CDM

14420 Albemarle Point Place, Suite 210
Chantilly, Virginia 20151
tel: +1 703 968-0900
fax: +1 703 968-0915

October 18, 2010

Ms. Laura Johnson
Remedial Project Manager
U.S. Environmental Protection Agency
1650 Arch Street
Philadelphia, PA 19103-2029

PROJECT: Contract No.: EP-S3-07-06
Work Assignment No.: 025-RICO-C368

DOCUMENT NO.: 3330-025-EO-CORR-01342
SUBJECT: Final Feasibility Study, Ravenswood PCE Superfund Site, Ravenswood West Virginia (DCN: 3330-025-RT-FEAS-01343)

Dear Ms. Johnson:

CDM Federal Programs Corporation (CDM) is pleased to submit two (2) copies of the Final Feasibility Study for the Ravenswood PCE Superfund Site. This report supersedes the Final FS submitted on September 20, 2010.

Note that one (1) copy of the Final FS has been sent to Mark Slusarski of the West Virginia Department of Environmental Protection under separate cover.

We appreciate the opportunity to support the EPA on this project. If you have any questions or comments, please contact me at [redacted].

Sincerely,

[redacted]

[redacted]
Project Manager
CDM Federal Programs Corporation

cc: J. Tralie, RAC III Project Officer (3HS42) (letter only)
M. Slusarski, Division of Land Restoration, WVDEP
[redacted], CDM Program Manager (letter only)
Document Control File

CDM

# U.S. Environmental Protection Agency Region III

## Ravenswood PCE Superfund Site
## Ravenswood, West Virginia

October 18, 2010

# *Final Feasibility Study*

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# Abbreviations and Acronyms

| | |
|---|---|
| 1,2-DCE | 1,2-dichloroethene |
| ARARs | Applicable or Relevant and Appropriate Requirements |
| AS | air sparge |
| bgs | below ground surface |
| CDM | CDM Federal Programs Corporation |
| CERCLA | Comprehensive Environmental Response, Compensation, and Liability Act |
| CLP | Contract Laboratory Program |
| COC | contaminant of concern |
| COD | Chemical Oxygen Demand |
| COPC | contaminant of potential concern |
| CSM | Conceptual Site Model |
| DNAPL | Dense Non-Aqueous Phase Liquid |
| DEP | Department of Environmental Protection |
| DPT | direct push technology |
| EPA | U.S. Environmental Protection Agency |
| ESL | Ecological Screening Levels |
| FS | Feasibility Study |
| ft | feet |
| ft msl | feet above mean sea level |
| ft/day | feet per day |
| GAC | granular activated carbon |
| GAI | GAI Consultants, Inc. |
| GPS | Global Positioning System |
| gpd | gallons per day |
| gpm | gallons per minute |
| HI | hazard index |
| HHRA | Human Health Risk Assessment |
| HQ | Hazard Quotient |

# Abbreviations and Acronyms (continued)

| | |
|---|---|
| ISB | in-situ bioremediation |
| lbs | pounds |
| Lockheed Martin | Lockheed Martin Technology Services Group |
| MCL | Maximum Contaminant Level |
| MNA | Monitored Natural Attenuation |
| MW | monitoring well |
| NAPL | Non-Aqueous Phase Liquid |
| NCP | National Contingency Plan |
| ND | non detect |
| O&M | operation and maintenance |
| OSHA | Occupational Safety and Health Administration |
| OSWER | Office of Solid Waste and Emergency Response |
| PARCC | precision, accuracy, representativeness, comparability and completeness |
| PCE | tetrachloroethene |
| POTW | Publicly Owned Treatment Works |
| ppmv | parts per million by volume |
| PRGs | Preliminary Remediation Goals |
| PWs | production wells |
| QA/QC | quality assurance/quality control |
| RAOs | Remedial Action Objectives |
| RPD | relative percent difference |
| RSLs | Regional Screening Levels |
| REAC | Response Engineering and Analytical Contract |
| RI | Remedial Investigation |
| ROD | Record of Decision |
| ROI | radius of influence |
| SARA | Superfund Amendments and Reauthorization Act of 1986 |
| SLERA | Screening Level Ecological Risk Assessment |
| scf | standard cubic feet |

# Abbreviations and Acronyms (continued)

| | |
|---|---|
| SOW | Statement of Work |
| SVE | soil vapor extraction |
| SVOCs | semi-volatile organic compounds |
| TBC | to be considered |
| TCE | trichloroethene |
| TCL | Target Compound List |
| TAL | Target Analyte List |
| TOC | Total Organic Carbon |
| TRV | Toxicity Reference Value |
| TS | Treatability Study |
| TSOP | Technical Standard Operating Procedure |
| ug/L | micrograms per liter |
| USGS | United States Geological Survey |
| VC | vinyl chloride |
| VI | vapor intrusion |
| VOCs | volatile organic compounds |
| VP | vapor monitoring point |
| VPGAC | vapor phase granular activated carbon |
| Weston | Roy F. Weston, Inc. |
| WVDEP | West Virginia Department of Environmental Protection |
| WVRWA | West Virginia Rural Water Authority |

# Section 1
# Introduction

## 1.1 Purpose and Organization of the Report

This Final Feasibility Study (FS) Report for the Ravenswood PCE Superfund Site (the Site), located in Ravenswood, Jackson County, West Virginia, has been prepared by CDM Federal Programs Corporation (CDM) for the U.S. Environmental Protection Agency (EPA) Region III, as authorized under Contract No. EP-S3-07-06 and Work Assignment No. 025-RICO-C368. This report supersedes all previously issued versions of the FS.

### 1.1.1 Purpose

This FS Report addresses contaminated groundwater at the Ravenswood PCE Site and considers alternatives that may provide a Site-wide remedy for groundwater. Information concerning the nature and extent of groundwater contamination at this Site was obtained from the following sources: the Interim Investigation Report by GAI Consultants, Inc. (GAI) (GAI, 2001), the 2001 Investigation Summary Addendum #1 (GAI, 2002), the Draft Hydrogeological Analysis Report (CDM, 2006a), the Technical Approach Report (CDM, 2006b), the Treatability Study System Installation and Baseline Conditions Report (CDM, 2010a), the Interim Evaluation of Treatability Study Effectiveness (CDM, 2010b), the Final Remedial Investigation (RI) Report (CDM, 2010d), a Direct Push Technology (DPT) Investigation conducted during February and March 2010, and several other sampling events.

The purpose of this FS Report is to document the basis and procedures used in identifying, developing, screening, and evaluating a range of remedial alternatives to remediate contaminated groundwater at the Site. The primary objective of this report is to provide the regulatory agencies with sufficient information to select a feasible and cost-effective remedial alternative that protects public health and the environment from the potential risks posed by groundwater contamination at the Site.

### 1.1.2 Report Organization

This FS Report is comprised of six sections as described below.

- **Section 1**, Introduction, provides a summary of Site background information including the Site description, Site history, description of physical characteristics of the Site, a summary of the nature and extent of contamination, a summary of the human health and ecological risk assessments, a summary of the ongoing Treatability Study (TS), and the Conceptual Site Model (CSM).

- **Section 2**, Identification and Screening of Remedial Technologies, develops a list of remedial action objectives (RAOs) by considering the characterization of contaminants, the results of the risk assessments completed for the Site, and compliance with Site-specific applicable or relevant and appropriate requirements (ARARs), Section 2 also defines preliminary remediation goals (PRGs); identifies general response actions; and identifies and screens remedial technologies and process options.

- **Section 3,** Development and Screening of Remedial Alternatives, develops remedial alternatives for the Site by combining feasible technologies and process options. Alternatives are described and an initial screening of the alternatives is performed based on effectiveness, implementability, and cost.
- **Section 4,** Description and Detailed Analysis of Alternatives, provides additional details on the alternatives that were retained and describes the detailed analysis of each alternative with respect to the following seven criteria: overall protection of human health and the environment; compliance with ARARs; long-term effectiveness and permanence; reduction of toxicity, mobility, or volume through treatment; short-term effectiveness; implementability; and cost.
- **Section 5,** Comparative Analysis of Alternatives, provides an overall comparison between the various remedial alternatives examined in Section 4.
- **Section 6,** References, provides a list of references used to prepare this FS Report.
- **Appendix A,** Interim Evaluation of Treatability Study Effectiveness, provides a full copy of the *Interim Evaluation of Treatability Study Effectiveness* report for additional TS information.
- **Appendix B,** Full Vapor Results, presents the complete set of vapor data collected to support the TS.
- **Appendix C,** Quality Assurance and Quality Control Report, provides a discussion of Quality Assurance and Quality Control samples collected to support the TS.
- **Appendix D,** Cost Estimates for Remedial Alternatives, presents FS level cost estimates for the remedial alternatives.

## 1.2 Site Location and Description

### 1.2.1 Site Location

The Ravenswood PCE Superfund Site is located in the City of Ravenswood (the City), West Virginia in Jackson County along the eastern bank of the Ohio River (**Figure 1-1**). The City covers an area approximately three miles long by one mile wide and has a population of over 4,000 people. The downtown business area of Ravenswood is located primarily along Washington Street (West Virginia State Route 68), with residential properties located in close proximity to the downtown area.

In general, the Site is comprised of the portion of the downtown area that is underlain by groundwater contaminated by tetrachloroethene (PCE). The plume extends approximately 1,400 feet northeast from the intersection of Broadway Street and Walnut Street, to the City of Ravenswood water supply well field on Virginia Street (**Figure 1-2**).

No contaminant sources have been confirmed during the previous phases of investigations; however, several potential sources were identified, including one potential source near the intersection of Sycamore Street and Virginia Street, as well as one near the intersection of Washington Street and Mulberry Street. Both of these potential sources are in the vicinity of the elevated PCE levels observed during various Site investigations.

## 1.2.2 Groundwater Use and Quality

### 1.2.2.1 City of Ravenswood Municipal Supply Wells

The residents and businesses in Ravenswood receive their water from the Ravenswood municipal water supply. The municipal supply is a blended system that combines the flow of up to seven production wells to meet the City's water needs. However, PCE contamination, first detected in 1989, has caused the recent shutdown of one production well and has contaminated two additional wells. A Venturi air stripper currently removes PCE to below regulatory limits. The City production wells are located north of Sycamore Street and east of Virginia Street. Three of the seven wells are located within the PCE plume that has affected the City water supply. The locations of the production and monitoring wells are shown on **Figure 1-2.**

The groundwater in Ravenswood is used as a source for municipal water supply. According to City personnel, the maximum well field capacity is approximately 1.1 million gallons per day (gpd) with a current average daily withdrawal of 858,000 gpd (GAI, 2001 and Cambarare, 2010).

City production well PW-3 has historically exhibited significantly higher PCE levels than the other production wells, with levels varying from under 10 micrograms per liter (µg/L) prior to March 1990 to as high as 91.4 µg/L in April 2000. In January 2010, the concentration of PCE in PW-3 was 29 µg/L.

Prior to the temporary shutdown of pumping in late January 2010, the City pumped PW-3 at an average rate of 200,000 gpd to control and contain the PCE plume as much as possible. The other supply wells were pumped at lower average rates:

- PW-1: 70,000 gpd,
- PW-2: 55, 000 gpd,
- PW-3: 200,000 gpd
- PW-4: 100,000 gpd,
- PW-5: 106,000 gpd,
- PW-6: 80,000 gpd, and
- PW-7: 55,000 gpd.

Following the temporary shutdown of PW-3 in January 2010, the City adjusted the pumping rates to make up for the removal of PW-3 from the pumping schedule. PW-3 was reactivated in May 2010; however, the water is being treated through the City's Venturi air stripper before being discharged to the Ohio River, rather than contributing to the City water supply. The current pumping rates are:

- PW-1: 132,000 gpd,
- PW-2: 138,000 gpd,
- PW-3: 100,000 gpd
- PW-4: 87,000 gpd
- PW-5: 150,000 gpd
- PW-6: 198,000 gpd, and
- PW-7: 156,000 gpd.

In addition to PW-3, PCE detections above the EPA Maximum Contaminant Level (MCL) continue to occur in six monitoring wells: (Department of Environmental Protection (DEP) monitoring wells DEP-5S, DEP-6, DEP- 7, DEP-8, monitoring well (MW)-06S, and MW-11S. Detections at levels less than the MCL continue to occur in PW-2, PW-5 and the finished water blend from the City production wells.

## 1.3 Site History

In October 1989, during routine health department analyses, PCE contamination was detected in two of the seven City of Ravenswood supply wells (PW-2 and PW-3) at levels exceeding the EPA MCL for PCE in drinking water. In January 1999, PW-5 exhibited contamination exceeding the MCL. Prior to February 2010, contamination had not been detected in PW-2 since August 1998. PW-2 is located approximately 50 feet to the north of PW-3, with both wells located inside the City Maintenance Building. Under natural, non-pumping conditions, or when PW-3 is operating, PW-2 is upgradient of PW-3. If PW-3 is operating, it captures PCE migrating from the west, blocking any contamination from reaching PW-2. When PW-3 was temporarily shut down by the City in February 2010, contaminated water was drawn past PW-3 into PW-2, and PCE was detected in PW-2.

PCE concentrations in the City's production wells and/or the finished water blend were monitored at various times from 1989 to 2010. PCE in the blended water exceeded the MCL on five occasions prior to November 1999 (GAI, 2001) but has not exceeded the MCL since the City installed a Venturi air stripper in 2000 to treat the extracted water.

### 1.3.1 Previous Investigations

In 1998, the West Virginia Rural Water Authority (WVRWA) requested the aid of EPA to address the contamination issue. Under EPA's direction, EPA's contractor, Roy F. Weston, Inc. (Weston), conducted a soil gas and groundwater survey (Weston, 1999). Based on the results of this study, EPA contracted Lockheed Martin Technology Services Group (Lockheed Martin) under the EPA Response Engineering and Analytical Contract (REAC) to install and collect samples from four monitoring wells (EPA-01 through EPA-04) (Lockheed Martin, 1999).

In 2000, Weston prepared a Site Inspection Narrative Report with the purpose of assessing the possible threat to human health and determining if additional investigations were warranted. Available data were used to prepare the report; no investigations were conducted during the task. Weston concluded that elevated concentrations of PCE were present in municipal well samples at levels significantly greater than background concentrations and that a significant threat to both human health and the environment was indeed posed by the existence of the contaminant (Weston, 2000).

With the assistance of an EPA Site Assessment Program grant, the West Virginia Department of Environmental Protection (WVDEP) contracted with GAI to perform additional groundwater and soil studies to further delineate the plume. In 2000, 37 Geoprobe® soil borings were advanced near suspected source areas. Groundwater samples were obtained from the production wells, the four monitoring wells, and from two levels within the aquifer in each of the soil borings. These results were presented in the Interim Investigation Report (GAI, 2001). In 2001, this study was expanded and an additional 18 Geoprobe® soil borings were advanced and seven additional monitoring wells were installed, DEP-05 (shallow and deep) through DEP-10. The results were reported in the 2001 Investigation Summary Addendum #1 (GAI, 2002).

During the investigatory work, the City installed a Venturi air stripper at the Ravenswood municipal well field to remove PCE from the drinking water and to eliminate the health threat from using contaminated groundwater for the City water supply. The air stripper, installed in May and June 2000, treats water from the contaminated production wells before the effluent is blended with the water from non-contaminated wells. From 1999 to late 2009, the only contaminated production wells have been PW-3 and PW-5; however, in early 2010, following the temporary shutdown of PW-3, low levels of PCE were detected in PW-2. Since the installation of the air stripper, analytical results have shown it is effective in removing PCE to below regulatory limits (GAI, 2002; CDM, 2010d). However, the Operator of the Ravenswood Water Treatment Plant reports that the Venturi air stripper requires frequent maintenance, and replacement parts are difficult to obtain (Cambarare, 2010).

In 2005, EPA requested that CDM perform additional characterization activities to better understand the extent of PCE contamination, the migration pathways, and the location of sources. CDM conducted a review of historic data and discovered discrepancies in well and soil boring locations that were rectified during a field Global Positioning System (GPS) survey. Based upon those data, EPA decided that no further monitoring wells should be installed at that time and that a groundwater flow model should be developed for the Site. CDM developed the groundwater flow model in early 2006. The model helped illustrate the complex flow conditions that occur during different water elevations of the Ohio River. The groundwater flow model also helped explain the mechanism by which PCE was transported to the Ravenswood pumping wells (CDM, 2006a).

In 2007, to collect additional data to complete the Human Health Risk Assessment (HHRA) and the Screening Level Ecological Risk Assessment (SLERA), as well as to evaluate the applicability of in-situ bioremediation and in-situ chemical oxidation, CDM conducted a groundwater sampling event to fill in data gaps identified in the 2006 Technical Approach Report for the Ravenswood PCE Superfund Site (CDM, 2006b).

In 2008, EPA authorized a Treatability Study (TS) to evaluate the effectiveness of an air sparge (AS) / soil vapor extraction (SVE) system in addressing the Site contamination. CDM relocated a portable treatment unit from the Vienna PCE Superfund Site, installed nine AS wells, three SVE wells, two shallow monitoring wells, and one vapor monitoring point to support the TS. The wells were located to help reduce the PCE concentrations in the vicinity of the City production wells during the TS.

During the TS system start up, and on a monthly basis afterwards, vapor samples were collected from vapor monitoring points and from different locations in the TS system. A baseline round of groundwater samples was collected during December 2008, and two additional rounds of groundwater monitoring were conducted in September 2009 and February 2010.

In 2010, to support a vapor intrusion (VI) study planned by EPA, CDM conducted a direct push technology (DPT) investigation to help identify the lateral extent of the plume and to further characterize the areas in the central portion of the plume. Thirty-two Geoprobe® soil borings were advanced across the Site, and 33 groundwater samples were collected (32 from the shallow groundwater and one from the deep groundwater).

Periodic sampling of the City water supply was conducted from December 2008 to March 2010 in conjunction with the TS and DPT investigation.

Groundwater and vapor data collected during March 2010 will be presented in the TS final report and are not discussed in this report.

## 1.4 Physical Characteristics of the Site

### 1.4.1 Surface Water Hydrology

The western boundary of the Site is approximately 50 feet from the Ohio River, which flows in a southeast direction. To the south of the Site, Sandy Creek flows west until it reaches the Ohio River. The southern portion of the Site is located in the 100-year flood plain of the Ohio River, which extends to the railroad tracks west of Race Street. The remainder of the Site is located outside the 100-year flood plain. In the vicinity of Ravenswood, the Ohio River is considered a riverine wetland and a high quality fishery area.

### 1.4.2 Geology and Hydrogeology

#### 1.4.2.1 Site Geology

The Site lies in a portion of the Ohio River floodplain known as the Ravenswood Bottom (Weston, 2000). Two hydrogeologic units that are significant to the movement of groundwater are present in this area: Pennsylvanian and Permian-Age (245 - 325 million years ago) Dunkard Group bedrock and the overlying Pleistocene-Age (11,000 - 1.8 million years ago) alluvium. A third unit of fine-grained, fluvially-deposited sediments overlies the alluvium but does not penetrate below the water table. Other units lie beneath the Dunkard Group but are assumed to be insignificant to the flow of groundwater in the study area due to the low permeability of this unit when compared to the overlying hydrostratigraphic units.

Jackson County lies near the southern end of the Dunkard sedimentary basin (Weston, 2000). Bedrock within the area consists of cyclic sequences of channel sandstones, lacustrine limestones, flat-lying shales and claystones (redbeds), and occasional coal beds (Cardwell, *et al.*, 1968). The dominant lithology of the Dunkard Group is sandstone (Kozar and Mathes, 2001). Bedrock across the Site is encountered from 65 to 90 feet below ground surface or at about 525 feet above mean sea level (ft msl). The bedrock is near ground surface in the hills at the perimeter of the study area.

Overlying the bedrock are unconsolidated, glacial-outwash, alluvial deposits of sand and gravel that form two prominent terraces on the Ravenswood Bottom. The lower terrace lies 30 to 40 feet above the normal pool elevation of the Ohio River, while the upper terrace lies 60 to 70 feet above the River (Weston, 2000). According to the United States Geological Survey (USGS) topographic quadrangle for Ravenswood, West Virginia, the normal pool elevation is 560 ft msl. Soil boring logs from Site monitoring well and Geoprobe® sampling locations show that the sand and gravel alluvium was encountered from 5 to 30 feet below ground surface and ranged in thickness from 48 to 85 feet. The sand is fine to coarse-grained, with some gravel and pebbles. Generally across the Site, medium-grained sands dominate within this layer. Lenticular interbeds of varying compositions are also not uncommon throughout the alluvium (Cross and Schemel, 1956). The water table occurs within this unit in the study area. This sand and gravel aquifer is considered unconfined.

Overlying the glacial outwash deposits are fluvially-deposited, fine-grained silts, clays, and sands deposited primarily by floods, (Kozar and McKoy, 2004). These sediments may be clay-rich near the surface, becoming coarser with depth (Weston, 2000). Site soil boring logs describe this layer as composed of silty sands and clayey sands with clay seams. The layer begins at the land surface and ranges in thickness from 5 to 30 feet. This unit occurs within the unsaturated zone in the study area.

#### 1.4.2.2 Site Hydrogeology

Aquifer characteristics of the hydrostratigraphic units in the study area were compiled from several sources including groundwater modeling reports for the region (Kozar and McCoy, 2004), published USGS West Virginia aquifer characteristics data (Kozar and Mathes, 2001) and Ravenswood well pump test data (West Virginia Rural Water Association, 1999).

The median horizontal hydraulic conductivity for the Dunkard Group bedrock is 3.3 feet per day (ft/day) (Kozar and Mathes, 2001). This value is one to two orders of magnitude lower than the range of values listed for the sand and gravel alluvium, which is 77 to 500 ft/day. Therefore, the occurrence and movement of groundwater in the bedrock is assumed to be negligible compared to the occurrence and movement of groundwater in the alluvium. The range of horizontal conductivities in the fine-grained alluvium is 0.1 to 8 ft/day.

The estimated vertical conductivities are based on the anisotropic ratios for the respective material types [$K_z = 0.1 K_{xy}$ (Domenico and Schwartz, 1990)]. Therefore, the vertical conductivity values are estimated to be 0.3 ft/day for bedrock; 8 to 50 ft/day for the sand and gravel; and 0.01 to 0.8 ft/day for the fine-grained alluvium.

The effective porosities for the sand and gravel unit range from 0.30 to 0.34, which are typical for sand and gravel. The effective porosities posted for the fine-grained alluvium range from 0.20 to 0.35. Note that these effective porosities are not based on Site-specific data. The values are from calibrated sub-regional groundwater flow models (Kozar and McCoy, 2004 and CDM, 2006a).

Bedrock is located approximately 90 feet below ground surface (bgs) in the vicinity of the City Maintenance Building; with groundwater present approximately 50 feet bgs.

## 1.5 Nature and Extent of Contamination

CDM performed four rounds of groundwater sampling from May 2007 to February 2010 to document the nature and extent of the groundwater contamination in support of the RI, the FS, the HHRA, the SLERA, and the ongoing TS.

### 1.5.1 Groundwater Sampling Program

Sixteen wells were sampled in May 2007. These wells included five production wells, seven monitoring wells installed by the WVDEP, and four monitoring wells installed by Lockheed Martin for the EPA. Twenty wells were sampled in December 2008 including seven production wells, seven wells installed by the WVDEP, and six wells installed for the EPA (two of which had been installed by CDM). Twelve wells were sampled in September 2009 including one production well (PW-3), five wells installed by the WVDEP, and six wells installed for the EPA (including two wells that had been installed by CDM). Eleven of the 12 wells sampled in September 2009 were sampled in February 2010 (PW-3 was not operational) along with PW-2 and PW-5.

During November 2009 and January 2010, two City production wells (PW-3 and PW-5) were sampled, and during March 2010, two City production wells (PW-2 and PW-5) were sampled.

Monitoring wells on the Site are screened at varying depths. There are three monitoring wells installed in the shallow groundwater, DEP-05S, MW-06S, and MW-11S. DEP-05S has a 10-foot screen from 63 to 73 feet bgs, and MW-06S and MW-11S have 20-foot screens, at depths from 44 to 64 feet bgs.

The remainder of the wells (EPA-1 through EPA-4, DEP-05D through DEP-10, and PW-1 through PW-5) were installed in the deeper groundwater. City wells PW-1 though PW-5 have 10-foot screens and are screened from approximately 82 to 93 feet bgs. EPA monitoring wells (EPA-1 through EPA-4) have 20-foot screens and are screened at depths ranging from 72 to 92 feet bgs to 77 to 97 feet bgs. DEP monitoring wells (DEP-05D through DEP-10) have 10-foot to 20-foot screens and are screened at varying depths. DEP-05D has a 10-foot screen from 80.5 to 90.5 feet. DEP-06 has a 10-foot screen from 76.5 to 86.5 feet bgs. DEP-07 has a 20-foot screen from 68 to 88 feet bgs. DEP-08 and DEP-10 have 20-foot screens from 59 to 79 feet bgs. DEP-09 has a 20-foot screen from 34 to 54 feet bgs.

One monitoring well (DEP-09) is located over 1000 feet to the south of the plume area, and two production wells (PW-6 and PW-7) are located a similar distance to the north of the plume area.

The remaining 14 wells are located within the plume area or in the immediate vicinity of the suspected source areas.

All groundwater samples collected during the May 2007 sampling event were analyzed for EPA's Target Compound List (organics)/Target Analyte List (metals) (TCL/TAL) compounds plus mercury and cyanide. Additionally, groundwater samples from two locations (DEP-06 and DEP-07) were analyzed for nitrate, sulfate, phosphate, chemical oxygen demand (COD), and total organic carbon (TOC). Samples from these two locations were also field analyzed for ferrous iron with a HACH kit, and ferric iron concentrations were calculated by subtracting the ferrous iron from the total iron in the sample.

Groundwater samples collected during the 2008 sampling events were analyzed for EPA TCL volatile organic compounds (VOCs) and semi-volatile organic compounds (SVOCs) by SOM01.2 for low or trace concentrations in water.

Groundwater samples collected during the 2009 and 2010 sampling events were analyzed for low and trace concentration VOCs via Method SOM01.2.

### 1.5.2 Contaminants of Potential Concern

Concentrations of contaminants found in the water samples were compared to Federal MCLs as well as Regional Screening Levels (RSLs) for drinking water. MCLs represent the maximum permissible level of a contaminant in drinking water. They are developed based upon health risk, detection limits, treatability, as well as the treatment costs associated with the best available technologies. The WVDEP standards for groundwater are identical to those established by the Federal Government.

RSLs are developed using protective default exposure scenarios suggested by the EPA and the best available reference doses and carcinogenic potency slope factors. They represent relatively protective environmental concentrations at which the EPA would typically not take action.

Any contaminant that was detected at a level exceeding either the MCL or RSL was considered a contaminant of potential concern (COPC). Three VOCs (PCE, trichloroethene (TCE), and bromodichloromethane) and five metals (arsenic, chromium, iron, manganese, and nickel) were determined to be COPCs. Of these, only PCE was detected above its MCL.

### 1.5.3 Distribution of COPCs

PCE is the primary COPC at the Ravenswood Site. Based on the February 2010 groundwater sampling event, four of the six samples containing PCE have concentrations exceeding the current MCL, with concentrations as high as 170 µg/L (MW-06S). The February/March 2010 DPT investigation identified a point at the intersection of Mulberry Street and Washington Street with a groundwater PCE concentration of 220 µg/L, as well as 14 additional points exceeding the MCL. The current plume distribution, based on the February 2010 groundwater sampling, the February/March 2010 DPT investigation, and the March 2010 City well sampling event, is presented in **Figure 1-3**.

PCE has been detected in both shallow and deep wells with the highest concentrations located in the upper portion of the aquifer in the vicinity of DEP-05S, with lower concentrations in the other shallow and deep wells. March 2010 sampling showed concentrations in the shallow groundwater ranged from Not Detected (ND < 0.5 μg/L) (in perimeter DPT locations) to 220 μg/L in DP-15. Concentrations in the deep groundwater ranged from ND in DEP-10 to 32 μg/L in DEP-08. One deep DPT point (DP-29D) in the parking lot of the City Maintenance Building had PCE at 4.8 μg/L.

During the recent sampling rounds (January and March 2010), PCE was detected in PW-2 (3.4 μg/L), PW-3 (29 μg/L), and PW-5 (1.4 μg/L). PW-3 was shut down in late January 2010 due to increasing PCE levels and was reactivated in April 2010.

The current (February/March 2010) distribution of PCE is consistent with the distribution observed in previous sampling events and the GAI investigation in 2001. The maximum observed concentration in DEP-05S decreased, following the maximum value of 1,200 μg/L detected in May 2007, to 69 μg/L in February 2010 as a result of the AS/SVE TS. The PCE plume extends from approximately the intersection of Broadway Street and Walnut Street north-northeast to the City Maintenance Building on Virginia Street.

Based on the May 2007 sampling event, the most recent event that included analysis for inorganics, inorganic COPCs are distributed across the Site and exceed RSLs in seven locations. The most prevalent inorganic COPC, manganese, was detected in seven wells. The sample collected from DEP-05S had five inorganic COPCs exceeding their respective RSLs. Samples were not collected from the City water supply for inorganic analysis during the May 2007 sampling event. A full discussion of the distribution of COPCs is presented in the Remedial Investigation Report (CDM, 2010d).

### 1.5.4 Contaminant Fate and Transport

An evaluation of the environmental fate and transport of contaminants within the study area is important in determining the potential for exposure to the contaminants. The fate and transport of the COPCs is determined by their physical and chemical properties, as well as the physical characteristics of the Site. The chemical and physical properties that affect the fate and transport of contaminants in the environment include: specific density, sorption, volatilization, dissolution/precipitation, photolysis, oxidation/reduction, hydrolysis, biodegradation, advection, diffusion, and dispersion.

The properties of the COPCs were examined in the HHRA (CDM, 2010c) that was completed concurrently with this FS. Important aspects of these properties with respect to PCE (the primary organic COPC) include the following:

1. PCE is denser then water in its non-aqueous phase; therefore, it has the potential to sink in the aquifer.

2. PCE is moderately to weakly sorbed to soil, producing low retardation factors.

3. PCE is highly volatile, indicating that it will partition from the aqueous state to the vapor state.

Based on this evaluation, it was determined that contaminant migration mechanisms that are active at the Site may include migration of the dissolved phase through the aquifer and migration of the vapor phase from the soil and groundwater through the unsaturated zone to air. However, based upon the relatively low PCE concentrations observed at the Site, these mechanisms will be relatively weak. Based on the near non-detect levels of PCE in vapor samples collected during the start up phase of the TS, there is no indication of residual non-aqueous phase liquid (NAPL) or of a significant source remaining in the vadose zone. This conclusion is reinforced by the February/March 2010 DPT study, which did not identify any areas with PCE levels consistent with a source area.

Because the PCE is primarily located in the groundwater phase, the dominant contaminant transport mechanism at the Site will be groundwater migration. The complex flow regime in the region is influenced by the stage of the Ohio River as well as the pumping rates of the City production wells. Groundwater flow modeling indicates that the majority of the plume is within the capture zone of the City production wells, specifically PW-3, with a smaller portion migrating toward the Ohio River. **Figures 1-4** and **1-5** illustrate the flow paths predicted under varying River stages and historic well production rates. In both scenarios, PW-3 captures the majority of the plume, thus protecting the remaining City production wells. The stagnation line dividing water that is in the capture zone of the production wells and water that will migrate to the Ohio River varies, but the line is in the vicinity of Race and Sycamore Streets.

As part of the groundwater monitoring event in May 2007, natural attenuation parameters (nitrate, phosphate, sulfate, COD, and TOC) were measured to determine if reductive dechlorination or natural biodegradation was occurring. The absence of PCE daughter products [TCE, cis-1,2 dichloroethene (cis-1,2 DCE), and vinyl chloride] in almost all analytical results indicate that the PCE is not being degraded. Additionally, the presence of nitrate and sulfate indicate that aerobic conditions are prevalent in the aquifer, and that reductive dechlorination, an anaerobic process, is not occurring on most of the Site.

However, during the 2010 DPT investigation, both TCE (8.6 µg/L) and cis-1,2 DCE (10 µg/L) were detected in the sample from DP-28, with PCE found only at 1.6 µg/L. DP-28 is located on the southwestern downgradient fringe of the plume, outside the area of the plume having greater than 5 µg/L PCE, and was the only sample where PCE daughter products were detected. The presence of these two daughter products indicates that anaerobic dechlorination of PCE is likely occurring in this area, with dechlorination proceeding to cis-1,2 DCE. This sampling point is located about 400 feet from the Ohio River, an environment where higher levels of organic material would be expected to be present in the subsurface sediments. The decay of this organic material could release gases, such as methane, that create the anaerobic conditions necessary for the dechlorination of PCE. This could produce a natural reductive dechlorination barrier that degrades the low levels of PCE flowing toward the Ohio River.

## 1.6 Human Health Risk Assessment Summary

Concurrent with this FS, CDM has prepared the Final Human Health Risk Assessment for the Ravenswood PCE Superfund Site (CDM, 2010c). A full discussion of the methods and results of the risk assessment can be found in the HHRA.

The HHRA addresses risks to human health as a result of contaminated groundwater and soil vapor at the Site. The purpose of the HHRA is to provide an analysis of baseline risks for determining cleanup levels which will adequately protect human health and the environment. This HHRA includes an exposure assessment, a toxicity assessment, and risk characterization. For the exposure assessment, qualitative and quantitative estimates of the magnitude, frequency, duration, and routes of exposure were developed. Pathways through which chemical contaminants may possibly migrate from source areas to potential receptors have been identified. As a result, the HHRA focused on groundwater pathways that directly affect residents of Ravenswood. The most likely current and future receptors for contaminated groundwater are area residents exposed to contaminated drinking water. The exposure includes ingestion of groundwater as well as inhalation of contaminants released from groundwater during showering and dermal contact with the water. A potential risk due to vapor intrusion has been identified, and it will be addressed separately from the groundwater risk.

The toxicity assessment used available toxicological data regarding the potential for either carcinogenic or toxic effects in exposed individuals. The risk characterization links the extent of exposure with toxicity information to predict the likelihood of potential adverse effects. For the risk characterization, toxicity and exposure assumptions were integrated into quantitative and qualitative expressions of carcinogenic risk and non-carcinogenic hazards. In general, EPA recommends target risk values (hazard index above 1 or risk above $1x10^{-4}$ to $1x10^{-6}$) to be used as threshold values for potential human health impacts.

Based on the results of the HHRA, cancer risks for adult, child, and lifetime (adult/child) residential receptors exceed EPA's target risk range of $1x10^{-4}$ to $1x10^{-6.}$ PCE is the predominant cancer Contaminant of Concern (COC), contributing over 99% of the total cumulative risk for these receptors. For non-cancer health hazards, the hazard index (HI) exceeds the threshold of unity for the adult and child residential receptors. However, when the HI is broken out by target organ, the individual target organ HIs do not exceed the threshold of unity for the adult resident. Therefore, non-carcinogenic health hazards are unlikely to occur in adult residents. The child resident HI exceeds unity for effects to the liver and body weight. The non-cancer COCs are PCE and nickel for the child receptors.

## 1.7 Ecological Risk Assessment Summary

CDM has prepared a Screening Level Ecological Risk Assessment for the Ravenswood PCE Superfund Site (CDM, 2010e). A full discussion of the methods and results of the ecological risk assessment can be found in the SLERA.

The SLERA addressed risks to ecological receptors as a result of contaminated groundwater at the Site. The purpose of the SLERA is to evaluate the potential ecological impact of contaminants at the Site. The SLERA includes an exposure assessment, an effects assessment, and a risk characterization. For the exposure assessment, qualitative and quantitative assessments of the exposure profiles for model receptor species were developed. Pathways through which chemical contaminants may possibly migrate from source areas to potential receptors were identified. As a result, the SLERA focuses on exposure to contaminated groundwater as well as contact with contaminants present in sediment, sediment pore water, and incidental ingestion. Exposure to higher trophic-level receptors may also occur through food chain exposure (ingestion of prey that has become contaminated by Site-related exposure).

The effects assessment used available data regarding the potential health effects in exposed biological receptors. Potential risks to ecological receptors were evaluated via the Hazard Quotient (HQ) approach. This process involves comparing the maximum contaminant concentrations measured at the Site to ecological screening levels (ESLs). Contaminants detected in groundwater samples that were considered bioaccumulative were evaluated through food chain exposure models using the mink, great blue heron, and belted kingfisher. For each receptor, a dose was calculated using conservative life history and exposure parameters. The resultant dose was then compared to a dietary-based toxicity reference value (TRV). For both approaches, a $HQ \geq 1$ indicated the potential for risk from exposure to contaminants at concentrations measured on the Site.

Based on comparison of maximum detected concentrations of contaminants in groundwater to conservatively derived ESLs, ecological risk was noted. Specifically, $HQs \geq 1.0$ were calculated for the following contaminants:

- VOCs: chloroform, toluene, and PCE
- SVOCs: bis (2-ethylhexyl)phthalate
- Total Inorganics: aluminum, arsenic, barium, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, nickel, selenium, and silver
- Dissolved Inorganics: barium, iron, manganese, and nickel

Results of the great blue heron and belted kingfisher models indicated the potential for risk from exposure to zinc. Risk from exposure to 1,2-dichloroethene, PCE, and 1,4-dichlorobenzene were not evaluated due to a lack of avian TRVs for these compounds. Results of the mink model indicated risk from exposure to PCE. In addition, the potential for risk from exposure to arsenic was also noted.

Based on the results of the SLERA, there is currently no risk to ecological receptors, as contaminants in groundwater have not reached a point where exposure to ecological receptors is expected. The assessment of future risk, as evaluated through the comparison of maximum Site concentrations with screening benchmarks and through food chain evaluations, indicates limited potential for ecological risk.

## 1.8 Treatability Study Summary

In 2009, CDM began an Air Sparge/Soil Vapor Extraction Treatability Study to evaluate the effectiveness of these two technologies together in addressing the PCE contamination at the Ravenswood Site. The pilot-scale treatability study system was installed during April and May 2009, and TS system startup occurred in June 2009. System installation was conducted in accordance with the Working Draft Treatability Study Plan (CDM, 2008a). A full description of the AS/SVE technology is discussed in Sections 3.2.7 and 4.2.4 and in the Interim Evaluation of Treatability Study Effectiveness (CDM, 2010b), which is attached to this report as **Appendix A**.

Baseline vapor samples were collected from the SVE wells (SVE-1, SVE-2, and SVE-3), dual purpose wells (MW-06S and MW-11S) and a vapor monitoring point (VP-1) immediately prior to and after the SVE TS system start up in June 2009. Samples were also collected prior to and following the initiation of TS air sparging (August 2009) and when the AS system was brought up to full capacity (September 2009). Following the activation of the unit at full capacity in September 2009, monthly samples were collected from the individual SVE wells, the dual purpose wells, the vapor monitoring point, and the influent and the effluent of the TS treatment unit.

PCE levels in vapor samples have remained relatively constant since the TS AS system was fully activated. Influent concentrations of SVE into the TS system have ranged from 0.304 parts per million by volume (ppmv) to 0.7094 ppmv. PCE levels in individual SVE wells have ranged from 0.2326 ppmv (SVE-1 in March 2010) to 1.6526 ppmv (SVE-3 in March 2010). Samples collected from SVE-3, on Sycamore Street near MW-06S, have consistently had the highest PCE levels, while samples from SVE-2 (0.1407 ppmv to 0.8474 ppmv), and SVE-1 (0.2326 ppmv to 0.3577 ppmv) have consistently had lower levels. Data for the vapor monitoring wells have shown increased PCE levels since the TS system startup, with values ranging from 0.0263 ppmv (MW-11S in September 2009) to 3.7931 ppmv (VP-1 in September 2009). PCE concentrations in MW-06S and VP-1 have remained above 2 ppmv, while concentrations in MW-11S have varied from 0.0263 ppmv to 0.852 ppmv. Full results from these sampling events are included as **Appendix B** to this report and a Quality Assurance/Quality Control discussion of these results is included as **Appendix C**.

Based on the results of the monthly vapor sampling conducted at the Site, the AS/SVE TS system has removed 3.3 pounds (lbs) of PCE from nearly 17,900,000 standard cubic feet (scf) of extracted soil vapor from system startup in June 2009 to March 2010. Trend graphs and tables presenting these data are included in the Interim Evaluation of Treatability Study Effectiveness (CDM, 2010b) provided in **Appendix A**.

The decreasing PCE values in monitoring wells in the vicinity of the AS wells (especially DEP-05S where observed PCE concentrations decreased from the May 2007 value of 1,200 μg/L to 69 μg/L in February 2010) indicate that PCE within the radius of influence (ROI) of the AS wells is being effectively sparged from the saturated zone. This conclusion is supported by the increased levels of PCE in the SVE and vapor monitoring wells. PCE levels in the SVE system influent indicate that the TS unit is capturing sparged PCE and retaining it on the vapor phase granular activated carbon (VPGAC) vessels. The relatively static PCE levels in wells outside the ROI of the AS wells are expected, as the AS is not affecting groundwater in these areas.

## 1.9 Conceptual Site Model

Based upon the available information from the investigations conducted at the Site, CDM projects that a small release or series of releases of PCE historically occurred from potential source(s) along a line from the intersection of Mulberry and Washington Streets to just north of the intersection of Virginia and Sycamore Streets, where the highest concentrations of PCE have been detected. The PCE migrated to groundwater, most likely through leaching by percolating precipitation, and was drawn northeastward due to the high-volume pumping at City wells PW-2, PW-3 and PW-5. PCE has been detected at levels above the MCL in PW-3 since 1989, creating a potential risk to human health. Since 2000, the City has treated water from wells PW-3 and PW-5 using a Venturi air stripper prior to entering the City's water distribution system.

The pumping at the City wells has likely had a controlling influence on the PCE plume, resulting in a long, thin plume of relatively low concentration PCE extending from between Broadway Street and Walnut Street to the City wells, and residing primarily in the upper portion of the aquifer. The PCE plume is approximately 400 feet wide by 1,400 feet long. The water table is located at approximately 50 to 60 feet bgs, and the bedrock surface is present at 90 feet bgs. As a result, the maximum thickness of the saturated zone is 40 feet. Using an assumed 20-foot thickness of the shallow zone, the estimated volume of contaminated shallow groundwater is 25,400,000 gallons with approximately 50.8 million gallons of groundwater in the shallow and deep zones. The current predicted area of the groundwater plume, based on February and March 2010 data, is shown on **Figure 1-3.**

The plume has been defined by the February/March 2010 DPT investigation, and is bound to the south by Broadway Street (DP-26), to the northwest by Sycamore and Washington Streets (DP-22), and to the southeast by Walnut and Washington Streets (DP-20). The plume tends to narrow to the north, toward the City's production wells. As discussed in the RI Report, there are several lines of evidence that indicate that no residual dense non-aqueous phase liquid (DNAPL) exists within the area of the TS or in the saturated aquifer. However, the presence of very small pockets of residual DNAPL in other areas of the vadose zone cannot be conclusively ruled out at this time.

Since 2000, the City has pumped PW-3 at an average rate of 200,000 gpd, with an average concentration of 32.7 µg/L. Concentrations of PCE in well PW-3 have been relatively stable since 2000, ranging from 14 µg/L to 30 µg/L, with the most recent sample from January 2010 at 29 µg/L. The water pumped from wells PW-3 and PW-5 has historically been treated using a Venturi air stripper, which removed approximately 9.39 lbs of PCE during 2009.

Based on the results of the monthly vapor sampling conducted at the Site, the AS/SVE TS system has removed 3.3 pounds (lbs) of PCE from nearly 17,900,000 standard cubic feet (scf) of extracted soil vapor from system startup in June 2009 to March 2010. Trend graphs and tables presenting these data are included in the Interim Evaluation of Treatability Study Effectiveness (CDM, 2010b) provided in **Appendix A**.

Based on information provided by the City, PW-3 was temporarily taken out of service in late January 2010, resulting in an increase in the pumping rate from the other City wells to maintain the supply in the distribution system. As of May 2010, the City resumed pumping PW-3 at approximately 100,000 gpd to maintain hydraulic control of the plume, and the City is treating the extracted groundwater with the Venturi air stripper prior to discharging it to the River, rather than contributing it to the City water supply.

# Section 2
# Identification and Screening of Remedial Technologies

The purpose of this section is to present the development of RAOs and to identify, screen, and select the most appropriate technologies to address contaminated groundwater at the Ravenswood PCE Site. The most representative technology types and process options are combined in Section 3 into remedial alternatives.

