# REMEDIATION SYSTEM EVALUATION

## BOOMSNUB/AIRCO SUPERFUND SITE
## HAZEL DELL, WASHINGTON

Report of the Remediation System Evaluation,
Site Visit Conducted at the Boomsnub/Airco Superfund Site
February 26-27, 2002

US Army
Corps of Engineers

US Environmental
Protection Agency

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# Remediation System Evaluation
# Boomsnub/Airco Superfund Site
# Hazel Dell, Washington

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# EXECUTIVE SUMMARY

A Remediation System Evaluation (RSE) involves a team of expert hydrogeologists and engineers, independent of the site, conducting a third-party evaluation of site operations. It is a broad evaluation that considers the goals of the remedy, site conceptual model, above-ground and subsurface performance, and site exit strategy. The evaluation includes reviewing site documents, visiting the site for up to 1.5 days, and compiling a report that includes recommendations to improve the system. Recommendations with cost and cost savings estimates are provided in the following four categories:

- improvements in remedy effectiveness
- reductions in operation and maintenance costs
- technical improvements
- gaining site closeout

The recommendations are intended to help the site team identify opportunities for improvements. In many cases, further analysis of a recommendation, beyond that provided in this report, is required prior to implementation of the recommendation.

This report documents a RSE of the Boomsnub/Airco Superfund Site. The site documents were reviewed and the site visit was conducted in February 2002. This report therefore describes the status of the site as of February 2002. Modifications or adjustments to operation at the site have likely occurred since that date.

The Boomsnub/Airco Superfund Site is located in Hazel Dell, Clark County, Washington north of Vancouver, Washington and consists of the 0.75-acre Boomsnub property, the 11-acre BOC Gases property, and a co-mingled ground water plume of chromium and trichloroethene (TCE) that extends approximately 4,000 feet downgradient (to the west-northwest) from the properties. The site is approximately two miles east of Interstate 5 and one mile west of Interstate 205 near NE 78$^{th}$ Street and NE 47$^{th}$ Avenue. The site is bordered by a mixture of residential, commercial, and light industrial properties. Extraction and treatment of chromium contaminated ground water by the Boomsnub Corporation began in May 1990 at the order of the Washington State Department of Ecology ("Ecology"), but Ecology assumed the majority of financial responsibility by August 1990. EPA involvement at the site began in 1994 with sampling in conjunction with a criminal search warrant for the Boomsnub property. The site was placed on the National Priorities List (NPL) in April of 1995 upon the request of Washington State Department of Ecology.

The chromium contamination stems from chrome plating operations at the former Boomsnub facility and the TCE contamination stems from previous operations at the BOC Gases facility. The pump and treat system addresses both plumes and the costs for operation are shared, with EPA paying the majority of those costs.

The RSE team found the site team and contractor committed to system optimization and cost-effective operation. The EPA Remedial Project Manager (RPM) is exemplary, basing site decisions on effective management and analysis of data, operation costs, and interactions between the various parties associated with the site (EPA, the State of Washington, and BOC Gases).

The RSE team has two primary recommendations. The first one consists of the following items:

- conduct a hydrogeological analysis based on historical and current data

- update the site ground water flow and contaminant transport models

- use those models to evaluate management options (considering both system effectiveness and cost) for ground water extraction, treatment, and subsequent discharge of treated water

- consider various alternatives for the discharge of treated ground water including reinjection, which may both enhance effectiveness and reduce costs

The second recommendation is to develop an exit strategy using the updated site ground water flow and contaminant transport models to assist in the necessary evaluations. A potential scenario to be included in an exit strategy and a number of questions that should be answered in the exit strategy are provided.

The cost of the hydrogeological analysis and model simulations might require approximately $130,000 in capital costs. The optimal scenario for extraction, treatment, and discharge might also require capital costs to implement, but would likely result in annual costs savings that would more than offset those capital costs. A number of potential scenarios are described in the RSE report with cost estimates.

The cost of developing the exit strategy is estimated at approximately $50,000. Additional funds would be required to pilot additional technologies or implement the steps specified in the exit strategy. Based on the progress to date of the pump and treat system, the RSE team suggests that the site team should be prepared to use the exit strategy within the next 10 years of operation. This does not suggest the site will be ready for closure within 10 years. Rather, it suggests that important decision points based on the remedy's performance will occur within the next 10 years.

The RSE team has additional recommendations regarding technical improvement, including removing an unnecessary tank and pump and improving the electrical work for the air stripper.

A table summarizing the recommendations, including estimated costs and/or savings associated with those recommendations, is presented in Section 7.0 of the report.

# PREFACE

This report was prepared as part of a project conducted by the United States Environmental Protection Agency (USEPA) Technology Innovation Office (TIO) and Office of Emergency and Remedial Response (OERR). The objective of this project is to conduct Remediation System Evaluations (RSEs) of pump-and-treat systems at Superfund sites that are "Fund-lead" (i.e., financed by USEPA).

The following organizations are implementing this project.

| Organization | Key Contact | Contact Information |
|---|---|---|
| USEPA Technology Innovation Office<br>(USEPA TIO) | Kathy Yager | 11 Technology Drive (ECA/OEME)<br>North Chelmsford, MA 01863<br>phone: 617-918-8362<br>fax: 617-918-8427<br>yager.kathleen@epa.gov |
| USEPA Office of Emergency and Remedial Response<br>(OERR) | Jennifer Griesert | 1235 Jefferson Davis Hwy, 12th floor<br>Arlington, VA 22202<br>Mail Code 5201G<br>phone: 703-603-8888<br>fax: 703-603-9112<br>griesert.jennifer@epa.gov |
| GeoTrans, Inc.<br>(Contractor to TIO and OERR) | Doug Sutton | GeoTrans, Inc.<br>2 Paragon Way<br>Freehold, NJ 07728<br>phone: (732) 409-0344<br>fax: (732) 409-3020<br>dsutton@geotransinc.com |
| Army Corp of Engineers:<br>Hazardous, Toxic, and Radioactive Waste Center of Expertise<br>(Contractor to TIO) | Dave Becker | 12565 W. Center Road<br>Omaha, NE 68144-3869<br>(402) 697-2655<br>Fax: (402) 691-2673<br>dave.j.becker@nwd02.usace.army.mil |

The project team is grateful for the help provided by the following EPA Project Liaisons.

| | | | |
|---|---|---|---|
| **Region 1** | Darryl Luce and Larry Brill | **Region 6** | Vincent Malott |
| **Region 2** | Diana Cutt | **Region 7** | Mary Peterson |
| **Region 3** | Kathy Davies | **Region 8** | Armando Saenz and Richard Muza |
| **Region 4** | Kay Wischkaemper | **Region 9** | Herb Levine |
| **Region 5** | Dion Novak | **Region 10** | Bernie Zavala |

They were vital in selecting the Fund-lead pump and treat systems to be evaluated and facilitating communication between the project team and the Remedial Project Managers (RPM's).

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# 1.0 INTRODUCTION

## 1.1 PROJECT BACKGROUND

In the *OSWER Directive No. 9200.0-33, Transmittal of Final FY00 - FY01 Superfund Reforms Strategy, dated July 7,2000*, the Office of Solid Waste and Emergency Response outlined a commitment to optimize Fund-lead pump-and-treat systems. To fulfill this commitment, the US Environmental Protection Agency (USEPA) Technology Innovation Office (TIO) and Office of Emergency and Remedial Response (OERR), through a nationwide project, is assisting the ten EPA Regions in evaluating their Fund-lead operating pump-and-treat systems. This nationwide project is a continuation of a demonstration project in which the Fund-lead pump-and-treat systems in Regions 4 and 5 were screened and two sites from each of the two Regions were evaluated. It is also part of a larger effort by TIO to provide USEPA Regions with various means for optimization, including screening tools for identifying sites likely to benefit from optimization and computer modeling optimization tools for pump and treat systems.

In fiscal year (FY) 2001, the nationwide effort identified all Fund-lead pump-and-treat systems in the EPA Regions, collected and reported baseline cost and performance data, and evaluated a total of 20 systems. The site evaluations are conducted by EPA-TIO contractors, GeoTrans, Inc. and the United States Army Corps of Engineers (USACE), using a process called a Remediation System Evaluation (RSE), which was developed by USACE and is documented on the following website:

http://www.environmental.usace.army.mil/library/guide/rsechk/rsechk.html

A RSE involves a team of expert hydrogeologists and engineers, independent of the site, conducting a third-party evaluation of site operations. It is a broad evaluation that considers the goals of the remedy, site conceptual model, above-ground and subsurface performance, and site exit strategy. The evaluation includes reviewing site documents, visiting the site for up to 1.5 days, and compiling a report that includes recommendations to improve the system. Recommendations with cost and cost savings estimates are provided in the following four categories:

- improvements in remedy effectiveness
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The recommendations are intended to help the site team identify opportunities for improvements. In many cases, further analysis of a recommendation, beyond that provided in this report, is required prior to implementation of the recommendation.

In FY 2002, additional RSEs have been commissioned to address sites either recommended by a Region or selected by the Office of Emergency and Remedial Response. The Boomsnub/Airco Superfund Site was recommended by Region 10. This site has high operation costs relative to the cost of an RSE and a long projected operating life. This report provides a brief background on the site and current operations, a summary of the observations made during a site visit, and recommendations for changes and additional studies. The cost impacts of the recommendations are also discussed. The data review and site visit for this RSE occurred in February 2002. This report therefore describes the status of the site as of February 2002. Modifications or adjustments to operation at the site have likely occurred since that date.

