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September 1998

Remediation Case Studies:
Groundwater Pump and Treat (Chlorinated Solvents)

Volume 9

Federal Remediation Technologies Roundtable
<www.frtr.gov>

Prepared by the

Member Agencies of the Federal Remediation Technologies Roundtable

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Federal Remediation Technologies Roundtable

Environmental Protection Agency
Department of Defense
- U.S. Air Force
- U.S. Army
- U.S. Navy

Department of Energy
Department of Interior
National Aeronautics and Space Administration
Tennessee Valley Authority
Coast Guard

September 1998

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FOREWORD

This report is a collection of fourteen case studies of groundwater pump and treat (chlorinated solvents) projects prepared by federal agencies. The case studies, collected under the auspices of the Federal Remediation Technologies Roundtable, were undertaken to document the results and lessons learned from technology applications. They will help establish benchmark data on cost and performance which should lead to greater confidence in the selection and use of cleanup technologies.

The Roundtable was created to exchange information on site remediation technologies, and to consider cooperative efforts that could lead to a greater application of innovative technologies. Roundtable member agencies, including the U.S. Environmental Protection Agency, U.S. Department of Defense, and U.S. Department of Energy, expect to complete many site remediation projects in the near future. These agencies recognize the importance of documenting the results of these efforts, and the benefits to be realized from greater coordination.

The case study reports and abstracts are organized by technology in a multi-volume set listed below. Remediation Case Studies, Volumes 1-6, and Abstracts, Volumes 1 and 2, were published previously, and contain 54 case studies. Remediation Case Studies, Volumes 7-13, and Abstracts, Volume 3, were published in September 1998. Volumes 7-13 cover a wide variety of technologies, including groundwater pump and treat of chlorinated solvents (Volume 9). The 14 pump and treat case studies in this report include completed full-scale remediations and large-scale field demonstrations. In the future, the set will grow as agencies prepare additional case studies.

1995 Series

Volume 1: Bioremediation, EPA-542-R-95-002; March 1995; PB95-182911

Volume 2: Groundwater Treatment, EPA-542-R-95-003; March 1995; PB95-182929

Volume 3: Soil Vapor Extraction, EPA-542-R-95-004; March 1995; PB95-182937

Volume 4: Thermal Desorption, Soil Washing, and In Situ Vitrification, EPA-542-R-95-005; March 1995; PB95-182945

1997 Series

Volume 5: Bioremediation and Vitrification, EPA-542-R-97-008; July 1997; PB97-177554

Volume 6: Soil Vapor Extraction and Other In Situ Technologies, EPA-542-R-97-009; July 1997; PB97-177562

1998 Series

Volume 7: Ex Situ Soil Treatment Technologies (Bioremediation, Solvent Extraction, Thermal Desorption), EPA-542-R-98-011; September 1998

Volume 8: In Situ Soil Treatment Technologies (Soil Vapor Extraction, Thermal Processes), EPA-542-R-98-012; September 1998

1998 Series (continued)

Volume 9: Groundwater Pump and Treat (Chlorinated Solvents), EPA-542-R-98-013; September 1998

Volume 10: Groundwater Pump and Treat (Nonchlorinated Contaminants), EPA-542-R-98-014; September 1998

Volume 11: Innovative Groundwater Treatment Technologies, EPA-542-R-98-015; September 1998

Volume 12: On-Site Incineration, EPA-542-R-98-016; September 1998

Volume 13: Debris and Surface Cleaning Technologies, and Other Miscellaneous Technologies, EPA-542-R-98-017; September 1998

Abstracts

Volume 1: EPA-542-R-95-001; March 1995; PB95-201711

Volume 2: EPA-542-R-97-010; July 1997; PB97-177570

Volume 3: EPA-542-R-98-010; September 1998

Accessing Case Studies

The case studies and case study abstracts are available on the Internet through the Federal Remediation Technologies Roundtable web site at: http://www.frtr.gov. The Roundtable web site provides links to individual agency web sites, and includes a search function. The search function allows users to complete a key word (pick list) search of all the case studies on the web site, and includes pick lists for media treated, contaminant types, and primary and supplemental technology types. The search function provides users with basic information about the case studies, and allows them to view or download abstracts and case studies that meet their requirements.

Users are encouraged to download abstracts and case studies from the Roundtable web site. Some of the case studies are also available on individual agency web sites, such as for the Department of Energy.

In addition, a limited number of hard copies are available free of charge by mail from NCEPI (allow 4-6 weeks for delivery), at the following address:

U.S. EPA/National Center for Environmental Publications and Information (NCEPI)
P.O. Box 42419
Cincinnati, OH 45242
Phone: (513) 489-8190 or
(800) 490-9198
Fax: (513) 489-8695

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INTRODUCTION

Increasing the cost effectiveness of site remediation is a national priority. The selection and use of more cost-effective remedies requires better access to data on the performance and cost of technologies used in the field. To make data more widely available, member agencies of the Federal Remediation Technologies Roundtable (Roundtable) are working jointly to publish case studies of full-scale remediation and demonstration projects. Previously, the Roundtable published a six-volume series of case study reports. At this time, the Roundtable is publishing seven additional volumes of case study reports, primarily focused on soil and groundwater cleanup.

The case studies were developed by the U.S. Environmental Protection Agency (EPA), the U.S. Department of Defense (DoD), and the U.S. Department of Energy (DOE). The case studies were prepared based on recommended terminology and procedures agreed to by the agencies. These procedures are summarized in the Guide to Documenting and Managing Cost and Performance Information for Remediation Projects (EPA 542-B-98-007; October 1998). (The October 1998 guide supersedes the original Guide to Documenting Cost and Performance for Remediation Projects, published in March 1995.)

The case studies present available cost and performance information for full-scale remediation efforts and several large-scale demonstration projects. They are meant to serve as primary reference sources, and contain information on site background and setting, contaminants and media treated, technology, cost and performance, and points of contact for the technology application. The studies contain varying levels of detail, reflecting the differences in the availability of data and information. Because full-scale cleanup efforts are not conducted primarily for the purpose of technology evaluation, data on technology cost and performance may be limited.

The case studies in this volume describe 14 pump and treat applications used to remediate contaminated groundwater, including 11 applications used to remediate contaminated groundwater, two applications used only to contain groundwater, and one application that was an interim action to recover free product. For all 14 applications, groundwater was contaminated with chlorinated solvents such as tetrachloroethene (PCE), trichloroethene (TCE), dichloroethene (DCE), and vinyl chloride. The quantity of groundwater treated in these applications ranged from 13 to 4,900 million gallons, and project durations ranged from one to nine years. Many of these applications are ongoing, and the case studies are interim reports about these applications.

Table 1 provides a summary including information on technology used, contaminants and media treated, and project duration for the 14 pump and treat projects in this volume. This table also provides highlights about each application. Table 2 summarizes cost data, including information on quantity of media treated and quantity of contaminant removed. In addition, Table 2 shows a calculated unit cost for some projects, and identifies key factors potentially affecting technology cost. (The column showing the calculated unit costs for treatment provides a dollar value per quantity of groundwater treated and contaminant removed, as appropriate.) Cost data are shown as reported in the case studies and have not been adjusted for inflation to a common year basis. The costs should be assumed to be dollars for the time period that the project was in progress (shown on Table 1 as project duration).

While a summary of project costs is useful, it may be difficult to compare costs for different projects because of unique site-specific factors. However, by including a recommended reporting format, the Roundtable is working to standardize the reporting of costs to make data comparable across projects. In addition, the Roundtable is working to capture information in case study reports that identify and describe the primary factors that affect cost and performance of a given technology. Key factors that potentially affect project costs for pump and treat applications include economies of scale, concentration levels in contaminated media, required cleanup levels, completion schedules, matrix characteristics such as soil classification, clay content and/or particle size distribution, hydraulic conductivity, pH, depth and thickness of zone of interest, total organic carbon, oil and grease or total petroleum hydrocarbons, presence of NAPLs, and other site conditions.

Table 1. Summary of Remediation Case Studies: Groundwater Pump and Treat (Chlorinated Solvents)

Site Name, State (Technology)	Principal Contaminants*						Media (Quantity Treated**)	Project Duration	Highlights
	Chlorinated Solvents	BTEX and/or TPH	PAHs	Pesticides/Herbicides	Explosives	Metals			
Des Moines TCE Superfund Site, OU 1, IA (Pump and Treat with Air Stripping)	●						Groundwater (4,900 million gallons)	Status: Ongoing Report Covers: 12/87 - 10/96	Met goals for off-site plume within two years of operation; nearly five billion gallons treated
Former Firestone Facility Superfund Site, CA (Pump and Treat with Air Stripping, Carbon Adsorption, and Oil/Water Separation)	●						Groundwater (1,800 million gallons)	2/86 - 11/92	Met goals within seven years of operation; site had relatively high hydraulic conductivity and was located near high-volume agricultural wells
JMT Facility RCRA Site (formerly Black & Decker RCRA Site), NY (Pump and Treat with Air Stripping)	●						Groundwater (50.1 million gallons)	Status: Ongoing Report Covers: 5/88 - 12/97	RCRA corrective action site with relatively low groundwater flow; greater than 90% reduction in average concentrations of contaminants
Keefe Environmental Services Superfund Site, NH (Pump and Treat with Air Stripping and Coagulation/Flocculation)	●						Groundwater (46 million gallons)	Status: Ongoing Report Covers: 4/93 - 5/97	Performed optimization study after two years of operation; relatively low groundwater flow
Lawrence Livermore National Laboratory (LLNL) Site 300 - General Services Area (GSA) Operable Unit, CA (Pump and Treat with Air Stripping and Carbon Adsorption; Soil Vapor Extraction)	●						Groundwater (93.8 million gallons)	Status: Ongoing Report Covers: 6/91 - 7/97	Combined use of groundwater pump and treat and SVE to remediate TCE and DNAPLs
Mystery Bridge at Hwy 20 Superfund Site, Dow/DSI Facility - Volatile Halogenated Organic (VHO) Plume, WY (Pump and Treat with Air Stripping; Soil Vapor Extraction)	●						Groundwater (192.8 million gallons)	Status: Ongoing Report Covers: 3/94 - 10/97	Remedial strategy includes use of pump and treat for the on-site plume and natural attenuation for the off-site plume

Table 1. Summary of Remediation Case Studies: Groundwater Pump and Treat (Chlorinated Solvents) (continued)

Site Name, State (Technology)	Principal Contaminants*						Media (Quantity Treated**)	Project Duration	Highlights
	Chlorinated Solvents	BTEX and/or TPH	PAHs	Pesticides/Herbicides	Explosives	Metals			
Offutt AFB, Site LF-12, NE (Pump and Treat with Air Stripping)	●						Groundwater (quantity not provided)	Not Available; System was operating in 1/97	Containment of groundwater using active pumping
Old Mill Superfund Site, OH (Pump and Treat with Air Stripping and Carbon Adsorption)	●						Groundwater (13 million gallons)	Status: Ongoing Report Covers: 9/89 - 7/97	Remediation at site with low groundwater flow; relatively small quantity of groundwater extracted
SCRDI Dixiana Superfund Site, SC (Pump and Treat with Air Stripping)	●						Groundwater (20.6 million gallons)	Status: Ongoing Report Covers: 8/92 - 3/97	Remediation at a site with complex hydrogeology, consisting of eight distinct hydrogeological units
Shaw AFB, Site OT-16B, SC (Hydraulic Containment Through Active Pumping)	●						Groundwater and Free Product	2/95 - 12/96	Groundwater containment of chlorinated solvents using active pumping
Shaw AFB, Sites SD-29 and ST-30, SC (Free Product Recovery with Air Stripping)	●	●					Groundwater and Free Product	3/95 - 2/96	Interim action to recover free product from groundwater
Solid State Circuits Superfund Site, MO (Pump and Treat with Air Stripping)	●						Groundwater (257 million gallons)	Status: Ongoing Report Covers: 1993 - 3/97	Groundwater characterized as a leaky artesian system occurring in a karst formation

Table 1. Summary of Remediation Case Studies: Groundwater Pump and Treat (Chlorinated Solvents) (continued)

Site Name, State (Technology)	Principal Contaminants*						Media (Quantity Treated**)	Project Duration	Highlights
	Chlorinated Solvents	BTEX and/or TPH	PAHs	Pesticides/Herbicides	Explosives	Metals			
Sol Lynn/Industrial Transformers Superfund Site, TX (Pump and Treat with Air Stripping, Carbon Adsorption, and Filtration)	●						Groundwater (13 million gallons)	Status: Ongoing Report Covers: 10/93 - 10/96	Contamination located in three zones at the site
Solvent Recovery Services of New England, Inc. Superfund Site, CT (Pump and Treat with Carbon Adsorption, Chemical Treatment, Filtration, and UV/Oxidation; Vertical Barrier Wall)	●					●	Groundwater (32.5 million gallons)	Status: Ongoing Report Covers: 7/95 - 6/98	UV/oxidation has been effective at treating water contaminated with pure phase contaminants, including a mix of VOCs, PCBs, and metals

* Principal contaminants are one or more specific constituents within the groups shown that were identified during site investigations.
** Quantity treated is the amount of groundwater extracted and treated above ground.