The identification and screening of remedial technologies is carried out in a step-wise manner. First, RAOs are developed in Section 2.1 based on the characterization of contaminants, the human health risk assessment, screening level ecological risk assessment, and compliance with Site-specific applicable or relevant and appropriate requirements and to be considered (TBC) requirements. Then, Site-specific ARARs and TBC requirements are identified in Section 2.2. COCs are identified in Section 2.3 and PRGs are identified in Section 2.4.

General response actions which address the contaminated groundwater and meet the RAOs are identified in Section 2.5. Potential technologies and process options associated with each response action are identified and screened based on effectiveness, implementability, and cost in Section 2.6. In addition, representative technologies and process options that have been retained for development of alternatives are described further in Section 2.6. These representative process options are intended to represent the broader range of applicable process options within a general technology type. The use of representative process options simplifies the development and analysis of alternatives while providing greater flexibility in the selected remedy.

## 2.1 Remedial Action Objectives

Several RAOs have been identified to mitigate the potential present and/or future risks associated with the Site to both human and ecological receptors. These RAOs include:

- Prevent human exposure, including ingestion, inhalation, and dermal contact by current and future residents and industrial workers to contaminated groundwater, to acceptable levels.

- Prevent the downgradient and offsite migration of contaminants in the groundwater to the Ohio River and Sandy Creek.

- Remediate contaminated groundwater to meet regulatory requirements.

The EPA target for remediation of Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) sites is to reduce human health risk from a site to within a target range of $1 \times 10^{-4}$ to $1 \times 10^{-6}$ increased incidences of cancer health effects, and to reduce the HI to below the threshold of unity for non-cancer health effects based on site contamination.

Remedial actions can be developed to protect human health and the environment using engineering controls (e.g., removing or isolating contaminants) or institutional controls (e.g., limiting access to the groundwater). Depending on the extent of the institutional controls, the engineering controls can be designed to reduce risk to acceptable levels. Acceptable levels have been defined as Federal and State remediation goals and standards (e.g., West Virginia Groundwater Standards, Federal MCLs), which were considered during the development of the preliminary remediation goals in Section 2.4 of this FS.

The medium being considered for implementation of remedial alternatives is the groundwater within the contaminant plume located in the area southwest of the City of Ravenswood production wells, extending from the intersection of Race Street and Walnut Street to PW-3. A Venturi air stripper is currently in use by the City to reduce the levels of PCE in the City water supply to levels below the MCL.

## 2.2 Site-Specific ARARs and TBCs

Section 121 of CERCLA specifies that remedial actions for cleanup of hazardous substances must comply with Federal or State environmental regulations and laws that are either applicable or relevant and appropriate to that substance or particular circumstance at a site.

Inherent in the interpretation of ARARs is the assumption that protection of human health and the environment is ensured. The primary concern in developing RAOs for a hazardous waste site under CERCLA is defining the degree of protection for each proposed remedy. Section 121 of the Superfund Amendments and Reauthorization Act of 1986 (SARA) requires that primary consideration be given to remedial alternatives that attain or exceed ARARs. The purpose of this requirement is to make response actions executed under CERCLA comply with all pertinent Federal and State environmental requirements.

This section provides a preliminary discussion of the regulations that are applicable or relevant and appropriate to the remediation of groundwater at the Ravenswood PCE Site. Both Federal and State of West Virginia environmental regulations and public health requirements are considered. In addition, this section identifies Federal and State criteria, advisories, and guidance that could be used for evaluating remedial alternatives.

### 2.2.1 Definition and Types of ARARs

EPA defines "Applicable Requirements" as those cleanup standards and requirements promulgated under Federal or State environmental or siting laws that specifically address a hazardous substance or chemical, remedial action, or location at a CERCLA site. Applicable requirements must directly and fully address the situation at the site. For example, the Safe Drinking Water Act is an applicable requirement for this Site, because it establishes specific limits on contaminants in public drinking water supplies, including groundwater in the vicinity of the Ravenswood PCE Site that is used as a drinking water source.

EPA defines "Relevant and Appropriate Requirements" as those cleanup standards and requirements promulgated under Federal or State environmental or siting laws that, while not directly applicable, are deemed well suited to address a hazardous substance or chemical, remedial action, or location at a CERCLA site. For example, the Clean Water Act is a relevant and appropriate requirement, because it provides for protection of surface waters that may be affected by Site contaminants.

State ARARs are used when similar Federal ARARs do not exist. Additionally, State ARARs take precedence over Federal counterparts when they are: 1) more stringent and 2) broader in scope than the Federal requirements.

ARARs are not currently available for every chemical, location, medium, or action that may be encountered. When ARARs are not available, remediation goals may be based upon other Federal or State criteria, guidance, or local ordinances. This information is known as "To Be Considered" or TBC. ARARs and TBCs are both used during the FS process to evaluate the remedial alternatives. ARARs and TBCs are evaluated and, as appropriate, may be used to derive PRGs that can be utilized throughout the FS process. These PRGs are developed such that they meet the intent of the ARAR or TBC to be protective of human health and the environment.

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

**Chemical-specific**: These ARARs and TBCs define acceptable exposure levels for a specific contaminant in an environmental medium and are used in establishing PRGs. They may be actual concentration-based cleanup levels, or they may provide the basis for calculating such levels. Examples of chemical-specific ARARs are drinking water standards for groundwater.

**Location-specific**: These ARARs and TBCs set restrictions on remedial activities at a site due to its proximity to specific natural or man-made features. Examples of location-specific ARARs are West Virginia groundwater protection regulations that provide for wellhead protection in vulnerable areas.

**Action-specific**: These ARARs and TBCs set controls or restrictions for particular remedial activities related to the management of hazardous substances. Selection of a particular remedial action at a site will invoke the appropriate action-specific ARARs that specify performance standards or technologies, as well as specific environmental levels for discharged or residual chemicals. Examples of action-specific ARARs are hazardous waste listing and disposal requirements.

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

Chemical, location, and action-specific ARARs for the Ravenswood PCE Site are presented in **Table 2-1.**

## 2.3 Identification of Contaminants of Concern

Based on the human health and ecological risk assessments conducted as part of the investigation activities at the Ravenswood Site, PCE was identified as a COC for groundwater. PCE is the primary risk driver for both cancer and non-cancer health effects.

## 2.4 Preliminary Remediation Goals

The PRGs for groundwater, the only medium addressed in this FS, has been set at the MCL for PCE. The PRG for PCE daughter products detected at the Site (TCE, cis-1,2 DCE, and trans-1,2 dichloroethene) have been set at the respective MCLs for these compounds; however, only one sample exceeded the MCL for TCE, and no samples exceeded the MCLs for either form of 1,2 dichloroethene.

## 2.5 General Response Actions

General response actions are defined as actions which may satisfy the RAOs and which characterize the range of remedial responses appropriate to the medium of concern at a site. Although an individual response action may be capable of satisfying the RAOs alone, combinations of response actions are usually required to adequately address site contamination. General response actions applicable to the Ravenswood PCE Site are described below.

### *No Action*

The NCP and SARA require the evaluation of a No Action alternative as a basis for comparison with other remedial alternatives. Under the No Action alternative, no remedial actions are implemented and the current status of the Site remains unchanged. For the Ravenswood PCE Site, a five-year review would be conducted to determine whether contamination has migrated beyond the presently defined extent. If necessary, appropriate action would be considered at that time.

### *Institutional Controls*

Institutional controls are limited measures that are implemented to minimize human exposure and to continue monitoring to track contaminant migration. Institutional controls are generally used in conjunction with other remedial action technologies. Alone they are not effective in protecting public health or the environment, preventing contaminant migration, or reducing contamination. Restriction of access to the contaminated source areas and the imposition of institutional controls (e.g., groundwater use restrictions) on future land use would be considered to provide some protection to human health and the environment.

### *Extraction*

Extraction technologies for groundwater typically involve extraction of the contaminant plume using extraction wells or interceptor trenches. This method reduces the mobility of the contaminants through physical removal or by changing the hydraulic gradient in the surrounding area. The selection of an appropriate groundwater collection system depends on the objectives of the remedial action, the depth of contamination, and the geologic and hydrogeologic characteristics of the aquifer. Extraction technologies are generally used in combination with treatment technologies.

*Containment*
Containment technologies consist of measures which physically isolate contaminants to eliminate routes of exposure or to reduce the rate of migration. Containment technologies may reduce contaminant movement, but do not involve treatment to reduce the toxicity or volume of the contaminants at a site. These technologies require long-term monitoring to determine whether containment measures are performing successfully.

*Treatment*
This category of response action is conducted to reduce the toxicity, mobility, and/or volume of contaminants by physical, chemical, biological, or thermal processes. Treatment systems can be located on site using mobile units or more permanent treatment plants contained within buildings, or located off site at a treatment facility. Treatment may also be performed ex-situ (above ground) or in-situ (in place below ground). Treatment to reduce toxicity or mobility includes methods to destroy or modify the properties of the chemical to render it less harmful. Treatment to reduce volume includes concentrating contaminants. The use of treatment technologies to achieve RAOs is favored by SARA, unless site conditions limit their application. Treatment technologies generally afford a higher degree of protection to public health and the environment.

*Discharge*
Discharge technologies are necessary to release extracted and treated groundwater back into the environment. They include release to a receiving body, such as surface water or a Publicly Owned Treatment Works (POTW), or infiltration into the aquifer. Discharge technologies do not reduce volume, risk, or toxicity, but are needed as an end-point of treatment and/or extraction of contaminated groundwater.

## 2.6 Identification and Screening of Remedial Technologies and Process Options

This section describes the methodology employed for the technology and process option identification and screening process for the FS prior to assembling remedial alternatives and presents the results of the screening evaluations. The technology screening approach that was followed is based upon the procedures outlined in "Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA" (EPA, 1988).

The screening level evaluation process uses three criteria: Effectiveness, Implementability, and Relative Cost. The guidance document recommends that this evaluation focus on the Effectiveness criterion, with less emphasis directed at the Implementability and Relative Cost criteria. Brief definitions of effectiveness, implementability, and relative cost, as they apply to the screening process, follow:

> **Effectiveness** – This evaluation criterion focuses on the potential effectiveness of process options in handling the estimated quantity of media and meeting the remedial goals, the potential impacts to human health and the environment during construction and implementation, and how proven and reliable the process is with respect to the contaminants and conditions at the site.

**Implementability** - This evaluation criterion encompasses both the technical and administrative feasibility of the technology or process option. It includes an evaluation of pretreatment requirements, residuals management, and the relative ease or difficulty in performing the operation and maintenance requirements. Process options that are clearly ineffective or unworkable at the site are eliminated.

**Relative Cost** - Cost plays a limited role in the screening process. Capital costs as well as operation and maintenance costs are considered. The cost analysis is based on engineering judgment, and each process is evaluated as to whether costs are low, moderate, or high relative to the other options within the same technology type.

Based on the evaluation criteria above, technologies and process options were screened from further consideration in the FS. Documentation of the identification and screening process is provided in **Table 2-2**. Technologies and process options that were retained following the screening process are marked with a "Y" in the "Retained (Y/N)" column. The technologies and process options that passed the screening step are described below.

Only those technologies and process options which have been retained are considered for the development of alternatives. With the exception of "No Action" (required by the NCP), the retained technologies and process options are those that are expected to achieve the RAOs for the Site, either alone or in combination with other technologies and process options. Combinations of these technologies and process options are considered to constitute the reasonable alternatives which are required by the NCP. The following is a list of the technologies and process options that were retained.

- No Action

- Institutional Controls
  - Groundwater Monitoring
  - Groundwater Use Restrictions

- Extraction
  - Extraction Wells

- Groundwater Treatment
  - Monitored Natural Attenuation
  - In-Situ Bioremediation
  - Air Stripping/Venturi
  - Carbon Adsorption
  - In-Situ Air Sparging / Soil Vapor Extraction
  - In-Situ Chemical Oxidation

Brief descriptions of each of these technologies and process options that have been retained are provided below.

### 2.6.1 No Action

The No Action alternative is developed as required by the NCP and evaluated to establish a baseline for comparison with other remedial alternatives. For the Ravenswood PCE Site, a review would be conducted every five years to determine whether or not the contamination has spread beyond the currently defined extent. If necessary, appropriate action would be considered at that time.

### 2.6.2 Institutional Controls

*Groundwater Monitoring*

Groundwater monitoring is useful in tracking contaminant levels in the groundwater to evaluate the effectiveness of a treatment system. While monitoring alone will not affect exposure to contaminated groundwater, it is a useful tool for measuring the performance of a selected remedy.

*Groundwater Use Restrictions*

Groundwater use restrictions limit exposure by preventing the extraction and use of contaminated groundwater by the general public. While use restrictions will not affect contaminant levels, they are a useful tool for preventing the installation of groundwater wells or restricting the use of existing wells.

### 2.6.3 Extraction

Groundwater extraction technologies involve the active manipulation and management of groundwater prior to subsequent treatment and/or disposal. Extraction technologies are used to remove the contaminated groundwater from the aquifer and to physically prevent or reduce contaminant plume migration. The selection of an appropriate groundwater extraction system depends on the depth of contamination and the hydrogeologic characteristics of the aquifer.

*Extraction Wells*

The extraction well system uses a single or multiple groundwater extraction wells to collect and extract the groundwater within or downgradient of the contaminant plume. This system is most useful in hydrogeologic formations with moderate or high permeability and when the flow of contaminated groundwater must be controlled over a small area. It creates a continuous zone of influence in which groundwater (and contaminant) flow is directed toward the extraction wells.

### 2.6.4 Groundwater Treatment

*Monitored Natural Attenuation*

Monitored natural attenuation (MNA) is an approach whereby periodic monitoring is performed for specific parameters to verify that natural attenuation processes (biodegradation, dispersion, sorption, and volatilization) are effective in preventing the contaminant plume from migrating further downgradient. This method is most appropriate for sites where it has been determined that the contaminant plume is either reducing in size or is being maintained by natural processes.

Natural attenuation in groundwater systems results from the integration of several subsurface attenuation mechanisms that are classified as either destructive or nondestructive.

Biodegradation is the most important destructive attenuation mechanism, although abiotic destruction of some compounds may also occur. Chlorinated solvents such as PCE typically are biodegraded under natural conditions via reductive dechlorination, a process that requires both electron acceptors (the chlorinated hydrocarbons) and an adequate supply of electron donors (food source). Electron donors include fuel hydrocarbons or other types of natural organic carbon. In general, highly substituted chlorinated organics (PCE, TCE) are more readily degraded under anaerobic conditions, while the breakdown products (1,2-DCE and vinyl chloride (VC)) may be degraded faster under aerobic conditions.

### *In-Situ Bioremediation*

In-situ bioremediation (ISB) involves the addition of substrate or nutrients to an aquifer to stimulate the growth of a target consortium of bacteria. Usually, the target bacteria are indigenous; however, enriched cultures of bacteria (from other sites) that are highly efficient at degrading a particular contaminant can be introduced into the aquifer (bioaugmentation).

ISB is used when it is desired to increase the rate of contaminant biotransformation, which may be limited by lack of required nutrients, electron donors, or electron acceptors. The type of amendment required depends on the target metabolism for the contaminant of interest. Aerobic ISB may only require the addition of oxygen, while anaerobic ISB often requires the addition of an electron donor (e.g., lactate, cheese whey). Chlorinated solvents, in particular, often require the addition of a carbon substrate to stimulate reductive dechlorination. The goal of accelerated ISB is to increase the biomass throughout the contaminated aquifer, thereby achieving effective biodegradation of dissolved contaminants.

Delivery of electron donors or nutrients is typically the limiting factor in the effectiveness of this technology, generally due to limitations in the soil conductivities at a site. Rapid growth of bacteria can also cause a reduction in hydraulic conductivity or plugging of the injection well. The radius of influence of the delivery mechanism can also be limited because of the technology or as a result of high concentrations of bacteria around the injection point.

### *Air Stripping*

Air stripping is a mass transfer process in which volatile contaminants in extracted water are transferred to a gaseous phase. This process works best on contaminants with high volatility and low solubility (i.e., high Henry's Law constant). Several contacting systems can be used, such as mechanical surface aerators, diffused aeration, spray or tray towers, open channel cascades, spray fountains, counter-current packed towers, and Venturi air strippers. The tray tower and packed tower are the most commonly used processes in which water cascades down through a packing material while air is forced up through the packing by means of a blower. Primary factors which govern the efficiency of the process include the air-to-water ratio, pressure drop, tower height, surface area of the packing material, contact time, and temperature of the effluent. The use of steam or heated influent air can be used to increase temperature and improve removal efficiencies, particularly for compounds which are less volatile and more soluble.

A Venturi air stripper introduces air directly into the water line leading from the pumping well, thereby aerating all of the water that is pumped. A Venturi nozzle is installed in the water line, and water is forced through the nozzle at high velocity. The passage of the high velocity water jet creates a suction that draws atmospheric air into the water stream. The primary factor which governs the efficiency of the air stripping process is the air-to-water ratio.

Pretreatment of suspended solids and inorganics such as iron and manganese (which become oxidized and precipitate out) may be necessary to avoid deposition on and subsequent clogging of the air stripper. In addition, pH adjustment may be a consideration to minimize the buildup of bacterial slime in the unit. Treatment of the offgas may be required prior to discharge to the atmosphere, depending on contaminant levels and location of potential receptors. Offgas treatment can be accomplished using vapor phase carbon adsorption or catalytic oxidation.

### *Carbon Adsorption*

Carbon adsorption removes contaminants from aqueous or vapor phase waste streams via surface attachment between the organic solutes and the large internal pore structure of the activated carbon. The major parameters which influence the effectiveness of the adsorption process include the solubility of the organic compound (low solubility compounds are more readily removed), the relative humidity and temperature of the influent, contact time within the unit, and the surface area to volume ratio of the adsorbent. Typical activated carbon adsorption treatment systems include gravity flow or pressure flow columns in series and/or parallel configurations with backwashing capabilities. This technology can treat single-phase waste streams with high molecular weights, high boiling points, low solubility and polarity, and relatively non-polar chlorinated hydrocarbons and aromatics. The process is most effective for aqueous streams with low suspended solids and no floating oil. As a result, a pre-treatment step is often required. The process can be used as a primary removal mechanism or as a polishing step following another organics treatment step, such as air stripping. The spent carbon must be regenerated at an appropriate facility, incinerated, or disposed of as a hazardous material.

### *In-Situ Air Sparging with Soil Vapor Extraction*

In-situ air sparging is a technique in which air is injected into the groundwater aquifer for the purpose of removing organic contaminants by a combination of volatilization and aerobic biodegradation processes. It is typically used in conjunction with SVE to eliminate offsite migration of vapors. Air sparging is relatively simple to implement and capital costs are modest. However, like most subsurface remediation techniques, in-situ air sparging relies on the interactions between complex physical, chemical, and biological processes. A treatability study and/or pilot testing may be necessary to design a system appropriate for specific site conditions. Air injection wells are generally placed below the targeted contaminants in a barrier pattern across the treatment area, to induce lateral spreading of air away from the injection wells. As the injected air moves up through the groundwater, volatile organic compounds partition into the gas phase and are transported to the vadose zone. At the same time, oxygen in the injected sparge air dissolves in the groundwater. This oxygen may also serve to stimulate the aerobic biodegradation of organic contaminants.

Air sparging is often paired with SVE to capture the released vapors. SVE is a technique in which a vacuum is applied to the vadose zone where contaminant vapors are present either due to the presence of a continued source or as a result of volatilization from a groundwater plume. Air present in the vadose zone (either naturally or injected during air sparge operations) is captured by the vacuum system and extracted and transported to a treatment unit where the contaminants are sequestered (e.g., on carbon) prior to the clean air being discharged. SVE is relatively simple to implement, and capital costs are modest. Like air sparging, SVE may require a treatability study to design a system appropriate for specific site conditions. SVE wells are generally placed in the vicinity of, but offset from, the AS wells to maximize contaminant capture efficiency.

### *In-Situ Chemical Oxidation*

In-situ chemical oxidation is a technology in which oxidizing compounds are injected into the groundwater in order to destroy chlorinated and non-chlorinated organic compounds in the subsurface. The oxidizing agent reacts with the organic contaminants to completely mineralize simple contaminants to carbon dioxide and water, and chloride ions (when chlorinated organics are being treated). Complex contaminants are transformed to simple, less toxic, compounds. The destruction occurs by cleavage of carbon-carbon bonds, creating fragments of the parent compound. Oxidizing agents include hydrogen peroxide, Fenton's reagent (catalyzed hydrogen peroxide), or potassium permanganate, which are all strong oxidizing agents. Hydroxyl radicals are formed and are the principal oxidant involved in the Fenton's process. The reaction occurs rapidly in the environment and is considered an aggressive treatment technology.

# Section 3
# Development and Screening of Remedial Alternatives

In this section, remedial alternatives for the Ravenswood PCE Site are assembled by combining the remedial technologies and process options which were retained following the screening step performed in Section 2. These alternatives were then screened against the general EPA evaluation criteria of effectiveness, implementability, and cost.

## 3.1 Remedial Alternative Development

### 3.1.1 Alternative Development Criteria

Alternatives developed in this section are designed to satisfy the Remedial Action Objectives described in Section 2. In addition, alternative development must conform to the requirements of CERCLA, as amended by SARA, and to the extent possible, the NCP. Section 300.68 of the NCP specifically refers to ARARs in the development of alternatives. CERCLA Section 121(d) requires that Superfund remedial actions attain ARARs or other Federal statutes. Superfund remedial actions must also attain State requirements that are more stringent than Federal requirements to the extent that they are also applicable or relevant and appropriate and are identified in a timely manner.

CERCLA Section 121(b) identifies the following statutory preferences that must be considered when developing and evaluating remedial alternatives:

- Remedial actions that involve treatment that permanently and significantly reduces the toxicity, mobility, or volume of the hazardous substances are preferred over remedial actions not involving treatment.
- Offsite transport and disposal of hazardous substances or contaminated materials without treatment is considered the least favorable remedial alternative when practical treatment technologies are available.
- Remedial actions using permanent solutions, alternative treatment technologies, or resource recovery technologies should be assessed.

EPA Office of Solid Waste and Emergency Response (OSWER) Directive Number 9355.0-19, dated December 24, 1986, provides guidance regarding implementation of CERCLA amendments during the remedy selection process. This directive states that the treatment alternatives should range from an alternative that, to the degree possible, would eliminate the need for long-term management (including monitoring) at the site to alternatives involving treatment that would reduce toxicity, mobility, or volume. This directive also indicates that a containment alternative (involving little or no treatment) and a no action alternative should be developed. These statutory preferences and the RAOs identified in Section 2.1 have been considered in developing and evaluating the various remedial alternatives.

### 3.1.2 Combination of Potentially Applicable Remedial Technologies into Remedial Alternatives

The potentially applicable technologies remaining after the initial screening in Section 2 have been combined into seven remedial alternatives, as follows:

Alternative 1: No Action

Alternative 2: Monitored Natural Attenuation

Alternative 3: Groundwater Extraction and Treatment Using Carbon Adsorption

Alternative 4: In-Situ Bioremediation

Alternative 5: Air Stripping

Alternative 6: In-Situ Chemical Oxidation

Alternative 7: In-Situ Air Sparging with Soil Vapor Extraction

Alternatives 1 and 2 do not include any extraction or treatment of contaminated groundwater.

Alternatives 3 and 5 include extraction and treatment of contaminated groundwater. The extraction/collection and treatment alternatives use extraction wells to extract and collect groundwater, and discharge to the Ohio River or the City water supply system following treatment. The extraction and treatment alternatives also employ granular activated carbon (GAC) or a Venturi air stripper.

Alternatives 4 and 7 are in-situ treatment methods for groundwater. The in-situ treatment alternatives include the installation of injection wells and the injection of an oxidizing agent or viable bacteria population directly into the groundwater.

Alternative 6 is a combination of in-situ and ex-situ treatment methods for groundwater. It involves the injection of clean air into the subsurface (in-situ) coupled with a soil vapor extraction system to remove and capture the contaminated vapors followed by ex-situ vapor treatment.

Alternatives 2 through 7 would incorporate periodic monitoring as well as groundwater use restrictions to prevent the installation of additional production wells on the Site.

### 3.1.3 Evaluation Criteria and Approach

The screening criteria discussed herein conform to the remedy selection requirements set forth in Section 121 of CERCLA, as amended, in the NCP (40 CFR 300.68(g)) and OSWER Directive 9355.3-01. The three criteria used for the initial screening of alternatives at the Ravenswood PCE Site are described below.

*Effectiveness:*
The primary criterion in screening the effectiveness of a remedial alternative is its ability to protect human health and the environment. Other factors to be considered are:

- The ability of a remedial alternative to reduce the toxicity, mobility, or volume of contamination.
- The capability of an alternative to attain the ARARs presented in Section 2.
- The persistence, toxicity, and mobility of the hazardous substances, and their propensity to bioaccumulate.
- Short-term and long-term potential for adverse health effects from human exposure.
- The potential for future remedial action costs if the remedial alternative in question were to fail.

*Implementability:*
Implementability is considered in the screening process as a measure of the technical and administrative feasibility of constructing, operating, and maintaining a remedial action. Factors considered in this evaluation include:

- The ability to construct and operate alternative technologies within site-specific and technology-specific regulations and constraints. Technical aspects to be considered include operation, maintenance, and post-implementation support.
- The extent of administrative coordination required to substantively comply with permit requirements and the coordination required with other government agencies.
- The availability of key alternative components and the time required for installation and attainment of the desired results.

*Cost:*
The intent of the cost screening is to make order-of-magnitude comparisons to screen out alternatives which have much higher costs than other alternatives without providing a comparative increase in protection. Alternatives that have excessive costs (at least an order of magnitude higher than a comparable alternative) and do not provide an increase in protection would be eliminated from further consideration.

## 3.2 Description and Screening of Remedial Alternatives

### 3.2.1 Alternative 1: No Action

The No Action alternative is considered in accordance with CERCLA and NCP requirements and provides a baseline for comparison with the other alternatives. Under this alternative, no further action would be implemented and the current status of the Site would remain unchanged.

***Evaluation:***
Effectiveness: The No Action alternative is not effective in protecting local residents or the environment from contaminants. It is not effective in reducing the toxicity, mobility, or volume of contaminants.

Implementability: There are no implementability difficulties with this alternative.

Cost: The cost of implementing this alternative is negligible.

***Conclusion:***
The No Action alternative will neither decrease the toxicity of on-site contaminants, nor protect public and ecological health. However, the No Action alternative has been retained for detailed analysis in accordance with CERCLA and the NCP to serve as a basis for comparison with other remedial alternatives.

### 3.2.2 Alternative 2: Monitored Natural Attenuation

Existing monitoring wells would be used to sample groundwater on a periodic basis to track natural attenuation mechanisms and the migration of the plume. Monitoring of natural attenuation parameters (e.g., electron acceptors, nutrients) would be performed in addition to monitoring Site contaminants to assess whether natural and biological processes are reducing contaminant levels and to evaluate the extent of further migration toward City production wells and the Ohio River. Groundwater use restrictions would also be implemented to prevent the installation of new production wells.

***Evaluation:***
Effectiveness: Monitored natural attenuation would be expected to have limited effectiveness in reducing contaminant concentrations and the mobility of the Site groundwater plume for several reasons. Only two breakdown products, TCE and 1,2-DCE, have been detected at very low levels in only one monitoring well during numerous sampling events and at only one DPT location during the 2010 investigation. This indicates that only limited natural biodegradation of PCE is occurring. Also, the relatively low levels of PCE observed in the subsurface are not sufficient to support a viable bacteria population. The highly permeable, high-yield aquifer, coupled with high rainfall infiltration rates, produces an aerobic environment that would be difficult to artificially change to an anaerobic state. Additionally, the presence of nitrate and sulfate, which would be reduced if the environment was suitable for reductive dechlorination of PCE, indicates that the aquifer is generally not a reducing environment. These factors indicate that natural biodegradation is not likely occurring over the majority of the Site and would be difficult to induce.

Implementability: The components of this alternative would be easily implemented, because there are no innovative or unusual construction techniques. There would be no associated issues with periodic sampling of groundwater.

Cost: The cost of the alternative would be relatively low, depending upon the frequency of groundwater sampling and the number of wells to be sampled.

*Conclusion:*
This alternative will not be retained for further consideration. Measurement of natural attenuation parameters has indicated that natural attenuation is not presently occurring at an appreciable rate, the hydrogeologic environment does not appear to be a good candidate based upon the lack of detected breakdown products over the majority of the Site, and the overall effectiveness is unlikely to be adequate to meet the community's needs.

### 3.2.3 Alternative 3: Groundwater Extraction and Treatment Using Carbon Adsorption

Under this alternative, extraction of contaminated groundwater would be accomplished using extraction wells installed within the central portion of the plume to capture the most highly contaminated groundwater. In order to control the migration of the contaminant plume, it is expected that relatively high pumping rates would be required, given the highly permeable aquifer as well as the proximity of several City production wells. Treatment of extracted groundwater would consist of a GAC system. Based on the relatively low PCE concentrations observed, air stripping prior to the carbon vessels would not be required, however, a pre-treatment step may be necessary using filtration to remove suspended solids to prevent clogging of the carbon filters. The treated groundwater would be blended with uncontaminated water from other production wells for use in the City water supply or discharged to the Ohio River. This alternative includes the installation of additional groundwater monitoring wells and periodic groundwater monitoring to track the migration of the plume and to verify that treatment standards would be met. Groundwater use restrictions would also be implemented to prevent the installation of new production wells.

*Evaluation:*
Effectiveness: This alternative would be effective in reducing the potential exposure of residents to onsite contaminants. Carbon adsorption is a common treatment technology for PCE in groundwater.

Implementability: This alternative would be readily implemented, because it requires typical extraction and construction equipment. The groundwater treatment components would be easy to implement given that the treatment technologies are commonly used for water treatment and there are no unusual construction techniques required. There may be some difficulties installing and operating the extraction wells, treatment plant, and discharge portion of the system in an urban setting.

Cost: The cost for this alternative would be high. The high pumping rates required for groundwater control would require a large carbon system. However the PCE loading rate would be relatively low, requiring only infrequent carbon change out.

*Conclusion:*
This alternative will be retained for further evaluation.

### 3.2.4 Alternative 4: In-Situ Bioremediation

This alternative would include the addition of materials via injection wells into the contaminated groundwater plume to enhance anaerobic bioremediation of PCE in the groundwater. Injection wells would be installed within the central portion of the plume to inject material to augment bioremediation by indigenous anaerobic bacteria. These materials may include electron donors, various nutrients, or co-metabolic food sources. This alternative would include the installation of additional groundwater monitoring wells and periodic groundwater monitoring to track the migration of the plume. Groundwater use restrictions would also be implemented to prevent the installation of new production wells.

***Evaluation:***

Effectiveness: In-situ bioremediation is a continually improving technology for the treatment of chlorinated VOCs under appropriate geochemical conditions. The biological transformation of chlorinated VOCs involves anaerobic reductive dechlorination using the saturated zone as an anaerobic bioreactor. The VOCs act as electron receptors, with simple organic compounds (i.e. sugars, alcohols, fatty acids, etc.) serving as electron donors. Anaerobic degradation of PCE results in the formation of TCE, 1,2-DCE and VC, of which the 1,2-DCE may be partially resistant to degradation. Only two breakdown products, TCE and 1,2-DCE, have been detected at very low levels in one monitoring well at the Site during numerous sampling events and one DPT location during the 2010 investigation. This indicates that only limited natural biodegradation of PCE is occurring at the Site.

The effectiveness of in-situ anaerobic bioremediation is dependent on many factors that need to be considered for effective treatment to occur, including redox potential, temperature, pH, ferrous iron, sulfate, and dissolved oxygen concentrations. Some of these parameters may be difficult to control in a large aerobic aquifer such as the one at the Ravenswood Site.

The relatively low levels of PCE observed in the subsurface are not sufficient to support a viable bacteria population. The highly permeable, high-yield aquifer, coupled with high rainfall infiltration rates, produces an aerobic environment that would be difficult to artificially change to an anaerobic state. Additionally, the presence of nitrate and sulfate, which would be reduced if the environment was suitable for reductive dechlorination of PCE, indicates that the aquifer is not a reducing environment. These factors indicate that natural biodegradation is not likely occurring and would be difficult to induce.

Implementability: This alternative would be moderately difficult to implement. Specific equipment and personnel needed for the injection wells can be procured relatively easily. The inherent uncertainty of using anaerobic bioremediation as a primary treatment approach could lead to design problems and, therefore, adversely affect implementability. A treatability study to assess the ability to reverse conditions in the highly aerobic aquifer, as well as to adjust bacterial populations, and the availability of electron donors would be necessary. The levels of PCE present at the Ravenswood Site are not high enough to provide a reliable food source to sustain a viable bacterial population, which would adversely affect the efficiency of this method. Additionally, the lack of naturally occurring degradation over the majority of the Site and the proximity to City of Ravenswood production wells further reduce the implementability of this option.

Cost: The cost for this alternative would be moderately high, depending on the types of materials that would need to be injected to create anaerobic conditions and achieve efficient degradation.

***Conclusion:*** The large size of the plume and relatively low PCE concentrations, combined with the lack of naturally occurring degradation across the majority of the Ravenswood Site, indicate that the probable effectiveness of this alternative is very low. While bioaugmentation may increase the degradation of PCE, this approach may result in the formation of other more toxic compounds (e.g., VC) which may be captured by the City production wells and enter the City water supply. Additionally, due to the proximity of the City production wells, the injection of materials into the subsurface may affect the City water supply. Due to difficulties in using anaerobic bioremediation in an uncontrolled environment and the lack of natural biodegradation at the Site, this alternative will not be retained for further consideration.

### 3.2.5 Alternative 5: Air Stripping

Under this alternative, contaminated groundwater would be extracted using a new extraction well located at the leading (north) edge of the plume to capture the most highly contaminated groundwater. In order to control the migration of the contaminant plume, it is expected that the pumping rate needed would be similar to the historic pumping rate of PW-3 (200,000 gpd). The extracted groundwater would be treated using a new Venturi air stripper. A pre-treatment filtration step, not currently in use, may be necessary to remove suspended solids. The treated groundwater would then be blended with uncontaminated water from other production wells for use in the City water supply. This alternative would include the installation of additional monitoring wells and periodic groundwater monitoring to track the migration of the plume and to verify whether treatment standards were being met. Groundwater use restrictions would also be implemented to prevent the installation of new production wells.

***Evaluation:***

Effectiveness: This alternative would be effective in reducing the potential exposure of residents to onsite contaminants. Air stripping is a common treatment technology for PCE in groundwater and has effectively reduced PCE concentrations in drinking water to below the MCL at the Ravenswood Site since the existing Venturi air stripper was installed in 2000. However, recent increases in PCE concentrations in PW-3 have created a concern by the Operator of the Ravenswood Water Treatment Plant that the existing Venturi air stripper system may not have the capacity to treat the existing PCE levels to below the MCL. The primary production well, PW-3, was temporarily shut down by the City from February to April 2010.

Implementability: This alternative would be readily implemented, because it is currently being used at the Site by the City of Ravenswood. Due to the high velocity of the influent water, periodic maintenance would be required to ensure the system functions at its designed effectiveness. The City's current Venturi air stripper system requires frequent maintenance to remove mineral deposits on the Venturi nozzles, and it is expected that the new system would require a similar degree of maintenance. There may be difficulties in obtaining the necessary replacement parts (Cambarare, 2010).

Cost: The cost of this alternative is moderate. A new extraction well would be required as well as new Venturi air strippers to treat the extracted groundwater.

*Conclusion:*
This alternative will be retained for further evaluation.

### 3.2.6 Alternative 6: In-Situ Chemical Oxidation

In-situ chemical oxidation involves the injection of reactive material (e.g., hydrogen peroxide, potassium permanganate, sodium permanganate) to oxidize the chlorinated organic compounds in the groundwater to carbon dioxide, chloride ions, and water. Injection wells would be constructed in a grid pattern within the most highly contaminated portion of the plume to reduce contaminant levels. Injection points would be installed vertically to provide efficient dispersal of reagents over the entire depth of contamination (50 to 80 feet bgs). In addition to the active treatment measures, this remedy would include the installation of additional groundwater monitoring wells and require periodic groundwater monitoring to track the migration of the plume and to verify that groundwater quality standards are being met. Groundwater use restrictions would also be implemented to prevent the installation of new production wells.

*Evaluation:*
Effectiveness: The process of using an aggressive oxidizing agent to destroy organic compounds has been successfully used at other Superfund sites; however, it is generally used in high concentration source areas, rather than in a widely dispersed plume. The effectiveness is dependent on how well the material is dispersed into the aquifer using injection wells. Given the sandy aquifer conditions at the Ravenswood Site, the injection fluid is expected to disperse well into the surrounding groundwater; however, the low levels of PCE at the Site would reduce the effectiveness of this remedy.

Implementability: This alternative would be relatively easy to implement, as injection points could be located in City streets and the City Maintenance Building parking lot. Many of the components of the in-situ chemical oxidation process are readily implemented using standard drilling processes, chemicals, and equipment. The injectors utilized in the latest technological applications are specially designed to withstand the mildly elevated temperatures and pressures associated with the process. Several proprietary chemical agents available only through specific vendors are utilized for the catalysts involved in the necessary reactions. Additionally, the proximity of the plume to the City of Ravenswood production wells may result in chemical oxidizers being introduced into the City water supply.

Cost: The cost for this alternative is moderate, depending on the number of injection wells/points and the quantity of oxidizing material which is necessary to effectively disperse underground to destroy the Site contaminants.

*Conclusion:*
This alternative would be effective in reducing the toxicity and volume of contaminants, and could be successful in a relatively short time period; however, this technology is not applicable

to low levels of PCE such as those found at the Ravenswood Site. Based upon the need to inject oxidants and the proximity of the contaminants to the City production wells and the associated potential risk, this alternative has not been retained for further evaluation.

### 3.2.7 Alternative 7: In-Situ Air Sparging with Soil Vapor Extraction

This alternative would include the installation of air sparging wells within the central portion of the plume and in the vicinity of the City water supply system to remove chlorinated organic compounds from the groundwater. Air sparging would be used to inject air into the groundwater contaminant zone to volatilize and remove PCE from the groundwater. The PCE stripped from the groundwater would then rise, along with the air, into the unsaturated zone, where it would be captured by SVE. This system would employ a number of AS wells aligned to intercept groundwater containing elevated PCE prior to its capture by the City water system. SVE wells would be placed between the AS wells to capture the vapor phase contaminants.

SVE wells would be installed above the water table to remove the PCE from the soil. A vacuum would be applied to the SVE wells to extract the vapor containing PCE. An offgas treatment system using vapor phase carbon adsorption may be necessary to limit the release of contaminants to the surrounding air. This alternative would also include the installation of additional groundwater monitoring wells and would require periodic groundwater and vapor monitoring to track the migration of the plume and to verify that treatment standards are being met. Groundwater use restrictions to prohibit the installation of new production wells in the plume area would also be instituted.

***Evaluation:***

Effectiveness: The ongoing AS/SVE treatability study at the Ravenswood PCE Site has demonstrated that the AS/SVE technology combination is effectively volatilizing aqueous phase PCE from the subsurface and extracting it from the vadose zone. The ROI of the existing AS wells was confirmed to exceed the design value, indicating that the sparged air is effectively permeating the sandy aquifer. The ROI of the SVE wells, as determined by sampling data, indicates the existing SVE wells are effectively capturing vapor phase PCE, thereby reducing the risk of volatilized PCE migrating into properties that are located in the vicinity of the system.

Implementability: This alternative should be relatively simple to implement. Nine AS wells, three SVE wells, and a treatment unit (compressor, blower, activated carbon and controls) were installed for the ongoing TS. The most important implementability issue to be considered would be the potential need for the installation of additional sparging and/or vapor extraction wells to control and treat other areas of the plume. These additional AS and SVE wells and associated piping would be constructed along roads and other public thoroughfares in order to limit the disruption that construction activities might cause to residents.

Cost: The cost of this alternative would be low, because the existing TS system could be utilized and expanded as needed.

***Conclusion:***

Due to favorable Site conditions, as demonstrated by the results of the ongoing TS and the availability of personnel trained in the Operation and Maintenance (O&M) of the system, this alternative is expected to be very effective. This alternative will be retained for further consideration.

# Section 4
# Description and Detailed Analysis of Alternatives

In this section, the alternatives that were retained following the initial screening step are evaluated against two threshold and five primary balancing criteria. These alternatives represent a range of actions that have been developed to be protective of human health and the environment. The evaluation criteria are described in Section 4.1, detailed descriptions of the alternatives are provided in Section 4.2, and each alternative is analyzed in Section 4.3.

## 4.1 Evaluation Criteria

EPA has outlined nine evaluation criteria to be used in assessing remedial alternatives in the NCP. These nine criteria take into consideration the statutory requirements specified in Section 121 of CERCLA as amended by SARA. In addition, EPA has issued additional guidance on the evaluation criteria in "Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA" (EPA, 1988). The criteria are classified into the following three groups:

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

- Overall Protection of Human Health and the Environment
- Compliance with ARARs

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

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

**Modifying Criteria.** These criteria are typically considered following review of the FS and the Proposed Plan by the regulatory agencies and the public, and they are formally documented as part of the Record of Decision (ROD). These modifying criteria are not evaluated in this FS.

- Support Agency (State) Acceptance
- Community Acceptance

Brief discussions for each of the above criteria follow.

**Overall Protection of Human Health and the Environment** - This criterion assesses each alternative's ability to provide adequate protection of human health and the environment. The evaluation focuses on whether a specific alternative achieves adequate protection, and how Site risks associated with each pathway are eliminated, reduced, or controlled through treatment, engineering, or institutional controls.

**Compliance with ARARs** - Alternatives are assessed as to whether they attain legally applicable or relevant and appropriate requirements of Federal and State environmental and public health laws, as well as non-promulgated advisories, criteria, and guidance.

**Long-Term Effectiveness and Permanence** - Alternatives are assessed for the long-term effectiveness and permanence they afford along with the degree of certainty that the remedy will prove successful. Factors which are considered include the magnitude of risks remaining following remedial action, and the adequacy and reliability of the engineering and institutional controls.

**Reduction of Toxicity, Mobility, or Volume Through Treatment** - This evaluation criterion addresses the statutory preference for selecting remedial actions that use treatment technologies to permanently and significantly reduce the toxicity, mobility, or volume of the hazardous substances as their principal element.

**Short-Term Effectiveness** - This criterion addresses the effects of the alternative on human health and the environment during construction and implementation of the remedial action. Factors that are considered include protection of remediation workers and the community during remedial actions, environmental impacts, and the length of time until the remedial action is completed.

**Implementability** - This criterion addresses the technical and administrative feasibility of implementing an alternative, as well as the availability of services and materials.

**Cost** - An estimate of the cost for each alternative is determined so that the cost can be compared to the level of protectiveness that each alternative provides. The typical cost estimate developed during the FS is intended to provide an accuracy of +50 percent to -30 percent, as discussed in the EPA RI/FS guidance document (EPA, 1988). The types of costs that are assessed include the capital costs, O&M costs, and present worth costs.

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

- O&M Costs - These costs include labor and materials associated with the operation and maintenance that follow the remedial action, such as groundwater treatment system operation and maintenance, long-term monitoring costs, and 5-year site reviews. The EPA

RI/FS guidance document recommends that O&M and monitoring costs be determined for 30 years.

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

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

**Community Acceptance** - The preferred remedy will be presented to the public in the Proposed Plan. Community acceptance will then be addressed in the Responsiveness Summary of the ROD, which will respond to public questions and concerns on the FS and Proposed Plan.

## 4.2 Detailed Descriptions of Alternatives

This section provides detailed descriptions of the remedial alternatives that have been retained following the initial screening in Section 3. The descriptions are provided in this section with sufficient information so that a detailed analysis can be carried out. Preliminary design assumptions have been made in this FS so that cost estimates can be developed to compare remedial alternatives. The final configuration of the remedial alternative selected for implementation will be determined during the remedial design process.

Each alternative description includes a summary of the alternative with descriptions of individual components of the alternative. These descriptions have been developed to address the Ravenswood PCE Site conditions that are expected to exist during remedial activities. The four alternatives that have been retained for detailed analysis have been re-numbered and are described below.

| | |
|---|---|
| Alternative 1: | No Action |
| Alternative 2: | Groundwater Extraction and GAC Treatment using a New Extraction Well (EW-1) |
| Alternative 3: | Venturi Air Stripping using a New Extraction Well (EW-1) |
| Alternative 4: | In-Situ Air Sparging with Soil Vapor Extraction |

### 4.2.1 Alternative 1- No Action

The No Action alternative is considered in accordance with CERCLA and NCP requirements and provides a baseline for comparison with the other alternatives. Under this alternative, no further action would be implemented and the current status of the Site would remain unchanged.