## 1.2 TEAM COMPOSITION

The team conducting the RSE consisted of the following individuals:

Doug Sutton, Water Resources Engineer, GeoTrans, Inc.
Rob Greenwald, Hydrogeologist, GeoTrans, Inc.
Peter Rich, Civil and Environmental Engineer, GeoTrans, Inc.
Bill Crawford, Chemical Engineer, USACE HTRW CX

## 1.3 DOCUMENTS REVIEWED

| Author | Date | Title |
|---|---|---|
| US EPA | September 1997 | Record of Decision for Interim Remedial Action, Boomsnub/Airco Superfund Site, Hazel Dell, Washington |
| ICF Kaiser | September 1998 | Trip Report, May-June 1998 Direct Push Temporary Well Sampling Boomsnub/Airco Superfund Site, Hazel Dell, Washington |
| ICF Kaiser | April 1999 | Ground-water Flow and Solute Transport Modeling, Boomsnub/Airco Superfund Site, Hazel Dell, Washington |
| ICF Kaiser | May 1999 | Remedial Investigation Report, Boomsnub/Airco Superfund Site, Hazel Dell, Washington |
| ICF Kaiser | May 1999 | Trip Report, Installation of Monitoring Well MW-35 and Extraction Well MW-41 and GeoProbe Ground-water Sampling between MW-35 and NE 30th Street, December 1998 - February 1999, Boomsnub/Airco Superfund Site, Hazel Dell, Washington |
| ICF Kaiser | July 1999 | Feasibility Study Report, Boomsnub/Airco Superfund Site, Hazel Dell, Washington |
| URS Greiner | August 1999 | Trip Report, GeoProbe Sampling and Well Installation (MW-46, MW-47, and MW-48), Boomsnub/Airco Superfund Site, Hazel Dell, Washington |

| Author | Date | Title |
|---|---|---|
| US EPA | February 2000 | Record of Decision, Boomsnub/Airco Superfund Site, Hazel Dell, Washington |
| URS Greiner | August 2001 | Trip Report, Semiannual Groundwater Sampling— May 2001, Boomsnub/Airco Superfund Site, Hazel Dell, Washington |
| US EPA | September 25, 2001 | Memorandum— Request for a Non-Time Critical Removal Action for the BOC Gases Soil Operable Unit, Boomsnub/Airco Superfund Site |
| URS Greiner | December 2001 | Operation and Maintenance Manual, Boomsnub/Airco Superfund Site, Hazel Dell, Washington |
| URS Greiner | December 28, 2001 | Letter, 4th Quarter 2001 Boomsnub/Airco Superfund Site Groundwater Treatment System Self Monitoring Report— Permit No. 99-03 Mod 1 |
| URS Greiner | January 2002 | Monthly System Operation and Maintenance Report, December 2001, Groundwater Treatment System, Boomsnub/Airco Superfund Site, Hazel Dell, Washington |
| US EPA | February 19, 2002 | Summary of System Operation for Remedial System Evaluation, Boomsnub/Airco Superfund Site, Hazel Dell, Washington |
| US EPA | February 8, 2002 | Historical ground water quality data, Boomsnub/Airco Superfund Site, Hazel Dell, Washington |
| URS Greiner | March 19, 2002 | Data Excerpts from a Draft Tech Memo |

## 1.4 PERSONS CONTACTED

The following individuals associated with the site were present for the site visit:

Dan Alexanian, Hydrogeologist, Washington State Department of Ecology
Cary Brown, Engineer, URS
Greg Burgess, Hydrogeologist, URS
Jerry DeMuro, Project Manager, URS
Glenn Hayman, EA Engineering (Consultant to BOC Gases)
Elizabeth Peterson, Operator, Whiteshield
Steve Wesley, Engineer, URS

Deborah Yamamoto, Remedial Project Manager, EPA Region 10
Bernie Zavala, Hydrogeologist, EPA Region 10

Two interns from the U.S. Army Corps of Engineers, Seattle District (Sheri Moore and Emile Pitre) also attended the RSE site visit as observers.

## 1.5 SITE LOCATION, HISTORY, AND CHARACTERISTICS

### 1.5.1 LOCATION

The Boomsnub/Airco Superfund Site is located in Hazel Dell, Clark County, Washington north of Vancouver, Washington and consists of the 0.75-acre Boomsnub property, the 11-acre BOC gases property, and a co-mingled ground water plume of chromium and trichloroethene (TCE) that extends approximately 4,400 feet downgradient (to the west-northwest) from the properties. The site is approximately two miles east of Interstate 5 and one mile west of Interstate 205 near NE 78$^{th}$ Street and NE 47$^{th}$ Avenue. The site is bordered by a mixture of residential, commercial, and light industrial properties. Extraction and treatment of contaminated ground water by the Boomsnub Corporation began in May 1990 at the order of the Washington State Department of Ecology ("Ecology"), but Ecology assumed the majority of financial responsibility by August 1990. EPA involvement at the site began in 1994 with sampling in conjunction with a criminal search warrant for the Boomsnub property. The site was placed on the National Priorities List (NPL) in April of 1995 upon the request of Washington State Department of Ecology.

### 1.5.2 POTENTIAL SOURCES

***Boomsnub Property***

Operation of a chrome plating facility on the 0.75-acre Boomsnub property was the source of the chromium ground water contamination. Operations began in 1967, and operations ceased in July 1994 under a Unilateral Administrative Order (UAO). EPA removed more than 400 drums of waste, demolished and removed buildings and plating tanks, and removed over 6,000 tons of chromium contaminated soil and disposed of it offsite in 1994. An additional 2,500 cubic yards of contaminated soil was excavated to a depth of 12 feet in 2001. The area underneath the treatment building was not excavated. Angle hand-held auger or direct push methods are being considered to sample this area and determine if further removal is necessary.

***BOC Gases Property***

Past use and disposal of TCE and other volatile organic compounds on the BOC Gases property resulted in contamination of the soil and ground water. Two distinct areas on the BOC Gases property indicate ground water contamination. The primary area is near well AMW-12A on the western side of the property, where TCE concentrations in ground water historically exceed 1 mg/L and have been as high as 19.3 mg/L. Soil sampling has also indicated TCE contamination, and pilot testing of soil vapor extraction in this area has removed TCE mass. TCE in the soil and ground water in this primary area serve as continuing sources of ground water contamination, contributing to a plume that extends approximately 1 mile downgradient to the west-northwest.

A secondary area of ground water contamination on the BOC Gases property is located upgradient near AMW-8A on the northeastern portion of the site. The site team reports that a private well to the east of the BOC Gases property, suggesting a potential source up gradient of BOC Gases. Concentrations in this area are approximately two orders of magnitude lower than those near AMW-12A. It is unclear to what extent contamination in this area contributes to the plume that extends to the west-northwest of the property.

### 1.5.3 HYDROGEOLOGIC SETTING

Four principal hydrogeological units underlay the site: recent flood plain alluvium, Pleistocene Alluvial deposits ("Alluvial aquifer"), the Upper Troutdale formation, and the Lower Troutdale formation. Site related contamination has been detected primarily in the Alluvial aquifer, but recent sampling indicates low concentrations of TCE, and possibly chromium, in the Upper Troutdale aquifer. The Upper Troutdale serves as a primary water supply for Clark County.

According to the 1999 Remedial Investigation, the Alluvial aquifer consists of highly permeable sandy sediments with interspersed silts and silt lenses. Compared to the underlying Troutdale aquifers, the Alluvial aquifer has lower permeability and serves only as a local water supply. The water table in the Alluvial aquifer is approximately 10 to 30 feet below ground surface (approximately 230 to 250 feet above mean sea level) with ground water flowing to the west-northwest at an estimated seepage velocity of approximately 100 to 200 feet per year. Vertical gradients also result in downward flow in the Alluvial aquifer. Based on hydraulic conductivities and vertical gradients documented in the 1999 Remedial Investigation, the estimated vertical seepage velocity is approximately 2 to 13 feet per year.

The Alluvial aquifer grades in depth to fine sands, silts, and clays. The silts and clays act as an aquitard that ranges in thickness from approximately 6 feet near the Boomsnub and BOC Gases properties to approximately 30 feet near the center of the plume, which is a half mile downgradient to the west-northwest (Remedial Investigation, 1999). The Upper Troutdale formation lies below the aquitard, and the ground water elevations in the Upper Troutdale formation are lower than the bottom of the aquitard suggesting that, at least in some locations, the Alluvial aquifer is "perched" above the Upper Troutdale aquifer. Therefore, ground water can infiltrate down through the aquitard to the Upper Troutdale from the Alluvial aquifer, but ground water cannot migrate upward from the Upper Troutdale to the Alluvial aquifer. Flow through the aquitard is primarily vertical and was estimated at approximately 10 inches per year in the 1999 report on site ground-water flow and solute transport modeling.

According to the 1999 Remedial Investigation, the Upper Troutdale aquifer consists of gravel and cobbles in a poorly sorted sandy matrix with variable amounts of silts. The ground water elevation in this aquifer is approximately 140 feet above mean sea level. Based on estimated parameters recorded prior to and recorded in the RI, the ground water seepage velocity exceeds 3,000 feet per year. The ground water flow direction in the Upper Troutdale is west-southwest.

Rainfall in the area averages approximately 40 inches per year with 75% of all precipitation occurring between the months of October and March (Remedial Investigation, 1999). Surface water in the area includes Vancouver Lake 3.5 miles to the west of the site, Salmon Creek 2.5 miles north of the site, and various tributaries to Salmon Creek all of which flow within 1.5 miles north or northwest of the site.

### 1.5.4 DESCRIPTION OF GROUND WATER PLUME

Ground water plumes of dissolved chromium and TCE flow west-northwest from the Boomsnub and BOC Gases properties, respectively. The plume extends approximately 4,400 feet from the site in a narrow band that is approximately 900 feet in width (ROD, 2000). The plume migrates downward in the aquifer with increasing distance from the origin of contamination. By mid-plume, the contamination is generally found moving along the bottom of the Alluvial aquifer. The chromium contamination appears to be confined to the Alluvial aquifer, including the silt layer and likely the underlying aquitard. The TCE contamination has apparently permeated through the aquitard near the BOC Gases property because it has been detected in MW-33, which screens the Upper Troutdale aquifer and is located approximately 500 feet to the west-southwest of the BOC property. TCE has also been detected in AMW-24, located downgradient from MW-33. TCE and other VOCs have also been detected in the silt layer of the Alluvial aquifer. The detection of VOCs in the Troutdale aquifer is a result of either a natural or artifical breach in the aquitard or migration through the aquitard. The site team reports that two additional wells are being installed in the Troutdale to better define the TCE contamination and its migration into the Troutdale aquifer.

The estimated extent of the October 1995 and October 2001 chromium plumes in the Alluvial aquifer are presented in Figure 1-1, and the estimated extent of the October 1995 and October 2001 TCE plumes in the Alluvial aquifer are presented in Figure 1-2. The site team reports that since the pump and treat operation began in 1990, approximately 20,000 pounds of chromium and 1,500 pounds of TCE have been removed from ground water. The concentrations within plumes for each contaminant have decreased significantly in magnitude as a result of the pump and treat operations, but the outline or extent of the plumes have remained relatively constant.

Results from direct push ground water sampling, both laterally and vertically along NE 30$^{th}$ Avenue, as well as sampling from subsequently installed monitoring wells (MW-47, AMW-43, AMW-44, AMW-45) and extraction wells (MW-46, MW-48) in that area, indicate chromium and TCE impacts below ground water cleanup standards. Therefore, the site team concludes that the area approximately 100 feet to the east of NE 30$^{th}$ Avenue represents the end of the plume.

# 2.0 SYSTEM DESCRIPTION

## 2.1 SYSTEM OVERVIEW

The chromium and TCE plumes have been addressed with one extraction and treatment system. The first and farthest up gradient extraction well is located on the Boomsnub property and is immediately downgradient of the chromium source area. To avoid pulling chromium impacts up gradient onto the BOC property, no groundwater extraction wells are located on the BOC gases property.