Table 2. Remediation Case Studies: Summary of Cost Data

Site Name, State (Technology)	Technology Cost ($)*	Quantity of Media Treated	Quantity of Contaminant Removed	Calculated Cost for Treatment**	Key Factors Potentially Affecting Technology Costs***
Des Moines TCE Superfund Site, OU 1, IA (Pump and Treat with Air Stripping)	Total: $2,596,000 C: $1,587,000 O: $1,009,000	4,900 million gallons	30,000 lbs	$0.53/1,000 gals GW $80/lb of cont.	Unit cost reflects economies-of-scale for treatment of large volume of extracted groundwater
Former Firestone Facility Superfund Site, CA (Pump and Treat with Air Stripping, Carbon Adsorption, and Oil/Water Separation)	Total: $12,884,813 C: $4,133,543 O: $8,751,270	1,800 million gallons	496 lbs	$7/1,000 gals GW $26,000/lb of cont.	Site operators frequently adjusted operation of extraction system to maximize contaminant removal; site had complex hydrogeology
JMT Facility RCRA Site (formerly Black & Decker RCRA Site), NY (Pump and Treat with Air Stripping)	Total: $2,163,000 C: $879,000 O: $1,284,000	50.1 million gallons	842 lbs	$47/1,000 gals GW $2,569/lb of cont.	Two modifications to treatment system (including enclosure for treatment system) increased capital costs by 35% over original estimate
Keefe Environmental Services Superfund Site, NH (Pump and Treat with Air Stripping and Coagulation/Flocculation)	Total: $2,408,000 C: $1,582,539 O: $826,000	46 million gallons	68 lbs	$52/1,000 gals GW $35,000/lb of cont.	As a result of an optimization study, replaced two extraction wells to increase removal of contaminant mass
Lawrence Livermore National Laboratory (LLNL) Site 300 - General Services Area (GSA) Operable Unit, CA (Pump and Treat with Air Stripping and Carbon Adsorption; Soil Vapor Extraction)	Total: $36,600,000 (costs not provided separately for P&T and SVE)	93.8 million gallons GW 399,000 ft^3 soil vapor	22 lbs (P&T) 67 lbs (SVE)	Not calculated	Costs relatively high because site uses three systems (two groundwater and one soil) to treat contaminated media
Mystery Bridge at Hwy 20 Superfund Site, Dow/DSI Facility - Volatile Halogenated Organic (VHO) Plume, WY (Pump and Treat with Air Stripping; Soil Vapor Extraction)	Total: $918,000 C: $305,000 O: $613,000	192.8 million gallons	21 lbs	$5.65/1,000 gals GW $44,000/lb of cont.	Relatively low concentrations in groundwater (20-70 ug/L) lead to relatively high unit costs per pound of contaminant removed
Offutt AFB, Site LF-12, NE (Pump and Treat with Air Stripping)	Total (not provided) C: $540,000 O: $20,000/year (average)	Not provided	12.81 gals	Not calculated	Information not provided

Table 2. Remediation Case Studies: Summary of Cost Data (continued)

Site Name, State (Technology)	Technology Cost ($)*	Quantity of Media Treated	Quantity of Contaminant Removed	Calculated Cost for Treatment**	Key Factors Potentially Affecting Technology Costs***
Old Mill Superfund Site, OH (Pump and Treat with Air Stripping and Carbon Adsorption)	Total: $3,236,000 C: $1,596,000 O: $1,640,000	13 million gallons	124 lbs	$250/1,000 gals GW $26,100/lb of cont.	Modifications to improve plume containment increased capital costs by 22%
SCRDI Dixiana Superfund Site, SC (Pump and Treat with Air Stripping)	Total: $1,439,700 (EPA-lead portion) C: $1,189,700 O: $250,000	20.6 million gallons	7 lbs	$464/1,000 gals GW $200,000/lb of cont.	Complex hydrogeology; major modifications were made by PRP to modify system used during EPA-lead portion of application
Shaw AFB, Site OT-16B, SC (Hydraulic Containment Through Active Pumping)	Total: $2,010,000 C: $1,960,000 O: $50,000	Not provided	40.5 gals	Total: $50,000/gal of cont. O&M (average): $15.12/gal of cont.	Containment system was operating efficiently and was meeting its operational objectives
Shaw AFB, Sites SD-29 and ST-30, SC (Free Product Recovery with Air Stripping)	Total (not provided) C: $394,000 (for SD-29) O: $17,000 (cum. for SD-29 and ST-30)	Not provided	102 gals	O&M (average): $166/gal of cont.	To reduce operating costs, passive skimmer bailers were installed in recovery wells
Solid State Circuits Superfund Site, MO (Pump and Treat with Air Stripping)	Total: $2,510,400 C: $893,700 O: $1,616,700	257 million gallons	2,754 lbs	$10/1,000 gals GW $913/lb of cont.	Capital costs do not include costs for installation of four deeper wells, which were installed as part of the RI/FS and not available as a separate cost element
Sol Lynn/Industrial Transformers Superfund Site, TX (Pump and Treat with Air Stripping, Carbon Adsorption, and Filtration)	Total: $2,547,387 C: $2,104,910 O: $442,477	13 million gallons	4,960 lbs	$196/1,000 gals GW $514/lb of cont.	Site characterization performed during RI did not identify extent of contamination and system had to be modified after the remedial design was completed

Table 2. Remediation Case Studies: Summary of Cost Data (continued)

Site Name, State (Technology)	Technology Cost ($)*	Quantity of Media Treated	Quantity of Contaminant Removed	Calculated Cost for Treatment**	Key Factors Potentially Affecting Technology Costs***
Solvent Recovery Services of New England, Inc. Superfund Site, CT (Pump and Treat with Carbon Adsorption, Chemical Treatment, Filtration, and UV/Oxidation; Vertical Barrier Wall)	Total: $5,556,900 C: $4,339,600 O: $1,217,300	32.5 million gallons	4,344 lbs	$265/1,000 gals GW $1,280/lb of cont.	Presence of DNAPLs contributed to elevated costs

Technology Cost*
C = Capital costs
O = Operation and maintenance (O&M) costs

Calculated Cost for Treatment**
Calculated based on sum of capital and O&M costs, divided by quantity treated or removed. Calculated costs shown as "Not Calculated" if an estimate of costs or quantity treated or removed was not available. Unit costs calculated based on both quantity of media treated and quantity of contaminant removed, as appropriate.

*** For full-scale remediation projects, this identifies factors affecting actual technology costs. For demonstration-scale projects, this identifies generic factors which would affect costs for a future application using this technology.

Groundwater Pump and Treat (Chlorinated Solvents)

Case Studies

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Pump and Treat of Contaminated Groundwater at the Des Moines TCE Superfund Site, OU 1, Des Moines, Iowa

Pump and Treat of Contaminated Groundwater at the Des Moines TCE Superfund Site, OU 1, Des Moines, Iowa

<table>
<tr><td>Site Name:
Des Moines TCE Superfund Site, Operable Unit 1 (OU 1)</td><td rowspan="2">Contaminants:
Chlorinated solvents
- Maximum concentrations detected during 1985 RI included TCE (8,467 ug/L), 1,2-DCE (2,000 ug/L), and vinyl chloride (95 ug/L)</td><td>Period of Operation:
Status: Ongoing
Report covers: 12/87 - 10/96</td></tr>
<tr><td>Location:
Des Moines, Iowa</td><td>Cleanup Type:
Full-scale cleanup (interim results)</td></tr>
<tr><td>Vendor:
Tonka Equipment Company</td><td rowspan="2">Technology:
Pump and Treat
- Groundwater is extracted using 7 wells, located on site, at an average total pumping rate of 1,041 gpm
- Extracted groundwater is treated with air stripping and discharged to a surface water under a NPDES permit</td><td>Cleanup Authority:
CERCLA Remedial
- ROD Date: 7/21/86</td></tr>
<tr><td>Additional Contacts:
None</td><td>EPA Point of Contact:
Mary Peterson, RPM
U.S. EPA Region 7
726 Minnesota Avenue
Kansas City, KS 66101
(913) 551-7882</td></tr>
<tr><td>Waste Source:
Land application of waste sludges, including use of waste sludges on road surfaces for dust control</td><td colspan="2" rowspan="2">Type/Quantity of Media Treated:
Groundwater
- 4,900 million gallons treated as of December 1996
- DNAPL suspected in groundwater at this site
- Groundwater is found at 10-25 ft bgs
- Extraction wells are located in 1 aquifer, which is influenced by a nearby surface water
- Hydraulic conductivity reported as 535 ft/day</td></tr>
<tr><td>Purpose/Significance of Application:
Met goals for off-site plume within two years of operation; nearly five billion gallons treated.</td></tr>
<tr><td colspan="3">Regulatory Requirements/Cleanup Goals:
- The cleanup goal for this site is to reduce the TCE concentration in groundwater on the west side of the Raccoon River to 5 ug/L or less for four consecutive months. At this time, on-site goals have not been specified.
- As a secondary goal, the remedial system is designed to create an inward gradient toward the site to contain and treat the on-site plume.</td></tr>
<tr><td colspan="3">Results:
- The pump and treat system met the cleanup goal for TCE within two years of system operation, and an inward hydraulic gradient appears to have been achieved within the first month of operation that encompasses the entire contaminant plume. Pumping continued after that time to maintain containment and provide for potential reductions in contaminant concentrations in on-site wells. However, on-site wells continue to show concentrations of TCE at greater than 5 ug/L.
- By February 1997, the pump and treat system had removed nearly 30,000 pounds of contaminants from the groundwater.</td></tr>
<tr><td colspan="3">Cost:
- Estimated costs for pump and treat were $2,596,000 ($1,587,000 in capital and $1,009,000 in O&M), which correspond to $0.53 per 1,000 gallons of groundwater extracted and $80 per pound of contaminant removed.</td></tr>
</table>

Pump and Treat of Contaminated Groundwater at the Des Moines TCE Superfund Site, OU 1, Des Moines, Iowa (continued)

Description:
An iron foundry operated on this property from approximately 1910 until Dico Corporation purchased the property in the early 1940s. Dico manufactured metal wheels and brakes at the site from 1961 through 1993. In September 1976, testing by the DMWW and EPA detected TCE in the city's north gallery groundwater infiltration system, which served as a source of drinking water for the city. Investigations by EPA suggested that solvent sludges used on road and parking lot surfaces could be the cause of the subsurface contamination. The site was placed on the NPL in September 1983 and a ROD was signed in July 1986.

The groundwater extraction system consists of seven wells installed in the plume east of the Raccoon River on the Dico property to a depth of 40 ft. These wells were designed for full containment and partial aquifer restoration (to achieve off-site groundwater goals). Extracted groundwater is treated using an air stripper and discharged under a NPDES permit. The pump and treat system met the off-site cleanup goal for TCE within two years of system operation, and plume containment appears to have been achieved.

SITE INFORMATION

Identifying Information:

Des Moines TCE Superfund Site
Des Moines, Iowa
Operable Unit 1

CERCLIS #: IAD98060687933

ROD Date: July 21, 1986

Treatment Application:

Type of action: Remedial

Period of operation: 12/87 - Ongoing (Contaminant concentration data collected through 1996; mass removal data collected through February 1997)

Quantity of material treated during application: As of December 1996, 4.9 billion gallons of groundwater

Background

Historical Activity that Generated Contamination at the Site: Manufacturing of metal wheels and brakes, and chemical storage/ distribution.