### 4.2.2 Alternative 2 - Groundwater Extraction and GAC Treatment using a New Extraction Well 1 (EW-1)

This alternative would involve a groundwater extraction and GAC treatment system for the elimination of groundwater contaminants. In this alternative, a new extraction well would be installed to capture and pump contaminated groundwater to the surface for treatment and discharge. Given the relatively low and dynamic hydraulic gradient, the most likely location for the extraction well would be in the area of EPA-02/PW-3 to the west of the Library. This extraction well placement would allow for the capture of the contaminated groundwater before it reaches the City of Ravenswood production wells. For the purposes of this FS, it has been assumed that one new extraction well pumping at 200,000 gpd (approximately 139 gallons per minute (gpm)) would replicate the current pumping rate of PW-3 which has, in effect, provided hydraulic control of the northern edge of the PCE. The precise number of wells needed to control the contaminated groundwater would be determined by groundwater modeling performed as part of the remedial design.

Based on the relatively low concentrations of PCE at the Ravenswood Site and observed in the influent of PW-3, it is not anticipated that air stripping would be necessary prior to carbon adsorption.

Carbon adsorption would remove contaminants from the extracted groundwater through contact with activated carbon in granular form. The organic compounds would be bound to the surface of the carbon particles, thereby removing contaminants from the groundwater. Once the carbon becomes exhausted, it would be removed and disposed or regenerated at an offsite location. Carbon adsorption is usually accomplished by passing the stream through one, or more often, two or more vessels (beds) containing granular carbon in series. A pre-filter would be placed before the carbon units to remove suspended solids (expected to be minimal) to extend the life of the carbon beds.

For the purposes of this FS, two potential discharge options are being considered:

- Alternative 2a assumes the treated groundwater would be discharged to the Ohio River.
- Alternative 2b assumes the treated groundwater would be blended with water from the City production wells and connected to the City water supply.

Periodic monitoring of the system effluent would be required to ensure the discharge water meets WVDEP standards or Federal Drinking Water Standards.

Site groundwater would continue to be used as a source of drinking water for the City, and portions of the plume may migrate towards the Ohio River and/or Sandy Creek. A groundwater monitoring program, including the installation of additional monitoring wells would be implemented to monitor the concentration and migration of the plume. The program will also monitor natural degradation processes at the southwest edge of the plume. Groundwater use restrictions would also be implemented to prevent the installation of new production wells in the plume area.

Until reduced PCE levels are observed in City production wells, it would be necessary to continue with some form of wellhead treatment at PW-3 (and possibly PW-2 and PW-5) in order to maintain PCE levels below the MCLs in the City drinking water.

### 4.2.3 Alternative 3 - Venturi Air Stripping Using a New Extraction Well (EW-1)

This alternative would involve replacing the City of Ravenswood's existing Venturi air stripper with a new unit on a newly installed extraction well (EW-1) to increase its capacity to remove PCE from the City's drinking water supply compared to the City's current system. The extracted water would pass through the new Venturi air stripper to remove PCE prior to the treated water being blended with water from the City's other wells. Given the relatively low and dynamic hydraulic gradient, the most likely location for the new extraction well would be in the area of EPA-02/PW-3 to the west of the Library. This extraction well placement would allow for the capture of the contaminated groundwater before it reaches the City of Ravenswood production wells. For the purposes of this FS, it has been assumed that one new extraction well pumping at 200,000 gpd (approximately 139 gpm) would replicate the current pumping rate of PW-3 which has, in effect, provided hydraulic control of the northern edge of the PCE. The precise number of wells needed to control the contaminated groundwater would be determined by groundwater modeling performed as part of the remedial design.

A Venturi air stripper would introduce air directly into the water line leading from the pumping well, thereby aerating all of the water that had been pumped. A Venturi nozzle would be installed in the water line, and water would be forced through the nozzle at high velocity. The passage of the high velocity water jet would create a suction that draws atmospheric air into the water stream. The Venturi nozzle would drastically restrict the size of the well line, which can cause backpressure on the well pump and reduce the flow of water. Precipitated minerals may clog the orifices of the Venturi nozzle, requiring frequent maintenance.

A Venturi system is currently plumbed to City wells PW-3 and PW-5 and is currently used by the City of Ravenswood to partially treat the water from contaminated well PW-5. Prior to late January 2010, the Venturi air stripper had treated water from PW-3 and PW-5 since its installation in 2000. Due to the high volume of water flow from these wells, all of the influent PCE is not removed from the treated water, and the water is blended with water from other, cleaner, wells to reduce PCE concentrations in the blended water to below the MCL. The City of Ravenswood has experienced some difficulty in obtaining parts to keep their current Venturi air strippers operating, and they do not consider the existing system to be highly reliable for treating the volume of water pumped from the contaminated well. Additionally, maintenance of their current Venturi air stripper system is labor intensive, because mineral deposits necessitate the frequent disassembly and servicing of the units (Cambarare, 2010).

Site groundwater would continue to be used as a source of drinking water for the City, and portions of the plume may migrate toward the Ohio River and/or Sandy Creek. A groundwater monitoring program, including the installation of additional monitoring wells, would be implemented to monitor the concentration and migration of the plume. The program would also monitor natural degradation processes at the southwest edge of the plume. Groundwater use restrictions would also be implemented to prevent the installation of new production wells in the plume area.

Until reduced PCE levels are observed in City production wells, it would be necessary to continue with some form of wellhead treatment at PW-3 (and possibly PW-2 and PW-5) in order to maintain PCE levels below the MCLs in the City drinking water.

### 4.2.4 Alternative 4 - In-Situ Air Sparging with Soil Vapor Extraction

Alternative 4 would involve an in-situ air sparging system and SVE to remove volatile organics from the groundwater.

In-situ air sparging is a technique in which air is injected into the groundwater to transfer aqueous phase volatile organic contaminants to the vapor phase. It is typically used in conjunction with soil vapor extraction to eliminate the migration of vapors. Air sparging would be relatively simple to implement at the Ravenswood Site and capital costs would be modest.

Air sparging wells would be installed across the area to be treated, using the anticipated radii of influence to obtain the desired coverage. As air moves up through the groundwater, volatile organic compounds partition from the aqueous phase into the vapor phase and are transported to the vadose zone. At the same time, oxygen in the injected sparge air dissolves in the groundwater. This oxygen might help stimulate the aerobic biodegradation of some organic compounds, although PCE would not be degraded under these conditions.

Like most subsurface remediation techniques, in-situ air sparging relies on the interactions between complex physical, chemical, and biological processes. The results from the pilot-scale AS/SVE treatability study that has been ongoing at the Ravenswood Site since June 2009 would be used to confirm Site-specific flow rates and the radii of influence before finalizing the system design.

This alternative would incorporate the TS treatment unit currently operating at the Site, which has sufficient capacity to supply compressed air and vacuum to an expanded AS/SVE well network, if needed. The TS AS/SVE well network could be expanded as necessary. This could include the installation of additional air sparge wells near the City production wells and also along Sycamore Street and Washington Street, near the center line of the groundwater plume.

Site groundwater would continue to be used as a source of drinking water for the City, and portions of the plume may migrate toward the Ohio River and/or Sandy Creek. A groundwater monitoring program, including the installation of additional monitoring wells, would be implemented to monitor the concentration and migration of the plume. The program would also monitor natural degradation processes at the southwest edge of the plume. Groundwater use restrictions would also be implemented to prevent the installation of new production wells in the plume area.

Air sparging/SVE was the remedy implemented at the Vienna PCE Superfund Site, which also is located on the Ohio River approximately 35 miles north of Ravenswood. The geology at

Vienna is very similar to the geology at Ravenswood, and PCE is also the contaminant of concern at Vienna. The four Vienna AS/SVE systems that began operation in late 2005 have significantly reduced the PCE concentrations in groundwater by as much as 99 percent in several monitoring wells, and portions of the Vienna Site have reached the RAO of 5 µg/L. For the purpose of this Ravenswood FS evaluation, it has been assumed that an AS/SVE system would need to be operated for ten years to achieve MCLs in the groundwater at Ravenswood.

Until reduced PCE levels are observed in City production wells, it would be necessary to continue with some form of wellhead treatment at PW-3 (and possibly PW-2 and PW-5) in order to maintain PCE levels below the MCLs in the City drinking water.

## 4.3 Individual Analysis of Alternatives

In this section, the four alternatives are assessed on the basis of the evaluation criteria described in Section 4.1.

### 4.3.1 Alternative 1 - No Action

#### 4.3.1.1 Overall Protection of Human Health and the Environment

This alternative would provide no protection of human health or the environment. Contaminated groundwater would persist and continue to be drawn into the City's production wells and may contaminate currently unaffected wells. Portions of the plume may also migrate toward the Ohio River.

Because this alternative does not satisfy this threshold criterion, it will not be evaluated further in this analysis.

### 4.3.2 Alternative 2 - Groundwater Extraction and GAC Treatment using a New Extraction Well (EW-1)

#### 4.3.2.1 Overall Protection of Human Health and the Environment

This alternative, shown in **Figure 4-1,** would be protective of human health and the environment by extracting groundwater and treating contaminants in the extracted groundwater. This alternative would reduce or eliminate risk to humans and ecological receptors through contact with extracted groundwater, provide hydraulic control of the plume, and reduce or eliminate contaminants being discharged to the Ohio River or entering the public water supply. This alternative would not significantly reduce contaminants in the groundwater.

#### 4.3.2.2 Compliance with ARARs

This alternative would meet chemical-specific Federal and State ARARs through active treatment of groundwater. Action- and location-specific ARARs would apply and would be met by this alternative. Treatment system monitoring would verify that West Virginia and Federal water quality standards are being met for groundwater being discharged to the Ohio River as well as for treated water entering the City water supply. This alternative would not meet the MCL in the Site groundwater.

Until reduced PCE levels are observed in City production wells, it would be necessary to continue with some form of wellhead treatment at PW-3 (and possibly PW-2 and PW-5) in order to maintain PCE levels below the MCLs in the City drinking water.

#### 4.3.2.3 Long-Term Effectiveness and Permanence

This alternative would provide some degree of hydraulic capture of the leading edge of the PCE plume effectively protecting the City production wells, although PW-2, PW-3 and PW-5 may continue to draw in contaminated water for some time. Once the RAO is met in City drinking water, this alternative would effectively and permanently maintain PCE levels below the MCL in City drinking water as well as extracted groundwater as long as the system is operational. If the treated water is used to supplement the City of Ravenswood water supply, it would provide a productive use of the water, reduce City pumping costs, and increase the capacity of the City water system. This alternative may alter the flow path of the plume in the vicinity of the City production wells and may not capture the entire plume.

Based on the significant volume of contaminated groundwater in the plume, it is estimated that it could take 25 to 50 years, or longer, to capture the portion of the PCE plume within the capture zone of the extraction well. This remedy is not expected to meet the MCL in the groundwater, and is, therefore, not effective in the long term nor is it a permanent solution to elevated PCE levels in the groundwater.

For this alternative the assumed O&M and monitoring period is 30 years.

#### 4.3.2.4 Reduction of Toxicity, Mobility or Volume Through Treatment

This treatment process would reduce the volume of contaminants by pumping groundwater and removing PCE mass from the aquifer. Mobility would not be affected, compared to the current system as the new extraction well is expected to provide the same hydraulic control of the plume currently provided by PW-3. This alternative would also reduce the migration of the plume past the pumping well into currently contaminated and uncontaminated production wells. The toxicity of groundwater would be reduced as the treatment process removes contaminants from the groundwater.

#### 4.3.2.5 Short-Term Effectiveness

This alternative has the potential to have limited short-term impacts on Site workers conducting the remediation activities. The risks are considered to be low and would be controlled by standard health and safety practices. The alternative could be implemented relatively quickly, given the standard technologies involved. Accordingly, the alterative could be installed in less than six months, thereby minimizing impacts to local residents during construction.

This alternative is expected to begin reducing PCE levels in the City water supply in under a year largely due to the addition of a large volume of treated water from the new pumping well and GAC system. It should also capture some of the contaminated water that would otherwise be contaminating PW-3 and PW-5, assuming the City continues to operate these wells.

Based on the significant volume of contaminated groundwater in the plume, it is estimated that it could take 25 to 50 years, or longer, to capture the portion of the PCE plume within the capture zone of the extraction well. This alternative is not expected to reduce PCE levels in the groundwater to below MCLs. Periodic groundwater and City water supply monitoring is expected to continue for 30 years.

#### 4.3.2.6 Implementability

This alternative would employ a commonly used treatment system. Construction of the GAC treatment system as well as the associated transfer piping and monitoring wells could be easily completed with minimal difficulties, although the system flow rate may require a large carbon system. Consultation with the Operator of the Ravenswood Water Treatment Plant would be required for the proper placement of the system components.

#### 4.3.2.7 Cost

Capital costs, O&M costs, and present worth costs are listed below. Details of the cost estimate are presented in **Appendix D**.

- Capital Cost - The capital cost for this alternative is estimated to be $578,500 for discharge to the Ohio River (Alternative 2a) and $513,800 for connection to the City water supply (Alternative 2b).

- O&M Cost - The present worth cost for 30 years of O&M and monitoring is projected to be $1,096,500.

- Present Worth - The present worth of these costs is $1,675,000 for discharge to the Ohio River (Alternative 2a) and $1,610,000 for connection to the City water supply (Alternative 2b).

### 4.3.3 Alternative 3 - Venturi Air Stripping Using a New Extraction Well (EW-1)

#### 4.3.3.1 Overall Protection of Human Health and the Environment

This alternative, shown in **Figure 4-3,** would be protective of human health and the environment by extracting groundwater and treating contaminants in the extracted groundwater. This alternative would reduce or eliminate risk to humans and ecological receptors through contact with extracted groundwater, provide hydraulic control of the plume and reduce or eliminate contaminants being discharged to the Ohio River or entering the public water supply. This alternative would not significantly reduce contaminants in the groundwater.

#### 4.3.3.2 Compliance with ARARs

This alternative would meet chemical-specific Federal and State ARARs through active treatment of groundwater. Action- and location-specific ARARs would apply and would be met by this alternative. Treatment system monitoring would verify that West Virginia and Federal water quality standards are being met for treated water entering the City water supply. This alternative will not meet the MCL in the Site groundwater.

Until reduced PCE levels are observed in City production wells, it would be necessary to continue with some form of wellhead treatment at PW-3 (and possibly PW-2 and PW-5) in order to maintain PCE levels below the MCLs in the City drinking water.

#### 4.3.3.3 Long-Term Effectiveness and Permanence

This alternative would provide some degree of hydraulic capture of the leading edge of the PCE plume effectively protecting the City production wells, although PW-2, PW-3 and PW-5 may continue to draw in contaminated water for some time. Once the RAO is met in City drinking water, this alternative would effectively and permanently maintain PCE levels below the MCL in City drinking water as well as extracted groundwater as long as the system is operational. If the treated water is used to supplement the City of Ravenswood water supply, it would provide a productive use of the water, reduce City pumping costs, and increase the capacity of the City water system. This alternative may alter the flow path of the plume in the vicinity of the City production wells and may not capture the entire plume.

Based on the significant volume of contaminated groundwater in the plume, it is estimated that it could take 25 to 50 years, or longer, to capture the portion of the PCE plume within the capture zone of the extraction well. This remedy is not expected to meet the MCL in the groundwater, and is therefore not effective in the long term nor is it a permanent solution to elevated PCE levels in the groundwater.

For this alternative the assumed O&M and monitoring period is 30 years.

#### 4.3.3.4 Reduction of Toxicity, Mobility or Volume Through Treatment

This treatment process would reduce the volume of contaminants by pumping groundwater and removing PCE mass from the aquifer. Mobility would not be affected, compared to the current system as the new extraction well is expected to provide the same hydraulic control of the plume currently provided by PW-3. This alternative would also reduce the migration of the plume past the pumping well into currently contaminated and uncontaminated production wells. The toxicity of groundwater would be reduced as the treatment process removes contaminants from the groundwater; although, as with the current Venturi system, 100 percent removal of PCE would not be likely to occur.

#### 4.3.3.5 Short-Term Effectiveness

This alternative has the potential to have limited short-term impacts on Site workers conducting the remediation activities. The risks are considered to be low and would be controlled by standard health and safety practices. The alternative could be implemented relatively quickly, given the standard technologies involved. Accordingly, the alterative could be installed in less than six months, thereby minimizing impacts to local residents during construction.

This alternative is expected to begin reducing PCE levels in the City water supply in under a year largely due to the addition of a large volume of treated water from the new pumping well and Venturi air stripper. It should also capture some of the contaminated water that would otherwise be contaminating PW-3 and PW-5, assuming the City continues to operate these wells.

Based on the significant volume of contaminated groundwater in the plume, it is estimated that it could take 25 to 50 years, or longer, to capture the portion of the PCE plume within the capture zone of the extraction well. This alternative is not expected to reduce PCE levels in the groundwater to below MCLs. Periodic groundwater and City water supply monitoring is expected to continue for 30 years.

#### 4.3.3.6 Implementability

This alternative would employ a commonly used treatment system. Construction of the Venturi air stripper system as well as the associated transfer piping and monitoring wells could be easily completed with minimal difficulties. Spare parts necessary for the routine O&M of the system are difficult to obtain and maintenance is time consuming. Consultation with the Operator of the Ravenswood Water Treatment Plant would be required for the proper placement of the system components.

#### 4.3.3.7 Cost

Capital costs, O&M costs, and present worth costs are listed below. Details of the cost estimate are presented in **Appendix D**.

- Capital Cost - The capital cost for this alternative is estimated to be $325,900.
- O&M Cost - The present worth cost for 30 years of O&M and monitoring is projected to be $874,800.
- Present Worth - The present worth of these costs is $1,201,000.

### 4.3.4 Alternative 4 - In-Situ Air Sparging with Soil Vapor Extraction

#### 4.3.4.1 Overall Protection of Human Health and the Environment

This alternative, shown in **Figure 4-3,** would be protective of human health and the environment by treating contaminants in the groundwater. Over time, this in-situ treatment would reduce or eliminate risk to humans and ecological receptors through contact with contaminated groundwater as well as reduce contaminants entering the City water supply protecting human health.

#### 4.3.4.2 Compliance with ARARs

This alternative would meet chemical-specific Federal and State ARARs through active treatment of groundwater. Action- and location-specific ARARs would apply and would be met by this alternative. City water supply monitoring would verify that water quality standards were being met for drinking water entering the City water supply. Air monitoring may be needed to ensure that air emissions from the AS/SVE system remain below regulatory levels. Additionally, targeting the potential source areas would decrease the potential for contaminants to migrate toward the Ohio River.

Until reduced PCE levels are observed in City production wells, it would be necessary to continue with some form of wellhead treatment at PW-3 (and possibly PW-2 and PW-5) in order to maintain PCE levels below the MCLs in the City drinking water.

#### 4.3.4.3 Long-Term Effectiveness and Permanence

The use of an AS/SVE system would reduce the concentration of contaminants in the plume by treating contaminated groundwater. Over time, due to the active treatment process, the concentration of contaminants in the groundwater would begin to drop below regulatory levels and the treatment process and associated monitoring could be discontinued.

Once MCL levels have been achieved, this alternative is expected to effectively and permanently maintain PCE levels below the MCL, both in groundwater across the Site and in City drinking water. This alternative would provide the greatest level of permanence of any of the alternatives in the long term.

The Vienna AS/SVE systems that began operation in late 2005 have significantly reduced the PCE concentrations in groundwater by as much as 99 percent in several monitoring wells and portions of the site have reached the RAO of 5 µg/L. For the purpose of this FS evaluation, it has been assumed that an AS/SVE system would need to be operated for ten years to achieve MCLs in the groundwater at Ravenswood.

Based on this ten-year O&M period, it has been assumed that after ten years of bi-annual monitoring, the sampling frequency will be decreased to one sampling event per year.

#### 4.3.4.4 Reduction of Toxicity, Mobility or Volume Through Treatment

This alternative consists of the active in-situ treatment of chlorinated organic compounds in groundwater. The mass of contaminants in the aquifer would be reduced by the AS/SVE system due to the volatilization and removal of PCE and treatment with activated carbon. Mobility would be reduced by removing contaminants from the aqueous phase and extracting and capturing them using the SVE system. The toxicity of groundwater would similarly be reduced by lowering the level of PCE contamination and removing contaminant mass from the groundwater.

#### 4.3.4.5 Short-Term Effectiveness

This alternative has the potential to have limited short-term impacts on Site workers conducting the remediation activities. The risks are considered to be low and would be controlled by standard health and safety practices. The alternative could be implemented relatively quickly, given the standard technologies involved. Accordingly, the alternative could be installed in less than six months, thereby minimizing impacts to local residents during construction.

This alternative is assumed to reduce PCE levels entering the City water supply and in the groundwater to below the MCL in approximately ten years. Until MCLs are reached in the groundwater and the City water supply, the existing Venturi air stripper will need to operate to protect the City water supply.

Periodic groundwater and City water supply monitoring is expected to continue for 30 years.

### 4.3.4.6 Implementability

Implementation of this alternative would be relatively easy, because a pilot-scale AS/SVE treatability study is currently being conducted on Site. Nine AS and three SVE wells have already been installed, a TS treatment unit is operating on Site, and trained operating personnel are in close proximity. The aquifer conditions, based on the ongoing TS, appear favorable with no indications of scaling or biofouling. The system may need to be expanded to address areas of higher PCE concentration identified during past and recent investigations. If system expansion occurs, any potential difficulties associated with the required construction in a City area are expected to be minimal. The remedial designers would need to consult with the City for the optimal placement of injection wells and extraction wells, in consideration of City utilities, neighborhoods, and existing roads. The installation of additional wells and piping could be accomplished in less than six months, reducing the impact on the local community. The existing TS treatment system has the capacity to add additional AS and SVE wells, especially if pulsing of the system is implemented.

### 4.3.4.7 Cost

Capital costs, O&M costs, and present worth costs are listed below. Details of the cost estimate are presented in **Appendix D.**

- Capital Cost - The capital cost for this alternative is estimated to be $282,400.
- O&M Cost - The present worth cost for ten years of O&M and 30 years of monitoring is projected to be $695,600.
- Present Worth - The present worth of these costs is $978,000.

# Section 5
# Comparative Analysis of Alternatives

This section presents an overall comparison of the remedial action alternatives that were evaluated in Section 4 for the Ravenswood PCE Superfund Site. The four retained alternatives are compared to each other based on the EPA evaluation criteria. A summary of the comparative analysis of remedial alternatives is provided in **Table 5-1.**

## 5.1 Overall Protection of Human Health and the Environment

Alternative 1 (No Action) provides no protection of human health and the environment. As it does not meet this threshold criterion it will not be evaluated further in this analysis.

Alternatives 2a, 2b (Groundwater Extraction and GAC Treatment using a New Extraction Well, EW-1) and 3 (Venturi Air Stripping using a New Extraction Well, EW-1) would provide a high degree of protection of human health and medium protection of the environment by removing and treating contaminated groundwater at the Site. However, only the extracted groundwater would be treated, which would have only a gradual effect on the remainder of the contaminated aquifer. Until reduced PCE levels are observed in City production wells, it would be necessary to continue with some form of wellhead treatment at PW-3 (and possibly PW-2 and PW-5) in order to maintain PCE levels below the MCLs in the City drinking water.

Alternatives 2a, 2b, and 3 would help minimize the potential for contaminated groundwater to migrate to other production wells, but would not significantly affect the migration of the plume toward the Ohio River. Because they involve wellhead treatment only, these alternatives would only help control the movement of groundwater by pumping rather than reduce the overall contamination in the aquifer.

Alternative 2a, with discharge to the Ohio River, would provide a high level of protection to human health and the environment; however an important resource would be wasted, without increasing the protectiveness of the remedy. If the extracted and treated water were instead added to the City water supply (Alternative 2b and 3), the protection would be identical to that provided by Alternative 2a. Both Alternatives 2b and 3 would remove PCE from contaminated water extracted by the new extraction well prior to blending that treated water with water from uncontaminated wells.

Alternative 4 (In-Situ Air Sparging with Soil Vapor Extraction) would provide a high degree of protection for human health and would also provide a high level of protection for the environment through in-situ treatment of the contaminated groundwater within the aquifer. The layout of the sparge system would include several sparge curtains constructed perpendicular to the groundwater gradient or along the center of the plume to intercept and remove PCE before the water is drawn into the existing City production wells. The arrangement of AS and SVE wells would be focused on protecting PW-3 and PW-5. Alternative 4 is the only alternative that would reduce PCE levels throughout the plume, and, therefore, the only alternative that could eventually achieve MCLs in the aquifer. However, it may take some time for the air sparging system to reduce the levels of PCE in groundwater, including the water that is drawn into PW-3 and PW-5. Until reduced PCE levels are observed in City production wells, it would be necessary to continue with some form of wellhead treatment at PW-3 (and possibly PW-2 and PW-5) in order to maintain PCE levels below the MCLs in the City drinking water.

## 5.2 Compliance with ARARs

Alternatives 2a, 2b, 3, and 4 would be expected to comply with chemical-, location-, and action-specific ARARs. These would include drinking water standards as well as emission standards during remedial activities. All three of the extraction alternatives (2a 2b, and 3) would achieve the MCL in drinking water by treating extracted water; however, as discussed above, Alternative 4 (In-situ Air Sparging with SVE) is the only alternative that would likely eventually achieve the MCL in the groundwater aquifer.

## 5.3 Long-Term Effectiveness and Permanence

Alternatives 2a, 2b, 3, and 4 would provide long-term protection for the Ravenswood municipal water supply and would prevent high concentrations of PCE from migrating to the Ohio River or other City production wells. As discussed above, Alternative 4 (In-situ Air Sparging with SVE) is the only alternative that would likely eventually achieve the MCL in the groundwater.

For the purposes of this evaluation, it was assumed that Alternative 4 would achieve the MCL in approximately ten years. It was assumed that treatment systems for Alternatives 2a, 2b, and 3 would need to be operated continually for at least 30 years; however, it could take 25 to 50 years or longer to capture the portion of the plume within the capture zone of the extraction well. Because Alternative 4 is the only alternative that would likely eventually achieve the MCL in the groundwater aquifer, this alternative would provide the greatest amount of permanence in the long-term.

The addition of a new pumping well that withdraws large volumes of water under Alternatives 2a, 2b, and 3 could change the groundwater flow paths near the other City wells. In order to balance this effect, the location and pumping rate of the new well would need to be determined using a Site-specific groundwater model. Pumping would also need to be coordinated with the operation of existing City wells.

Alternative 2a, with discharge to the Ohio River, would not make effective use of the high volume of groundwater that would be pumped and treated to non-detect levels. This would not be a sustainable alternative and would waste energy and a valuable treated groundwater resource. The other two extraction alternatives would make effective use of the treated groundwater.

All four treatment alternatives would require regular maintenance to ensure they were functioning as designed.

## 5.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

Alternatives 2a, 2b, 3, and 4 would all utilize various active treatment technologies to reduce the mobility and volume of PCE in the groundwater.

Alternatives 2a, 2b, and 3 would slightly reduce the contaminant volume by actively extracting and treating contaminated groundwater. The toxicity of the extracted groundwater would be reduced as the contamination was removed by the pump and treat systems or the City wells. Alternatives 2a and 2b would sequester the extracted contaminants in an aqueous-phase activated carbon system, while in Alternative 3, the volatile contaminants would be stripped from the extracted groundwater and the vapors would be discharged in accordance with applicable West Virginia air quality regulations. (Note that the current Venturi system discharges stripped PCE directly to the atmosphere with no treatment.) Alternatives 2a, 2b, and 3 would not reduce the mobility of the contaminants compared to the current systems.

The AS/SVE process in Alternative 4 would reduce the mobility of contaminants by in-situ treatment of PCE in the aquifer. The reduction of the higher-concentration portions of the plume would reduce the dispersion and further migration of PCE, especially under the influence of the hydraulic control established by the existing City well system. The volume of contaminants in the aquifer would be reduced due to volatilization and the subsequent vapor extraction of volatile groundwater contaminants. The toxicity of the groundwater in the aquifer would be reduced as contaminants were removed from the aqueous phase. This would differ from the other treatment alternatives (2a, 2b, and 3), which would only reduce the toxicity in the extracted water and not substantially affect the level of PCE in the rest of the plume. Because Alternative 4 would directly treat a large portion of the contaminant plume, it would be expected to be the most effective in reducing the toxicity of the groundwater across the entire plume. The GAC in the SVE system of Alternative 4 would also capture the extracted PCE, allowing essentially no emissions to the atmosphere.

## 5.5 Short-term Effectiveness

All of the retained alternatives would have limited short-term impacts on Site workers conducting construction activities related to the remedial alternatives. Based on the low PCE concentrations, which are found only in the groundwater, the risks would be considered to be very low and would be controlled by standard health and safety practices.

All four alternatives are expected to reduce PCE levels in the drinking water to below the MCL. Until reduced PCE levels are observed in City production wells, it would be necessary to continue with some form of wellhead treatment at PW-3 (and possibly PW-2 and PW-5) in order to maintain PCE levels below the MCLs in the City drinking water.

Based on the significant volume of contaminated groundwater in the plume, it is estimated that Alternatives 2a, 2b, and 3 could take 25 to 50 years, or longer, to capture the portion of the PCE plume within the capture zone of the extraction well. These alternatives are not expected to reduce PCE levels in the groundwater to below MCLs.

Alternative 4 would likely achieve the MCL in approximately ten years.

## 5.6 Implementability

Alternatives 2a, 2b, 3, and 4 are all readily implementable, because they use standard construction equipment and services. Because of the setting of the Site and specifically the City Maintenance Yard, the placement of treatment equipment associated with all of the treatment alternatives would need to be evaluated with respect to the surrounding land use.

The construction of Alternatives 2a, 2b, and 3 might cause some disruption to roads, depending on the location of the wells, treatment system, and discharge pipe. The size of the carbon system (Alternatives 2a and 2b) and the difficulty in obtaining O&M components (Alternative 3) slightly reduce the implementability of these alternatives.

Construction of Alternative 4 might create a short disruption in the surrounding area as additional AS/SVE and monitoring wells were installed. There might be access issues related to installing the wells and associated piping in the optimum locations. The sparging and extraction wells would use common drilling techniques for their installation.

## 5.7 Cost

The retained alternatives are ranked by present worth cost in the following table from least to most expensive.

| Alternative | Capital Cost | Present Worth of O&M Costs | Present Worth |
|---|---|---|---|
| Least Expensive | | | |
| Alternative 4 - Air Sparging with SVE | $282,400 | $695,600 | $978,000 |
| Alternative 3 - Venturi Air Stripping Using a New Extraction Well (EW-1) | $325,900 | $874,800 | $1,201,000 |
| Alternative 2 - Groundwater Extraction and GAC Treatment using a New Extraction Well (EW-1)<br>2a)Discharge to Ohio River<br>2b)Discharge to City water supply | a - $578,500<br>b- $513,800 | a-$1,096,500<br>b-$1,096,500 | a- $1,675,000<br>b- $1,610,000 |
| Most Expensive | | | |

Of the retained alternatives, Alternative 4 would be the least expensive having a capital cost of $282,400 and a long term O&M and monitoring cost of $695,600. Alternative 3 would be the next least expensive having a capital cost of $325,900 and a long term O&M and monitoring cost of $874,800. Alternative 2 would have a capital cost of $513,800 for discharge to the City water supply (2b) and $578,500 for discharge to the Ohio River (2a), with a long term O&M and monitoring cost of $1,096,500. The O&M costs for Alternatives 2a, 2b, and 3 are based on a standard 30-year period; however, it could take 25 to 50 years or longer to capture the portion of the plume within the capture zone of the extraction well. It is expected that Alternative 4 would meet remediation goals in a significantly shorter time period, thereby reducing the corresponding O&M costs. Accordingly, a time period of ten years was estimated for the O&M for Alternative 4 based on the performance of the Treatment Unit at the nearby Vienna PCE Site. Based on this ten-year O&M period for Alternative 4, it has been assumed that after ten years of bi-annual monitoring, the sampling frequency will be decreased to one sampling event per year.

# Section 6
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# Tables

# Table 2-1
# Applicable or Relevant and Appropriate Requirements (ARARs) and To Be Considered Material (TBCs) for the selected remedy
# Ravenswood PCE Superfund Site

**Note: Not all ARARs apply to each alternative**

| ARAR or TBC | Legal Citation | Type of ARAR | Classification | Summary of Requirement | Further Detail Regarding ARARs in the Context of the Selected Remedy |
|---|---|---|---|---|---|
| **FEDERAL** | | | | | |
| **Groundwater**<br>Safe Drinking Water Act Maximum Contaminant Levels (MCLs) | 42 U.S.C. § 300g-l<br>40 CFR Part 141.61 | Chemical-specific | Applicable | MCLs are enforceable standards for public drinking water supply systems which have at least 15 service connections or are used by at least 25 persons. These requirements are directly applicable because groundwater in the vicinity of the site is used as private drinking water supply. | The groundwater cleanup levels for COPCs will meet MCLs. |
| Maximum Contaminant Level Goals (MCLGs) | 40 CFR Part 141.50-51 | Chemical-specific | Relevant and Appropriate | MCLGs are non-enforceable health goals for public water supplies which have at least 15 service connections or are used by 25 persons. Under the circumstances of this Site, MCLGs are relevant and appropriate requirements which were considered in establishing groundwater cleanup levels. | The groundwater remedy will consider these requirements. |
| EPA Regional Screening Levels (RSLs) | | Chemical-specific | TBC | Provides reference doses, carcinogenic slope factors, and risk-based concentrations used for initial screening of contaminants during risk assessment. | RSLs are useful for determining PRGs. |
| **Surface Water**<br>Clean Water Act (CWA) Ambient Water Quality Criteria (AWQC) | 30 U.S.C. § 303 and 304 | Chemical-specific | Relevant and Appropriate | Establishes Federal AWQC for restoration and maintenance of chemical, and biological integrity of the nation's surface waters. | May guide groundwater remedial action in order to meet AWQC in the Ohio River. |
| Clean Water Act - National Pollution Discharge Elimination System (NPDES) Permitting Requirements for Discharge of Treatment System Effluent | 40 CFR Part 122-125 | Action-specific | Relevant and Appropriate | Defines allowable concentrations in effluent from a groundwater treatment system. | Required if an alternative discharges material to the Ohio River. Substantive requirements of the permit must be met, although the permit itself is not required. |
| **Air**<br>Resource Conservation and Recovery Act (RCRA) Air Emission Standards for Process Vents | 40 CFR Part 264.1030 - 264.1034 and 40 CFR Part 264.1053 - 264.1063 | Action-specific | Applicable | Establishes requirements for process vents and equipment leaks. | To the extent the groundwater remedy includes treatment by air stripping or other processes that would generate air releases, these requirements would apply. |

## Table 2-1 (Continued)
## Applicable or Relevant and Appropriate Requirements (ARARs) and To Be Considered Material (TBCs) for the selected remedy
## Ravenswood PCE Superfund Site

**Note: Not all ARARs apply to each alternative**

| ARAR or TBC | Legal Citation | Type of ARAR | Classification | Summary of Requirement | Further Detail Regarding ARARs in the Context of the Selected Remedy |
|---|---|---|---|---|---|
| Regulations Governing Hazardous Air Pollutants (NESHAPS) | 40 CFR Part 61.242-1 through 61.244 | Action-specific | Applicable | Requires emissions of Hazardous Air Pollutants (HAPs) from new/existing sources to be quantified; establishes ambient air quality standards and emissions limitations for HAP emissions from new sources. | To the extent the groundwater remedy includes treatment by air stripping or other processes that would generate air releases, these requirements would apply. |
| Clean Air Act<br>State Implementation Plan to Meet National Ambient Air Quality Standards (NAAQS) | Section 110 | Action-specific | TBC | Requires states to adopt a plan for the implementation, maintenance, and enforcement of NAAQS. | To the extent the groundwater remedy includes treatment by air stripping or other processes that would generate air releases, these requirements would apply. |
| Control of Air Emissions from Air Strippers at Superfund Groundwater Sites | OSWER Directive 9355.0-28, June 15,1989 | Action-specific | To Be Considered | This policy guides the decision of whether additional controls (beyond those required by statute or regulation) are needed for air strippers at Superfund groundwater sites. | This policy would be considered in determining the necessary emission controls. Sources most in need of additional controls are those with emission rates in excess of 3 lbs/hour or a potential rate of 10 tons/year of total VOCs. |
| **Waste Handling and Disposal**<br>RCRA - Part 264, Subtitle C | 40 CFR Part 264, Subpart E | Action-specific | Applicable | Applicable to the testing, manifesting and transportation of hazardous waste defined under 40 CFR Part 261. | Applicable to spent carbon generated during groundwater treatment system operation. |
| **STATE OF WEST VIRGINIA** | | | | | |
| **Groundwater**<br>WV Groundwater Standards | WV CSR §47-12-3.1 to -3.5.a and Appendix A | Chemical-specific | Applicable | Establishes minimum standards of pureness and quality for groundwater resources within the State. | The groundwater remedy will comply with these standards to the extent they are more stringent than the federal standards. |

## Table 2-1 (Continued)
## Applicable or Relevant and Appropriate Requirements (ARARs) and To Be Considered Material (TBCs) for the selected remedy Ravenswood PCE Superfund Site

**Note: Not all ARARs apply to each alternative**

| ARAR or TBC | Legal Citation | Type of ARAR | Classification | Summary of Requirement | Further Detail Regarding ARARs in the Context of the Selected Remedy |
|---|---|---|---|---|---|
| WV Groundwater Protection Act | WV CSR §22-12-4(b) | Chemical-specific | Relevant and Applicable | Establishes maximum contaminant levels permitted in groundwater. Where levels exceed that value, every reasonable effort will be made to identify, remove or mitigate the source and strive where practical to reduce the level of contamination over time to support drinking water use. | The groundwater remedy will comply with this standard to the extent they are more stringent than the federal standards. |
| WV Requirements Governing Water Conditions Not Allowable in State Waters | WV CSR §47-2-3.2 a-g | Action-specific | Relevant and Appropriate | Sewage, industrial waste, and other waste present in waters of the State will not contribute to certain conditions including odors in the vicinity of waters, materials in concentrations which are harmful, hazardous, or toxic to man, animal, or aquatic life. | Discharge from the Site, such as discharge associated with pump and treat operations, if any, into the waters of the State will comply with these requirements. |
| Anti- Degradation Policy | WV CSR §47-2-4.a.,b. | Action-specific | Relevant and Appropriate | Requires protection of existing uses of State waters. Requires all new and existing point sources to achieve highest established requirements and employ best management practices for non-point sources. | Any point source discharge from the Site into the Ohio River will meet the substantive requirements of this regulation. |
| Subsurface borings | WV CSR §47-58.4.2 | Action-specific | Relevant and Appropriate | Subsurface borings will be constructed, operated, and closed in a manner that protects groundwater. | To the extent the remedial activities include subsurface borings, this requirement will be met. |
| Groundwater monitoring stations | WV CSR §47-58-4-9.d. to 4.9g. | Action-specific | Applicable | Establishes standards for location and construction of groundwater monitoring stations. | The remedy will comply with these requirements. |
| Groundwater remediation | WV CSR §47-58-8.1.b. | Action-specific | Applicable | Cleanup action will not rely primarily on dilution and dispersion of the substance if active remedial measures are technically and economically feasible. | The selected remedy will achieve these requirements. |
| Groundwater monitoring | WV CSR §47-58-8-1.c. | Action-specific | Applicable | Requires adequate groundwater monitoring to demonstrate control and containment of the substance. | The remedy will comply with these requirements. |

## Table 2-1 (Continued)
## Applicable or Relevant and Appropriate Requirements (ARARs) and To Be Considered Material (TBCs) for the selected remedy
## Ravenswood PCE Superfund Site

**Note: Not all ARARs apply to each alternative**

| ARAR or TBC | Legal Citation | Type of ARAR | Classification | Summary of Requirement | Further Detail Regarding ARARs in the Context of the Selected Remedy |
|---|---|---|---|---|---|
| Monitoring Well Design Standards | WV CSR §47-60-1 to -60-21 | Action-specific | Applicable | This rule establishes minimum acceptable documentation and standards for the design, installation, construction, and abandonment of monitoring wells and for the abandonment of all boreholes. | The substantive requirements of this regulation will be met. |
| WV Groundwater Protection Regulations Practices for Industrial Establishments | WV CSR §47-58-4.10 | Location-specific | Relevant and Appropriate | Facility or activity design must adequately address the issues arising from locating in karst, wetlands, faults, subsidences, or delineated wellhead protection areas determined vulnerable by the Director. | The substantive requirements of this regulation will apply if implementation of the remedy affects such vulnerable areas. |
| **Surface Water**<br>Surface Water Mixing Zones | WV CSR §47-2-5 | Action-specific | Relevant and Appropriate | Discusses conditions to be included in a permit concerning mixing zones. | Any point source discharge from the Site will meet the substantive requirements of this regulation. No permit will be required. |
| Surface Water Use Categories | WV CSR §47-2-6.6 | Action-specific | Relevant and Appropriate | Defines water use categories for waters of the State. | The Ohio River is a Category E water use category (water supply industrial, water transport, cooling and power). |
| Requirements for Surface Water Use Categories | WV CSR §47-2-7.2 | Action-specific | Relevant and Appropriate | Discusses water use categories applicable to specific waters of the State. | The substantive requirements applicable to the portion of the Ohio River which receives the discharge will be met. |
| Specific Surface Water Quality Criteria | WV CSR §47-2-8 | Action-specific | Relevant and Appropriate | Requires that water designated for certain uses meet certain criteria. | Any point source discharge from the Site will meet these criteria. |
| WV Pollutant Discharge Elimination System (WVPDES) Program Permits | WV CSR §47-10-3 to 10-8 and 10-11 to 10-14. | Action-specific | Applicable | Establishes substantive requirements and limits for discharges to waters of the State and U.S. | Any point source discharge from the Site into the Ohio River will meet the substantive requirements of this regulation. No permit will be required. |
| Federal Effluent Limitations Guidelines and Standards | WV CSR §47-10-15 | Action-specific | Applicable | Incorporates the federal standards of 40 CFR Parts 400-460 concerning which discharges are permitted and which are not and sets standards for allowable discharges. | Any point source discharge from the Site into the Ohio River will meet the substantive requirements of this regulation. No permit will be required. |
| WV Water Quality Standards | WV CSR §47-2 Appendix E | Action-specific | TBC | Facility must apply for NPDES permit if discharges are above specified concentration for a particular contaminant. | Defines allowable concentrations of contaminants in the Ohio River. |

## Table 2-1 (Continued)
## Applicable or Relevant and Appropriate Requirements (ARARs) and To Be Considered Material (TBCs) for the selected remedy
## Ravenswood PCE Superfund Site

**Note: Not all ARARs apply to each alternative**

| ARAR or TBC | Legal Citation | Type of ARAR | Classification | Summary of Requirement | Further Detail Regarding ARARs in the Context of the Selected Remedy |
|---|---|---|---|---|---|
| Ohio River Valley Water Sanitation Commission, ORSANCO | | Action - specific | TBC | Facility must apply for NPDES permit if discharges are above specified concentration for a particular contaminant. | Defines allowable concentrations of contaminants in the Ohio River. |
| **Air**<br>Facility Requirements for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal (TSD) facilities | WV CSR §45-25-4.3 | Action-specific | Applicable | Requires owners and operators of hazardous waste surface impoundments, waste piles, land treatment units, and other units to operate and manage such facilities to minimize the possibility of release of hazardous waste constituents into the air. | Applies to any remedial activities that may result in the release of hazardous waste constituents into the air. |
| Operating Permit Requirements | WV CSR §45-30-1 to -30-6 | Action-specific | Applicable | Establishes requirements for permitting of air emission sources. | The substantive standards of these requirements will be complied with to the extent that remedial activities will result in emissions of air pollutants. No permit will be required. |
| **Waste Handling and Disposal**<br>WV Hazardous Waste Management Regulations<br>Standards applicable to Generators of Hazardous Waste Pre-Transport Requirements | WV CSR §33-20-5<br>or<br>40 CFR Part 262.30-34 | Action-specific | Applicable | Pre-Transport Requirements for Generators of Hazardous Waste re: packaging, labeling, placarding, and accumulation on site. | The requirements will apply to transportation of soil for off-site disposal if excavated soils are determined to be hazardous. |
| Proof of Proper Solid Waste Disposal | WV CSR §33-7-2 | Action-specific | Applicable | Specifies that any residence or business must provide proof that solid waste is disposed of at an approved solid waste facility. | The requirements will apply if any solid waste is generated. |