The pump and treat system consists of an extraction system with 23 extraction wells in the Alluvial aquifer (17 of which were pumping at the time of the RSE), a treatment system designed to remove both chromium and TCE from the extracted water, and discharge to a POTW through a sewer line. The treatment system is located on the Boomsnub property. At the time of the RSE, BOC gases maintained the air stripper and EPA maintained the rest of the system including the extraction wells and the other treatment components.

According to the EPA RPM and State PM, the 10-year clock for turning the site over to the State has not officially begun because the final remedy specified in the ROD (including a system with a minimum capacity of 200 gpm) has not yet been constructed.

## 2.2 EXTRACTION SYSTEM

Over time, several extraction wells have been added along the axis of the plume. At the time EPA assumed operation and maintenance of the interim remedy in 1994, the extraction system consisted of 13 wells, and pumping rate was originally 100 gpm. Since that time, 8 additional extraction wells have been installed, and 17 of the 23 are operated at any one time based on recent concentration data. The total flow rate at the time of the RSE is 149 gpm, with individual well rates varying from 1 or 2 to 15 gpm. The extraction network extends approximately 4,400 feet west-northwest of the Boomsnub property to the toe of the plume. The ROD signed in 2000 stipulates a total pumping rate of 200 gpm, which is not currently achieved and exceeds the current discharge permit (which is 160 gpm, both average and peak).

## 2.3 TREATMENT SYSTEM

The treatment system removes both volatile organic compounds and chromium from the process water. Extracted water is transported to a 1,200 gallon influent tank where acid was historically added to lower the pH prior to pumping water through filters and the ion exchange vessels to remove chromium. The acid addition is not currently used. The water from the ion exchange units flows into another 1,200 gallon tank where caustic was historically added before it is transferred to a 6,000 gallon air stripper influent tank and sent through a packed tower air stripper. The caustic addition is not currently used. Water from the air stripper is pumped to a 6,000 gallon effluent tank before final discharge to the sanitary sewer (POTW). At the time of the RSE, water was pumped to the sanitary sewer but a new gravity discharge line was under construction (designed and constructed by BOC gases, which will also use the line for other purposes). Air emissions from the air stripper are pre-heated and then treated by vapor phase carbon units.

## 2.4 MONITORING PROGRAM

Ground water monitoring consists of sampling the 23 extraction wells and 4 monitoring wells at the toe of the plume on a quarterly basis (VOC's, chromium, pH), and also sampling approximately 55 additional monitoring wells in the spring and 75 additional wells in the fall. Each sample is analyzed for VOCs and chromium (labor split between EPA and BOC gases). At the time of the RSE, BOC Gases covered the cost of analysis for the VOCs and EPA performed chromium analyses (at the EPA Regional laboratory). Updated plume maps are not presented in each trip report, but are prepared on a periodic basis as requested by the RPM. These maps are used by EPA for system performance evaluation and public presentations.

Ground water elevations are measured from all 102 accessible monitoring and extraction wells during the spring and fall sampling events. Potentiometric surface maps are developed for each event and are included in the associated trip report.

Process monitoring includes sampling the plant influent and effluent for VOCs and chromium and measuring the average flow, peak flow, and pH. The sampling occurs on a monthly basis and the monthly results are reported for the discharge permit on a quarterly basis (i.e., three months are reported for a specific quarter). Flow is continuously measured during system operation, and actual total monthly discharge flows (total gallons per month) are reported to the POTW for billing purposes. The influent and effluent air to the vapor phase carbon units are sampled on a weekly basis with Draeger tubes.

# 3.0 SYSTEM OBJECTIVES, PERFORMANCE AND CLOSURE CRITERIA

## 3.1 CURRENT SYSTEM OBJECTIVES AND CLOSURE CRITERIA

According to the ROD, EPA has established the following cleanup objectives for the site-wide ground water operable unit:

- prevent further impacts to the Alluvial aquifer
- restore impacted ground water to drinking water standards (MCLs, MTCA Method B standards or the Practical Quantitation Limit, PQL)
- prevent ingestion of contaminated ground water above federal and state drinking water standards
- prevent impacts to the Upper Troutdale aquifer and the public drinking water supply by reducing contamination in the Alluvial aquifer

The contaminants of concern, according to the ROD, are presented in the following table along side the MCLs, MTCA B standards, PQLs, and selected cleanup criteria.

| Chemical of Concern | MCL (ug/L) | MTCA B (ug/L) | PQL (ug/L) | Cleanup Level (ug/L) | Basis for Cleanup level |
|---|---|---|---|---|---|
| Hexavalent chromium | no MCL | 80 | 5 | 80 | MTCA B |
| Chromium (total) | 100 | no MTCA B | 5 | 100 | MCL |
| Bromodichloromethane | 100 | 0.706 | 1 | 1 | PQL |
| Carbon tetrachloride | 5 | 0.337 | 1 | 1 | PQL |
| 1,2-Dibromo-3-chloropropane | 0.2 | 0.0313 | 1 | 0.2 | MCL |
| Dibromochloromethane | 100 | 0.521 | 1 | 1 | PQL |
| 1,2-Dichloroethane | 5 | 0.481 | 1 | 5 | MCL |
| 1,1-Dichloroethene | 7 | 0.0729 | 1 | 1 | PQL |
| Hexachlorobutadiene | no MCL | 0.561 | 5 | 5 | PQL |
| Tetrachloroethene | 5 | 0.858 | 1 | 5 | MCL |
| 1,1,1-Trichloroethane | 200 | 7,200 | 1 | 200 | MCL |
| Trichloroethene | 5 | 3.98 | 1 | 5 | MCL |

## 3.2 TREATMENT PLANT OPERATION GOALS

The following table presents the parameters, limits, and sample type for the industrial wastewater discharge permit.

| Parameter | Permit Limit | Sample Type |
|---|---|---|
| Average flow | 160 gpm | continuous |
| Peak flow | 160 gpm | continuous |
| Peak chrome | 1.7 mg/L | grab |
| Trichloroethene | 0.71 mg/L | grab |
| pH | 5.5 to 9.0 | grab |

Although the influent concentrations of the contaminants of concern meet the discharge requirements, treatment of the extracted ground water with the best available technology is still required by the State before discharging to the POTW.

# 4.0 FINDINGS AND OBSERVATIONS FROM THE RSE SITE VISIT

## 4.1 FINDINGS

In general, the RSE team found the system to be well operated and maintained. The observations and recommendations given below are not intended to imply a deficiency in the work of either the designers or operators, but are offered as constructive suggestions in the best interest of the EPA and the public. These recommendations obviously have the benefit of site characterization data and the operational data unavailable to the original designers.

The RSE team found the RPM an effective manager of a complex site, making decisions based on a comprehensive understanding of the site that considers the hydrogeology, engineering, costs, and relationships with the local municipality, State, and responsible party. The RPM effectively utilizes Regional technical resources including hydrogeologists, the laboratory, and direct push sampling equipment. Consideration has routinely been given to optimization of the current system and potential alternative remedial approaches. A pilot study was conducted to determine the effectiveness of in-well stripping combined with in-situ reduction of hexavalent chromium. Although the pilot test showed a significant reduction in TCE and chromium in the effluent, reductions in the nearby monitoring wells during the test were not sufficient to reach cleanup levels. Additional testing would have been necessary to determine the radius of influence for in-well stripping.

## 4.2 SUBSURFACE PERFORMANCE AND RESPONSE

### 4.2.1 WATER LEVELS

Water levels are collected semi-annually (once in the Spring and once in the Fall) while the system is operating, and the data from each event are interpreted by hand to develop a potentiometric surface map that represents pumping conditions. In addition, water levels have been collected when the system was not operational for an extended period of time. The most recent measurement of “static” water levels was in the Summer of 2001. The potentiometric surface maps support the conceptual model of contamination flowing to the west-northwest of the properties in a narrow plume. In addition, water levels demonstrate vertical gradients within the Alluvial aquifer and between the Alluvial aquifer and the Upper Troutdale aquifer (i.e., across the aquitard).

### 4.2.2 CAPTURE ZONES

To improve capture and mass removal, eight extraction wells have been installed or converted from existing monitoring wells since EPA took over management of the system. The EPA site hydrogeologist routinely uses a two dimensional model to evaluate capture.

A capture zone analysis of the current extraction system is not documented, but potentiometric surface maps based on measured water levels are generated on a semi-annual basis. These maps, however, cannot be used to effectively evaluate the extent of capture because the ground water elevations from operating extraction wells are included in the interpretation. The substantial drawdown that occurs in an operating extraction well does not accurately reflect the drawdown or ground water elevation in the aquifer, due to well losses. As a result, the extent of drawdown may be overestimated and the interpretation of ground water elevations may be biased in favor of capture. In addition, substantial vertical gradients are present in the Alluvial aquifer and also between the Alluvial aquifer and the Troutdale aquifer. The 1999 Remedial Investigation reported vertical gradients in the Alluvial aquifer ranging from 0.00173 and 0.0266 feet/foot. For example, monitoring wells CPU-10 and CPU-14 are in the same general vicinity but CPU-14 is screened in the Alluvial aquifer and CPU-10 is screened over 100 feet lower in the Upper Troutdale. According to the water level measurements in the May 2001 Trip Report, the water elevation in CPU-14 is over 100 feet greater than the water level in CPU-10.

The The two-dimensional analysis of ground water elevations does not account for the depths of different wells or piezometers within the Alluvial aquifer and therefore, the potentiometric surface map may reflect changes in ground water elevation that are due to both depth and horizontal distance. Accounting for vertical flow may also play an important role in evaluating capture at the site; however, the effects of vertical flow on capture cannot be considered properly from the two-dimensional potentiometric surface maps.

Although a ground water flow model is available for the site and has been used in the past to evaluate a variety of remedial strategies including pump and treat, the model has not been updated or calibrated recently. Therefore, it does not account for the current extraction system and likely cannot reproduce the ground water elevations associated with the current extraction scenario.

#### 4.2.3 CONTAMINANT LEVELS

Chromium concentrations measured from PW-1B, near the Boomsnub property, were as high as 368 mg/L in 1991 and first dropped below 10 mg/L in November 1994. Wells in the immediate vicinity of PW-1B have historically had similarly high concentrations. Prior to EPA management of the pump and treat system, concentrations exceeding 10 mg/L of chromium extended over 1,500 feet to the west-northwest of the Boomsnub property along the center axis of the plume (MW-21D and MW-22D), and concentrations exceeding 1 mg/L up to 1,000 feet beyond (MW-27D and CPU-13) and possibly further. GeoProbe sampling and well installations and sampling in 1998 and 1999 confirmed contamination further from the Boomsnub property. For example, in May 1999 AMW-27 and MW-35 had concentrations of 6,390 ug/L and 4,690 ug/L, respectively. However, these sampling events also established what appears to be the end of the plume along NE 30$^{th}$ Avenue.