Corresponding SIC Code: 3523 (Manufacturing of farm machinery and equipment)

Waste Management Practice That Contributed to Contamination: Use of waste sludges on road surfaces for dust control and land application of waste sludges

Location: Des Moines, Iowa

Facility Operations: [8]

- An iron foundry operated on the property from approximately 1910 until Dico Corporation purchased the property in the early 1940s.
- Dico manufactured metal wheels and brakes at the site from 1961 through 1993. Dico was purchased by Titan Wheel International, Inc. in 1993. Production at the facility ceased in 1995.
- In September 1976, testing by the DMWW and the EPA detected TCE in the City's north gallery groundwater infiltration system, which served as a source of drinking water for the city. TCE levels ranged from 200 to 450 µg/L in samples collected from the gallery.
- EPA studies conducted between April and September 1978 identified TCE contamination in the production well on the Dico property. Investigations by EPA suggested that solvent sludges used on road and parking lot surfaces could be the cause of subsurface contamination.
- In October 1978, Dico agreed to discontinue the surface application of solvent sludges. No other source control measures were undertaken.
- In 1981 and 1982, an EPA Field Investigation Team (FIT) performed an assessment and RCRA Interim Status Inspection of the Dico area. Monitoring wells were installed on site and samples collected. Quarterly sampling of these monitoring wells was initiated in 1982.
- The site was placed on the National Priorities List (NPL) in September 1983.
- In April 1984, DMWW closed the north gallery water infiltration system.
- Remedial investigation (RI) field work was conducted in 1984 and 1985.

Regulatory Context: [9]

- On July 21, 1986, EPA issued a ROD for OU1, which addresses contaminated groundwater at this site.
- A Unilateral Administrative Order was issued to Dico on July 21, 1986 designating it as the lead for remedial activities.
- Site activities are conducted under provisions of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980, as amended by the Superfund Amendments and Reauthorization Act (SARA) of 1986 §121, and the National Contingency Plan (NCP), 40 CFR 300.

SITE INFORMATION (CONT.)

Background (Cont.)

Remedy Selection [9]:
Groundwater extraction and treatment via air stripping was selected in the 1986 ROD as the remedy for this OU.

Site Logistics/Contacts

Site Management:
PRP Lead

Oversight:
U.S. EPA Region VII

Treatment System Vendor:
Tonka Equipment Company

*Indicates primary contact

Remedial Project Manager:
Mary Peterson*
U.S. EPA Region VII
726 Minnesota Avenue
Kansas City, Kansas 66101
913-551-7882

MATRIX DESCRIPTION

Matrix Identification

Type of Matrix Processed Through the Treatment System: Groundwater

Contaminant Characterization [1,2,3,4,5,6]

Primary Contaminant Groups: Halogenated volatile organic compounds (VOCs)

- Contaminants of greatest concern at the site are trichloroethylene (TCE), trans-1,2-dichloroethylene (trans-1,2-DCE), and vinyl chloride (VC).
- Maximum concentrations detected during the 1985 RI/FS include TCE (8,467 µg/L), 1,2-DCE (2,000 µg/L), and VC (95 µg/L).
- Figures 1 and 2 provide TCE concentration contour maps prepared in 1985 and 1995, respectively. The 1985 figure shows the 500 µg/L TCE contour line crossing the Raccoon River (from the Des Moines TCE site). The 1995 figure shows the 10 µg/L TCE contour line pulled back to the same side of the Raccoon River as the Des Moines TCE site.
- The contaminant plume was estimated in the 1988 Annual Performance Report to be up to 45 feet thick and cover a 130-acre area. Assuming a standard porosity of 30%, the volume of contaminated groundwater was calculated to be 512 million gallons.

MATRIX DESCRIPTION (CONT.)

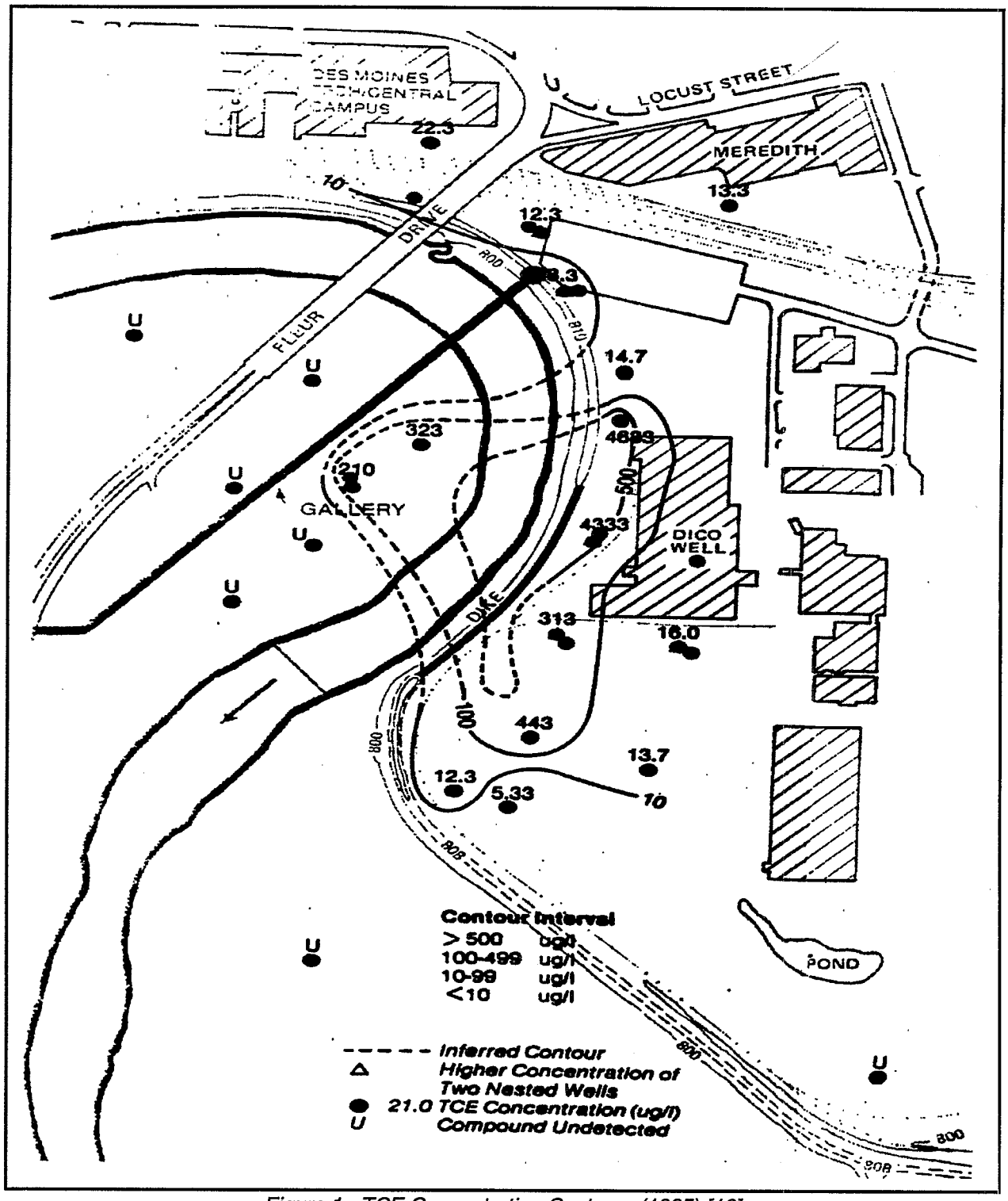

Figure 1. TCE Concentration Contours (1985) [10]

MATRIX DESCRIPTION (CONT.)

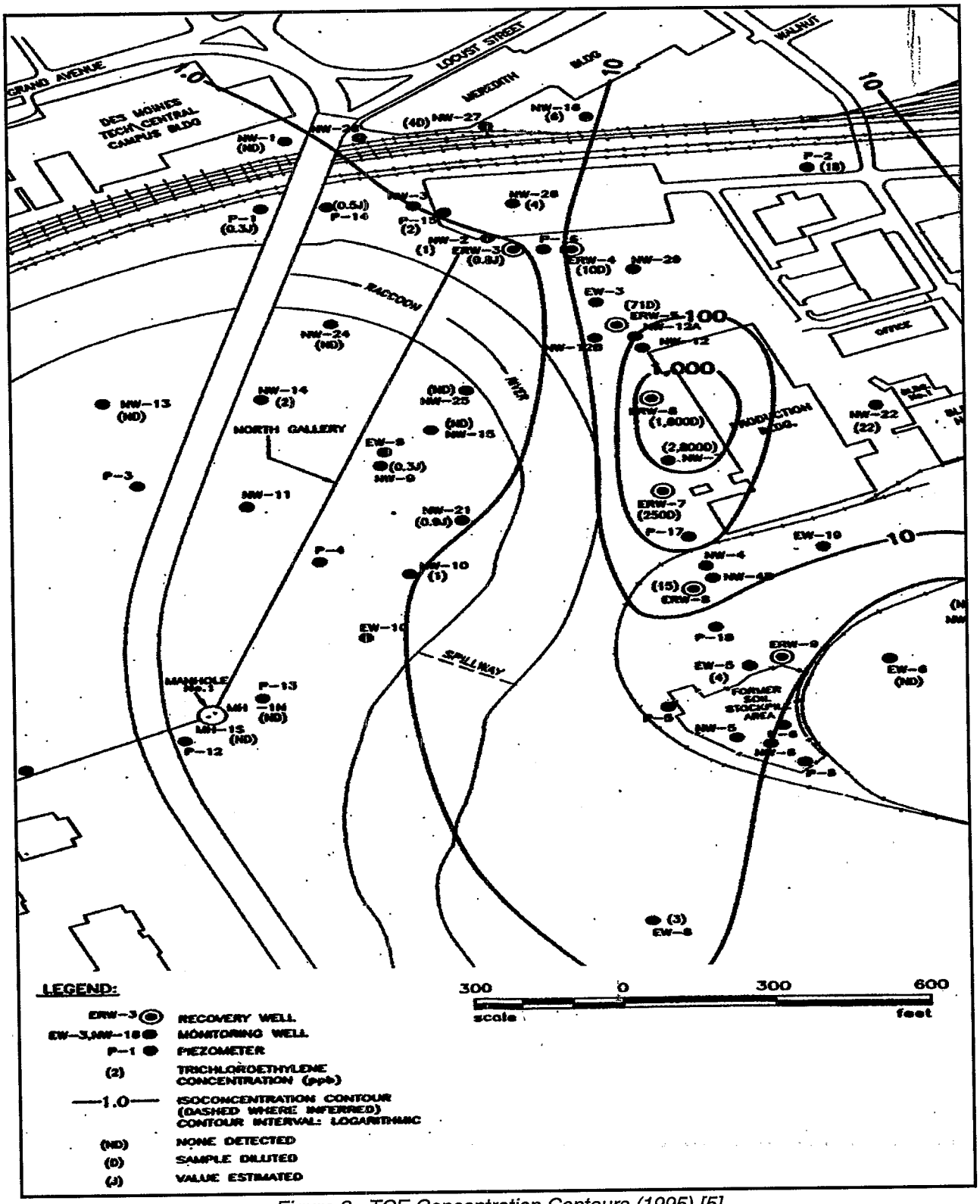

Figure 2. TCE Concentration Contours (1995) [5]

MATRIX DESCRIPTION (CONT.)

Matrix Characteristics Affecting Treatment Costs or Performance

Hydrogeology [8]:

Two distinct hydrogeologic units have been identified beneath this site.

Upper Unit	The geology of this unit consists of 40 to 60 feet of unconsolidated alluvial silt, clay, sand, and gravel overlying consolidated shale bedrock. The top 10 feet of the alluvial materials consist of silt and clay overbank deposits. The bottom 30 to 50 feet of aquifer consist of sand and gravel, which extend to the top of the shale bedrock.
Lower Unit	The shale bedrock extends over 100 feet in depth. This unit is not contaminated.

Water levels range from 10 to 25 feet below ground surface. Groundwater flow is to the southeast; however, high-volume pumping from the DMWW infiltration galleries may affect the flow direction in some areas. The Raccoon River, which flows between the site to the east and the DMWW facility to the west, can gain from or lose to the aquifer depending on water levels.

Tables 1 and 2 include technical aquifer information and technical well data. A discussion of extraction wells is included in the following section.

