REMEDIATION SYSTEM EVALUATION

BOG CREEK FARM SUPERFUND SITE
HOWELL TOWNSHIP, MONMOUTH COUNTY, NEW JERSEY

Report of the Remediation System Evaluation,
Site Visit Conducted at the Bog Creek Farm Superfund Site
April 16-17, 2002

US Army
Corps of Engineers

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Remediation System Evaluation
Bog Creek Farm Superfund Site
Howell Township, Monmouth County, New Jersey

NOTICE

Work described herein was performed by GeoTrans, Inc. (GeoTrans) and the United States Army Corps of Engineers (USACE) for the U.S. Environmental Protection Agency (U.S. EPA). Work conducted by GeoTrans, including preparation of this report, was performed under Dynamac Contract No. 68-C-99-256, Subcontract No. 91517. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

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 Bog Creek Farm Superfund Site. The site documents were reviewed and the site visit was conducted in April 2002. This report therefore describes the status of the site as of April 2002. Modifications or adjustments to operation at the site have likely occurred since that date.

The Bog Creek Farm Superfund site is located in Howell Township, Monmouth County, New Jersey on County Road 547. The site is bordered by two residences to the west, the north branch of Squankum Brook to the north, and open fields to the south and east. The site soil and ground water has volatile organic compound (VOC) contamination reportedly resulting from dumping of chemical wastes associated with the former property owner's paint manufacturing operation. Contaminated soils and sediments were excavated and incinerated onsite in accordance with the 1985 Record of Decision (ROD). As part of this action, contaminated water from the former pond and former bog (see Figure 1-1) were collected and treated in an aqueous waste treatment system. Based on a second ROD issued in 1989, a slurry wall and a pump and treat system were installed to address the remaining ground water contamination. The pump and treat system, which incorporated components of the former aqueous waste treatment system from the previous action, began full operation in August 1994.

In general, the RSE team found the system operating within design parameters. The observations and recommendations in this report 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 the operational data unavailable to the original designers.

The RSE team has the following recommendations to enhance the effectiveness of the remedy:

- A two-day GeoProbe investigation should be conducted to greater evaluate the extent of contamination beyond slurry wall. The samples should be analyzed for VOCs. This event, the sampling, and analysis could be performed for approximately $25,000.

- A more comprehensive approach to evaluating capture provided by the extraction system should be developed and implemented by continuing to monitor VOCs in the piezometers between the slurry wall and the brook and installing additional piezometers in the same area to help determine the direction of ground water flow. This recommendation could be implemented for a capital cost of approximately $20,000 and an increase in the annual O&M cost of approximately $2,500 per year.

- Because 1,1 DCE is a breakdown product of 1,1,1 TCA, which is present at the site in concentrations above 1 mg/L, and because it is more toxic that 1,1,1 TCA, analytical results for 1,1 DCE should be reported by the laboratory to the site managers along with the site's contaminants of concern. Because analysis of 1,1 DCE is already done, reporting the results should not increase the annual O&M costs.

These items might require approximately $45,000 in capital costs and an increase of $2,500 per year in annual costs. The costs of these recommendations could be offset by the cost savings from the following recommendations to reduce annual O&M costs:

- The RPM should review the services provided and the costs associated with oversight and should eliminate or significantly reduce the analysis of split samples currently done for quality assurance. Sufficient quality assurance is provided by a historical database of monitoring data. The RSE has not rigorously quantified the savings that can be realized but expects that the costs for oversight and quality assurance combined can be reduced by over $150,000 per year.

- The site managers should consider approaches to reducing operator labor without sacrificing the effectiveness of the remedy. One approach is discussed with potential savings as high as $80,000 per year.

- Modifications to the ground water monitoring program that include discontinuation of the purging of extraction wells prior to sampling and having onsite staff perform the monitoring would likely result in cost savings of approximately $20,000 per year.

In addition to recommendations regarding enhanced protectiveness and reduced costs, the RSE team also provides recommendations pertaining to technical improvement and recommendations pertaining to site closeout and reduction in life-cycle costs. The recommendations pertaining to site closeout and reduction in life-cycle costs include implementing a modified pump and treat system (i.e., both simplified and automated with respect to the current system). Any of the proposed modified pump and treat systems could be installed and operated for a 30-year time period for approximately 50% lower total costs than operating the current system over the same time period. This 50% reduction would translate to a total savings of approximate $5 million to $10 million over the 30-year period, depending on the discount rate used to calculate the net present value. The use of air sparging, in situ chemical oxidation, excavation, and bioremediation for aggressive mass removal are also discussed. The additional capital costs for aggressive mass removal range from under $1 million for air sparging to over $5 million for site-wide excavation.

Table 7-1 summarizes the recommendations pertaining to enhanced protectiveness, reduced costs, and technical improvement. It includes estimated costs and/or savings associated with those recommendations. The potential for life-cycle savings associated with each approach are presented in Table 6-6.

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

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 Bog Creek Farm Superfund Site was cooperatively selected by OERR, EPA Region 2, and the New Jersey Department of Environmental Protection. 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.

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.
Chuck Coyle, Environmental Engineer, USACE HTRW CX

1.3 DOCUMENTS REVIEWED

Author	Date	Title
NUS Corporation	August 1986	Remedial Investigation Volumes 1 and 2 for Bog Creek Farm Site, Howell Township, New Jersey
Ebasco	January 1989	Final Draft Remedial Investigation Report, Bog Creek Farm Site, Howell Township, Monmouth County, New Jersey
Ebasco	April 1989	Final Draft Second Operable Unit Feasibility Study Report, Bog Creek Farm Site, Howell Township, Monmouth County, New Jersey
US EPA	September 30, 1985	Record of Decision (OU1), Bog Creek Farm, Howell Township, New Jersey
US EPA	June 28, 1989	Record of Decision (OU2), Bog Creek Farm, Howell Township, New Jersey
Moretrench Environmental Services, Inc.	December 1991	Bog Creek Farm Site, Operable Unit 2, Design of Groundwater Recovery and Reinjection System
Dow Environmental, Inc.	November 1995	Volume 1, Operable Unit 2, Operations and Maintenance Manual, Aqueous Waste Treatment System, Bog Creek Farm Superfund Site, Howell Township, New Jersey
US EPA	September 1997	Five-Year Review Report, Bog Creek Farm Superfund Site, Howell Township, New Jersey
USACE, Kansas City District	May 2001	Specifications, Bog Creek Farm Superfund Site, Operation and Maintenance, Howell Township, New Jersey
US Filter	August 2001 to September 2001	Analytical Reports, Bog Creek Superfund Site

Author	Date	Title
US Filter	August 2001 to September 2001	Monthly O&M Reports, Bog Creek Superfund Site
Cape Environmental	October 2001 to January 2002	Analytical Reports, Bog Creek Superfund Site
Cape Environmental	October 2001 to January 2002	Monthly O&M Reports, Bog Creek Superfund Site
Lockheed Martin (REACs contractor)	December 21, 2001	Groundwater and soil sampling, Bog Creek Site Work Assignment 0-229– Trip Report

1.4 PERSONS CONTACTED

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

Ed Finnerty, Remedial Project Manager, EPA Region 2
Bob McKnight, Section Chief, EPA Region 2
Jeanette Abels, Project Manager, NJDEP
Tom O'Neill, Bureau of Construction, NJDEP
George Paprocki, Project Engineer, USACE, New York District
Terri Somers, Plant Operator, Cape Environmental
Bill Weseloski, Plant Operator, Cape Environmental

1.5 SITE LOCATION, HISTORY, AND CHARACTERISTICS

1.5.1 LOCATION

The Bog Creek Farm Superfund site is located in Howell Township, Monmouth County, New Jersey on County Road 547. The site is bordered by two residences to the west, the north branch of Squankum Brook to the north, and open fields to the south and east. The site soil and ground water has volatile organic compound (VOC) contamination reportedly resulting from dumping of chemical wastes associated with the former property owner's paint manufacturing operation. Contaminated soils and sediments were excavated and incinerated onsite in accordance with the 1985 Record of Decision (ROD). As part of this action, contaminated water from the former pond and former bog (see Figure 1-1) were collected and treated in an aqueous waste treatment system. Based on a second ROD issued in 1989, a slurry wall and a pump and treat system were installed to address the remaining ground water contamination. The pump and treat system, which incorporated components of the former aqueous waste treatment system from the previous action, began full operation in August 1994.

1.5.2 POTENTIAL SOURCES

Various chemical wastes were reportedly dumped on open areas and in excavated pits onsite in 1973 and 1974. Wastes included lacquer thinners, paint solvents and resins, animal carcasses, and residential debris. Two primary waste sources were identified at the site. The major waste source was a trench located approximately 300 feet south of brook in the center of the site (see Figure 1-1). The trench filled with chemicals and debris was approximately 150 feet long, 40 feet wide, and 10 feet deep. A number drums located approximately 130 feet east of the trench were also found during investigations. This area is referred to as the "former disposal area" on Figure 1-1.

Although excavation and associated treatment of the contaminated soils, the bog, and the pond sediments has occurred, ground water concentrations in excess of 10 mg/L and a sheen evident in select monitoring wells suggests the presence of continuing sources of ground water contamination. These continuing sources may include soil contamination and light non-aqueous phase liquid (LNAPL).

1.5.3 HYDROGEOLOGIC SETTING

The site is underlain by the Kirkwood formation, which is subdivided into the Upper Kirkwood and Lower Kirkwood. Onsite, the Upper Kirkwood varies in thickness from 9.5 feet near the north branch of Squankum Brook to approximately 30 feet near the source areas. The Upper Kirkwood is predominantly sand with a high iron content. Based on four borings conducted during the Remedial Investigation in 1986, the Lower Kirkwood is depicted as having relatively uniform thickness across the site of approximately 30 feet and consists of silty sands, silts, and clays. According to a summary of previous investigations provided in the 1986 Remedial Investigation, the top of the Lower Kirkwood appears to act as a semi-confining layer based upon head differences between wells screened in different subunits.

Depth to water across the site is approximately 6 to 10 feet below ground surface. The 1989 Remedial Investigation shows that ground water in the Upper Kirkwood flows to the north and east with discharge to the north branch of Squankum Brook. Water elevations in this upper aquifer range from approximately 48 feet above mean sea level (AMSL) in the southwest to approximately 45 feet AMSL to the north and 42 feet AMSL to the east. An aquifer test conducted in this upper aquifer at MW-E suggests a hydraulic conductivity of 25 to 30 feet per day with semi-confined conditions resulting from stratification of sediments. Based on water level measurements from three wells in the Lower Kirkwood, the 1986 Remedial Investigation suggests flow in this lower aquifer is to the east with the Manasquan River (over a mile to the northeast) as the likely discharge point. Water elevations from three wells in the Lower Kirkwood, measured during the RI in 1986, ranged from approximately 48 feet AMSL to the west of the site to 44 feet AMSL to the east of the site and suggest an upward gradient based on relative water levels in the overlying Upper Kirkwood. Although water levels are consistently measured in the Upper Kirkwood, water levels in the Lower Kirkwood wells are not sampled on a routine basis; therefore, the variation in this vertical gradient between aquifers cannot be determined.

Underlying the Lower Kirkwood formation is the Manasquan formation which is predominantly clayey silt. Previous investigations have found contamination limited to the Upper Kirkwood, thus the stratigraphy of unconsolidated sediments below the Manasquan formation are not discussed further in this report.

According to the 1986 Remedial Investigation, ground water is the sole source of potable water in the area surrounding the site. Two wells, less than 50 feet in depth, are located on the property near the residences (upgradient from the impacts). Another well of similar depth is located approximately 0.3 miles east of the site. The remaining wells, as summarized in the 1986 Remedial Investigation, are over 350 feet below ground surface and are hydraulically isolated from potential site-related contamination. According to the site managers, these wells have not been impacted by site-related contamination. The wells are likely still in use.

1.5.4 DESCRIPTION OF GROUND WATER PLUME

The ground water plume has historically been considered an approximately semi-circular area, roughly 300 feet in radius, directly south and west of the north branch of Squankum Brook and limited to the Upper Kirkwood aquifer. This area included the former waste trench and waste disposal area (described in Section 1.5.2) and extended to the brook, including the former pond along the northern border of the site and the former bog along the eastern border of the site. Annual data reports show two primary areas of VOC contamination with benzene, toluene, and 1,1,1 trichloroethane (1,1,1 TCA) as the primary contaminants of concern. The two primary areas are down gradient from the former waste trench and the former disposal area (see Figure 1-1). Lower impacts also appear to extend upgradient from these two likely sources on Figure 1-1; however, these apparent upgradient impacts might be due to extrapolation between high concentrations in downgradient monitoring points and low or undetectable concentrations in upgradient monitoring points. According to the preliminary data, however, the impact at PZ-36 was determined directly from monitoring and is not an artifact of extrapolation.

