCs for Metals

Chromium Transfer Lines

The Chromium Transfer Line conveyed chromium-containing wastewater from the Cold Rolling and Finishing Departments to the IWT until 1986, after the last process using chromium ceased operation. Remedial actions in this area included subsurface soils and groundwater investigation conducted in June 1990 and then cleanup actions were conducted between November 1990 and June 1991. Cleanup activities consisted of the removal of the transfer line, the nearby storm drain, phosphate line, three concrete sumps (and associated sludge), a previously unknown UST, and the excavation and disposal of chromium-impacted soil identified during removal activities (Hart Crowser 1990 and 1991a).

After remedial activities were completed, 14 discrete and composite soil verification samples were collected for analysis. Discrete surface soil verification samples were below total chromium screening levels with the exception of TL-7, which had total chromium detected at a concentration of 5,350 mg/kg. The estimated boundary of this AOC is depicted on Figure 2-5b and its area is approximately 385 square feet. The sample was collected from a depth of 8 to 16 feet bgs, it was assumed that impacts started at 8 feet and extended to 20 feet bgs. The estimated mass of lead in this area is approximately 2,600 pounds.

The total chromium concentration in composite sample TL-7 was collected from the maximum southern extent of the excavation and represents the maximum range of chromium concentrations left behind within the excavation due to constraints caused by the stability of the building’s foundation (Hart Crowser 1991a).

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Table B-1 - Calculation of Soil Volumes and Mass of Constituents of Concern (COCs) for Near-Surface Soil Areas of Concern (AOCs)

General Area	AOC	COC	Samples/AOC ID	Area (ft^2)	Depth Interval (ft.)	ROM Volume (ft3)	ROM Volume (CY)	ROM Mass Soil (ton)	Avg. COC Conc. (mg/kg) [a]	ROM Mass of COC Contained in Soil (lbs)
ORB	**Man-Made Depressions - West**	Diesel	B-22/S-1	1223	4.5	5504	204	285	5,000	2900
	Man-Made Depressions - West	Heavy Oil	B-22/S-1,B-22/S-2,B-22/S-3,B-22/S-4,B-22/S-5, B-25/S-1,B-25/S-4	1223	20	24464	906	1269	7,571	19000
	Man-Made Depressions - East and Small	Diesel	B-14/S-2	1095	7	7665	284	397	5,700	4500
	Man-Made Depressions - East and Small	Heavy Oil	05ORTP-6 , B-14/S-2	1916	7	13415	497	696	7,050	10000
	Man-Made Depressions - East	Lead	05ORTP-4	2724	20	54480	2018	2825	1,280	7000
	Man-Made Depressions - Small	cPAH	05ORTP-100	447	20	8940	331	464	0.73	1
	Man-Made Depressions - Small	Stoddard	05ORTP-6	447	20	8940	331	464	360	300
	G1 Transfer Line	Stoddard	Location #1 (G-1)	956	20	19120	708	991	330	700
	G2 Transfer Lines	Heavy Oil	TL-BS-2	121	2	242	9	13	2,100	50
	G2 Transfer Lines	Heavy Oil	TL-BS-3	103	2	206	8	11	6,500	140
	G3 Transfer Lines - W of ORB	Diesel	TL-3	4173	12	50082	1855	2597	4,100	21000
	G3 Transfer Lines - W of ORB	Heavy Oil	TL-3	4173	12	50082	1855	2597	6,900	36000
	ORB	Diesel	B-7/S-1, B-7/S-2, B-7/S-3, B-13/S-1, B-13/S-2, B-13/S-3, HL-MW-21S-5', HL-MW-21S-10', TL-1, TL-2, B-12/S-1, B-12/S-2, B-12/S-3, B-15/S-1, B-15/S-2, B-15/S-3, B-19/S-1, B-19/S-2, B-19/S-3, Location #1 (G-1), Location #1 (G-1) CS	16579	9.5	157501	5833	8167	3,090	50500
	ORB	Heavy Oil	B-1/S-4, B-1/S-7, B-2/S-6, B-2/S-7, B-3/S-6, B-3/S-7, B-6/S-4, B-6/S-5, B-7/S-1, B-7/S-2, B-7/S-3, B-7/S-4, B-7/S-5, B-7/S-6, B-8/S-1, B-8/S-2, B-8/S-4, B-8/S-5, B-8/S-6, B-9/S-1, B-9/S-2, B-9/S-3, B-9/S-4, B-9/S-5, B-9/S-6, B-10/S-1, B-10/S-2, B-10/S-3, B10/S-4, B-10/S-5, B-10/S-7, B-12/S-1, B-12/S-2, B-12/S-3, B-12/S-4, B-13/S-1, B-13/S-2, B-13/S-3, B-13/S-4, B-13/S-5, B-13/S-6, B-15/S-1, B-15/S-2, B-15/S-3, B-15/S-5, B-19/S-1, B-19/S-2, B-19/S-3, B-19/S-4, B-19/S-5, HL-MW-20S/S-3, OR-SB-31/S-1, OR-SB-31/S-2, S-1, S-2, S-3, S-4, S-5, S-6, S-7, S-8, S-9, HL-MW-21S-10', HL-MW-21S-5', TL-1, TL-2, Location #1 (G-1), Location #1 (G-1) CS	43469	20	289380	10718	15005	2,630	79000
	ORB-South	Gasoline	S-3, S-8	440	20	8800	326	456	240	220
RCU	**RCU Area - SE Corner**	Diesel	TP2-S1	7515	2.5	18787	696	974	3,600	7000
	RCU Area - SE Corner	Heavy Oil	TP2-S1 and TP2A -S1	7515	2.5	18787	696	974	6,350	12000
	RCU Area - SE Corner	cPAH	TP2A -S1	7515	2.5	18787	696	974	0.78	2
	RCU Area (S end)	Diesel	RCU-TP-FL-SW-1, RCU-TP-FL-SW-2, TP-11-Bottom	3963	3	11890	440	616	2,480	3100
	RCU Area (S end)	Heavy Oil	RCU-TP-FL-SW-1, RCU-TP-FL-SW-2, TP-11-Bottom	3963	3	11890	440	616	3,780	4700
	RCU Area (N end)	Diesel	RU1-S3	4472	4.75	21243	787	1102	2,700	5900
	RCU Area (N end)	cPAH	TP9-S1	8147	2.25	18330	679	950	1.19	2
Cold Mill Finishing Areas	**CCPL Cell 4**	cPAH	CCPL-C4	1374	10	13745	509	713	0.49	1
	Chromium Transfer Lines	Total Chromium	TL-7	385	12	4620	171	240	5,350	2600

	Cold Mill Electrical Grounding Pit	Diesel	G-Pit-A, G-Pit-B	5	17	83	3	4	645,000	5600
	Cold Mill Electrical Grounding Pit	Heavy Oil	G-Pit-A, G-Pit-B	5	17	83	3	4	36,150	310
Oil House Area	**20,000-Gallon Leaded Gasoline UST**	Gasoline	GT-D	205	2	410	15	21	1,700	70
	Tank Farm Kensol Spill Area	TPH (418.1)	TF#3 Bottom, CM-EX-S1	3527	11	38,797	1,437	2,012	7,050	28400
	Eight USTs Excavation	Kensol	5-SW	106	5	531	20	28	6,380	350
	Eight USTs Excavation	Kensol	EW, 1-SW, 2-SW, OH-SB-1-S1 (9-10)	241	5	1,203	45	62	6,380	800
	Eight USTs Excavation	Kensol	2-NW	68	5	338	13	18	6,380	220
	Oil House Drum Storage/French Drain	PCBs	SA-1/S-1, SA-1/S-2, SA-1/S-3, SA-2/S-1, SA-2/S-2, SA-2/S-3, SA-5/S-1, SA-5/S-2, SA-5/S-3, SA-6/S-1, SA-6/S-2, SA-6/S-3 Plus nine bottom of excavation composite samples shown on Figure 5-6 of the RI.	4214	14	59,001	2,185	3,059	356	2200
	Oil House Drum Storage/French Drain	TPH (418.1)	SA-1/S-1	519	6.5	3,376	125	175	2,700	950
Waste Water Treatment Area	**Field-Constructed Tanks**	Arsenic	FCT-TP-2 Bottom, FCT-TP-400, FCT-TP-5 Bottom, FCT-TP-7 Bottom, FCT-TP-10 Bottom, FCT-FCT-TP-11 Bottom, FCT-TP-12 Bottom, FCT-TP-13 Bottom	8812	20	176,240	6,527	9,138	17	300
	Field-Constructed Tanks	TPH (418.1)	WW-SB-5/S-1	1481	15	22,222	823	1,152	3,400	7800
	Field-Constructed Tanks	Diesel	FCT-TP-6-S1, FCT-TP-6-S2, FCT-TP-9-S1	2573	7	18,011	667	934	5,033	9400
	Field-Constructed Tanks	Heavy Oil	FCT-SB-2-S3, FCT-TP-6-S1, FCT-TP-6-S2	2573	7	18,011	667	934	3,033	5700
	Hoffman Tank Excavation	Arsenic	HTE6	1226	15	18,389	681	953	12	20
	Hoffman Tank Excavation	TPH (418.1)	HTE5, HTE6, HTE7	4020	10	40,205	1,489	2,085	6,720	28000
	Hydrogen Sulfide Scrubber Building	Diesel	WW-T-O-SCRUB-COMP (EPH)	93	13	1,210	45	63	12,382	1600
	Hydrogen Sulfide Scrubber Building	Heavy Oil	WW-T-O-SCRUB-COMP (EPH)	93	13	1,210	45	63	18,300	2300
	Hydrogen Sulfide Scrubber Building	Arsenic	HT-SB-1-S2	292	13	3,802	141	197	20	10
Truck Shop Tank Area	**Truck Shop Tank Area**	Heavy Oil	TSMW-1S/S-3, TSMW-1S/S-4	857	7	5,998	222	311	5,100	3200
	Truck Shop Tank Area	Stoddard	TSMW-1S/S-3	857	7	5,998	222	311	700	440
Discharge Ravines	**Final WDR Excavation**	PCBs	cells 1 thru 11	3518	3	10,554	391	547	6.47	10
	Final WDR Excavation	PCBs	cell 12	157	3	470	17	24	6.50	0.32
	Final WDR Excavation	PCBs	cells 14 thru 16	393	3	1,180	44	61	6.50	1
	Final WDR Excavation	PCBs	cells 17-23	800	3	2,400	89	124	6.50	2
	Former South Discharge Ravine	PCBs	SDR-SS-1 thru SDR-SS-5, SDR-SS1-PH2-2-S3, SDR-SS1-PH2-3-S1, SDR-SS1-PH2-3-S2, SDR-SS1-PH2-3-S3, SDR-SS1-PH2-4-S1, SDR-SS1-PH2-4-S2, SDR-SS1-PH2-4-S3	5589	3	16,767	621	869	4.06	10
Discharge Ravines (Continued)	**Former South Discharge Ravine**	PCBs	SDR-SS-7, SDR-SS-8, SDR-SS7-PH2-1-S1, SDR-SS7-PH2-1-S2, SDR-SS7-PH2-1-S3, SDR-SS7-PH2-2-S1, SDR-SS7-PH2-2-S2, SDR-SS7-PH2-2-S3, SDR-SS7-PH2-3-S1, SDR-SS7-PH2-3-S2, SDR-SS7-PH2-3-S3	1013	3	3,038	113	158	4.00	1
	Former South Discharge Ravine	Heavy Oil	SDR-SS-1, SDR-SS1-PH2-3-S1	1380	0.75	1,035	38	54	13,000	1400
Remelt/Casting Areas	**DC-1 Furnace Area East Excavation**	PCBs	B-2	8	4	31	1.17	1.63	0.78	0.0025
	DC-1 Furnace Area West Excavation	PCBs	S-2, B-3	20	15	303	11	16	0.53	0.017
	DC-4 Furnace Vent Trench	PCBs	TB-5 to TB-8, DC#4-N, DC#4-S	55	15	821	30	43	8.40	1
	Remelt Area Wells/Borings - RM-MW-8S	PCBs	RM-MW-8S-S3	1007	5	5,037	187	261	0.58	0.30
	Remelt Area Wells/Borings - RM-MW-9S	PCBs	RM-MW-9S-S3, RM-MW-9S S-4	2826	7	19,782	733	1,026	76.0	200

	Remelt Area Wells/Borings - RM-F4-SB	PCBs	RM-F4-SB-1 S-1, RM-F4-SB-1 S-2, RM-F4-SB-1 S-3, RM-F4-SB-1 S-4	1778	20	35,563	1,317	1,844	13.6	50
	Remelt Area Wells/Borings - INDBG-SB-1	PCBs	INDBG-SB-1 S-2	2826	7	19,782	733	1,026	0.44	1
	Remelt Area Wells/Borings - INDBG-SB-1	Heavy Oil	INDBG-SB-1 S-1, INDBG-SB-1 S-2, INDBG-SB-1 S-3	2826	20	56,520	2,093	2,931	4,733	27700
	Hotline Area Wells/Borings- HL-DW-SB-2	Heavy Oil	HL-DW-SB-2/S-1	4876	14.5	70,696	2,618	3,666	4,400	32300

[a] Concentration represents the average concentration of COCs if more than one sample is included in each AOC. One-half of the reporting limit was used in averaging calculations if non-detect samples were present in the AOC.