Over time, chromium concentrations have in general decreased substantially, with temporary increases in some locations due to movement of the plume. The following table summarizes chromium and TCE concentrations measured in May 2001 (versus maximum concentrations observed in the first year of measurement) from select wells. TCE concentrations have also generally decreased over time in the Alluvial aquifer with most individual wells showing decreases of 70 to greater than 95%. PW-1B, near the Boomsnub property has increased since 1995 likely due to the TCE source remaining at the BOC Gases site that has not been contained. Pumping at the BOC Gases site has not been initiated to prevent pulling chromium upgradient from the Boomsnub facility. Detections and increasing concentrations of TCE in the Upper Troutdale aquifer (e.g., MW-33) indicate transport of TCE downward from the Alluvial aquifer.

| Well | Historic Chromium Concentration* (ug/L) | May 2001 Chromium Concentration (ug/L) | Historic TCE Concentration (ug/L) | May 2001 TCE Concentration (ug/L) |
|---|---|---|---|---|
| PW-1B | 368,000 (1991) | 373 | 68 (1995) | 240 |
| MW-21D | 44,000 (1993) | 299 | 3,000 (1995) | 85 |
| MW-22D | 36,000 (1993) | 913 | 350 (1995) | 88 |
| MW-27D | 2,000 (1993) | 142 | 100 (1995) | 17 |
| CPU-13 | 8,000 (1994) | 235 | 98 (1995) | 10 |
| AMW-27 | 5,250 (1998) | 3,870 | 66 (1998) | 78 |
| MW-35 | 8,050 (1999) | 80 | 110 (1995) | 28 |
| MW-41 | 81 (1999) | ND | ND (1999) | ND |
| MW-46 | 26 (1999) | 5.5 | ND (1999) | ND |
| MW-48 | 6 (1999) | ND | ND (1999) | ND |
| AMW-42 | 2,280 (1999) | 170 | 73 (1999) | 5 |

* Historic concentration is the highest value determined during the 1st calendar year the well was monitored for that parameter.

Rebounding of concentrations does occur to a limited extent when the extraction wells are shut down for a period of time. Extraction wells AMW-42, MW-41, MW-46, and MW-48 are all located at the toe of the plume and represent the last opportunity for capture of the plume without installation of additional wells in a residential neighborhood to the west. Sentinel wells AMW-43, AMW-44, and AMW-45 are all located downgradient of these extraction wells.

## 4.3 COMPONENT PERFORMANCE

### 4.3.1 EXTRACTION WELLS

Each extraction well is outfitted with a Grundfos submersible pump and individual flow meters with totalizers. The pumps that were initially installed were set manually with throttling valves, but newer pumps, that have replaced some of the original ones, have variable frequency drives that must be adjusted at the well head. The pumps are powered locally, but the system control wiring allows shutdown of the pumps at alarm conditions. Several well vaults have flooding problems, particularly during the wet season from October to March. Double-walled piping carries the extracted water from the wells to the treatment system. The carrier and containment pipe is HDPE. Based on discussions during the RSE site visit, the pump sizes appear appropriately sized or are outfitted with variable speed drives. If oversized pumps are present and flow is reduced by throttling valves, smaller pumps or variable speed drives should be considered, if such modifications are deemed cost-effective.

### 4.3.2 INFLUENT TANK

The extracted ground water flows from the extraction system to a 1,200 gallon influent tank located in a shed enclosure. This tank has a bubbler system as part of the level control system. An acid addition system is present for reducing the pH of the influent water prior to entering the ion exchange vessels; however, pH adjustment has been discontinued to facilitate operations and improve cost-effectiveness.

### 4.3.3 FILTERS AND ION EXCHANGE VESSELS

A 20 HP pump moves process water from the influent tank through parallel cannister filters to one of the two parallel trains of 4 ion exchange vessels. Each ion exchange vessel has a capacity of 25 cubic feet. Recent efforts have considered replacing the 8 vessels with two larger vessels to increase flow capacity and to facilitate resin change outs. Resin in the vessels is changed out approximately twice a year. Effluent from the ion exchange vessels flows into a 1,200 gallon tank where caustic was historically added to raise the pH to within discharge limits. This caustic has been removed because chromium hydroxide was forming and fouling the subsequent treatment components. In addition, the operators determined that the air stripping sufficiently raises the pH to meet the discharge limits.

### 4.3.4 AIR STRIPPER

Water from the 1,200 gallon ion-exchange effluent tank is pumped by a 15 HP pump with a variable speed drive to a 6,000 gallon air stripper influent tank. An air stripper influent pump that operates on level switches in the tank conveys water to the top of the air stripper. The air stripper is a packed tower Carbonair unit 4 feet in diameter and 28 feet high. The tower is packed with approximately 12 feet of 3.5 inch Lanpac polypropylene packing. A 5 HP fan provides the necessary air. The fan suction was open and should be guarded for personnel safety. The air stripper has a capacity of 425 gpm. The air pressure into the stripper was reading 13.5 in. w.c. and the outlet gage read 15.5 in. w.c. during operation, indicating that these gages should be replaced or calibrated.

The air stripper efficiency is relatively poor compared to other systems observed by the RSE team. Since December 2000, effluent concentrations have ranged from 2.9ug/l to 4.6 ug/l representing only 95% to 98% treatment efficiency based on influent concentrations of approximately 100 to 200 ug/l observed during 2001. The poor efficiency could be due to any of the following: air flow, packing type, packing height, flow below specifications when pump is off. Air strippers can easily be designed for 99.5+% removal of TCE, and for the influent concentrations at this site, effluent with non-detectable TCE should be achievable. Although not a problem at this point in time (because effluent limits are achieved), it may be important in the future to reach non-detectable concentrations in the effluent if other discharge options are considered (discussed in Section 6).

### 4.3.5 DISCHARGE

Treated water from the air stripper sump is transferred by a 5 HP pump to the final 6,000 gallon discharge tank. At the time of the RSE treated water was pumped to the sanitary sewer, but a gravity feed line was being constructed by BOC Gases to allow treated water to be transferred to the sewer without pumping.

### 4.3.6 VAPOR PHASE CARBON

Emissions from the ion exchange influent tank are treated through a 200-pound vapor phase carbon unit prior to discharge to the atmosphere. The emissions from the air stripper go through a moisture separator and 6 kilowatt duct heater prior to 5 parallel 500-pound vapor phase carbon units and a final 500-pound vapor phase carbon unit. Therefore, a total of 3,200 pounds of vapor phase carbon are used to control emission of TCE from the treatment system.

## 4.4 COMPONENTS OR PROCESSES THAT ACCOUNT FOR MAJORITY OF MONTHLY COSTS

As detailed during the site visit by the EPA RPM and the contractor, EPA's estimated monthly costs for future O&M of the pump and treat system are outlined in the following table. These estimates are based on a reduced amount of ongoing system improvements (relative to recent years) and does not include public relations support, non-routine project management, and non-routine data analysis currently done at the site. The costs also do not include those incurred by BOC Gases for their contribution to O&M (vapor phase carbon change outs and sampling), by the Regional EPA lab for chemical analysis, or by EPA for internal site management.

| | |
|---|---|
| Project management | $1,500/month |
| Monthly reporting | $3,000/month |
| Routine maintenance | $12,000/month |
| Semi-annual sampling ( $45,000/year for labor, $20,000/year for equipment, and $16,000/year for reports) | ~$7,000/month |
| Data management | $3,500/month |
| Chemical analysis (routine process monitoring) | $2,000/month |
| Electricity | $1,500/month |
| POTW | $22,250/month |
| Ion exchange resin | $1,600/month |
| **Total** | **$52,550/month** |

This translates to an annual cost of approximately $630,000 per year for EPA's O&M contractor.

### 4.4.1 UTILITIES

Electricity is the only utility of significant cost. The average monthly cost for operating the extraction system and both the TCE and chromium aspects of the treatment system is approximately $1,500 per month.

### 4.4.2 NON-UTILITY CONSUMABLES AND DISPOSAL COST

The discharge of treated water to the sanitary sewer represents the single largest cost (over 40% of the total) for system O&M. This cost is based on flow and will increase substantially (by approximately 25% per year, plus a one-time fee of approximately $230,000) if discharge rate increases to 200 gpm, which is the ground water extraction rate specified in the ROD. Replacement of ion exchange resin costs approximately $1,600 per month. The current efforts to replace the 8 vessels with 2 larger vessels will not decrease the costs for new resin but may decrease the amount of labor required for replacement. Previous costs associated with chemicals for pH adjustment have been eliminated.

### 4.4.3 LABOR

Total labor costs incurred by EPA for O&M is approximately $300,000 per year and consists of $45,000 per year for ground water sampling, $144,000 per year for routine maintenance, $18,000 for routine project management, $40,000 per year for data management, and $52,000 per year for reporting. For the semi-annual sampling events, 42 man-days are required for the fall event (75 monitoring locations) and 36 man-days are required for the spring event (55 monitoring locations).

### 4.4.4 CHEMICAL ANALYSIS

Routine sampling and analysis process monitoring costs incurred by EPA are approximately $24,000 per year. Additional costs are incurred by BOC Gases for sampling and analysis of TCE and by the EPA Regional Lab for chemical analysis for the semi-annual sampling events.

## 4.5 RECURRING PROBLEMS OR ISSUES

Despite thorough data management by the RPM, the contaminant plume in the Alluvial aquifer was initially difficult to contain for two primary reasons. First, EPA recognized early on that the existing extraction network it acquired at takeover did not capture the full extent of the plume. Second, containment efforts were hampered by access restrictions which prevented characterization and installation of the needed extraction wells. Eventually, EPA ordered and obtained access to the necessary property. GeoProbe sampling events were used to cost effectively assist in determining contaminant extent and locate additional extraction and monitoring wells. The TCE plume, however, has migrated downward through the aquitard and is impacting the Troutdale aquifer. These impacts may increase over time. At the time of the RSE, the extent of the plume in the Alluvial aquifer and the relatively high flow rate through the Upper Troutdale aquifer could further complicate efforts to contain the impacts. Continued extraction/treatment is necessary to remove the mass in the Alluvial aquifer and maintain an upward hydraulic gradient and minimize impacts on the Troutdale aquifer. Additional monitoring wells in the Troutdale and the source control action (in-well stripping with soil vapor extraction) planned for the BOC Gases property should assist with characterization and cleanup efforts.

The increases in the extent of the extraction system have complicated the extraction system piping, aspects of the treatment system, and discharge of the treated water. The extraction system piping was once large enough to accommodate the total flow, but as other wells have been added further from the treatment system adaptations in pipe sizes and booster pumps have become necessary. Also, the cost of discharging treated water is a function of flow. Increases in flow from the current flow rate to 200 gpm would require capital costs associated with improvements to portions of the extraction line and the ion exchange system as well as payment of City system development charges. Additional monthly costs would also be required for the increased discharge. Distance to surface water and the absence of storm drains that discharge to surface water have limited the options for alternative discharge.