In 2001 and 2002, the plume was further characterized and delineated under a REACs contract through the EPA Emergency Response Team (ERT) out of Edison, New Jersey. This effort was not considered an emergency; rather the ERT was used due to convenience in location and EPA budgeting. Preliminary data from this characterization effort improve delineation of the plume and also show that ground water contamination is found between the slurry wall and the brook in all four locations evaluated.

Ground water monitoring in the Lower Kirkwood has not been conducted as part of site-related activities since the ROD. Site managers have assumed, based on Remedial Investigation data, that an upward gradient exists between the Upper and Lower Kirkwood aquifers and that contamination is confined to the Upper Kirkwood.

2.0 SYSTEM DESCRIPTION

2.1 SYSTEM OVERVIEW

The pump and treat system is comprised of an extraction system (augmented by a slurry wall), treatment plant, and reinjection gallery. The extraction system operates continuously at a capacity of approximately 25 to 30 gpm, and the treatment plant is operated in batch mode at approximately 160 to 168 gpm between 6:30am and 2:30pm on weekdays when the operators are present. The treatment plant is a modification of the plant originally used for water treatment during excavation and treatment of the pond and bog. Discharge to the reinjection gallery results in flushing of water through the site in an effort to enhance cleanup. Between August 2001 and January 2002, influent concentrations for total VOCs were approximately 1.5 mg/L with the maximum of approximately 2.3 mg/L occurring in December 2001. Based on an average flow rate of approximately 30 gpm and an approximate VOC influent concentration of 1.5 mg/L the VOC loading to the plant is approximately

$$\frac{30\text{ gal.}}{\text{min.}} \times \frac{3.785\text{ L}}{\text{gal.}} \times \frac{1.5\text{ mg}}{\text{L}} \times \frac{1440\text{ min.}}{\text{day}} \times \frac{2.2\text{ lbs.}}{1 \times 10^6\text{ mg}} = \frac{0.54\text{ lbs.}}{\text{day}}$$

2.2 EXTRACTION SYSTEM

The extraction system consists of 33 extraction wells aligned along the southern/western bank of the north branch of Squankum Brook in 25 foot intervals. The wells are screened from 15 to 30 feet below ground surface and are attached to a single manifold with a vacuum maintained by a vacuum pump near the plant. Water extracted by the vacuum continuously enters an influent tank 24 hours per day, 7 days per week unless interrupted by alarms or a loss of power. A slurry wall approximately 3 feet thick and 20 feet deep is located between the extraction well network and the brook. The location of the slurry wall is not marked at the site, but the center of the slurry wall is approximately 10 feet downgradient (north or east) from the extraction wells. Accounts of the slurry wall construction vary. Site documents indicate that the wall was constructed to limit the amount of clean water extracted from the brook by the extraction system and was not keyed into any specific unit. In discussions associated with the RSE visit, the site team suggested the wall was keyed into a clay or silt layer (likely the upper portion of the Lower Kirkwood) and provides a barrier to contamination migrating toward the river. If the slurry wall is keyed into a lower conductivity layer, the extraction wells are also predominantly completed into a lower conductivity layer based on the reported screen intervals, which would limit the extraction rate. The screen likely intercepts the lower 5 feet of the Upper Kirkwood aquifer and 10 feet of the silt and clay that comprises the upper portion of the Lower Kirkwood aquifer. Logs from monitoring well installations (MW-10, MW-11, MW-12, MW-13, MW-14, and MW-15) indicate dense or stiff silt layer is present at 10 to 15 feet below ground surface near the brook.

2.3 TREATMENT SYSTEM

Extracted ground water passes through an oil/water separator and a lift tank before it is transported to the equalization tank. The equalization tank stores the extracted water until the operators arrive to batch the water through the treatment system. Water from the influent tank flows through the following components:

- pH adjustment tank where caustic is added
- coagulation and flocculation tank where polymer is added
- clarifier
- sand filter
- pH adjustment where acid is added
- two packed tower air strippers aligned in series
- two granular activated carbon (GAC) units aligned in series
- effluent tank
- reinjection gallery

Vapor phase carbon is used to treat the off gas from the vacuum pump, the head space of the first pH adjustment tank, and the first air stripper. Sludge generated from pH adjustment, flocculation, and coagulation is thickened and dewatered before storage in drums and disposal.

2.4 MONITORING PROGRAM

Ground water monitoring occurs on an annual basis from 9 monitoring wells and 33 extraction wells. In the future, sampling might also occur at new wells and piezometers installed in 2001 and 2002 during the characterization effort. For example, during the 2001 sampling effort, 4 piezometers were sampled. The decision to continue sampling from recently installed wells/piezometers has not yet been made.

For all sampled monitoring wells, low-flow sampling is conducted with a bladder pump. Because bladder pumps cannot fit into the extraction wells, low flow sampling from the extraction wells is conducted with peristaltic pumps. Although use of a peristaltic pump for collecting a VOC sample is inconsistent with the NJDEP Field Sampling and Procedures Manual (May 1992, page 177) the sampling is compliant to the extent possible. Samples are analyzed in an independent offsite laboratory for VOCs. Ferrous iron, alkalinity, dissolved oxygen, pH, temperature, and turbidity are also measured. For quality assurance, split samples are also sent to the USACE New England District for VOC analysis and data validation.

Depths to ground water from 9 monitoring wells are measured on a monthly basis but are not converted to measurements of ground water elevation. The depths to ground water measured during the annual sampling event, however, are converted to ground water elevations, which are used to generate a potentiometric surface map.

Process monitoring is conducted monthly as described in the table on the following page.

Sample Location	**VOCs**	**SVOCs**	**Metals**	**General Chemistry**
Plant influent	X	X	X	X
Sand filter effluent		X	X	X
Stripper #1 influent	X			
Stripper #2 influent	X			
Stripper #2 effluent	X			
GAC #1 effluent		X		
GAC #2 effluent		X		
Final effluent		X	X	X

Notes:

- X denotes that the sample is analyzed for that constituent.
- A blank denotes that a sample is not analyzed for the corresponding constituent.
- General chemistry includes
  - pH
  - biochemical oxygen demand (BOD)
  - total recoverable hydrocarbons
  - total organic carbon (TOC)

3.0 SYSTEM OBJECTIVES, PERFORMANCE AND CLOSURE CRITERIA

3.1 CURRENT SYSTEM OBJECTIVES AND CLOSURE CRITERIA

The 1989 ROD groups the soil and the ground water in the shallow aquifer as a single operable unit, and states that soil and ground water contamination do not pose a health threat to the public because of the absence of wells or structures with basements within the impacted areas. Although wells do exist on the property, they are upgradient of the site impacts. Therefore, the ROD objectives primarily address the risks associated with contaminated ground water discharge to the north branch of Squankum Brook rather than the use of ground water for human consumption. The cleanup standards for the aquifer and the discharge standards for the treatment plant are based on a New Jersey Pollution Discharge Elimination System (NJPDES) permit and not the more stringent maximum contaminant levels (MCLs). The cleanup/discharge standards, as summarized in the ROD and the O&M manual, are presented in the following table.

Constituent/Parameter	Cleanup/Discharge Goal (average)	Cleanup/Discharge Goal (maximum)
Total organic carbon (TOC)		50 mg/L
Biochemical oxygen demand (BOD) - 5 day		15 mg/L
Petroleum hydrocarbons	10 mg/L	15 mg/L
pH	6 - 9	6 - 9
Copper, total		8 ug/L
Lead, total		56 ug/L
Zinc, total		52 ug/L
Benzene		5 ug/L
Toluene	28 ug/L	74 ug/L
1,1,1-Trichloroethane (TCA)	22 ug/L	59 ug/L
trans 1,2-Dichloroethylene (trans 1,2-DCE)	26 ug/L	66 ug/L
Phenol	19 ug/L	47 ug/L
2,4-Dimethylphenol	19 ug/L	47 ug/L
Acute toxicity (LC50)		NMAT*

* No measurable acute toxicity (NMAT) - less than 10% mortality in all concentrations including 100% effluent.

A total of 9 permanent monitoring wells and 33 extraction wells exist at the site, but the ROD does not clearly state the point of compliance locations for these concentrations.

3.2 TREATMENT PLANT OPERATION GOALS

The discharge limits for the treated water are equivalent to the cleanup goals summarized in the Table in Section 3.1. In addition, the treatment plant also has air emission limitations that are summarized in the following table, which is taken from the O&M manual.

Air Pollutant	**AWTS Air Emission Limits (lbs/hr)**						
	MES-3	**TK-1**	**TK-15**	**TK-4**	**V-12**	**V-6**	**V-4**
Total volatile organic substances (TVOS)	0.001	0.06	0.005	0.01	0.005	0.10	0.07
Benzene	-	-	-	0.002	-	0.04	0.011
Chloroform	-	-	-	0.0001	-	0.0026	0.012
Tetrachloroethene	-	-	-	0.0001	-	0.001	0.001
Trichloroethene	-	-	-	0.0003	-	-	0.003
1,2-Dicholorethane	-	-	-	0.0001	-	0.001	0.025
1,1,1-Trichloroethane	-	-	-	-	-	0.005	-

Notes:

Continuous emissions to be monitored at MES-3, TK-4, and V-6.

- TK-1 Flow equalization tank
- TK-4 pH reaction tank
- V-12 Lamella clarifier
- V-6 Primary air stripper
- V-4 Secondary air stripper
- TK-15 Lift Station
- MES-3 Vacuum extraction system

4.0 FINDINGS AND OBSERVATIONS FROM THE RSE SITE VISIT

4.1 FINDINGS

In general, the RSE team found the system operating within design parameters. The observations and recommendations 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 the operational data unavailable to the original designers.

4.2 SUBSURFACE PERFORMANCE AND RESPONSE

4.2.1 WATER LEVELS

The depth to water is measured from nine monitoring wells on a monthly basis by the USACE New York District as part of their site oversight. These data are sent to the USACE Kansas City District for conversion to ground water elevations. The data are recorded and compiled each month into two spreadsheets: one spreadsheet that reports the depth to water and the ground water elevation for each monitoring well and another spreadsheet that reports the depth to water and the change in depth from the previous month. However, these data and the technical evaluations of the data are not reported in any of the site documents reviewed by the RSE team. In general, ground water is approximately 6 to 10 feet below ground surface at the site.

Ground water elevations from one of the monthly events are used to generate potentiometric surfaces for the Upper Kirkwood that are presented in the annual data reports. The potentiometric surfaces for both August 2000 and December 2001 confirm that ground water flows to the north or northeast toward the brook.

4.2.2 CAPTURE ZONES

The capture zone at the site has not been analyzed; rather, it is assumed by the site managers that the slurry wall and extraction network provide capture. Sampling from the December 2001 GeoProbe event indicates benzene impacts beyond the slurry wall and extraction network at all four locations evaluated. The highest benzene concentration in the four locations was 540 ug/L at PZ-3. The site mangers assume that these impacts were present before the installation of these remedy components, and they plan to continue monitor concentrations in the piezometers beyond the slurry wall. An increasing trend in concentration will indicate a lack of capture and decreasing concentrations will indicate sufficient capture.

4.2.3 CONTAMINANT LEVELS

VOC analyses of ground water samples collected during December 2001 show 1,1,1 TCA concentrations as high as 1,429 ppb, benzene concentrations as high as 3,287 ppb, and toluene concentrations as high as 28,412 ppb. Although *cis* 1,2-DCE is not a specific contaminant of concern denoted in the ROD concentrations were detected as high as 5,395 ppb in EW-9. Contrastingly, the concentrations for trans

1,2 DCE, which is a contaminant of concern denoted in the ROD, are undetectable. The highest concentrations for all constituents exist along the extraction network on the upgradient side. For benzene and toluene, these concentrations indicate an increase (by approximately a factor of 2) from the results of the August 2000 monitoring event.

Further exploratory sampling conducted through the REACs contractor in December 2001 and Spring 2002 yielded further delineation of the benzene and toluene impacts. The December 2001 event consisted of GeoProbe sampling of ground water with temporary wells. The results show areas of benzene concentrations exceeding 10,000 ppb and toluene concentrations of up to 100,000 ppb further upgradient (more than 50 feet) of the extraction network. These elevated concentrations mark a significant departure from the understanding of ground water impacts throughout the site because previous sampling was limited to monitoring wells that had comparatively low impacts. Moreover, all four piezometers located downgradient of the extraction network and slurry wall reveal impacts of benzene. At PZ-3, these impacts exceed 500 ppb.

The Spring 2002 event involved installing 33 new piezometers throughout the site, sampling them, and analyzing the samples. Preliminary data for benzene analyses, dated May 2002, were provided to the RSE team for review. These results confirm the December 2001 results but also indicate an area of 7,800 ppb of benzene on the upgradient border of the former waste trench and an area of 13,000 ppb of benzene side gradient to the former disposal area on the eastern portion of the site. Site managers report that continued monitoring from these 33 piezometers is not planned as it will increase O&M costs and result in more compliance points.