APPENDIX C
DESCRIPTION OF AREAS OF CONCERN FOR DEEP VADOSE ZONE SOILS

CONTENTS

TABLE

APPENDIX C
DESCRIPTION OF AREAS OF CONCERN FOR DEEP VADOSE ZONE SOILS

C.1 AREAS OF CONCERN FOR DEEP VADOSE ZONE SOIL CONTAMINATED WITH VOCS

There are two AOCs for VOCs (Stoddard solvent) in the deep vadose zone soil. These AOCs are located in the Oil House area and include the Tank Farm Kensol Spill area and the French Drain/Drum Storage area.

The following subsections describe the two AOCs for VOCs and discuss the apparent sources for each VOC. More comprehensive descriptions of all AOCs examined in the FSTM are provided in the Final Soil RI (Hart Crowser2012b).

Table 3-16 provides a summary of the approximate quantities of impacted soil and the mass of Stoddard solvent in each AOC. Figures 3-4b and 3-4d depict the Oil House area AOCs for VOCs. Table C-1 provides the assumptions used to estimate the soil volume and mass of COCs in each AOC.

Oil House AOCs for VOCs

As discussed in Appendix B, Kaiser formerly had several UST systems containing volatile hydrocarbons including gasoline and Stoddard solvent. These included the 20,000-Gallon Leaded Gasoline tank; two 10,000-gallon USTs containing Stoddard solvent; and a 1,000-gallon gasoline UST. All of these tanks were located in the Oil House area and were removed in the early 1990s.

Tank Farm Kensol Spill

Three samples in the Kensol Spill area, TF-MW-1/S-10, TF-MW-1/S-11, and TF-MW-4/S-6, exceeded the SL for Stoddard solvent. Samples collected in between TF-MW-1 and TF-MW-4 were non-detect or below the SL for Stoddard solvent in the same depth intervals as the exceedances found in these borings. Therefore two separate areas of Stoddard solvent exceedance were assigned as depicted on Figure 3-4b. Samples TF-MW-1/S-10, collected at 56 feet bgs with a Stoddard solvent concentration of 230 mg/kg, and TF-MW-1/S-11, collected at 66 feet bgs with a Stoddard solvent concentration of 290 mg/kg, were the only samples chemically analyzed during the installation of this well. Sample TF-MW-4/S-6, collected at 66 feet bgs had a Stoddard concentration of 150 mg/kg. No samples were collected deeper than 66 feet bgs during investigations at the Kensol Spill area. With two exceedances at 66 feet bgs it was assumed that the lower bounds to these areas of exceedance is 68 feet bgs (lower bounds of the area if interest for deep vadose zone soil in this area). Sample TF-MW-4/S-2, collected at 26 feet bgs, was non-detect for Stoddard solvent and was used to estimate the upper bounds of the Stoddard solvent areas of exceedance. Half the distance from 56 (uppermost sample which exceeded SLs.) to 26 feet bgs and extending the lower bounds to the water table results in a 27-foot-thick zone of soil in both Stoddard solvent exceedance areas.

The AOC around soil borings TF-MW-1 and TF-MW-4 (Figure 3-4b) were estimated to be 885 and 1,930 square feet with soil volumes of approximately 885 and 1,930 cubic yards, respectively. The soil volume is based on the conservative assumption that there is a 27 foot thickness of soil exceeding the SL for this AOC.

Applying the average concentrations for the two samples from TF-MW-1 (260 mg/kg) to the 885 cubic yards of soil equates to 645 pounds of Stoddard solvent. Likewise, applying the TF-MW-4/S-6 sample concentration (150 mg/kg) to the 1,930 cubic yards of soil results in a mass of approximately 810 pounds of Stoddard solvent in the area around TF-MW-4. Both of these Stoddard solvent AOCs are currently paved with asphalt.

French Drain/Drum Storage Area

One sample, SA-6/S-12, collected from boring SA-6 (Figure 3-4d) at 65 feet bgs tested above the SL for Stoddard solvent with a concentration of 230 mg/kg. No other VOCs were detected in the deep vadose zone in this AOC. Sample SA-6/S-11, collected at 60 feet bgs, was non-detect for Stoddard solvent while sample SA-6/S-13, collected at 70 feet bgs (below the vadose zone), contained Stoddard solvent at a concentration of 1,500 mg/kg. The vertical extent of Stoddard solvent impacted soil in this AOC was taken to be half the distance from SA-6/S-12 to the non-detect sample at 60 feet bgs and assumed to extend downward to the water table interface at 68 feet bgs. The areal extent of this AOC was estimated to be 690 square feet with a deep vadose zone thickness of 5.5 feet. This equates to a soil volume of approximately 140 cubic yards. Assuming that this volume is represented by sample SA-6/S-12 (230 mg/kg Stoddard solvent), this AOC contains approximately 90 pounds of Stoddard solvent. This AOC, depicted on Figure 3-4d, is currently paved with asphalt.

C.2 AREAS OF CONCERN FOR DEEP VADOSE ZONE SOILS CONTAMINATED WITH SVOCS

SVOCs include carcinogenic Polycyclic Aromatic Hydrocarbon (cPAHs) and diesel- and heavy oil-range petroleum hydrocarbons for the purposes of this FSTM. No cPAHs in exceedance of the SLs were detected in the deep vadose zone soil. Diesel- and heavy oil-range petroleum hydrocarbons are the most common COCs on this site (refer to Table 3-16), contributing more than 97 percent of the COC loading at the site. As such, 10 of the 12 subsites with identified COCs in the deep vadose zone soil contain TPH in the diesel- and heavy oil-ranges at concentrations exceeding the SLs.

The following subsections describe the AOCs for SVOCs and provide additional background information on SVOC COCs and their apparent sources. More comprehensive descriptions of all AOCs examined in the FSTM are provided in the 2012 Final Soil RI (Hart Crowser 2012b).

Table 3-16 provides the calculated mass of COCs in each AOC for SVOCs. Figures 3-1 through 3-7 depict the AOCs for SVOCs across the site. Table C-1 includes the calculations used to arrive at the estimates of soil volume and mass of COCs.

ORB AOCs for SVOCs

Man-Made Depressions

As described in Section 2, the Man-Made Depressions are located in the west-central area of the Facility (Figure 3-1). The nature, duration of use, and historical uses of the depressions and sources of COCs are unknown. Soil data from the deep vadose zone is limited in this area as the majority of impacts were assumed to be near surface and associated with the depressions. Nonetheless, an AOC in the deep vadose zone was identified for diesel and heavy oil based in five samples collected from boring B-25 at depths ranging from 20 to 69 feet bgs. Boring B-25 was terminated at 69 feet bgs, approximately at the transition zone from the deep vadose zone to the water table.

The AOC was estimated to be approximately 1,220 square feet in size (Figure 3-1). Four of the five samples collected in the deep vadose zone exceeded the SL for heavy oil. Therefore the vertical extent of heavy oil in this AOC is assumed to extend from 20 to 68 feet bgs. This equates to a soil volume of 2,175 cubic yards with a mass of 30,000 pounds of heavy oil using the 4,880 mg/kg average concentration of heavy oil from these samples.

Rail Car Unloading AOCs for SVOCs

There is one AOC in the RCU area associated with diesel contamination as shown on Figure 3-2. Historically, the RCU area served as an area where fuel oil was delivered by rail tank cars and transported to the plant and storage areas via underground fuel lines.

Deep vadose zone data is limited in the RCU area. An AOC was identified based on samples collected from boring RU-1.

The AOC around RU-1 is estimated to be 4,500 square feet. Soil samples RU1-S4 through RU1-S8 were collected from 20 to 44 feet bgs exceeded the SL for diesel. Boring RU-1 was terminated at 44 feet bgs. Without data below 44 feet, it was conservatively assumed that contamination extended down to the 68-foot bgs (assumed depth to groundwater) and could be represented by the average concentration of samples RU1-S4 through RU1-S8 (4,300 mg/kg). The volume of diesel-impacted deep vadose zone soil near RU-1 is estimated as 7,950 cubic yards. This soil is estimated to contain 96,000 pounds of diesel. The surface of this AOC consists of bare ground.

Cold Mill/Finishing AOC for SVOCs

Monitoring well CM-MW-7S was the only well in the Cold Mill/Finishing area that had diesel exceedances in the deep vadose zone soil horizon; therefore, a circle centered on CM-MW-7S with a radius of 30 feet was used to define this AOC (Figure 3-3a). Note the nearby wells CM-MW-2S and CM-MW-3S were sampled below the water table and had diesel exceedances. Impacted soils at these locations may be due to the downward migration of diesel in upper soil horizons and then lateral migration once the water table was reached. Note that exceedances at CM-MW-2S and CM-MW-3S were addressed in the smear zone soil in Section 4.

Samples from the near-surface and smear zone soil also exceeded the SL; therefore, the vertical extent was assumed to be from 20 to 68 feet bgs. The volume of impacted soil is estimated as 5,030 cubic yards. This soil is estimated to contain 117,000 pounds of diesel.

Oil House AOCs for SVOCs

The sources of SVOCs (diesel- and heavy oil-range petroleum hydrocarbons) in the Oil House area deep vadose zone soils are assumed to be the same as those described in Section 2.

Four areas in the Oil House operating area are identified as AOCs for SVOCs in the deep vadose zone soil: the Oil House Tank area, the Tank Farm Kensol Spill area, Eight USTs area, and the Oil House Drum Storage/French Drain area. COCs in these areas include Kensol, diesel-, and heavy oil-range petroleum hydrocarbons introduced to the surrounding soils from failed UST systems and past handling practices.

Oil House Tank Area

A 10,000-gallon Oil House Tank (UST), formerly located immediately south of the Oil House, was removed for disposal in October 1990 along with TPH-contaminated soil removed from the UST excavation (Hart Crowser 1991c). This tank was previously used for waste oil storage at the Facility. The tank appeared to be the primary source of elevated TPH concentrations in the near-surface soils close to the UST and in smear zone soils near the water table throughout the vicinity of the Oil House Tank (Figure 3-4a).

Only one sample collected in this AOC within the deep vadose zone soil exceeded SLs for TPH compounds. Sample OH-SB-2/S-8, collected at the depth interval of 58-60 feet bgs had a concentration of 4,000 mg/kg TPH. Note that this sample was analyzed via EPA Method 418.1 which only provides an estimate of total TPH present in a sample and does not provide further details of the composition of the TPH. Based on comparisons to nearby data providing TPH composition and past use of this area, it is assumed that the TPH represented by sample OH-SB-2/S-8 is in the diesel- to heavy oil-range.

The upper bound to the TPH exceedance in the deep vadose zone was estimated by considering sample OH-SB-3/S-5, collected adjacent to boring OH-SB-2 at a depth of 23 to 25 feet bgs, which was below the SL for TPH. Other nearby samples collected during the installation of adjacent monitoring wells indicate a smear zone of TPH below approximately 68 feet bgs, so the lower bound of this AOC was assumed to extend to 68 feet bgs (approximate depth to groundwater) resulting in an impact zone 26.5 feet thick.

The AOC for the Oil House Tank was estimated to be 1,260 square feet in area (Figure 3-4a). An estimated 26.5-foot zone in this area yields a soil volume of 1,230 cubic yards containing an estimated 13,800 pounds of diesel and heavy oil.

Tank Farm Kensol Spill

Four deep vadose zone soil samples in the Kensol Spill area (TF-MW-1/S-10, TF-MW-1/S-11, TF-MW-4/S-6, and TF-MW-5/S-6) exceeded the SL for Kensol. The AOC, depicted on Figure 3-4b, is estimated to be 5,500 square feet in area, and assumed to extend from TF-MW-1 through TF-MW-4. The assumed thickness of the Kensol-impacted zone is approximately 27 feet which is the same as that described in Section 3.5.1. The resulting soil volume is 5,500 cubic yards containing an estimated 230 thousand pounds of Kensol, based on the average concentrations from samples TF-MW-1/S-10, TF-MW-1/S-11, TF-MW-4/S-6, and TF-MW-5/S-6.

This is a conservative estimate and likely inflates the mass of COCs actually present in this AOC. Assuming a density of Kensol oil of 7.4 pounds/ gallon (within the range of diesel fuel densities), the calculated mass of Kensol in the deep vadose zone soil in this AOC would equate to over 31,000 gallons of Kensol oil.

Eight USTs Area

Eight USTs, located immediately north of the Oil House, were removed in May 1991 (Hart Crowser 2012b). Approximately 7,000 cubic yards of soil were removed from a common excavation where the tanks were formerly located (Figure 3-4c). The excavation area was backfilled with clean fill and capped with asphalt. Twenty-four soil verification samples were collected from the final excavation side walls and bottom. The side wall samples were collected at an estimated 15 feet bgs and were discussed in Appendix B of the FSTM. Six of the eight excavation bottom samples, collected at an estimated 32 feet bgs, exceeded the Kensol SL.

Without data from deeper than 32 feet bgs below the footprints of the eight former USTs, it was conservatively assumed that the zone of Kensol-impacted soil extended down to 68 feet bgs and is represented by the average of the excavation bottom samples collected during tank removal. The AOC is assumed to be discontinuous, with a combined total area of approximately 1,300 square feet. The volume of impacted soil in this AOC is estimated to be 1,700 cubic yards, containing approximately 71,000 pounds of Kensol.

Similar to the estimate of the mass of SVOCs in the Tank Farm Kensol Spill AOC, this estimate for the Eight USTs area may exaggerate the mass of Kensol currently present in the deep vadose zone soil in this AOC. Data from the recent soil boring OH-SB-1 was examined to validate this assumption. Soil from boring OH-SB-1, driven within 10 feet of two of the former eight USTs (Figure 3-4c) in 2008, was non-detect for Kensol or any other TPH compound, until the depth interval of 88 to 89 feet bgs, which represents the smear zone. The approximate western half of this AOC is covered by asphalt.