Table 1: Technical Aquifer Information

Unit Name	Thickness (ft)	Conductivity (ft/day)	Average Velocity (ft/day)	Flow Direction
Upper Aquifer	40-60	535	0.1-0.8	South and Southeast

Source: [9]

TREATMENT SYSTEM DESCRIPTION

Primary Treatment Technology

Pump and treat with air stripping

Supplemental Treatment Technology

None

TREATMENT SYSTEM DESCRIPTION (CONT.)

System Description and Operation

Table 2: Technical Well Data [7]

Well Name	Unit Name	Depth (ft)	Design Yield (gal/day)
ERW-3	Upper Aquifer	40	230,400
ERW-4	Upper Aquifer	40	201,600
ERW-5	Upper Aquifer	40	187,200
ERW-6	Upper Aquifer	40	230,400
ERW-7	Upper Aquifer	40	302,400
ERW-8	Upper Aquifer	40	302,400
ERW-9	Upper Aquifer	40	252,000

Note: Overall the average total extraction rate is approximately 1.5 million gpd, based on the volume of water pumped since operations began.

System Description [7,10]

- The groundwater extraction system consists of seven wells installed in the plume east of the Raccoon River on the Dico property. Extraction wells are constructed of 12-inch diameter galvanized steel pipe with seven feet of screen placed near the bottom of the sand and gravel aquifer. The purpose of the design was to achieve off-site groundwater goals and to capture the on-site plume to eliminate further off-site contamination. The two-dimensional Modflow model was used in the design process.

- The extraction system was designed for full containment and partial aquifer restoration. Extraction wells were located within the heart of the plume, and hydraulic manipulation of the groundwater gradient was used to contain the contaminant plume.

- Groundwater is withdrawn from the aquifer, treated through an air stripper, and discharged to the Raccoon River under a National Pollution Discharge Elimination System (NPDES) permit. During the nine years of operation, the system has achieved an average extraction rate of 1,000 gpm.

- The treatment system consists of a 39-foot tall stainless steel tower with an internal diameter of 7½ feet. Countercurrent flows of air and groundwater are sent through the tower at a ratio of 60 to 1, respectively. The tower is designed for a maximum flow of 1,850 gpm for a minimum 96% removal efficiency. Treated groundwater is discharged to the Raccoon River through an 18-inch sewer outfall.

System Operation [1,2,3,4,5,6]

- A system of 29 on- and off-site monitoring wells is used to measure changes in groundwater concentrations on a quarterly basis and water levels on a monthly basis.

- The average system extraction rate was 1,270 gpm from start-up until February 1990, 1,000 gpm from February 1990 through January 1995, and 800 gpm since January 1995. The reduction in extraction rates has been due to wells clogging from iron corrosion. Hydraulic containment was still achieved at the reduced extraction rates. The overall pumping history is listed below:

Year	Average Gallons/Year Pumped
1988-1989	667,512,000
1990-1994	525,600,000
1995-1996	420,480,000

TREATMENT SYSTEM DESCRIPTION (CONT.)

System Description and Operation (Cont.)

- From December 1987 through December 1996, the system has been operational approximately 95% of the time. Downtime has been due to routine maintenance activities.
- Iron corrosion resulted in severe plugging of the air stripping media in September 1988. Spherical shaped media were replaced with chandelier type media in January 1991.
- An in-line pump was installed in June 1991 to provide a continuous injection of organophosphanic acid and biological growth inhibitor (chlorine) into the system. This reduced iron corrosion and bio-fouling problems.
- By 1993, iron encrustation and corrosion caused various problems with the extraction system. Wells ERW-5 and ERW-7 were redeveloped, and ERW-9 was completely taken out of service. Redevelopment of wells ERW-5 and ERW-7 flushed corrosion and iron build-up from the wells and re-opened screened intervals to improve water flow.

Operating Parameters Affecting Treatment Cost or Performance

Table 3 presents the major operating parameters affecting cost or performance for this technology and the values measured for each.

Table 3: Performance Parameters

Parameter	Value
Average Pump Rate	1,041 gpm
Performance Standard (effluent)	1. 96% removal efficiency 2. NPDES effluent limitations: TCE 80.7 µg/L PCE 8.85 µg/L *trans*-1,2-DCE 135,000 µg/L VC 43.5 µg/L
Remedial Goal (aquifer)	5 µg/L TCE (off-site only)

Source: [1, 2, 3, 4, 5, 6, 9]

Timeline

Table 4 presents a timeline for this remedial project.

Table 4: Project Timeline

Start Date	End Date	Activity
7/86	---	ROD and UAO issued
10/86	3/87	Remedial design performed
9/87	12/87	Remedial construction performed
12/87	ongoing	Operation of remedial system and quarterly remedial monitoring
6/91	---	Installation of organophosphanic acid and chlorine pumps
5/92	---	Final inspection of groundwater extraction and treatment system by EPA
6/93	10/93	Redevelopment of wells ERW-5, 7, and 9

Source: [7]

TREATMENT SYSTEM PERFORMANCE

Cleanup Goals/Standards

The cleanup goal for this site is to reduce the TCE concentration in groundwater on the west side of Raccoon River (opposite the facility) to 5 µg/L or less for four consecutive months. This goal must be met in all monitoring wells located on the west side of Raccoon River. At this time, on-site goals have not been specified [9].

Treatment Performance Goals

- The groundwater treatment system is required to remove, at a minimum, 96% of the influent TCE concentration [7].
- Effluent discharged from the treatment system must meet surface water criteria for the Raccoon River. The NPDES permit limits are included in Table 3 [7].
- As a secondary goal, the remedial system is designed to create an inward gradient toward the site to contain and treat the on-site plume [9].

Performance Data Assessment

For this report, total contaminant concentration includes TCE, trans-1,2-DCE, and VC concentrations.

- The first goal of the remedial system is aquifer restoration on the west side of Raccoon River. Based on 1989 sampling data from all off-site monitoring wells, the system appears to have achieved this goal within the first two years [3].
- The secondary goal of the treatment system is to capture and treat the on-site plume to prevent future off-site contamination. Figure 3 depicts groundwater elevation contours measured in October 1996. The figure shows that groundwater elevations closest to the source areas are approximately 1 foot lower than at the outer edges of the plume [6]. Groundwater levels have been measured monthly during the remedial action. Based on data provided in the 1988 Annual Performance Report, an inward hydraulic gradient appears to have been achieved within the first month of operation. The area affected by the inward hydraulic gradient encompasses the entire contaminant plume [1].
- Figure 4 depicts the TCE concentrations detected in off-site wells NW-15 and NW-21 from 1987 to 1996. These are the off-site wells closest to the source area and have historically had the highest off-site TCE concentrations. TCE concentration in wells NW-15 and NW-21 dropped from levels as high as 12 µg/L and 25 µg/L, respectively, to below the goal of 5 µg/L by the December 1989 sampling event.
- Figure 5 illustrates changes in average contaminant concentrations in the groundwater over time. This figure depicts total concentrations of TCE, trans-1,2-DCE and VC, as well as TCE concentrations alone. All monitoring wells, on-site and off-site, were used for this figure. Average total contaminant concentrations declined steadily from 1987 through October 1996. Average TCE concentrations have declined from 45 µg/L to less than 5 µg/L.
- Figure 6 depicts the concentration of TCE detected in on-site wells ERW-6, ERW-7, and NW-7. These wells are located in the most contaminated part of the plume. The maximum concentrations of contaminants in the groundwater during the October 1996 sampling event were 2,400 µg/L (TCE), 150 µg/L (1,2-DCE), and 100 µg/L (VC). These concentrations were found in well ERW-6, which is in the center of the plume.
- By December 1996, a total of 4.9 billion gallons of groundwater were treated [6]. Taking into account the life of the system and a 95% operational rate, the average treatment rate was 1,000 gpm.

TREATMENT SYSTEM PERFORMANCE (CONT.)

Performance Data Assessment (Cont.)

- Figure 7 presents data on contaminant removal from 1988 to 1997. By February 1997, the P&T system had removed nearly 30,000 pounds of contaminant mass from the groundwater. The mass flux rate declined from 62 lbs/day to 16 lbs/day within the first 6 months of operation. During the last 8 years of operation, the mass flux rate declined from 16 lbs/day to less than 2 lbs/day. The decrease in mass flux can be attributed to a decrease in contaminant concentrations in the influent to the treatment system as well as a reduction in the volume of groundwater treated.
- At the 6-month sampling event, the influent concentration to the treatment system was 1,100 µg/L and the average groundwater concentration was 70 µg/L.

Performance Data Completeness

- Data are available for concentrations of contaminants in the groundwater on a quarterly basis. Data for influent and effluent concentrations from the treatment system are available on a weekly basis.
- Contaminant concentrations detected during annual sampling events were used for analyses performed in this report. As of the date of this report, data are available for the 1987, 1988, 1989, 1990, 1991, 1992, 1993, 1995, and 1996 annual sampling events. References 1-6 contain annual sampling data.
- In Figure 5, a geometric mean was used for average groundwater concentrations detected in 13 monitoring wells and 6 extraction wells located within the original plume area. It should be noted that for the October 1996 sampling event, data from 4 of the 13 monitoring wells was not available.
- Contaminant mass removal was determined using analytical results from influent samples, along with flow rate data. Quarterly data were used for the first year to better depict the rapidly changing mass flux rate.
- Data from all monitoring and extraction wells within the original plume were used to calculate the mean concentration. When concentrations below detection limits were encountered, half of the detection limit was used in the calculation of the mean.

Performance Data Quality

The QA/QC program used throughout the remedial action met the EPA and the State of Iowa requirements. All monitoring was performed using EPA-approved methods, and the vendor did not note any exceptions to the QA/QC protocols.

TREATMENT SYSTEM PERFORMANCE (CONT.)

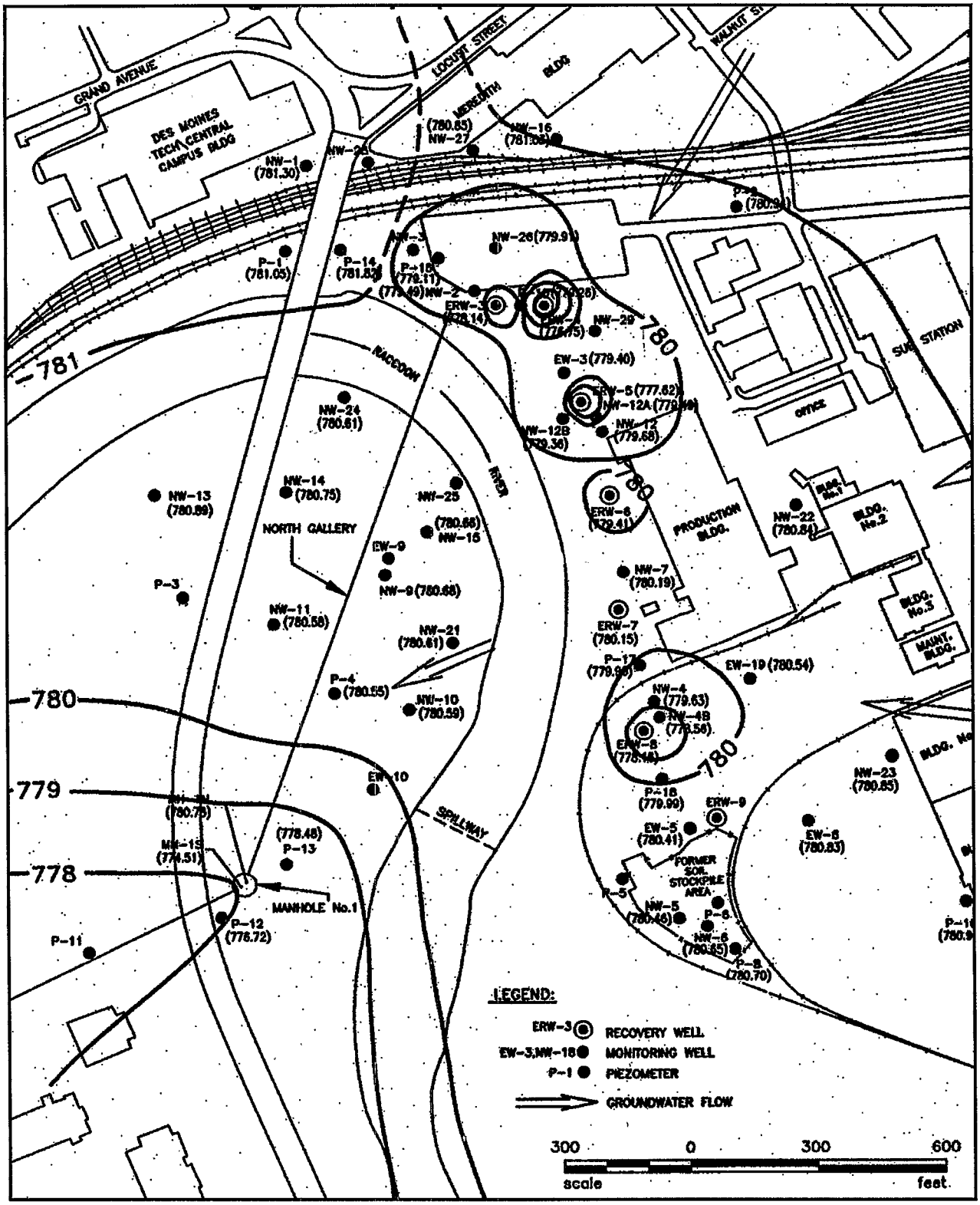

Figure 3. Groundwater Elevation Contours (1996) [6]

TREATMENT SYSTEM PERFORMANCE (CONT.)