# Table 2-2
# SCREENING OF TECHNOLOGIES AND PROCESS OPTIONS APPLICABLE TO GROUNDWATER
# RAVENSWOOD PCE SUPERFUND SITE

| General Response Action | Technology Type | Process Option | Description | Effectiveness | Implementability | Cost | Retained (Y/N) |
|---|---|---|---|---|---|---|---|
| No Action | No Action | No Action | No action is conducted at the Site. | Required for consideration by the NCP. Would not be acceptable because the groundwater is used for the City of Ravenswood water supply. | Easily implemented. | None | Y |
| Institutional Controls | Institutional Controls | Groundwater Monitoring | Monitors contaminants in the groundwater. | Effective in tracking contaminant levels in the groundwater. Will not affect public exposure to contaminated groundwater. | Easily implemented. | Low | Y |
| | | Groundwater Use Restrictions | Restricts the use of groundwater at the Site. | Effective in limiting public exposure to contaminated groundwater. Would not be acceptable due to use of groundwater as City of Ravenswood water supply. | Easily implemented. | Low | Y |
| | | | Restrict or prohibit the installation of new extraction wells. | Effective in limiting pubic exposure to contaminated groundwater. | Easily implemented. | Low | Y |
| Extraction | Extraction | Extraction Wells | Use of wells to extract groundwater from the aquifer. | Highly permeable aquifer, high well yields, and depth of contamination will require high volume of pumping. | Difficult to implement at Ravenswood. | Moderate | Y |

## Table 2-2 (CONTINUED)
## SCREENING OF TECHNOLOGIES AND PROCESS OPTIONS APPLICABLE TO GROUNDWATER
## RAVENSWOOD PCE SUPERFUND SITE

| General Response Action | Technology Type | Process Option | Description | Effectiveness | Implementability | Cost | Retained (Y/N) |
|---|---|---|---|---|---|---|---|
| Extraction (continued) | Extraction (continued) | Extraction Trench | Use of a trench to collect and extract groundwater from the aquifer. | Not effective due to highly permeable aquifer, high well yields, and depth of contamination. | Not easily implemented at Ravenswood. | High | N |
| Containment | Vertical Barriers | Sheet Pile Wall | Use of metal sheets that are pushed into the subsurface in order to block lateral movement of groundwater. | Not effective due to highly permeable aquifer and depth of contamination. | Difficult to implement due to highly permeable aquifer, depth of contamination, and depth to confining unit. | High | N |
| | | Slurry Wall | Use of a trench that is filled with a low permeability slurry material (e.g., clay) that blocks lateral movement of groundwater. | Not effective due to highly permeable aquifer and depth of contamination. | Difficult to implement due to highly permeable aquifer, depth of contamination, and depth to confining unit. | High | N |
| Treatment | Biological | Monitored Natural Attenuation | Technique of monitoring the groundwater for reduction in contaminant levels and indicator parameters to track natural degradation of contaminants. | Effective for organics when aquifer conditions are favorable for natural biodegradation. Will not be effective at Ravenswood as PCE daughter products are generally not present. | Easily implemented | Low | Y |

## Table 2-2 (CONTINUED)
## SCREENING OF TECHNOLOGIES AND PROCESS OPTIONS APPLICABLE TO GROUNDWATER
## RAVENSWOOD PCE SUPERFUND SITE

| General Response Action | Technology Type | Process Option | Description | Effectiveness | Implementability | Cost | Retained (Y/N) |
|---|---|---|---|---|---|---|---|
| Treatment (continued) | Biological (continued) | Bioremediation | Uses bacteria to break down organics in a bioreactor tank. | Moderately effective in treating PCE extracted in groundwater but may not completely treat breakdown products. Does not address aquifer contamination. | Relatively easy to implement. | Moderate | N |
| | | In-Situ Bioremediation | Electron donors, nutrients, and reductive dehalogenating bacteria are added to aquifer to stimulate bioremediation. | Moderately effective, depending on soil and water chemistry, movement of groundwater, and contaminant level. Will not be suitable at Ravenswood due to low level contamination and general absence of PCE daughter products. | Moderately easy to implement. | Moderate | Y |
| | Physical | Air Stripping/ Venturi | Venturi air strippers draw atmospheric air in contact with groundwater to strip volatile organics. | Effective in removing PCE from extracted groundwater. Current method used by the City to reduce PCE concentrations from contaminated pumping wells for blending with water from other wells. Does not address aquifer contamination. | Easily implemented. | Low/ Moderate | Y |

## Table 2-2 (CONTINUED)
## SCREENING OF TECHNOLOGIES AND PROCESS OPTIONS APPLICABLE TO GROUNDWATER
## RAVENSWOOD PCE SUPERFUND SITE

| General Response Action | Technology Type | Process Option | Description | Effectiveness | Implementability | Cost | Retained (Y/N) |
|---|---|---|---|---|---|---|---|
| Treatment (continued) | Physical (continued) | Air Stripping / Tower | Tower containing material with high surface area to allow contact between groundwater and applied air. | Effective in removing PCE from extracted groundwater. High volumes of pumped water from contaminated wells would require a very large tower. Does not address aquifer contamination. | Moderately difficult to implement at high pumping volumes. | Moderate | N |
| | | Carbon Adsorption | Uses carbon adsorption media to bind organic materials. | Effective in removing PCE from extracted groundwater. Carbon media can be regenerated or disposed of when exhausted. Does not address aquifer contamination. | Easily implemented, though large systems would be necessary to treat high volumes of contaminated water. | High | Y |
| | | In Well Air Stripping | Performs air stripping within a specialized well to avoid extraction of groundwater. | Effective in removing VOCs from groundwater, but treatment is limited to area immediately surrounding treatment well. | Moderately difficult to implement over large areas. | Moderate/ High | N |

## Table 2-2 (CONTINUED)
## SCREENING OF TECHNOLOGIES AND PROCESS OPTIONS APPLICABLE TO GROUNDWATER
## RAVENSWOOD PCE SUPERFUND SITE

| General Response Action | Technology Type | Process Option | Description | Effectiveness | Implementability | Cost | Retained (Y/N) |
|---|---|---|---|---|---|---|---|
| Treatment (continued) | Physical (continued) | In-Situ Air Sparging/ Soil Vapor Extraction | Injection of air into the subsurface below the water table to volatilize organics. Soil vapor extraction removes vapors from the vadose zone for discharge or treatment. | Effective in stripping VOCs from the groundwater present in sandy aquifers. | Moderately easy to implement with standard construction equipment and labor. | Moderate | Y |
| | Chemical | UV/Oxidation | Employs ultraviolet light in combination with ozone to destroy organic materials. | Commonly available technology, effective for organics. Generally used with lower volume extracted flow. Does not address aquifer contamination. | Difficult to implement at high flow rates. | High | N |
| | | Reverse Osmosis | Uses high pressure to force water through a membrane leaving contaminants behind in a concentrated form. | Relatively effective in removing organics from extracted groundwater. Does not address aquifer contamination. | Relatively easy to implement, but it is a fairly slow treatment process. | High | N |
| | | Photocatalysis | Employs an intense light source to break down organics. | Potentially applicable for destruction of VOCs in extracted groundwater. Does not address aquifer contamination. | Difficult to implement due to experimental status. | High | N |

## Table 2-2 (CONTINUED)
## SCREENING OF TECHNOLOGIES AND PROCESS OPTIONS APPLICABLE TO GROUNDWATER
## RAVENSWOOD PCE SUPERFUND SITE

| General Response Action | Technology Type | Process Option | Description | Effectiveness | Implementability | Cost | Retained (Y/N) |
|---|---|---|---|---|---|---|---|
| Treatment (continued) | Chemical (continued) | In-Situ Chemical Oxidation | Injection of reactive chemicals (e.g., hydrogen peroxide, potassium permanganate) into the aquifer to oxidize organic compounds. | Applicable to treat highly contaminated portions of groundwater source areas contaminated with chlorinated compounds. If chemicals are injected close to City pumping wells, oxidizers may be drawn into the City water distribution system. | Moderately easy to implement, especially in sandy aquifer materials that allow for material movement. Many injection points are necessary for large vertical and horizontal areas. | Medium | Y |
| | | In-Situ Permeable Reactive Barrier | Use of a funnel-and-gate configuration to direct groundwater toward a treatment zone (e.g., zero valent iron). | Applicable for chlorinated organic compounds. | Difficult to implement at the depths and large area found at Ravenswood. | High | N |
| Discharge | Discharge | Discharge to Surface Water | Discharge of treated groundwater into Ohio River. | Applicable to treated groundwater. | Discharge options not applicable for groundwater pumped for use in drinking water supply. | Low | N |
| | | Discharge to Waste Water Treatment Plant (WWTP) | Transport of treated groundwater to local WWTP via piping. | Applicable to treated/untreated groundwater, depending on levels of contamination. | Discharge options not applicable for groundwater pumped for use in drinking water supply. | Moderate | N |

## Table 2-2 (CONTINUED)
## SCREENING OF TECHNOLOGIES AND PROCESS OPTIONS APPLICABLE TO GROUNDWATER
## RAVENSWOOD PCE SUPERFUND SITE

| General Response Action | Technology Type | Process Option | Description | Effectiveness | Implementability | Cost | Retained (Y/N) |
|---|---|---|---|---|---|---|---|
| Discharge (continued) | Discharge (continued) | Reinjection into Groundwater | Reinjection of treated groundwater. | Applicable to treated groundwater. | Discharge options not applicable for groundwater pumped for use in drinking water supply. | Low | N |

# TABLE 5-1
# SUMMARY OF COMPARATIVE ANALYSIS OF REMEDIAL ALTERNATIVES
# RAVENSWOOD PCE SUPERFUND SITE
# RAVENSWOOD, WEST VIRGINIA

| Alternative | 1. Overall Protection of Human Health & Environment | 2. Compliance with ARARs | 3. Long-Term Effectiveness & Permanence | 4. Reduction of Toxicity, Mobility or Volume Through Treatment | 5. Short-Term Effectiveness | 6. Implementability | 7. Total Present Worth Cost |
|---|---|---|---|---|---|---|---|
| **1. No Action** | • No treatment of groundwater, providing no reduction of risk.<br>• No actions taken to reduce the potential for migration to Ohio River.<br>• Overall: Low | • Does not meet chemical-specific ARARs for groundwater and surface water because no treatment occurs.<br>• Will not meet groundwater MCL.<br>• Overall: Low | • Does not treat groundwater.<br>• Does not prevent exposure to contaminants.<br>• Overall: Low | • Does not reduce toxicity, mobility, or volume through treatment.<br>• Overall: Low | • No actions to reduce Short-Term risks will be necessary.<br>• Overall: High | • No implementability issues.<br>• Overall: High | $0 |
| **2. Groundwater Extraction and GAC Treatment Using a New Extraction Well (EW-1)**<br>**a) Discharge to Ohio River**<br>**b) Discharge to City water supply** | • Ex-situ treatment of extracted, contaminated groundwater.<br>• Will provide hydraulic protection of existing production wells as well as provide treated groundwater for drinking water use (2b only)<br>• Will not reduce contamination in groundwater.<br>• Overall: High/Medium | • Meets chemical-, action-, and location-specific ARARs for extracted and treated groundwater.<br>• Should meet water quality criteria for discharge to water supply or surface water.<br>• Will not meet groundwater MCL.<br>• Overall: Medium | • Removes and treats 200 gpm of contaminated groundwater.<br>• May not capture entire contaminated plume, PW-2, PW-3 and PW-5 may continue to capture contaminated groundwater.<br>• May significantly alter flow paths of plume.<br>• Overall: Medium | • Pumping will somewhat reduce the volume of contaminated groundwater as well as the toxicity of the groundwater.<br>• Mobility in the groundwater, will not be affected, compared to the current system.<br>• Overall: Medium | • Short-Term risks to remediation workers will be controlled by health and safety program.<br>• Groundwater MCL is not likely to be met.<br>• Should meet drinking water MCL in extracted groundwater in under one year.<br>• Overall: Medium | • Readily implemented using standard construction equipment and services.<br>• High pumping rate of EW-1 will require a large carbon system.<br>• Overall: Medium | Capital Costs(a) - $578,500<br>Capital Costs(b) - $513,800<br>O&M Costs - $1,096,500<br>Present Worth (a) - $1,675,000<br>Present Worth (b) - $1,610,000 |
| **3. Venturi Air Stripping Using a New Extraction Well (EW-1)** | • Ex-situ treatment of extracted, contaminated groundwater.<br>• Will provide hydraulic protection of existing production wells as well as provide treated groundwater for drinking water use.<br>• Will not reduce contamination in groundwater.<br>• Overall: High/Medium | • Meets chemical-, action-, and location-specific ARARs for extracted and treated groundwater.<br>• Should meet water quality criteria for drinking water<br>• Will not meet groundwater MCL.<br>• Overall: Medium | • Removes and treats 200 gpm of contaminated groundwater.<br>• May not capture entire contaminated plume, PW-2, PW-3 and PW-5 may continue to capture contaminated groundwater.<br>• May significantly alter flow paths of plume.<br>• Overall: Medium | • Pumping will somewhat reduce the volume of contaminated groundwater as well as the toxicity of the groundwater.<br>• Mobility in the groundwater, will not be affected, compared to the current system.<br>• Overall: Medium | • Short-Term risks to remediation workers will be controlled by health and safety program.<br>• Groundwater MCL is not likely to be met.<br>• Should meet drinking water MCL in extracted groundwater in under one year.<br>• Overall: Medium | • Readily implemented using standard construction equipment and services.<br>• Venturi air stripper replacement parts may be difficult to obtain.<br>• Will require frequent maintenance.<br>• Overall: Low to Medium | Capital Costs - $325,900<br>O&M Costs - $874,800<br>Present Worth - $1,201,000 |
| **4. In-Situ Air Sparging/Soil Vapor Extraction** | • Uses an in-situ system to remove contaminants from groundwater, reducing contaminant levels over time.<br>• Will eventually reduce or eliminate contaminants in drinking water.<br>• Overall: High | • Meets chemical-, action-, and location-specific ARARs for groundwater.<br>• Will eventually meet water quality criteria for drinking water.<br>• Will eventually meet groundwater MCL for drinking water.<br>• Overall: High | • In-situ treatment of groundwater will reduce the size and concentration of contaminant plume and prevent further migration of the plume for the Long-Term.<br>• Overall: Medium to High | • Sparging/vapor extraction process will reduce the mobility and volume of contaminants in the groundwater.<br>• Toxicity of groundwater will decrease as PCE is partitioned into the vapor phase and removed from the subsurface.<br>• Overall: High | • Short-Term risks to remediation workers will be controlled by health and safety program.<br>• Groundwater MCL is likely to be met in approximately ten years.<br>• Overall: Medium to High | • Readily implemented using standard construction equipment and services.<br>• Presence of businesses and residences may affect location of AS/SVE wells.<br>• Overall: Medium to High | Capital Costs - $282,400<br>O&M Costs - $695,600<br>Present Worth - $978,000 |

# Figures

\\Chyfedsvr1\ecaffx\Ravenswood\GIS\MXD\RI FS\Site Location Map.mxd 04/12/2010 12:25:41 PM

Notes:
Source of aerial photo: Google Earth Pro 3/31/2010.

Ravenswood PCE Superfund Site
Ravenswood, West Virginia

Figure 1-1
Site Location Map

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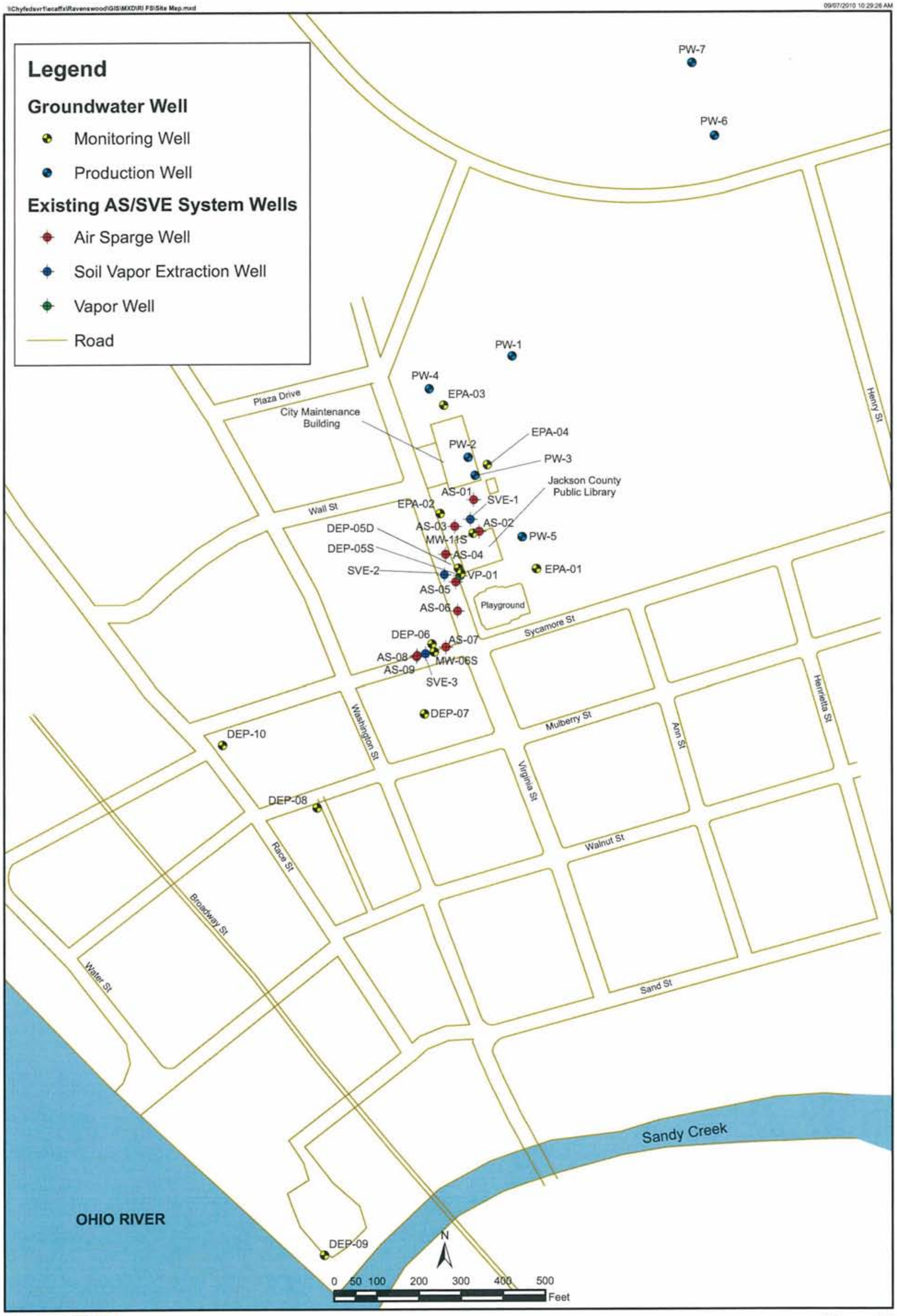

**CDM**

Ravenswood PCE Site
Ravenswood, West Virginia

Figure 1-2
Site Map

\\Chyfedsvr1\Ecaffx\Ravenswood\GIS\MXD\RI FS\FS Figure 1-3.mxd

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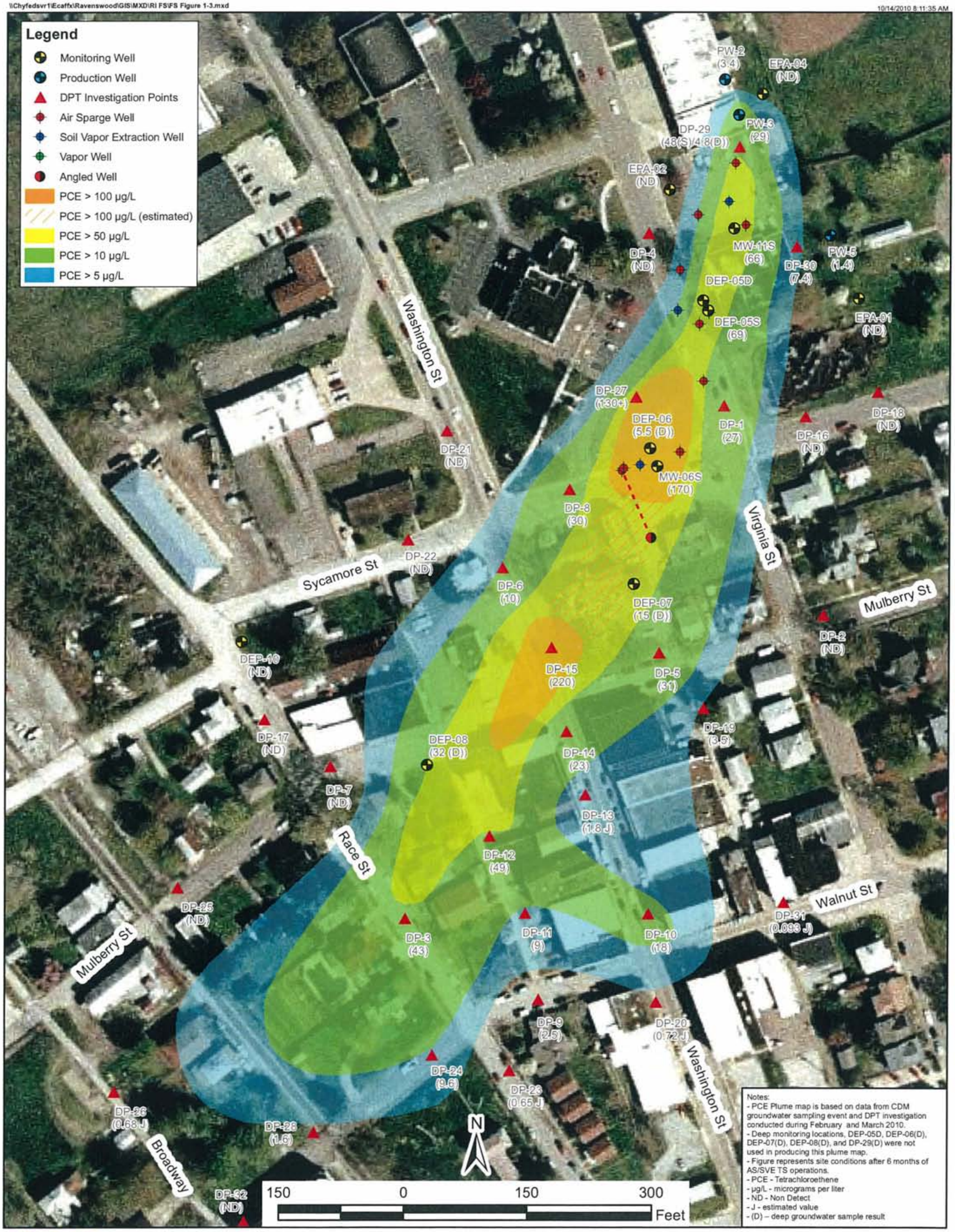

Notes:
- PCE Plume map is based on data from CDM groundwater sampling event and DPT investigation conducted during February and March 2010.
- Deep monitoring locations, DEP-05D, DEP-06(D), DEP-07(D), DEP-08(D), and DP-29(D) were not used in producing this plume map.
- Figure represents site conditions after 6 months of AS/SVE TS operations.
- PCE - Tetrachloroethene
- µg/L - micrograms per liter
- ND - Non Detect
- J - estimated value
- (D) – deep groundwater sample result

**CDM**

Ravenswood PCE Site
Ravenswood, West Virginia

Figure 1-3
PCE in Shallow Groundwater
February/March 2010

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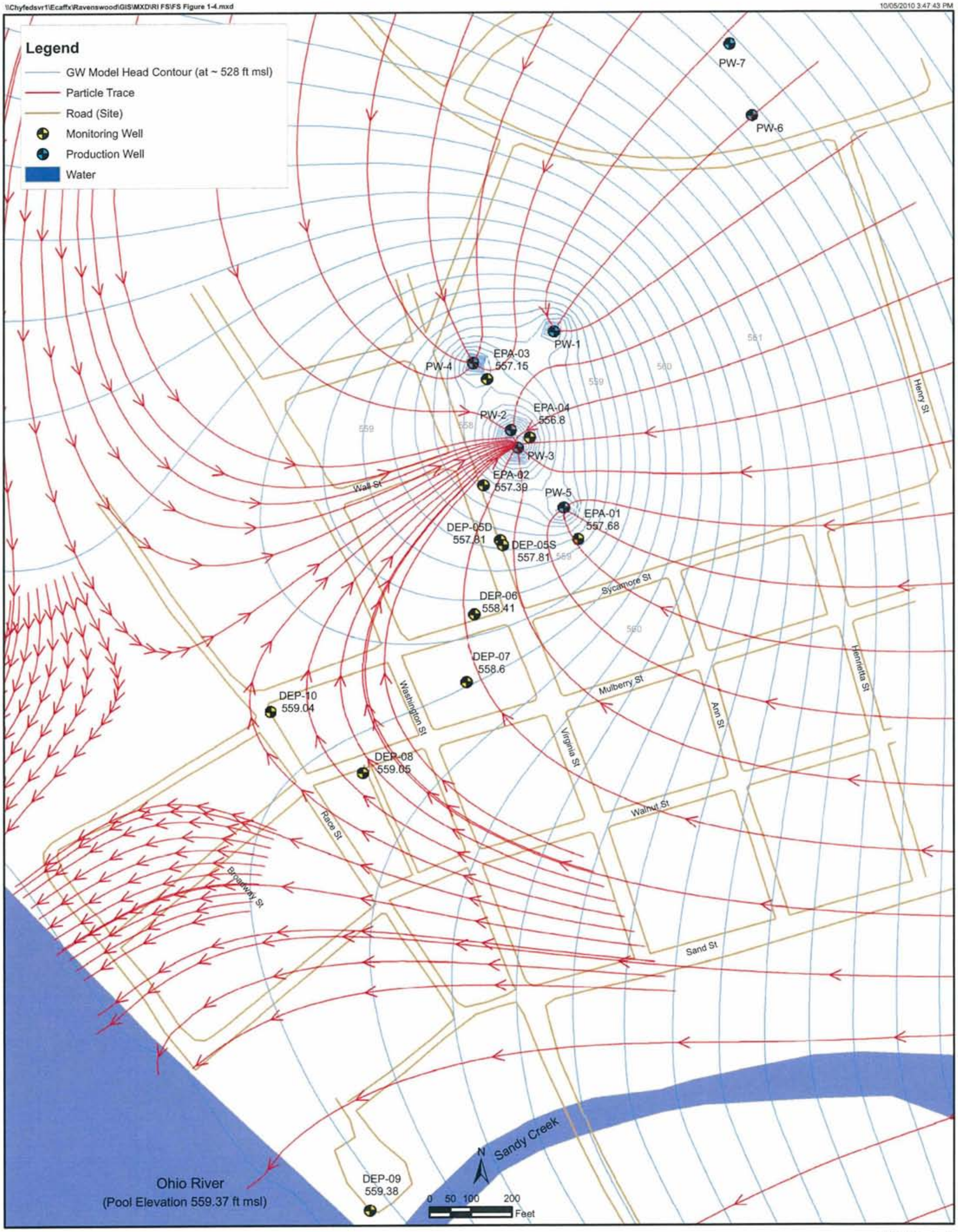

**CDM**

Ravenswood PCE Site
Ravenswood, West Virginia

Figure 1-4
Estimated Head Contours - Alluvium ( ~ 530 ft msl)
Groundwater Flow Model Date = October 23, 2001

Notes:
Head contour interval = 0.2 ft.
Flowpath arrows placed at 1-yr intervals.
Observed water levels listed beneath each monitoring well.
Ohio River pool Elevation = Low (559.37 ft msl)

\\Chyfedsvr1\Ecaffx\Ravenswood\GIS\MXD\RI FS\FS Figure 1-5.mxd

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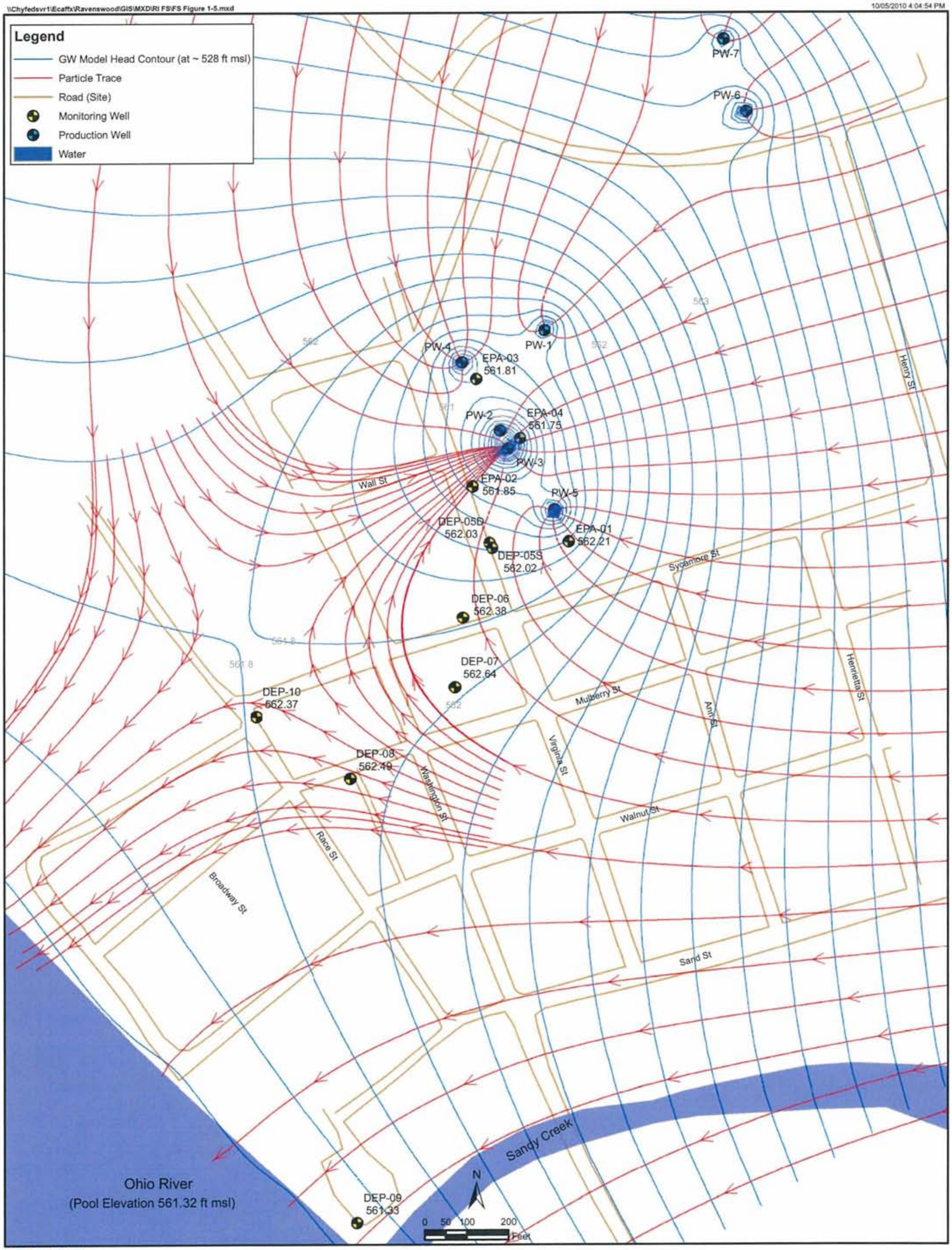
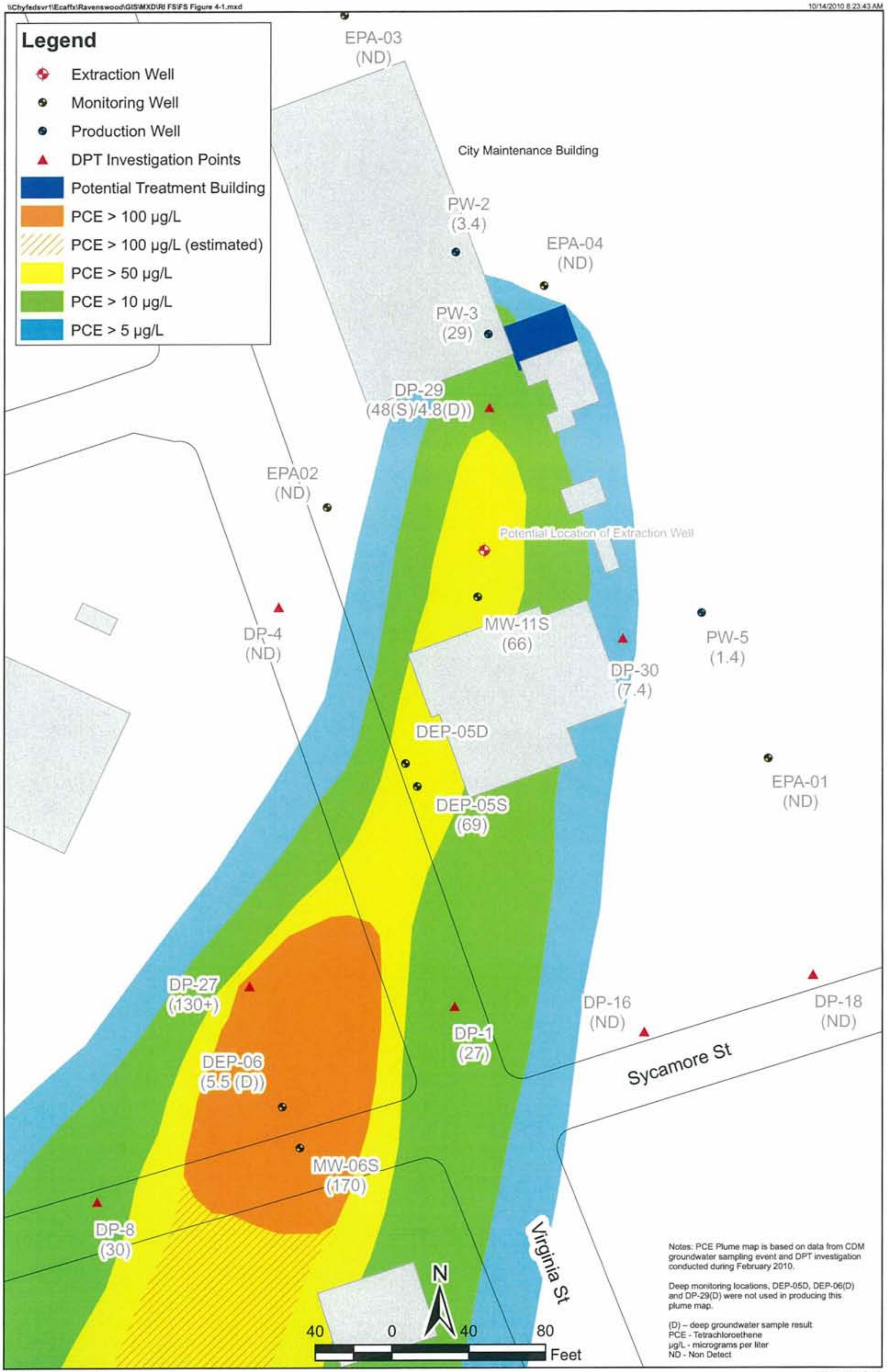


Ravenswood PCE Site
Ravenswood, West Virginia

Figure 1-5
Estimated Head Contours - Alluvium (~530 ft msl)
Groundwater Flow Model Date = March 22, 2005

Notes:
Head contour interval = 0.2 ft.
Flowpath arrows placed at 1-yr intervals.
Observed water levels listed beneath each monitoring well.
Ohio River Pool Elevation = High (561.32 ft msl)



Notes: PCE Plume map is based on data from CDM groundwater sampling event and DPT investigation conducted during February 2010.

Deep monitoring locations, DEP-05D, DEP-06(D) and DP-29(D) were not used in producing this plume map.

(D) – deep groundwater sample result
PCE - Tetrachloroethene
µg/L - micrograms per liter
ND - Non Detect

CDM

Ravenswood PCE Site
Ravenswood, West Virginia

Figure 4-1
Alternative 2 - Groundwater Extraction and GAC Treatment Using a New Extraction Well (EW-1)

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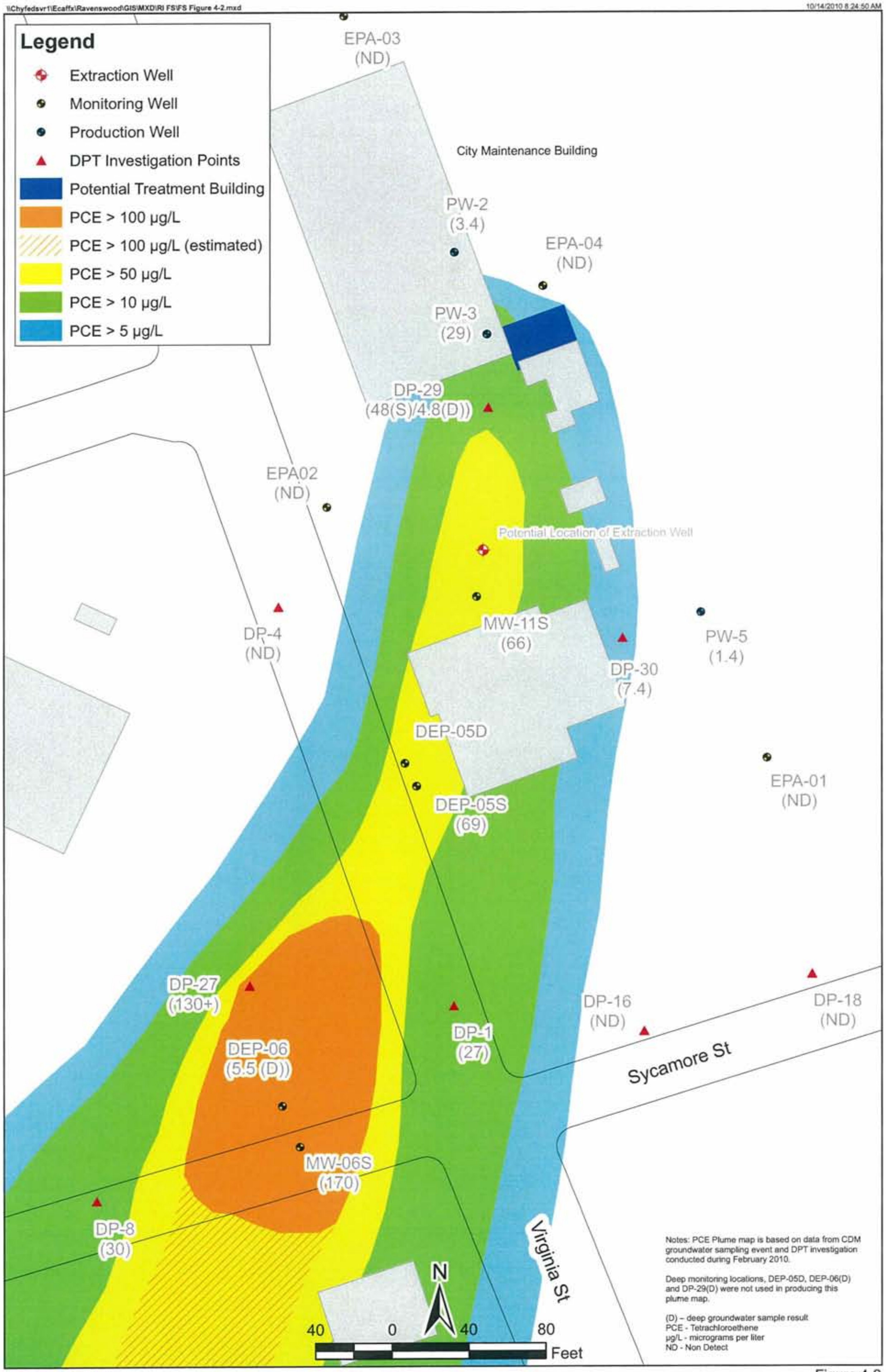

Notes: PCE Plume map is based on data from CDM groundwater sampling event and DPT investigation conducted during February 2010.

Deep monitoring locations, DEP-05D, DEP-06(D) and DP-29(D) were not used in producing this plume map.

(D) – deep groundwater sample result
PCE - Tetrachloroethene
µg/L - micrograms per liter
ND - Non Detect

Ravenswood PCE Site
Ravenswood, West Virginia

Figure 4-2
Alternative 3 - Venturi Air Stripping Using a New Extraction Well (EW-1)

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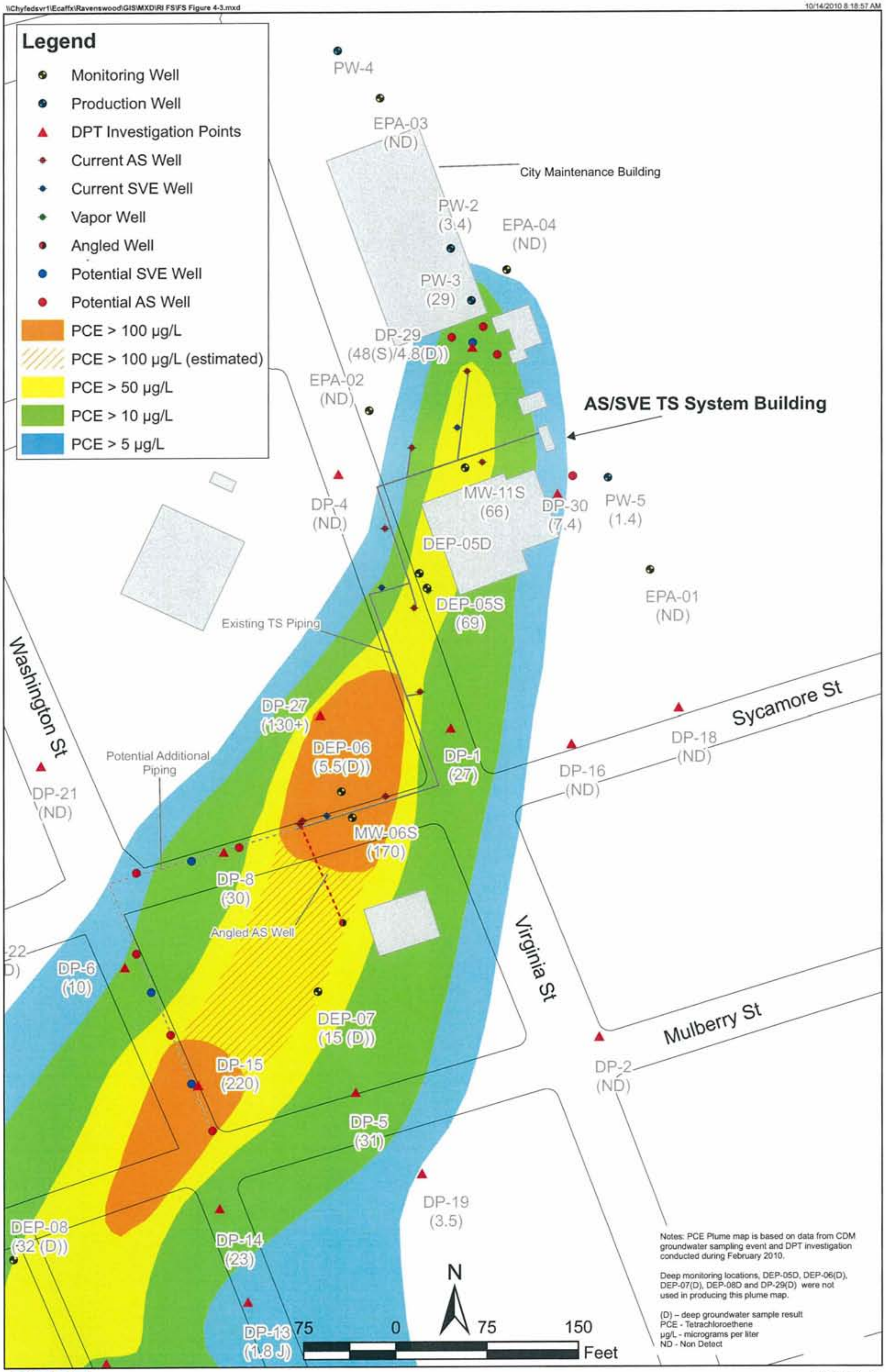


Notes: PCE Plume map is based on data from CDM groundwater sampling event and DPT investigation conducted during February 2010.

Deep monitoring locations, DEP-05D, DEP-06(D), DEP-07(D), DEP-08D and DP-29(D) were not used in producing this plume map.