Oil House Drum Storage/French Drain Area

Two samples from boring SA-6 collected in the Drum Storage and French Drain areas exceeded the SLs for Kensol and heavy oil (Figure 3-4d). Sample SA-6/S-12, collected at a depth of 65 feet bgs, contained Kensol at a concentration of 7,400 mg/kg. Sample SA-6/S-11, collected at 60 feet bgs, was non-detect for Kensol. The upper bounds of the Kensol-impacted area were defined as 62.5 feet bgs, or half the distance between the samples at 60 and 65 feet bgs. The lower bounds were assumed to be at 68 feet (assumed groundwater elevation) as the sample collected at 70 feet bgs also exceeded the SL for Kensol. The AOC is depicted in Figure 3-4d and is estimated to be 690 square feet in area. This yields an estimated 140 cubic yards of impacted soil in the 5.5 foot soil horizon which contains an estimated 2,900 pounds of Kensol.

The heavy oil AOC associated with boring SA-6 is assumed to occupy the same footprint as the Kensol area of exceedance shown on Figure 3-4d. One sample, SA-6/S-4 collected at 25 feet bgs contained heavy oil at a concentration of 2,800 mg/kg. Samples collected above and below SA-6/S-4 at 20 and 30 feet bgs, were below the SL for heavy oil. Therefore, the zone of impacted soil associated with heavy oil was assumed to be from 22.5 to 27.5 feet bgs, or half the distance to the adjacent clean samples. This yields an estimated 130 cubic yards of impacted soil in the 5-foot soil horizon which contains an estimated 1,000 pounds of heavy oil. This AOC is currently paved with asphalt.

Wastewater Treatment AOCs for SVOCs

One area in the Wastewater Treatment area, the former Hoffman Tank site, was identified as an AOC for SVOCs in the deep vadose zone soil.

Hoffman Tank Area

One sample, WW-MW-4/S-5, collected at a depth of 48 to 50 feet bgs, exceeded the SL for diesel and heavy oil with a concentration of 2,800 mg/kg. Based on past site use and sampling conducted in the vicinity of WW-MW-4/S-5, it was assumed that the detected TPH was in the form of diesel- to heavy oil-range compounds. No other samples collected in the deep vadose zone in this AOC exceeded any SLs for SVOCs. The removal of the Hoffman tank and subsequent excavation removed approximately 35 feet of soil above the location where WW-MW-4/S-5 was collected. Clean fill was put back into the excavation above WW-MW-4/S-5. The assumed level of the water table in the Wastewater area, and the limit to the evaluation in this Section, is 55 feet, so the zone of TPH impacted soil is considered to be 35 to 55 feet bgs. Figure 3-5a depicts the AOC for TPH that is estimated to be 2,430 square feet in size. This yields an estimated volume of TPH impacted soil of 1,800 cubic yards with a mass of 14,000 pounds of TPH. A portion of this AOC is below the engineered cap installed after the removal of the Hoffman Tank.

Truck Shop AOCs for SVOCs

One sample collected from the deep vadose zone in the Truck Shop area, TSMW-1S/S-5, exceeded the SL for heavy oil. No other SVOCs were detected in deep vadose zone soil in this AOC. Sample TSMW-1S/S-5, collected at 25 feet bgs was vertically bracketed by a 20 foot bgs sample that was above SLs and a 30 feet bgs sample that was below SLs. Therefore, the impacted zone was estimated to extend from 20 to 27.5 feet bgs. The AOC for heavy oil is depicted on Figure 3-6 and is estimated to be 860 square feet in area. The 7.5-foot interval equates to 240 cubic yards of impacted soil containing an estimated 1,500 pounds of heavy oil. Note that a large portion of this AOC resides below the adjacent buildings, based upon the assumptions used to establish the size of the AOC.

Remelt/Hot Line AOCs for SVOCs

In 2007, a soil boring was advanced through Drywell 2 (DW-2) located near the southwest corner of the Remelt building. One sample, HL-DW-SB-2 S-6 collected at 59 to 63 feet bgs, exceeded the SL for heavy oil with a concentration of 3,500 mg/kg. This sample may represent a smear zone sample. It was vertically bracketed by two samples collected at 52 and 79 feet bgs that were below SLs. Drawing the impact zone at half the distance to these clean samples results in an impacted soil horizon of 12.5 feet (55.5 feet to the deep vadose zone termination at 68 feet bgs). The AOC is depicted on Figure 3-7 and is approximately 4,900 square feet in area. The volume of soil associated with this AOC is estimated to be 2,260 cubic yards with a mass of heavy oil of 22,000 pounds.

C.3 AREAS OF CONCERN FOR DEEP VADOSE ZONE SOILS CONTAMINATED WITH PCBS

Three AOCs for PCBs have been identified in this FSTM for deep vadose zone soil. These AOCs are located in three general operating areas:

- Oil House Area (Drum Storage/French Drain area)
- Wastewater Area (Hoffman Tank)
- Remelt/Hot Line Area (several locations)

More comprehensive descriptions of these AOCs are provided in the Final Soil RI (Hart Crowser 2012b).

Table 3-16 provides the calculated mass of PCBs in each AOC. Figures 3-4d, 3-5a, and 3-7 depict the AOCs for PCBs. Table C-1 includes the calculations used to arrive at the estimates of soil volumes and mass of COCs.

Oil House Area AOC for PCBs

Oil House Drum Storage/French Drain

Past releases of PCB-containing oils to the former French Drains discussed in Appendix B are the source of PCBs to the deep vadose zone soil in this AOC. Two separate areas are considered: one centered on boring SA-1, below the north French Drain, and one centered around boring SA-6 below the south French Drain (Figure 3-4d).

Samples analyzed from boring SA-1 exceeded the SL for PCBs at 20, 30, 35, 45, 50, and 65 feet bgs. Samples were non-detect or below the SL at 55, 60, and 70 feet bgs. It was conservatively assumed that the 20- to 68-foot interval was impacted at a level represented by the average of SA-1 samples from 25 to 65 feet bgs (0.49 mg/kg). The sample collected at 20 feet bgs was used to calculate the quantity of contaminated near-surface soil and was not included here to avoid double counting. The area of exceedance centered on SA-1 is estimated to be 320 square feet. This equates to a soil volume of 575 cubic yards containing less than 1 pound of PCBs.

The second area centered on boring SA-6, shown on Figure 3-4d, is estimated to be 690 square feet in size. PCBs were detected above the SL in boring SA-6 samples at 20, 25, 30, 45, 50, 60, 65, and 70 feet bgs. Samples collected at 35, 40, and 55 feet bgs had detections of PCBs below the SL. Again, it was conservatively assumed that the 20- to 68-foot interval was impacted at a level represented by the average of SA-6 samples from 25 to 65 feet bgs (79 mg/kg). This AOC equates to a soil volume of 1,230 cubic yards containing approximately 270 pounds of PCBs. As stated above, this entire AOC is covered with asphalt paving.

Wastewater Treatment Area AOC for PCBs

Hoffman Tank Area

One base of excavation sample, HTE-4, collected subsequent to the tank removal and prior to cap installation, exceeded the SL for PCBs (Figure 3-5a). This was the only sample from this AOC in the deep vadose zone to exceed the SL for PCBs. Sample HTE-4 was collected at an estimated depth of 35 feet bgs and contained PCBs at a concentration of 0.52 mg/kg. The upper approximate

35 feet of the excavation was backfilled with clean fill following excavation and cap installation. Considering that the transition from the vadose zone occurs at 55 feet bgs in this area, the impacted horizon was assumed to extend from 35 to 55 feet bgs.

The deep vadose zone AOC is an estimated 4,800 square feet in area. This equates to an impacted soil volume of 3,500 cubic yards with an estimated PCB mass of 5 pounds.

Remelt/Hot Line AOCs for PCBs

Several distinct areas within the Remelt building have been identified as AOCs for PCBs in the deep vadose zone soil. These AOC are very similar in areal extent to the AOCs determined for near-surface soil in Appendix B. Several soil borings (some completed as monitoring wells) have identified PCBs in the near-surface soil.

Two samples in the Remelt area near furnace DC-4, RM-F4-SB-1 S-6 and RM-F4-SB-1 S-8, collected in the 20- to 68-foot horizon exceeded the SL for PCBs. The AOC associated with RM-F4-SB-1 is shown on Figure 3-7 and is approximately 1,800 square feet in area. Samples RM-F4-SB-1 S-6 and RM-F4-SB-1 S-8 collected at 30 and 40 feet bgs respectively, were vertically bracketed by samples at 26.5 and 60 feet with analytical results below SLs. Drawing the impact zone boundary at half the distance to the clean samples results in a PCB-impacted horizon that is 22.25 feet deep or from 28.25 to 50.5 feet bgs. This equates to a soil volume of 1,470 cubic yards containing an estimated 3 pounds of PCBs.

Eleven soil samples collected in the deep vadose zone during the installation of RM-MW-8S and RM-SW-MW-11S, near furnace DC-1, exceeded the SL for PCBs. Samples from both RM-MW-8S and RM-SW-MW-11S were below the SL at 20 feet but exceeded it at 25 feet bgs in RM-SW-MW-11S. All eight samples collected during the installation of RM-SW-MW-11S at depths between 25 and 70 feet bgs were greater than the PCB SL. Four samples ranging from 30 to 50 feet bgs from RM-MW-8S were also greater than the SL for PCBs. Assuming that the impacted zone extends from half the distance to clean soil (22.5 feet - half the distance to clean samples at 20 feet bgs) to the saturated soil interface at 68 feet, the zone of PCB impacts in this AOC was considered to extend from 22.5 and 68 feet bgs. The average concentration from RM-MW-8S and RM-SW-MW-11S samples (350 mg/kg) was applied to this area. The AOC is shown on Figure 3-7 and is estimated to total 1,990 square feet in area. This equates to a soil volume of 3,350 cubic yards containing an estimated 3,300 pounds of PCBs.

Monitoring well RM-MW-9S is one of the more isolated wells inside of the Remelt building in terms of proximity to other wells (Figure 3-7). It is located in the far eastern portion of the building and is over 200 feet from the nearest well (and soil data) inside the building. Without other soil data reasonably close to RM-MW-9S, a circle centered on RM-MW-9S with a radius of 30 feet was used to define this AOC. This results in an area of approximately 2,800 square feet. This is considered a conservative assumption based on the relatively narrow AOCs defined above for RM-F4-SB-1 and RM-MW-8S which were based on comparisons to nearby data.

All seven samples collected from the deep vadose zone exceeded the SL for PCBs. Further, these samples were vertically bracketed by dirty samples at 20 and 75 feet bgs. Therefore, the entire 48 feet of the deep vadose zone (20 to 68 feet bgs) is considered impacted at a level represented by the average of the seven deep vadose samples (553 mg/kg). This equates to a soil volume of 5,000 cubic yards containing an estimated 7,800 pounds of PCBs.

C.4 AREAS OF CONCERN FOR DEEP VADOSE ZONE SOILS CONTAMINATED WITH METALS

Five AOCs for metals (arsenic and chromium) have been identified in this FSTM for deep vadose zone soil. These five sites are located in four general operating areas:

- Cold Mill/Finishing Area (chromium);
- Oil House Area (arsenic);
- Wastewater Treatment Area (arsenic); and
- Remelt/Casting Areas (arsenic).

More comprehensive descriptions of these AOCs are provided in the 2012 Final Soil RI (Hart Crowser 2012b).

Table 3-15 provides the quantities of impacted soil and mass of COCs in each AOC for metals. Figures 3-3b, 3-4ba 3-4c, 3-5b, and 3-7 detail the AOCs across the site for metals.

Cold Mill/Finishing AOCs for Metals

Chromium Transfer Lines

In June 1990, four monitoring wells and two soil borings (TL-SB-1 and TL-SB-2) were installed along the Chromium Transfer Line and within an area of the inner courtyard north of the line as presented on Figure 3-3b

Hexavalent chromium slightly exceeding the screening level of 18 mg/kg was detected in deep vadose zone soil sample TL-SB-1/S-6 at a concentration of 24 mg/kg. Sample TL-SB-1/S-6 is a duplicate sample of TL-SB-1/S-5, which contained hexavalent chromium concentrations below the screening levels at 13 mg/kg. TL-SB-1/S-6 is located between depths of 24 and 26 feet below grade. TL-SB-1/S-4 was sampled from 19 to 21 feet below grade and had hexavalent chromium detections below screening level and no samples were collected below 26 feet. Based on this information, the upper boundary was half the distance to the clean sample (22.5 feet) and terminated at transition to saturated soils sample (68 feet). A 45.5-foot-thick impact zone is a very conservative assumption that was made due to the lack of data below 26 feet bgs. For the lateral extent we assumed a circle with a radius equal to half of the distance between TL-SB-1 and TL-SB-2. TL-SB-2 samples collected from 19 to 24 feet bgs were below SLs. The area for this is approximately 1,350 square feet, the total soil volume is approximately 2,280 cubic yards, and the mass of hexavalent chromium is 150 pounds.

Oil House AOCs for Metals

Oil House Tank Area

As mentioned above, a subsurface soil and groundwater quality assessment was performed in the Oil House Tank area in 1989 to assess the general extent of contamination in the area. Nine soil borings (OH-MW-1 through OH-MW-6 and OH-SB-1 through OH-SB-3) were advanced in the Oil House Tank area (Figure 3-4a).