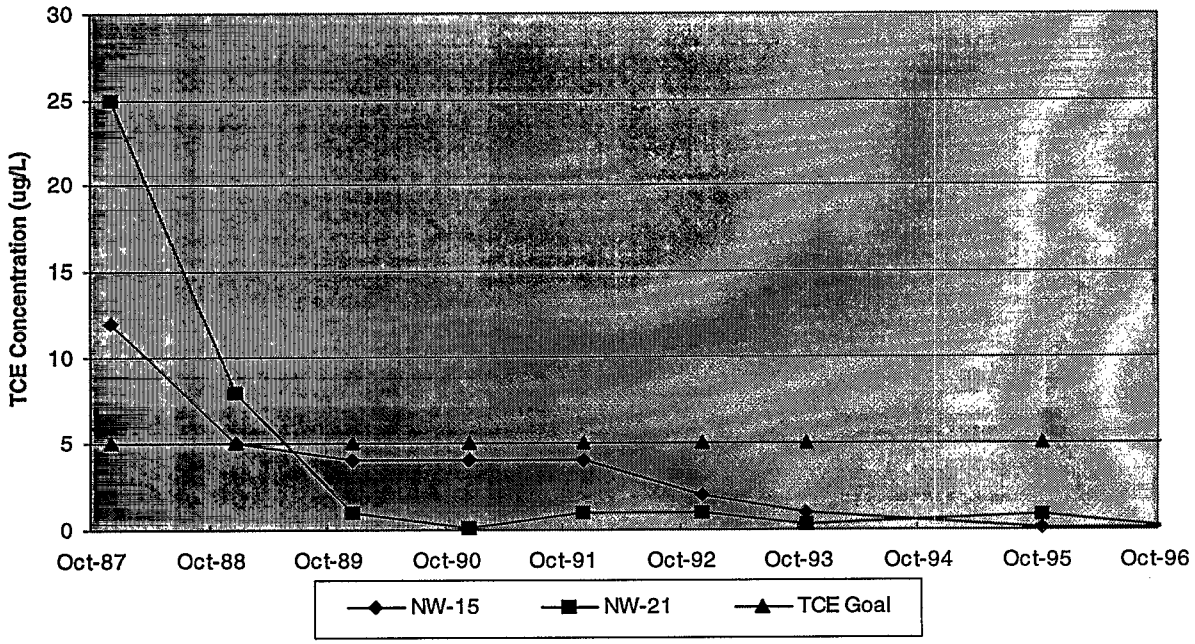

Figure 4. TCE Concentration for Two Off-Site Monitoring Wells [1-6]

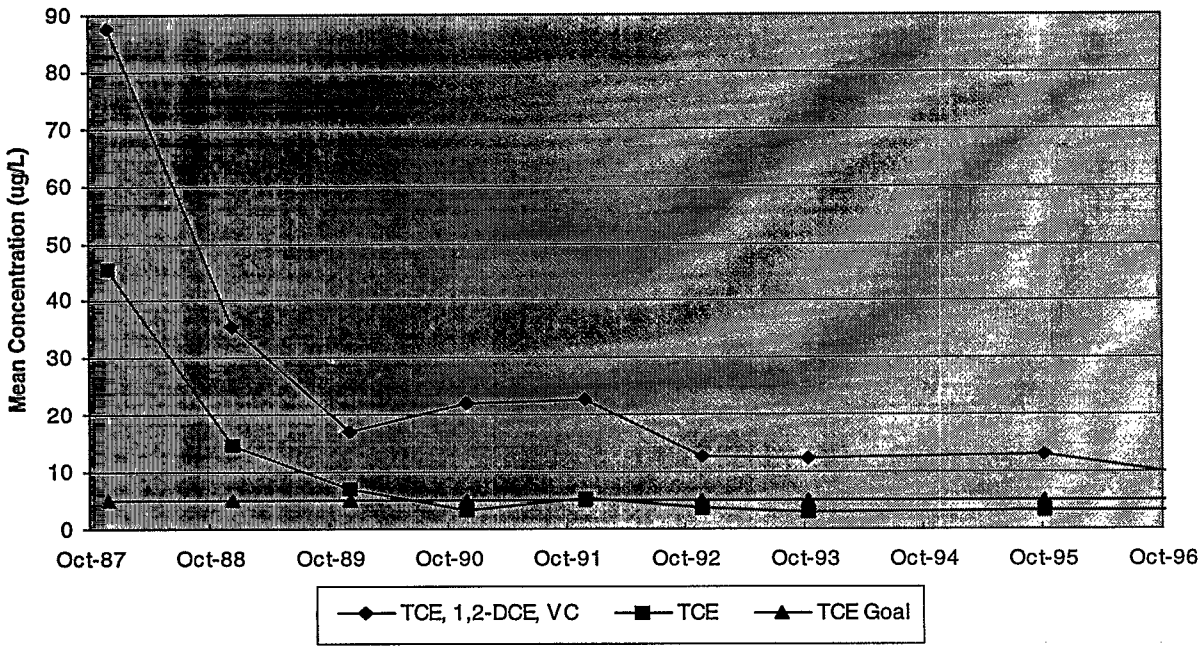

Figure 5. Geometric Mean of Total Contaminants and TCE [1-6]

TREATMENT SYSTEM PERFORMANCE (CONT.)

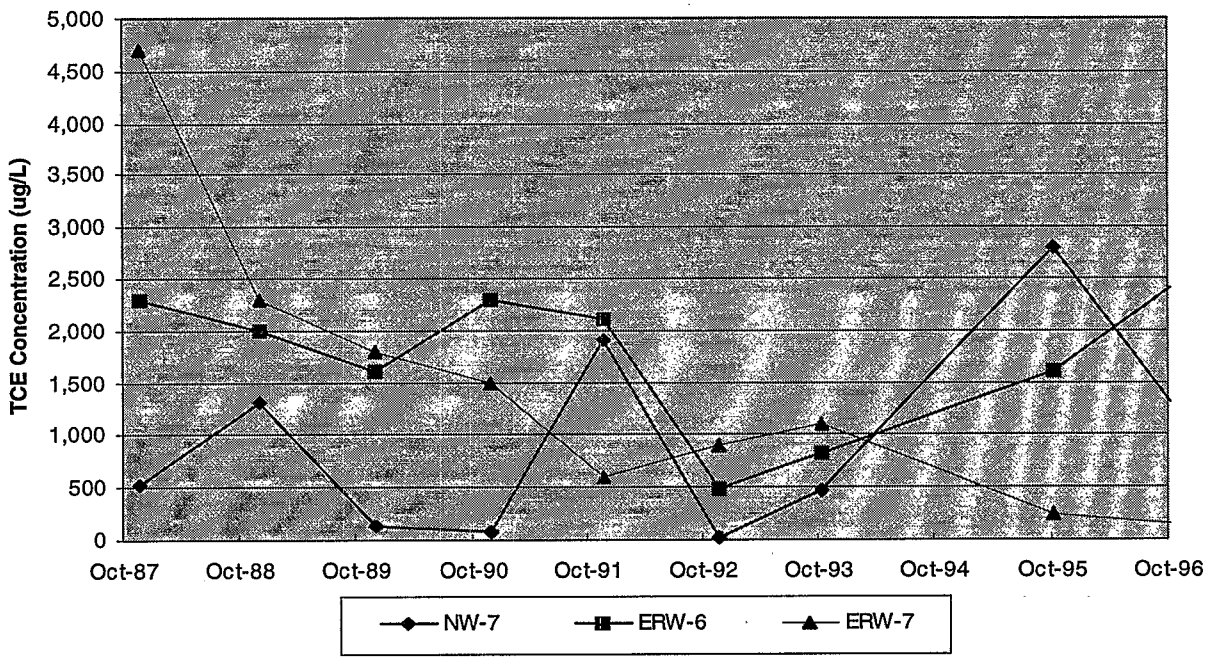

Figure 6. On-Site Wells with Highest TCE Concentrations [1-6]

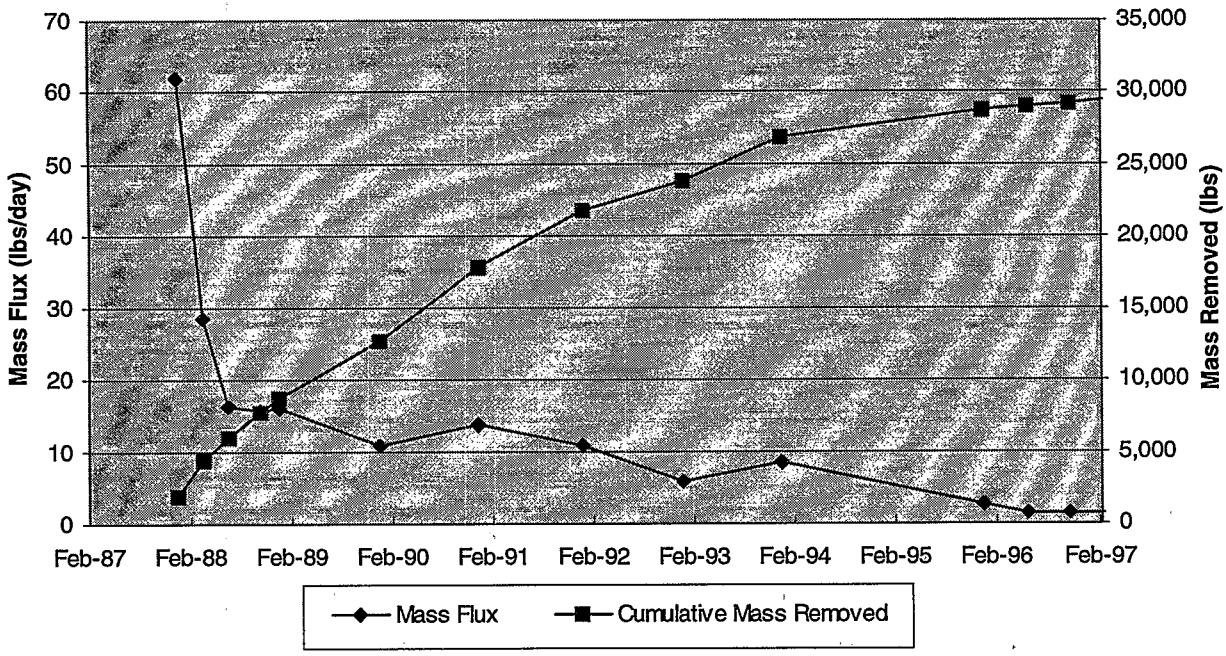

Figure 7. Mass Flux and Total Contaminants Removed [1-6]

TREATMENT SYSTEM COST

Procurement Process

Dico Corporation contracted with Eckenfelder, Inc. to construct and operate the treatment system. Dico maintains responsibility for operations and maintenance of the treatment system.

Cost Analysis

All costs for investigation, design, construction and operation of the treatment system at this site were borne by Dico Corporation.