The site managers have reported a sheen on the ground water surface in monitoring well MW-A. This sheen is evidence of a continuing source of ground water contamination.

4.3 COMPONENT PERFORMANCE

4.3.1 SLURRY WALL, EXTRACTION WELLS, AND VACUUM PUMP

A slurry wall and extraction network consisting of 33 wells are in place along the northern and northeastern border of the site to prevent discharge of impacted ground water to the brook. The slurry wall is three feet wide and approximately 20 feet deep. The design document (Moretrench 1991) for the ground water recovery and reinjection system specifies that the slurry wall would be keyed at least two feet into the Lower Kirkwood aquifer. During the site visit, the site managers confirmed that these specifications were met during implementation. Given that the upper portion of the Lower Kirkwood is of relatively lower permeability material, it serves as confining or semi-confining layer.

The 33 extraction wells were completed at 25-foot intervals along the slurry wall, with the wells 10 feet upgradient of the slurry wall midpoint. The wells are stainless steel and 2 inches in diameter with 15-foot screened intervals to a total depth of 30 feet. Therefore, the wells screen both the Upper Kirkwood aquifer and the upper portion of Lower Kirkwood aquifer. These wells are connected by a common 4-inch diameter reinforced fiberglass header pipe. Water is extracted continuously from the wells by inducing a vacuum with vacuum pump located in a pump house next to the treatment plant. Water is extracted from each well through a drop tube that extends to the bottom of the well. The wells can be tuned individually to ensure the water level does not drop below the drop tube, which would allow air to be extracted and would reduce the vacuum in the extraction system. Shutting down individual wells or series of wells does not increase the flow from other wells as the maximum vacuum is already induced.

No current means is in place to measure the extraction rate or performance of individual wells. Biofouling is an issue with the extraction wells and is addressed during the annual sampling events.

Extracted water enters a sump can where a vacuum is induced by a 10-horsepower vacuum pump. A submersible pump transfers the water from the sump can to an oil/water separator. The vacuum pump is replaced on a yearly basis for a cost of approximately $3,000 per replacement. Replacement of the cooling water filter is required on a weekly basis. Overheating is the most common problem, but this has been mitigated by installation of a vacuum relief valve. Vapor from the vacuum pump is treated with vapor phase carbon before emission to the atmosphere.

4.3.2 OIL/WATER SEPARATOR, LIFT TANK, AND EQUALIZATION TANK

Water from the extraction system passes through an oil/water separator to a lift tank, which uses a 1.5 horsepower submersible pump to transfer the water to the equalization tank. No measurable oil has been recovered from the oil/water separator to date. The lift tank is present because the head from the extraction system is insufficient to overcome the elevation change to the equalization tank. The equalization tank is open to the atmosphere, has a 78,000 gallon capacity, and serves as a storage tank until the operators arrive onsite to batch water through the treatment plant. The tank capacity is generally sufficient for 2 days of extraction at a constant rate of 25 gpm when treatment is not occurring. The operators are present Monday through Friday from 6:30am to 2:30pm and batch water through the treatment system at approximately 160 gallons per minute. On weekends, the capacity of the tanks is reached by Sunday afternoon, and the extraction system automatically shuts down until Monday morning when batch processes begin. The equalization tank has overflowed three times since operation began in 1996. The overflow was contained in the secondary containment dike. A redundant level switch was added to prevent further overflows.

4.3.3 METALS REMOVAL SYSTEM

Water is batched from the influent tank to the pH adjustment tank where a 50% sodium hydroxide solution is added by a metering pump to increase the pH to approximately 9.2. Mixing is provided by aeration, which also oxidizes the iron present in the extracted ground water. The offgas from the tank is treated by vapor phase carbon before discharge to the atmosphere.

Water flows by gravity from the pH adjustment tank to the rapid-mix tank where cationic polymer (Zetalyte 300C) is added as a coagulant and mixed with a high-speed propeller. Process water than proceeds to the flocculation tank where anionic polymer is added (Zetalyte 1A) and mixed at slow speed.

An inclined plate separator clarifies the water from the flocculation tank by allowing the suspended solids to settle. Approximately 1 drum of dewatered sludge is collected from the bottom of the clarifier and filter pressed each month. At 25% solids and a specific gravity of 2.65, this equates to approximately 300 pounds per month of dry solids. Drums are stored onsite and are disposed in bulk as non-hazardous waste at GROWS Landfill in Pennsylvania.

The clarifier is a limiting component of the treatment system in terms of flow capacity. At rates higher than 170 gpm, overflow would likely occur.

4.3.4 SAND FILTER

A continuously backwashing sand filter removes additional suspended solids. A sufficient driving force is provided to the sand filter by the water elevation (head) in the clarifier. Once every two months the operators acid wash the sand filter to avoid fouling. In August 2001, the sand was replaced for the first time since operation (approximately 8 years). The sand filter has a maximum capacity of 220 gpm. Although no minimum capacity is stated in the O&M manual, the operators state that the filter must have sufficient flow (over 100 gpm) to operate effectively. Air flow (for the continuous backwashing) is set between 100 and 150 cubic feet per hour.

4.3.5 PH READJUSTMENT

The process water pH can be readjusted by adding acid in the stripper feed tank. Readjustment of the pH is typically not required because air stripping brings the pH back within the discharge criteria of 6 to 9.

4.3.6 AIR STRIPPERS

Two packed tower air strippers are aligned in series, each with a 7.5 horsepower influent pump. The first air stripper is 5 feet in diameter, 36 feet high, and contains 28 feet of 2-inch Jaeger Tripack packing. An air flow rate of 950 cubic feet per minute is provided by a 2 horsepower blower. The air stripper protudes through the top of the treatment building and the exposure of the fiberglass shell to sunlight makes it susceptible to algae fouling during the summer. The second stripper is 4 feet in diameter, 28 feet high, and contains 20 feet of 3.5-inch Jaeger Tripack packing. Emissions from the first tower are transported by a 2.5 horsepower blower to two vapor phase carbon units aligned in a parallel before discharging to the atmosphere. A pre-heater warms the air prior to the carbon vessels to reduce the relative humidity and increase the efficiency of the carbon. Emissions from the second tower are discharged directly to the atmosphere. Scaling is rinsed out once a month from the bottom of the strippers, and both strippers are washed with sodium hypochlorite every two months. The packing was inspected in 1996 and was found to be in good condition. It has not been checked since. Based on the January 2002 process monitoring, the first air stripper is approximately 90% efficient and the second one is approximately 75% efficient.

4.3.7 LIQUID PHASE UNITS CARBON

A 7.5 horsepower pump transfers the water from the air strippers through two liquid phase carbon units. These units each contain 15,000 pounds of carbon and are aligned in series. The carbon in the lead vessel is changed every 6 months on a schedule that was based on pressure drop performance. The GAC units are backwashed daily though the operators say sufficient head is not available for proper backwashing.

4.3.8 EFFLUENT HOLDING TANKS AND REINJECTION SYSTEM

Cumulatively, the two effluent tanks hold a total of 78,000 gallons. A 1.5 horsepower pump reinjects water from the storage tanks to the Upper Kirkwood aquifer through two 400-foot long reinjection trenches located upgradient of the extraction system. The trenches contain 4-inch PVC slotted pipe laid about 4 feet below ground surface in washed gravel with a geotextile on top of the gravel to prevent fouling. Ponding at the eastern edges of the trenches was observed during the RSE visit.

4.3.9 CONTINUOUS EMISSIONS MONITOR

A continuous emissions monitor samples air from the emissions points where vapor phase carbon is in place to meet the air discharge standards (the vacuum pump, rapid-mix tank, and the first air stripper). The monitor was out of service between September 2001 and January 2002. Based on the amount of contaminants removed from the ground water, the discharge standards would be met without treatment with the vapor phase carbon. The following table summarizes the air discharge criteria for this air stripper as well as the chemical loading (as determined by the January 2002 monitoring results) based on complete removal of VOCs present in the treatment plant influent.

Constituent	Air Discharge Criteria for the First Air Stripper, V-6 (lbs/hr)	January 2002 Influent (ug/L)	Actual Discharge (lbs/hr)**
Total volatile organic substances	0.10	1441	0.022
Benzene	0.04	80	0.0012
Chloroform	0.0026	ND	0
Tetrachloroethene	0.001	ND	0
Trichloroethene	-	ND	0
1,2-Dicholorethane	0.001	ND	0
1,1,1-Trichloroethane	0.005	20	0.0003

* These reported values are from the sample labeled "influent". The values from the "influent duplicate" are not used. The results from influent and the duplicate are statistically equivalent.

**These values (*y* lbs/hour) are calculated from the following equation, where *x* ug/L is obtained from the concentration reported in column 3.

$$\frac{x\text{ ug}}{\text{L}} \times \frac{30\text{ gal.}}{\text{min.}} \times \frac{3.785\text{ L}}{\text{gal.}} \times \frac{60\text{ min.}}{\text{hour}} \times \frac{2.2\text{ lbs.}}{1\times 10^{9}\text{ ug}} = \frac{y\text{ lbs.}}{\text{hour}}$$

4.4 COMPONENTS OR PROCESSES THAT ACCOUNT FOR MAJORITY OF MONTHLY COSTS

Since 1996, the site has had approximately $1 million of funding authorized for site activities per year. Less than that amount has been spent each year. Thus, USACE, which oversees site activities, has held the remaining funding for site contingencies. That contingency funding is currently being used to operate the plant. From 1997 through 2000, the contract for O&M (which includes O&M labor, chemicals, materials, disposal, utilities, and corrective maintenance) ranged from approximately $220,000 to approximately $470,000. However, the estimated costs for similar items under the current contract are approximately $584,000 (the costs below excluding contract and technical oversight as well as environmental sampling). The costs under the current contract are provided because they are more indicative of future costs without system optimization. The following estimates are based on the bid schedule provided by USACE during the RSE site visit.

Item Description	Amount Estimated
Contract oversight (USACE field and central office and quality assurance)	$220,000
Technical assistance/oversight (USACE)	$125,000
O&M labor, office support, phones, reporting, etc.	$376,600*
Environmental sampling	$25,900
Chemicals and materials	$45,000**
Sludge removal and disposal	$1,500
Utilities	$80,000
Corrective maintenance	$80,000
Total	**$953,400**

* Estimate based on 10,500,000 gallons treated and the rate of $35.87 provided on the bid schedule. This volume treated is consistent with the extraction rate and system uptime discussed during the RSE site visit.

** Estimate based on bid schedule with the exception of the cost for liquid phase carbon. This estimate assumes 2 vessel replacements per year, which is consistent with discussions during the RSE site visit.

4.4.1 UTILITIES

Electricity is the only energy used at the site. Electricity bills range from approximately $3,000 during the summer months to $7,000 or $10,000 in the winter months. The seasonal variation is primarily due to the use of electric heat during the winter months. The room with the caustic requires heating in excess of 60E F to prevent the caustic from gelling. On average, electricity for site operations costs approximately $75,000 per year. More than this amount is estimated in the bid schedule.

4.4.2 NON-UTILITY CONSUMABLES AND DISPOSAL COST

Consumables include carbon for vapor and liquid treatment, polymer for coagulation and flocculation, caustic for pH adjustment, and acid for acid washing the sand filter and air stripper. The estimated unit cost for the replacement of liquid phase carbon is $0.73 per pound. For changeouts in two vessels per year (at 15,000 pounds each) the total estimated cost per year for liquid phase carbon is $21,900. The bid schedule estimates for vapor phase carbon and caustic are the other major cost items in this category, and the estimated costs per year are approximately $13,300 and $5,400, respectively.

4.4.3 LABOR

Labor for plant operations consists of two operators, each at 40 hours per week. These two operators are supported by a part time project manager, other office support, and a monthly health and safety inspection by a certified industrial hygienist. Monthly O&M reports are generated to summarize plant operations. The total cost for these items is based on the volume treated. A rate of $35.87 per 1,000 gallons applies to the first 10,500,000 gallons treated. A rate of $11.78 per 1,000 gallons applies to the next 3,000,000 gallons treated. The extraction rate and plant up time suggest that approximately 10,500,000 gallons will be treated during the current contract.

Additional labor is also required for contract administration and technical oversight as well as the quality assurance provided by USACE. The summary costs provided in Section 4.4 represent annual averages of the costs incurred from 1997 through 2000.

4.4.4 CHEMICAL ANALYSIS

Chemical analysis consists of both process monitoring conducted by the O&M contractor (“environmental sampling” in the summary costs) and ground water monitoring subcontracted by the USACE, Kansas City District to a local environmental firm. Process monitoring is consistent with the summary table provided in Section 2.4 of this report, and ground water monitoring consists of sampling 9 monitoring wells and 33 extraction wells for VOCs on an annual basis.