(D) – deep groundwater sample result
PCE - Tetrachloroethene
µg/L - micrograms per liter
ND - Non Detect

CDM

Ravenswood PCE Site
Ravenswood, West Virginia

Figure 4-3
Alternative 4 - AS/SVE System

# Appendix A

# Interim Evaluation of Treatability Study Effectiveness

CDM
14420 Albemarle Point Place, Suite 210
Chantilly, Virginia 20151

March 29, 2010

Ms. Laura Johnson
Remedial Project Manager
U.S. Environmental Protection Agency
1650 Arch Street
Philadelphia, PA 19103-2029

PROJECT: Contract No.: EP-S3-07-06
Work Assignment No.: 025-RICO-C368

DOCUMENT NO.: 3330-025-EO-CORR-01078
SUBJECT: Interim Evaluation of Treatability Study Effectiveness
Ravenswood PCE Superfund Site, Ravenswood West Virginia
Technical Memorandum (DCN: 3330-025-RT-OTHR-01079)

Dear Ms. Johnson:

CDM Federal Programs Corporation (CDM) is pleased to submit two (2) of the above-referenced technical memorandum in partial fulfillment of this work assignment.

Note that one (1) copy of the Memorandum has been sent to Mark Slusarski of the West Virginia Department of Environmental Protection, under separate cover.

We appreciate the opportunity to support the EPA on this project and look forward to completing the Treatability Study for the site. If you have any questions or comments, please contact me at [redacted].

Sincerely,

[redacted]

[redacted]
Project Manager
CDM Federal Programs Corporation

cc: J. Tralie, RAC III Project Officer (3HS42) (letter only)
M. Slusarski, Division of Land Restoration, WVDEP
[redacted], CDM Program Manager (letter only)
Document Control File

CDM

# Technical Memorandum

*To:* *Laura Johnson, EPA RPM*

*From:* [redacted]*, CDM Project Manager*

*Date:* *March 29, 2010*

*Subject:* *Interim Evaluation of Treatability Study Effectiveness, Ravenswood PCE Superfund Site, Ravenswood, West Virginia*
*DCN: 3330-025-RT-OTHR-01079*

This Technical Memorandum (TM) provides an interim evaluation of the performance of the Air Sparge (AS)/Soil Vapor Extraction (SVE) Treatability Study (TS) system at the Ravenswood Tetrachloroethene (PCE) Superfund Site (the Site) in Ravenswood, WV. Specifically, this memorandum summarizes the treatability study system operational history, the sampling associated with this study and the system's performance to support the finalization of EPA's Feasibility Study (FS) for this Site. CDM Federal Programs Corporation (CDM) has installed and operated this treatability study system at the Site under EPA contract EP-S3-07-06, Work Assignment 025-RICO-C368 for Remedial Investigation (RI) and FS services at the Site.

A full presentation of all vapor and groundwater analytical data discussed in this TM, including a quality assurance review of the data, will be included in the FS and RI reports, respectively. These reports are currently in preparation.

## Treatability Study System Background and Description

CDM conducted the AS / SVE treatability study system installation during April and May 2009. The treatment unit (TU) was transported to the Ravenswood from the Vienna PCE Superfund Site in Vienna, WV on May 4, 2009, and system startup occured in June 2009. The SVE and AS elements of the system operate in conjunction to volatilize aqueous phase PCE from the groundwater and extract the PCE vapors from the vadose zone. System installation was conducted in accordance with the Working Draft Treatability Study Plan issued on October 27, 2008. The layout of the completed treatability study system is shown on Figure 1.

The AS wells inject air below the water table to volatilize aqueous phase contaminants in groundwater. The volatilized contaminants migrate upward to the vadose zone, where they are removed by SVE. Nine AS wells were installed in the study area.

For the SVE application, a vacuum is applied to extraction wells installed in the vadose zone. This vacuum creates a negative pressure gradient in the unsaturated zone causing movement of vapors toward these wells. The extracted vapors are then treated by vapor-phase granular activated carbon units and discharged to the atmosphere. Three SVE wells were installed in the study area.

The process equipment includes an air compressor, an air sparge well manifold, an SVE well manifold, an air/water separator, an SVE blower, two vapor-phase granular activated carbon (VPGAC) units, and an exhaust stack. Solenoid valves in both the AS and SVE wells allow the system Programmable Logic Controller (PLC) to pulse wells independently, allowing greater control and energy efficiency in the system

**Treatability Study Operational History**

Treatability study system start up was conducted in several phases. During the initial two months of operation, only the SVE system was operated to sweep PCE vapors from the subsurface. After monitoring data confirmed that no high PCE levels were present in the vadose zone, the AS network was activated at half capacity while continuing to operate the SVE unit. This helped ensure that the sparge air did not rapidly mobilize high concentrations of PCE that might be present in the saturated zone, and that all released vapors would be captured by the SVE vacuum. Following the receipt of data confirming that there were no releases of elevated PCE into the vadose zone , the AS system was activated at full capacity. To ensure effective capture of sparged vapors, the SVE unit is operational whenever the AS wells are functioning.

Initial start up of the SVE blower occurred in June 2009. The AS well network was activated at half capacity in August 2009 and at full capacity beginning in September 2009. Since initial system start up in June 2009 the system has been running as designed with routine Operations & Maintenance (O&M) performed as necessary.

**Treatability Study Sampling**

To support the treatability study, groundwater and vapor samples were collected to establish baseline conditions, monitor system start up and evaluate system performance. Groundwater samples were analyzed for EPA Target Compound List (TCL) volatile organic compounds (VOCs) and semi-volatile organic compounds (SVOCs) by SOM01.2 low concentration or trace water. Soil vapor samples were analyzed for selected chlorinated VOCs by Microseeps, Inc. Standard Operating Procedure (SOP) AM 4.02.

Samples were collected in accordance with the Ravenswood Final Site Management Plan (SMP) Addendum issued on December 17, 2008 SMP (CDM 2008) and the SMP Addendum 2 issued on January 19, 2010.

*Groundwater Monitoring*

Baseline groundwater samples were collected from 13 monitoring wells and 7 production wells in December 2008, following screening samples collected during well installation in November 2008. Two subsequent rounds of groundwater sampling were conducted in September/October 2009 and in February 2010.

During February 2010, a supplementary Direct Push Technology (DPT) investigation to support a Vapor Intrusion (VI) assessment was performed. Groundwater samples were collected from

26 points in the shallow groundwater. Although not part of the TS, these data are used to enhance the understanding of the PCE distribution in the shallow groundwater.

*Vapor Monitoring*

Baseline samples were collected from the SVE wells (SVE-1, SVE-2, and SVE-3), dual purpose wells (MW-06S and MW-11S) and vapor monitoring point (VP-1) immediately prior to and after system start up in June 2009. Samples were also collected prior to and following the initiation of air sparging (August 2009) and when the air sparging system was brought up to full capacity (September 2009).

Following these start up and confirmatory samples, monthly treatment system samples were collected from the individual SVE wells, the dual purpose wells, the vapor monitoring point and the influent and the effluent of the TS treatment unit beginning in September 2009.

### Sampling Results and Discussion

*Groundwater Results*

PCE levels have decreased in areas within the influence of the TS system sparge wells, especially in DEP-05S (in front of the Jackson County Public Library), where PCE levels have decreased from a baseline concentration of 370 micrograms per liter (ug/L) in December 2008 to 69 ug/L in February 2010. As shown on **Figure 2**, sampling conducted prior to the start of the TS (May 2007) indicated that PCE levels in DEP-05S had spiked as high as 1,200 ug/L after remaining steady in the 250 ug/L to 323 range for several years. This spike may have indicated that a zone of higher contamination may have been drawn towards PW-3.

Concentrations of PCE at newly installed well MW-11S (in the City Maintenance Yard parking lot) have also decreased by nearly 30% from a baseline value of 93 ug/L in December 2008 to 66 ug/L in February 2010. PCE levels in MW-06S have decreased from 200 ug/L in September 2009 to 170 ug/L in February 2010, after increasing slightly from the December 2008 value of 180 ug/L.

PCE concentrations at monitoring wells (DEP-07, DEP-08) outside of the immediate vicinity of the treatment system sparge wells have remained relatively constant since the December 2008 baseline sampling event.

PCE levels in City Production Well 3 (PW-3) have increased from the baseline value of 24 ug/L in December 2008 to 29 ug/L in January 2010. Based on data obtained from the City of Ravenswood, PW-3 is screened from 80 ft to 90 ft below ground surface (bgs). PCE levels in PW-2 and PW-5 have also increased since baseline sampling. PW-2 has increased from not detected (ND) in December 2008 to 3.4 ug/L in March 2010, and PW-5 has increased from 0.43 J ug/L in December 2008 to 1.4 ug/L in March 2010. The increases in PW-2 and PW-5 correspond to shutdown of PW-3 in early February 2010. The City has historically pumped PW-3 at a relatively high flow rate; pumping it whenever other nearby wells were in operation. Since PW-3 is on the plume side of PW-2, this operational strategy has helped to protect PW-2 and, to a lesser extent, PW-5, from being affected by the contamination.

The current plume, depicted on Figure 2, is based on data collected during the February 2010 groundwater sampling event and the February 2010 DPT investigation. PCE results from the previous groundwater sampling rounds are presented on Table 1 and results from the DPT investigation are presented on Table 2. Additional DPT investigation samples were collected in mid-March 2010, and those data will be included in subsequent reports when available.

Data collected during the DPT investigation identified an area of higher PCE concentration (220 ug/l) on Washington Street north of the intersection with Mulberry Street that may be connected to the equally elevated values seen in MW-11. These wells are near the stagnation zones identified in the groundwater flow models presented in the Hydrogeolocial Analysis Report submitted on March 31, 2006. Contaminant flow may alternate toward the City Production wells or the Ohio River, depending on the seasonal fluctuation in groundwater and river elevations.

*Vapor Results*

PCE levels in vapor sampling have remained relatively constant since the AS system was fully activated. Influent concentrations have ranged from 0.304 parts per million by volume (ppmv) to 0.7094 ppmv, with PCE levels in individual SVE wells ranging from 0.2326 ppmv (SVE-1 in March 2010) to 1.6526 ppmv (SVE-3 in March 2010). Samples collected from SVE-3, on Sycamore Street near MW-06S, have consistently had the highest PCE levels, with samples from SVE-2 (0.1407 ppmv to 0.8474 ppmv) and SVE-1 (0.2326 ppmv to 0.3577 ppmv) having consistently lower levels. Data for vapor monitoring wells have shown increased PCE levels since the TS system startup, with values ranging from 0.0263 ppmv (MW-11S in September 2009) to 3.7931 ppmv (VP-1 in September 2009). PCE concentrations in MW-06S and VP-1 have remained above 2 ppmv while concentrations in MW-11S have varied from 0.0263 ppmv to 0.852 ppmv. Results from these sampling events are presented in Table 3 and Figure 3.

Based on the results of the monthly vapor sampling conducted at the Site, the TS system has removed 3.3 pounds (lbs) of PCE from nearly 17,900,000 standard cubic feet (scf) of extracted soil vapor. These calculations are presented in Table 4 and a graphical depiction is presented on Figure 4.

**Conclusions and Recommendations**

The decreasing PCE values in monitoring wells in the vicinity of the AS wells indicate that PCE within the radius of influence (ROI) of the AS wells is being effectively sparged from the saturated zone. This conclusion is supported by the increased levels of PCE in the SVE and vapor monitoring wells. PCE levels in the system influent indicate the TU is capturing sparged PCE and retaining it on the VPGAC vessels. The relatively static PCE levels in wells outside the ROI of the AS wells is expected, as the AS is not affecting this groundwater.

The slight increase in PCE levels in PW-3 are likely a result of more highly contaminated groundwater, as indicated by the spike in PCE concentration observed in DEP-05S during the May 2007 sampling event being drawn into PW-3. Groundwater modeling performed as part of the Hydrogeologcial Analysis Report (CDM 2006)) indicated that the expected travel time from

DEP-05S to PW-3 is approximately 2 years. Based on the screened interval of PW-3, PW-3 is likely drawing water downward where the ROI of the AS is narrower. The AS wells in the vicinity of the City Maintenance Yard should eventually address this contamination, but it is likely that residual PCE from the May 2007 spike at DEP-05S is now being captured by PW-3.

The results of the DPT investigation have more completely defined the extent of the PCE plume. The new data also confirm that the AS and SVE wells were installed in locations that should effectively intercept the PCE plume as it is drawn toward the City Production Wells. The plume should pass through the ROI of the AS and SVE wells and be stripped of a high percentage of the PCE mass prior to reaching the City wells.

Continued monitoring as well as a supplemental phase of the DPT investigation conducted in early May 2010 will further characterize the PCE plume in the vicinity of the TS system and the City Production Wells and provide additional data with which a final evaluation of the applicability of the AS/SVE system can be made.

Groundwater and vapor monitoring have confirmed that the Ravenswood AS/SVE Treatability Study system is removing PCE from the saturated zone at the Site. Therefore, CDM recommends that the operation of the AS/SVE system be continued, while EPA progresses toward a Record of Decision for the Ravenswood PCE Superfund Site.

## Table 1 - Treatability Study Groundwater Data
## Ravenswood PCE Superfund Site, Ravenswood, West Virginia

| | November 2008 | December 2008 | September 2009 | November 2009 | January 2010 | February 2, 2010 | February 17, 2010 | March 2010 | Units |
|---|---|---|---|---|---|---|---|---|---|
| **Monitoring Wells** | | | | | | | | | |
| DEP05D | NS | 0.15 J | | NS | NS | | NS | NS | ug/L |
| DEP05S | NS | 370 + | 230 | NS | NS | 69 | NS | NS | ug/L |
| DEP06 | NS | 2.2 J | 3.9 | NS | NS | 5.5 | NS | NS | ug/L |
| DEP07 | NS | 17 J | 11 | NS | NS | 15 | NS | NS | ug/L |
| DEP08 | NS | 40 + J | 44 | NS | NS | 32 | NS | NS | ug/L |
| DEP09 | NS | | NS | NS | NS | NS | NS | NS | ug/L |
| DEP10 | NS | | NS | NS | NS | NS | NS | NS | ug/L |
| EPA01 | NS | | | NS | NS | | NS | NS | ug/L |
| EPA02 | NS | | | NS | NS | | NS | NS | ug/L |
| EPA03 | NS | | | NS | NS | | NS | NS | ug/L |
| EPA04 | NS | | | NS | NS | | NS | NS | ug/L |
| MW06 | NS | 180 + J | 200 | NS | NS | 170 | NS | NS | ug/L |
| MW11S | 16 | 93 + J | 56 | NS | NS | 66 | NS | NS | ug/L |
| **City Production Wells** | | | | | | | | | |
| PW01 | NS | | NS | NS | NS | NS | NS | NS | ug/L |
| PW02 | NS | | NS | NS | NS | 1.9 | 3.5 J | 3.4 | ug/L |
| PW03 | NS | 24 + J | 14 | 28 | 29 | NS | NS | NS | ug/L |
| PW04 | NS | | NS | NS | NS | NS | NS | NS | ug/L |
| PW05 | NS | 0.43 J | NS | NS | NS | 1.2 | 1.5 J | 1.4 | ug/L |
| PW06 | NS | | NS | NS | NS | NS | NS | NS | ug/L |
| PW07 | NS | | NS | NS | NS | NS | NS | NS | ug/L |
| **Treatability Study System Wells** | | | | | | | | | |
| AS01 | 5.4 | NS | NS | NS | NS | NS | NS | NS | ug/L |
| AS02 | 210 | NS | NS | NS | NS | NS | NS | NS | ug/L |
| AS03 | | NS | NS | NS | NS | NS | NS | NS | ug/L |
| AS04 | | NS | NS | NS | NS | NS | NS | NS | ug/L |
| AS05 | 0.48 J | NS | NS | NS | NS | NS | NS | NS | ug/L |
| AS06 | 140 | NS | NS | NS | NS | NS | NS | NS | ug/L |
| AS07 | 110 + | NS | NS | NS | NS | NS | NS | NS | ug/L |
| AS08 | 64 + | NS | NS | NS | NS | NS | NS | NS | ug/L |
| AS09 | NS | NS | NS | NS | NS | NS | NS | NS | ug/L |

Notes:

Results for Tetrachloroethene

ug/l - micrograms per liter

NS - not sampled

Blank Cell - Non Detect

+ - Result reported from diluted analysis

J - Analyte present. Reported value may not be accurate or precise

## Table 2: Results of DPT Investigation, February 2010
## Ravenswood PCE Superfund Site, Ravenswood WV

| Sample Location | Result (ug/L) |
|---|---|
| DP-1 | 27 |
| DP-2 | ND |
| DP-3 | 43 |
| DP-4 | ND |
| DP-5 | 31 |
| DP-6 | 10 |
| DP-7 | ND |
| DP-8 | 30 |
| DP-9 | 2.5 |
| DP-10 | 18 |
| DP-11 | 9 |
| DP-12 | 49 |
| DP-13 | 1.8 J |
| DP-14 | 23 |
| DP-15 | 220 |
| DP-16 | ND |
| DP-17 | ND |
| DP-18 | ND |
| DP-19 | 3.5 |
| DP-20 | 0.72 J |
| DP-21 | ND |
| DP-22 | ND |
| DP-23 | 0.65 J |
| DP-24 | 9.6 |
| DP-25 | ND |
| DP-26 | 0.68 J |

Notes:

Results are for Tetrachloroethene (PCE)

ug/L - micrograms per liter

J - estimated value.

ND - not detected

Data from DP 27 through 32 were not available at the time this report was prepared

## Table 3: PCE Vapor Sample Results
## Ravenswood PCE Superfund Site

| | Sampling Date | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | June 2009 (SVE System Only) | | | | | | August 2009 (AS Start up) | | September | October | November | December | January | February | March | |
| **Sample Location** | **6/3/2009** | **6/3/2009** | **6/4/2009** | **6/5/2009** | **6/9/2009** | **6/16/2009** | **8/4/2009** | **8/5/2009** | **9/2/2009** | **10/8/2009** | **11/6/2009** | **12/2/2009** | **1/6/2010** | **2/2/2010** | **3/2/2010** | **Sample Location** |
| SVE 1 | 0.0193 | 0.0127 | 0.012 | 0.0085 | 0.0116 | 0.0133 | 0.0202 | 0.0251 | 0.295 | 0.3565 | 0.3577 | 0.2512 | 0.3048 | 0.2461 | 0.2326 | SVE 1 |
| SVE 2 | 0.002 | 0.0022 | 0.0021 | 0.0012 | 0.0028 | 0.0021 | 0.0179 | 0.0037 | 0.1407 | 0.5478 | 0.7355 | 0.8474 | 0.6889 | 0.6425 | 0.5616 | SVE 2 |
| SVE 3 | 0.0174 | 0.0228 | 0.0109 | 0.0158 | 0.01 | 0.0222 | 0.0023 | 0.0238 | 0.9184 | 1.2995 | 1.0818 | 0.9406 | 1.1006 | 1.6154 | 1.6526 | SVE 3 |
| INFLUENT | NS | NS | 0.0083 J | 0.0115 B | 0.0053 B | NS | NS | NS | 0.4801 | NS | 0.6202 | 0.7094 | 0.5318 | 0.304 | 0.6347 | INFLUENT |
| EFFLUENT | NS | NS | NS | NS | NS | NS | NS | NS | NS | 0.0017 | | | | | | EFFLUENT |
| MW-06S | 0.0256 | 0.0256 | 0.0451 | 0.0385 | | 0.0418 | 0.0745 | 0.0707 | 2.2409 | 3.4598 | 2.1925 | 2.7444 | 3.2676 | 2.177 | 2.7265 | MW-6S |
| MW-11S | 0.0174 | 0.0188 | 0.0115 | 0.0132 | 0.0113 | 0.0189 | 0.0087 | 0.0183 | 0.0263 | 0.0658 | 0.088 | 0.1329 | 0.6239 | 0.5884 | 0.852 | MW-11S |
| VP-1 | 0.0105 | 0.0172 | 0.0142 | 0.0104 | | 0.0117 | 0.0148 | 0.0166 | 3.7931 | 1.5737 | 3.2239 | 3.0318 | 2.0536 | 3.2523 | 2.01 | VP-1 |

Note: Results are in parts per million by volume (ppmv)

J = Analyte present. Reported value is estimated; concentration is outside the range for accurate quantification.

B = Not detected substantially above the level reported in laboratory or field blanks.

NS = Well was not sampled.

Empty cell indicates non-detect.

## Table 4: Treatability Study System - Mass Removal (PCE)
## Ravenswood PCE Superfund Site, Ravenswood, West Virginia

| Date | PCE Results SVE Influent | Total SVE Flow | Mass Removed | Cumulative Mass Removed |
|---|---|---|---|---|
| | (ppmv) | (scf) | (lbs) | (lbs) |
| 6/3/09 | 0.0127 | 103,000 | 0.0005 | 0.0005 |
| 6/4/09 | 0.0080 | 169,000 | 0.0002 | 0.0008 |
| 6/5/09 | 0.0085 | 234,000 | 0.0002 | 0.0010 |
| 6/9/09 | 0.0080 | 484,000 | 0.0008 | 0.0018 |
| 6/16/09 | 0.0125 | 956,000 | 0.0025 | 0.0043 |
| 8/4/09 | 0.0135 | 4,174,000 | 0.0181 | 0.0224 |
| 8/5/09 | 0.0175 | 4,240,000 | 0.0005 | 0.0229 |
| 9/2/09 | 0.4801 | 6,082,000 | 0.3694 | 0.3924 |
| 10/8/09 | 0.7340 | 8,458,000 | 0.7285 | 1.1209 |
| 11/6/09 | 0.6202 | 10,259,000 | 0.4666 | 1.5875 |
| 12/2/09 | 0.7094 | 11,950,000 | 0.5011 | 2.0886 |
| 1/6/2010 | 0.5318 | 14,208,000 | 0.5016 | 2.5902 |
| 2/2/2010 | 0.3040 | 15,959,000 | 0.2224 | 2.8126 |
| 3/4/2010 | 0.6347 | 17,892,000 | 0.5125 | 3.3251 |

Notes:

PCE - Tetrachloroethene

SVE - Soil Vapor Extraction

ppmv - parts per million by volume

scf - standard cubic feet

lbs - pounds

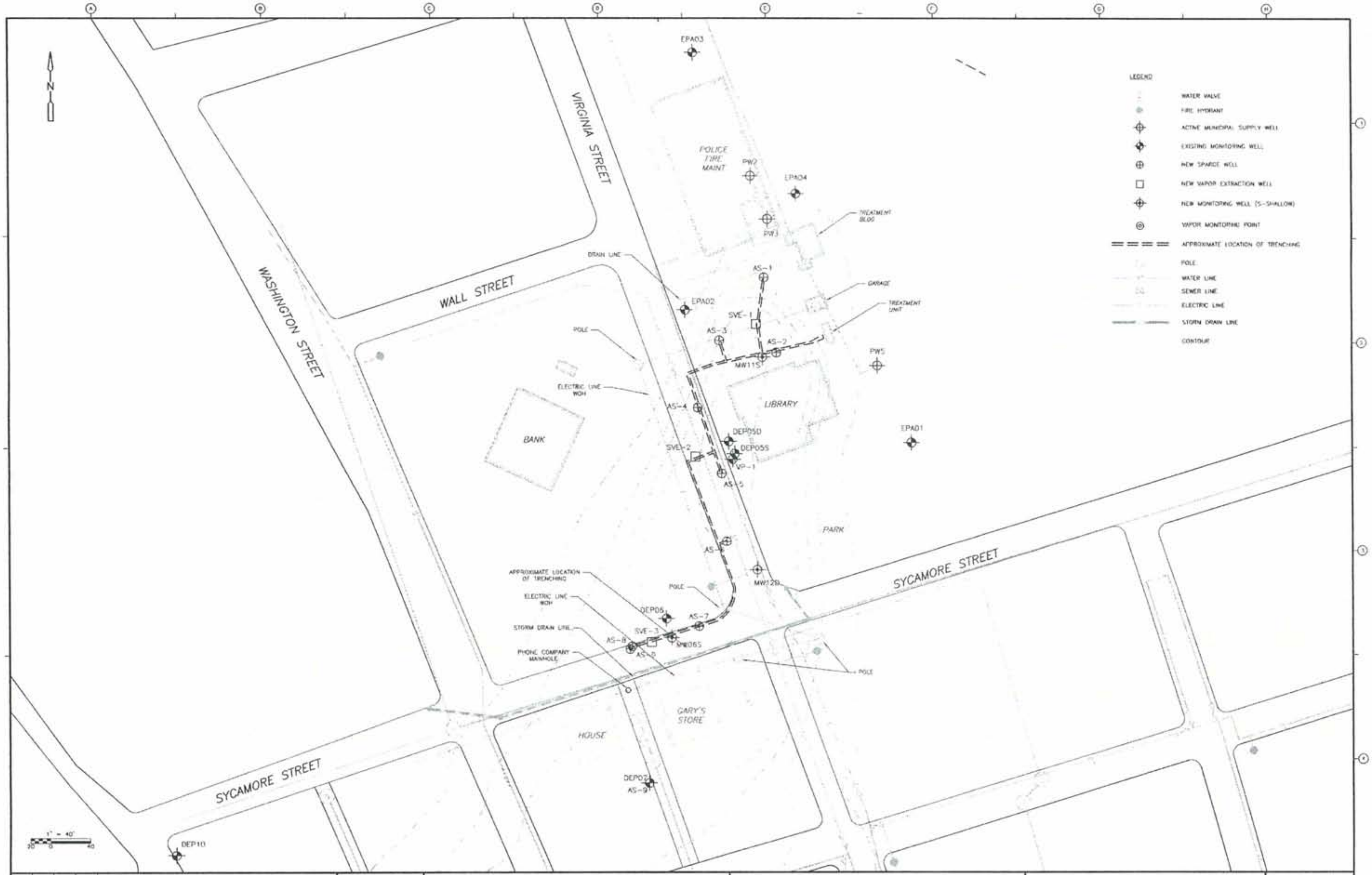
PCE mass removal is calculated using the following formula:
Removal Rate (lbs) = Concentration (ppmv) / Universal Gas Constant (atm m^3/mole K) x Molecular Weight (g/mole) x 1000 mg/g x 1/T(K) x Total flow (scf) x 1 $m^3$/35.315 cf x 1 lb/453,592 mg

Universal Gas Constant (R) = 8.206 x 10^-5 atm m^3/ mole K

Molecular weight for PCE is 165.82 g/mole

T(K): TU = 302 (84 F)

Solid line indicates AS system startup



| REV. NO. | DATE | DRWN | CHKD | REMARKS |
|---|---|---|---|---|

DESIGNED BY: DW
DRAWN BY: MD
SHEET CHK'D BY: JR
CROSS CHK'D BY: CK
APPROVED BY: CK
DATE: 10/2008

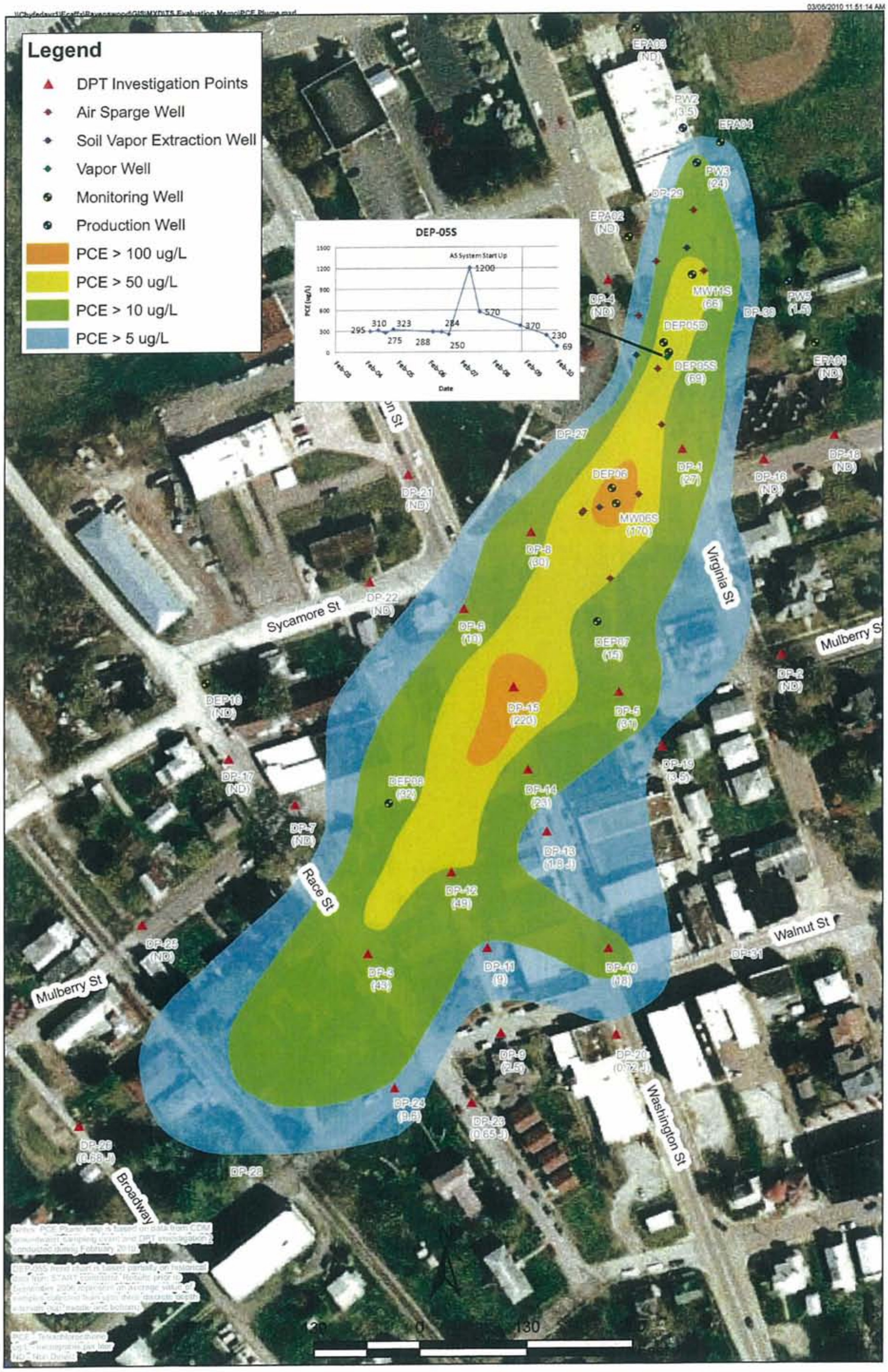
CDM Federal Programs Corporation

Ravenswood PCE Superfund Site
Ravenswood, West Virginia

Figure 1
Treatability Study System Layout

\\Chyfedsvr1\Ecaffs\Ravenswood\GIS\MXD\TS Evaluation Memo\PCE Plume.mxd

03/05/2010 11:51:14 AM



Notes: PCE Plume map is based on data from CDM groundwater sampling event and DPT investigation 2 conducted during February 2010.

DEP-05S trend chart is based partially on historical data from START contractor. Results prior to September 2006 represent an average value of samples collected from upto three discrete depth intervals (top, middle and bottom).

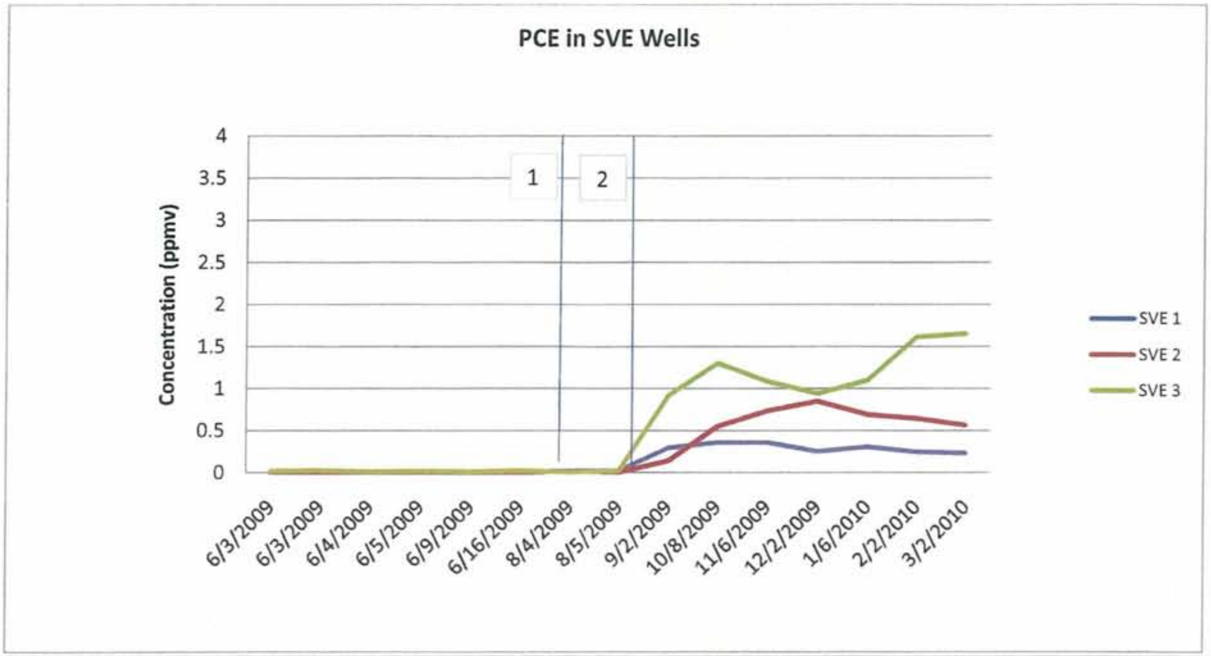
PCE - Tetrachloroethene
ug/L - micrograms per liter
ND - Non Detect

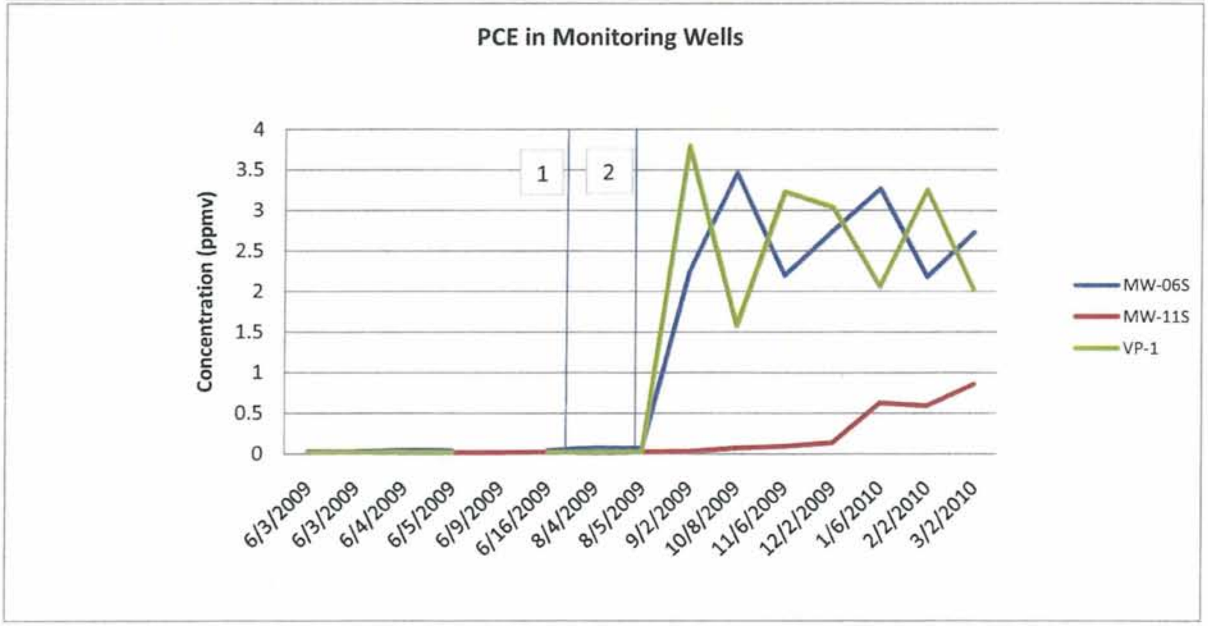
CDM

Ravenswood PCE Site
Ravenswood, West Virginia

Figure 2
PCE in Shallow Groundwater
February 2010

## Figure 3: PCE Vapor Sample Results - AS Wells and Monitoring Points
## Ravenswood PCE Superfund Site



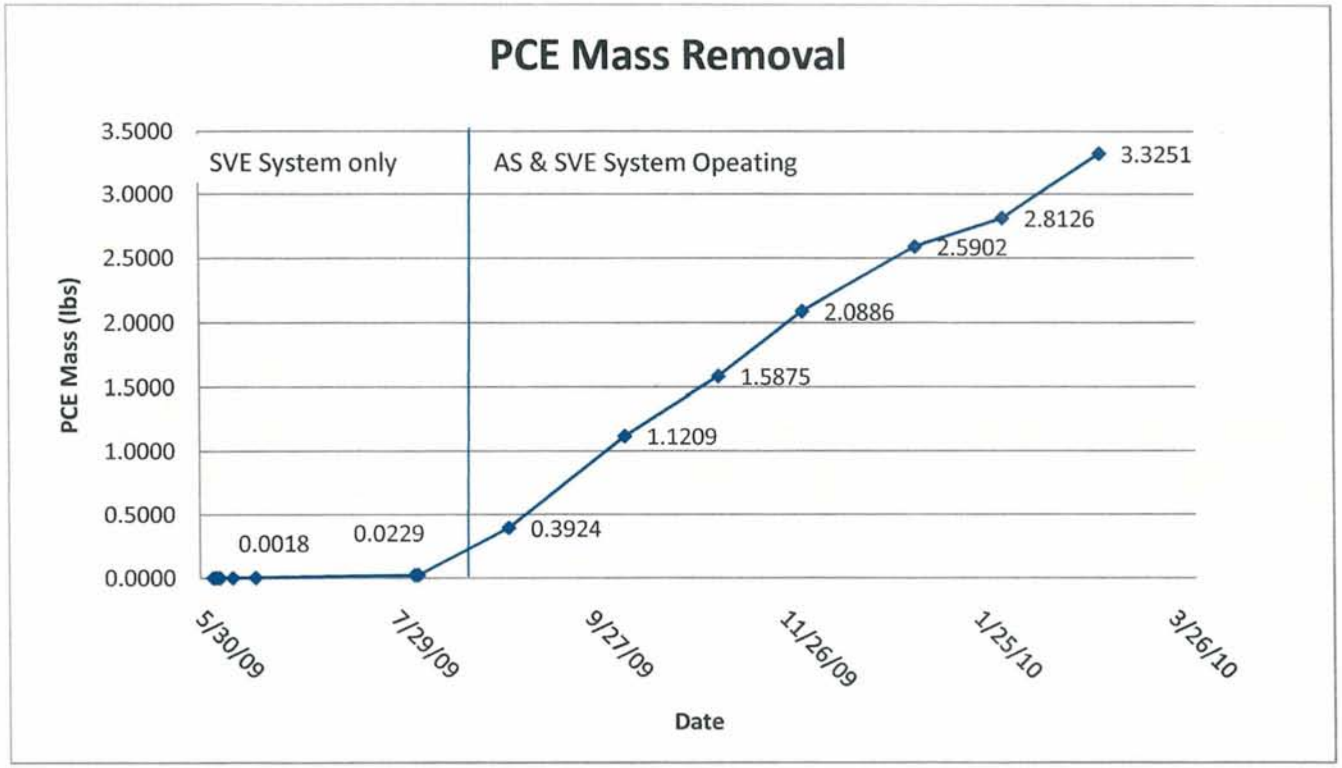


Notes:

Point 1 - AS Activation - Half Capacity

Point 2 - AS Activiation - Full Capacity

## Figure 4: PCE Mass Removal - SVE Component
## Ravenswood PCE Superfund Site, Ravenswood, West Virginia



Note: Vertical line indicates AS system startup

# Appendix B

# Full Vapor Results

# Vapor Sampling Results
# Ravenswood PCE Superfund Site

| Sample Location | Date | Chemical | Result (ppmv) | Data Qualifiers | Detection Limit |
|---|---|---|---|---|---|
| MW06-0910 | 08-Oct-09 | 1,1,1-Trichloroethane | 0.0016 | J | 0.005 |
| MW06-0911 | 06-Nov-09 | 1,1,1-Trichloroethane | 0.0014 | J | 0.005 |
| MW06-0912 | 02-Dec-09 | 1,1,1-Trichloroethane | 0.0015 | J | 0.005 |
| MW06-1001 | 06-Jan-10 | 1,1,1-Trichloroethane | 0.0013 | J | 0.005 |
| MW06-1002 | 02-Feb-10 | 1,1,1-Trichloroethane | 0.0009 | J | 0.005 |
| MW06-1003 | 04-Mar-10 | 1,1,1-Trichloroethane | 0.0015 | J | 0.005 |
| MW11-0910 | 08-Oct-09 | 1,1,1-Trichloroethane | 0.0013 | J | 0.005 |
| MW11-0911 | 06-Nov-09 | 1,1,1-Trichloroethane | 0.0019 | J | 0.005 |
| MW11-0912 | 02-Dec-09 | 1,1,1-Trichloroethane | 0.0012 | J | 0.005 |
| MW11-1001 | 06-Jan-10 | 1,1,1-Trichloroethane | 0.0026 | J | 0.005 |
| MW11-1002 | 02-Feb-10 | 1,1,1-Trichloroethane | 0.0021 | J | 0.005 |
| MW11-1003 | 04-Mar-10 | 1,1,1-Trichloroethane | 0.0019 | J | 0.005 |
| MW6-0909 | 03-Sep-09 | 1,1,1-Trichloroethane | 0.0015 | J | 0.005 |
| TU4INF-0909 | 02-Sep-09 | 1,1,1-Trichloroethane | 0.0011 | J | 0.005 |
| TU4INF-0909P | 02-Sep-09 | 1,1,1-Trichloroethane | 0.001 | J | 0.005 |
| TU4INF-0911 | 06-Nov-09 | 1,1,1-Trichloroethane | 0.0012 | J | 0.005 |
| TU4INF-0911P | 06-Nov-09 | 1,1,1-Trichloroethane | 0.0012 | J | 0.005 |
| TU4INF-0912 | 02-Dec-09 | 1,1,1-Trichloroethane | 0.0012 | J | 0.005 |
| TU4INF-0912P | 02-Dec-09 | 1,1,1-Trichloroethane | 0.0011 | J | 0.005 |
| TU4INF-1001 | 06-Jan-10 | 1,1,1-Trichloroethane | 0.0009 | J | 0.005 |
| TU4INF-1001P | 06-Jan-10 | 1,1,1-Trichloroethane | 0.0009 | J | 0.005 |
| TU4INF-1002 | 02-Feb-10 | 1,1,1-Trichloroethane | 0.0007 | J | 0.005 |
| TU4INF-1002P | 02-Feb-10 | 1,1,1-Trichloroethane | 0.0008 | J | 0.005 |
| TU4INF-1003 | 04-Mar-10 | 1,1,1-Trichloroethane | 0.0011 | J | 0.005 |
| TU4INF-1003P | 04-Mar-10 | 1,1,1-Trichloroethane | 0.0011 | J | 0.005 |
| VD1-0908 | 04-Aug-09 | 1,1,1-Trichloroethane | 0.0005 | J | 0.005 |
| VD1-0908POST | 05-Aug-09 | 1,1,1-Trichloroethane | 0.0006 | J | 0.005 |
| VD1-0909 | 02-Sep-09 | 1,1,1-Trichloroethane | 0.0011 | J | 0.005 |
| VD1-0910 | 08-Oct-09 | 1,1,1-Trichloroethane | 0.0012 | J | 0.005 |
| VD1-0911 | 06-Nov-09 | 1,1,1-Trichloroethane | 0.0012 | J | 0.005 |
| VD1-0912 | 02-Dec-09 | 1,1,1-Trichloroethane | 0.0008 | J | 0.005 |
| VD1-1001 | 06-Jan-10 | 1,1,1-Trichloroethane | 0.0008 | J | 0.005 |
| VD1-1002 | 02-Feb-10 | 1,1,1-Trichloroethane | 0.0006 | J | 0.005 |
| VD1-1003 | 04-Mar-10 | 1,1,1-Trichloroethane | 0.0007 | J | 0.005 |
| VD2-0909 | 02-Sep-09 | 1,1,1-Trichloroethane | 0.0005 | J | 0.005 |
| VD2-0910 | 08-Oct-09 | 1,1,1-Trichloroethane | 0.0009 | J | 0.005 |
| VD2-0911 | 06-Nov-09 | 1,1,1-Trichloroethane | 0.0011 | J | 0.005 |
| VD2-0912 | 02-Dec-09 | 1,1,1-Trichloroethane | 0.0011 | J | 0.005 |
| VD2-1001 | 06-Jan-10 | 1,1,1-Trichloroethane | 0.0008 | J | 0.005 |
| VD2-1002 | 02-Feb-10 | 1,1,1-Trichloroethane | 0.0008 | J | 0.005 |
| VD2-1003 | 04-Mar-10 | 1,1,1-Trichloroethane | 0.0012 | J | 0.005 |
| VD3-0909 | 02-Sep-09 | 1,1,1-Trichloroethane | 0.0014 | J | 0.005 |
| VD3-0910 | 08-Oct-09 | 1,1,1-Trichloroethane | 0.0016 | J | 0.005 |
| VD3-0910P | 08-Oct-09 | 1,1,1-Trichloroethane | 0.0017 | J | 0.005 |
| VD3-0911 | 06-Nov-09 | 1,1,1-Trichloroethane | 0.0014 | J | 0.005 |
| VD3-0912 | 02-Dec-09 | 1,1,1-Trichloroethane | 0.0012 | J | 0.005 |
| VD3-1001 | 06-Jan-10 | 1,1,1-Trichloroethane | 0.0012 | J | 0.005 |
| VD3-1002 | 02-Feb-10 | 1,1,1-Trichloroethane | 0.0011 | J | 0.005 |