In deep vadose zone soil, sample OH-SB-3/S-5 collected at 23 to 25 feet had arsenic concentration of 11 mg/kg which exceeds the SL of 10.32 mg/kg. The screening level is based on the upper limit of the natural background arsenic concentration range in the Spokane Valley (1.13 to 10.32 mg/kg). Since the sample collected from 18 to 20 feet (OH-SB-3/S-4) also exceeded the screening level and no sample was collected below 25 feet, the vertical extent was assumed to start at 20 feet and terminate at the transition to saturated soils (68 feet). A localized area of impact was assumed due to a lack of data and equal to approximately 15, 000 square feet. This equates to an impacted soil volume of 555 cubic yards with an estimated arsenic mass of 17 pounds.

Eight USTs Area

Eight USTs, located immediately north of the Oil House, were removed in May 1991(Figure 3-4c). The maximum depth of the excavation was 32 feet in some areas. During the excavation, field indications of petroleum impacts were noted in soil samples collected from the side walls and bottom of the excavation. The excavation area was backfilled with clean fill and capped with asphalt.

Bottom samples 2-B and 4-B had arsenic screening level exceedances with concentrations of 12.4 and 11.2 mg/kg, respectively. Two distinct areas of concern were assumed and each was approximately equal to 210 square feet. For each area, no samples were collected deeper than 32 feet, so it was assumed that the upper boundary was 32 feet and terminated at 68 feet (transition to the water table). Since concentrations for 2-B and 4-B are similar and slightly above the screening level, the average of these two values was taken and used for both AOCs. This equates to an impacted soil volume of 560 cubic yards with an estimated arsenic mass of 18 pounds.

Wastewater Treatment AOCs for Metals

Hydrogen Sulfide Scrubber Building

Soil boring HT-SB-1 was advanced on August 12, 2008, to a depth of 70 feet bgs (Figure 3-5b). Three samples collected at depths of 19, 38, and 59 feet bgs were also analyzed for VOCs, PAHs, PCBs, and metals. In the deep vadose zone, sample HT-SB-1-S4 had an arsenic exceedance from 38 to 39 feet bgs. In this same boring, samples collected in near-surface soils also had arsenic screening exceedance; therefore, the vertical extent is assumed to start at 20 feet bgs. Sample HT-SB-1-S6 collected at 59 to 60 feet bgs was below arsenic screening levels, so the lower boundary went to 49 feet (half the distance to a clean sample). A localized lateral area of concern around the sample was assumed, identical to the area assumed for near-surface soils. The size of this AOC is approximately 290 square feet. This equates to an impacted soil volume of 315 cubic yards with an estimated arsenic mass of 11 pounds.

Remelt/Hot Line AOCs for Metals

Remelt/Hot Line Area

There are two isolated arsenic exceedances in the Hot Line area. Samples HL-MW-24DD-S4 (collected from 40.3 to 43 feet) and HL-MW-30S 40′ (collected from 40 to 41 feet) exceeded the SL (Figure 3-7). Since the deep vadose zone arsenic data in the Hot Line area is scattered, a 30-foot radius circle around each location was assumed, resulting in an area of concern of approximately 2,830 square feet. The upper bound was assumed to be half the distance from the top of the vadose zone (20 feet bgs) to the samples depth. In both locations, there are samples collected near the water table that have arsenic concentrations below screening levels; therefore, the lower boundary is half the distance to this clean sample. The total mass of arsenic in the Hot Line area is 173 pounds in approximately 5,500 cubic yards of soil.

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Table C-1 - Calculation of Soil Volumes and Mass of Constituents of Concern (COCs) for Deep Vadose Zone Soil Areas of Concern (AOCs)

General Area	AOC	COC	Samples/AOC ID	Area (feet^2)	Depth Interval (feet)	Volume (feet^3)	Volume (CY)	Mass Soil (ton)	Avg. COC Conc. (mg/kg)[a]	ROM Mass of COC Contained in Soil (lbs)
ORB	**Man made depressions**	Heavy Oil	B-25/S-5, B-25/ S-7, B-25/S-9, B-25/S-11, B-25/S-13	1223	48	58714	2175	3044	4,880	30,000
RCU	**RCU Area - SE Corner**	Diesel	RU1-S4, RU1-S5, RU1-S7, RU1-S8	4472	48	214669	7951	11131	4,300	96,000
Cold Mill/Finishing Areas	**Eastern Cold Mill/Finishing Area**	Diesel	CM-MW-7S-S1, CM-MW-7S-S2	2827	48	135717	5027	7037	8,300	117,000
	Chromium Transfer Lines	Cr 6	TL-SB-1/S6	1351	45.5	61454	2276	3186	24	150
Oil House Area	**Oil House Tank Area**	TPH	OH-SB-2/S-8	1255	26.5	33,267	1,232	1,725	4,000	13,800
	Oil House Tank Area	Arsenic	OH-SB-3/S-5	312	48	14,983	555	777	11	17
	Tank Farm Kensol Spill Area	Kensol	TF-MW-1-S10, TF-MW-1-S11, TF-MW-4-S6, TF-MW-5-S6	5483	27	148,033	5,483	7,676	14,925	230,000
	Tank Farm Kensol Spill Area	Stoddard	TF-MW-1-S10, TF-MW-1-S11	885	27	23,907	885	1,240	260	645
	Tank Farm Kensol Spill Area	Stoddard	TF-MW-4-S6	1927	27	52,029	1,927	2,698	150	810
	Eight USTs Excavation	Kensol	1-B, 2-B, 3-B	583	36	21,004	778	1,089	28,700	62,500
	Eight USTs Excavation	Kensol	5-B, 6-B, 7-B	699	36	25,174	932	1,305	3,100	8,100
	Eight USTs Excavation	Arsenic	2-B	211	36	7,590	281	394	11.8	9
	Eight USTs Excavation	Arsenic	4-B	210	36	7,559	280	392	11.8	9
	Oil House Drum Storage/French Drain	PCB	SA-1/S-5 , SA-1/S-6 , SA-1/S-8, SA-1/S-9, SA-1/S-12	323	48	15,497	574	804	0.49	1
	Oil House Drum Storage/French Drain	PCB	SA-6/S-4, SA-6/S-5c, SA-6/S-8, SA-6/S-9, SA-6/S-11, SA-6/S-12	690	48	33,136	1,227	1,718	79	270
	Oil House Drum Storage/French Drain	Kensol	SA-6/S-12	690	5.5	3,797	141	197	7,400	2,900
	Oil House Drum Storage/French Drain	Stoddard	SA-6/S-12	690	5.5	3,797	141	197	230	90
	Oil House Drum Storage/French Drain	Heavy Oil	SA-6/S-4	690	5	3,452	128	179	2,800	1,000
Wastewater Treatment Area	**Hoffman Tank Excavation**	TPH	WW-MW-4/S-5 (48-50)	2432	20	48,637	1,801	2,522	2,800	14,000
	Hoffman Tank Excavation	PCB	HTE-4	4780	20	95,604	3,541	4,957	0.52	5
	H2S Scrubber Building	Arsenic	HT-SB-1-S2	292	29	8,468	314	439	12	11
Truck Shop Tank Area	**Truck Shop Tank Area**	Heavy Oil	TSMW-1S/S-5	857	7.5	6,426	238	333	2,300	1,500
Remelt/Casting Areas	**Remelt/Hot Line Area**	PCB	RM-F4-SB-1 S-6, RM-F4-SB-1 S-8	1778	22.25	39,564	1,465	2,051	0.80	3
	Remelt/Hot Line Area	PCB	RM-MW-8S S-6, RM-MW-8S S-7, RM-MW-8S S-8, RM-MW-8S S-9, RMSW-MW-11S-S3, RMSW-MW-11S-S4, RMSW-MW-11S-S5, RMSW-MW-11S-S6, RMSW-MW-11S-S7, RMSW-MW-11S-S8, RMSW-MW-11S-S9	1989	45.5	90,504	3,352	4,693	351	3,300
	Remelt/Hot Line Area	PCB	RM-MW-9S S-5, RM-MW-9S S-6, RM-MW-9S S-7, RM-MW-9S S-8, RM-MW-9S S-9, RM-MW-9S S-10	2827	48	135,717	5,027	7,037	553	7,800
	Remelt/Hot Line Area	Arsenic	HL-MW-24DD-S4	2827	26	73,513	2,723	3,812	12	88
	Remelt/Hot Line Area	Arsenic	HL-MW-30S 40'	2827	26	73,513	2,723	3,812	11	85
	Remelt/Hot Line Area	Heavy Oil	HL-DW-SB-2 S-6	4876	12.5	60,945	2,257	3,160	3,500	22,000

[a] Concentration represents the average concentration of COCs if more than one sample is included in each AOC. One-half of the reporting limit was used in averaging calculations if non-detect samples were present in the AOC

APPENDIX D
DESCRIPTION OF AREAS OF CONCERN FOR SMEAR ZONE SOIL

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TABLE

APPENDIX D
DESCRIPTION OF AREAS OF CONCERN FOR SMEAR ZONE SOIL

D.1 AREAS OF CONCERN FOR SMEAR ZONE SOIL CONTAMINATED WITH VOCS

There are two AOCS for VOCs (Stoddard solvent) in the smear zone soil. Both are located in the Oil House area, and are depicted on Figure 4-3b.

The following subsections describe the two AOCs for VOCs and discuss the apparent sources for each VOC. More comprehensive descriptions of all AOCs examined in this FSTM are provided in the 2012 Final Soil RI (Hart Crowser 2012b).

Tables 4-19 and 4-21 provide a summary of the samples exceeding the SLs, the estimated average Stoddard solvent concentration calculated, the estimated quantity of impacted soil, and the estimated mass of Stoddard solvent in each AOC. Table D-1 provides the calculation approach and assumptions used to estimate the soil volume and mass of COCs in each AOC.

Oil House AOCs for VOCs

As discussed in greater detail in Appendix B, Kaiser formerly had several UST systems containing volatile hydrocarbons including gasoline and Stoddard solvent. These USTs included the 20,000-Gallon Leaded Gasoline tank, two 10,000-gallon USTs containing Stoddard solvent, and a 1,000-gallon gasoline UST, all located in the Oil House area. All four of these tanks were removed in the early 1990s.

Eastern Oil House Stoddard Solvent AOC

The Eastern Oil House AOC for Stoddard solvent is defined by a single sample, GUST-SB2-S4, collected at 74 to 75 feet bgs with a Stoddard solvent concentration of 7,100 mg/kg using Method NWTPH-Gx. The sample was non-detect for gasoline and Stoddard solvent via Method NWTPH-HCID. This boring sample was taken in October 2008 and assumed to be on the location of the former 20,000-gallon gasoline UST dispenser. Sample GUST-SB2-S3, collected at 61 to 63 feet bgs from this boring, was non-detect for Stoddard solvent or any other TPH compound. Sample GUST-SB2-S4 was the deepest sample collected from this boring. Therefore the impacted interval was assumed to extend from 68 feet (groundwater interface) to 80 feet bgs (the demonstrated lower extent of the smear zone in other areas of the Oil House). This AOC is estimated to be approximately 10,350 square feet in area. Applying the concentrations from

GUST-SB2-S4 to this area equates to 91,000 pounds of Stoddard solvent in 4,600 cubic yards of soil. This area is currently paved with asphalt.

Western Oil House Stoddard Solvent AOC

The Western Stoddard solvent AOC in the Oil House area is mainly defined by samples collected around the former French Drain/Drum Storage area but includes several samples collected to the southeast around the Oil House Tank area (Figure 4-3b). Three samples from soil boring SA-1: SA-1/S-13, SA-1/S-14, and SA-1/S-15 were analyzed by EPA Method 418.1 which reports only total TPH. SA-1 was the only French Drain investigation SA series boring that was run by Method 418.1. All other SA series borings were analyzed by EPA Method 8015 Modified, which is capable of differentiating TPH compounds.

The majority of French Drain SA boring samples analyzed by EPA Method 8015 Modified showed both elevated levels of Stoddard solvent and Kensol. Based on the EPA 8015 Method analytical results, an average relative percentage of Stoddard Solvent to Kensol was developed. This relative percentage was applied to the soil samples analyzed by Method 418.1 (samples SA-1/S-13, S-14, and S-15 to assign a portion of the total TPH values to Stoddard solvent and Kensol The average percentage applied to SA-1 total TPH data was 46 percent Stoddard solvent to 54 percent Kensol. No other adjustments were made to the data used in the evaluation of this AOC.

The defined Western Stoddard AOC depicted on Figure 4-3b is estimated to be about approximately 68,300 square feet in size. Based on soil sample analytical results, the impacted interval is assumed to extend from 68 feet to 80 feet bgs. Assuming that this volume is represented by average Stoddard solvent concentration exceedances in this area (1,082 mg/kg Stoddard solvent), this AOC contains approximately 92,000 pounds of Stoddard solvent in a soil volume of 30 thousand cubic yards. This AOC, depicted on Figure 4-3b, is currently paved with asphalt except for the southern portion, which is in a landscaped area.

D.2 AREAS OF CONCERN FOR SMEAR ZONE SOIL CONTAMINATED WITH SVOCS

SVOCs are considered to include cPAHs and TPH in the diesel- and heavy oil-range for the purposes of this FSTM. TPH in the diesel- and heavy oil-range are the most common COCs on this site (refer to Table 4-21), contributing approximately 95 percent of the COC loading at the site in the smear zone soil.

As such, all smear zone AOCs contain TPH in the diesel- and heavy oil-range at concentrations that exceed SLs.

The following subsections describe the AOCs for SVOCs and provide additional background information on SVOC COCs and their apparent sources. More comprehensive descriptions of the AOCs examined in the FSTM are provided in the 2012 Final Soil RI (Hart Crowser 2012b).