## 4.6 REGULATORY COMPLIANCE

The site has an excellent record with respect to regulatory compliance. There have been a few minor permit violations (e.g., discharge at 167 gpm for several hours versus permitted rate of 160 gpm due to a faulty flow meter). A few chromium effluent concentration violations have occurred due to system upsets.

## 4.7 TREATMENT PROCESS EXCURSIONS AND UPSETS, ACCIDENTAL CONTAMINANT/REAGENT RELEASES

The plant typically shuts down approximately once or twice per month for unexplained reasons (perhaps power surges) or high levels in tanks or vaults. The shutdown triggers a call out alarm to the operator. A spill occurred in 1996 at the outdoor air stripper caused by failure of a high-level float in the air stripper surge tank. Floats were replaced and increased maintenance was put in place. BOC Gases designed and installed a leak detection system to detect releases of large volumes of water and divert the water to certain areas of the site that contain float alarms designed to shutdown the system. In 1995 there was a chromium hydroxide buildup downstream of the caustic addition (including the air stripper) due to caustic increasing pH such that chromium precipitated. Piping was replaced and system components were cleaned. Caustic is no longer added.

## 4.8 SAFETY RECORD

The system has an excellent safety record. There was one incident of vandalism associated with a stolen electric generator located off site in a locked fenced area near the toe of the plume. There were no other major security problems noted during the RSE site visit.

# 5.0 EFFECTIVENESS OF THE SYSTEM TO PROTECT HUMAN HEALTH AND THE ENVIRONMENT

## 5.1 GROUND WATER

The pump and treat system is effectively reducing concentrations of both chromium and TCE in the alluvial aquifer (see Section 4.2.3). There are two main concerns regarding protection of human health and the environment related to groundwater:

- Has containment been achieved at the toe of the plume?
- Is impacted groundwater in the alluvial aquifer migrating to the underlying Upper Troutdale formation, which serves as a regional drinking water aquifer?

Results from GeoProbe sampling in 1998 and 1999 and from subsequent sampling of monitoring wells MW-47, AMW-43, AMW-44, and AMW-45 and extraction wells MW-46 and MW-47 delineate the downgradient edge of the plume. The site team currently believes the plume is contained at the toe (near NE 30th Avenue), and sampling of these wells over time will indicate whether or not containment is adequate.

The site team indicates that some minor impacts (specifically for TCE) are observed in the underlying Upper Troutdale formation, and that those impacts are likely the result of downward transport from the alluvial aquifer. The minor impacts in the Upper Troutdale are not considered severe enough by the site team to merit remedial action in the Upper Troutdale at this time. It is very likely that the reduction of contaminant mass in the Alluvial aquifer provided by the pump and treat system is reducing the potential for impacts to the Upper Troutdale. Use of in-well stripping or other TCE source removal technologies in the source area may further reduce potential impacts to the Upper Troutdale. The RSE team believes that continued mass removal in the alluvial aquifer (regardless of technology employed), particularly in the most highly impacted areas, is a prudent approach to minimizing the risk of potential future impacts in the Upper Troutdale.

## 5.2 SURFACE WATER

There are no known or suspected impacts to surface water caused by the site.

## 5.3 AIR

Vapor phase carbon is used to treat off-gas from the air stripper. It is currently monitored, and there is no known or suspected impacts to air quality.

## 5.4 SOILS

Extensive soil removal has occurred on the Boomsnub property. In 2001 EPA completed the Phase II Soil Removal of approximately 2500 cubic yards of chromium-contaminated soil for off-site disposal. During the removal EPA discovered chromium contamination above cleanup levels extended under the ion exchange building. EPA plans additional sampling in 2002 to determine if this contamination must be removed.

## 5.5 WETLANDS AND SEDIMENTS

There are no known or suspected impacts to wetlands or sediments caused by the site.

# 6.0 RECOMMENDATIONS

Cost estimates provided have levels of certainty comparable to those done for CERCLA Feasibility Studies (-30/+50%), and these cost estimates have been prepared in a manner consistent with EPA 540-R-00-002, *A Guide to Developing and Documenting Cost Estimates During the Feasibility Study*, July 2000.

## 6.1 PRIMARY RECOMMENDATION FOR ENHANCED EFFECTIVENESS AND POTENTIAL COST REDUCTION

### 6.1.1 CONDUCT A HYDROGEOLOGICAL ANALYSIS

There are two predominant concerns regarding subsurface effectiveness of the remedy:

- preventing further migration of contamination to the west in the Alluvial aquifer
- limiting migration of contamination from the Alluvial aquifer to the Upper Troutdale aquifer

An optimized extraction system that involves a modified extraction rate and potential reallocation of extraction among the extraction wells may help address both of these concerns.

With respect to the first concern, it appears that the downgradient edge of the plume has been delineated and that monitoring wells have been appropriately placed to help evaluate capture over time. If plume capture at the toe of the plume is adequate, the TCE and chromium concentrations in MW-28, MW-29, MW-30, MW-47, AMW-43, AMW-44, AMW-45, and CPU-16 should remain constant below the cleanup criteria. If concentrations in these wells increase over time, that would be an indication that capture is inadequate. In such a case, further concentrating extraction at the toe of the plume could be used to conservatively provide capture. However, the total flow rate of the system is limited by the discharge permit, and reallocating extraction to the toe of the plume would sacrifice mass removal in other portions of the plume, which is crucial for addressing the second concern.

Accelerated mass removal from the hot spot areas provides two prime benefits: it might speed site closout, and it mitigates the amount of mass that is available for transport across the aquitard into the Upper Troutdale aquifer. Vertical gradients at the site suggest downward flow and infiltration of water from the Alluvial aquifer to the Upper Troutdale aquifer, and no practical amount of pumping in the Alluvial aquifer will completely eliminate this potential for downward migration. Given that the Upper Troutdale aquifer is a source of drinking water for both the public and private residences, protection of the Upper Troutdale is of paramount importance. Increasing concentrations of TCE in Upper Troutdale monitoring well MW-33 (9 ug/L in March 1999 to 19 ug/L in October 2001) provide evidence of the potential for further impacts to this source of drinking water.

Therefore, a thorough hydrogeological analysis is required for two primary reasons:

- estimate the potential for further contamination of the Upper Troutdale aquifer from site-related contaminants

- assist in selecting the appropriate cumulative extraction rate, the allocation of extraction among existing extraction wells, and the optimal locations and magnitude for potential reinjection of treated ground water

The hydrogeological analysis should be based on thorough analysis of both current and historical water levels measured at the site as well as ground water quality data. Unless large data gaps are discovered during the analysis, additional monitoring wells in the Alluvial aquifer should not be necessary. Additional wells in the Upper Troutdale, however are likely merited due to the already present impacts. As part of the hydrogeological analysis, site data should be used for the following two purposes:

- developing potentiometric surfaces and estimating flow paths

- updating and calibrating the existing 3-dimensional ground water flow and contaminant transport models

Development of the potentiometric surfaces should NOT include the water levels from operating extraction wells because these wells do not accurately represent the water levels in the surrounding aquifer, especially if well losses are present.

The ground water flow model, when updated and properly calibrated, should be able to reproduce the measured water levels under various extraction scenarios. A number of extraction scenarios have existed at the site because extraction wells have been added over time and extraction has been allocated to various wells on numerous occasions. Similarly, the transport model should be able to approximate the plume shape and magnitude. Special care should be given to estimate the transport across the aquitard from the Alluvial aquifer to the Upper Troutdale aquifer. Measurements of hydrogeological parameters (i.e., hydraulic conductivity) and existing TCE concentrations in the Upper Troutdale should be used as data in updating the model.

The potentiometric surface maps, ground water flow and contaminant transport models, and the concentration trends from the monitoring wells should be used as multiple lines of evidence to interpret capture offered by the current extraction system. The results should be compared to a target capture zone clearly outlined on a site map. Determination of the appropriate target capture zone will likely include review of the plume based on historical ground water quality data.

The estimated costs for these analyses are as follows:

- Development or redevelopment of potentiometric surface maps based on current and historical ground water elevations will likely require approximately $10,000 in capital costs.

- Modification/calibration of the existing 3-dimensional ground water flow and contaminant transport models based on existing data from multiple pumping scenarios will likely require approximately $75,000 in capital costs.

- A capture zone analysis with the updated models and current water level and ground water quality data will likely require approximately $15,000.

- Future, routine hydrogeological analyses with the above tools could likely be accomplished for an additional $7,500 above and beyond the current semi-annual reporting costs.

### 6.1.2 EVALUATE POTENTIAL MANAGEMENT OPTIONS FOR EXTRACTION AND DISCHARGE

The models developed as part of the recommended hydrogeological analysis should also be used to help evaluate potential extraction and reinjection scenarios. Attention should be paid to determining an optimal system in terms of both protectiveness and life-cycle costs. Potential scenarios include the following (each of which have multiple potential configurations):

| Scenario | Change in Extraction Rate | Reinjection |
|---|---|---|
| A | decrease | no reinjection |
| B | decrease | at least partial reinjection |
| C | no change | no reinjection |
| D | no change | at least partial reinjection |
| E | increase | no reinjection |
| F | increase | at least partial reinjection |

Those scenarios that include discharging less water to the POTW (i.e., a decreased extraction rate and/or reinjection of treated water) will likely result in life-cycle cost savings. Discharge alternatives other than the POTW and reinjection (see Section 6.1.3) also might result in a decrease in life-cycle costs.

Simulations with the models and other analysis for the purpose of identifying optimal extraction and injection options will likely require an additional $20,000 beyond those costs highlighted in Section 6.1.1. An optimization analysis uses mathematical algorithms in conjunction with existing ground water flow and contaminant transport models could also be considered, though the cost of the optimization analysis might require an additional $30,000.

### 6.1.3 CONSIDERATIONS FOR POTENTIAL EXTRACTION AND DISCHARGE OPTIONS

Considering both effectiveness and cost, the RSE team believes that the optimal solution will potentially include reinjection of some treated ground water and will likely include either the current extraction rate of 160 gpm or an increased rate, such as the 200 gpm specified in the ROD. Four discharge scenarios are discussed below, each considering two different extraction rates of 160 gpm and 200 gpm. It is assumed that the appropriate flow rate for the system (160 gpm or 200 gpm) is determined by an evaluation of effectiveness and that the discharge option is determined by cost-effectiveness for a prescribed flow rate. Therefore, the costs for the discharge options assuming 160 gpm are compared to the baseline costs of discharging the current 160 gpm to the POTW, and the costs for discharge options assuming 200 gpm are compared to the baseline costs of discharging 200 gpm to the POTW. The estimated costs of the various options and baselines are presented in Table 6-1.