Notes:
ppmv - parts per million by volume
J - Analyte present. Reported value may not be accurate or precise.
B - Not detected substantially above the level reported in laboratory or field blanks.

| Sample Location | Date | Chemical | Result (ppmv) | Data Qualifiers | Detection Limit |
|---|---|---|---|---|---|
| VD3-1003 | 04-Mar-10 | 1,1,1-Trichloroethane | 0.0017 | J | 0.005 |
| VP1-0909 | 02-Sep-09 | 1,1,1-Trichloroethane | 0.0024 | J | 0.005 |
| VP1-0910 | 08-Oct-09 | 1,1,1-Trichloroethane | 0.002 | J | 0.005 |
| VP1-0911 | 06-Nov-09 | 1,1,1-Trichloroethane | 0.0018 | J | 0.005 |
| VP1-0912 | 02-Dec-09 | 1,1,1-Trichloroethane | 0.0014 | J | 0.005 |
| VP1-1001 | 06-Jan-10 | 1,1,1-Trichloroethane | 0.0011 | J | 0.005 |
| VP1-1002 | 02-Feb-10 | 1,1,1-Trichloroethane | 0.0012 | J | 0.005 |
| VP1-1003 | 04-Mar-10 | 1,1,1-Trichloroethane | 0.0016 | J | 0.005 |
| | | | | | |
| MW06-DAY4- | 05-Jun-09 | 1,1-Dichloroethene | 0.0019 | J | 0.01 |
| MW06-PRE-0906 | 03-Jun-09 | 1,1-Dichloroethene | 0.0014 | J | 0.01 |
| MW11-DAY1- | 03-Jun-09 | 1,1-Dichloroethene | 0.0015 | J | 0.01 |
| MW11-DAY4- | 05-Jun-09 | 1,1-Dichloroethene | 0.0014 | J | 0.01 |
| MW11-PRE-0906 | 03-Jun-09 | 1,1-Dichloroethene | 0.0021 | J | 0.01 |
| MW11-WEEK1- | 09-Jun-09 | 1,1-Dichloroethene | 0.0013 | J | 0.01 |
| MW11-WEEK2- | 16-Jun-09 | 1,1-Dichloroethene | 0.0012 | J | 0.01 |
| TU4INF-DAY4- | 05-Jun-09 | 1,1-Dichloroethene | 0.0013 | J | 0.01 |
| VD1-WEEK2- | 16-Jun-09 | 1,1-Dichloroethene | 0.0013 | J | 0.01 |
| VD2-WEEK1- | 09-Jun-09 | 1,1-Dichloroethene | 0.0015 | J | 0.01 |
| VD3-DAY4-0906 | 05-Jun-09 | 1,1-Dichloroethene | 0.0019 | J | 0.01 |
| VD3-WEEK1- | 09-Jun-09 | 1,1-Dichloroethene | 0.0014 | J | 0.01 |
| VP1-DAY2-0906 | 04-Jun-09 | 1,1-Dichloroethene | 0.0016 | J | 0.01 |
| VP1-DAY4-0906 | 05-Jun-09 | 1,1-Dichloroethene | 0.0014 | J | 0.01 |
| VP1-WEEK1-0906 | 09-Jun-09 | 1,1-Dichloroethene | 0.0012 | J | 0.01 |
| | | | | | |
| MW06-DAY1- | 03-Jun-09 | 1,2,4-Trmethylbenzene | 0.0217 | J | 0.1 |
| MW06-DAY2- | 04-Jun-09 | 1,2,4-Trmethylbenzene | 0.0262 | J | 0.1 |
| MW06-PRE-0906 | 03-Jun-09 | 1,2,4-Trmethylbenzene | 0.0254 | J | 0.1 |
| MW06-WEEK1- | 09-Jun-09 | 1,2,4-Trmethylbenzene | 0.0321 | J | 0.1 |
| MW06-WEEK2- | 16-Jun-09 | 1,2,4-Trmethylbenzene | 0.0155 | J | 0.1 |
| MW11-WEEK1- | 09-Jun-09 | 1,2,4-Trmethylbenzene | 0.0325 | J | 0.1 |
| TU4INF-WEEK1- | 09-Jun-09 | 1,2,4-Trmethylbenzene | 0.0188 | J | 0.1 |
| VD1-DAY1-0906 | 03-Jun-09 | 1,2,4-Trmethylbenzene | 0.0182 | J | 0.1 |
| VD1-PRE-0906 | 03-Jun-09 | 1,2,4-Trmethylbenzene | 0.0215 | J | 0.1 |
| VD2-DAY1-0906P | 03-Jun-09 | 1,2,4-Trmethylbenzene | 0.0203 | J | 0.1 |
| VD2-PRE-0906 | 03-Jun-09 | 1,2,4-Trmethylbenzene | 0.0313 | J | 0.1 |
| VD2-WEEK1- | 09-Jun-09 | 1,2,4-Trmethylbenzene | 0.0208 | J | 0.1 |
| VD3-DAY1-0906 | 03-Jun-09 | 1,2,4-Trmethylbenzene | 0.0441 | J | 0.1 |
| VP1-DAY1-0906 | 03-Jun-09 | 1,2,4-Trmethylbenzene | 0.0353 | J | 0.1 |
| | | | | | |
| MW06-DAY1- | 03-Jun-09 | 1,3,5-Trimethylbenzene | 0.0128 | J | 0.1 |
| MW06-DAY4- | 05-Jun-09 | 1,3,5-Trimethylbenzene | 0.0088 | J | 0.1 |
| MW06-WEEK1- | 09-Jun-09 | 1,3,5-Trimethylbenzene | 0.0382 | J | 0.1 |
| MW11-DAY4- | 05-Jun-09 | 1,3,5-Trimethylbenzene | 0.0076 | J | 0.1 |
| TU4EFF-0912 | 02-Dec-09 | 1,3,5-Trimethylbenzene | 0.0357 | B | 0.1 |
| TU4INF-0912 | 02-Dec-09 | 1,3,5-Trimethylbenzene | 0.0348 | B | 0.1 |
| TU4INF-0912P | 02-Dec-09 | 1,3,5-Trimethylbenzene | 0.0359 | B | 0.1 |
| VD1-0912 | 02-Dec-09 | 1,3,5-Trimethylbenzene | 0.0382 | B | 0.1 |

Notes:
ppmv - parts per million by volume
J - Analyte present. Reported value may not be accurate or precise.
B - Not detected substantially above the level reported in laboratory or field blanks.

# Vapor Sampling Results
# Ravenswood PCE Superfund Site

| Sample Location | Date | Chemical | Result (ppmv) | Data Qualifiers | Detection Limit |
|---|---|---|---|---|---|
| VD1-WEEK1- | 09-Jun-09 | 1,3,5-Trimethylbenzene | 0.008 | J | 0.1 |
| VD2-0909 | 02-Sep-09 | 1,3,5-Trimethylbenzene | 0.0202 | J | 0.1 |
| VD2-DAY1-0906 | 03-Jun-09 | 1,3,5-Trimethylbenzene | 0.0096 | J | 0.1 |
| VD2-PRE-0906 | 03-Jun-09 | 1,3,5-Trimethylbenzene | 0.0226 | J | 0.1 |
| VD2-WEEK1- | 09-Jun-09 | 1,3,5-Trimethylbenzene | 0.0082 | J | 0.1 |
| VD3-0909 | 02-Sep-09 | 1,3,5-Trimethylbenzene | 0.0283 | J | 0.1 |
| VD3-0912 | 02-Dec-09 | 1,3,5-Trimethylbenzene | 0.0187 | B | 0.1 |
| VD3-DAY1-0906 | 03-Jun-09 | 1,3,5-Trimethylbenzene | 0.0256 | J | 0.1 |
| VD3-DAY4-0906 | 05-Jun-09 | 1,3,5-Trimethylbenzene | 0.0092 | J | 0.1 |
| VD3-PRE-0906 | 03-Jun-09 | 1,3,5-Trimethylbenzene | 0.0147 | J | 0.1 |
| VP1-DAY1-0906 | 03-Jun-09 | 1,3,5-Trimethylbenzene | 0.0251 | J | 0.1 |
| VP1-DAY4-0906 | 05-Jun-09 | 1,3,5-Trimethylbenzene | 0.0094 | J | 0.1 |
| VP1-WEEK1-0906 | 09-Jun-09 | 1,3,5-Trimethylbenzene | 0.0284 | J | 0.1 |
| | | | | | |
| MW06-0911 | 06-Nov-09 | 2-Butanone | 1.1768 | L | 0.5 |
| MW06-1002 | 02-Feb-10 | 2-Butanone | 0.0866 | B | 0.5 |
| MW06-DAY1- | 03-Jun-09 | 2-Butanone | 0.0548 | J | 0.5 |
| MW06-DAY2- | 04-Jun-09 | 2-Butanone | 0.0305 | J | 0.5 |
| MW06-DAY4- | 05-Jun-09 | 2-Butanone | 0.0193 | J | 0.5 |
| MW06-PRE-0906 | 03-Jun-09 | 2-Butanone | 0.058 | J | 0.5 |
| MW06-WEEK1- | 09-Jun-09 | 2-Butanone | 0.0621 | J | 0.5 |
| MW06-WEEK2- | 16-Jun-09 | 2-Butanone | 0.0192 | J | 0.5 |
| MW11-1002 | 02-Feb-10 | 2-Butanone | 0.0666 | B | 0.5 |
| MW11-DAY1- | 03-Jun-09 | 2-Butanone | 0.0244 | J | 0.5 |
| MW11-PRE-0906 | 03-Jun-09 | 2-Butanone | 0.0673 | J | 0.5 |
| MW11-WEEK1- | 09-Jun-09 | 2-Butanone | 0.0332 | J | 0.5 |
| TU4EFF-1002 | 02-Feb-10 | 2-Butanone | 0.0768 | B | 0.5 |
| TU4INF-1002 | 02-Feb-10 | 2-Butanone | 0.0765 | B | 0.5 |
| TU4INF-1002P | 02-Feb-10 | 2-Butanone | 0.0874 | B | 0.5 |
| TU4INF-DAY2- | 04-Jun-09 | 2-Butanone | 0.0215 | J | 0.5 |
| TU4INF-DAY2- | 04-Jun-09 | 2-Butanone | 0.0489 | J | 0.5 |
| TU4INF-WEEK1- | 09-Jun-09 | 2-Butanone | 0.0538 | J | 0.5 |
| VD1-1002 | 02-Feb-10 | 2-Butanone | 0.2768 | B | 0.5 |
| VD1-DAY1-0906 | 03-Jun-09 | 2-Butanone | 0.0252 | J | 0.5 |
| VD1-DAY2-0906 | 04-Jun-09 | 2-Butanone | 0.0286 | J | 0.5 |
| VD1-PRE-0906 | 03-Jun-09 | 2-Butanone | 0.0799 | J | 0.5 |
| VD1-WEEK1- | 09-Jun-09 | 2-Butanone | 0.7171 | L | 0.5 |
| VD2-1002 | 02-Feb-10 | 2-Butanone | 0.283 | B | 0.5 |
| VD2-DAY1-0906 | 03-Jun-09 | 2-Butanone | 0.0239 | J | 0.5 |
| VD2-DAY4-0906 | 05-Jun-09 | 2-Butanone | 0.0236 | J | 0.5 |
| VD2-PRE-0906 | 03-Jun-09 | 2-Butanone | 0.0497 | J | 0.5 |
| VD2-WEEK1- | 09-Jun-09 | 2-Butanone | 0.1399 | J | 0.5 |
| VD3-1001 | 06-Jan-10 | 2-Butanone | 0.2428 | J | 0.5 |
| VD3-1002 | 02-Feb-10 | 2-Butanone | 0.2487 | B | 0.5 |
| VD3-DAY1-0906 | 03-Jun-09 | 2-Butanone | 0.0853 | J | 0.5 |
| VD3-DAY2-0906 | 04-Jun-09 | 2-Butanone | 0.0212 | J | 0.5 |
| VD3-DAY4-0906 | 05-Jun-09 | 2-Butanone | 0.0312 | J | 0.5 |
| VD3-PRE-0906 | 03-Jun-09 | 2-Butanone | 0.0485 | J | 0.5 |

Notes:

ppmv - parts per million by volume

J - Analyte present. Reported value may not be accurate or precise.

B - Not detected substantially above the level reported in laboratory or field blanks.

## Vapor Sampling Results
## Ravenswood PCE Superfund Site

| Sample Location | Date | Chemical | Result (ppmv) | Data Qualifiers | Detection Limit |
|---|---|---|---|---|---|
| VD3-WEEK1- | 09-Jun-09 | 2-Butanone | 0.1365 | J | 0.5 |
| VD3-WEEK2- | 16-Jun-09 | 2-Butanone | 0.0292 | J | 0.5 |
| VP1-1001 | 06-Jan-10 | 2-Butanone | 0.2193 | J | 0.5 |
| VP1-1002 | 02-Feb-10 | 2-Butanone | 0.0667 | B | 0.5 |
| VP1-DAY1-0906 | 03-Jun-09 | 2-Butanone | 0.1062 | J | 0.5 |
| VP1-DAY4-0906 | 05-Jun-09 | 2-Butanone | 0.0452 | J | 0.5 |
| VP1-PRE-0906 | 03-Jun-09 | 2-Butanone | 0.0556 | J | 0.5 |
| VP1-WEEK1-0906 | 09-Jun-09 | 2-Butanone | 0.0357 | J | 0.5 |
| | | | | | |
| MW06-WEEK1- | 09-Jun-09 | 4-Methyl-2-Pentanone | 0.0287 | J | 1 |
| MW11-1002 | 02-Feb-10 | 4-Methyl-2-Pentanone | 0.0572 | J | 1 |
| MW11-WEEK1- | 09-Jun-09 | 4-Methyl-2-Pentanone | 0.0151 | J | 1 |
| VD1-PRE-0906 | 03-Jun-09 | 4-Methyl-2-Pentanone | 0.0228 | J | 1 |
| VD3-DAY1-0906 | 03-Jun-09 | 4-Methyl-2-Pentanone | 0.0285 | J | 1 |
| VD3-DAY4-0906 | 05-Jun-09 | 4-Methyl-2-Pentanone | 0.0184 | J | 1 |
| | | | | | |
| MW06-0908 | 05-Aug-09 | Acetone | 0.1643 | J | 1 |
| MW06-0908POST | 05-Aug-09 | Acetone | 0.2045 | J | 1 |
| MW06-0910 | 08-Oct-09 | Acetone | 0.2132 | J | 1 |
| MW06-0911 | 06-Nov-09 | Acetone | 0.0958 | J | 1 |
| MW06-0912 | 02-Dec-09 | Acetone | 0.0551 | J | 1 |
| MW06-1001 | 06-Jan-10 | Acetone | 0.1052 | J | 1 |
| MW06-1002 | 02-Feb-10 | Acetone | 0.0646 | J | 1 |
| MW06-DAY1- | 03-Jun-09 | Acetone | 0.6473 | J | 1 |
| MW06-DAY2- | 04-Jun-09 | Acetone | 0.3514 | J | 1 |
| MW06-DAY4- | 05-Jun-09 | Acetone | 0.3538 | J | 1 |
| MW06-PRE-0906 | 03-Jun-09 | Acetone | 0.6865 | J | 1 |
| MW06-WEEK1- | 09-Jun-09 | Acetone | 0.5287 | J | 1 |
| MW06-WEEK2- | 16-Jun-09 | Acetone | 0.4808 | J | 1 |
| MW11-0908 | 04-Aug-09 | Acetone | 0.2466 | J | 1 |
| MW11-0908POST | 05-Aug-09 | Acetone | 0.1834 | J | 1 |
| MW11-0909 | 02-Sep-09 | Acetone | 0.1663 | J | 1 |
| MW11-0910 | 08-Oct-09 | Acetone | 0.2283 | J | 1 |
| MW11-0911 | 06-Nov-09 | Acetone | 0.0732 | J | 1 |
| MW11-0912 | 02-Dec-09 | Acetone | 0.0492 | J | 1 |
| MW11-1001 | 06-Jan-10 | Acetone | 0.09 | J | 1 |
| MW11-1002 | 02-Feb-10 | Acetone | 0.0649 | J | 1 |
| MW11-DAY1- | 03-Jun-09 | Acetone | 0.4257 | J | 1 |
| MW11-DAY2- | 04-Jun-09 | Acetone | 0.2383 | J | 1 |
| MW11-DAY4- | 05-Jun-09 | Acetone | 0.3184 | J | 1 |
| MW11-PRE-0906 | 03-Jun-09 | Acetone | 0.3643 | J | 1 |
| MW11-WEEK1- | 09-Jun-09 | Acetone | 0.4006 | J | 1 |
| MW11-WEEK2- | 16-Jun-09 | Acetone | 0.3673 | J | 1 |
| MW6-0909 | 03-Sep-09 | Acetone | 0.1748 | J | 1 |
| TU4EFF-0910 | 08-Oct-09 | Acetone | 0.2767 | J | 1 |
| TU4EFF-0912 | 02-Dec-09 | Acetone | 0.0333 | J | 1 |
| TU4EFF-1001 | 06-Jan-10 | Acetone | 0.0905 | J | 1 |
| TU4EFF-1002 | 02-Feb-10 | Acetone | 0.0653 | J | 1 |

Notes:

ppmv - parts per million by volume

J - Analyte present. Reported value may not be accurate or precise.

B - Not detected substantially above the level reported in laboratory or field blanks.

# Vapor Sampling Results
# Ravenswood PCE Superfund Site

| Sample Location | Date | Chemical | Result (ppmv) | Data Qualifiers | Detection Limit |
|---|---|---|---|---|---|
| TU4EFF-1003 | 04-Mar-10 | Acetone | 0.1107 | J | 1 |
| TU4INF-0909 | 02-Sep-09 | Acetone | 0.1718 | J | 1 |
| TU4INF-0909P | 02-Sep-09 | Acetone | 0.1755 | J | 1 |
| TU4INF-0911 | 06-Nov-09 | Acetone | 0.0569 | J | 1 |
| TU4INF-1001 | 06-Jan-10 | Acetone | 0.0799 | J | 1 |
| TU4INF-1001P | 06-Jan-10 | Acetone | 0.083 | J | 1 |
| TU4INF-1002 | 02-Feb-10 | Acetone | 0.0587 | J | 1 |
| TU4INF-1002P | 02-Feb-10 | Acetone | 0.0477 | J | 1 |
| TU4INF-1003 | 04-Mar-10 | Acetone | 0.0845 | J | 1 |
| TU4INF-DAY2- | 04-Jun-09 | Acetone | 0.3199 | J | 1 |
| TU4INF-DAY2- | 04-Jun-09 | Acetone | 0.397 | J | 1 |
| TU4INF-DAY4- | 05-Jun-09 | Acetone | 0.2618 | J | 1 |
| TU4INF-DAY4- | 05-Jun-09 | Acetone | 0.3003 | J | 1 |
| TU4INF-WEEK1- | 09-Jun-09 | Acetone | 0.7908 | J | 1 |
| TU4INF-WEEK1- | 09-Jun-09 | Acetone | 0.3624 | J | 1 |
| VD1-0908 | 04-Aug-09 | Acetone | 0.317 | J | 1 |
| VD1-0908POST | 05-Aug-09 | Acetone | 0.2042 | J | 1 |
| VD1-0909 | 02-Sep-09 | Acetone | 0.3069 | J | 1 |
| VD1-0910 | 08-Oct-09 | Acetone | 0.2643 | J | 1 |
| VD1-0911 | 06-Nov-09 | Acetone | 0.0972 | J | 1 |
| VD1-0912 | 02-Dec-09 | Acetone | 0.0463 | J | 1 |
| VD1-1001 | 06-Jan-10 | Acetone | 0.0743 | J | 1 |
| VD1-1002 | 02-Feb-10 | Acetone | 0.089 | J | 1 |
| VD1-DAY1-0906 | 03-Jun-09 | Acetone | 0.3856 | J | 1 |
| VD1-DAY2-0906 | 04-Jun-09 | Acetone | 0.3729 | J | 1 |
| VD1-DAY4-0906 | 05-Jun-09 | Acetone | 0.3265 | J | 1 |
| VD1-PRE-0906 | 03-Jun-09 | Acetone | 0.485 | J | 1 |
| VD1-WEEK1- | 09-Jun-09 | Acetone | 0.3692 | J | 1 |
| VD1-WEEK2- | 16-Jun-09 | Acetone | 0.4379 | J | 1 |
| VD2-0908 | 04-Aug-09 | Acetone | 0.317 | J | 1 |
| VD2-0908POST | 05-Aug-09 | Acetone | 0.1977 | J | 1 |
| VD2-0909 | 02-Sep-09 | Acetone | 0.2966 | J | 1 |
| VD2-0910 | 08-Oct-09 | Acetone | 0.195 | J | 1 |
| VD2-0911 | 06-Nov-09 | Acetone | 0.0667 | J | 1 |
| VD2-0912 | 02-Dec-09 | Acetone | 0.0691 | J | 1 |
| VD2-1001 | 06-Jan-10 | Acetone | 0.0754 | J | 1 |
| VD2-1002 | 02-Feb-10 | Acetone | 0.0633 | J | 1 |
| VD2-DAY1-0906 | 03-Jun-09 | Acetone | 0.4378 | J | 1 |
| VD2-DAY1-0906P | 03-Jun-09 | Acetone | 0.3141 | J | 1 |
| VD2-DAY2-0906 | 04-Jun-09 | Acetone | 0.3729 | J | 1 |
| VD2-DAY4-0906 | 05-Jun-09 | Acetone | 0.3092 | J | 1 |
| VD2-PRE-0906 | 03-Jun-09 | Acetone | 0.5912 | J | 1 |
| VD2-WEEK1- | 09-Jun-09 | Acetone | 0.3525 | J | 1 |
| VD2-WEEK2- | 16-Jun-09 | Acetone | 0.3574 | J | 1 |
| VD2-WEEK2- | 16-Jun-09 | Acetone | 0.2614 | J | 1 |
| VD3-0908 | 04-Aug-09 | Acetone | 0.3047 | J | 1 |
| VD3-0908P | 04-Aug-09 | Acetone | 0.3154 | J | 1 |
| VD3-0908POST | 05-Aug-09 | Acetone | 0.1866 | J | 1 |

Notes:

ppmv - parts per million by volume

J - Analyte present. Reported value may not be accurate or precise.

B - Not detected substantially above the level reported in laboratory or field blanks.

| Sample Location | Date | Chemical | Result (ppmv) | Data Qualifiers | Detection Limit |
|---|---|---|---|---|---|
| VD3-0909 | 02-Sep-09 | Acetone | 0.2401 | J | 1 |
| VD3-0910 | 08-Oct-09 | Acetone | 0.1893 | J | 1 |
| VD3-0910P | 08-Oct-09 | Acetone | 0.2135 | J | 1 |
| VD3-0911 | 06-Nov-09 | Acetone | 0.0573 | J | 1 |
| VD3-1001 | 06-Jan-10 | Acetone | 0.0698 | J | 1 |
| VD3-1002 | 02-Feb-10 | Acetone | 0.0899 | J | 1 |
| VD3-DAY1-0906 | 03-Jun-09 | Acetone | 0.536 | J | 1 |
| VD3-DAY2-0906 | 04-Jun-09 | Acetone | 0.4406 | J | 1 |
| VD3-DAY4-0906 | 05-Jun-09 | Acetone | 0.4167 | J | 1 |
| VD3-PRE-0906 | 03-Jun-09 | Acetone | 0.6775 | J | 1 |
| VD3-WEEK1- | 09-Jun-09 | Acetone | 0.481 | J | 1 |
| VD3-WEEK2- | 16-Jun-09 | Acetone | 0.4881 | J | 1 |
| VP1-0908 | 04-Aug-09 | Acetone | 0.4727 | J | 1 |
| VP1-0908POST | 05-Aug-09 | Acetone | 0.1331 | J | 1 |
| VP1-0909 | 02-Sep-09 | Acetone | 0.1679 | J | 1 |
| VP1-0910 | 08-Oct-09 | Acetone | 0.2433 | J | 1 |
| VP1-0911 | 06-Nov-09 | Acetone | 0.0731 | J | 1 |
| VP1-0912 | 02-Dec-09 | Acetone | 0.0949 | J | 1 |
| VP1-1001 | 06-Jan-10 | Acetone | 0.0509 | J | 1 |
| VP1-1002 | 02-Feb-10 | Acetone | 0.0663 | J | 1 |
| VP1-DAY1-0906 | 03-Jun-09 | Acetone | 0.5314 | J | 1 |
| VP1-DAY2-0906 | 04-Jun-09 | Acetone | 0.3917 | J | 1 |
| VP1-DAY4-0906 | 05-Jun-09 | Acetone | 0.6063 | J | 1 |
| VP1-PRE-0906 | 03-Jun-09 | Acetone | 0.3526 | J | 1 |
| VP1-WEEK1-0906 | 09-Jun-09 | Acetone | 0.464 | J | 1 |
| VP1-WEEK2-0906 | 16-Jun-09 | Acetone | 0.3465 | J | 1 |
| | | | | | |
| MW06-DAY2- | 04-Jun-09 | Benzene | 0.0073 | J | 0.1 |
| MW11-DAY1- | 03-Jun-09 | Benzene | 0.0221 | J | 0.1 |
| VP1-DAY2-0906 | 04-Jun-09 | Benzene | 0.0109 | J | 0.1 |
| | | | | | |
| MW06-0910 | 08-Oct-09 | Carbon Tetrachloride | 0.0009 | J | 0.005 |
| MW06-0911 | 06-Nov-09 | Carbon Tetrachloride | 0.0007 | J | 0.005 |
| MW06-0912 | 02-Dec-09 | Carbon Tetrachloride | 0.0007 | J | 0.005 |
| MW06-1001 | 06-Jan-10 | Carbon Tetrachloride | 0.0007 | J | 0.005 |
| MW06-1002 | 02-Feb-10 | Carbon Tetrachloride | 0.0005 | J | 0.005 |
| MW06-1003 | 04-Mar-10 | Carbon Tetrachloride | 0.0006 | J | 0.005 |
| MW6-0909 | 03-Sep-09 | Carbon Tetrachloride | 0.0009 | J | 0.005 |
| VP1-0909 | 02-Sep-09 | Carbon Tetrachloride | 0.0007 | J | 0.005 |
| VP1-0910 | 08-Oct-09 | Carbon Tetrachloride | 0.0006 | J | 0.005 |
| VP1-0911 | 06-Nov-09 | Carbon Tetrachloride | 0.0005 | J | 0.005 |
| | | | | | |
| MW06-0910 | 08-Oct-09 | Chloroform | 0.0017 | J | 0.005 |
| MW06-0911 | 06-Nov-09 | Chloroform | 0.001 | J | 0.005 |
| MW06-0912 | 02-Dec-09 | Chloroform | 0.0008 | J | 0.005 |
| MW06-1001 | 06-Jan-10 | Chloroform | 0.001 | J | 0.005 |
| MW06-1003 | 04-Mar-10 | Chloroform | 0.0014 | J | 0.005 |
| MW6-0909 | 03-Sep-09 | Chloroform | 0.0009 | J | 0.005 |

Notes:
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J - Analyte present. Reported value may not be accurate or precise.
B - Not detected substantially above the level reported in laboratory or field blanks.

# Vapor Sampling Results
# Ravenswood PCE Superfund Site

| Sample Location | Date | Chemical | Result (ppmv) | Data Qualifiers | Detection Limit |
|---|---|---|---|---|---|
| VD3-0910 | 08-Oct-09 | Chloroform | 0.0008 | J | 0.005 |
| VD3-0910P | 08-Oct-09 | Chloroform | 0.0009 | J | 0.005 |
| VD3-0911 | 06-Nov-09 | Chloroform | 0.0006 | J | 0.005 |
| VD3-0912 | 02-Dec-09 | Chloroform | 0.0007 | J | 0.005 |
| VD3-1001 | 06-Jan-10 | Chloroform | 0.0006 | J | 0.005 |
| VD3-1003 | 04-Mar-10 | Chloroform | 0.0007 | J | 0.005 |
| VP1-0909 | 02-Sep-09 | Chloroform | 0.0053 | | 0.005 |
| VP1-0910 | 08-Oct-09 | Chloroform | 0.0065 | | 0.005 |
| VP1-0911 | 06-Nov-09 | Chloroform | 0.0067 | | 0.005 |
| VP1-0912 | 02-Dec-09 | Chloroform | 0.0058 | | 0.005 |
| VP1-1001 | 06-Jan-10 | Chloroform | 0.0038 | J | 0.005 |
| VP1-1002 | 02-Feb-10 | Chloroform | 0.003 | J | 0.005 |
| VP1-1003 | 04-Mar-10 | Chloroform | 0.002 | J | 0.005 |
| | | | | | |
| TU4EFF-1001 | 06-Jan-10 | Dichlorodifluoromethane | 0.0037 | J | 0.005 |
| TU4EFF-1002 | 02-Feb-10 | Dichlorodifluoromethane | 0.003 | J | 0.005 |
| TU4INF-1001 | 06-Jan-10 | Dichlorodifluoromethane | 0.0047 | J | 0.005 |
| TU4INF-1001P | 06-Jan-10 | Dichlorodifluoromethane | 0.0046 | J | 0.005 |
| TU4INF-1002 | 02-Feb-10 | Dichlorodifluoromethane | 0.0029 | J | 0.005 |
| TU4INF-1002P | 02-Feb-10 | Dichlorodifluoromethane | 0.003 | J | 0.005 |
| VD1-1001 | 06-Jan-10 | Dichlorodifluoromethane | 0.0029 | J | 0.005 |
| VD2-0912 | 02-Dec-09 | Dichlorodifluoromethane | 0.0036 | J | 0.005 |
| VD2-1001 | 06-Jan-10 | Dichlorodifluoromethane | 0.0088 | | 0.005 |
| VD2-1002 | 02-Feb-10 | Dichlorodifluoromethane | 0.0066 | | 0.005 |
| | | | | | |
| VD2-1002 | 02-Feb-10 | Ethylbenzene | 0.0139 | J | 0.1 |
| | | | | | |
| MW06-0911 | 06-Nov-09 | m&p-Xylenes | 0.0165 | J | 0.2 |
| MW06-0912 | 02-Dec-09 | m&p-Xylenes | 0.0162 | J | 0.2 |
| TU4EFF-0911 | 06-Nov-09 | m&p-Xylenes | 0.0174 | J | 0.2 |
| TU4EFF-0912 | 02-Dec-09 | m&p-Xylenes | 0.0211 | J | 0.2 |
| TU4INF-0911P | 06-Nov-09 | m&p-Xylenes | 0.0161 | J | 0.2 |
| VD1-0911 | 06-Nov-09 | m&p-Xylenes | 0.0179 | J | 0.2 |
| VD2-0912 | 02-Dec-09 | m&p-Xylenes | 0.0211 | J | 0.2 |
| | | | | | |
| MW11-0912 | 02-Dec-09 | MethyleneChloride | 0.1683 | J | 2 |
| | | | | | |
| MW06-DAY1- | 03-Jun-09 | Methyl-tert-butylether | 0.0348 | J | 0.1 |
| MW06-WEEK1- | 09-Jun-09 | Methyl-tert-butylether | 0.0164 | J | 0.1 |
| MW11-DAY4- | 05-Jun-09 | Methyl-tert-butylether | 0.0175 | J | 0.1 |
| TU4INF-0911P | 06-Nov-09 | Methyl-tert-butylether | 0.0422 | J | 0.1 |
| TU4INF-DAY2- | 04-Jun-09 | Methyl-tert-butylether | 0.0158 | J | 0.1 |
| TU4INF-WEEK1- | 09-Jun-09 | Methyl-tert-butylether | 0.0366 | J | 0.1 |
| VD1-0911 | 06-Nov-09 | Methyl-tert-butylether | 0.0488 | J | 0.1 |
| VD1-PRE-0906 | 03-Jun-09 | Methyl-tert-butylether | 0.0192 | J | 0.1 |
| VD2-PRE-0906 | 03-Jun-09 | Methyl-tert-butylether | 0.0175 | J | 0.1 |
| VD3-DAY1-0906 | 03-Jun-09 | Methyl-tert-butylether | 0.0321 | J | 0.1 |
| VD3-PRE-0906 | 03-Jun-09 | Methyl-tert-butylether | 0.0178 | J | 0.1 |

Notes:

ppmv - parts per million by volume

J - Analyte present. Reported value may not be accurate or precise.

B - Not detected substantially above the level reported in laboratory or field blanks.

| Sample Location | Date | Chemical | Result (ppmv) | Data Qualifiers | Detection Limit |
|---|---|---|---|---|---|
| VD3-WEEK1- | 09-Jun-09 | Methyl-tert-butylether | 0.021 | J | 0.1 |
| VP1-DAY1-0906 | 03-Jun-09 | Methyl-tert-butylether | 0.0313 | J | 0.1 |
| VP1-DAY4-0906 | 05-Jun-09 | Methyl-tert-butylether | 0.0287 | J | 0.1 |
| | | | | | |
| MW06-0911 | 06-Nov-09 | o-Xylene | 0.3466 | B | 0.1 |
| MW06-0912 | 02-Dec-09 | o-Xylene | 0.2538 | | 0.1 |
| MW06-DAY1- | 03-Jun-09 | o-Xylene | 0.0196 | B | 0.1 |
| MW06-DAY2- | 04-Jun-09 | o-Xylene | 0.0259 | B | 0.1 |
| MW06-WEEK1- | 09-Jun-09 | o-Xylene | 0.0352 | B | 0.1 |
| MW06-WEEK2- | 16-Jun-09 | o-Xylene | 0.0234 | B | 0.1 |
| MW11-0911 | 06-Nov-09 | o-Xylene | 0.2619 | B | 0.1 |
| MW11-0912 | 02-Dec-09 | o-Xylene | 0.217 | | 0.1 |
| MW11-WEEK1- | 09-Jun-09 | o-Xylene | 0.0222 | B | 0.1 |
| TU4EFF-0911 | 06-Nov-09 | o-Xylene | 0.2766 | B | 0.1 |
| TU4EFF-0912 | 02-Dec-09 | o-Xylene | 0.3053 | | 0.1 |
| TU4INF-0911 | 06-Nov-09 | o-Xylene | 0.29 | B | 0.1 |
| TU4INF-0911P | 06-Nov-09 | o-Xylene | 0.2956 | B | 0.1 |
| TU4INF-0912 | 02-Dec-09 | o-Xylene | 0.2906 | | 0.1 |
| TU4INF-0912P | 02-Dec-09 | o-Xylene | 0.2488 | | 0.1 |
| TU4INF-WEEK1- | 09-Jun-09 | o-Xylene | 0.0264 | B | 0.1 |
| VD1-0911 | 06-Nov-09 | o-Xylene | 0.3265 | B | 0.1 |
| VD1-0912 | 02-Dec-09 | o-Xylene | 0.3113 | | 0.1 |
| VD1-PRE-0906 | 03-Jun-09 | o-Xylene | 0.0279 | B | 0.1 |
| VD1-WEEK1- | 09-Jun-09 | o-Xylene | 0.0203 | B | 0.1 |
| VD2-0912 | 02-Dec-09 | o-Xylene | 0.2972 | | 0.1 |
| VD2-DAY2-0906 | 04-Jun-09 | o-Xylene | 0.023 | B | 0.1 |
| VD2-PRE-0906 | 03-Jun-09 | o-Xylene | 0.0431 | B | 0.1 |
| VD2-WEEK1- | 09-Jun-09 | o-Xylene | 0.0253 | B | 0.1 |
| VD3-0911 | 06-Nov-09 | o-Xylene | 0.3266 | B | 0.1 |
| VD3-0912 | 02-Dec-09 | o-Xylene | 0.2451 | | 0.1 |
| VD3-DAY1-0906 | 03-Jun-09 | o-Xylene | 0.0385 | B | 0.1 |
| VD3-DAY2-0906 | 04-Jun-09 | o-Xylene | 0.0107 | B | 0.1 |
| VD3-PRE-0906 | 03-Jun-09 | o-Xylene | 0.0329 | B | 0.1 |
| VD3-WEEK2- | 16-Jun-09 | o-Xylene | 0.0237 | B | 0.1 |
| VP1-0908POST | 05-Aug-09 | o-Xylene | 0.0934 | B | 0.1 |
| VP1-0911 | 06-Nov-09 | o-Xylene | 0.3156 | B | 0.1 |
| VP1-0912 | 02-Dec-09 | o-Xylene | 0.2774 | | 0.1 |
| VP1-1001 | 06-Jan-10 | o-Xylene | 0.2205 | | 0.1 |
| VP1-DAY1-0906 | 03-Jun-09 | o-Xylene | 0.0273 | B | 0.1 |
| VP1-DAY2-0906 | 04-Jun-09 | o-Xylene | 0.0267 | B | 0.1 |
| VP1-DAY4-0906 | 05-Jun-09 | o-Xylene | 0.0286 | B | 0.1 |
| VP1-WEEK1-0906 | 09-Jun-09 | o-Xylene | 0.0353 | B | 0.1 |
| | | | | | |
| MW06-1001 | 06-Jan-10 | Styrene | 0.0739 | J | 0.5 |
| MW06-1002 | 02-Feb-10 | Styrene | 0.0875 | B | 0.5 |
| MW06-1003 | 04-Mar-10 | Styrene | 0.1026 | B | 0.5 |
| MW11-1001 | 06-Jan-10 | Styrene | 0.1228 | J | 0.5 |
| MW11-1002 | 02-Feb-10 | Styrene | 0.0832 | B | 0.5 |

Notes:

ppmv - parts per million by volume

J - Analyte present. Reported value may not be accurate or precise.

B - Not detected substantially above the level reported in laboratory or field blanks.

| Sample Location | Date | Chemical | Result (ppmv) | Data Qualifiers | Detection Limit |
|---|---|---|---|---|---|
| MW11-1003 | 04-Mar-10 | Styrene | 0.1742 | J | 0.5 |
| TU4EFF-1001 | 06-Jan-10 | Styrene | 0.1385 | J | 0.5 |
| TU4EFF-1002 | 02-Feb-10 | Styrene | 0.1222 | B | 0.5 |
| TU4EFF-1003 | 04-Mar-10 | Styrene | 0.1316 | B | 0.5 |
| TU4INF-1001 | 06-Jan-10 | Styrene | 0.1647 | J | 0.5 |
| TU4INF-1001P | 06-Jan-10 | Styrene | 0.1941 | J | 0.5 |
| TU4INF-1002 | 02-Feb-10 | Styrene | 0.1023 | B | 0.5 |
| TU4INF-1002P | 02-Feb-10 | Styrene | 0.1475 | B | 0.5 |
| TU4INF-1003 | 04-Mar-10 | Styrene | 0.1373 | B | 0.5 |
| TU4INF-1003P | 04-Mar-10 | Styrene | 0.0885 | B | 0.5 |
| VD1-1001 | 06-Jan-10 | Styrene | 0.2328 | J | 0.5 |
| VD1-1002 | 02-Feb-10 | Styrene | 0.262 | B | 0.5 |
| VD1-1003 | 04-Mar-10 | Styrene | 0.1727 | J | 0.5 |
| VD2-0911 | 06-Nov-09 | Styrene | 0.1687 | J | 0.5 |
| VD2-1001 | 06-Jan-10 | Styrene | 0.2203 | J | 0.5 |
| VD2-1002 | 02-Feb-10 | Styrene | 0.2591 | B | 0.5 |
| VD2-1003 | 04-Mar-10 | Styrene | 0.1335 | B | 0.5 |
| VD3-1001 | 06-Jan-10 | Styrene | 0.2552 | J | 0.5 |
| VD3-1002 | 02-Feb-10 | Styrene | 0.2723 | B | 0.5 |
| VD3-1003 | 04-Mar-10 | Styrene | 0.1953 | J | 0.5 |
| VP1-1002 | 02-Feb-10 | Styrene | 0.2176 | B | 0.5 |
| VP1-1003 | 04-Mar-10 | Styrene | 0.1369 | B | 0.5 |
| | | | | | |
| MW06-0908 | 05-Aug-09 | Tetrachloroethene | 0.0745 | | 0.01 |
| MW06-0908POST | 05-Aug-09 | Tetrachloroethene | 0.0707 | | 0.01 |
| MW06-0910 | 08-Oct-09 | Tetrachloroethene | 3.4598 | | 0.01 |
| MW06-0911 | 06-Nov-09 | Tetrachloroethene | 2.1925 | | 0.01 |
| MW06-0912 | 02-Dec-09 | Tetrachloroethene | 2.7444 | | 0.01 |
| MW06-1001 | 06-Jan-10 | Tetrachloroethene | 3.2676 | | 0.01 |
| MW06-1002 | 02-Feb-10 | Tetrachloroethene | 2.177 | | 0.01 |
| MW06-1003 | 04-Mar-10 | Tetrachloroethene | 2.7265 | | 0.01 |
| MW06-DAY1- | 03-Jun-09 | Tetrachloroethene | 0.0256 | | 0.01 |
| MW06-DAY2- | 04-Jun-09 | Tetrachloroethene | 0.0451 | | 0.01 |
| MW06-DAY4- | 05-Jun-09 | Tetrachloroethene | 0.0385 | | 0.01 |
| MW06-PRE-0906 | 03-Jun-09 | Tetrachloroethene | 0.0256 | | 0.01 |
| MW06-WEEK2- | 16-Jun-09 | Tetrachloroethene | 0.0418 | | 0.01 |
| MW11-0908 | 04-Aug-09 | Tetrachloroethene | 0.0087 | J | 0.01 |
| MW11-0908POST | 05-Aug-09 | Tetrachloroethene | 0.0183 | | 0.01 |
| MW11-0909 | 02-Sep-09 | Tetrachloroethene | 0.0263 | | 0.01 |
| MW11-0910 | 08-Oct-09 | Tetrachloroethene | 0.0658 | | 0.01 |
| MW11-0911 | 06-Nov-09 | Tetrachloroethene | 0.088 | | 0.01 |
| MW11-0912 | 02-Dec-09 | Tetrachloroethene | 0.1329 | | 0.01 |
| MW11-1001 | 06-Jan-10 | Tetrachloroethene | 0.6239 | | 0.01 |
| MW11-1002 | 02-Feb-10 | Tetrachloroethene | 0.5884 | | 0.01 |
| MW11-1003 | 04-Mar-10 | Tetrachloroethene | 0.852 | | 0.01 |
| MW11-DAY1- | 03-Jun-09 | Tetrachloroethene | 0.0188 | | 0.01 |
| MW11-DAY2- | 04-Jun-09 | Tetrachloroethene | 0.0115 | | 0.01 |
| MW11-DAY4- | 05-Jun-09 | Tetrachloroethene | 0.0132 | B | 0.01 |

Notes:

ppmv - parts per million by volume

J - Analyte present. Reported value may not be accurate or precise.

B - Not detected substantially above the level reported in laboratory or field blanks.