Tables 4-19 and 4-21 provides a summary of samples exceeding the SLs, estimated average SVOC concentration calculated, quantities of impacted soil, and mass of SVOCs in each AOC. Figures 4-1 through 4-5 depict the AOCs across the site for SVOCs. Table D-1 includes the calculations used to arrive at the estimates of soil volume and mass of COCs.

ORB AOCs for SVOCs

Saturated soil data in the vicinity of the ORB area is relatively limited as the majority of past investigations in this area focused on the shallower soil impacted by known releases from ORB operations. The relatively large AOC for heavy oil is defined by data from six samples collected from four borings: HL-MW-20S, OR-SB-31, B-25, and HL-MW-2 (Figure 4-1). Soil samples collected during the installation of HL-MW-2 were analyzed for total TPH by EPA Method 418.1. This data was assumed to be heavy oil detections for the purposes of statistical calculation based on the predominance of heavy oil in this AOC. The ORB heavy oil AOC was estimated to be approximately 59,000 square feet in size. The thickness of the smear zone in this area was estimated to be 12 feet, based on detections at the water table interface (68 feet bgs) and at 80 feet bgs. Applying the calculated average heavy oil concentration of 3,940 mg/kg results in an estimated mass of 290,000 pounds of heavy oil contained in 26,000 cubic yards of soil.

One smear zone diesel exceedance was detected in sample B-25/S-13 collected at 67.5 to 69 feet bgs at a concentration of 4,900 mg/kg. This exceedance also results in a relatively large AOC based on the limited smear zone data in this area. The estimated diesel AOC is 18,300 square feet. Sample B-25/S-13 was the deepest sample collected in this area. Without deeper soil data it was conservatively assumed that a 12 foot smear zone (similar to the heavy oil) was impacted at levels defined by sample B-25/S-13. The resultant mass of diesel is estimated to be 112,000 pounds contained in approximately 8,100 cubic yards of soil.

Sample S-7, collected from boring OR-SB-31 at a depth of 80 to 81.5 feet bgs, exceeded the SL for cPAHs. This was the only smear zone sample collected in this area that was run for cPAHs. Without nearby data to compare against, the AOC was defined by drawing a circle with a radius of 30 feet centered on OR-SB-31, similar to the procedures used in the previous sections when lack of nearby data prevented a reasonable application of the “half the distance” rule. It was conservatively assumed that the cPAH-impacted zone extended from the water table interface (68 feet bgs) to 80 feet bgs. Applying the OR-SB-31/S-7 TEQ concentration, 0.03 mg/kg, to this volume results in a mass of 0.1 pounds cPAHs in 1,250 cubic yards of soil. With the exception of a small area directly adjacent to the ORB, the majority of this AOC is unpaved.

Cold Mill AOCs for SVOCs

Two SVOC AOCs have been identified in the Cold Mill area smear zone soil (Figure 4-2); one for diesel and one for heavy oil. These AOCs were defined by five samples collected during the installation of three wells: CM-MW-2S, CM-MW-3S, and CM-MW-7S.

The Cold Mill AOC for diesel was defined by three samples: CM-MW-2S-S1 (75-77 feet), CM-MW-3S-S1 (75-77 feet), and CM-MW-7S-S3 (70-73 feet). The majority of samples collected during the installation of Cold Mill wells were collected at depths greater than 70 feet bgs. Sample CM-MW-7S-S3, collected at 70 to 73 feet bgs, exceeded the diesel SL. Samples CM-MW-2S-S2 and CM-MW-3S-S2 collected at 85 feet were below the diesel SL. With a limited data set the smear zone for this AOC was assumed to extend from 68 feet bgs (water table interface) to 78 feet bgs.

Due to the limited data and the large area between data points in the Cold Mill area, the diesel AOC has been estimated to be a relatively large area of approximately 111,000 square feet. Applying the average diesel concentration from the three samples, 5,470 mg/kg, to this AOC results in an estimated 630,000 pounds of diesel contained in 41,000 cubic yards of soil.

Heavy oil exceeded the SL in two locations in the Cold Mill, CM-MW-2S-S1 (75-77 feet), and CM-MW-3S-S1 (75-77 feet). The average concentration from these samples is 2,800 mg/kg of heavy oil. Only two soil samples were collected from CM-MW-2S and CM-MW-3S during installation: samples S-1 at 75 to 77 feet bgs, and S-2 at 85 to 87 feet bgs. Heavy oil was below the SL at 85 feet bgs in both CM-MW-2S-S2 and CM-MW-3S-S2. Once again, the impacted depth interval was assumed to extend from 68 to 78 feet bgs. The AOC associated with these two locations is estimated to be approximately 55,000 square feet. Applying the average heavy oil concentration from the two samples to this AOC results in an estimated 160,000 pounds of heavy oil contained in 20,250 cubic yards of soil. The two Cold Mill AOCs for SVOCs are located under the Cold Mill building.

Oil House AOC for SVOCs

A large portion of the Oil House area has been identified as a smear zone soil AOC for SVOCs due to numerous exceedances of the diesel range hydrocarbon SL (Figure 4-3a). The TPH data used in evaluating this AOC was obtained from several different test methods including Method 418.1. Due to the predominance of Kensol detections obtained from other test methods in the vicinity of 418.1 data, the total TPH values were wholly combined with the Kensol data with the exception of samples SA-1/S-13, SA-1/S-14, and SA-1/S-15. These samples were collected within the Western Oil House Stoddard solvent AOC where several nearby samples tested high for both Stoddard solvent and Kensol. Refer to the above discussion of these samples in the Stoddard solvent AOC in the Western Oil House area. Therefore, SA-1/S-13, SA-1/S-14, and SA-1/S-15 total TPH values were assumed to be 54 percent Kensol. No other adjustments were made to the data used in the evaluation of this AOC.

This AOC encompasses the entire Oil House area and extends south towards the Cold Mill. It is likely that the contamination in smear zone soil in this AOC is from several different sources such as the numerous USTs and transfer lines that formerly resided in this area. As such, this is the largest smear zone AOC, with an estimated 374,000-square-foot impacted area. The majority of exceedances were located in the 68 to 80 foot interval as discussed in the in the introduction to this section. Based on the soil data, the impact zone was considered to extend from 68 to 80 feet bgs. Applying the average Kensol concentration, 3,900 mg/kg, to this AOC results in an estimated 1.8 million pounds of Kensol contained in 166,000 cubic yards of soil. The northern half of this AOC is paved or under the Oil House. Much of the southern half is unpaved.

Wastewater AOC for SVOCs

The Wastewater smear zone AOC is a result of Kensol and diesel exceedances along with numerous total TPH SL exceedances by Method 418.1. The 418.1 total TPH data was assumed to be Kensol/diesel-range TPH based on the predominance of diesel-range hydrocarbons in this AOC. Sources of the smear zone TPH is related to past operations in the Wastewater treatment area, releases from the Field Constructed Tanks, and possibly releases from former transfer lines that terminated in the Wastewater Treatment Area. The spread of data points in the Wastewater Treatment area results in a large smear zone AOC estimated at 256,000 square feet (Figure 4-4). The depth interval of SVOC impacts was assumed to extend from 55 feet bgs (water table interface) to 65 feet bgs based on the predominance of exceedances in this zone. Sample WW-MW-8/S-3, collected from 74-76 feet had a total TPH concentration of 3,400 mg/kg which was the only SL exceedance outside of the 55- to 65-foot smear zone within this AOC. WW-MW-8, which is closer to the higher elevation Mill area, has a greater depth to groundwater and therefore the smear zone is expected to be deeper.

Applying the average Kensol/diesel-range TPH concentration, 2,080 mg/kg, to this AOC results in an estimated 500,000 pounds of petroleum contained in 86,000 cubic yards of soil. About half of this area is either under pavement, building, or maintained synthetic liners (e.g., Lagoon and Hoffman Tank area).

Remelt AOC for SVOCs

One exceedance of the heavy oil SL was detected in RM-MW-14S/S-7 collected at 70 to 71.5 feet bgs (Figure 4-5). Sample RM-MW-14S/S-8, collected at 80 to 81.5 feet bgs, contained heavy oil below the SL. It was therefore assumed that the interval of impacted soil begins at 68 feet bgs (water table interface) and extends to 80 feet bgs. As this sample location is relatively isolated, a circle with a radius of 30 feet was centered on RM-MW-14S to define this AOC, as previously done on other isolated samples. The area of this AOC is 2,830 square feet. Applying the average heavy oil concentration from RM-MW-14S/S-7 and RM-MW-14S/S-8, 4,050 mg/kg, to this AOC results in an estimated 14,000 pounds of heavy oil contained in 1,260 cubic yards of soil. This AOC is located under the Remelt/Casting building.

D.3 AREAS OF CONCERN FOR SMEAR ZONE SOIL CONTAMINATED WITH PCBS

Three AOCs for PCBs have been identified in the FSTM for smear zone soil. These AOCs are located in three general operating areas:

- Cold Mill Area;
- Oil House Area (several locations); and
- Remelt Area.

More comprehensive descriptions of these AOCs are provided in the Final Soil RI (Hart Crowser 2012b).

Tables 4-19 and 4-21 provide a summary of samples exceeding the SLs, average PCB concentrations calculated, quantities of impacted soil, and mass of PCBs in each AOC. Figures 4-2, 4-3c, and 4-5 depict the AOCs across the site for PCBs. Table D-1 includes the calculations used to arrive at the estimates of soil volume and mass of COCs.

Cold Mill AOC for PCBs

One sample, CM-MW-2S-S1 collected at 75 to 77 feet bgs, exceeded the PCB SL with a concentration of 0.02 mg/kg. This location coincides with a former area of free phase product and is collocated within the SVOC AOCs for the Cold Mill. Past releases of PCB-containing hydraulic oils is the assumed source of PCBs to the smear zone soil in this AOC.

The 75 to 77 sample interval was the shallowest sample collected in groundwater monitoring well CM-MW-2S. The concentration of PCBs in sample CM-MW-2S-S-3, collected at 85 to 87 feet bgs was below the PCB SL. The zone of contamination was considered to extend from 68 to 78 feet bgs similar to the SVOC AOCs in the Cold Mill. The AOC is estimated to be 39,000 square feet in size. Applying the CM-MW-2S-S1 concentration to this AOC results in an estimated 1 pound of PCB contained in approximately 14,500 cubic yards of soil. This AOC is located below the Cold Mill building.

Oil House AOCs for PCBs

Three distinct areas in the Oil House area have been identified as AOCs for PCBs in the smear zone soil (Figure 4-3c); one area coincides with the former French Drain area, one with the former Oil House UST area, and a third area is located around OH-MW-16. The first two AOCs for PCBs are located within areas of known releases of TPH and associated PCBs. The source of PCBs around OH-MW-16 is likely associated with migration of PCBs associated with TPH from Oil House area sources. OH-MW-16 is in the area of historic free phase product (Figure 4-6).

All smear zone PCB levels were relatively low, all Oil House PCB exceedances were combined to obtain an average concentration of 0.4 mg/kg and applied to the three Oil House PCB AOCs. The majority of PCB detections were located within the identified 68- to 80-foot smear zone. The deepest exceedance for PCBs in the Oil House area was 81 feet bgs (sample interval 79 to 81 feet bgs). Therefore the zone of concern for all three PCB AOCs was assumed to extend from 68 to 80 feet bgs.

The total area of the three Oil House PCB AOCs is approximately 50,000 square feet. Applying the average concentration to these AOCs results in an estimated 20 pounds of PCBs contained in approximately 22,000 cubic yards of soil. The northern PCB AOC associated with the former French Drains is located under paving and structures. The two southern AOCs are located under a combination of structures and unpaved areas.

Remelt Area AOC for PCBs

A large smear zone soil AOC for PCBs resides under the Remelt/Hot Line buildings (Figure 4-5). This AOC is approximately 306,000 square feet in size. With the exception of the PCB exceedance in RM-MW-14S, the Remelt PCB smear zone AOC largely coincides with the narrow PCB groundwater plume as discussed in the Final Groundwater RI (Hart Crowser 2012a). The PCBs in the Remelt groundwater plume are not associated with TPH. It is assumed that groundwater transport of PCBs in this area is facilitated by colloidal particles in the groundwater.

Only sample RM-MW-14S/S-7, collected at 70 to 71.5 feet bgs, was co-located with TPH as discussed in Section 4.5.2. The calculated average concentration in Remelt smear zone soil is 0.08 mg/kg. The zone of PCB impacts is shown to extend from 68 feet bgs (water table interface) to 80 feet bgs. Applying the average concentration to this AOC results in an estimated 30 pounds of PCBs contained in approximately 136,000 cubic yards of soil. This AOC mainly resides below the Remelt and Hot Line buildings.

D.4 AREAS OF CONCERN FOR SMEAR ZONE SOIL CONTAMINATED WITH METALS

Two AOCs for metals have been identified in the FSTM for smear zone soil. Both of these AOCs are for arsenic and are located within the Oil House area.

More comprehensive descriptions of these AOCs are provided in the Final Soil RI (Hart Crowser 2012b).

Tables 4-19 and 4-21 provide a summary of samples exceeding the SLs, average concentrations calculated, quantities of impacted soil, and mass of arsenic in each AOC. Figure 4-3d depicts the Oil House area AOCs for arsenic. Table D-1 includes the calculations used to arrive at the estimates of soil volume and mass of arsenic.

Oil House AOCs for Metals

There are two arsenic areas of concern in the Oil House area. Samples collected from OH-MW-2/S-7 and OH-MW-4/S-4 had an exceedance for arsenic from 68 to 70 feet. Based on horizontal distance between these samples it was assumed the exceedances were not related, therefore, a lateral extent equal to a 30-foot radius circle around each well was assumed. The samples listed above were the deepest sample collected from this boring analyzed for arsenic.