Capital Costs [14]

Remedial Construction	
Site Management	$639,962
Site Work	$10,934
Supplies	$28,118
Piping	$463,399
Monitoring Wells	$63,189
Extraction Wells	$231,541
Air Monitoring	$2,046
Air Stripper	$103,807
Analyses	$44,287
Total Remedial Construction	**$1,587,283**

Operating Costs [14,15]

Operation and Maintenance	
Labor	$48,438
Utilities	$435,946
Analyses	$141,279
Maintenance	$383,471
Cumulative Operating Expenses through 1996	**$1,009,134**

Other Costs

Remedial Design	
Air Stripper and Manhole	$271,717
Engineering Work	$87,137
Analyses	$128,570
Remedial Design	**$487,424**
EPA Personnel	$247,398

Cost Data Quality

Capital and operations and maintenance costs are provided in an unpublished EPA document entitled "Groundwater Remedial Cost Estimates." Estimates of operating costs for 1995 and 1996 were provided by the former Remedial Project Manager, Mr. Glenn Curtis.

OBSERVATIONS AND LESSONS LEARNED

- Total costs for the P&T system at this site were approximately $2,596,000 ($1,587,000 in capital costs and $1,009,000 in operating costs), which corresponds to $80 per pound of contaminants removed and $0.53 per 1,000 gallons of groundwater treated.
- Reports from as early as 1984 identify a separate plume of groundwater contamination that is moving southward from points north of the Dico property.
- The costs for this project were approximately $833,000 more than the projected costs in the ROD. This cost figure exceeds the ROD estimate by 47%, which falls within the confidence interval of no greater than 50% and no less than 30% as stated in the ROD.
- As of October 1996, the mean concentration of contaminants in the groundwater was 18 µg/L. The mean concentration is computed from 19 sampling points and provides an average measurement across all points. The maximum concentration detected was 2,650 µg/L at extraction well ERW-6 [6]. Although the average groundwater concentration has declined significantly, areas of high contamination still remain on site.

OBSERVATIONS AND LESSONS LEARNED (CONT.)

- Within several wells placed near the center of the plume, TCE concentration levels have fluctuated dramatically. In Figure 7, concentrations in well NW-7 can be seen to vary between 22 µg/L and 2,800 µg/L. This variation in contaminant concentrations typically indicates DNAPL presence.

- The most rapid reductions in contaminant concentrations occurred during the first two years of operation when mean concentration levels in groundwater fell by 81%. The mean groundwater concentrations only declined an additional 9% over the next eight years.

- Nearly 30,000 pounds of contaminants were removed from the groundwater over 108 months [6]. The P&T system was able to meet the cleanup goal on the west side of Racoon River, and contain and treat the on-site plume. However, TCE concentrations in on-site extraction wells remain above the remedial goal of 5 µg/L, with concentrations in well ERW-6 remaining in excess of 2,600 µg/L.

- Because groundwater concentrations of TCE have remained at elevated levels after nine years of groundwater extraction, the presence of a subsurface source zone, potentially a residual or sorbed DNAPL within the saturated zone, is suggested.

- Initial estimates of contaminant mass released predicted that less than 10 gallons of pure TCE would be removed from the aquifer [7]. In contrast, more than 2,800 gallons of contaminants have been removed as of December 1996, 80% of which is TCE.

- Dico has submitted a "Petition for Reimbursement of Costs" to the U.S. EPA for remedial costs incurred in addressing a northern plume of contamination. Dico claims that an off-site source has contributed to groundwater contamination that is flowing onto the Des Moines TCE site. Dico estimates that 29% of all costs incurred are attributed to the northern plume. This argument is made based on the fact that 2 of the 7 wells used in the remedial design for this site are placed in an area deemed the northern plume area. Dico claims that the northern plume was created by other parties to the north of their property [12]. The petition is in court at this time and no ruling has been made.

REFERENCES

1. Performance Evaluation Report No. 1 (December 1987 through March 1988), Aware, Inc. April 1988.

2. Performance Evaluation Report No. 3 (June 1988 through January 1989), Eckenfelder, Inc. May 1989.

3. Performance Evaluation Report No. 4 (January through December 1989), Eckenfelder, Inc. February 1990.

4. Performance Evaluation Report No. 8 (January through December 1993), Eckenfelder, Inc. July 1994.

5. Performance Evaluation Report No. 10 (January through December 1995), Eckenfelder, Inc. June 1996.

6. Progress Report for October 1996, Des Moines TCE Site, Eckenfelder, Inc. December 1996.

7. Remedial Action Report for Ground Water Treatment at the Des Moines TCE Site, U.S. EPA Region VII. July 21, 1992.

REFERENCES (CONT.)

8. Case Studies and Updates, U.S. EPA, "Case Study 3, Des Moines TCE." March 25, 1992.

9. Record of Decision, U.S. EPA, Des Moines TCE. July 1986.

10. Correspondence with U.S. EPA Remedial Project Manager, Mary Peterson, Region VII, March 4, 1997.

11. Groundwater Regions of the United States. Heath, Ralph. U.S. Geological Survey Water Supply Paper 2242. 1984.

12. Petition for Reimbursement of Costs, July 8, 1988. Dico, Inc.

13. Dense Nonaqueous Phase Liquids, Huling, Scott G. and J. W. Weaver. U.S. EPA. March 1991.

14. Groundwater Remedial Cost Estimates, prepared for Des Moines TCE Superfund Site, U.S. EPA, Unpublished.

15. Correspondence with Mr. Glen Curtis, former Remedial Project Manager, 3-4-97.

Analysis Preparation

This case study was prepared for the U.S. Environmental Protection Agency's Office of Solid Waste and Emergency Response, Technology Innovation Office. Assistance was provided by Eastern Research Group, Inc. and Tetra Tech EM Inc. under EPA Contract No. 68-W4-0004.

Pump and Treat of Contaminated Groundwater at the Former Firestone Facility Superfund Site, Salinas, California

Pump and Treat of Contaminated Groundwater at the Former Firestone Facility Superfund Site, Salinas, California

<table>
<tr><td>Site Name:
Former Firestone Facility Superfund Site</td><td rowspan="2">Contaminants:
Chlorinated solvents and volatiles - nonhalogenated
- Contaminants included 1,1-DCE, TCE, PCE, 1,1-DCA, 1,1,1-TCA, benzene, toluene, and xylene
- Maximum concentration for 1,1-DCE detected in 1983-1984 was 120 ug/L</td><td>Period of Operation:
2/86 - 11/92</td></tr>
<tr><td>Location:
Salinas, California</td><td>Cleanup Type:
Full-scale cleanup</td></tr>
<tr><td>Vendor:
Construction: Monterey Mechanical; Woodward/Clyde
Operations: International Technology Corporation (ITC)</td><td rowspan="2">Technology:
Pump and Treat
- Groundwater is extracted using 25 wells, located on- and off-site, at an average total pumping rate of 480 gpm
- Extracted groundwater is treated with oil/water separation, air stripping, and carbon adsorption, and discharged to a surface water under a NPDES permit</td><td>Cleanup Authority:
CERCLA Remedial
- ROD Date: 9/30/89</td></tr>
<tr><td>State Point of Contact:
Dr. Wei Lui
CA RWQCB
Central Coast Region
81 Higuera St., Ste. 200
San Luis Obispo, CA 93401-5427
(805) 542-4648</td><td>EPA Point of Contact:
Elizabeth Adams, RPM
U.S. EPA Region 9
75 Hawthorne St.
San Francisco, CA 94105
(415) 744-2261</td></tr>
<tr><td>Waste Source:
Accidental releases of chemicals to soil and groundwater from a RCRA-permitted facility.</td><td colspan="2" rowspan="2">Type/Quantity of Media Treated:
Groundwater
- 1,800 million gallons treated
- Groundwater is found at near ground surface at the site
- Extraction wells are located in 3 aquifers, which are influenced by production wells in the area
- Hydraulic conductivity ranges from 100 to 1,200 ft/day</td></tr>
<tr><td>Purpose/Significance of Application:
Met goals within seven years of operation; site had relatively high hydraulic conductivity and was located near high-volume agricultural wells.</td></tr>
<tr><td colspan="3">Regulatory Requirements/Cleanup Goals:
- Remedial goals were identified based on chemical-specific ARARs that included maximum contaminant levels (MCLs) and health-based restrictions. Remedial goals were established for 1,1-DCE (6 ug/L), 1,1-DCA (5 ug/L), TCE (3.2 ug/L), PCE (0.7 ug/L), benzene (0.7 ug/L), toluene (20 ug/L), and xylene (70 ug/L).
- A secondary goal of the system was to prevent migration of contaminants into the adjoining property.</td></tr>
</table>

Pump and Treat of Contaminated Groundwater at the Former Firestone Facility Superfund Site, Salinas, California (continued)

Results:

- 1,1-DCE was identified as the index contaminant to identify compliance with remedial goals for this site. Monitoring results showed that concentrations of this contaminant decreased from as high as 120 ug/L in 1986 to 4.8 ug/L in 1994 and 6 ug/L in 1995. From 1986 to 1992, 496 pounds of total VOCs had been removed from the groundwater.
- By 1987, monitoring data indicated that plume containment had been achieved. There had been some migration of contaminants noted in 1986, but an addition of five off-site wells in the deep aquifer in 1987 prevented further migration.

Cost:

- Actual costs for pump and treat were $12,884,813 ($4,133,543 in capital and $8,751,270 in O&M), which correspond to $7 per 1,000 gallons of groundwater extracted and $26,000 per pound of contaminant removed.

Description:

The former Firestone facility operated as a tire manufacturing plant from 1963 until 1980. During pre-closure investigations of the facility's solid waste management units in 1983, 11 areas were investigated, and results showed that soil and groundwater were contaminated. A plume of VOCs was identified in the groundwater that extended 2.5 miles down-gradient. The site was placed on the NPL in July 1987 and a ROD was signed in September 1989.

The extraction system originally consisted of 25 wells installed both on- and off-site. In July 1987, five additional wells were installed off-site in the deep aquifer to prevent plume migration, and in October 1989, five additional wells were installed off-site in the intermediate zone to treat contamination in that area. The system design was performed using a computer model. The remedial goals at this site were met within approximately seven years of treatment. Site operators frequently adjusted the extraction system to maximize the removal of contaminants from the groundwater and maintain the highest possible level of contaminants in the influent stream to the treatment system.

SITE INFORMATION

Identifying Information:

Former Firestone Facility Superfund Site
Salinas, California

CERCLIS #: CAD990793887

ROD Date: September 30, 1989

Treatment Application:

Type of Action: Remedial

Period of operation: February 1986 - November 1992
(Monitoring data collected through July 1993)

Quantity of groundwater treated during application: 1.8 billion gallons

Background

Historical Activity that Generated Contamination at the Site: Manufacture of tires

Corresponding SIC Code: 3011

Waste Management Practice That Contributed to Contamination: Accidental releases of chemicals to soil and groundwater from a RCRA-permitted facility.

Location: California

Operations [1, 2, 4]:

- The former Firestone facility is located in a suburban industrial area with mixed local land use, both industrial and agricultural. Bordered on the north by a rail line and on the south by a river, the facility operated as a tire manufacturing plant from 1963 until 1980.

- During preclosure investigations of the facility's solid waste management units in 1983, 11 areas were investigated; soil contamination was identified in a materials storage area and in the sludge drying beds. The groundwater investigation found that the levels of several volatile organic compounds (VOCs) exceeded state Primary Drinking Standards. The same investigation identified a plume of VOCs that extended 2.5 miles downgradient.

- On- and off-site groundwater pumping was initiated to reduce further contaminant migration. The evaluation of potential sources of contamination led to the removal of 22 storage tanks and excavation of 5,300 cubic yards of inorganic- and organic-contaminated soils for off-site disposal. The tanks and soil were determined later by the site contractor not to be sources of groundwater contamination.

- After extensive investigation, the principal source of groundwater contamination was believed to be from the use of 1,1,1-trichloroethane (TCA) for maintenance and cleaning of equipment. The site contractor determined that small amounts were released through floor cracks, sumps, and drains. The TCA had degraded to 1,1-dichloroethylene (DCE) and other breakdown products by the time contamination was detected.

- The site was placed on the National Priorities List (NPL) in July 1987.

Regulatory Context:

- Remedial actions were underway before the site was placed on the NPL in July 1987. The final ROD was signed on September 30, 1989.