Vapor Sampling Results
Ravenswood PCE Superfund Site

| Sample Location | Date | Chemical | Result (ppmv) | Data Qualifiers | Detection Limit |
|---|---|---|---|---|---|
| MW11-PRE-0906 | 03-Jun-09 | Tetrachloroethene | 0.0174 | | 0.01 |
| MW11-WEEK1- | 09-Jun-09 | Tetrachloroethene | 0.0113 | B | 0.01 |
| MW11-WEEK2- | 16-Jun-09 | Tetrachloroethene | 0.0189 | | 0.01 |
| MW6-0909 | 03-Sep-09 | Tetrachloroethene | 2.2409 | | 0.01 |
| TU4EFF-0910 | 08-Oct-09 | Tetrachloroethene | 0.0017 | J | 0.01 |
| TU4EFF-0912 | 02-Dec-09 | Tetrachloroethene | 0.0022 | J | 0.01 |
| TU4EFF-1001 | 06-Jan-10 | Tetrachloroethene | 0.0008 | J | 0.01 |
| TU4INF-0909 | 02-Sep-09 | Tetrachloroethene | 0.4801 | | 0.01 |
| TU4INF-0909P | 02-Sep-09 | Tetrachloroethene | 0.4775 | | 0.01 |
| TU4INF-0911 | 06-Nov-09 | Tetrachloroethene | 0.6202 | | 0.01 |
| TU4INF-0911P | 06-Nov-09 | Tetrachloroethene | 0.505 | | 0.01 |
| TU4INF-0912 | 02-Dec-09 | Tetrachloroethene | 0.7094 | | 0.01 |
| TU4INF-0912P | 02-Dec-09 | Tetrachloroethene | 0.5876 | | 0.01 |
| TU4INF-1001 | 06-Jan-10 | Tetrachloroethene | 0.5318 | | 0.01 |
| TU4INF-1001P | 06-Jan-10 | Tetrachloroethene | 0.735 | | 0.01 |
| TU4INF-1002 | 02-Feb-10 | Tetrachloroethene | 0.304 | | 0.01 |
| TU4INF-1002P | 02-Feb-10 | Tetrachloroethene | 0.4138 | | 0.01 |
| TU4INF-1003 | 04-Mar-10 | Tetrachloroethene | 0.6347 | | 0.01 |
| TU4INF-1003P | 04-Mar-10 | Tetrachloroethene | 0.6991 | | 0.01 |
| TU4INF-DAY2- | 04-Jun-09 | Tetrachloroethene | 0.0083 | J | 0.01 |
| TU4INF-DAY2- | 04-Jun-09 | Tetrachloroethene | 0.0111 | | 0.01 |
| TU4INF-DAY4- | 05-Jun-09 | Tetrachloroethene | 0.0115 | B | 0.01 |
| TU4INF-DAY4- | 05-Jun-09 | Tetrachloroethene | 0.0102 | B | 0.01 |
| TU4INF-WEEK1- | 09-Jun-09 | Tetrachloroethene | 0.0053 | B | 0.01 |
| TU4INF-WEEK1- | 09-Jun-09 | Tetrachloroethene | 0.0062 | B | 0.01 |
| VD1-0908 | 04-Aug-09 | Tetrachloroethene | 0.0202 | | 0.01 |
| VD1-0908POST | 05-Aug-09 | Tetrachloroethene | 0.0251 | | 0.01 |
| VD1-0909 | 02-Sep-09 | Tetrachloroethene | 0.295 | | 0.01 |
| VD1-0910 | 08-Oct-09 | Tetrachloroethene | 0.3565 | | 0.01 |
| VD1-0911 | 06-Nov-09 | Tetrachloroethene | 0.3577 | | 0.01 |
| VD1-0912 | 02-Dec-09 | Tetrachloroethene | 0.2512 | | 0.01 |
| VD1-1001 | 06-Jan-10 | Tetrachloroethene | 0.3048 | | 0.01 |
| VD1-1002 | 02-Feb-10 | Tetrachloroethene | 0.2461 | | 0.01 |
| VD1-1003 | 04-Mar-10 | Tetrachloroethene | 0.2362 | | 0.01 |
| VD1-DAY1-0906 | 03-Jun-09 | Tetrachloroethene | 0.0127 | | 0.01 |
| VD1-DAY2-0906 | 04-Jun-09 | Tetrachloroethene | 0.012 | | 0.01 |
| VD1-DAY4-0906 | 05-Jun-09 | Tetrachloroethene | 0.0085 | B | 0.01 |
| VD1-PRE-0906 | 03-Jun-09 | Tetrachloroethene | 0.0193 | | 0.01 |
| VD1-WEEK1- | 09-Jun-09 | Tetrachloroethene | 0.0116 | B | 0.01 |
| VD1-WEEK2- | 16-Jun-09 | Tetrachloroethene | 0.0133 | | 0.01 |
| VD2-0908 | 04-Aug-09 | Tetrachloroethene | 0.0179 | | 0.01 |
| VD2-0908POST | 05-Aug-09 | Tetrachloroethene | 0.0037 | J | 0.01 |
| VD2-0909 | 02-Sep-09 | Tetrachloroethene | 0.1407 | | 0.01 |
| VD2-0910 | 08-Oct-09 | Tetrachloroethene | 0.5478 | | 0.01 |
| VD2-0911 | 06-Nov-09 | Tetrachloroethene | 0.7355 | | 0.01 |
| VD2-0912 | 02-Dec-09 | Tetrachloroethene | 0.8474 | | 0.01 |
| VD2-1001 | 06-Jan-10 | Tetrachloroethene | 0.6889 | | 0.01 |
| VD2-1002 | 02-Feb-10 | Tetrachloroethene | 0.6425 | | 0.01 |

Notes:
ppmv - parts per million by volume
J - Analyte present. Reported value may not be accurate or precise.
B - Not detected substantially above the level reported in laboratory or field blanks.

# Vapor Sampling Results
# Ravenswood PCE Superfund Site

| Sample Location | Date | Chemical | Result (ppmv) | Data Qualifiers | Detection Limit |
|---|---|---|---|---|---|
| VD2-1003 | 04-Mar-10 | Tetrachloroethene | 0.5616 | | 0.01 |
| VD2-DAY1-0906 | 03-Jun-09 | Tetrachloroethene | 0.0022 | J | 0.01 |
| VD2-DAY1-0906P | 03-Jun-09 | Tetrachloroethene | 0.0022 | J | 0.01 |
| VD2-DAY2-0906 | 04-Jun-09 | Tetrachloroethene | 0.0021 | J | 0.01 |
| VD2-DAY4-0906 | 05-Jun-09 | Tetrachloroethene | 0.0012 | B | 0.01 |
| VD2-PRE-0906 | 03-Jun-09 | Tetrachloroethene | 0.002 | J | 0.01 |
| VD2-WEEK1- | 09-Jun-09 | Tetrachloroethene | 0.0028 | B | 0.01 |
| VD2-WEEK2- | 16-Jun-09 | Tetrachloroethene | 0.0021 | J | 0.01 |
| VD2-WEEK2- | 16-Jun-09 | Tetrachloroethene | 0.0022 | J | 0.01 |
| VD3-0908 | 04-Aug-09 | Tetrachloroethene | 0.0023 | J | 0.01 |
| VD3-0908P | 04-Aug-09 | Tetrachloroethene | 0.0043 | J | 0.01 |
| VD3-0908POST | 05-Aug-09 | Tetrachloroethene | 0.0238 | | 0.01 |
| VD3-0909 | 02-Sep-09 | Tetrachloroethene | 0.9184 | | 0.01 |
| VD3-0910 | 08-Oct-09 | Tetrachloroethene | 1.2995 | | 0.01 |
| VD3-0910P | 08-Oct-09 | Tetrachloroethene | 1.5737 | | 0.01 |
| VD3-0911 | 06-Nov-09 | Tetrachloroethene | 1.0818 | | 0.01 |
| VD3-0912 | 02-Dec-09 | Tetrachloroethene | 0.9406 | | 0.01 |
| VD3-1001 | 06-Jan-10 | Tetrachloroethene | 1.1006 | | 0.01 |
| VD3-1002 | 02-Feb-10 | Tetrachloroethene | 1.6154 | | 0.01 |
| VD3-1003 | 04-Mar-10 | Tetrachloroethene | 1.6526 | | 0.01 |
| VD3-DAY1-0906 | 03-Jun-09 | Tetrachloroethene | 0.0228 | | 0.01 |
| VD3-DAY2-0906 | 04-Jun-09 | Tetrachloroethene | 0.0109 | | 0.01 |
| VD3-DAY4-0906 | 05-Jun-09 | Tetrachloroethene | 0.0158 | B | 0.01 |
| VD3-PRE-0906 | 03-Jun-09 | Tetrachloroethene | 0.0174 | | 0.01 |
| VD3-WEEK1- | 09-Jun-09 | Tetrachloroethene | 0.01 | B | 0.01 |
| VD3-WEEK2- | 16-Jun-09 | Tetrachloroethene | 0.0222 | | 0.01 |
| VP1-0908 | 04-Aug-09 | Tetrachloroethene | 0.0148 | | 0.01 |
| VP1-0908POST | 05-Aug-09 | Tetrachloroethene | 0.0166 | | 0.01 |
| VP1-0909 | 02-Sep-09 | Tetrachloroethene | 3.7931 | | 0.01 |
| VP1-0910 | 08-Oct-09 | Tetrachloroethene | 4.8467 | | 0.01 |
| VP1-0911 | 06-Nov-09 | Tetrachloroethene | 3.2239 | | 0.01 |
| VP1-0912 | 02-Dec-09 | Tetrachloroethene | 3.0318 | | 0.01 |
| VP1-1001 | 06-Jan-10 | Tetrachloroethene | 2.0536 | | 0.01 |
| VP1-1002 | 02-Feb-10 | Tetrachloroethene | 3.2523 | | 0.01 |
| VP1-1003 | 04-Mar-10 | Tetrachloroethene | 2.01 | | 0.01 |
| VP1-DAY1-0906 | 03-Jun-09 | Tetrachloroethene | 0.0172 | | 0.01 |
| VP1-DAY2-0906 | 04-Jun-09 | Tetrachloroethene | 0.0142 | | 0.01 |
| VP1-DAY4-0906 | 05-Jun-09 | Tetrachloroethene | 0.0104 | B | 0.01 |
| VP1-PRE-0906 | 03-Jun-09 | Tetrachloroethene | 0.0105 | | 0.01 |
| VP1-WEEK2-0906 | 16-Jun-09 | Tetrachloroethene | 0.0117 | | 0.01 |
| | | | | | |
| MW06-DAY2- | 04-Jun-09 | Toluene | 0.0216 | J | 0.1 |
| MW11-DAY1- | 03-Jun-09 | Toluene | 0.0504 | J | 0.1 |
| MW11-DAY4- | 05-Jun-09 | Toluene | 0.0166 | J | 0.1 |
| MW11-WEEK2- | 16-Jun-09 | Toluene | 0.0201 | J | 0.1 |
| VP1-DAY2-0906 | 04-Jun-09 | Toluene | 0.0366 | J | 0.1 |
| | | | | | |
| MW06-0908 | 05-Aug-09 | Trichlorofluoromethane | 0.0009 | J | 0.005 |

Notes:

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B - Not detected substantially above the level reported in laboratory or field blanks.

## Vapor Sampling Results
## Ravenswood PCE Superfund Site

| Sample Location | Date | Chemical | Result (ppmv) | Data Qualifiers | Detection Limit |
|---|---|---|---|---|---|
| MW06-0908POST | 05-Aug-09 | Trichlorofluoromethane | 0.0009 | J | 0.005 |
| MW06-0910 | 08-Oct-09 | Trichlorofluoromethane | 0.0005 | J | 0.005 |
| MW06-0911 | 06-Nov-09 | Trichlorofluoromethane | 0.0007 | J | 0.005 |
| MW06-0912 | 02-Dec-09 | Trichlorofluoromethane | 0.0007 | J | 0.005 |
| MW06-1001 | 06-Jan-10 | Trichlorofluoromethane | 0.0005 | J | 0.005 |
| MW06-1002 | 02-Feb-10 | Trichlorofluoromethane | 0.0003 | J | 0.005 |
| MW06-1003 | 04-Mar-10 | Trichlorofluoromethane | 0.0003 | J | 0.005 |
| MW06-DAY1- | 03-Jun-09 | Trichlorofluoromethane | 0.0006 | J | 0.005 |
| MW06-DAY2- | 04-Jun-09 | Trichlorofluoromethane | 0.0005 | J | 0.005 |
| MW06-DAY4- | 05-Jun-09 | Trichlorofluoromethane | 0.0005 | J | 0.005 |
| MW06-PRE-0906 | 03-Jun-09 | Trichlorofluoromethane | 0.0006 | J | 0.005 |
| MW06-WEEK1- | 09-Jun-09 | Trichlorofluoromethane | 0.0004 | J | 0.005 |
| MW06-WEEK2- | 16-Jun-09 | Trichlorofluoromethane | 0.0006 | J | 0.005 |
| MW11-0908 | 04-Aug-09 | Trichlorofluoromethane | 0.0005 | J | 0.005 |
| MW11-0908POST | 05-Aug-09 | Trichlorofluoromethane | 0.0006 | J | 0.005 |
| MW11-0909 | 02-Sep-09 | Trichlorofluoromethane | 0.0005 | J | 0.005 |
| MW11-0910 | 08-Oct-09 | Trichlorofluoromethane | 0.0005 | J | 0.005 |
| MW11-0911 | 06-Nov-09 | Trichlorofluoromethane | 0.0006 | J | 0.005 |
| MW11-0912 | 02-Dec-09 | Trichlorofluoromethane | 0.0006 | J | 0.005 |
| MW11-1001 | 06-Jan-10 | Trichlorofluoromethane | 0.0005 | J | 0.005 |
| MW11-1002 | 02-Feb-10 | Trichlorofluoromethane | 0.0003 | J | 0.005 |
| MW11-1003 | 04-Mar-10 | Trichlorofluoromethane | 0.0003 | J | 0.005 |
| MW11-DAY1- | 03-Jun-09 | Trichlorofluoromethane | 0.0005 | J | 0.005 |
| MW11-DAY2- | 04-Jun-09 | Trichlorofluoromethane | 0.0006 | J | 0.005 |
| MW11-DAY4- | 05-Jun-09 | Trichlorofluoromethane | 0.0004 | J | 0.005 |
| MW11-PRE-0906 | 03-Jun-09 | Trichlorofluoromethane | 0.0004 | J | 0.005 |
| MW11-WEEK1- | 09-Jun-09 | Trichlorofluoromethane | 0.0006 | J | 0.005 |
| MW11-WEEK2- | 16-Jun-09 | Trichlorofluoromethane | 0.0005 | J | 0.005 |
| MW6-0909 | 03-Sep-09 | Trichlorofluoromethane | 0.0005 | J | 0.005 |
| TU4EFF-0910 | 08-Oct-09 | Trichlorofluoromethane | 0.0006 | J | 0.005 |
| TU4EFF-0911 | 06-Nov-09 | Trichlorofluoromethane | 0.0028 | J | 0.005 |
| TU4EFF-0912 | 02-Dec-09 | Trichlorofluoromethane | 0.0002 | J | 0.005 |
| TU4EFF-1001 | 06-Jan-10 | Trichlorofluoromethane | 0.0014 | J | 0.005 |
| TU4EFF-1002 | 02-Feb-10 | Trichlorofluoromethane | 0.0007 | J | 0.005 |
| TU4EFF-1003 | 04-Mar-10 | Trichlorofluoromethane | 0.0007 | J | 0.005 |
| TU4INF-0909 | 02-Sep-09 | Trichlorofluoromethane | 0.0025 | J | 0.005 |
| TU4INF-0909P | 02-Sep-09 | Trichlorofluoromethane | 0.0024 | J | 0.005 |
| TU4INF-0911 | 06-Nov-09 | Trichlorofluoromethane | 0.0023 | J | 0.005 |
| TU4INF-0911P | 06-Nov-09 | Trichlorofluoromethane | 0.0023 | J | 0.005 |
| TU4INF-0912 | 02-Dec-09 | Trichlorofluoromethane | 0.002 | J | 0.005 |
| TU4INF-0912P | 02-Dec-09 | Trichlorofluoromethane | 0.0021 | J | 0.005 |
| TU4INF-1001 | 06-Jan-10 | Trichlorofluoromethane | 0.0021 | J | 0.005 |
| TU4INF-1001P | 06-Jan-10 | Trichlorofluoromethane | 0.0021 | J | 0.005 |
| TU4INF-1002 | 02-Feb-10 | Trichlorofluoromethane | 0.0012 | J | 0.005 |
| TU4INF-1002P | 02-Feb-10 | Trichlorofluoromethane | 0.0013 | J | 0.005 |
| TU4INF-1003 | 04-Mar-10 | Trichlorofluoromethane | 0.0012 | J | 0.005 |
| TU4INF-1003P | 04-Mar-10 | Trichlorofluoromethane | 0.0012 | J | 0.005 |
| TU4INF-DAY2- | 04-Jun-09 | Trichlorofluoromethane | 0.0012 | J | 0.005 |

Notes:
ppmv - parts per million by volume
J - Analyte present. Reported value may not be accurate or precise.
B - Not detected substantially above the level reported in laboratory or field blanks.

| Sample Location | Date | Chemical | Result (ppmv) | Data Qualifiers | Detection Limit |
|---|---|---|---|---|---|
| TU4INF-DAY2- | 04-Jun-09 | Trichlorofluoromethane | 0.0012 | J | 0.005 |
| TU4INF-DAY4- | 05-Jun-09 | Trichlorofluoromethane | 0.0011 | J | 0.005 |
| TU4INF-DAY4- | 05-Jun-09 | Trichlorofluoromethane | 0.0011 | J | 0.005 |
| TU4INF-WEEK1- | 09-Jun-09 | Trichlorofluoromethane | 0.0011 | J | 0.005 |
| TU4INF-WEEK1- | 09-Jun-09 | Trichlorofluoromethane | 0.0011 | J | 0.005 |
| VD1-0908 | 04-Aug-09 | Trichlorofluoromethane | 0.0011 | J | 0.005 |
| VD1-0908POST | 05-Aug-09 | Trichlorofluoromethane | 0.0012 | J | 0.005 |
| VD1-0909 | 02-Sep-09 | Trichlorofluoromethane | 0.0008 | J | 0.005 |
| VD1-0910 | 08-Oct-09 | Trichlorofluoromethane | 0.0008 | J | 0.005 |
| VD1-0911 | 06-Nov-09 | Trichlorofluoromethane | 0.0008 | J | 0.005 |
| VD1-0912 | 02-Dec-09 | Trichlorofluoromethane | 0.0005 | J | 0.005 |
| VD1-1001 | 06-Jan-10 | Trichlorofluoromethane | 0.0006 | J | 0.005 |
| VD1-1002 | 02-Feb-10 | Trichlorofluoromethane | 0.0005 | J | 0.005 |
| VD1-1003 | 04-Mar-10 | Trichlorofluoromethane | 0.0003 | J | 0.005 |
| VD1-DAY1-0906 | 03-Jun-09 | Trichlorofluoromethane | 0.0014 | J | 0.005 |
| VD1-DAY2-0906 | 04-Jun-09 | Trichlorofluoromethane | 0.0014 | J | 0.005 |
| VD1-DAY4-0906 | 05-Jun-09 | Trichlorofluoromethane | 0.0014 | J | 0.005 |
| VD1-PRE-0906 | 03-Jun-09 | Trichlorofluoromethane | 0.0014 | J | 0.005 |
| VD1-WEEK1- | 09-Jun-09 | Trichlorofluoromethane | 0.0007 | J | 0.005 |
| VD1-WEEK2- | 16-Jun-09 | Trichlorofluoromethane | 0.0017 | J | 0.005 |
| VD2-0908 | 04-Aug-09 | Trichlorofluoromethane | 0.0006 | J | 0.005 |
| VD2-0908POST | 05-Aug-09 | Trichlorofluoromethane | 0.0073 |  | 0.005 |
| VD2-0909 | 02-Sep-09 | Trichlorofluoromethane | 0.0069 |  | 0.005 |
| VD2-0910 | 08-Oct-09 | Trichlorofluoromethane | 0.0065 |  | 0.005 |
| VD2-0911 | 06-Nov-09 | Trichlorofluoromethane | 0.0068 |  | 0.005 |
| VD2-0912 | 02-Dec-09 | Trichlorofluoromethane | 0.0063 |  | 0.005 |
| VD2-1001 | 06-Jan-10 | Trichlorofluoromethane | 0.0048 | J | 0.005 |
| VD2-1002 | 02-Feb-10 | Trichlorofluoromethane | 0.0043 | J | 0.005 |
| VD2-1003 | 04-Mar-10 | Trichlorofluoromethane | 0.0029 | J | 0.005 |
| VD2-DAY1-0906 | 03-Jun-09 | Trichlorofluoromethane | 0.0009 | J | 0.005 |
| VD2-DAY1-0906P | 03-Jun-09 | Trichlorofluoromethane | 0.0009 | J | 0.005 |
| VD2-DAY2-0906 | 04-Jun-09 | Trichlorofluoromethane | 0.0011 | J | 0.005 |
| VD2-DAY4-0906 | 05-Jun-09 | Trichlorofluoromethane | 0.0011 | J | 0.005 |
| VD2-PRE-0906 | 03-Jun-09 | Trichlorofluoromethane | 0.0009 | J | 0.005 |
| VD2-WEEK1- | 09-Jun-09 | Trichlorofluoromethane | 0.001 | J | 0.005 |
| VD2-WEEK2- | 16-Jun-09 | Trichlorofluoromethane | 0.0013 | J | 0.005 |
| VD2-WEEK2- | 16-Jun-09 | Trichlorofluoromethane | 0.0013 | J | 0.005 |
| VD3-0908 | 04-Aug-09 | Trichlorofluoromethane | 0.0069 |  | 0.005 |
| VD3-0908P | 04-Aug-09 | Trichlorofluoromethane | 0.0073 |  | 0.005 |
| VD3-0908POST | 05-Aug-09 | Trichlorofluoromethane | 0.0006 | J | 0.005 |
| VD3-0909 | 02-Sep-09 | Trichlorofluoromethane | 0.0006 | J | 0.005 |
| VD3-0910 | 08-Oct-09 | Trichlorofluoromethane | 0.0006 | J | 0.005 |
| VD3-0910P | 08-Oct-09 | Trichlorofluoromethane | 0.0006 | J | 0.005 |
| VD3-0911 | 06-Nov-09 | Trichlorofluoromethane | 0.0008 | J | 0.005 |
| VD3-0912 | 02-Dec-09 | Trichlorofluoromethane | 0.0008 | J | 0.005 |
| VD3-1001 | 06-Jan-10 | Trichlorofluoromethane | 0.0006 | J | 0.005 |
| VD3-1002 | 02-Feb-10 | Trichlorofluoromethane | 0.0006 | J | 0.005 |
| VD3-1003 | 04-Mar-10 | Trichlorofluoromethane | 0.0003 | J | 0.005 |

Notes:
ppmv - parts per million by volume
J - Analyte present. Reported value may not be accurate or precise.
B - Not detected substantially above the level reported in laboratory or field blanks.

# Vapor Sampling Results
# Ravenswood PCE Superfund Site

| Sample Location | Date | Chemical | Result (ppmv) | Data Qualifiers | Detection Limit |
|---|---|---|---|---|---|
| VD3-DAY1-0906 | 03-Jun-09 | Trichlorofluoromethane | 0.0007 | J | 0.005 |
| VD3-DAY2-0906 | 04-Jun-09 | Trichlorofluoromethane | 0.0007 | J | 0.005 |
| VD3-DAY4-0906 | 05-Jun-09 | Trichlorofluoromethane | 0.0006 | J | 0.005 |
| VD3-PRE-0906 | 03-Jun-09 | Trichlorofluoromethane | 0.0006 | J | 0.005 |
| VD3-WEEK1- | 09-Jun-09 | Trichlorofluoromethane | 0.0006 | J | 0.005 |
| VD3-WEEK2- | 16-Jun-09 | Trichlorofluoromethane | 0.0007 | J | 0.005 |
| VP1-0908 | 04-Aug-09 | Trichlorofluoromethane | 0.0006 | J | 0.005 |
| VP1-0908POST | 05-Aug-09 | Trichlorofluoromethane | 0.0006 | J | 0.005 |
| VP1-0909 | 02-Sep-09 | Trichlorofluoromethane | 0.0004 | J | 0.005 |
| VP1-0910 | 08-Oct-09 | Trichlorofluoromethane | 0.0004 | J | 0.005 |
| VP1-0911 | 06-Nov-09 | Trichlorofluoromethane | 0.0006 | J | 0.005 |
| VP1-0912 | 02-Dec-09 | Trichlorofluoromethane | 0.0006 | J | 0.005 |
| VP1-1001 | 06-Jan-10 | Trichlorofluoromethane | 0.0005 | J | 0.005 |
| VP1-1002 | 02-Feb-10 | Trichlorofluoromethane | 0.0003 | J | 0.005 |
| VP1-1003 | 04-Mar-10 | Trichlorofluoromethane | 0.0003 | J | 0.005 |
| VP1-DAY1-0906 | 03-Jun-09 | Trichlorofluoromethane | 0.0005 | J | 0.005 |
| VP1-DAY2-0906 | 04-Jun-09 | Trichlorofluoromethane | 0.0005 | J | 0.005 |
| VP1-PRE-0906 | 03-Jun-09 | Trichlorofluoromethane | 0.0005 | J | 0.005 |
| VP1-WEEK2-0906 | 16-Jun-09 | Trichlorofluoromethane | 0.0005 | J | 0.005 |
| | | | | | |
| MW06-0908 | 05-Aug-09 | Vinyl Chloride | 0.1415 | J | 1 |
| MW06-0908POST | 05-Aug-09 | Vinyl Chloride | 0.0951 | J | 1 |
| MW06-0910 | 08-Oct-09 | Vinyl Chloride | 0.0645 | J | 1 |
| MW06-0911 | 06-Nov-09 | Vinyl Chloride | 0.1124 | J | 1 |
| MW06-0912 | 02-Dec-09 | Vinyl Chloride | 0.258 | B | 1 |
| MW06-1002 | 02-Feb-10 | Vinyl Chloride | 0.0767 | B | 1 |
| MW06-1003 | 04-Mar-10 | Vinyl Chloride | 0.0985 | J | 1 |
| MW06-DAY1- | 03-Jun-09 | Vinyl Chloride | 0.2356 | B | 1 |
| MW06-DAY2- | 04-Jun-09 | Vinyl Chloride | 0.2902 | B | 1 |
| MW06-DAY4- | 05-Jun-09 | Vinyl Chloride | 0.064 | B | 1 |
| MW06-PRE-0906 | 03-Jun-09 | Vinyl Chloride | 0.1772 | B | 1 |
| MW06-WEEK1- | 09-Jun-09 | Vinyl Chloride | 0.3016 | J | 1 |
| MW06-WEEK2- | 16-Jun-09 | Vinyl Chloride | 0.0667 | J | 1 |
| MW11-0908 | 04-Aug-09 | Vinyl Chloride | 0.2325 | J | 1 |
| MW11-0908POST | 05-Aug-09 | Vinyl Chloride | 0.143 | J | 1 |
| MW11-0909 | 02-Sep-09 | Vinyl Chloride | 0.1509 | J | 1 |
| MW11-0910 | 08-Oct-09 | Vinyl Chloride | 0.0802 | J | 1 |
| MW11-0911 | 06-Nov-09 | Vinyl Chloride | 0.0777 | J | 1 |
| MW11-0912 | 02-Dec-09 | Vinyl Chloride | 0.1681 | B | 1 |
| MW11-1002 | 02-Feb-10 | Vinyl Chloride | 0.0912 | B | 1 |
| MW11-1003 | 04-Mar-10 | Vinyl Chloride | 0.1067 | J | 1 |
| MW11-DAY1- | 03-Jun-09 | Vinyl Chloride | 0.1796 | B | 1 |
| MW11-DAY2- | 04-Jun-09 | Vinyl Chloride | 0.1697 | B | 1 |
| MW11-DAY4- | 05-Jun-09 | Vinyl Chloride | 0.1493 | B | 1 |
| MW11-PRE-0906 | 03-Jun-09 | Vinyl Chloride | 0.1531 | B | 1 |
| MW11-WEEK1- | 09-Jun-09 | Vinyl Chloride | 0.1709 | B | 1 |
| MW6-0909 | 03-Sep-09 | Vinyl Chloride | 0.1058 | J | 1 |
| TU4EFF-0911 | 06-Nov-09 | Vinyl Chloride | 0.0743 | J | 1 |

Notes:

ppmv - parts per million by volume

J - Analyte present. Reported value may not be accurate or precise.

B - Not detected substantially above the level reported in laboratory or field blanks.

| Sample Location | Date | Chemical | Result (ppmv) | Data Qualifiers | Detection Limit |
|---|---|---|---|---|---|
| TU4EFF-0912 | 02-Dec-09 | Vinyl Chloride | 0.1433 | B | 1 |
| TU4EFF-1002 | 02-Feb-10 | Vinyl Chloride | 0.1453 | B | 1 |
| TU4EFF-1003 | 04-Mar-10 | Vinyl Chloride | 0.0689 | J | 1 |
| TU4INF-0909 | 02-Sep-09 | Vinyl Chloride | 0.0837 | J | 1 |
| TU4INF-0911 | 06-Nov-09 | Vinyl Chloride | 0.0436 | J | 1 |
| TU4INF-0912 | 02-Dec-09 | Vinyl Chloride | 0.1538 | B | 1 |
| TU4INF-0912P | 02-Dec-09 | Vinyl Chloride | 0.1275 | B | 1 |
| TU4INF-1001P | 06-Jan-10 | Vinyl Chloride | 0.0638 | J | 1 |
| TU4INF-1002 | 02-Feb-10 | Vinyl Chloride | 0.1309 | B | 1 |
| TU4INF-1002P | 02-Feb-10 | Vinyl Chloride | 0.0599 | B | 1 |
| TU4INF-1003 | 04-Mar-10 | Vinyl Chloride | 0.0552 | J | 1 |
| TU4INF-1003P | 04-Mar-10 | Vinyl Chloride | 0.0632 | J | 1 |
| TU4INF-DAY2- | 04-Jun-09 | Vinyl Chloride | 0.1221 | B | 1 |
| TU4INF-DAY2- | 04-Jun-09 | Vinyl Chloride | 0.0997 | B | 1 |
| TU4INF-DAY4- | 05-Jun-09 | Vinyl Chloride | 0.1045 | B | 1 |
| TU4INF-DAY4- | 05-Jun-09 | Vinyl Chloride | 0.103 | B | 1 |
| TU4INF-WEEK1- | 09-Jun-09 | Vinyl Chloride | 0.151 | B | 1 |
| TU4INF-WEEK1- | 09-Jun-09 | Vinyl Chloride | 0.0811 | B | 1 |
| VD1-0908 | 04-Aug-09 | Vinyl Chloride | 0.115 | J | 1 |
| VD1-0910 | 08-Oct-09 | Vinyl Chloride | 0.082 | J | 1 |
| VD1-0911 | 06-Nov-09 | Vinyl Chloride | 0.1198 | J | 1 |
| VD1-1002 | 02-Feb-10 | Vinyl Chloride | 0.1875 | B | 1 |
| VD1-1003 | 04-Mar-10 | Vinyl Chloride | 0.0652 | J | 1 |
| VD1-DAY1-0906 | 03-Jun-09 | Vinyl Chloride | 0.2069 | B | 1 |
| VD1-DAY2-0906 | 04-Jun-09 | Vinyl Chloride | 0.1058 | B | 1 |
| VD1-DAY4-0906 | 05-Jun-09 | Vinyl Chloride | 0.0909 | B | 1 |
| VD1-PRE-0906 | 03-Jun-09 | Vinyl Chloride | 0.1796 | B | 1 |
| VD1-WEEK1- | 09-Jun-09 | Vinyl Chloride | 0.1063 | B | 1 |
| VD1-WEEK2- | 16-Jun-09 | Vinyl Chloride | 0.1366 | J | 1 |
| VD2-0908 | 04-Aug-09 | Vinyl Chloride | 0.0941 | J | 1 |
| VD2-0908POST | 05-Aug-09 | Vinyl Chloride | 0.2141 | B | 1 |
| VD2-0909 | 02-Sep-09 | Vinyl Chloride | 0.1575 | J | 1 |
| VD2-0912 | 02-Dec-09 | Vinyl Chloride | 0.1331 | B | 1 |
| VD2-1002 | 02-Feb-10 | Vinyl Chloride | 0.1409 | B | 1 |
| VD2-DAY1-0906 | 03-Jun-09 | Vinyl Chloride | 0.1223 | B | 1 |
| VD2-DAY1-0906P | 03-Jun-09 | Vinyl Chloride | 0.1174 | B | 1 |
| VD2-DAY2-0906 | 04-Jun-09 | Vinyl Chloride | 0.0729 | B | 1 |
| VD2-DAY4-0906 | 05-Jun-09 | Vinyl Chloride | 0.0895 | B | 1 |
| VD2-PRE-0906 | 03-Jun-09 | Vinyl Chloride | 0.1255 | B | 1 |
| VD2-WEEK1- | 09-Jun-09 | Vinyl Chloride | 0.1112 | B | 1 |
| VD2-WEEK2- | 16-Jun-09 | Vinyl Chloride | 0.1026 | J | 1 |
| VD2-WEEK2- | 16-Jun-09 | Vinyl Chloride | 0.0888 | J | 1 |
| VD3-0908 | 04-Aug-09 | Vinyl Chloride | 0.0922 | J | 1 |
| VD3-0908P | 04-Aug-09 | Vinyl Chloride | 0.0769 | J | 1 |
| VD3-0908POST | 05-Aug-09 | Vinyl Chloride | 0.1492 | B | 1 |
| VD3-0910P | 08-Oct-09 | Vinyl Chloride | 0.0517 | J | 1 |
| VD3-0911 | 06-Nov-09 | Vinyl Chloride | 0.0578 | J | 1 |
| VD3-0912 | 02-Dec-09 | Vinyl Chloride | 0.0674 | B | 1 |

Notes:
ppmv - parts per million by volume
J - Analyte present. Reported value may not be accurate or precise.
B - Not detected substantially above the level reported in laboratory or field blanks.

| Sample Location | Date | Chemical | Result (ppmv) | Data Qualifiers | Detection Limit |
|---|---|---|---|---|---|
| VD3-1003 | 04-Mar-10 | Vinyl Chloride | 0.0795 | J | 1 |
| VD3-DAY1-0906 | 03-Jun-09 | Vinyl Chloride | 0.1327 | B | 1 |
| VD3-DAY2-0906 | 04-Jun-09 | Vinyl Chloride | 0.1014 | B | 1 |
| VD3-DAY4-0906 | 05-Jun-09 | Vinyl Chloride | 0.0795 | B | 1 |
| VD3-PRE-0906 | 03-Jun-09 | Vinyl Chloride | 0.0956 | B | 1 |
| VD3-WEEK1- | 09-Jun-09 | Vinyl Chloride | 0.1172 | B | 1 |
| VD3-WEEK2- | 16-Jun-09 | Vinyl Chloride | 0.0754 | J | 1 |
| VP1-0908 | 04-Aug-09 | Vinyl Chloride | 0.0961 | J | 1 |
| VP1-0908POST | 05-Aug-09 | Vinyl Chloride | 0.1459 | B | 1 |
| VP1-0911 | 06-Nov-09 | Vinyl Chloride | 0.0715 | J | 1 |
| VP1-0912 | 02-Dec-09 | Vinyl Chloride | 0.0912 | B | 1 |
| VP1-DAY1-0906 | 03-Jun-09 | Vinyl Chloride | 0.1118 | B | 1 |
| VP1-DAY4-0906 | 05-Jun-09 | Vinyl Chloride | 0.0723 | B | 1 |
| VP1-PRE-0906 | 03-Jun-09 | Vinyl Chloride | 0.0757 | B | 1 |
| VP1-WEEK1-0906 | 09-Jun-09 | Vinyl Chloride | 0.1072 | B | 1 |
| VP1-WEEK2-0906 | 16-Jun-09 | Vinyl Chloride | 0.0861 | J | 1 |

Notes:
ppmv - parts per million by volume
J - Analyte present. Reported value may not be accurate or precise.
B - Not detected substantially above the level reported in laboratory or field blanks.

# Appendix C

# QA Discussion

# Quality Assurance and Quality Control Report

## Section 1 - Introduction

This Quality Assurance and Quality Control Report covers soil vapor data collected to support the ongoing AS/SVE Treatability Study. A full discussion of groundwater data is presented in the Final Remedial Investigation Report (CDM, 2010d) which was prepared concurrently with this report.

Soil vapor samples were collected from June 2009 to March 2010. Samples collected in 2009 were collected on June 3, June 4, June 5, June 9, August 4, August 5, September 2, October 8, November 6 and December 2, 2009. Samples collected in 2010 were collected on January 6, February 2 and March 2, 2010. All samples were analyzed by Microseeps, Inc for a select set of VOC using their standard operation procedure AM 4.02.

## Section 2 - Controlling Documents

The sampling activities performed at the Site were conducted in accordance with the Final Site Management Plan Addendum, Ravenswood PCE Superfund Site (CDM 2008b) and the Final Site Management Plan, Ravenswood PCE Superfund Site (CDM, 2007).

### Quality Control Samples

Field sample-duplicate pairs were collected from a single sampling location, collected identically and consecutively over a minimum period of time to measure the total system variability (field and laboratory variability). The minimum required frequency of field duplicate collection was one per twenty samples (5%).

Duplicate samples were collected during each sampling event, which resulted in a frequency of approximately one per eight to ten samples.

### Deviations from the SMP

Vapor samples were not collected from between the carbon vessels or from the system effluent during baseline or TS system startup sampling.

Data from these samples are typically used to determine "breakthrough" to ensure the carbon vessels are changed out as needed during long term operation of the TS. These samples were not collected during these initial sampling events, as no vapor had been run through the vessels; therefore no breakthrough would have been expected.

The lack of this data has no impact on the overall quality and conclusions of the treatability study, because these samples are solely used in determining when carbon change out is required.

## Section 3 - Data Validation

Data validation was performed on the results from the vapor sampling events. The data validation was performed by the EPA Region III Environmental Services Assistance Team in accordance with the EPA Region III "Innovative Approaches for Validation of Organic Data (Level M2)," June 1995.

As a result of the data validation, various flags were applied to the data. Flags applied to the data covered by this report were:

U - Not detected. The associated number indicates approximate sample concentration necessary to be detected.

B - Not detected substantially above the level reported in laboratory or field blanks.

J - Analyte Present. Reported value may not be accurate or precise.

L - Analyte Present. Reported value may be biased low. Actual value is expected to be higher.

UL - Not detected, quantitation limit is probably higher.

# Section 4 - Precision, Accuracy, Representativeness, Comparability, and Completeness

Precision, accuracy, representativeness, comparability, and completeness (PARCC) parameters are indicators of data quality. PARCC goals are established for the site characterization to aid in assessing data quality. The following paragraphs define these PARCC parameters as they relate to this project and evaluate the data collected with regard to the parameters.

## Precision

Precision is an expression of mutual agreement among individual measurements of the same property taken under prescribed similar conditions. Precision is quantitative and most often expressed in terms of relative percent difference (RPD).

$$RPD = |S-D| / ((S+D)/2) \times 100$$

Where: S = First sample value (original value); and
D = Second sample value (duplicate value)

Duplicate samples were submitted to the laboratory as blind duplicates to mask the identity of the parent sample. A comparison between the duplicate and parent samples presented in Table C-1, shows that there was variability in the duplicate pairs associated with the vapor samples. RPD were calculated for data greater than five times the detection limit. The RPD value was calculated as the difference between the parent and duplicate sample results, divided by the average of the parent and duplicate sample results. RPDs for vapor ranged from 0 to 61%, with an average value of 21%. The high variability of RPDs observed in some vapor samples may be a result of the low values observed in the majority of the samples. No acceptable RPD limits are established in the SMP for vapor samples.

## Accuracy

Accuracy is a measure of the bias in a system. It is the degree of agreement of a measurement with an accepted reference or true value. Accuracy for this project was estimated from the analysis of QC samples whose true values are known (surrogate or matrix spikes) and was expressed as percent recovery.

$$\text{Percent Recovery} = (\text{SSR}-\text{SR})/\text{SA} \times 100$$

Where:
SSR = Spiked Sample Result
SR = Sample Result
SA = Spike Added

No surrogates were used during the field investigation but they were used for laboratory QC evaluation. Percent recovery results generated by the laboratory were evaluated in accordance with the EPA Contract Laboratory Program (CLP) Statement of Work ( SOW) by the EPA data validators.

Accuracy goals were met by laboratory QC procedures and checked by EPA data validators.

## Representativeness

Representativeness is a qualitative and quantitative parameter that is most concerned with the proper sampling design and the absence of cross-contamination of samples. Acceptable representativeness will be achieved through (a) careful, informed selection of sampling sites, (b) selection of testing parameters and methods that adequately define and characterize the extent of possible contamination and meet the required parameter reporting limits, (c) proper gathering and handling of samples to avoid interferences and prevent contamination and loss, and (d) collection of a sufficient number of samples to allow characterization. The representativeness will be assessed qualitatively by reviewing the sampling and analytical procedures and quantitatively by reviewing the blank samples. If an analyte is detected in a method, preparation, or rinsate blank, any associated positive result less than five times (10 times for common laboratory contaminants) the concentration found in the associated blank should be qualified with a "B".

Representativeness goals were met through selecting appropriate sampling locations and following CDM Technical Standard Operating Procedures (TSOPs) for sample collecting and shipping. Analytes detected at levels less than five time (or 10 for common laboratory contaminants) the concentration found in the associated blank were qualified with a "B".

## Comparability

Comparability is a qualitative parameter. Consistency in the acquisition, handling, and analysis of samples is necessary for comparing results. Data developed under this investigation were collected and analyzed using standard EPA analytical methods and

QC to ensure comparability of results with other analysis performed in a similar manner.

Comparability goals were met by collecting Microseeps sample in accordance with the SOPs, analyzing the samples using standard analytical methods and laboratory internal QC procedures.

## Completeness

Completeness is a measure of the amount of usable data obtained from a measurement system compared to the amount that was expected to be obtained under correct normal conditions. Usability will be determined by evaluation of the PARCC parameters excluding completeness. Those data that are validated or evaluated and are not considered estimated or are qualified as estimated or non-detect are considered usable. Rejected data are not considered usable. A completeness goal of 90% is projected.

Completeness is calculated using the following equation:

$$\text{Completeness}\ (\%) = (DO\ /\ DP) \times 100$$

Where: DO = Data Obtained and usable.
DP = Data Planned to be obtained.

Completeness goals were met as no data were rejected during the validation process, and planned samples were collected.

# Section 5 - Audits

The RAC III QA program includes both self-assessments and independent assessments as checks on quality of data generated on this work assignment. Self-assessments include management systems reviews, trend analyses, calculation checking, and technical reviews. Independent assessments include office, field, and laboratory audits and performance audits.

The contract Quality Management Plan requires that office audits be performed once per year for each work assignment (WA), and that one field audit be performed for every five weeks of field work that involve sample collection. However, on this work assignment, EPA has approved the replacement of office audits with self assessments.

The original AS/SVE treatability study vapor sampling was conducted over a nine-month period; however, each sampling event lasted less than a day so no field audit was performed. Technical reviews were performed on all technical submittals and three self assessments have been performed since the start of the work assignment.