Therefore the impacted interval was assumed to extend from 68 feet (water table interface) to 78 feet bgs (the demonstrated average fluctuation in groundwater). The concentration of arsenic in samples OH-MW-2/S-7 and OH-MW-4/S-4 were the same, 11 mg/kg. Since both areas had identical lateral areas, vertical extents and contaminant concentration, the mass of arsenic is the same, or 30 pounds, in approximately 1,050 cubic yards of soil.

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Table D-1 - Calculation of Rough Order of Magnitude (ROM) Soil Volumes and Mass of Constituents of Concern (COCs) for Smear Zone Soil Areas of Concern (AOCs)

General Area	AOC	COC	Samples/AOC ID	Area (feet^2)	Depth Interval (feet)	ROM Volume (feet^3)	ROM Volume (CY)	ROM Mass Soil (tons)	Avg. COC Conc. (mg/kg)[a]	ROM Mass of COC Impacted Soil (pounds)	ROM Volume of FPP (gallons)
ORB Area	**Oil Reclaimation Building**	Heavy oil/TPH (418.1)	OR-SB-31 S-7 (80 to 81.5 feet), B-25/S-13 (67.5 to 69 feet), HL-MW-2/S-1 (74-76 feet) (TPH 418.1), HL-MW-2/S-2 (79-81 feet)(TPH 418.1), HL-MW-20S/S1 (75 to 75.8 feet), OR-SB-31/S-6 (70 to 70.4 feet)	58,955	12	707,460	26,202	36,683	3,938	290,000	
		Diesel	B-25/S-13 (67.5 to 69 feet)	18,300	12	219,595	8,133	11,386	4,900	112,000	
		cPAH	OR-SB-31 S-7 (80 to 81.5 feet)	2,827	12	33,929	1,257	1,759	0.03	0.10	
Cold Mill Finishing Areas	**Cold Mill**	Diesel	CM-MW-2S-S1 (75-77 feet), CM-MW-3S-S1 (75-77 feet), CM-MW-7S-S3 (70-73 feet)	111,089	10	1,110,894	41,144	57,602	5,467	630,000	
		Residual Range Organics (Heavy Oil)	CM-MW-2S-S1 (75-77 feet), CM-MW-3S-S1 (75-77 feet)	54,674	10	546,741	20,250	28,350	2,800	160,000	
		PCBs	CM-MW-2S-S1 (75-77 feet)	39,060	10	390,596	14,467	20,253	0.02	1	
Oil House Area	**Oil House**	Kensol/TPH (418.1)	OH-MW-1/S-7 (68-70 feet), OH-MW-3/S-2 (68-70 feet), OH-MW-4/S-4 (68-70 feet), OH-MW-5/S-8 (68.5-70.5 feet), OH-MW-7/S-3 (74-76 feet), OH-MW-9/S-2 (74-76 feet), OH-MW-10/S-3 (74-76 feet), OH-MW-13/S-2 (74-76 feet), OH-MW-14/S-1 (74-76 feet), OH-EW-1/S-3 (75 feet), GUST-SB2-S4 (74-75 feet), OH-MW-19/S-3 (74-76 feet), OH-MW-19/S-4 (79-81 feet), OH-MW-20/S-2 (69-71 feet), OH-MW-20/S-3 (74-76 feet), OH-MW-22/S-2 (68-70 feet), OH-MW-22/S-3 (73-75 feet), SA-1/S-13 (70 feet), SA-1/S-14 (75 feet), SA-1/S-15 (80 feet), SA-3/S-13 (70 feet), SA-3/S-14 (75 feet), SA-3/S-15 (80 feet), SA-4/S-13 (70 feet), SA-4/S-14 (75 feet), SA-4/S-15 (80 feet), SA-5/S-13 (70 feet), SA-5/S-14 (75 feet), SA-5/S-15 (80 feet), SA-6/S-13 (70 feet), SA-6/S-14 (75 feet), SA-6/S-15 (80 feet), SA-7/S-14 (70 feet), SA-7/S-15 (75 feet), SA-7/S-16 (80 feet), OH-MW-23/S-2 (68-70 feet), OH-MW-23/S-3 (73-75 feet), OH-MW-23/S-4 (78-80 feet), OH-MW-24/S-13 (68-70 feet), OH-MW-24/S-14 (73-75 feet), OH-MW-24/S-15 (78-80 feet), OH-MW-25/S-15 (73-75 feet), OH-MW-25/S-16 (78-80 feet), GUST-SB-1-S-4 (77 to 80 feet), OH-EW-1/S-4 (80 feet), OH-MW-20/S-4 (79 to 81 feet), OH-MW-22/S-4 (78 to 80 feet), OH-EW-1/S-2 (70 feet), OH-SB-1-S7 (68 to 69 feet), OH-MW-25/S-14 (68 to 70 feet), OH-MW-19/S-2 (69 to 71 feet), OH-MW-13/S-3 (79 to 81 feet), OH-MW-10/S-4 (79 to 81 feet), OH-MW-2/S-7 (68 to 70 feet), OH-MW-6/S-5 (69 to 70.5 feet), OH-MW-9/S-3 (79 to 81 feet), OH-MW-7/S-2 (69.5 to 71.5 feet)	374,264	12	4,491,171	166,340	232,876	3,932	1,800,000	
		Stoddard (East)	GUST-SB2-S4 (74-75 feet)	10,350	12	124,204	4,600	6,440	7,100	91,000	
		Stoddard (West)	OH-EW-1/S-3 (75 feet), OH-MW-19/S-3 (74-76 feet), OH-MW-19/S-4 (79-81 feet), OH-MW-20/S-2 (69-71 feet), OH-MW-20/S-3 (74-76 feet), SA-1/S-13 (70 feet), SA-1/S-14 (75 feet), SA-1/S-15 (80 feet), SA-3/S-13 (70 feet), SA-3/S-14 (75 feet), SA-3/S-15 (80 feet), SA-4/S-13 (70 feet), SA-4/S-14 (75 feet), SA-4/S-15 (80 feet), SA-5/S-13 (70 feet), SA-5/S-14 (75 feet), SA-5/S-15 (80 feet), SA-6/S-13 (70 feet), SA-6/S-14 (75 feet), SA-6/S-15 (80 feet), SA-7/S-14 (70 feet), SA-7/S-15 (75 feet), SA-7/S-16 (80 feet), OH-MW-24/S-13 (68-70 feet), OH-MW-24/S-14 (73-75 feet), OH-MW-24/S-15 (78-80 feet), OH-MW-25/S-15 (73-75 feet), OH-MW-25/S-16 (78-80 feet), OH-EW-1/S-2 (70 feet), OH-EW-1/S-4 (80 feet), OH-MW-19/S-2 (69 to 71 feet), OH-MW-20/S-4 (79 to 81 feet), OH-MW-25/S-14 (68 to 70 feet)	68,280	12	819,358	30,347	42,485	1,082	92,000	
		PCBs	OH-MW-16/S-3 (74-75.5 feet), OH-MW-19/S-3 (74-76 feet), OH-MW-19/S-4 (79-81 feet), OH-MW-20/S-3 (74-76 feet), OH-MW-20/S-4 (79-81 feet), OH-MW-24/S-14 (73-75 feet), OH-MW-24/S-15 (78-80 feet), SA-6/S-13 (70 feet), SA-6/S-14 (75 feet), SA-6/S-15 (80 feet), SA-7/S-14 (70 feet), SA-7/S-15 (75 feet), SA-7/S-16 (80 feet), OH-MW-16/S-4 (79 to 79.5 feet), OH-MW-17/S-3 (74 to 76 feet), OH-MW-17/S-4 (79 to 81 feet), OH-MW-24S/S-13 (68 to 70 feet)	50,027	12	600,328	22,234	31,128	0.39	20	
		Arsenic	OH-MW-2/S-7 (68-70 feet)	2,827	10	28,274	1,047	1,466	11	30	
		Arsenic	OH-MW-4/S-4 (68-70 feet)	2,827	10	28,274	1,047	1,466	11	30	
	West Oil House FPP Area	FPP	OH-MW-04, OH-MW-06, OH-SK-01, OH-SK-02, OH-SK-03, OH-SK-04	9,633	0.02	58	---	---	---	---	400
	East Oil House FPP Area	FPP	TF-MW-01, TF-MW-02	5,365	0.01	21	---	---	---	---	200
Waste Water Treatment Area		Kensol/Diesel/TPH (418.1)	WW-MW-5/S-6 (58.5-60.5 feet), WW-MW-6/S-6 (63-65 feet), WW-MW-9/S-2 (64-66 feet), WW-MW-12/S-8 (61.5-62.5 feet), WW-MW-13/S-4 (58-60 feet), HT-SB-1-S6 (59-60 feet) (Kensol), HT-SB-1-S6 (59-60 feet) (diesel), HT-SB-1-S7 (65 to 66 feet), WW-MW-12/S-6 (56.5 to 58 feet), WW-MW-12/S-7 (59 to 61 feet), WW-MW-13/S-5 (63 to 65 feet), WW-MW-9/S-1 (59 to 61 feet)	232,158	10	2,321,584	85,985	120,378	2079	500,000	
	North WW FFP Area	FPP	WW-MW-06, WW-MW-13, WW-SK-03	59,537	0.02	357	---	---	---	---	3,000
	South WW FFP Area	FPP	WW-MW-03, WW-SK-02	12,198	0.07	256	---	---	---	---	2,000
Remelt/Casting Areas	**Remelt Area Wells/Borings**	PCBs	RM-MW-1S S-1 (75-80 feet), RM-MW-9S S-11 (75-76.2 feet), RM-F4-SB-1 S-11 (76-76.5 feet), RM-MW-10S S-4 (70.5-71 feet), RMSW-MW-11S-S10 (70 feet), RMSW-MW-11S-S10 (80 feet), RM-MW-14S/S-7 (70-71.5 feet), RM-MW-16S/S-7 (70-70.6 feet), RM-MW-17S/S-7 (70-71.5 feet), RM-MW-17S/S-8 (80-81.5 feet), RM-MW-2D S-1 (75 to 80 feet), RM-MW-3S S5 (75 to 75.9 feet), RM-MW-8S/S-11 (75 to 75.8 feet), RM-MW-12S-S11 (75 feet), RM-MW-13S-S11 (75 feet), RM-MW-14S/S8 (81 to 81.5 feet), RM-MW-15S/S7 (70 to 71.5 feet), RM-MW-15S/S8 (80 to 81.5 feet), RM-MW-16S/S-8 (80 to 81.5 feet)	306,667	12	3,680,000	136,296	190,815	0.11	40	
		Heavy oil	RM-MW-14S/S-7 (70-71.5 feet), RM-MW-14S/S-8 (80 to 81.5 feet)	2,827	12	33,929	1,257	1,759	4050	14,000	

[a] Concentration represents the average concentration of COCs if more than one sample is included from each AOC. One-half of the reporting limit was used in averaging calculations if non-detect samples were present in the AOC.

APPENDIX E
CAPTURE ZONE ANALYSIS AND EVALUATION OF CLEANUP TIMES

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TABLES

APPENDIX E
CAPTURE ZONE ANALYSIS AND EVALUATION OF CLEANUP TIMES

This Appendix presents the basis for capture zone analysis and evaluation of cleanup times for the petroleum plumes at Kaiser.

HYDRAULIC CONTAINMENT ANALYSIS

Capture zone analysis was performed to determine the pumping rate for hydraulic containment of the petroleum plumes at Kaiser. Capture zone refers to the three-dimensional region that contributes the groundwater extracted by one or more wells or drains. A capture zone in this context is equivalent to the "zone of hydraulic containment." If a contaminant plume is hydraulically contained, contaminants moving with the groundwater will not spread beyond the capture zone.

Capture zone analysis was performed using the following procedure.

- Step 1: Review site geology and hydrogeology data, site conceptual model, and remedy objectives.

- Step 2: Define target capture zone based on containment-specific 3-dimensional (3-D) plume dimensions.

- Step 3: Define pumping rates to achieve hydraulic containment using site-specific groundwater flow model in combination with particle tracking.

Four petroleum plumes were identified that will potentially require hydraulic containment. These petroleum plumes are located in the following areas of the site:

- Oil House Area;
- Wastewater Treatment Area;
- Cold Mill Area; and
- Oil Reclamation Building (ORB) Area.

The footprint of each plume is based on the extent of contamination presented in the Final Groundwater RI (Hart Crowser 2012a).

The existing site 3-D groundwater flow model was used to estimate the pumping rates required to hydraulically contain the contaminant plumes. The groundwater flow model was developed using MODFLOW and pre- and post-model processing was provided with Groundwater Vistas Version 5. To provide hydraulic containment, one or two extraction wells were assigned to the leading edge of each plume, depending on the size and shape of the plume.

Particle tracking was used to evaluate the capture zone created by the hypothetical extraction wells. Particle tracking was performed using the version of MODPATH provided with Groundwater Vistas. Particle tracking simulates simple advective migration of particles through the groundwater flow regime. At the beginning of the simulation, clouds of particles corresponding to the footprint of each plume were released and allowed to migrate toward the extraction wells. Capture zones were evaluated using particles assigned to model layers 1 and 2. One particle was assigned to each model cell within the footprint of the contaminant plume. Particles were placed at the midpoint of each layer and were specified to stop as they enter the cell containing an extraction well. The pumping rate was adjusted until all the particles were captured by extraction well(s). The pumping rates to achieve hydraulic containment for each of the plumes are summarized in Table E-1. The time required for the last particle to be captured in each contaminant plume was used to define the travel time for pore volume flushing analysis.