4.5 RECURRING PROBLEMS OR ISSUES

The majority of recurring issues have been addressed through modifications or maintenance programs. For example, a redundant level switch has been added to prevent the equalization tank from overflowing. Maintenance programs are also in place for the sand filter, air strippers, and pumps and motors. Despite modifications to the vacuum pump, it still requires replacement on a yearly basis.

4.6 REGULATORY COMPLIANCE

The plant routinely meets all water and air discharge requirements.

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

As mentioned previously, the equalization tank has overflowed three times since operation began in 1996. The overflow was contained by the secondary containment dike. A redundant level switch has been installed to prevent future incidents.

4.8 SAFETY RECORD

The plant has reportedly not had any recordable incidents during operation.

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

5.1 GROUND WATER

Ground water in the Upper Kirkwood aquifer continues to be impacted by the benzene, toluene, 1,1,1 TCA and cis 1,2 DCE. Both the site managers and RSE team agree that aquifer cleanup upgradient of the slurry wall would require decades of operation of the current pump and treat system.

The benzene concentrations at all four recently installed piezometers between the slurry wall and the brook (PZ-1, PZ-2, PZ-3, and PZ-4) exceed the discharge/cleanup standards for the site. The greatest impact (exceeding 500 ppb of benzene) was detected at PZ-3. The source of this contamination is unknown. It may have been present before the construction of the slurry wall and extraction network, but it could also indicate a breach in the extraction system and slurry wall. These impacts between the slurry wall and the brook are important because the documented objective of the pump and treat system is to prevent discharge of impacted water to the brook, and it is quite possible that such discharge is occurring.

5.2 SURFACE WATER

Surface water samples from three locations in the brook were collected during the 1989 Remedial Investigation. The samples revealed trace impacts in two of the locations and impacts below 100 ug/L of total volatile organics at the location taken at the downstream end of the site. Samples were also collected in similar locations by the Emergency Response Team during a separate investigation for the Biological Endangerment Assessment Study in 1988. The maximum concentration of total volatile organics in these samples exceeded 4,000 ug/L. Surface water samples have not been collected since that investigation to determine if impacts remain.

5.3 AIR

Approximately 0.54 pounds of organic contaminant are removed from extracted ground water per day. The majority of this is removed in this first air stripper, and the offgas from that stripper passes through vapor phase carbon before discharge to the atmosphere. Even without treatment with vapor phase carbon, the discharge criteria for the air strippers (see table in Section 3.2) would be met (see calculations and table in Section 4.3.9).

5.4 SOILS

Over 15,000 cubic yards of soil, including soils below the water table, have been excavated and treated. Soils continue to be impacted at the site, especially soils near the water table where a sheen has been observed. As stated in the ROD, the implemented pump and treat remedy is intended to address soil contamination. When the contamination is rinsed from the soil to the ground water by rain, it will be extracted and treated.

5.5 WETLANDS AND SEDIMENTS

Sediments from the pond and bog were excavated/dredged and the areas were backfilled with native clean soil. Impacts to the wetlands and the sediments associated with the brook may be impacted by benzene as indicated by the sampling results (over 500 ppb of benzene) from PZ-3 during the December 2001 REACs contract field event.

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 RECOMMENDATIONS TO IMPROVE EFFECTIVENESS

6.1.1 EVALUATE GROUND WATER IMPACTS BETWEEN SLURRY WALL AND BROOK WITH A GEOPROBE

The four new piezometers between the slurry wall and the brook (PZ-1, PZ-2, PZ-3, and PZ-4) demonstrated ground water impacts above the cleanup/discharge criteria. In particular, the impacts at PZ-3 exceed 540 ug/L of benzene. The extent of impacts exceeding 540 ug/L is unknown, and greater impacts could exist beyond the slurry wall. The RSE team, therefore, recommends a two-day GeoProbe investigation to greater evaluate the extent of contamination beyond the slurry wall with particular emphasis on the area near PZ-3. The samples should be analyzed for VOCs. This event, the sampling, and analysis could be performed for approximately $25,000. The results of the study will help the site managers determine the need for remediation beyond the slurry wall and perhaps the degree of capture provided by the slurry wall and extraction system.

6.1.2 MONITOR VOCS AND WATER LEVELS IN PIEZOMETERS BETWEEN SLURRY WALL AND BROOK

The December 2001 field event conducted with REACs contractor showed impacts to ground water above the cleanup/discharge criteria between the slurry wall and the brook at all four locations evaluated. At one of these locations, the impacts are two orders of magnitude above the cleanup/discharge criteria. It is likely that these impacts are due to contamination that was present before the slurry wall and extraction network were put in place because of all the contaminants found upgradient of the slurry wall, only benzene has been found downgradient of the slurry wall. Regardless, ground water impacted with benzene may be discharging to the brook at concentrations greater than 5 ug/L, which is inconsistent with the overall ROD objectives. Because the flow rates from the individual wells cannot be determined, reduced capture of the extraction wells due to fouling or formation heterogeneity could go unnoticed by the site managers. Therefore, if the current extraction system is expected to operate for a number of years, a more comprehensive approach to evaluating plume capture should be implemented.

Monitoring for VOCs should continue from PZ-1, PZ-2, PZ-3, and PZ-4 to determine if a trend in the concentrations is evident. A downward trend would likely suggest that sufficient capture is occurring while an upward trend would likely suggest a breach in the containment offered by the slurry wall and the extraction network. A trend of unchanging values overtime is also possible. However, ground water flow through this area is likely very slow and concentrations could persist for a long time due to a lack of capture or a lack of flushing of previous impacts rendering such analysis inconclusive. The additional cost due to adding these piezometers to the annual sampling event is approximately $2,500 per year.

To more rigorously determine if capture is adequate, at least two sets of three piezometers should be installed. Each set of three piezometers would be installed in line perpendicular to the slurry wall with one piezometer just upgradient of the slurry wall and the other two piezometers between the slurry wall and the brook. The piezometers should be approximately 5 to 10 feet apart, should screen the same elevation, and should be surveyed. The ground water elevation in each well should then be measured, and the direction of the hydraulic gradient determined. Figures 6-1 through 6-4 demonstrate potential outcomes and interpretations. At least one of the two piezometer sets should be added where PZ-3 is located. PZ-3 could be used if measures can be taken to assure settling or frost heaves do not change the reference point from which the water levels are measured. The information gained from these additional points would help determine the effectiveness of the current system or design parameters for other potential remedies. Installation and surveying for two piezometer couplets could be accomplished for under $20,000. Measuring water levels in these piezometers could be done under the current sampling program for no additional cost.

6.1.3 ANALYZE FOR 1,1 DCE IN GROUND WATER SAMPLES

1,1 dichloroethene (1,1 DCE) is a common breakdown product of 1,1,1 TCA. Although the laboratory analyzes for 1,1 DCE in samples taken from monitoring and extraction wells it does not report the results. The site managers should request that the laboratory report the results for 1,1 DCE because it might be present as a breakdown product, is more toxic than 1,1,1 TCA, and has a lower MCL (7 ug/L for 1,1 DCE compared to 200 ug/L for 1,1,1 TCA). Although the treatment plant influent has undetectable concentrations of 1,1 DCE, this could be due to dilution (i.e., higher concentrations may exist in portions of the aquifer). For example, the influent concentration for 1,1,1 TCA in 2001 was only approximately 20 ug/L despite concentrations in some wells that exceed 1 mg/L. Implementation of this recommendation will help in determining the effectiveness of the remedy and should not require additional cost.

6.2 RECOMMENDATIONS TO REDUCE COSTS

The RSE team has a number of considerations for improving the cost-effectiveness of the remedy at the Bog Creek Farm Superfund Site. Many of these recommendations require substantial capital costs and address both life-cycle costs and site closeout and should therefore be considered for long-term implementation. For this reason, these recommendations are discussed in more detail in Section 6.4 of this report, Recommendations for Gaining Site Closeout. The items in Section 6.2 can be implemented immediately to realize cost savings.

6.2.1 REVIEW USACE OVERSIGHT COSTS

Oversight and quality assurance costs account for approximately $345,000 per year. The total annual cost for a number of Fund-lead pump and treat systems (including both O&M and oversight) that treat similar chemicals (VOCs) operate for under $345,000 per year. By comparison, USACE oversight costs are under $40,000 per year at a very complex Fund-lead pump and treat system in Region 1. Therefore, the RSE team strongly encourages the RPM to review the services provided by USACE at the Bog Creek Farm site and to compare these services with the associated annual costs.

Some services provided by USACE could also be eliminated without sacrificing system effectiveness or increasing work for the RPM. For example, USACE collects water levels from the 9 monitoring wells on a monthly basis. The collection and processing of these data does not affect the operations of the plant and does not appear to be used for further analysis that would improve effectiveness or reduce costs. Therefore, this service could either be eliminated or conducted by the onsite staff during their daily routine. Furthermore, the site operators are well experienced with the treatment plant and have minimized the number issues or emergencies. USACE could likely reduce the number of site visits without sacrificing effectiveness. Quality assurance (QA) provided by the USACE New England District involves the analysis of split samples from the process monitoring. The routine process monitoring is conducted by Severn Trent Laboratories, a well-respected laboratory that uses certified analytical methods. Also, given that the project is in the O&M phase, the historical database already provides a measure of QA. For this reason, split samples and the quality assurance provided by the New England District is not necessary. It is recommended that the quality assurance analysis of split samples for routine monitoring be eliminated. At a minimum, the frequency of QA analysis of split samples should be reduced to annually or less. It is important to note that, in a survey of 23 Fund-lead pump and treat systems, QA analysis of split samples during O&M is either extremely rare or non-existent.

The cost savings associated with this recommendation have not been quantified but should at least be $150,000 per year, if not more.

6.2.2 REDUCE OPERATOR LABOR

The treatment plant is currently staffed by two full time operators. This labor, represents a significant portion of the O&M line item for $376,900 per year, and a reduction in labor and cost could likely be achieved. To avoid having an operator on site alone, the reduction could occur by reducing the time both operators are present on site. In general, labor reductions are often achieved through improved automation. However, at this site, labor reduction is more easily achieved by taking advantage of batch treatment.

Extraction at the site occurs throughout the week at approximately 25 to 30 gpm. Treatment is accomplished in batch mode at an approximate rate 160 gpm between 6:30am and 2:30pm every week day while the operators are on site. The treatment system is shutdown each evening and on weekends while extraction continues until the influent tank is filled. The influent tank has a capacity of 78,000 gallons and takes approximately 2 days to fill if treatment is not occurring. Currently, extraction continues over the weekend until Sunday afternoon when the influent tank reaches capacity. Extraction can begin again on Monday once the batch treatment of stored water allows for additional storage of extracted water.

At a treatment rate of 160 gpm, nearly all of the 78,000 gallons of extracted water in the influent tank can be treated in 8 hours of operation on Mondays (160gpm × 8 hours × 60 minutes/hour = 76,800 gallons). Between the end of treatment on Monday at 2:30pm and the beginning of treatment on Tuesday at 6:30am the influent tank has gained a capacity of between 24,000 and 30,000 gallons if the extraction rate is between 25 gpm and 30 gpm (30 gpm × 16 hours × 60 minutes/hour = 28,800 gallons). At a treatment rate of 160 gpm, up to 30,000 gallons could be treated in as little as 3.5 hours on Tuesday (160 gpm × 3.5 hours × 60 minutes/hour = 33,600 gallons). Alternatively, treatment could be delayed until Wednesday at 6:30am, by which time, the extraction will have continued for 40 hours without treatment and approximately 72,000 gallons (30 gpm × 40 hours × 60 minutes/hour = 72,000 gallons) will be stored in the influent tank. This is a shorter time frame without treatment compared to the amount of time between system shutdown on Friday at 2:30pm and Sunday afternoon when the influent tank fills up. As calculated above, 72,000 gallons could be treated in 8 hours at a treatment rate of 160 gpm.

The above calculations suggest two options for labor reductions: 1) reduce the operator time on site on Tuesdays through Thursdays or 2) reduce the treatment schedule to Mondays, Wednesdays, and Fridays. The second option is likely more practical. Assuming an hour is required for system startup and shutdown, the two operators would be required for 9 hours 3 days per week. This is a total of 27 hours per week per operator compared to the current 40 hours per week. Given the population base in the area, qualified operators should be available that are willing to work with the part time schedule.

The operators have other responsibilities at the site, and because of the age of some of the components, the system may require significant maintenance. However, the items required could likely be accomplished and the system maintained in the reduced schedule. If needed, an additional day one week per month could be spent at the site to accomplish remaining or unattended maintenance issues.

Assuming operator rates of approximately $70 per hour for one operator and $50 per hour for the second operator, the current full time operator labor translates to an annual cost of approximately $250,000 per year of the $376,900 O&M line item. If labor is reduced as suggested, a savings of approximately $80,000 per year may be realized. Even in the unlikely event that rates must be increased by 10% to acquire qualified operators that would take the part time opportunity a savings of approximately $65,000 per year could be realized. Furthermore, even if an additional day per month at the increased rates is required for additional maintenance, a savings of $50,000 per year could still be realized. Therefore, the RSE strongly encourages the site managers to pursue various options, including the one described here, to reduce labor and realize a savings of up to $80,000 per year.