It should be noted that upgrading the treatment system and portions of the extraction system from a capacity of 160 gpm to 200 gpm would likely require approximately $50,000. This additional cost is not provided in the following comparisons because the cost comparisons are provided to determine the cost-effective option for a prescribed flow rate.

***Option 1: Injection of treated water at the toe of the plume***

*Effectiveness*

Injection of the treated water at the toe of the plume would help create a hydraulic barrier to ensure that further plume migration to the west is prevented. The treated ground water meets cleanup standards (5 ug/L for TCE and 100 ug/L for total chromium); therefore, by reinjecting it, the site team could ensure that water to the west of the reinjection system is below cleanup standards. The efficiency of the air stripper could be improved to reliably meet the TCE cleanup standards. Furthermore, the discharge of treated water would no longer limit the capacity of the system. Extraction rates could be increased to 200 gpm or more without a substantial increase in annual O&M. This increase in extraction could be allocated appropriately to the toe of the plume (upgradient of the proposed reinjection area) and to various plume hot spots.

Based on discussions during the RSE site visit, the RSE team understands that reinjection options are limited by the following constraints generally imposed by the State:

- Treated ground water cannot be reinjected off site if it degrades ground water quality.
- Treated ground water cannot be reinjected within the plume boundary if it will result in spreading of the plume.

At the Boomsnub site, the plume boundary defines the site boundary and the treated water, although it meets MCLs, exceeds background contaminant concentrations. Therefore, injecting the treated water outside of the plume boundary would result in degradation of ground water (i.e., contaminant concentrations above background levels). On the other hand, reinjecting treated ground water within the site boundary is, by definition, reinjecting treated ground water within the plume boundary, which would result in spreading of the plume.

The option presented here involves injection of treated ground water at the fringe of the plume. Therefore, as stated earlier, contaminant concentrations in ground water downgradient of the plume fringe (although above natural levels) will be below MCLs. An ARAR waiver could be pursued.

*Cost*

Reinjection of all treated water to the toe of the plume will eliminate a primary cost of O&M— discharge of already treated water to the POTW. Implementation of this option would require approximately $700,000 in capital costs to construct a discharge line to the toe of the plume, install 10 reinjection wells (each with a diameter of 8 inches), and provide the associated controls. Additionally, approximately $50,000 per year would be required for injection well maintenance. Assuming the current extraction rate of 160 gpm, this would eliminate approximately $267,000 per year in discharge costs. Combining the costs of the additional maintenance with the cost savings from reduced discharge, annual costs would be reduced by approximately $217,000. Therefore, the capital costs would be recovered in approximately 5 years.

If the increased flow is required, annual costs associated with the discharge of 200 gpm to the POTW would be approximately $335,000 per year. A one-time fee of approximately $230,000 would also be required for POTW system upgrades. Therefore, with a flow rate of 200 gpm, reinjecting treated water to the toe of the plume would require approximately $470,000 more in capital costs compared to the baseline of discharging all 200 gpm of treated water to the POTW. It would also, however, save approximately $285,000 per year in annual costs (savings from eliminating discharge to the POTW minus the maintenance costs for the reinjection wells). Within the first two to three years, the difference in capital costs would be recovered and savings would be realized for a 200 gpm scenario.

***Option 2: Distributing Discharge to Subsurface Reinjection and the POTW***

*Effectiveness*

**Consideration A** - The site team could consider reinjecting a fraction of the treated water into the onsite injection galleries up gradient of the plume on the Boomsnub property and discharging the remaining fraction to the POTW. Because discharge to the POTW would be reduced, additional capacity would exist for increased extraction. Reinjecting the treated water to the onsite infiltration gallery up gradient of the chromium hot spots would serve to flush water through the hot spots toward downgradient extraction wells and speed mass removal. Proper hydrogeological analysis would be required to ensure plume capture. Downgradient extraction wells would have to capture both water flowing onsite due to natural gradients and water being reinjected through the infiltration galleries. Thus, downgradient extraction will need to exceed injection. Inadequate capture will lead to spreading of the plume, which is unprotective and conflicts with the State's criteria for reinjection.

**Consideration B -** For partial discharge to subsurface reinjection, the site team could consider reinjecting treated water up gradient of the BOC Gases plume to address the TCE source area. This approach would be similar to Consideration A but would be unnecessary and inappropriate if other source removal technologies, such as the proposed in-well stripping, are employed. Compared to implementing specific source removal technologies, flushing through upgradient reinjection cannot be targeted as well and may be less effective.

*Cost*

If the partial reinjection is implemented as discussed in either of the two considerations above, the amount of water reinjected and the amount of water discharged to the POTW will depend on the results of model simulations and other analysis. For the purpose of this example, it is assumed that half of the extracted water is reinjected and half is discharged to the POTW. If the extraction rate is 160 gpm, with 80 gpm reinjected, approximately $133,500 per year could be saved due to a reduction in the POTW fee. If a 200 gpm extraction rate is required, with 100 gpm reinjected, approximately $167,000 per year would be saved compared to a baseline of discharging all 200 gpm to the POTW. No fee for POTW system upgrades would be required.

**Consideration A -** For reinjection to the on-site infiltration gallery, approximately $10,000 in capital costs would be required for piping modifications, regardless of the flow rate. An additional $50,000 in capital costs would be required for an extraction rate of 200 gpm for treatment system upgrades. Maintenance of the gallery would insignificantly affect annual costs.

**Consideration B -** If treated water is discharged up gradient of the BOC Gases plume, reinjection wells would likely used. Capital costs for implementing this option would likely depend on the BOC Gases facility operations but would probably be on the order of $200,000. Annual maintenance costs may be as high as $50,000 per year.

***Option 3: Locate Acceptable Discharge Point to Surface Water or Utilize Treated Water for BOC Gases Facility Operations***

Effectiveness

If the hydrogeological analysis suggests that reinjection of treated water compromises effectiveness despite various extraction scenarios, other discharge options could also be considered. The two options in this category that were discussed during the RSE site visit included discharging treated water to surface water (or a storm sewer that discharges to surface water) or using the treated water for the cooling system at the BOC Gases facility. Because most storm sewers in Clark County discharge to ground water rather than surface water and because most surface water bodies are over 2 miles from the site, an acceptable discharge point may not be available. No suitable discharge points were identified during the RSE visit; however, a more thorough investigation by the site team may yield possibilities. Any potential discharge points beyond 2 miles from the site will likely be impracticable due to cost. Using the treated water for the cooling system would result in vaporization of that water and further discharge would not be required. The viability of this option depends on the design specifications of the BOC Gases facility and other factors that do not fall within the scope of an RSE to investigate. The RSE team encourages the site team to further investigate both of these options as well as any others the site team discovers.

Cost

For discharge to surface water, costs would depend on the distance between the treatment system and the discharge point. If the distance is less than 2 miles, a capital investment of up to $1 million might be required for piping water to that discharge point. Minimal costs would be incurred for maintaining the discharge line, and no annual fees should be charged to the site. A NPDES permit and associated monitoring reports would likely be required, but costs for these items would likely be similar to the current reporting requirements for the POTW. A suitable discharge point would allow for the optimal flow rate determined by the hydrogeological analysis. Annual costs savings would depend on the flow rate. If the flow rate remains at 160 gpm, the cost savings is approximately $267,000 per year. For a 200 gpm system, the annual cost savings would be approximately $335,000 per year compared to a baseline of discharging 200 gpm to the POTW. The capital and annual costs for using the treated water for the cooling system are not quantified because a review of the BOC Gases manufacturing facility is beyond the scope of an RSE.

***Option 4: Complete reinjection to the Upper Troutdale Aquifer***

Effectiveness

Reinjecting treated water to the Upper Troutdale aquifer could also be considered, if allowed by the State. This option has the benefit of reinjecting all treated water without spreading the plume and has lower capital costs than discharging treated water to surface water or through reinjection at the toe of the plume. However, this approach may not be consistent with the no-degradation policy of the State's reinjection program. Although the air stripper efficiency could be improved such that TCE effluent concentrations were undetectable, comparable improvements are unlikely for the ion exchange system. Additional evaluation and failsafes due to the nearby potable wells should also be considered when considering the costs.

Costs

Cost reductions associated with eliminating discharge to the POTW would be similar to those provided for Option 3. The costs for implementing the option, however, would be highly dependent on the State's requirements for effluent quality and additional evaluation. Capital costs for constructing the discharge point would be on the order of $200,000 and annual maintenance costs may be as high as $50,000 per year. The additional costs to address the State's requirements have not been estimated.

The costs analyses provided above are summarized in Table 6-1 along with the change in life-cycle costs relative to the baselines for each of the two extraction rates. Calculation of the life-cycle costs assumes a 10-year system duration and a 5% discount rate with no discounting in the first year. A 10-year duration is assumed because it is possible that the pump and treat system as it currently operates, will reach its limit of effectiveness in approximately 10 years. This system could also run longer than this, but for a conservative cost comparison (i.e., ensuring that annual savings catch up to and exceed capital costs) it is more appropriate to use a shorter lifetime. The limit of the system's effectiveness and other items associated with the site's exit strategy are discussed further in Section 6.3 of this report.

**Table 6-1. Cost Analysis Summary for Various Extraction and Discharge Options**

| Option | Discharge Location and Rate | Change in Costs Compared to Baseline | | | Years to Payoff Capital Costs |
|---|---|---|---|---|---|
| | | Capital Costs | Annual Costs | Life-cycle costs* | |
| **Assuming a Total Flow Rate of 160 gpm** | | | | | |
| Baseline | 160gpm to the POTW | - | - | - | - |
| Option 1 | 160gpm at toe of plume | $700,000 | ($217,000) | ($1,060,000) | 4 |
| Option 2 | 80gpm to Alluvial aq./80gpm to POTW<br>• reinjection at on-site infiltration gallery<br>• reinjection up gradient of BOC Gases | <br>$10,000<br>$200,000 | <br>($133,000)<br>($83,000) | <br>($1,069,000)<br>($473,000) | <br>1<br>2 |
| Option 3 | 160gpm to surface water | ~$1,000,000 | ($267,000) | ($1,165,000) | 4 |
| Option 4 | 160gpm to Troutdale aquifer | >$200,000 | (<$217,000) | not quantified | not quantified |
| **Assuming a Total Flow Rate of 200 gpm** | | | | | |
| Baseline | 200gpm to the POTW | - | - | | - |
| Option 1 | 200gpm at toe of plume | $470,000 | ($285,000) | ($1,841,000) | 2 |
| Option 2 | 100gpm to Alluvial aq./100gpm to POTW<br>• reinjection at on-site infiltration gallery<br>• reinjection up gradient of BOC Gases | <br>$10,000<br>$200,000 | <br>($167,000)<br>($117,000) | <br>($1,344,000)<br>($749,000) | <br>1<br>2 |
| Option 3 | 200gpm to surface water | ~$1,000,000 | ($335,000) | ($1,717,000) | 3 |
| Option 4 | 200gpm to Troutdale aquifer | >$200,000 | (<$285,000) | not quantified | not quantified |

* Change in life-cycle cost assumes 10 years of operation with a discount rate of 5% and no discounting in the first year.