EVALUATION OF CLEANUP TIMES

The time required to meet the groundwater cleanup goals was estimated using the number of pore volumes of groundwater that must be pumped from the contaminated zone to attain cleanup concentrations. One pore volume equals the total amount of water stored within the contaminated portion of the aquifer. The mixed reactor or batch flush model (Brusseau 1996; EPA 1988c; National Research Council 1994) was used to estimate how many times the contaminated aquifer has to be flushed to meet the cleanup goals.

The batch flush model uses several simplifying assumptions to estimate cleanup times. This model assumes that the sorption/desorption process is linear and that the reaction is virtually instantaneous. The model also assumes a simple adsorption of contaminant between the soil and water phases in the aquifer, that incoming water, free of contaminant, mixes completely within the aquifer in a time interval that is very small relative to the hydraulic residence time. The batch flush model further assumes that there are no continuing sources of contamination such as NAPL or residual oil in the unsaturated zone. In general, the cleanup time estimates generated using the batch flush model should be considered to be the minimum time required to meet the cleanup objectives because the model does not account for the effect of heterogeneities, presence of FPP, the nonlinear sorption processes and the production of leachate from the original source of contamination.

Estimating Pore Volumes

The number of pore volumes of water that must be circulated through the contaminated zone to achieve cleanup is calculated from the following relationship:

$$N_{pv} = -RLn\left(\frac{C_s}{C_i}\right)$$

where:

N_{pv} is the number of pore volumes of clean water that must be circulated through the contaminated zone to reduce the concentration of a given constituent from an initial value C_i, to a cleanup value C_s; and
R is the retardation factor for the chemical of concern. Values for C_i used in this evaluation were the average petroleum concentrations for each AOC as presented in Table 5-15.

Calculating Retardation Factor

The majority of organic chemicals are removed from solution by sorption onto the aquifer particles. Sorption of dissolved contamination onto the aquifer matrix results in slowing or retardation of the contaminant relative to advective groundwater flow velocity and a reduction in dissolved contaminant concentrations. Sorption is typically represented by a retardation factor. The retardation factor is the rate at which dissolved contaminants moving through an aquifer can be reduced by sorption of contaminants to the solid aquifer matrix. The degree of retardation depends on both aquifer and constituent properties. The retardation factor is the ratio of the groundwater seepage velocity to the rate that organic chemicals migrate in the groundwater. A retardation value of 2 indicates that if the groundwater seepage velocity is 100 feet/year, then the organic chemicals migrate at approximately 50 feet/yr.

The retardation factor is estimated using the following equation:

$$R = 1 + K_d\,(\rho_b/n)$$

where:

K_d is the distribution coefficient;
ρ_b is the bulk density of the aquifer material; and
n is the aquifer porosity.

Distribution Coefficient

The distribution coefficient is defined by the following expression:

$$K_d = K_{oc} * f_{oc}$$

where:

K_d = distribution coefficient;
K_{oc} = organic carbon partition coefficient; and
f_{oc} = total organic carbon fraction

Physical and Chemical Properties

Organic Carbon Partition Coefficient (K_{oc})

The organic carbon partition coefficient (K_{oc}) describes the relationship between the soil organic carbon and the aqueous phase. Larger values of K_{oc} indicate a greater affinity of contaminants for the organic carbon fraction of soil. K_{oc} values are chemical specific and are found in various published reports (EPA 1996j; Pankow and Cherry 1996).

Because petroleum hydrocarbons are a mixture of chemicals we took the approach of defining the chemical properties of the TPH fraction. Typically, the concentration of petroleum mixtures is measured as total petroleum hydrocarbons (TPH) that represents the expected range of these materials such as the gasoline range or the diesel range. These measured concentrations are the collective concentration of the individual petroleum compounds. MTCA allows for mixture-specific chemical characterization of released petroleum in order to develop a cleanup level based on the types of compounds actually present. This method, known as TPH fractionation, measures the concentration of twelve sub-groups, or fractions, of TPH within the released mixture and is based on work by the TPH Criteria Working Group (TPHWG 1997). These fraction groups are defined based upon their relative average molecular size, with the lighter-weight (and typically more volatile and soluble) compounds in one group, and heavier, less volatile and soluble compounds in others. The chemical properties for the fraction groups were obtained from Ecology (Ecology

2001, Appendix F). A summary of the K_{oc} for the fractions of TPH are provided in Table E-2. Table E-3 specifies the K_{oc} values assigned to the TPH mixtures at Kaiser. The geometric mean, based on the minimum and maximum K_{oc} value for each petroleum fraction, was used for this study.

Organic Carbon

Fraction of organic carbon (f_{oc}) is the fraction of the aquifer soil matrix consisting of natural organic carbon. More natural organic carbon typically means higher adsorption of organic constituents on the aquifer matrix. Typical values of f_{oc} are 0.0002 to 0.02. A f_{oc} value of 0.001 was used for this study because this was the representative value for subsurface soil reported in the Final Groundwater RI (Hart Crowser 2012a).

Soil Bulk Density

The soil bulk density, in kg/L, of the aquifer matrix is related to porosity and pure solids density. Although this value can be measured in the lab, in most cases estimated values are used. A default value of 1.7 kg/L was used.

Estimating Time to Achieve Cleanup

The time required to achieve the cleanup goal was calculated using the following relationship:

$$t_c = N_{pv} t_{pv}$$

where:

t_c is the cleanup time; and
t_{pv} is the time required for movement of one pore volume of clean water through the contaminated zone.

RESULTS

The results of the capture zone and cleanup time estimates are presented in the following series of tables.

- The pumping rates to achieve hydraulic containment of each plume are summarized in Table E-1.

- A summary of the K_{oc} for the fractions of TPH are provided in Table E-2.

- Table E-3 specifies the K_{oc} ranges assigned to the TPH mixtures at Kaiser.

- The calculated retardation factors are presented in Table E-4.

- The number of pore volumes to achieve cleanup goals at the site were calculated and are presented in Table E-5.

- The estimated pumping rates to achieve cleanup of the TPH plumes assuming a 30-year aquifer flushing treatment period are presented in Table E-6.

- The number of years to achieve cleanup from aquifer flushing, assuming the minimum pumping rates for hydraulic containment, are shown in Table E-7.

Oil House Plume

The footprint of the Oil House plume is 5.2 x 10^5 ft^2. The pumping rate to hydraulically contain the Oil House plume is estimated to be nearly 3,400 gpm. The estimated pumping rate to achieve cleanup of the Oil House plume within 30 years is 451,000 gpm. The estimated time to cleanup, assuming the pumping rate required for hydraulic containment, is 25,000 years.

Wastewater Plume

The footprint of the Wastewater plume is 4.7 x 10^5 ft^2. The pumping rate to hydraulically contain the Wastewater plume is estimated to be 2,900 gpm. The estimated pumping rate to achieve cleanup of the Wastewater plume within 30 years is 59,000 gpm. The estimated time to cleanup, assuming the pumping rate required for hydraulic containment, is 3,650 years.

Cold Mill Plume

The footprint of the Cold Mill plume is 1 x 10^5 ft^2. The pumping rate to hydraulically contain the Cold Mill plume is estimated to be 1,600 gpm. The estimated pumping rate to achieve cleanup of the Cold Mill plume within 30 years is 23,700 gpm. The estimated time to cleanup, assuming the pumping rate required for hydraulic containment, is 6,800 years.

Oil Reclamation Building Plume

The footprint of the ORB plume is 3.3 x 10^4 ft^2. The pumping rate to hydraulically contain the ORB plume is estimated to be 1,040 gpm. The estimated pumping rate to achieve cleanup of the ORB plume within 30 years is

5,100 gpm. The estimated time to cleanup, assuming the pumping rate required for hydraulic containment, is 4,600 years.

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Table E-1 - Groundwater Model-Predicted Pumping Rates Required for Hydraulic Containment of TPH Plumes

		Pumping Rates by Layer			Pumping Rates by Well			Total Pumping Rates for Containment	
Plume Name	**Well Location**	**Model Layer**	**in ft3/d**	**in gpd**	**in gpd**	**in gpm**	**Plume Name**	**in gpd**	**in gpm**
Oil House	41-71	1	207,183	1,549,726	2,618,000	1,818	Oil House	4,862,000	3,376
	41-71	2	142,817	1,068,274					
	44-71	1	204,980	1,533,249	2,244,000	1,558			
	44-71	2	95,020	710,751					
Wastewater	46-50	1	212,540	1,589,798	2,094,400	1,454	Wastewater	4,188,800	2,909
	46-50	2	67,460	504,602					
	49-54	1	213,844	1,599,550	2,094,400	1,454			
	49-54	2	66,156	494,850					
Cold Mill	46-86	1	228,924	1,712,349	2,318,800	1,610	East	2,318,800	1,610
	46-86	2	81,076	606,451					
Oil Reclamation Building	36-64	1	137,688	1,029,903	1,496,000	1,039	North	1,496,000	1,039
	36-64	2	62,312	466,097					

Table E-2 - Petroleum EC Fraction and K_{oc}

Petroleum Range	Petroleum EC Fraction	K_{oc} in L/kg
Gasoline	AL_EC >5-6	8.0E+02
	AL_EC >6-8	3.8E+03
	AL_EC >8-10	3.0E+04
	AL_EC >10-12	2.3E+05
Diesel	AL_EC >12-16	5.4E+06
	AL_EC >16-21	9.6E+09
	AL_EC >21-34	1.1E+10
Gasoline	AR_EC >8-10	1.6E+03
	AR_EC >10-12	2.5E+03
Diesel	AR_EC >12-16	5.0E+03
	AR_EC >16-21	1.6E+04
	AR_EC >21-34	1.3E+05

Note:

Source: Ecology 2001

Table E-3 - Petroleum Mixtures and K_{oc}

		K_{oc} in L/kg			
Petroleum Mixture	**EC Range**	**Min**	**Average**	**Geometric Mean**	**Max**
Gasoline	EC7 - EC12	1.6E+03	1.2E+05	1.9E+04	2.3E+05
Mineral Spirits	EC7 - EC12	1.6E+03	1.2E+05	1.9E+04	2.3E+05
Kerosene/Jet Fuel	EC10 - EC18	2.5E+03	4.8E+09	4.9E+06	9.6E+09
Diesel/Fuel Oil	EC12 - EC24	5.0E+03	5.4E+09	7.3E+06	1.1E+10
Kensol	EC16 - EC20	1.6E+04	4.8E+09	1.2E+07	9.6E+09
Heavy Oil	EC24 - EC37	1.3E+05	5.4E+09	3.7E+07	1.1E+10
Bunker C	EC12 - EC37	5.0E+03	5.4E+09	7.3E+06	1.1E+10
Motor Oil	EC24 - EC27	1.3E+05	5.4E+09	3.7E+07	1.1E+10

Note:

K_{oc} from Table E-2 based on Ecology 2001

Table E-4 - Calculating Retardation Factor for Petroleum Mixtures

Retardation Factor Calculations				
R	**K_{oc} in L/kg**	**f_{oc}**	**ρ_b in kg/L**	**n**
For Kensol				
7.0E+04	1.2E+07	0.001	1.7	0.3
For Diesel				
4.1E+04	7.3E+06	0.001	1.7	0.3
For Heavy Oil				
2.1E+05	3.7E+07	0.001	1.7	0.3

Notes:

R is the retardation factor calculated using the following equation

$R = 1 + (K_{oc})(f_{oc})(\rho_b/n)$

where

K_{oc} is the organic partition coefficient; geometric mean from Table E-3

f_{oc} is the fraction of organic carbon in the aquifer = 0.001

ρ_b is the bulk density of the aquifer - 1.7 kg/L

n is the aquifer porosity = 0.3

Table E-5 - Calculating Number of Pore Volumes for Specific Petroleum Mixtures

Range	Pore Volume Estimates			
	N_{pv}	R	C_s in mg/L	C_i in mg/L
Oil House				
Kensol	3.0E+05	7.0E+04	0.8	63
Wastewater				
Diesel	4.4E+04	4.1E+04	0.8	2.3
Heavy Oil	4.6E+04	2.1E+05	0.8	1
Cold Mill				
Kensol	8.2E+04	7.0E+04	0.8	2.6
Oil Reclamation Building				
Diesel	5.5E+04	4.1E+04	0.8	3
Heavy Oil	3.6E+05	2.1E+05	0.8	4.5

Notes:

The number of pore volumes to cleanup estimated using the batch flushing model based on the equation

$N_{pv} = -R\ln(C_s/C_i)$

where

N_{pv} is the number of pore volumes to achieve cleanup standard

R is the retardation factor

C_s is the cleanup standard or target concentration

C_i is the initial concentration; value used is the mean as presented in Table 5-15.