6.2.3 REVISE THE GROUND WATER SAMPLING PROGRAM

Currently, the annual ground water sampling event is conducted by an environmental consulting firm out of White Plains, New York subscontracted through the USACE Kansas City District. The event consist of sampling for VOCs in 9 monitoring wells and 33 extraction wells and takes two weeks with a two person sampling team. The protocol involves purging and sampling all wells, including the extraction wells. Two primary changes to this sampling program would result in immediate cost savings without sacrificing effectiveness. First, because the extraction wells continually draw water from the aquifer, they do not need to be purged during sampling. Therefore, simply shutting off the extraction wells and then sampling them without purging will not compromise the sample quality and will cut the time of the sampling effort by approximately one week. Second, the onsite operators should conduct the ground water sampling rather than contracting the work through Kansas City to another contractor in New York. A review of the operator tasks by the RSE team plus additional feedback from technical support from the USACE Kansas City District suggest that the operators would have enough time within their current schedule to conduct the sampling. Therefore, the ground water sampling could be worked into the existing O&M labor responsibilities with no change in cost. This recommendation would eliminate the current labor costs for sampling, which the RSE team estimates is approximately $20,000 per year. This recommendation should be implemented by the next sampling event. If the labor is reduced as suggested in Section 6.2.2, the additional savings from this recommendation may only be $15,000 per year rather than $20,000 per year because the operators may need to spend additional time on site than is budgeted in 6.2.2.

6.3 MODIFICATIONS INTENDED FOR TECHNICAL IMPROVEMENT

6.3.1 ELIMINATE CONTINUOUS EMISSIONS MONITOR

The calculation provided in Section 2.1 of this report shows that approximately 0.54 pounds per day of organic contaminants are removed from the extracted ground water. Based on the values summarized in Section 4.3.9, the actual discharge from the first air stripper is well below the air discharge criteria. Based on these results, the continuous emissions monitor is not required. The site managers are encouraged to determine if other the other discharge points are regularly meeting discharge criteria as the RSE team suspects. If, in fact, these other points do regularly meet discharge criteria, the use of the continuous emissions monitor should be discontinued. Furthermore, the site managers should seriously consider the cost savings that could result from not replacing the vapor phase carbon. A savings of approximately $13,300 per year would result, but the decision to not replace the vapor phase carbon should be consistent with any EPA policy regarding the transfer of contaminant mass from one media to another.

6.3.2 TEST INDIVIDUAL EXTRACTION WELLS TO DETERMINE YIELD

The current extraction system provides no means for determining the flow rate in individual extraction wells. If the extraction rates of individual wells are reduced due to fouling or subsurface heterogeneity, both capture and mass recovery could be limited. Step drawdown tests with peristaltic pumps can be conducted to determine potential yields and specific capacities of individual wells. These test should be conducted on an annual basis for the extraction wells, particularly those extracting impacted ground water. Each event might require approximately a period of one week for a two person team. If the current operator labor is maintained, this task could be added to the existing O&M tasks at no increase in annual costs. If operator labor is reduced, as is suggested in Section 6.4, this task should be conducted during the annual sampling event. The cost for such an event is included in the cost estimates provided in Section 6.4.

6.3.3 REPAIR AND CLEAN VARIOUS ITEMS

Probably as a result of the treatment system being modified from the existing aqueous waste treatment system from previous onsite remedies, a number of items require repair and cleaning. Several pumps leak and several pipes are poorly supported. On the day of the RSE, it appeared that the floors, walls, and equipment should be cleaned. In addition, the electrical system does not appear to be up to code and should be inspected and modified by a licensed electrician. These are short-term repair items. Prior to implementing major repairs, the site managers should consider the recommendations in Section 6.4 and the future of the existing remedy. Repair costs should be limited to under $5,000.

6.4 CONSIDERATIONS PERTAINING TO SITE CLOSE OUT AND REDUCTION OF LIFE-CYCLE COSTS

Although the current remedy is removing mass from the subsurface and reducing impacts to the creek, it is doing so at substantial cost and has a long projected life time. Current estimated annual costs for the system approach $1 million per year. Recent sampling conducted by the REACs contractor identified ground water VOC concentrations three orders of magnitude above cleanup levels over 100 feet from the nearest extraction wells. In addition, a sheen on the surface of the ground water has been observed in a number of wells. The elevated concentrations and the presence of sheen indicate contamination present as a non-aqueous phase liquid (NAPL). Aquifer restoration will be limited by slow ground water flow, sorption of contamination to soil, and the continuing dissolution of NAPL. Given that the current system has been operating for 8 years and concentrations have remained elevated throughout the site, it is a reasonable assumption that the site will be operating for decades. Assuming a 30-year cleanup, which may be an underestimate, and the current annual costs, the life-cycle costs for the remainder of the remedy is approximately $16 million dollars (net present value assuming a 5% discount rate) or $30 million (not discounted). Therefore, in an effort to reduce the life time of the remedy and therefore the life-cycle costs, a more aggressive approach to remediation at this site appears merited. Given that contamination is limited to a shallow area (less than 30 feet below ground surface), a number of technologies or approaches are feasible and are provided below for consideration by the site managers.

6.4.1 A MODIFIED PUMP AND TREAT SYSTEM

Additional extraction wells would allow for greater mass recovery, and a modified treatment plant with automation would allow for savings in labor, utilities, and materials. In addition, reaching site close out faster would reduce the life-cycle cost for the remedy.

For enhanced mass recovery, new extraction wells could be located in each of the hot spots identified by the work conducted by the REACs contractor. Based on the preliminary results for benzene contamination from the Spring 2002 REACs results, at least three areas warrant new extraction wells (near PZ-13, near PZ-34, and near PZ-24). In addition, data from the December 2001 REACs sampling event suggested toluene impacts of greater extent. The focus of the REACs work, after finalized data is available, should be to determine the appropriate locations for additional extraction wells or trenches. Up to 10 new extraction wells could be added to the vacuum extraction system for approximately $100,000. An annual cost of approximately $5,000 would be required for including these wells in the ground water monitoring program. The modified treatment plant should have a sufficient capacity for the additional extraction (perhaps a total capacity of approximately 50 gpm).

The current treatment plant is designed for batching water through the system at approximately 160 gpm. In addition to limiting the overall extraction rate to approximately 25 to 30 gpm, the current system is operator intensive and would be difficult to automate. In addition, costs to maintain and repair the system will increase over time as components require replacement. It appears more appropriate to replace the system with a 50 gpm automated system within the next few years. To save on heating costs, the system should be contained in a smaller building (approximately 24 feet by 30 feet) with a concrete foundation and a containment berm. Also, because operator labor is expensive, it should be limited when possible. A reasonable goal for operator labor to be limited to a maximum of 16 hours per week. To help minimize labor, the team should invest in another vacuum pump that requires minimal maintenance and does not require replacement once a year. Capital should also be invested into proper controls, failsafes, and alarms for the plant to operate without attention. These controls are common and have been incorporated at 21 of the 23 Fund-lead pump and treat systems that were visited by the RSE team.

The primary contaminants of concern that continue to require treatment at the site are the VOCs because the SVOC influent levels have generally been below discharge standards. Therefore, the primary treatment components should either be air stripping or liquid phase carbon. Only one of these two technologies is necessary for removal of VOCs, so the two should not have to be used together. Filtration should be included, however, to reduce fouling or clogging of the treatment components or the reinjection trenches. The metals concentrations (zinc, lead, and copper) in the influent have been below the discharge criteria for some time, and even with additional extraction wells online, the metals concentrations will either remain below the discharge criteria or would be addressed by either filtration or indirectly by treatment of the VOCs. If continued SVOC removal is necessary due to the chance that influent SVOC concentrations may occur above standards, then GAC must be included in the new system.

Option 1: A filtration/GAC treatment system

The use of a filtration/GAC system would have relatively low capital and annual costs but could be complicated with frequent fouling of the GAC units with solids. Some preliminary testing could be conducted with the existing treatment plant during typical batch operations to determine if a filtration/GAC system would be practical.

The test would involve a one-month trial period using only filtration and liquid phase GAC for treatment. A dilute solution of sodium hypochlorite (approximately 1 mg/L) should be added at the plant influent to help control fouling of the treatment units and piping by iron bacteria. Provided that ammonia is not present at a significant level in the waste stream, the chlorine will be removed by the activated carbon prior to discharge. For the test, the metals treatment and air stripping should be discontinued. The process water should be directed through the metals removal system tanks (without pH adjustment and polymer addition), through the sand filter, then directly to what is now the lagging carbon vessel (the vessel where carbon was most recently changed out), and finally to the effluent storage tanks for reinjection. The air strippers should be bypassed in order to pilot test the GAC as the sole treatment component, and the other GAC unit should be bypassed to ensure that contaminants that have already sorbed to its carbon does not desorb into the treated water. A conservative estimate of carbon usage provided by a vendor and based strictly on contaminant loading suggests that a single 15,000-pound GAC unit will be sufficient treatment to meet the discharge criteria for over 3 years at the current flow rate and batching schedule. Fouling, however, would likely require a more frequent changeout than once every 3 years.

During the one-month test period, the plant operators should monitor the pressure differential across the carbon, backwash the unit only as required, and record in a log book the pressure differential before and after backwashing. Reductions in dissolved oxygen from bypassing the air strippers should result in reduced mineral precipitation and biofouling. Therefore, backwashing the carbon vessels should be required less frequently. Samples should be collected and analyzed to ensure the system meets discharge standards and that chlorine (or chloramine if ammonia is present) is not present in the effluent at unacceptable levels.

Site information and the results of this test should be reviewed by site managers and EPA technical assistance to determine if a filtration/GAC treatment system would be practical and cost-effective to operate. This testing and evaluation could be completed within 2 months of receipt of the finalized RSE report. If such a system is practical and cost effective, it could be implemented. The primary concern of the RSE team with regard to this type of system is the required frequency for backwashing the units. The above pilot tests should yield additional information on this concern. If possible, efforts should be made to use a larger pump to ensure thorough backwashing of the carbon units during the test.

The RSE team estimates that the capital cost for designing and installing this treatment system could be accomplished for approximately $535,000 and that annual costs for operating this system (including ground water sampling, reporting, project management, profit, etc.) would be approximately $275,000 per year. Please refer to Tables 6-1 and 6-2 for a breakdown of this cost estimate. Because the GAC units would likely be replaced due to fouling rather than chemical loading, an increase in contaminant loading from additional extraction wells should not greatly impact the annual cost estimates.

Option 2: An air stripping treatment system

If the above GAC system is not practical or cost effective due to backwashing or fouling issues, an air stripping system with adequate filtration is another potential option. Efforts should be made to limit the system to consist of filtration and air stripping. Filtration could be necessary before the air stripper to prevent it from fouling, after the air stripper to prevent fouling of the reinjection gallery, or both. An air stripping system with various filtration scenarios should be pilot tested for period of one month with the appropriate filters and a tray aerator rated for 50 gpm. If filtration is inadequate to prevent mineral precipitation and biofouling of the stripper and reinjection gallery, an automated iron precipitation system or green sand filter with a 50 gpm capacity could be included. Once again, the RSE team emphasizes that the system should operate continuously with the necessary controls to allow remote operation with minimal operator labor. The RSE team estimates that the capital cost for designing and installing a metals removal system and air stripper treatment could be accomplished for approximately $875,000 and that annual costs for operating the system (including ground water sampling, reporting, project management, profit, etc.) would be approximately $350,000. Please refer to Tables 6-3 and 6-4 for a breakdown of this cost estimate.

If metals removal is not required, the capital cost could likely be reduced to approximately $535,000 and the annual costs could likely be reduced to approximately $275,000 per year, both of which are comparable to the GAC system described above.

6.4.2 AIR SPARGING

Air sparging is another option in addition to or as a replacement of a modified pump and treat system. Air sparging relies on direct removal of VOCs from the subsurface through volatilization of the chemicals into air that is injected into the aquifer and recovered through a soil vapor extraction (SVE) system. Additional mass removal could occur through aerobic biodegradation because the injection of air increases the dissolved oxygen in the ground water. At the Bog Creek Farm site, the presence of high dissolved iron concentrations indicate an oxygen poor environment. Biodegradation could be enhanced with an increase in dissolved oxygen.

Air sparging could be implemented through multiple vertical or horizontal wells and could be used for containment purposes or for aggressive source removal. The potential benefits of air sparging at this site may include the following:

- Treatment is achieved in situ without withdrawing, treating, and discharging water.
- Mass removal is aggressive and the remedy lifetime is frequently shorter in duration than that of a pump and treat system.
- Contamination present as LNAPL should be removed by volatilization more readily than through ground water extraction.
- Maintenance of an air sparging and SVE system is limited to maintenance on the blower motors and replacement of vapor phase carbon.
- Capital costs of installing the system would likely be less than the capital costs of modifying or replacing the pump and treat system.
- The depth of contamination is relatively shallow and vertical sparging points or horizontal sparging trenches could be installed for a relatively low cost compared to sites with deeper contamination.
- Increases in dissolved oxygen to the aquifer could assist aerobic biodegradation of the benzene and toluene.