Based on the life-cycle costs presented in Table 6-1, it appears that the three options with cost estimates have similar life-cycle costs for the 160 gpm extraction rate. The option with the lowest capital costs, however, is reinjecting part of the flow to the on-site infiltration gallery and discharging the rest to the POTW. It should be noted, however, that cost calculation for this scenario assumes 50% of the flow is reinjected and

50% of the flow is discharged to the POTW. Site modeling might suggest a different distribution of flow to avoid plume spreading and therefore the cost savings may be greater or less than that shown.

For a 200 gpm extraction rate, there is added incentive to decrease discharge to the POTW by either reinjectig more treated water or finding an alternate discharge point. However, these two options also have significantly higher capital costs than splitting the discharge between the on-site infiltration gallery and the POTW. Therefore, reinjecting to the on-site infiltration gallery may be favored. Once again, it should be noted, that the calculations provided assume 50% of the flow would be reinjected and 50% of the flow would be discharged to the POTW. The actual distribution of discharge and the associated costs might be different.

### 6.1.4 OTHER CONSIDERATIONS FOR IMPLEMENTATION

As discussed in Section 6.1.1, reinjection of treated water at this site is not straightforward with respect to the Washington State regulations. The acceptance of reinjection of treated water will likely require that the site team convinces the Underground Injection Control (UIC) program that added protectiveness is achieved by reinjecting all or a portion of the treated ground water. The recommended hydrogeological analysis should demonstrate the most viable option and the degree of protectiveness added. The life-cycle cost reductions associated with these options should also be considered strongly by the State because the State might assume financial responsibility for the site in the future.

## 6.2 MODIFICATIONS INTENDED FOR TECHNICAL IMPROVEMENT

### 6.2.1 ELIMINATE ION EXCHANGE EFFLUENT TANK AND PUMP

The ion exchange effluent tank and pump could be eliminated from the system with no negative impact. The ion exchange effluent piping could be led directly to the air stripper influent tank or possibly directly to the top of the air stripper. This could eliminate the use of a 15 and 5 HP pump that operate part time. The associated cost savings would be approximately $300 per month or $3,600 per year. The modification would also provide more consistent flow to the stripper and would eliminate system balancing issues.

### 6.2.2 IMPROVE ELECTRIC WORK FOR AIR STRIPPER

The electric work associated with the air stripping system should be improved to meet any code requirements and prevent future spills. The sump floats and pump and other components should have galvanized steel conduit, appropriate junction boxes, and disconnects installed properly to avoid trip hazards. The outside pump float should provide a shutoff to prevent additional water from entering the air stripper system if it reaches a high level. The area may require reconfiguration to prevent rain water from causing alarm conditions. The costs associated with these modifications are expected to be under $5,000.

## 6.3 CONSIDERATIONS RELATED TO SITE CLOSE-OUT

### 6.3.1 LIMITATIONS OF PASSIVE TECHNOLOGIES

During the RSE visit, the use of passive technologies, such as permeable reactive barrier walls, were discussed. The RSE team feels that such technologies do not adequately address mass removal in the Alluvial aquifer. Mass removal for the purposes of aquifer restoration may take a number of years, but mass removal in the Alluvial aquifer is also pertinent to mitigate the amount of contamination that migrates through the aquitard to the Upper Troutdale aquifer. The strong downward gradient at the site dictates that ground water (and contaminants) will continue to infiltrate into the Upper Troutdale aquifer despite active pumping. Therefore, the only practicable way to reduce the impact to the Upper Troutdale aquifer is to remove contaminant mass in the Alluvial aquifer. Whereas a permeable reactive barrier will offer horizontal containment of the Alluvial aquifer plume, it will not reduce the impact to the Upper Troutdale. The current pump and system provides both benefits to an extent, and a modified pump and treat system (increased extraction and reinjection of treated water) would provide additional benefit at a reduction in life-cycle costs. Also, if the passive barrier wall is placed mid-plume, as presented during the RSE visit, containment at the toe of the plume may not be addressed.

Use of a permeable reactive barrier in conjunction with a pump and treat system would not be cost effective because capital costs associated with the permeable reactive barrier would be incurred in addition to the costs of operating the pump and treat system.

### 6.3.2 DEVELOP AND EXIT STRATEGY

Figures 1-1 and 1-2 illustrate substantial reduction in the magnitudes of the chromium and TCE plumes between October 1995 and 2001. Additional mass removal will occur and the concentrations will decrease further. However, at some point, mass removal rates will decline, influent concentrations will plateau, and progress toward restoration will slow. However, it is unknown when, in what pattern, and at what contaminant concentrations this will occur. The RSE team believes that the site team should prepare for this to occur within the next 10 years.

The site team should consider various scenarios of what may occur in the subsurface as the system continues to operate. Based on these scenarios, various options should be considered to determine a protective and cost-effective approach. To help determine appropriate approaches and at what point to implement them, the site team should develop a number of metrics to measure the performance of the remedy. The well-calibrated flow and transport models may help the site team determine likely scenarios and set reasonable metrics. An abbreviated example of a potential scenario and various questions to be answered by the exit strategy are presented below.

***Example of a Potential Scenario:***

It is 2007 and the chromium and TCE concentrations downgradient of extraction wells MW-21D and MW-22D have fallen below cleanup levels for the first time in a single sampling event, with the exception of elevated chromium levels in MW-26D and MW-49. Chromium and TCE mass removal from the entire extraction system is approximately 0.6 and 0.15 pounds per day, respectively. Additional TCE mass removal is occurring from source removal activities on the BOC Gases property. The highest chromium and TCE concentrations within the plume are located beneath the Boomsnub property and are approximately 700 ppb and 450 ppb, respectively.

- Can another technology or remedial approach address the small area of elevated chromium levels immediately surrounding the Woodaege well? For example, the site team mentioned the use of iron-based nanoscale particles.

- What are the costs of implementing each of those technologies and how do those costs compare to continuing to extract from ground water recovery wells in that area?

- How will the site team evaluate when it is appropriate to shutdown any or all of the extraction wells downgradient of MW-21D and MW-22D?

- If extraction wells are shutdown and rebound occurs, at what point will extraction wells be turned back on? Is monitored natural attenuation appropriate for the areas where rebound has occurred? What precedents for monitored natural attenuation of chromium have been set in the Region, in the State, and in Clark County?

- If extraction wells are shutdown, will the additional extraction capacity be reallocated to up gradient wells near hot spot areas or will the extraction rate be reduced to decrease the costs for discharge of treated water? What factors will influence this decision? Speeding site close-out? Reducing the potential for mass to migrate into the Upper Troutdale? Reducing costs?

- If extraction wells are shutdown, do additional monitoring points need to be installed to more adequately evaluate capture provided by the remaining extraction system?

- As the plume shrinks further, are the other, more aggressive technologies that can be used to address the smaller plume and remaining hot spots?

- Must the pump and treat operate until cleanup levels are reached throughout the plume or is there some point at which the remedy can be switched to monitored natural attenuation and still be protective. What analyses are required? What precedents for monitored natural attenuation of chromium and TCE have been set in the Region, in the State, and in Clark County?

These are only some of the questions that the site team should have answered before this scenario or other similar scenarios actually occur. By having these questions answered, it forces the site team to highlight various decision points where the remedy can be optimized. It is beyond the scope of the RSE to conduct the evaluations that provide such answers. Simulations with the calibrated flow and transport models may help evaluate the likelihood of such a scenario, the protectiveness of switching to monitored natural attenuation at a given point, the cost-effectiveness of reallocating flow or increasing the pumping rate, other relevant aspects. Development of such an exit strategy with the use of the ground water flow and contaminant transport models should cost approximately $50,000.

# 7.0 SUMMARY

In general, the RSE team found a well-operated pump and treat system with a Remedial Project Manager that based site decisions on effective management and analysis of data, operation costs, and interactions between the various parties associated with the site (EPA, the State of Washington, and the remaining responsible party). Decreasing chromium and TCE concentrations in site monitoring wells suggest that the pump and treat system is having a positive impact on reducing the maximum concentrations measured when system operation began.

The observations and recommendations mentioned are not intended to imply a deficiency in the work of either the designers or operators but are offered as constructive suggestions in the best interest of the EPA and the public. These recommendations have the obvious benefit of the operational data unavailable to the original designers.

The RSE team has two primary recommendations. The first one consists of the following items:

- conduct a hydrogeological analysis based on historical and current data
- update the site ground water flow and contaminant transport models
- use those models to evaluate management options (considering both system effectiveness and cost) for ground water extraction, treatment, and subsequent discharge of treated water
- consider various alternatives for the discharge of treated ground water including reinjection, which may both enhance effectiveness and reduce costs

The second recommendation is to develop an exit strategy using the updated site ground water flow and contaminant transport models to assist in the necessary evaluations. A potential scenario to be included in an exit strategy and a number of questions that should be answered in the exit strategy are provided.

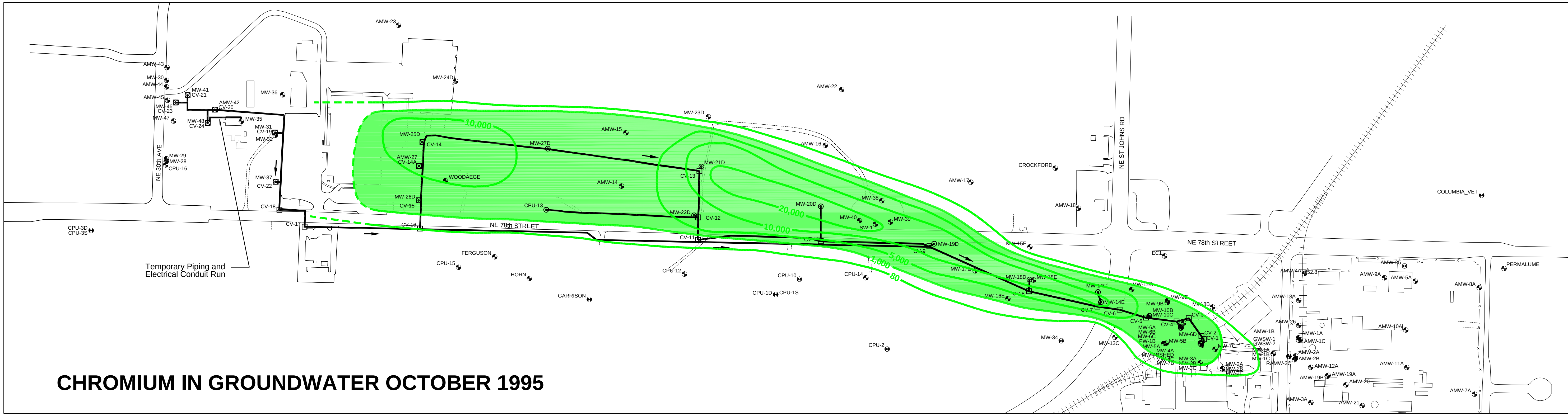
Table 7-1 summarizes the costs and cost savings associated with each recommendation in Section 6. Both capital and annual costs are presented. The expected change in life-cycle costs over a 10-year period is also provided for each recommendation both with discounting (i.e., net present value) and without it.