- Site activities are conducted under provisions of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA) §121, and the National Contingency Plan (NCP), 40 CFR 300.

Groundwater Remedy Selection:

- The selected remedy for this site was groundwater extraction and treatment via carbon adsorption and air stripping with discharge to a river.

SITE INFORMATION (CONT.)

Site Logistics/Contacts

Site Lead: PRP

Oversight: California Regional Water Quality Control Board (CARWQCB)

Remedial Project Manager:
Elizabeth Adams*
U.S. EPA Region 9
75 Hawthorne St.
San Francisco, CA 94105
415-744-2261

State Contact:
Dr. Wei Lui*
CARWQCB
Central Coast Region
81 Higuera St., Ste. 200
San Luis Obispo, CA 93401-5427
805-542-4648

Treatment System Vendor:
Construction: Monterey Mechanical
Woodward/Clyde
Operations: International Technology Corporation (ITC)

*Indicates Primary Contacts

MATRIX DESCRIPTION

Matrix Identification

Type of Matrix Processed Through the Treatment System: Groundwater

Contaminant Characterization [1, 2, 3]

Primary Contaminant Groups: Volatile organic compounds

- The contaminants of greatest concern include benzene, 1,1-dichloroethane (1,1-DCA), 1,1,1 trichlorethane (1,1,1-TCA), trichloroethylene (TCE), tetrachloroethylene (PCE), 1,1-dichloroethylene (1,1-DCE), toluene, and xylene.
- 1,1-DCE was selected during the design process as the index compound for the remedial action. The maximum concentration detected on site during the 1983-1984 groundwater investigation was 120 µg/L.
- The plume shown in Figure 1 was based on 1986 sampling events. It was estimated to be 1,300 feet wide and extend 3,400 feet downgradient. In the areas downgradient of the source, the plume was identified in the deeper hydrogeologic zones. High-volume agricultural wells screened in this zone influenced groundwater flow patterns, affecting plume migration.
- Using the surface area in Figure 1, the unit thickness given in Table 1, and an average porosity of 0.3, this report estimates the plume could contain as much as 2.9 billion gallons of contaminated groundwater.

MATRIX DESCRIPTION (CONT.)

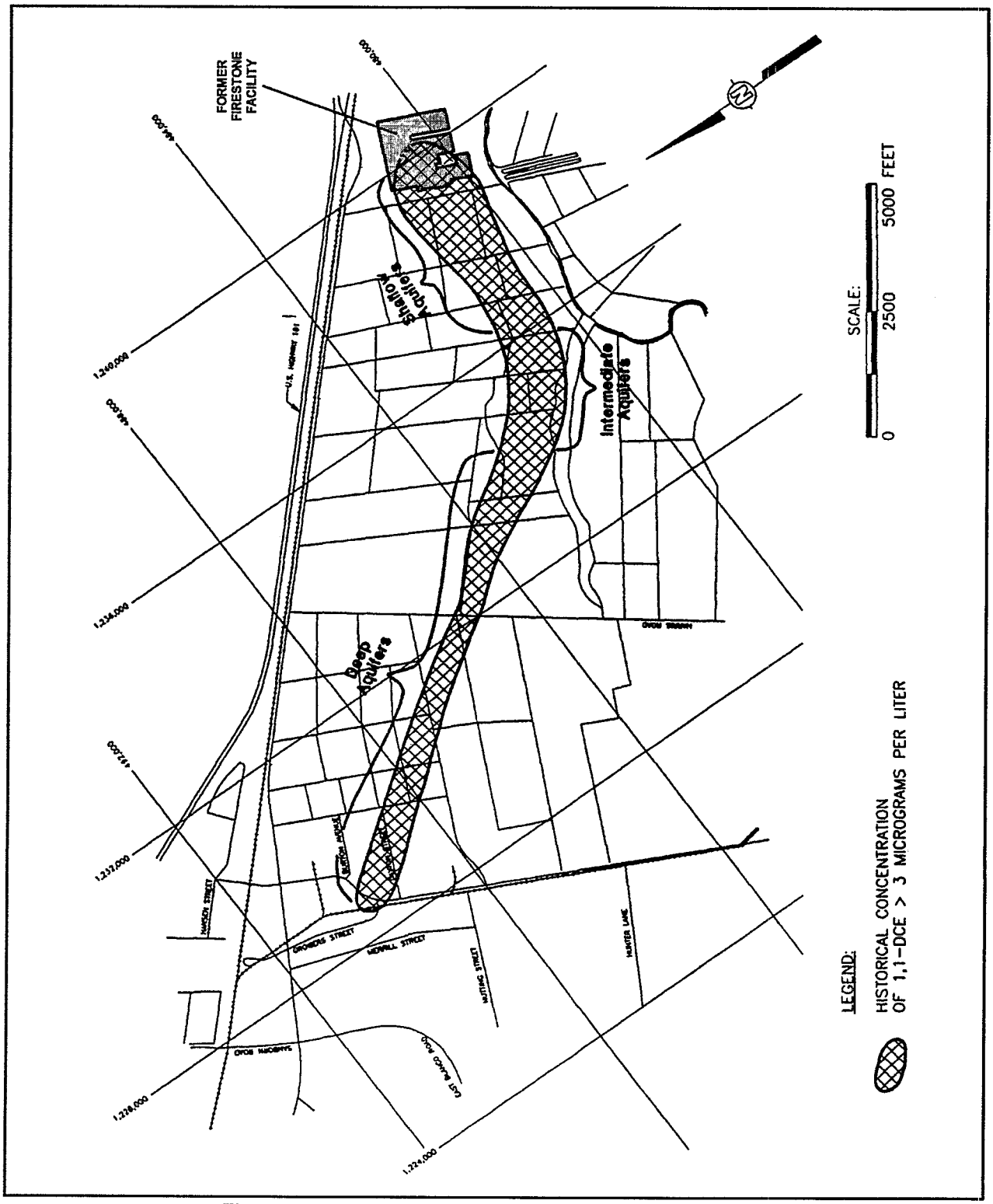

Figure 1. 1,1-DCE Groundwater Contamination in 1986 [2]

MATRIX DESCRIPTION (CONT.)

Matrix Characteristics Affecting Treatment Costs or Performance [2]

Hydrogeology:

Groundwater in the vicinity of the site occurs in three interconnected, aquifer zones, designated the shallow, intermediate, and deep aquifers. The groundwater at this site is contaminated by high levels of nitrate from agricultural activities in the area and is not a suitable drinking water source. The shallow aquifer extends from ground surface to a depth of about 90 feet. The intermediate zone is about 40 feet thick and extends from 100 to 140 feet below ground surface. Locally, the deep aquifer system has four distinct zones at depths of approximately 200, 300, 400, and 500 feet. The various aquifers are separated by locally discontinuous clay or silt layers (aquitards) of varying thicknesses. Where the aquitards are thin or discontinuous, flow and/or dispersion can occur between the overlying and underlying aquifers. The shallow aquifer has limited use because it dries up during drought years. The intermediate aquifer also has limited use because it is very localized and does not yield a large quantity of water. The deep aquifer yields water and is used agriculturally and domestically.

Unit 1	Shallow Aquifer	Composed of permeable sands and gravels enclosed by impermeable silts and clays. This aquifer is underlain by a thin, discontinuous clay horizon. It is of limited use and is dry in drought years.
Unit 2	Intermediate Aquifer	Composed of alluvial channels of sands and underlain by a discontinuous layer of estuarine clay. It is of limited use because of low yield and is highly localized in the area of the site.
Unit 3	Deep Aquifer	Composed of sands and gravel with discontinuous clay aquitards that divide the aquifer into four zones at depths of about 200, 300, 400, and 500 feet. It is extensively developed for agricultural and some domestic uses.

Tables 1 and 2 present technical aquifer information and well data, respectively.

Table 1. Technical Aquifer Information

Unit Name	Thickness (ft)	Conductivity (ft/day)	Average Velocity (ft/day)	Flow Direction
Shallow	90	100	2 - 3	West
Intermediate	10 - 45	200 - 1,200	2 - 3	Downward
Deep	200 - 500	200 - 1,200	3 - 4	Northwest

Source: [2]

TREATMENT SYSTEM DESCRIPTION

Primary Treatment Technology

Pump and treat (P&T) with air stripping and carbon adsorption

Supplemental Treatment Technology

Oil/water separation

System Description and Operation [2, 3, 4]

Table 2. Extraction Well Data

Well Name	Unit Name	Depth (ft)	Yield (gal/day)
S1 - S4	Shallow	60 - 72	57,600
S5 - S8	Shallow	60 - 89	72,000
S9 - S11	Shallow	52 - 69	50,400
S12 - S13	Shallow	49 - 57	14,400
M1	Shallow	98	172,800
M2	Shallow	82	72,000
5 wells	Intermediate	90	576,000
5 wells	Off-site Deep	100 - 150	345,000

Source: [2]

System Description [2, 3]

- The extraction system originally comprised 25 wells installed both on and off site, as listed in Table 2. Fifteen wells were screened in the shallow aquifer and five each were installed in the intermediate and deep aquifers. The extraction system was designed to prevent off-site migration, and the shallow extraction wells were placed along the facility boundary to intercept the plume. In July 1987, five wells were installed off site in the deep aquifer to prevent migration of the plume up into the intermediate zones. In October 1989, five wells were installed off site in the intermediate zone to treat off-site contamination in that zone. The system was designed using a computer model.

- The treatment system consisted of an oil/water separator, an air stripper, and a series of carbon filters. Most of the extracted groundwater was treated in two fixed-bed carbon adsorption filters, operated in series.

- Groundwater from two specific areas was pretreated before being processed through the carbon filters to avoid clogging. Groundwater from the first area, where high levels of oil and grease had been identified, was pretreated using two fixed-bed adsorbers containing Klensorb® adsorbent. The adsorbers were designed to operate in series at a rate of 15 gpm.

- Groundwater from the second area, containing high levels of chlorinated solvents, was pre-treated in an air stripper. The stripper was designed to treat water at a rate of 50 gpm using an air flow of 750 cfm to achieve greater than 98 percent removal.

- Groundwater from all other areas was mixed with the water from the Klensorb® and the air stripping units before passing through the final set of carbon filters at a design rate of 550 gpm.

- Treated groundwater was aerated in effluent tanks prior to discharge to the Salinas River. The aerated water was required to meet minimum dissolved oxygen requirements of the NPDES permit.

TREATMENT SYSTEM DESCRIPTION (CONT.)

System Description and Operation (Cont.)

- Groundwater quality is monitored semi-annually in a system of 190 wells, installed in all aquifers both on and off site.

System Operation [2, 3, 4, 15]

- Quantity of groundwater pumped from aquifer in gallons:

Year	Volume Pumped (gal)
1987	264,100,000
1988	>160,000,000
1989	266,190,000
1990	360,600,000
1991	> 182,200,000
1992	Not Available
Total	**1,800,000,000**

[Missing data points for six months in 1988, 1991, and all of 1992.]
Source: [3, 6-14]

- Over the life of this project, the treatment system was 97 percent operational. Downtime was due to regular periodic maintenance and the construction of new wells in 1987.

- The media in the air stripper was not changed over the life of the remedial action. There were at least 15 changeouts of the carbon beds.

- The Remedial Action Plan provided the site manager flexibility to adjust the number of extraction wells pumped and the pumping rates for each well. The site operator reviewed the monitoring data monthly and shifted pumping patterns to optimize contaminant extraction. Examples of the specific operational changes are provided below.

- Over time, pumping was discontinued at the lateral edges of the plume to prevent the plume from migrating transverse to the groundwater flow.

- When on-site pumping began to reduce the flow gradient between the on-site intermediate and deep extraction wells and the on-site shallow extraction wells, the shallow wells were turned off to allow the groundwater flow to increase. Increased groundwater flow carried the remaining contamination to the off-site intermediate wells faster.

- For a two-week period in July 1986, site operators evaluated aquifer response to increased pumping rates. The treatment system flow rate was increased to 950 gpm and the carbon filter system was changed to parallel operations to accommodate the increased flow [2, 4]. As a result of the aquifer response test, the extraction rate was increased.

- In February 1987, the Klensorb® unit was removed from service. From that point, the groundwater was treated directly in the carbon filter system.

- In June 1992, cleanup levels were achieved in all extraction wells, and remediation operations were suspended. Groundwater monitoring has continued since that date.