The potential limitations of air sparging at this site include the following:

- Uniform distribution of air through the subsurface is difficult to achieve. This could make it difficult to provide capture or containment of the plume through air sparging. This might be overcome by increasing the density of sparging points.
- Aeration of the subsurface could lead to mineral precipitation and biofouling within the aquifer leading to a reduction in permeability near the sparging points. This could limit the effectiveness of ground water extraction wells if pump and treat at the site is still required. Therefore, this limitation of air sparging, which is of particular importance for sparging wells located in the immediate vicinity of ground water extraction wells, should be considered prior to implementation.

The above limitations can be addressed to an extent by constructing high-permeability air sparging trenches and periodically rehabilitating the trenches to control iron bacteria related fouling and mineral precipitation. Periodic injection/extraction of an acid-based solution could be used to control fouling/encrustation in the trenches. A procedure analogous to a typical protocol for rehabilitation of ground water injection wells could be used.

One option is to implement a modified pump and treat system as suggested in Section 6.4.1, but instead of adding additional extraction wells in the hot spots, add multiple vertical sparging points and vapor recovery wells to enhance mass removal. Implementing this recommendation would likely include approximately 10 vertical air sparging points distributed among the hot spots (near PZ-13, near PZ-34, and near PZ-24) but possibly another 10 or more depending on the extent of toluene impacts. Up to 10 vapor extraction wells would likely be required in each hot spot to recover the volatilized contaminants. Over 300 feet of shallow trenching and piping to these locations as well as a 10 horsepower compressor and a 5 horsepower blower would be required for air delivery and recovery, respectively. A vapor phase GAC unit would be required to remove contaminants from the recovered air. The blowers and GAC unit could be housed in the pump and treat building. This system would likely require approximately $250,000 to design and install. To operate this system, an increase of approximately $75,000 per year over the above-estimated pump and treat annual O&M costs would likely be required.

Alternatively, horizontal sparging wells could be installed. This approach would be particularly helpful for the hot spot near the treatment plant (near PZ-34) where the influent tank and other structures would prevent the installation of vertical sparging points. Using horizontal wells at other parts of the site could be useful. Installing a horizontal well for sparging near the treatment plant in place of approximately 4 sparging points would not significantly change the above cost estimate. Horizontal sparging could also be used to establish an air curtain, but such an approach could potentially be complicated by non-uniform distribution of air caused by channeling of air through preferential portions of the horizontal well. This channeling of could be minimized by constructing trenches for placement of horizontal sparge and vapor extraction wells. The trenches would be backfilled with relatively high permeability materials such as uniform sand. The uniformity of air distribution could be further controlled by limiting the length of the horizontal sections. Instead of using long horizontal sections, there could be several, relatively short horizontal sections with central "Tees" connected to vertical injection casings. Using this approach, the pump and treat system could potentially be replaced by air sparging.

6.4.3 IN SITU CHEMICAL OXIDATION

Aggressive mass removal could also be achieved through chemical oxidation. This approach would likely involve injection or delivery of strong oxidants to the subsurface that would oxidize organic contaminants, converting them into harmless by products. A relatively high demand for oxidants is expected at this site for the following reasons:

- Chlorinated ethanes such as TCA are more saturated than BTEX compounds and chlorinated ethenes and therefore require additional oxidation.

- The site exhibits high contaminant concentrations and evidence of NAPL in several locations.

- High levels of natural organic matter that will compete for oxidants are expected to be present given the bog-like setting.

Chemical oxidation is accompanied by intense heat and gas production, so additional safety precautions would be necessary. In addition, if chemical oxidation is used in the vicinity of the extraction wells, these wells could be permanently damaged. Therefore, the RSE team recommends that if this approach is considered, the application of chemical oxidants is limited to the significant VOC contamination areas located upgradient from the extraction network (i.e., near PZ-13, PZ-34, and PZ-24 but likely greater in extent due to toluene impacts).

Figure 6-5 illustrates the areas of significant VOC contamination (based on preliminary data) where treatment of this technology should be considered. To proceed with this approach, the site managers will either need to make assumptions about the extent of the contamination or will need to conduct additional direct-push sampling to help further delineate the exact areas for treatment. Considering the constituents of concern, the observed concentrations, the volume to be treated, and the depth to ground water, approximately 60 injection wells might be required. The cost of each well—including installation, injection, and monitoring of the injection— would range from $5,000 to $10,000. Therefore, the cost of implementation would likely range from approximately $300,000 to $600,000. Because contamination is limited to shallow portions of the aquifer, delivery could be accomplished through trenches or infiltration galleries, which might reduce the cost. As a contingency, the RSE team will assume that the cost of such a remedy will be up to $1 million.

Applying this technology would not necessarily result in immediate site closure or immediate discontinuation of pump and treat, and contaminant rebound may occur. Therefore, additional applications of chemical oxidation and/or continued operation of the pump and treat system would likely be required. However, a large reduction in contaminant mass site-wide (including beneath the influent tank) would be achieved by chemical oxidation and could likely reduce the time site closeout by a number of years. Thus, life-cycle savings (by reducing the number of years of pump and treat operation) would likely be realized.

The RSE team recommends that a brief site description be developed for distribution to vendors of the chemical oxidation technology. These vendors could then be contacted to provide free cost estimates of applying the technology. EPA technical assistance should then be consulted to evaluate the cost estimates and to help determine the cost-benefit of proceeding. After addressing the items in Section 6.1, 6.2, and 6.3, the application of chemical oxidation should be considered. If the site managers, with guidance provided by EPA technical assistance, opt to apply this technology, the results may have significant implications for considering the other recommendations provided in Section 6.4. Influent concentrations may be lower, hot spot wells may not be required, and influent iron concentrations may decrease due to a change in the redox conditions of the aquifer.

A number of vendors for this technology exist including GeoCleanse, ISOTEC, EBSI, and C-Sparge. Mention of these vendors does not constitute an endorsement by the RSE team or EPA. Rather, this information is provided to provide the site managers with a starting point in contact vendors about the technology. A number of other vendors exist and could be consulted.

6.4.4 EXCAVATION OF IMPACTED SOILS

Because the areas of high contamination are relatively shallow and the above-ground area is undeveloped, excavation of impacted soils and areas with NAPL is another viable remedial approach. NAPL at the site is evidenced by high concentrations and an observable sheen in some wells. However, despite approximately 60 sampling points from the REACs work, no pools of free product were found. Rather, NAPL is likely present as residual in various locations across the site within a few feet above and below the water table. In addition, substantial dissolved impacts and soil contamination extend well below the water table as evidenced by impacts at TW-10, which was completed to approximately 18 feet bgs or 12 feet below the water table. Excavation, therefore, would potentially need to extend to 15 feet below ground surface or even further in some locations.

Excavation could be extensive and comparable in size to the area of significant VOC impacts depicted on Figure 6-5 or it could be limited to specifically defined areas with residual NAPL or source material. The area of significant contamination is approximately 60,000 square feet. Assuming an excavation depth of 15 feet, extensive excavation would involve removal of approximately 900,000 cubic feet (approximately 30,000 cubic yards). Perhaps 75% of this material (or over 20,000 cubic yards) would require treatment. Assuming a cost approximately $200 per cubic yard to account for dewatering, on-site treatment, and local labor costs, extensive excavation could reach a cost of approximately $4 million or more. Due to the high contamination levels, health and safety concerns could further elevate the costs. Furthermore, additional costs, perhaps on the order of $1 million, would likely be required to address the contamination beneath the influent tank (i.e., removal and replacement of the tank to allow excavation or use of an alternative remedial technology in that area). Costs for extensive excavation with the intent of substantially reducing the time for additional pump and treat would therefore likely increase to over $5 million. Limited excavation would obviously cost less and the extent of the limited excavation would be better understood upon completion of the REACs work. To adequately address many of the source areas and reach below the water table, costs of limited excavation would likely be in excess of $1 million.

As with other aggressive approaches, the high up front costs associated with excavation suggest that it should only be conducted if the duration of the long-term pump and treat remedy could be substantially shortened. Removing residual NAPL or other source material, if well delineated by the REACs work, may shorten the duration of the remedy, but given the breadth of high contamination throughout the site, it is likely that the pump and treat system would need to continue operating for a number of years, potentially decades. More importantly, unless the influent tank is removed, excavation could not address the substantial contamination beneath the influent tank that is evidenced by sheen in MW-A and benzene concentrations of 12,000 ppb in PZ-34. An alternative remedial approach such as air sparging or chemical oxidation would be more appropriate for the contamination residing beneath the influent tank. It should be noted that even with limited excavation, continued pump and treat may be required for as many as 30 years because substantial contaminant mass appears to exist beyond limited source areas.

6.4.5 CONSIDERATIONS FOR ENHANCED BIOREMEDIATION

No literature references could be located by the RSE team to support the tenet that aerobic biodegradation of 1,1,1-TCA is a viable degradation pathway. Abiotic breakdown of TCA, however, has been shown to be an important degradation mechanism, and results in production of acetic acid and 1,1-DCE. Production of 1,1-DCE is significant in that 1,1-DCE is considered more toxic than TCA. Although aerobic cometabolic biodegradation of 1,2-DCE (which may occur in the presence of an inducing substrate such as methane, toluene, or phenol) has been studied extensively, very few studies have been performed to investigate whether aerobic cometabolic biodegradation of 1,1-DCE is a viable degradation pathway.

Biotransformation of 1,1,1-TCA under reducing conditions can result in complete mineralization (carbon dioxide and chloride). However, production of the recalcitrant intermediate (1,1-DCA), is also likely. According to literature references, further biodegradation of 1,1-DCA occurs only under strongly reducing conditions.

Toluene and benzene are more amenable to in-situ bioremediation than TCA. Bioremediation of dissolved-phase toluene and benzene would involve establishing and maintaining oxidizing conditions in the affected zones to increase degradation rates. Candidate electron acceptors include: air, a nitrate solution, a hydrogen peroxide solution (via a drip-feed system), and ORC. Because the contaminated groundwater is relatively shallow, delivery of electron acceptor could be accomplished via injection trenches positioned upgradient of toluene and benzene hot spot areas. This alternative is not expected to be very effective in areas where NAPL contamination is present. A source removal action should be considered prior to implementing in-situ bioremediation in areas where NAPL contamination is present.

A potential in-situ bioremediation alternative for the TCA contaminated zones (primarily applicable to dissolved-phase TCA) would be an accelerated anaerobic bioremediation strategy. This would involve establishing and maintaining strongly reducing conditions in the TCA contaminated zones. Monitoring of breakdown products would be necessary (especially 1,1-DCA) to determine if complete degradation was occurring. Rates of benzene and toluene biodegradation would be reduced in an anaerobic environment. Thus, use of accelerated anaerobic bioremediation would have to be limited to those areas where levels benzene and toluene are at or near cleanup goals.

Because bioremediation would be more successful after source areas have been addressed or benzene and toluene have reached cleanup goals, the RSE team suggests postponing further consideration of bioremedation at this point. It should, however, be regularly revisited as site conditions change due to natural factors or results from other remedial activities.

6.5 SUGGESTED APPROACH TO IMPLEMENTATION

Due to the high potential for both improving effectiveness and reducing costs at the site, the RSE team recommends immediate consideration of the above recommendations. The site managers should begin with a thorough evaluation of the final results from the REAC characterization to better delineate the source material and areas of greatest contamination. Though the recommendations in Section 6.4 will take planning and preparation, the recommendations in Section 6.1, 6.2, and 6.3 could be implemented without delay. The recommendations in Section 6.1, in particular, should be implemented immediately because the results of the suggested activities will likely affect planning and preparation for the larger scale recommendations in Section 6.4.

A number of possible directions for the site remedy are suggested in Section 6.4, and other options may also exist. Due to the extent of contamination and the likelihood of continuing sources in the form of residual LNAPL, the remedy will probably continue for decades. Pump and treat or another containment strategy will likely be require for continued capture of the plume. A modified pump and treat system is a strong option for a protective and cost-effective system. The RSE team recommends beginning with the pilot test of the GAC/filtration pump and treat system (option 1 in Section 6.4.1). The results of this approach could be known within 6 months of the submission of the final RSE report. If successful, the pump and treat system should continue to operate in the GAC/filtration mode until a more automated system can be implemented. Operating the system in this mode wold reduce costs due to utilities, materials, and possibly labor.