## Table C-1
## Summary of Duplicate Sample Results for PCE
## Ravenswood PCE Superfund SIte

| Month, Year | SAMPLE ID | DUPLICATE ID | LOCATION | SAMPLE RESULT | DUPLICATE RESULT | UNITS | RPD |
|---|---|---|---|---|---|---|---|
| **VAPOR SAMPLES** | | | | | | | |
| June, 2009 | VD2-DAY1-0906 | VD2-DAY1-0906P | VD1 | 0.0022 | 0.0022 | ppmv | 0 |
| June, 2009 | TU4INF-DAY2-0906 | TU4INF-DAY2-0906P | TU4INF | 0.0083 | 0.0111 | ppmv | 29 |
| June, 2009 | TU4INF-DAY4-0906 | TU4INF-DAY4-0906P | TU4INF | 0.0115 | 0.0102 | ppmv | 12 |
| June, 2009 | TU4INF-WEEK1-0906 | TU4INF-WEEK1-0906P | TU4INF | 0.0053 | 0.0062 | ppmv | 16 |
| June, 2009 | VD2-WEEK2-0906 | VD2-WEEK2-0906P | VD1 | 0.0021 | 0.0022 | ppmv | 5 |
| August, 2009 | VD3-0908 | VD3-0908P | VD3 | 0.0023 | 0.0043 | ppmv | 61 |
| September, 2010 | TU4INF-0909 | TU4INF-0909P | TU4INF | 0.4801 | 0.4775 | ppmv | 1 |
| October, 2010 | TU4INF-0910 | TU4INF-0910P | TU4INF | 0.3565 | 0.5478 | ppmv | 42 |
| November, 2010 | TU4INF-0911 | TU4INF-0911P | TU4INF | 0.6202 | 0.505 | ppmv | 20 |
| December, 2010 | TU4INF-0912 | TU4INF-0912P | TU4INF | 0.7094 | 0.5876 | ppmv | 19 |
| January, 2010 | TU4INF-1001 | TU4INF-1001P | TU4INF | 0.5318 | 0.735 | ppmv | 32 |
| Februrary, 2010 | TU4INF-1002 | TU4INF-1002P | TU4INF | 0.304 | 0.4138 | ppmv | 31 |
| March, 2010 | TU4INF-1003 | TU4INF-1003P | TU4INF | 0.6347 | 0.6991 | ppmv | 10 |
| | | | | | | **AVERAGE** | 21 |

Notes:

ppmv - parts per million by volume

RPD - relative percent difference

# Appendix D

# Cost Estimates for Remedial Alternatives

## Alternative 2 - Groundwater Extraction and GAC Treatment Using a New Extraction Well (EW-1)
## Ravenswood PCE Superfund Site
## Ravenswood, WV

| Item No. | Item Description | Quantity | Unit Cost | Unit | Extension (a) | Extension (b) |
|---|---|---|---|---|---|---|
| | | | | | | |
| | | | | | | |
| 1. | Work Plan Preparation | 1 | $ 27,800 | LS | $ 27,800 | $ 27,800 |
| 2. | On-Site Facilities | 1 | $ 32,000 | LS | $ 32,000 | $ 32,000 |
| 3. | Construction Management | 1 | $ 34,739 | LS | $ 34,739 | $ 34,739 |
| 4a | Treatment System Installation (a) | 1 | $ 231,596 | LS | $ 231,596 | - |
| 4b | Treatment System Installation (b) | 1 | $ 191,155 | LS | - | $ 191,155 |
| 5. | Institutional Controls | 1 | $ 17,700 | LS | $ 17,700 | $ 17,700 |
| 6. | Groundwater Flow Modeling | 1 | $ 17,700 | LS | $ 17,700 | $ 17,700 |
| | | | | | | |
| | **SUBTOTAL CONSTRUCTION COSTS** | | | | $ 361,535 | $ 321,094 |
| | General Contractor Fee (10% construction) | | | | $ 36,154 | $ 32,109 |
| | Design Engineering (20% construction) | | | | 72,307 | 64,219 |
| | Resident Engineering/Inspection (10% construction) | | | | $ 36,154 | $ 32,109 |
| | Contingency (20%) | | | | $ 72,307 | $ 64,219 |
| | | | | | | |
| | **TOTAL CAPITAL COSTS** | | | | **$ 578,456** | **$ 513,751** |
| | | | | | | |
| **ANNUAL MONITORING COSTS** | | | | | | |
| 7. | Project Planning and Organization | 1 | $ 1,700 | LS | $ 1,700 | $ 1,700 |
| 8. | Sampling Labor | 1 | $ 7,200 | LS | $ 7,200 | $ 7,200 |
| 9. | Sampling Equipment | 1 | $ 4,960 | LS | $ 4,960 | $ 4,960 |
| 10. | Sample Analysis and Data Validation | 1 | $ 12,400 | LS | $ 12,400 | $ 12,400 |
| 11. | Data Evaluation and Reporting | 1 | $ 19,200 | LS | $ 19,200 | $ 19,200 |
| | **Total Annual Monitoring Costs** | | | | **$ 45,460** | **$ 45,460** |
| | | | | | | |
| **ANNUAL O&M COSTS** | | | | | | |
| 12. | Annual Operations and Maintenance | 1 | $ 36,769 | LS | **$ 36,769** | **$ 36,769** |
| | | | | | | |
| **FIVE YEAR REVIEW** | | | | | | |
| 13. | Five Year Review Report | 1 | $ 35,300 | LS | **$ 35,300** | **$ 35,300** |
| | | | | | | |
| **PRESENT WORTH OF COSTS** | | | | | | |
| | | | | | | |
| 14. | Total Capital Costs | | | | $ 578,456 | $ 513,751 |
| 15. | Long-term Monitoring (30 year duration) | | | | $ 564,113 | $ 564,113 |
| 16. | Long-term O&M (30 year duration) | | | | $ 456,263 | $ 456,263 |
| 17. | Five-Year Reviews (30 year duration) | | | | $ 76,171 | $ 76,171 |
| | | | | | | |
| | **TOTAL PRESENT WORTH** | | | | **$ 1,675,003** | **$ 1,610,298** |

Notes: **Assume $ 1,675,000 $ 1,610,000**
(a) - Discharge to Sandy Creek or Ohio River (a) (b)
(b) - Discharge to City Water Supply

## Alternative 2 - Groundwater Extraction and GAC Treatment Using a New Extraction Well (EW1)

### No. 1 Work Plan Preparation

Assume 1 junior engineer for 1 month.
Assume salary rate of $35/hour.
Assume 1 senior engineer for 2 weeks
Assume salary rate of $40/hour
Assume salary multiplier of 3.

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 persons x | $ | 35 /hour x | 40 hours/week x | 4.2 weeks/month x | 1 month x | 3 multiplier |
| 1 persons x | $ | 40 /hour x | 40 hours/week x | 4.2 weeks/month x | 0.5 month x | 3 multiplier |
| = $ 27,720 | | | | | | |
| | | | **Assume:** | **$ 27,800** | | |

### No. 2 On-Site Facilities

| | | | | | |
|---|---|---|---|---|---|
| Materials/supplies | 4 mo | x | 1500 per mo | $ | 6,000 |
| Utilities during construction | 4 mo | x | 1500 per mo | $ | 6,000 |
| Temp Facilities | 4 mo | x | 1500 per mo | $ | 6,000 |
| Misc | 4 mo | x | 3500 per mo | $ | 14,000 |
| | | | **Total:** | **$** | **32,000** |

### No. 3 Construction Management

| | | | |
|---|---|---|---|
| PM/construction supervision at 15% of construction cost | **Assume:** | **$** | **34,739** |

Alternative 2 - Groundwater Extraction and GAC Treatment Using a New Extraction Well (EW1)

**No. 4 Total Construction Cost (labor & material)**

| | | | |
|---|---|---|---|
| Well Construction | $ | 76,000 | **See page 4 for details** |
| Treatment System (a) | $ | 155,596 | **See page 5 for details** |
| Treatment System (b) | $ | 115,155 | **See page 5 for details** |
| **4a Total Construction Cost (a)** | **$** | **231,596** | |
| **4b Total Construction Cost (b)** | **$** | **191,155** | |

**No. 5 Institutional Controls**

Assistance to EPA for possible implementation of groundwater usage controls

Assume 1 persons for 2 weeks.
Assume salary rate of $35/hour.
Assume salary multiplier of 3.

1 person x $ 35 /hour x 40 hours/week 4.2 weeks/month x 1 month x 3 multiplier

= $ 17,640
**Assume: $ 17,700**

**No. 6 Groundwater Flow Modeling**

Flow modeling to deterimne impact of new pumping well

Assume 1 persons for 1 month.
Assume salary rate of $35/hour.
Assume salary multiplier of 3.

1 person x $ 35 /hour x 40 hours/week 4.2 weeks/month x 1 month x 3 multiplier

= $ 17,640
**Assume: $ 17,700**

Alternative 2 - Groundwater Extraction and GAC Treatment Using a New Extraction Well (EW1)

**4c. Driller Procurement and Statement of Work Preparation**

$ 30 per hour x 80 hours x 3 multiplier = $ 7,200

**4d. Groundwater Extraction Wells**

Depth 90 Number 1

| | Number | Unit | | Unit Cost | Unit | Total |
|---|---|---|---|---|---|---|
| Sonic drilling 16" borehole | 90 | ft | x | $ 80 | per LF | $ 7,200 |
| 12" dia SS Screen | 10 | ft | x | $ 437 | per LF | $ 4,370 |
| 12" dia well casing (CS or SS) | 80 | ft | x | $ 428 | per LF | $ 34,240 |
| bentonite | 5 | ft | x | $ 20 | per LF | $ 98 |
| Sand in borehole | 15 | ft | x | $ 9 | per LF | $ 135 |
| Grout | 70 | ft | x | $ 8 | per lf | $ 560 |
| Surface Finish | 1 | ea | x | $ 200 | each | $ 200 |
| | | | | | | |
| Total Cost | | | | | | $ 46,803 |
| Per Well Cost | | | | | | $ 46,803 |

**4e. Groundwater/Vapor Monitoring Wells**

Depth 70 Number 4

| | Number | Unit | | Unit Cost | Unit | Total |
|---|---|---|---|---|---|---|
| Sonic Drill 6" Borehole | 280 | ft | x | $ 37 | per LF | $ 10,360 |
| 2" dia PVC Screen | 80 | ft | x | $ 19 | per LF | $ 1,520 |
| PVC casing | 200 | ft | x | $ 14 | per LF | $ 2,800 |
| Bentonite | 8 | ft | x | $ 20 | per LF | $ 157 |
| Sand | 80 | ft | x | $ 9 | per LF | $ 720 |
| Grout | 192 | ft | x | $ 8 | per lf | $ 1,536 |
| Well Vault | 4 | ea | x | $ 200 | each | $ 800 |
| | | | | | | |
| Total Cost | | | | | | $ 17,893 |
| Per Well Cost | | | | | | $ 4,473 |

**4f. IDW Disposal**

| | Number | Unit | | Unit Cost | Unit | Total |
|---|---|---|---|---|---|---|
| Water Disposal | 4000 | gal | x | $ 0.35 | gal | $ 1,400 |
| Tank Rental | 4 | month | x | $ 700.00 | month | $ 2,800 |
| Total | | | | | | $ 4,200 |
| | | | | **TOTAL** | | **$ 76,096** |

Job No. 3330-025
Project Ravenswood PCE FS
Subject Alternative2 -EW1 - Cost Backup

Prepared by: [redacted]
Checked by:

## Alternative 2 - Groundwater Extraction and GAC Treatment Using a New Extraction Well (EW1)

### 4g. Treatment Unit

| | | | | |
|---|---|---|---|---|
| LPGAC Vessels | | $23,209 each | $92,836.00 | http://h2ktech.com/download/LC_cutsheet.PDF |
| Assume 4 filters, in series 200 gpm | | | | 33132026 (includes installation) |
| Bag Filters | | $800 each | $8,000.00 | |
| Assume 10 x #2 bag filters - Carbon Steel | | | | http://www.filtersource.com/prod_detail.asp?Category=3 |
| Extraction well - Well Head | | | | |
| Pump | | $4,512 each | $4,512.00 | RS Means 33 23 0561 |
| Vault | | $5,609 each | $5,609.00 | RS Means 33 23 2205 |
| | | **Subtotal** | $110,957.00 | |
| **Trenching** | | | | |
| *a - Discharge to Ohio River* | Number | Unit | Unit Cost | Extended Cost |
| Excavation | | 474 cy | $3.62 | $1,716.15 |
| Backfill/Compaction | | 369 cy | $1.88 | $694.39 |
| Fill Material | | 369 cy | $35.00 | $12,927.40 |
| Pipe | | 1,600 ft | $15.35 | $24,560.00 |
| Paving | | 119 sy | $40.00 | $4,740.74 |
| | | | **Subtotal (a)** | $44,638.68 |
| *b - Discharge to Treatment System* | | | | |
| Excavation | | 44 cy | $3.62 | $160.89 |
| Backfill/Compaction | | 35 cy | $1.88 | $65.10 |
| Fill Material | | 35 cy | $35.00 | $1,225.00 |
| Pipe | | 150 ft | $15.35 | $2,302.50 |
| Paving | | 11 sy | $40.00 | $444.44 |
| | | | **Subtotal (b)** | $4,197.93 |
| | | **Total Cost (a)** | **$155,596** | |
| | | **Total Cost (b)** | **$115,155** | |

### 12. O & M Costs

| | | |
|---|---|---|
| Electricity | $5,000.00 | Based on 200 gpm, always on, $0.08 /kwh |
| Routine Maintenance | $3,328.71 | 3% of capital costs |
| Carbon Change Out (semi-anually) | | |
| New Carbon (24,000 lb) @0.79/lb | $9,480.00 | |
| Disposal of Spent Carbon (24,000 lb) @ 0.28/lb | $3,360.00 | |
| Operations | $15,600.00 | |
| Assume 1 technician for 4 hours per week for 52 weeks | | RS Means E 33-22-0107 |
| Assume $25 per hour, salary multiplier of 3 | | |
| | $36,768.71 | |

**Alternati Annual O&M**
Assume annual monitoring on long-term basis

**No. 7 Project Planing and Organization**
Assume 1 Project Manager @ $40 per hour for 4 hours
Assume 1 Engineer @ $30 per hour for 8 hours
Assume 1 Technician @ $20 per hour for 8 hours
Assume salary multiplier of 3

| | | | | | | |
|---|---|---|---|---|---|---|
| = $ | 40 | per hour x | 4 | hours x | 3 | multiplier + |
| $ | 30 | per hour x | 8 | hours x | 3 | multiplier + |
| $ | 20 | per hour x | 8 | hours x | 3 | multiplier |
| = $ | 1,680 | per sampling event | | | | |
| **Assume: $** | **1,700** | **per sampling event** | | | | |

**No. 8 Sampling Labor**
Assume 2 persons for 4 days x 10 hour days @ $30 per hour
Assume 3 wells per day including purging and sampling
Two sampling personnel
Assume salary multiplier of 3

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 2 | persons x | 10 hours/day x | 4 | days x | $ | 30 | / h | 3 multiplier |
| = $ | **7,200** | **per sampling event** | | | | | | |

**No. 9 Sampling Equipment**
Assume sample shipping cost of $200 per day
Assume sampling equipment (pumps/generators etc) @ $300 per day
Assume miscellaneous materials @ $200 per day

| | | | | | |
|---|---|---|---|---|---|
| Shipping | $ | 200 | per day x | 4 days = | $ 800 |
| Sampling Equipment | $ | 300 | per day x | 4 days = | $ 1,200 |
| Monitoring Equipment | $ | 200 | per day x | 4 days = | $ 800 |
| Vehicle Rental | $ | 80 | per day x | 4 days = | $ 320 |
| Per Diem | $ | 130 | Per person/day x | 8 man days = | $ 1,040 |
| Misc | $ | 200 | per day x | 4 days = | $ 800 |
| **Assume:** | **$** | **4,960** | **per sampling event** | | |

**No. 10 Sample Analysis and Data Validation**
Assume groundwater samples will be collected from 16 monitoring and production wells and analyzed for VOCs
Assume groundwater samples will be collected from system influent, between the carbon vessels and the effluent

| | | |
|---|---|---|
| Total No. of Samples: | 20 | samples |
| | 2 | field duplicate |
| | 2 | MS |
| | 2 | MSD |
| | 3 | Rinsate Blanks |
| | 2 | Trip Blanks |
| | 31 | Total Samples Per Sampling Event |
| | 2 | events per year |

| | | | |
|---|---|---|---|
| Assume | $ | 200 | per sample for VOCs |
| | $ | 200 | Total sample cost |

| | | | | |
|---|---|---|---|---|
| Analysis Cost: | 31 | samples x | $ | 200 |
| = $ | 6,200 | per year | | |

| | | |
|---|---|---|
| Total Analysis & Validation: | $ | 12,400 |
| **Assume:** | **$** | **12,400** |

**No. 11 Data Evaluation & Reporting (Annual Monitoring)**

Assume 1 senior/ 1junior engineer/chemist at an average rate of $40 per hour for 80 hours per sampling event
Assume salary multiplier of 3

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| = | 2 | person x | $ | 40 | per hour x | 80 | hours x | 3 multiplier |
| = $ | **19,200** | | | | | | | |

**Alternative 2 - Groundwater Extraction and GAC Treatment Using a New Extraction Well (EW1)**
**No. 13 Five Year Review**

Assume 5-year reviews will be conducted every 5 years for 30 years.

| | |
|---|---|
| Work includes: | 5-year review of groundwater monitoring data |
| | Preparation of report |

Assume 2 person for 1 weeks
Assume salary rate of $35/hour.
assume multiplier of 3

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2 persons x | $ | 35 | /hour x | 40 | hours/week | x | 4.2 weeks/month x | 1 month x | 3 | multiplier |
| | $ 35,280 | | | | | | | | | | |
| **Assume:** | **$ 35,300** | | | | | | | | | | |

**Alternative 2 - Groundwater Extraction and GAC Treatment Using a New Extraction Well (EW1)**
**Present Worth Calculations**

**Assume discount rate is 7%:** **0.07**

This is a problem of the form find (P give A, i, n) or ( P/A,i,n)

P = Present Worth
A= Annual amount
i = interest rate
Assume 7%

**Total Long-term Monitoring Costs**

This is a recurring cost every year for 30 years

This is a problem of the form find (P given A, i, n) or ( P/A,i,n)

P = Present Worth
A= Annual amount
i = interest rate
Assume 7%

*Looking up the interest rate tables for i = 7% and n = 30 years*
The multiplier for (P/A) = **12.409**

**Total 5-year review costs**

This cost occurs every 5 years for 30 years.

need to calculate the effective interest rate $i_e$

| | |
|---|---|
| Given i = 7% (nominal interest rate) | 0.07 |
| m = # of compounding periods = 5 years | 5 |

$i_e = (1+i)^m - 1$ 0.403 = 40% / 5 years

$$\mathbf{P= A^*} \frac{(1+i)^n - 1}{i(1+i)^n}$$

in this case there are 6 - 5yr periods

| | |
|---|---|
| n = 6 | 6 |
| i = | 0.403 |

The multiplier is = **2.158**

## Alternative 3 - Venturi Air Stripping Using New Extraction Well (EW-1)
## Ravenswood PCE Superfund Site
## Ravenswood, WV

| Item No. | Item Description | Quantity | Unit Cost | Unit | Extension |
|---|---|---|---|---|---|
| | | | | | |
| | | | | | |
| 1. | Work Plan Preparation | 1 | $ 17,700 | LS | $ 17,700 |
| 2. | On-Site Facilities | 1 | $ 5,000 | LS | $ 5,000 |
| 3. | Construction Management | 1 | $ 18,995 | LS | $ 18,995 |
| 4. | Treatment System Installation | 1 | $ 126,636 | LS | $ 126,636 |
| 5. | Institutional Controls | 1 | $ 17,700 | LS | $ 17,700 |
| 6. | Groundwater Modeling | 1 | $ 17,700 | LS | $ 17,700 |
| | | | | | |
| | **SUBTOTAL CONSTRUCTION COSTS** | | | | $ 203,732 |
| | General Contractor Fee (10% construction) | | | | $ 20,373 |
| | Design Engineering (20% construction) | | | | 40,746 |
| | Resident Engineering/Inspection (10% construction) | | | | $ 20,373 |
| | Contingency (20%) | | | | $ 40,746 |
| | | | | | |
| | **TOTAL CAPITAL COSTS** | | | | **$ 325,971** |
| | | | | | |
| **ANNUAL MONITORING COSTS** | | | | | |
| 7. | Project Planning and Organization | 1 | $ 1,700 | LS | $ 1,700 |
| 8. | Sampling Labor | 1 | $ 7,200 | LS | $ 7,200 |
| 9. | Sampling Equipment | 1 | $ 4,960 | LS | $ 4,960 |
| 10. | Sample Analysis and Data Validation | 1 | $ 11,200 | LS | $ 11,200 |
| 11. | Data Evaluation and Reporting | 1 | $ 19,200 | LS | $ 19,200 |
| | **Total Annual Monitoring Costs** | | | | **$ 44,260** |
| | | | | | |
| **ANNUAL O&M COSTS** | | | | | |
| 12. | Annual Operations and Maintenance | 1 | $ 20,100 | LS | **$ 20,100** |
| | | | | | |
| **FIVE YEAR REVIEW** | | | | | |
| 13. | Five Year Review Report | 1 | $ 35,300 | LS | **$ 35,300** |
| | | | | | |
| **PRESENT WORTH OF COSTS** | | | | | |
| | | | | | |
| 14. | Total Capital Costs | | | | $ 325,971 |
| 15. | Long-term Monitoring (30 year duration) | | | | $ 549,222 |
| 16. | Long-term O&M (30 year duration) | | | | $ 249,421 |
| 17. | Five-Year Reviews (30 year duration) | | | | $ 76,171 |
| | | | | | |
| | **TOTAL PRESENT WORTH** | | | | **$ 1,200,785** |

**Assume $ 1,201,000**

## No. 1 Work Plan Preparation

Assume 1 persons for 1 months.
Assume salary rate of $35/hour.
Assume salary multiplier of 3.

1 persons x $ 35 /hour x 40 hours/week x 4.2 weeks/month x 1 month x 3 multiplier

= $ 17,640

**Assume: $ 17,700**

## No. 2 On-Site Facilities

| | | | | | |
|---|---|---|---|---|---|
| Materials/supplies | 1 mo | x | 1500 per mo | $ | 1,500 |
| Misc | 1 mo | x | 3500 per mo | $ | 3,500 |
| | | | **Total:** | **$** | **5,000** |

## No. 3 Construction Management

PM/construction supervision at 15% of construction cost **Assume: $ 18,995**

### No. 4 Total Construction Cost (labor & material)

| | | | |
|---|---|---|---|
| Treatment System | $ | 52,200 | **See page 5 for details** |
| Wells | $ | 74,436 | **See page 6 for details** |
| **Total Construction Cost** | **$** | **126,636** | |

### No. 5 Institutional Controls

Possible implementation of groundwater usage controls

Assume 1 persons for 1 month.
Assume salary rate of $35/hour.
Assume salary multiplier of 3.

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 person x | $ | 35 /hour x | 40 hours/week | 4.2 weeks/month x | 1 month x | 3 multiplier |
| | = $ | 17,640 | | | | |
| **Assume:** | **$** | **17,700** | | | | |

### No. 6 Groundwater Modeling

Flow modeling to deterimne impact of new pumping well

Assume 1 persons for 1 month.
Assume salary rate of $35/hour.
Assume salary multiplier of 3.

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 person x | $ | 35 /hour x | 40 hours/week | 4.2 weeks/month x | 1 month x | 3 multiplier |
| | = $ | 17,640 | | | | |
| **Assume:** | **$** | **17,700** | | | | |

**4a. Procurement and Statement of Work Preparation**

$ 30 per hour x 80 hours x 3 multiplier =

| | | |
|---|---|---|
| Subtotal | $ | **7,200** |

**4b. Treatment Unit**

| | | |
|---|---|---|
| 3 Module - 350H Maxi-Strip or Equivilant | $45,000.00 | http://www.hazletonenvr.com/ |
| Estimated at $10-$15,000 per module | | Vendor Quote |
| **Total Cost** | **$45,000** | |

**12. O & M Costs**

| | | |
|---|---|---|
| Routine Maintenance | $4,500.00 | 10% of capital costs |
| Operations | $15,600.00 | |
| Assume 1 technician at for 4 hours per week for 52 weeks | | RS Means E 33-22-0107 |
| Assume $25 per hour, salary multiplier of 3 | | |
| **Total Cost** | **$20,100.00** | |

**4c. Driller Procurement and Statement of Work Preparation**

$ 30 per hour x 48 hours x 3 multiplier = $ 4,320

**4d. Groundwater/Vapor Monitoring Wells**

Depth 70 Number 4

| | | | | | | |
|---|---|---|---|---|---|---|
| Sonic Drilling 6" | 280 | ft | x | $ 37 | per LF | $ 10,360 |
| 2" dia PVC Screen | 80 | ft | x | $ 19 | per LF | $ 1,520 |
| PVC casing | 200 | ft | x | $ 14 | per LF | $ 2,800 |
| Bentonite | 8 | ft | x | $ 20 | per LF | $ 157 |
| Sand | 80 | ft | x | $ 9 | per LF | $ 720 |
| Grout | 192 | ft | x | $ 8 | per lf | $ 1,536 |
| Well Vault | 4 | ea | x | $ 200 | each | $ 800 |
| | | | | | | |
| Total Cost | | | | | | $ 17,893 |
| Per Well Cost | | | | | | $ 4,473 |

**4e. Groundwater Extraction Wells**

Depth 90 Number 1

| | Number | Unit | | Unit Cost | Unit | Total |
|---|---|---|---|---|---|---|
| Sonic drilling 16" borehole | 90 | ft | x | $ 80 | per LF | $ 7,200 |
| 12" dia SS Screen | 10 | ft | x | $ 437 | per LF | $ 4,370 |
| 12" dia well casing (CS or SS) | 80 | ft | x | $ 428 | per LF | $ 34,240 |
| bentonite | 5 | ft | x | $ 20 | per LF | $ 98 |
| Sand in borehole | 15 | ft | x | $ 9 | per LF | $ 135 |
| Grout | 70 | ft | x | $ 8 | per lf | $ 560 |
| Surface Finish | 1 | ea | x | $ 200 | each | $ 200 |
| | | | | | | |
| Total Cost | | | | | | $ 46,803 |
| Per Well Cost | | | | | | $ 46,803 |

| | | | | | | |
|---|---|---|---|---|---|---|
| **4f. IDW Disposal** | 16 | each | x | $ 120 | each | $ 1,920 |
| Drum disposal | 10000 | gal | x | $ 0.35 | gal | $ 3,500 |
| Development/Decon Water Disposal | | | | | | $ 5,420 |
| Total | | | | | | |
| | | | | **TOTAL** | | **$ 74,436** |

**Annual O&M**

Assume annual monitoring on long-term basis

**No. 7 Project Planing and Organization**

Assume 1 Project Manager @ $40 per hour for 4 hours
Assume 1 Engineer @ $30 per hour for 8 hours
Assume 1 Technician @ $20 per hour for 8 hours
Assume salary multiplier of 3

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| = | $ | 40 | per hour x | 4 | hours x | 3 | multiplier + |
| | $ | 30 | per hour x | 8 | hours x | 3 | multiplier + |
| | $ | 20 | per hour x | 8 | hours x | 3 | multiplier |
| = | $ | 1,680 | per sampling event | | | | |
| **Assume:** | **$** | **1,700** | **per sampling event** | | | | |

**No. 8 Sampling Labor**

Assume 2 persons for 4 days x 10 hour days @ $30 per hour
Assume 3 wells per day including purging and sampling
Two sampling personnel
Assume salary multiplier of 3

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 2 | persons x | 10 hours/day x | 4 | days x | $ | 30 / h | 3 multiplier |
| = $ | **7,200** | **per sampling event** | | | | | |

**No. 9 Sampling Equipment**

Assume sample shipping cost of $200 per day
Assume sampling equipment (pumps/generators etc) @ $300 per day
Assume miscellaneous materials @ $200 per day

| | | | | | | |
|---|---|---|---|---|---|---|
| Shipping | $ | 200 | per day x | 4 days = | $ | 800 |
| Sampling Equipment | $ | 300 | per day x | 4 days = | $ | 1,200 |
| Monitoring Equipment | $ | 200 | per day x | 4 days = | $ | 800 |
| Vehicle Rental | $ | 80 | per day x | 4 days = | $ | 320 |
| Per Diem | $ | 130 | Per person/day x | 8 man days = | $ | 1,040 |
| Misc | $ | 200 | per day x | 4 days = | $ | 800 |
| **Assume:** | **$** | **4,960** | **per sampling event** | | | |

**No. 10 Sample Analysis and Data Validation**

Assume groundwater samples will be collected from 16 monitoring and production wells and analyzed for VOCs
Assume groundwater samples will be collected from system effluent

Total No. of Samples:

| | |
|---|---|
| 17 | samples |
| 2 | field duplicate |
| 2 | MS |
| 2 | MSD |
| 3 | Rinsate Blanks |
| 2 | Trip Blanks |
| 28 | Total Samples Per Sampling Event |
| 2 | events per year |

| | | | |
|---|---|---|---|
| Assume | $ | 200 | per sample for VOCs |
| | $ | 200 | Total sample cost |

| | | | | | |
|---|---|---|---|---|---|
| Analysis Cost: | | 28 | samples x | $ | 200 |
| | = $ | 5,600 | per year | | |

| | | |
|---|---|---|
| Total Analysis & Validation: | $ | 11,200 |
| **Assume:** | **$** | **11,200** |

**No. 11 Data Evaluation & Reporting (Annual Monitoring)**

Assume 1 senior/ 1junior engineer/chemist at an average rate of $40 per hour for 80 hours per sampling event
Assume salary multiplier of 3

= 2 person x $ 40 per hour x 80 hours x 3 multiplier
= $ **19,200**

Job No. 3330-025
Project Ravenswood PCE FS
Subject Alternative 3 - Venturi - Cost Backup

Prepared by: [redacted]
Checked by: _____

## No. 13 Five Year Review

Assume 5-year reviews will be conducted every 5 years for 30 years.

| | |
|---|---|
| Work includes: | 5-year review of groundwater monitoring data<br>Preparation of report |

Assume 2 person for 1 weeks
Assume salary rate of $35/hour.
assume multiplier of 3

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | 2 persons x | $ 35 /hour x | 40 hours/week | x | 4.2 weeks/month x | 1 month x | 3 multiplier |
| | $ 35,280 | | | | | | |
| **Assume:** | **$ 35,300** | | | | | | |

**Present Worth Calculations**

**Assume discount rate is 7%:** **0.07**

This is a problem of the form find (P give A, i, n) or ( P/A,i,n)

P = Present Worth
A= Annual amount
i = interest rate
Assume 7%

**Total Long-term Monitoring Costs**

This is a recurring cost every year for 30 years

This is a problem of the form find (P given A, i, n) or ( P/A,i,n)

P = Present Worth
A= Annual amount
i = interest rate
Assume 7%

*Looking up the interest rate tables for i = 7% and n = 30 years*
The multiplier for (P/A) = **12.409**

**Total 5-year review costs**

This cost occurs every 5 years for 30 years.

need to calculate the effective interest rate $i_e$
Given i = 7% (nominal interest rate) 0.07
m = # of compounding periods = 5 years 5

$i_e = (1+i)^m - 1$ 0.403 = 40% / 5 years

$$\mathbf{P= A^*}\ \frac{(1+i)^n - 1}{i(1+i)^n}$$

in this case there are 6 - 5yr periods
n = 6 6
i = 0.403

The multiplier is = **2.158**

## Alternative 4 - In-Situ Air Sparging with Soil Vapor Extraction
## Ravenswood PCE Superfund Site
## Ravenswood, WV

| Item No. | Item Description | Quantity | Unit Cost | Unit | Extension |
|---|---|---|---|---|---|
| | | | | | |
| | | | | | |
| 1. | Work Plan Preparation | 1 | $ 17,640 | LS | $ 17,640 |
| 2. | On-Site Facilities | 1 | $ 3,000 | LS | $ 3,000 |
| 3. | Construction Management | 1 | $ 18,018 | LS | $ 18,018 |
| 4. | Treatment System Expansion | 1 | $ 120,121 | LS | $ 120,121 |
| 5. | Institutional Controls | 1 | $ 17,700 | LS | $ 17,700 |
| | | | | | |
| | **SUBTOTAL CONSTRUCTION COSTS** | | | | $ 176,479 |
| | General Contractor Fee (10% construction) | | | | $ 17,648 |
| | Design Engineering (20% Construction) | | | | 35,296 |
| | Resident Engineering/Inspection (10% construction) | | | | $ 17,648 |
| | Contingency (20%) | | | | $ 35,296 |
| | | | | | |
| | **TOTAL CAPITAL COSTS** | | | | **$ 282,367** |
| | | | | | |
| **ANNUAL** | **MONITORING COSTS** | | | | |
| 6. | Project Planning and Organization | 1 | $ 1,700 | LS | $ 1,700 |
| 7. | Sampling Labor | 1 | $ 7,200 | LS | $ 7,200 |
| 8. | Sampling Equipment | 1 | $ 4,960 | LS | $ 4,960 |
| 9. | Sample Analysis and Data Validation | 1 | $ 13,200 | LS | $ 13,200 |
| 10. | Data Evaluation and Reporting | 1 | $ 19,200 | LS | $ 19,200 |
| | **Total Annual Monitoring Costs** | | | | **$ 46,260** |
| | | | | | |
| **ANNUAL** | **O&M COSTS** | | | | |
| 11. | Annual Operations and Maintenance | 1 | $ 24,204 | LS | **$ 24,204** |
| | | | | | |
| **FIVE YEAR** | **REVIEW** | | | | |
| 12. | Five Year Review Report | 1 | $ 35,300 | LS | **$ 35,300** |
| | | | | | |
| **PRESENT** | **WORTH OF COSTS** | | | | |
| | | | | | |
| 13. | Total Capital Costs | | | | $ 282,367 |
| 14. | Long-term Monitoring | | | | $ 449,185 |
| 15. | Long-term O&M (10 year duration) | | | | $ 169,997 |
| 16. | Five-Year Reviews (30 year duration) | | | | $ 76,171 |
| | | | | | |
| | **TOTAL PRESENT WORTH** | | | | **$ 977,719** |

**Assume $ 978,000**

**No. 1 Work Plan Preparation**

Assume 2 persons for 1 months.
Assume salary rate of $35/hour.
Assume salary multiplier of 3.

1 persons x $ 35 /hour x 40 hou 4.2 weeks/month x 1 month x 3 multiplier

= $ 17,640

**Assume: $ 17,640**

**No. 2 On-Site Facilities**

| | | | | | |
|---|---|---|---|---|---|
| Materials/supplies | 2 mo | x | 1500 per mo | $ | 3,000 |
| Utilities during construction | 0 mo | x | 1500 per mo | $ | - |
| Temp Facilities | 0 mo | x | 1500 per mo | $ | - |
| Misc | 0 mo | x | 3500 per mo | $ | - |
| | | | **Total:** | **$** | **3,000** |

**No. 3 Construction Management**

PM/construction supervision at 15% of construction cost **Assume: $ 18,018**

**No. 4 Total Construction Cost (labor & material)**

| | | | |
|---|---|---|---|
| AS/SVE/Vapor Monitoring Wells | $ | 88,324 | **See page 5 for details** |
| AS/SVE Trenching & Piping | $ | 23,797 | **See page 4 for details** |
| Treatment System | $ | 8,000 | **See page 6 for details** |
| **Total Construction Cost** | **$** | **120,121** | |

**No. 5 Institutional Controls**

Implementation of groundwater usage controls

Assume 1 persons for 1 month.
Assume salary rate of $35/hour.
Assume salary multiplier of 3.

1 person x $ 35 /hour x 40 hours/week 4.2 weeks/month x 1 month x 3 multiplier

= $ 17,640
**Assume: $ 17,700**

**4a. Driller Procurement and Statement of Work Preparation**

$ 30 per hour x 48 hours x 3 multiplier = $ 4,320

**4b. Soil Vapor Extraction Well**

Depth 50 Number 4

| | Number | Unit | | Unit Cost | Unit | Total |
|---|---|---|---|---|---|---|
| Sonic drilling 8" borehole | 200 | ft | x | $ 45 | per LF | $ 9,000 |
| 10' 4" dia PVC Screen | 40 | ft | x | $ 33 | per LF | $ 1,320 |
| PVC casing | 160 | ft | x | $ 22 | per LF | $ 3,520 |
| Bentonite | 8 | ft | x | $ 20 | per LF | $ 157 |
| Sand | 20 | ft | x | $ 9 | per LF | $ 180 |
| Grout | 172 | ft | x | $ 8 | per lf | $ 1,376 |
| Well Valult | 4 | ea | x | $ 200 | each | $ 800 |
| | | | | | | |
| Total Cost | | | | | | $ 16,353 |
| Per Well Cost | | | | | | $ 4,088 |

**4c. Air Sparge Well**

Depth 90 Number 8

| | Number | Unit | | Unit Cost | Unit | Total |
|---|---|---|---|---|---|---|
| Sonic drilling 6" borehole | 720 | ft | x | $ 37 | per LF | $ 26,640 |
| 2" dia PVC Screen | 16 | ft | x | $ 19 | per LF | $ 304 |
| PVC casing | 440 | ft | x | $ 14 | per LF | $ 6,160 |
| Bentonite | 16 | ft | x | $ 20 | per LF | $ 314 |
| Sand | 40 | ft | x | $ 9 | per LF | $ 360 |
| Grout | 400 | ft | x | $ 8 | per lf | $ 3,200 |
| Well Vault | 8 | ea | x | $ 200 | each | $ 1,600 |
| | | | | | | |
| Total Cost | | | | | | $ 38,578 |
| Per Well Cost | | | | | | $ 4,822 |

**4d. Groundwater/Vapor Monitoring Wells**

Depth 70 Number 4

| | Number | Unit | | Unit Cost | Unit | Total |
|---|---|---|---|---|---|---|
| Sonic Drill 6" Borehole | 280 | ft | x | $ 37 | per LF | $ 10,360 |
| 2" dia PVC Screen | 80 | ft | x | $ 19 | per LF | $ 1,520 |
| PVC casing | 200 | ft | x | $ 14 | per LF | $ 2,800 |
| Bentonite | 8 | ft | x | $ 20 | per LF | $ 157 |
| Sand | 80 | ft | x | $ 9 | per LF | $ 720 |
| Grout | 192 | ft | x | $ 8 | per lf | $ 1,536 |
| Well Vault | 4 | ea | x | $ 200 | each | $ 800 |
| | | | | | | |
| Total Cost | | | | | | $ 17,893 |
| Per Well Cost | | | | | | $ 4,473 |

**4e. IDW Disposal**

| | Number | Unit | | Unit Cost | Unit | Total |
|---|---|---|---|---|---|---|
| Drum disposal | 64 | each | x | $ 120 | each | $ 7,680 |
| Development/Decon Water Disposal | 10000 | gal | x | $ 0.35 | gal | $ 3,500 |
| Total | | | | | | $ 11,180 |

**TOTAL $ 88,324**

Job No. 3330-025
Project Ravenswood PCE FS
Subject Alternative 4 AS/SVE - Cost Backup

Prepared by: [redacted]
Checked by: _____

**4f. Trenching**

| Length (ft) | Width (ft) | Depth (ft) |
|---|---|---|
| 500 | 2 | 4 |

| | Number | Unit | Unit Cost | Total | |
|---|---|---|---|---|---|
| Exacavate | 148.15 | BCY | $3.62 | $536 | MCACES |
| Sand base | 74.07 | LCY | $19.51 | $1,445 | MCACES |
| Gravel fill | 74.07 | LCY | $19.51 | $1,445 | MCACES |
| Compaction | 148.15 | ECY | $1.88 | $279 | MCACES |
| Pavement Replacement | 37.04 | SY | $40.00 | $1,481 | Means - 02740-310-1050 |
| **4g. Piping** | | | | | |
| 2" PVC for SVE | 1000 | LF | $13.61 | $13,610 | Means 22 11 1374 1910 |
| 3/4" Tubing for AS | 5000 | LF | $1.00 | $5,000 | Ravenswood PCE Cost / Cost Works Labor (rounded up to $1/lf) |
| | | | **Total Cost** | **$ 23,797** | |

**4h. Treatment Unit**

Completion of Well heads and connection to lines

| | | | |
|---|---|---|---|
| TU4 System | | | |
| Assembly | | | |
| Electric/process piping | | | |
| Well head Completion | 8 wells @ 1000/well | $8,000.00 | Ravenswood Cost (est) |
| | **Total Cost** | **$8,000** | |

**11. O & M Costs**

| | | |
|---|---|---|
| Electricity | $5,000.00 | Vienna TU4 cost plus 10% |
| Routine Maitenance | $3,603.63 | 3% of capital costs |
| Operations | $15,600.00 | |
| Assume 1 technician at for 4 hours per week for 52 weeks | | RS Means E 33-22-0107 |
| Assume $25 per hour, salary multiplier of 3 | | |
| | $24,203.63 | |

**Annual O&M**
Assume annual monitoring on long-term basis

**No. 6 Project Planing and Organization**
Assume 1 Project Manager @ $40 per hour for 4 hours
Assume 1 Engineer @ $30 per hour for 8 hours
Assume 1 Technician @ $20 per hour for 8 hours
Assume salary multiplier of 3

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| = | $ | 40 | per hour x | 4 | hours x | 3 | multiplier + |
| | $ | 30 | per hour x | 8 | hours x | 3 | multiplier + |
| | $ | 20 | per hour x | 8 | hours x | 3 | multiplier |
| = | $ | 1,680 | per sampling event | | | | |
| **Assume:** | **$** | **1,700** | **per sampling event** | | | | |

**No. 7 Sampling Labor**
Assume 2 persons for4 days x 10 hour days @ $30 per hour
Assume 3 wells per day including purging and sampling
Two sampling personnel
Assume salary multiplier of 3

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 2 | persons x | 10 | hours/day | 4 | days x | # / h | 3 multiplier |
| = $ | 7,200 | **per sampling event** | | | | | |

**No. 8 Sampling Equipment**
Assume sample shipping cost of $200 per day
Assume sampling equipment (pumps/generators etc) @ $300 per day
Assume miscellaneous materials @ $200 per day

| | | | | | | |
|---|---|---|---|---|---|---|
| Shipping | $ | 200 | per day x | 4 | days = | $ 800 |
| Sampling Equipment | $ | 300 | per day x | 4 | days = | $ 1,200 |
| Monitoring Equipment | $ | 200 | per day x | 4 | days = | $ 800 |
| Vehicle Rental | $ | 80 | per day x | 4 | days = | $ 320 |
| Per Diem | $ | 130 | Per person/day x | 8 | man days = | $ 1,040 |
| Misc | $ | 200 | per day x | 4 | days = | $ 800 |
| **Assume:** | **$** | **4,960** | **per sampling event** | | | |

**No. 9 Sample Analysis and Data Validation**
Assume groundwater samples will be collected from 16 monitoring and production wells and analyzed for VOCs
Assume vapor samples will be collected from the influent, between the carbon and effluent of the system

| Total No. of Samples: | | |
|---|---|---|
| | 20 | samples |
| | 2 | field duplicate |
| | 3 | MS |
| | 3 | MSD |
| | 3 | Field Blank |
| | 2 | Trip Blanks |
| | 33 | Total Samples Per Sampling Event |
| | 2 | events per year |

| | | | |
|---|---|---|---|
| Assume | $ | 200 | per sample for VOCs |
| | $ | 200 | Total sample cost |

| | | | | |
|---|---|---|---|---|
| Analysis Cost: | 66 | samples x | $ | 200 |
| = $ | 13,200 | per year | | |

| | | |
|---|---|---|
| Total Analysis & Validation: | $ | 13,200 |
| **Assume:** | **$** | **13,200** |

**No. 10 Data Evaluation & Reporting (Annual Monitoring)**

Assume 1 senior/ 1junior engineer/chemist at an average rate of $40 per hour for 80 hours per sampling event
Assume salary multiplier of 3

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| = | 2 | person x | $ | 40 | per hour x | 80 ours | 3 multiplier |
| = $ | **19,200** | | | | | | |

**No. 12 Five Year Review**

Assume 5-year reviews will be conducted every 5 years for 30 years.

| | |
|---|---|
| Work includes: | 5-year review of groundwater monitoring data<br>Preparation of report |

Assume 2 person for 1 weeks
Assume salary rate of $35/hour.
assume multiplier of 3

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 2 persons x | $ | 35 | /hour x | 40 hours/week x | 4.2 weeks/month x | 1 month x | 3 multiplier |
| | $ | 35,280 | | | | | |
| **Assume:** | **$** | **35,300** | | | | | |

**Present Worth Calculations**

**Assume discount rate is 7%:** **0.07**

This is a problem of the form find (P give A, i, n) or ( P/A,i,n)

P = Present Worth
A= Annual amount
i = interest rate
Assume 7%

**Total Long-term O&M Costs**

This is a recurring cost every year for 6 years

This is a problem of the form find (P given A, i, n) or ( P/A,i,n)

P = Present Worth
A= Annual amount
i = interest rate
Assume 7%

*Looking up the interest rate tables for i = 7% and n = 10 years*
The multiplier for (P/A) = **7.0236**

Total Long-term Monitoring Costs
The multiplier for (P/A) (i=7, n = 30) 12.4

| | |
|---|---|
| Moitoring (1-10) | 7.02 |
| Monitoring (1-3( | 12.40 |

**Total 5-year review costs**

This cost occurs every 5 years for 30 years.

need to calculate the effective interest rate $i_e$
Given i = 7% (nominal interest r: 0.07
m = # of compounding periods = 5

$i_e = (1+i)^m - 1$ 0.403 = 40% / 5 years

**P= A*** $\frac{(1+i)^n - 1}{i(1+i)^n}$

in this case there are 6 - 5yr periods
n = 6 6
i = 0.403

The multiplier is = **2.158**