Table E-6 - Groundwater Pumping Rate Estimates Based on Pore Volume Flushing Volumes

Step 1

Plume Name	Aquifer Characteristics				Water Volume in ft^3
	Area in ft^2	Depth in ft	Volume in ft^3	Porosity	
Oil House	521,634	20	1.0E+07	0.3	3,129,804
Wastewater	474,956	20	9.5E+06	0.3	2,849,736
Cold Mill	101,600	20	2.0E+06	0.3	609,600
Oil Reclamation Building	32,720	20	6.5E+05	0.3	196,320

Step 2

Plume Name	N_{pv}	Total Volume in ft3
Oil House	303,931	9.5E+11
Wastewater	43,816	1.2E+11
Cold Mill	82,045	5.0E+10
Oil Reclamation Building	54,840	1.1E+10

Step 3

Plume Name	Pumping Rate per year for 30 years	
	in ft^3	in gpm
Oil House	3.2E+10	450,942
Wastewater	4.2E+09	59,193
Cold Mill	1.7E+09	23,710
Oil Reclamation Building	3.6E+08	5,104

Notes:

Pore volume flushing volumes in the plumes was calculated

Step 1: Estimate volume of contaminated groundwater in plumes of interest

Step 2: Estimate the amount of water to flush through the contaminanted portion of the aquifer using number of pore volumes estimated:

total volume of water = N_{pv}*water volume assuming mean concentrations

Step 3: Estimate the pumping rate to meet cleanup objectives: Pumping Rate = total volume/remediation period

Table E-7 - Summary of Pore Volume and Cleanup Time Estimates to Achieve Groundwater Cleanup Goals

Plume Name	Pore Volume Estimates	Time of Travel in Years	Time to Cleanup Under Existing Conditions in Years
Oil House	303,931	0.083	25,328
Wastewater	43,816	0.083	3,651
Cold Mill	82,045	0.083	6,837
Oil Reclamation Building	54,840	0.083	4,570

Notes:

Retardation factors and pore volume estimate calculations provided in previous Tables

Maximum time of travel calculated using particle tracking analysis and pumping rates presented in Table E-1

Time to cleanup calculated using equation: Tc = time of travel * pore volume estimate

Table E-8 - Calculation of Rough Order of Magnitude (ROM) Mass of Chemicals of Concern (COCs) for Groundwater Areas of Concern (AOCs)

General Area	COC	Samples/AOC ID	Area (feet^2) of TPH Plume	ROM Hydraulic Containment Pump Rate (GPD)[a]	Calculated Concentration[b] (mg/L)	ROM Mass of COC in one day of pumping (lbs)
ORB Area	Heavy oil	HL-MW-2 (24-Jan-08), HL-MW-2 (22-Apr-08), HL-MW-2 (19-Oct-08), HL-MW-20S (22-Oct-08), HL-MW-20S (20-Apr-08)	32,721	1,496,000	4.5E+00	5.43E+01
	Diesel	HL-MW-2 (24-Jan-08), HL-MW-2 (22-Apr-08), HL-MW-2 (19-Oct-08), HL-MW-20S (22-Oct-08), HL-MW-20S (20-Apr-08)	32,721	1,496,000	3.0E+00	3.64E+01
	cPAH	HL-MW-2 (24-Jan-08), HL-MW-2 (22-Apr-08), HL-MW-2 (19-Oct-08), HL-MW-20S (22-Oct-08), HL-MW-20S (20-Apr-08)	32,721	1,496,000	1.1E-05	1.28E-04
	Arsenic	HL-MW-20S (22-Oct-08), HL-MW-20S (20-Apr-08)	32,721	1,496,000	1.9E-03	2.27E-02
	Manganese	HL-MW-20S (22-Oct-08), HL-MW-20S (20-Apr-08)	32,721	1,496,000	1.9E-01	2.23E+00
	Iron	HL-MW-20S (22-Oct-08), HL-MW-20S (20-Apr-08)	32,721	1,496,000	2.2E-01	2.66E+00
Cold Mill/Finishing Areas	Heavy oil	CM-MW-1S (21-Apr-08), CM-MW-1S (19-Oct-08), CM-MW-2S (21-Apr-08), CM-MW-2S (20-Oct-08), CM-MW-3S (21-Apr-08), CM-MW-3S (21-Oct-08), CM-MW-7S (21-Apr-08), CM-MW-7S (20-Oct-08)	101,601	2,318,800	5.9E-01	1.10E+01
	Kensol	CM-MW-1S (21-Apr-08), CM-MW-1S (19-Oct-08), CM-MW-2S (21-Apr-08), CM-MW-2S (20-Oct-08), CM-MW-3S (21-Apr-08), CM-MW-3S (21-Oct-08), CM-MW-7S (21-Apr-08), CM-MW-7S (20-Oct-08)	101,601	2,318,800	2.6E+00	4.82E+01
	cPAH	CM-MW-1S (21-Apr-08), CM-MW-1S (19-Oct-08), CM-MW-2S (21-Apr-08), CM-MW-2S (20-Oct-08), CM-MW-3S (21-Apr-08), CM-MW-3S (21-Oct-08), CM-MW-7S (21-Apr-08), CM-MW-7S (20-Oct-08)	101,601	2,318,800	5.4E-06	9.95E-05
	Arsenic	CM-MW-1S (21-Apr-08), CM-MW-2S (21-Apr-08), CM-MW-3S (21-Apr-08), CM-MW-7S (21-Apr-08)	101,601	2,318,800	4.3E-03	7.90E-02
	Manganese	CM-MW-1S (21-Apr-08), CM-MW-2S (21-Apr-08), CM-MW-3S (21-Apr-08), CM-MW-7S (21-Apr-08)	101,601	2,318,800	1.2E-02	2.22E-01
	Iron	CM-MW-1S (21-Apr-08), CM-MW-2S (21-Apr-08), CM-MW-3S (21-Apr-08), CM-MW-7S (21-Apr-08)	101,601	2,318,800	1.9E-01	3.58E+00
Oil House Area	Kensol	OH-EW-1 (22-Oct-08), OH-EW-1 (23-Apr-08), OH-MW-10 (22-Oct-08), OH-MW-10 (22-Apr-08), OH-MW-13 (23-Apr-08), OH-MW-13 (23-Oct-08), OH-MW-18 (23-Apr-08), OH-MW-18 (22-Oct-08), OH-MW-24 (23-Oct-08), OH-MW-24 (24-Apr-08), OH-MW-25 (24-Apr-08), OH-MW-25 (23-Oct-08), OH-MW-26 (22-Apr-08), OH-MW-26 (23-Oct-08), TF-MW-1 (21-Oct-08), TF-MW-1 (24-Apr-08), TF-MW-2 (24-Apr-08), TF-MW-2 (21-Oct-08), TF-MW-3 (23-Apr-08), TF-MW-3 (20-Oct-08), TF-MW-4 (20-Oct-08), TF-MW-4 (24-Apr-08)	521,634	4,862,000	6.3E+01	2.46E+03
	cPAH	OH-MW-10 (22-Oct-08), OH-MW-10 (22-Apr-08), OH-MW-24 (23-Oct-08), OH-MW-24 (24-Apr-08), OH-MW-25 (24-Apr-08), OH-MW-25 (23-Oct-08), TF-MW-1 (21-Oct-08), TF-MW-1 (24-Apr-08), TF-MW-2 (24-Apr-08), TF-MW-2 (21-Oct-08), TF-MW-4 (20-Oct-08), TF-MW-4 (24-Apr-08)	521,634	4,862,000	1.9E-05	7.40E-04
	PCBs	OH-MW-4 (6/28/1994), OH-SK-1 (6/28/1994), OH-MW-6 (9/22/1991), OH-MW-16 (11/3/1993), OH-MW-3 (6/23/1994), OH-MW-5 (9/22/1991), OH-MW-26 (23-Oct-08), OH-MW-24 (23-Oct-08), OH-MW-20 (5/14/1992)	57,266	935,000	3.6E+01	2.69E+02
	Arsenic	OH-MW-10 (22-Oct-08), OH-MW-10 (22-Apr-08), OH-MW-24 (23-Oct-08), OH-MW-24 (24-Apr-08), OH-MW-25 (24-Apr-08), OH-MW-25 (23-Oct-08), TF-MW-1 (21-Oct-08), TF-MW-1 (24-Apr-08), TF-MW-2 (24-Apr-08), TF-MW-2 (21-Oct-08), TF-MW-4 (20-Oct-08), TF-MW-4 (24-Apr-08)	521,634	4,862,000	1.2E-02	4.61E-01
	Manganese	OH-MW-10 (22-Oct-08), OH-MW-10 (22-Apr-08), OH-MW-24 (23-Oct-08), OH-MW-24 (24-Apr-08), OH-MW-25 (24-Apr-08), OH-MW-25 (23-Oct-08), TF-MW-1 (21-Oct-08), TF-MW-1 (24-Apr-08), TF-MW-2 (24-Apr-08), TF-MW-2 (21-Oct-08), TF-MW-4 (20-Oct-08), TF-MW-4 (24-Apr-08)	521,634	4,862,000	5.2E-01	2.01E+01
	Iron	OH-MW-10 (22-Oct-08), OH-MW-10 (22-Apr-08), OH-MW-24 (23-Oct-08), OH-MW-24 (24-Apr-08), OH-MW-25 (24-Apr-08), OH-MW-25 (23-Oct-08), TF-MW-1 (21-Oct-08), TF-MW-1 (24-Apr-08), TF-MW-2 (24-Apr-08), TF-MW-2 (21-Oct-08), TF-MW-4 (20-Oct-08), TF-MW-4 (24-Apr-08)	521,634	4,862,000	3.1E+00	1.22E+02

Table E-8 - Calculation of Rough Order of Magnitude (ROM) Mass of Chemicals of Concern (COCs) for Groundwater Areas of Concern (AOCs)

General Area	COC	Samples/AOC ID	Area (feet^2) of TPH Plume	ROM Hydraulic Containment Pump Rate (GPD)[a]	Calculated Concentration[b] (mg/L)	ROM Mass of COC in one day of pumping (lbs)
Wastewater Treatment Area	Heavy oil	WW-EW-1 (23-Apr-08), WW-EW-1 (22-Oct-08), WW-EW-2 (24-Apr-08), WW-EW-2 (22-Oct-08), WW-MW-7 (24-Apr-08), WW-MW-7 (23-Oct-08), WW-MW-8 (24-Apr-08), WW-MW-8 (23-Oct-08), WW-MW-15 (24-Apr-08), WW-MW-15 (23-Oct-08), WW-MW-17 (24-Apr-08), WW-MW-17 (23-Oct-08), WW-MW-18 (24-Apr-08), WW-MW-18 (23-Oct-08), MW-14 (23-Apr-08), MW-14 (21-Oct-08), MW-21S (23-Apr-08) MW-21S (23-Oct-08), MW-22D (23-Apr-08), MW-22D (23-Oct-08)	474,956	4,188,800	6.0E-01	1.99E+01
	Diesel	WW-EW-1 (23-Apr-08), WW-EW-1 (22-Oct-08), WW-EW-2 (24-Apr-08), WW-EW-2 (22-Oct-08), WW-MW-7 (24-Apr-08), WW-MW-7 (23-Oct-08), WW-MW-8 (24-Apr-08), WW-MW-8 (23-Oct-08), WW-MW-15 (24-Apr-08), WW-MW-15 (23-Oct-08), WW-MW-17 (24-Apr-08), WW-MW-17 (23-Oct-08), WW-MW-18 (24-Apr-08), WW-MW-18 (23-Oct-08), MW-14 (23-Apr-08), MW-14 (21-Oct-08), MW-21S (23-Apr-08) MW-21S (23-Oct-08), MW-22D (23-Apr-08), MW-22D (23-Oct-08)	474,956	4,188,800	2.3E+00	7.62E+01
	Kensol	WW-EW-1 (23-Apr-08), WW-EW-1 (22-Oct-08), WW-EW-2 (24-Apr-08), WW-EW-2 (22-Oct-08), WW-MW-7 (24-Apr-08), WW-MW-7 (23-Oct-08), WW-MW-8 (24-Apr-08), WW-MW-8 (23-Oct-08), WW-MW-15 (24-Apr-08), WW-MW-15 (23-Oct-08), WW-MW-17 (24-Apr-08), WW-MW-17 (23-Oct-08), WW-MW-18 (24-Apr-08), WW-MW-18 (23-Oct-08), MW-14 (23-Apr-08), MW-14 (21-Oct-08), MW-21S (23-Apr-08) MW-21S (23-Oct-08), MW-22D (23-Apr-08), MW-22D (23-Oct-08)	474,956	4,188,800	1.1E-01	3.75E+00
	cPAH	WW-MW-7 (24-Apr-08), WW-MW-8 (24-Apr-08), WW-MW-8 (23-Oct-08), MW-21S (23-Apr-08), MW-21S (23-Oct-08)	474,956	4,188,800	7.8E-06	2.60E-04
	PCBs	WW-MW-6 (9/21/1991), WW-MW-8 (10/23/2008), WW-MW-11 (4/27/1994), WW-MW-13 (12/4/1991)	110,242	1,645,600	6.2E+00	8.16E+01
	Arsenic	WW-MW-18 (24-Apr-08), WW-MW-18 (23-Oct-08), MW-14 (23-Apr-08), MW-14 (21-Oct-08), MW-21S (23-Apr-08) MW-21S (23-Oct-08), MW-22D (23-Apr-08), MW-22D (23-Oct-08)	474,956	4,188,800	4.4E-03	1.47E-01
	Manganese	WW-MW-18 (24-Apr-08), WW-MW-18 (23-Oct-08), MW-14 (23-Apr-08), MW-14 (21-Oct-08), MW-21S (23-Apr-08) MW-21S (23-Oct-08), MW-22D (23-Apr-08), MW-22D (23-Oct-08)	474,956	4,188,800	1.5E-03	4.96E-02
	Iron	WW-MW-18 (24-Apr-08), WW-MW-18 (23-Oct-08), MW-14 (23-Apr-08), MW-14 (21-Oct-08), MW-21S (23-Apr-08) MW-21S (23-Oct-08), MW-22D (23-Apr-08), MW-22D (23-Oct-08)	474,956	4,188,800	8.1E-03	2.70E-01

Notes

a - The depth of groundwater impacts was conservatively assumed to be 20 feet in each of the AOCs

b - Based on four quarters of groundwater monitoring conducted in January, April, July, and October 2008. Concentration represents the average concentration of COCs in each AOC. One half of the reporting limit was used in averaging calculations if non-detect sample were present in the AOC.