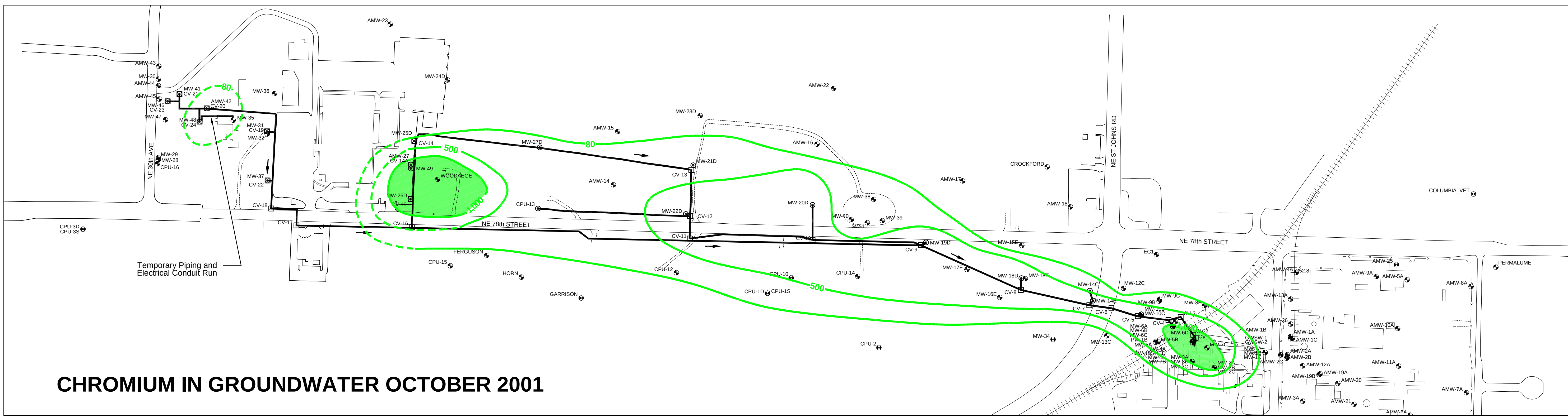
**Table 7-1. Cost Summary Table**

| Recommendation | Reason | Additional Capital Costs ($) | Estimated Change in Annual Costs ($/yr) | Estimated Change In Lifecycle Costs ($) * | Estimated Change In Lifecycle Costs ($) ** |
|---|---|---|---|---|---|
| 6.1.1 Conduct a hydrogeological analysis | Effectiveness | $100,000 | $5,000 | $120,000 | $110,540 |
| 6.1.2 Evaluate potential management options for extraction and discharge | Effectiveness and Cost reduction | $30,000 | $0 | $20,000 | $20,000 |
| 6.1.3 Considerations for potential extraction and discharge options (160 gpm***) | Effectiveness and Cost reduction | | | | |
| • option 1: Reinjection at the toe of the plume | | $700,000 | ($217,000) | ($1,470,000) | ($1,060,900) |
| • option 2: Partial reinjection through existing infiltration galleries | | $10,000 | ($133,000 | ($1,320,000) | ($1,069,000) |
| • option 3: Discharge to surface water | | $1,000,000 | ($267,000) | ($1,670,000) | ($1,165,000) |
| • option 4: Reinject to Troutdale aquifer | | >$200,000 | (<$217,000) | not quantified | not quantified |
| • other options | | not quantified | not quantified | not quantified | not quantified |
| 6.1.4 Consider other discharge options | Effectiveness and Cost reduction | not quantified | not quantified | not quantified | not quantified |
| 6.2.1 Eliminate Ion Exchange Effluent Tank and Pump | Technical improvement | $2,000 | ($3,600) | ($34,000) | ($27,200) |
| 6.2.2 Improve Electric Work for Air Stripper | Technical improvement | $5,000 | $0 | $5,000 | $5,000 |
| 6.3.1 Limitations of passive technologies | Site close-out | N/A | N/A | N/A | N/A |
| 6.3.2 Develop an exit strategy | Site close-out | $50,000 | $0 | $50,000 | $50,000 |

Costs in parentheses imply cost reductions.
* assumes 10 years of operation with a discount rate of 0% (i.e., no discounting)
** assumes 10 years of operation with a discount rate of 5% and no discounting in the first year
*** costs provided are for the current extraction rate of 160 gpm. Table 6-1 within the report also contains similar cost summaries for an extraction rate of 200 gpm.

**FIGURES**




## LEGEND

- Groundwater Extraction Pipeline 1990-1998
- Alluvial Monitoring and Domestic Wells
- CPU-3S Troutdale Monitoring and Domestic Wells
- Containment Vaults
- Extraction Wells
- Chromium Concentration Contour

Shaded Area Represents > 1,000 ug/L

0 100 200 400
SCALE IN FEET

## Concentration Contours For Chromium in Groundwater October 1995, 2001

EPA REGION 10

Boomsnub/Airco Superfund Site
Hazel Dell, WA

Source: ICF KAISER

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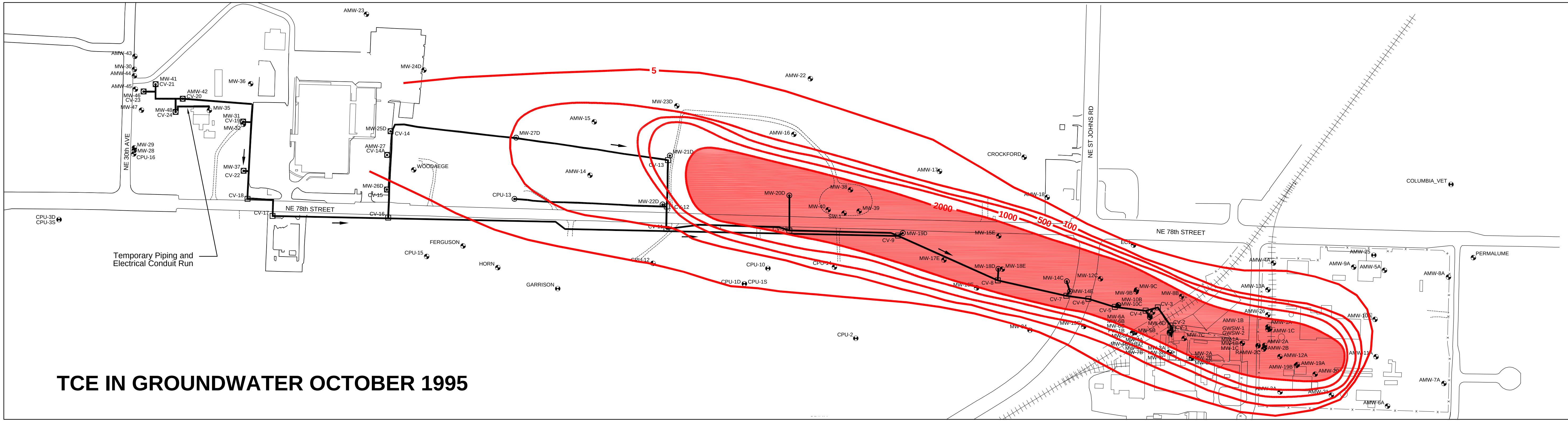


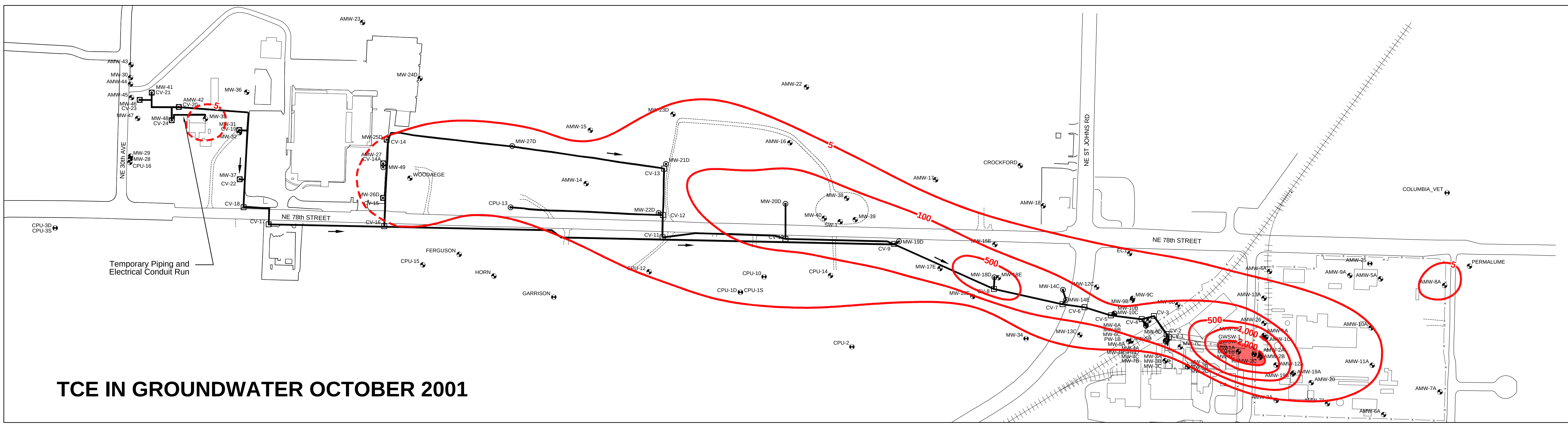


## LEGEND

Groundwater Extraction Pipeline 1990-1998

Alluvial Monitoring and Domestic Wells

Troutdale Monitoring and Domestic Wells

Containment Vaults

Extraction Wells

TCE Concentration Contour

Shaded Area Represents > 2,000 ug/L

N

0 100 200 400
SCALE IN FEET

**Concentration Contours For TCE in Groundwater October 1995, 2001**

EPA
REGION 10

Boomsnub/Airco Superfund Site
Hazel Dell, WA

Source: ICF KAISER

FILENAME: T:\RAC\Boomsnub\Sub-Tasks\SPECIAL REQUEST\Misc\TCE 95-01 FIG 4B.dwg
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