Concurrent with the above pilot test, the site managers should consult the vendors of chemical oxidation and discuss air sparging and excavation options. Additional vendors to those listed above could also be approached. Although aggressive mass removal may not result in immediate site closeout, the significant mass removal could reduce the lifetime of the remedy. Furthermore, a potential change in the oxidative state of the aquifer due to decreased contaminant mass and the addition of oxygen (from air sparging or chemical oxidation) could decrease the metals concentrations entering the plant. This could result in a simpler system that costs less to install and operate. Therefore, the RSE team recommends full consideration of using chemical oxidation or excavation prior to piloting the air stripping/filtration system (option 2 in Section 6.4.1) or air sparging (Section 6.4.2). Once again, the site managers should being with the REAC characterization work to delineate those areas most in need of aggressive treatment.

To help compare the various options presented, Table 6-5 (presented at the end of Section 6.5) summarizes the costs of modified P&T systems compared to continued operation of the existing P&T system. For continued operation, contract oversight costs are excluded (because they are not representative of oversight costs under State lead) and the cost savings from implementing recommendations 6.2 and 6.3 are considered. Such a system would operate for approximately $640,000 per year.

Total Current Cost	$953,400
Exclude contract oversight	($220,000)
Include costs from 6.1.2	$2,500
Include savings from 6.2.2	($80,000)
Include savings from 6.2.3	($15,000)
Total expected cost	~$641,000

Review of Table 6-5 suggests that installing and operating a modified the pump and treat system results in estimated life-cycle cost savings of approximately 50%, assuming a 30-year time period. Assuming net present value with a discount rate of 5%, this estimated cost savings may be approximately $3.5 million to $5 million. Assuming no discounting, this estimated savings is approximately $7.5 million to $10 million. Table 6-5 does not account for cost savings resulting from increased mass removal associated with the larger extraction rate of a modified system.

Table 6-6 summarizes the costs of 6 different remedial approaches that are discussed in this report. Hypothetical durations for the various approaches are specified so that life-cycle costs can be roughly estimated. Due to discounting, life-cycle costs in net present value do not change significantly when the time period exceeds 30 years. For example, with a discount rate of 5 %, doubling the duration of the remedy from 30 years to 60 years would only result in an increase in life-cycle cost of less than 25%. Therefore, none of the hypothetical durations exceed a 30-year time period even though the remedial approach may take longer. Of the three more aggressive approaches remedy time frames of 10 and 20 years were arbitrarily chosen to demonstrate the potential benefit of reaching closure in less time.

A review of Table 6-6 demonstrates that, as presented, all of the alternative options have significantly smaller life-cycle costs than continuing with the existing pump and treat system. However, the majority of the savings between the alternatives and the current option are largely due to the lower annual costs associated with operating a modified pump and treat system compared to operating, maintaining, and repairing the current system.

A review of Table 6-6 also shows that the financial benefit of aggressive mass removal is highly dependent on discounting and the remedial approach. With a discount rate of 5%, aggressive mass removal (air sparging, chemical oxidation, or extensive excavation) does not further reduce the life-cycle costs of the system, even if the remedy duration is shortened by 10 years (i.e., from 30 years to 20 years). In the case of extensive excavation, it significantly increases the cost even if the remedy duration is shortened by 20 years. For a significant life-cycle savings in net present value to result from chemical oxidation or air sparging, Table 6-6 suggests the remedy duration would need to be shortened by approximately 20 years (i.e., from 30 years to 10 years). Such a reduction in remedy duration, however, is difficult to predict. Without discounting, the life-cycle costs in Table 6-6 show mixed results. As presented, the most favorable approach is chemical oxidation; however, the actual results of these different approaches may vary from what is presented in the table. Table 6-6 suggests that an investment of $1 million in chemical oxidation could result in life-cycle savings of $3 million if the remedy duration is shortened by 10 years (i.e., from 30 years to 20 years) and $4.5 million if the remedy duration is shortened by 20 years (i.e., from 30 years to 10 years). If the remedy duration with chemical oxidation is not shortened at all, the additional life-cycle cost would be the cost of the chemical oxidation (i.e., $1 million). Therefore, aggressive mass removal can be seen as an investment with a degree of risk. The likelihood of recovering the invested amount and realizing life-cycle savings is lower if that investment is high or if future costs are discounted.

The site managers' decision on how to proceed with remediation should account for the following:

- Despite up front costs, implementing a modified pump and treat system as discussed in Section 6.4.1 will most likely result in significant life-cycle savings compared to operating an optimized version of the existing system, but implementation of a modified system should be done after aggressive mass removal options are fully considered.
- If a discount rate of approximately 5% is appropriate for determining life-cycle costs of the remedy, achieving life-cycle savings by applying chemical oxidation or air sparging would likely require that the remedy duration shorten from 30 years to approximately 10 years.
- If discounting is not appropriate for determining the life-cycle costs of the remedy, chemical oxidation and air sparging would likely provide life-cycle savings if they can shorten the remedy duration by 10 years.
- Excavation, whether extensive or limited to source areas, would not likely increase the life-cycle savings over a 30-year time period, compared to operating a modified pump and treat system for 30 years.

Table 6-1. Estimated Capital Costs for Installing a Filtration/GAC Treatment System

Item	Capital Cost
Vacuum pump for extraction system	$25,000
New filtration unit with automatic backwashing (50 gpm)	$50,000
Building modifications or a new building	$50,000
Controls, Piping, Electrical, tank modifications	$200,000
Engineering	$50,000
Startup/shakedown	$50,000
Contingencies (~25%)	$110,000
Total	**$535,000**

Table 6-2. Estimated O&M Costs for Filtration/GAC Treatment System

Item	Annual O&M Cost
Project management	$30,000/year
Reporting (monthly O&M and annual ground water report)	$20,000/year
Operator labor (16 hours per week)	$55,000/year
Quarterly Engineering inspections and maintenance	$10,000/year
Chemical analysis for process sampling	$15,000/year
Materials (carbon replacement, etc.)	$25,000/year
Utilities	$30,000/year
Ground water sampling and analysis (assuming 40 extraction wells and 13 monitoring wells annually for VOCs, including analysis and testing well yields)	$35,000/year
Contingencies/non-routine maintenance (~25%)	$55,000/year
Total	**$275,000/year**

Table 6-3. Estimated Capital Costs for Designing and Installing Automated Iron Removal and Air Stripping Treatment System

Item	Capital Cost
Vacuum pump for extraction system	$25,000
Iron removal system (50 gpm)	$200,000
Tray aerator (50 gpm capacity)	$50,000
Building modification or new building and foundation	$100,000
Controls, piping, and electrical	$160,000
Engineering	$115,000
Startup/shakedown	$50,000
Contingencies (~25%)	$175,000
Total	**$875,000**

Table 6-4. Estimated Annual O&M Costs for Automated Iron Removal and Air Stripping Treatment System

Item	Annual O&M Cost
Project management	$30,000/year
Reporting (monthly O&M and annual ground water report)	$20,000/year
Operator labor (20 hours per week)	$80,000/year
Quarterly Engineering inspections and maintenance	$20,000/year
Chemical analysis for process sampling	$15,000/year
Materials and disposal (chemicals, filtration media, etc.)	$30,000/year
Utilities	$50,000/year
Ground water sampling and analysis (assuming 40 extraction wells and 13 monitoring wells annually for VOCs, including analysis)	$35,000/year
Contingencies/non-routine maintenance (~25%)	$70,000/year
Total	**$350,000/year**

Table 6-5 Cost summary table of modified P&T systems compared to the existing P&T system

Pump and Treat System	Estimated Capital Costs ($)	Estimated Annual Costs ($/yr)	Estimated Life-cycle Costs ($) [1]	Estimated Life-cycle Costs ($)[2]
Current System[3]	$0	$641,000	$19.2 M	$10.3 M
6.4.1 A modified pump and treat system with additional wells and extraction capacity				
• option 1 (GAC and filtration)	$635,000	$275,000	$8.9 M	$5.1 M
• option 2 (air stripping and metals removal)	$975,000	$350,000	$11.5 M	$6.6 M
• option 2 (air stripping and filtration)	$635,000	$275,000	$8.9 M	$5.1 M

Note: "M" stands for "million"

[1] assumes 30 years of operation with a discount rate of 0% (i.e., no discounting)

[2] assumes 30 years of operation with a discount rate of 5% and no discounting in the first year

[3] assumes the costs summarized in the table in Section 6.5

Table 6-6 Cost summary table for various remedial approaches

Remedial Approach	Estimated Capital Costs ($)	Hypothetical Remedy Duration (yrs)[1]	Estimated Annual Costs ($/yr)	Estimated Life-cycle Costs ($) [2]	Estimated Life-cycle Costs ($)[3]
1. Existing system[4]	$0	30	$641,000	$19.2 M	$10.3 M
2. Modified system with additional wells[5]	$635,000	30	$275,000	$8.9 M	$5.1 M
3. Modified system with air sparging hot spots[6]	$785,000		$350,000		
• hypothetical scenario A		20		$7.8 M	$5.4 M
• hypothetical scenario B		10		$4.3 M	$3.6 M
4. Chemical oxidation followed by P&T with a modified system[7]	$1,635,000		$275,000		
• hypothetical scenario A		20		$5.8 M	$5.2 M
• hypothetical scenario B		10		$4.4 M	$3.9 M
5. Extensive excavation followed by P&T with a modified system[7]	$5,635,000		$275,000		
• hypothetical scenario A		20		$11.2 M	$9.2 M
• hypothetical scenario B		10		$8.4 M	$7.9 M
6. Limited excavation followed by P&T with a modified system[7,8]	$1,635,000	30	$275,000	$9.9 M	$5.2 M

Note: "M" stands for "million"

[1] Remedy durations under various scenarios are hypothetical for the sole purpose of comparing the life-cycle costs of various remedial approaches. The actual duration for each remedial approach may be significantly longer or shorter than that specified. Due to discounting, life-cycle costs in net present value do not change significantly when the time period exceeds 30 years.

[2] assumes a discount rate of 0% (i.e., no discounting)

[3] assumes a discount rate of 5% and no discounting in the first year

[4] The costs for the existing system are discussed in Section 6.5.

[5] The costs for the modified system are discussed in Section 6.4.1 and assume metals removal is not necessary.

[6] The costs for the air sparging and SVE are discussed in Section 6.4.2. Assumes air sparging locations may be temporarily adjusted over the lifetime of the remedy at negligible cost for optimal mass removal.

[7] The costs for chemical oxidation and excavation are discussed in Sections 6.4.3 and 6.4.4, respectively.

[8] Limited excavation may not result in significantly decreasing the remedy duration to less than 30 years. Excavation options intermediate in extent to those provided in this table may be more cost effective than the two excavation options provided.

7.0 SUMMARY

In general, the RSE team found the system operating within design parameters. 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 offers number of recommendations with respect to enhancing effectiveness, reducing cost, improving technical operations, and gaining site closeout. The effectiveness recommendations primarily pertain to evaluating benzene impacts found downgradient of the extraction system. Continued monitoring of select points and additional piezometers is recommended. With respect to cost reduction, three recommendations are provided for immediate implementation. A potential reduction in USACE oversight, reduction of operator labor, and a modification to the ground water sampling program could result in immediate cost savings without sacrificing effectiveness. Operations at the plant can be further improved by eliminating the use of the continuous emissions monitor, repairing leaks, and testing the yield of the extraction wells. The recommendations with respect to site closeout offer a number of options for the site managers to consider including a modified pump and treat system, the use of air sparging, and the use of in situ chemical oxidation.

Table 7-1 summarizes the costs and cost savings associated with each recommendation in Sections 6.1 through 6.3. Both capital and annual costs are presented. Also, presented is the expected change in life-cycle costs over a 30-year period for each recommendation both with discounting (i.e., net present value) and without it. The reader is referred to Table 6-6 in the text of this report for a cost summary of the recommendations discussed in Sections 6.4.

Table 7-1. Cost summary table assuming the existing P&T system remains as the site remedy

Recommendation	Reason	Additional Capital Costs ($)	Estimated Change in Annual Costs ($/yr)	Estimated Change In Life-cycle Costs ($) [1]	Estimated Change In Life-cycle Costs ($)[2]
6.1.1 Evaluate ground water impacts between slurry wall and brook with a GeoProbe	Effectiveness	$25,000	$0	$25,000	$25,000
6.1.2 Monitor VOCs and water levels in piezometers between slurry wall and brook	Effectiveness	$20,000	$2,500	$95,000	$60,400
6.1.3 Analyze for 1,1 DCE in ground water samples	Effectiveness	$0	<$500	<$15,000	<$8,100
6.2.1 Review USACE oversight costs	Cost Reduction	$0	(>$150,000)	($300,000)[3]	($293,900)[3]
6.2.2 Reduce operator labor	Cost Reduction	$0	($80,000)	($2,400,000)	($1,291,000)
6.2.3 Revise the ground water sampling program	Cost Reduction	$0	($15,000)[4]	($450,000)[4]	($242,000)[4]
6.3.1 Eliminate continuous emissions monitor	Technical Improvement	$0	$0	$0	$0
6.3.2 Test Individual extraction wells to determine yield	Technical Improvement	$0	$0	$0	$0
6.3.3 Repair and clean various items	Technical Improvement	$5,000	$0	$5,000	$5,000
6.4 Recommendations pertaining to site closeout and reduction of life-cycle costs	See Table 6.6				

Costs in parentheses imply cost reductions.

[1] assumes 30 years of operation with a discount rate of 0% (i.e., no discounting)

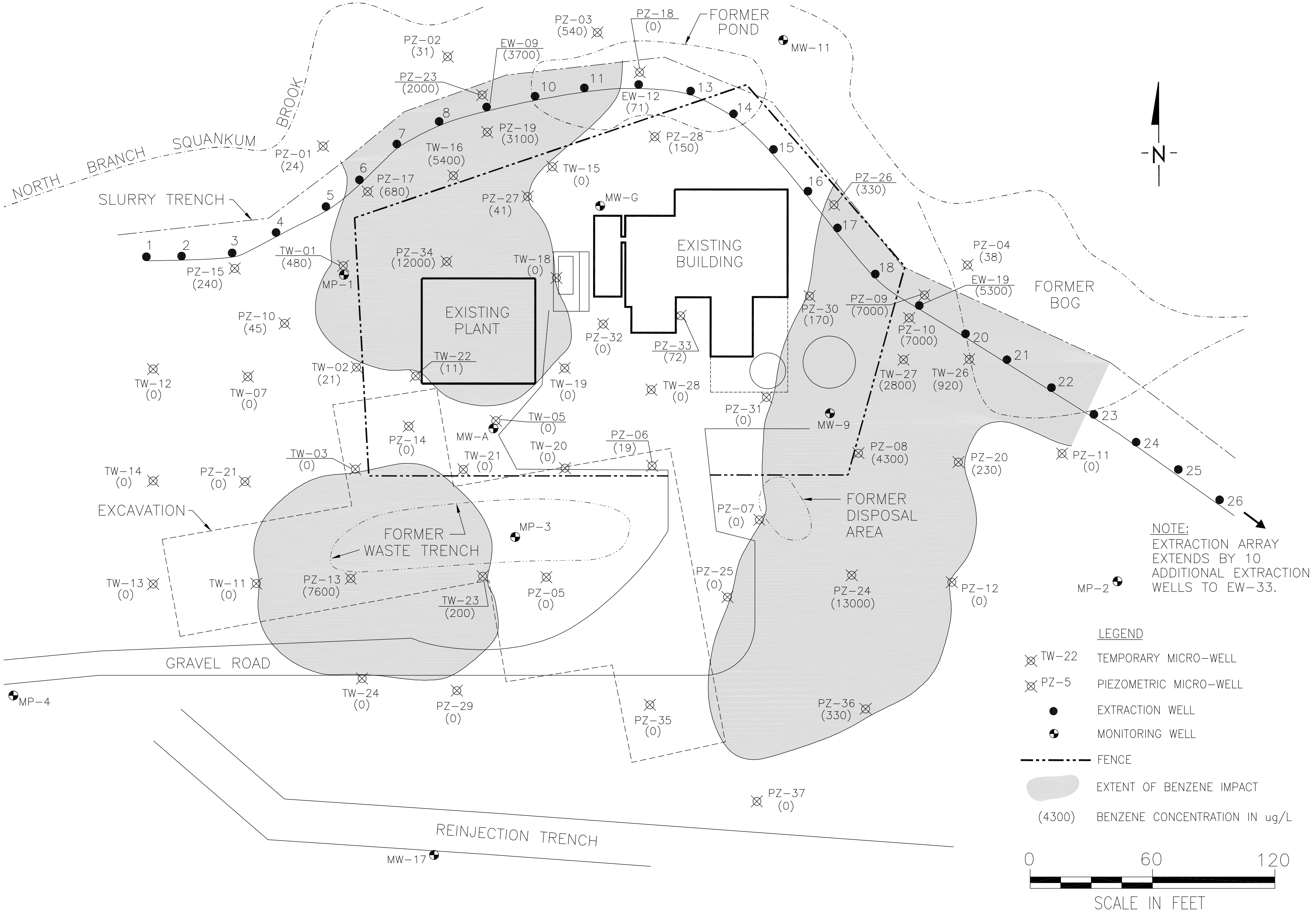
[2] assumes 30 years of operation with a discount rate of 5% and no discounting in the first year

[3] assumes current oversight mechanism will only continue for a period of 2 years

[4] savings assumes recommendation 6.2.2 is implemented. If 6.2.2 is not implemented greater savings could be realized

FIGURES

FIGURE 1-1. SITE FEATURES AND THE UPGRADIENT EXTENT OF BENZENE GROUND WATER IMPACTS AS DELINEATED BY PRELIMINARY DATA FROM THE SPRING 2002 SAMPLING EVENT.



(Note: This figure is based on preliminary data from the Spring 2002 sampling event conducted by the REAC's contractor. Concentration extent and magnitude may differ upon final analysis).

FIGURE 6-1. INCOMPLETE CAPTURE OF SITE CONTAMINANTS

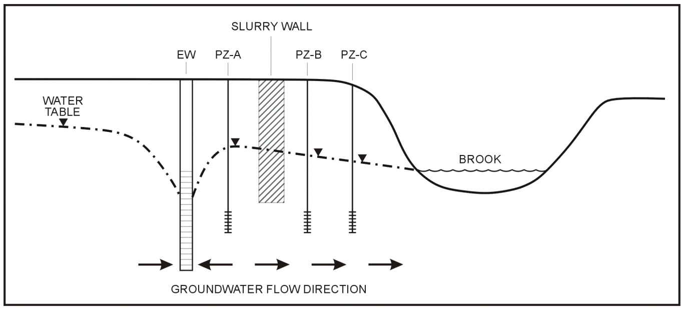


FIGURE 6-2. CAPTURE OF CONTAMINANTS UPGRADIENT OF SLURRY WALL

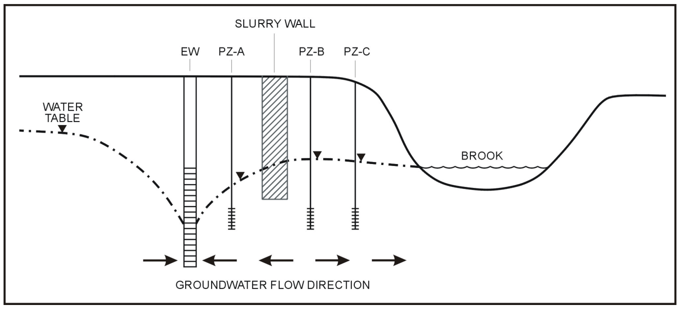


FIGURE 6-3. CAPTURE OF CONTAMINANTS UPGRADIENT OF SLURRY WALL AND PARTIAL CAPTURE OF CONTAMINANTS DOWNGRADIENT OF SLURRY WALL

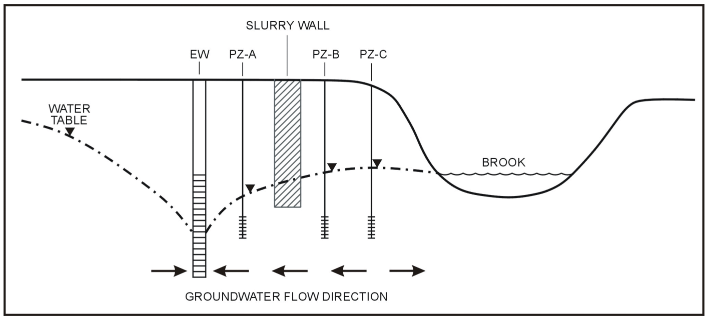


FIGURE 6-4. CAPTURE OF CONTAMINANTS UPGRADIENT AND DOWNGRADIENT OF SLURRY WALL

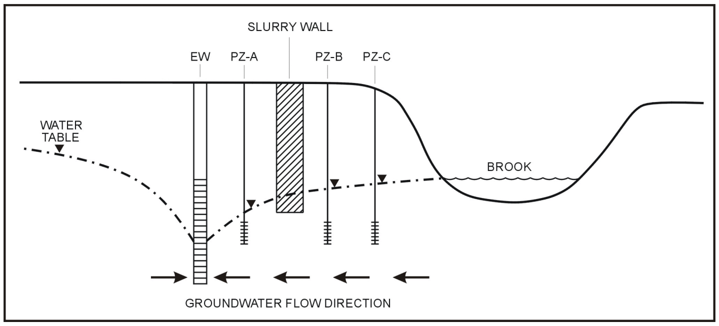
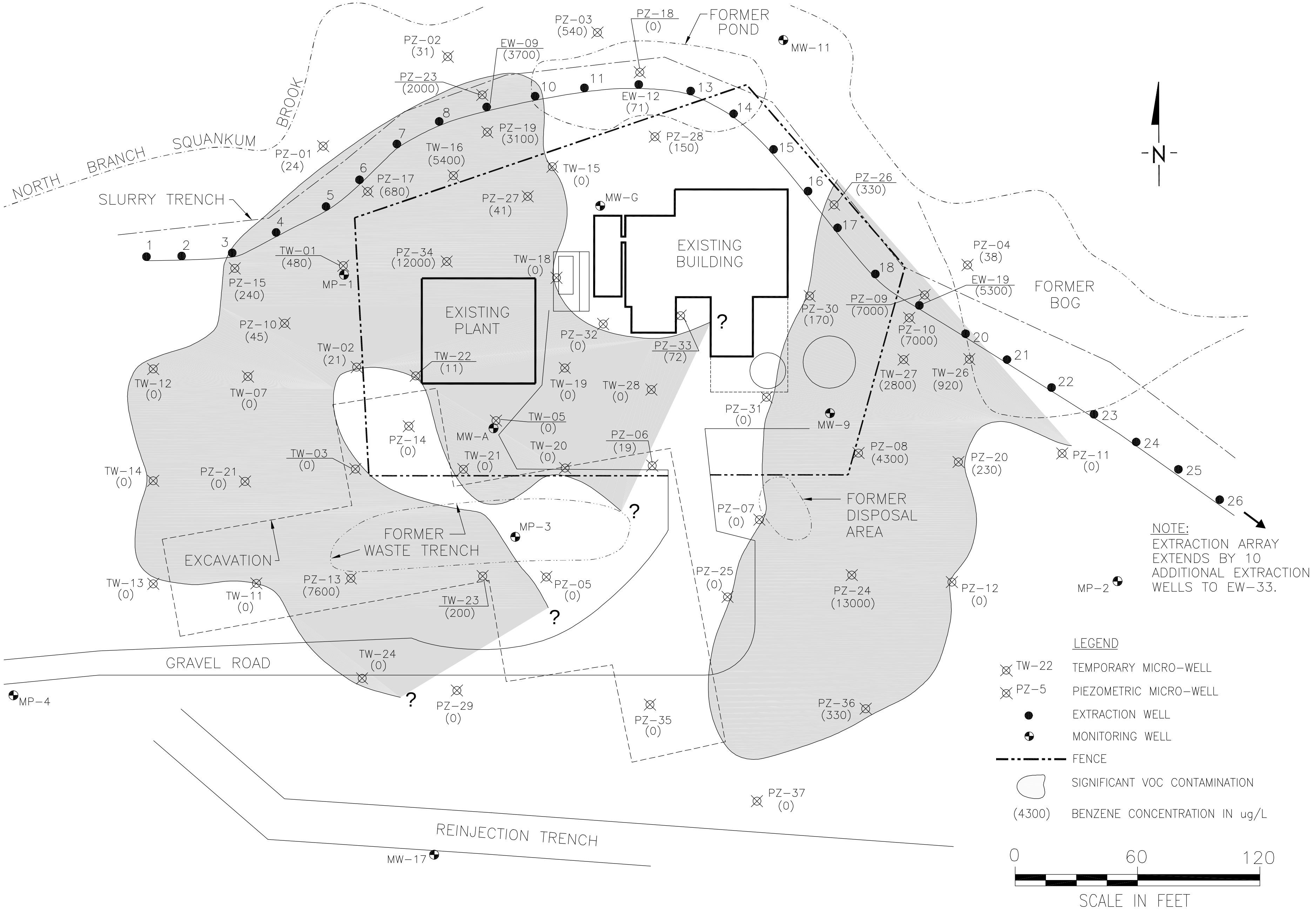


FIGURE 6-1. THE ESTIMATED EXTENT OF SIGNIFICANT VOC CONTAMINATION AS INDICATED BY DATA FROM THE DECEMBER 2001 SAMPLING EVENT AND PRELIMINARY DATA FROM THE SPRING 2002 SAMPLING EVENT.



(Note: This figure is partially based on preliminary data from the Spring 2002 sampling event conducted by the REAC's contractor. Concentration extent and magnitude may differ upon final analysis).