- As of July 1995, 142 of the 190 extraction and monitoring wells had been decommissioned.

Operating Parameters Affecting Treatment Cost or Performance

The major operating parameter affecting cost and performance for this technology is the average extraction rate. Table 3 presents the values measured for this and other parameters.

TREATMENT SYSTEM DESCRIPTION (CONT.)

Operating Parameters Affecting Treatment Cost or Performance (Cont.)

Table 3: Operating Parameters

Parameter	Value	
Average Pump Rate	**480 gpm**	
	Remedial Goal	**Performance Standard**
1, 1-DCE	6 µg/L	0.21 µg/L
Benzene	0.7 µg/L	0.7 µg/L
1,1-DCA	5.0 µg/L	None
TCE	3.2 µg/L	5 µg/L
PCE	0.7 µg/L	None
Toluene	20 µg/L	100 µg/L
Xylene	70 µg/L	620 µg/L
Note: Average system pump rate over life of project was an estimated 696,000 gpd, as reported in monthly performance reports.		

Source: [1, 4, 6-14]

Timeline

Table 4 presents a timeline for this remedial project.

Table 4: Project Timeline

Start Date	End Date	Activity
10/85	2/86	Multicomponent treatment system constructed
2/86	6/86	System operated at design rate of 550 gpm
7/1/86	7/14/86	System extraction rate increased to 950 gpm to assess effect on vertical groundwater flow
7/15/86	10/87	System modified to operate at 700 gpm
2/87	---	Klensorb® unit removed from system; Area 2 wells integrated into remaining system
9/87	---	Five deep aquifer extraction wells installed off site
9/89	---	Record of Decision issued
9/89	---	Five extraction wells installed in intermediate aquifer off site
6/92	---	Remedial goals achieved in extraction wells
11/92	---	System operations ended for aquifer stability test
11/93	---	Seven wells decommissioned
	7/95	Remedial system decommissioned by state; confirmation sampling continues in 10 wells

Source: [2, 4, 15]

TREATMENT SYSTEM PERFORMANCE

Cleanup Goals/Standards [1]

- The remedial goals shown in Table 3 were based on chemical-specific applicable or relevant and appropriate requirements (ARARs), that include Maximum Contaminant Levels (MCLs) and health-based restrictions such as carcinogenic risk levels of less than 10^{-6} and a Hazard Index of 1. These goals were to be achieved throughout the affected aquifers [1].

Additional Information on Goals [4]

- The initial remedial goal for 1,1-DCE was 0.2 µg/L, based on state drinking water standards. In June 1986, the California Department of Health Services (DHS) revised the state drinking water action level for 1,1-DCE to 6 µg/L. This level became the final remedial goal.

Treatment Performance Goals [2]

- The primary goal of the treatment system was to reduce levels of 1,1-DCE in the influent to below NPDES standards, listed in Table 3.
- The secondary goal of the system was to prevent the migration of contaminants into the adjoining property to the northwest.

Performance Data Assessment [1, 5-14]

Total VOCs include 1,1-DCA, 1,1,1-TCA, TCE, PCE, and 1,1-DCE for the purposes of this section.

- Figure 2 illustrates the decline of average 1,1-DCE contaminant concentrations in groundwater over time. As shown in this figure, the average level of 1,1-DCE (the index contaminant) in the groundwater dropped by half in the first year, from 120 µg/L to an average of 61 µg/L. The average concentration dropped by half again in the following year. The average concentrations for 1994 and 1995 were 4.8 and 6.0, respectively. Average concentrations in monitoring wells were provided by the system operator.
- There were no reported exceedences of the NPDES limits over the life of the remedial action [5-13].
- Contaminants were detected in downgradient monitoring wells during a 1986 sampling event, indicating that full containment had not been achieved. This led to the installation of five off-site wells in the deep aquifer in 1987. No further migration of contaminants has been noted in subsequent sampling events. Therefore, it appears that the contaminant plume was contained by 1987 [1, 4].
- Figure 3 shows that from 1986 to 1992, 496 pounds of total VOCs were removed from the groundwater. The shape of the mass removed curve indicates a continuous reduction in removal efficiency over the life of the operating system.
- The mass flux rate declined steadily from 77 lbs during the first half of 1986 to 0.7 lbs in the last six months of operations. The sharpest decline in the removal rate was noted in the first 36 months during which the removal rate dropped 84 percent from 77 lbs/6-month period to 18.7 lbs/6-month period. Over the next four years, the removal rate declined to 0.7 lbs/6-month period [6-14].

Performance Data Completeness

- NPDES monitoring reports, containing treatment system flow volumes, influent concentrations, and contaminant mass removed, are available on a semi-annual basis from June 1986 to July 1993 [5-13].
- Groundwater monitoring data are available in monthly reports from February 1986 to July 1993.

TREATMENT SYSTEM PERFORMANCE (CONT.)

Performance Data Completeness (Cont.)

- Contaminant removal data were supplied by the system operator for each six-month period from June 1986 to November 1992 [4].
- The data used in Figure 2 are the highest concentrations found in any well over a 12-month period [4].
- Annual concentrations in monitoring wells were provided by the system operator for 1986, 1987, 1988, and 1993.

Performance Data Quality

- The QA/QC program used throughout the remedial action met the EPA and the State of California requirements. All monitoring was performed using EPA-approved methods, and the site engineer did not note any exceptions to the QA/QC protocols.

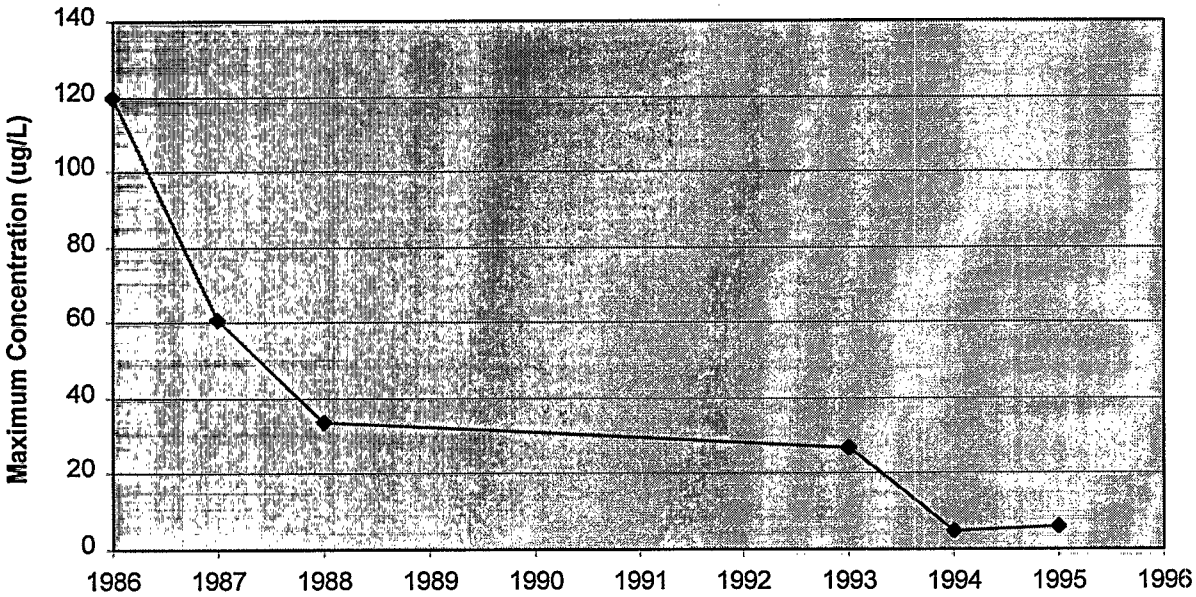

Figure 2. Groundwater 1,1-DCE Concentrations, 1986 - 1992 [4]

TREATMENT SYSTEM PERFORMANCE (CONT.)

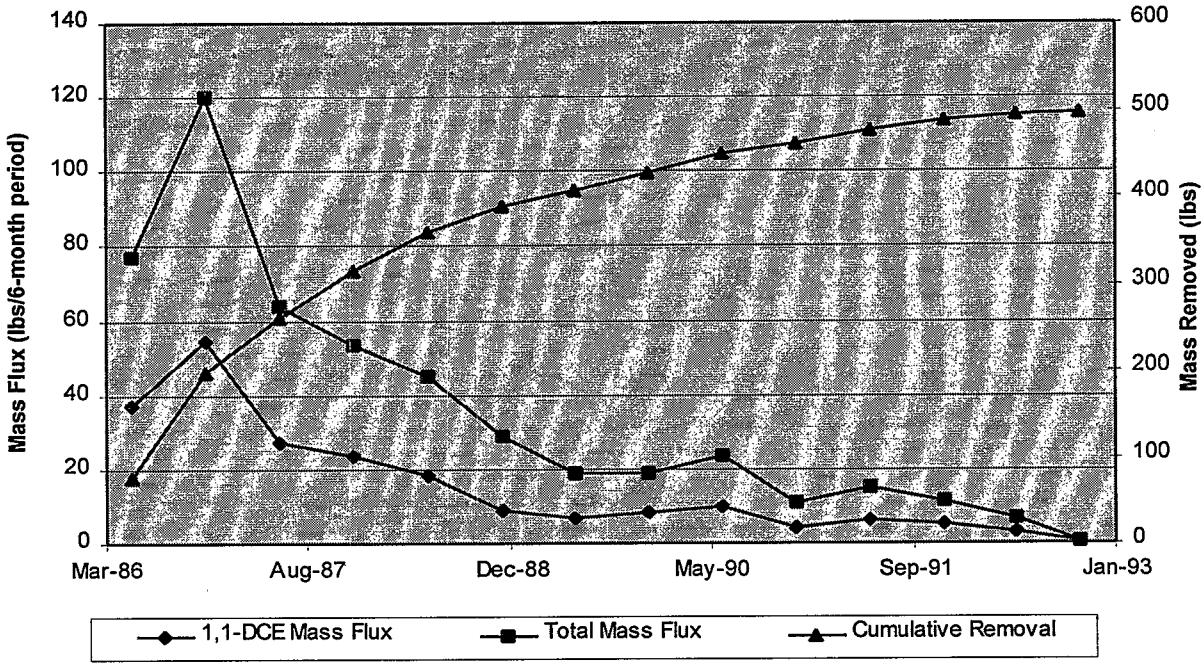

Figure 3. Mass Flux Rate and Cumulative Contaminant Removal, 1986 - 1992 [4]

TREATMENT SYSTEM COST

Procurement Process

- From 1983 to 1986, Woodward-Clyde constructed and operated the remedial treatment system. In August 1986, International Technology Corp. took over the operations and maintenance of the system.

Cost Analysis

- All costs for design, construction, and operation of the treatment system at this site were borne by the PRPs.

Capital Costs [4, 5]

Remedial Construction	
Extraction Wells Treatment	$749,344
System/Wells/Caps	$3,314,899
Site Restoration	$69,300
Total Construction	**$4,133,543**

Operating Costs [4, 5]

Plant Operations	$3,056,430
Monitoring/Analysis/Data Management	$3,524,622
Project Management	$2,170,218
Total Operating Expenses	**$8,751,270**

Other Costs [5]

Remedial Design	$3,030,175
Miscellaneous Cost	$9,176,300

Note: UST removal, lagoon closure, soil removal and disposal, and other costs unrelated to groundwater cleanup are not included here.

TREATMENT SYSTEM COST (CONT.)

Cost Data Quality

Actual capital and operations and maintenance cost data were available from the PRPs.

OBSERVATIONS AND LESSONS LEARNED

- The cleanup standards were met at this site within approximately seven years.
- There were no changes in system construction or operation that significantly changed the expected cost of remediation.
- Actual costs for the P&T treatment application were $4.1 million in capital costs and $8.8 million in operating and maintenance costs, which corresponds to $26,000 per pound of contaminants removed and $7 per thousand gallons of groundwater pumped.
- The site operators frequently adjusted the extraction system to control contaminant removal from the aquifers [4]. The effect of this flexible operation was to maximize the removal of contaminants from the groundwater and maintain the highest possible level of concentrations in the influent stream. This operational strategy was key to avoiding the asymptotic decline in contaminant removal that other P&T systems have experienced.
- Often, concentrations of 1,1-DCA were higher at the sample point before the second carbon bed than at the point directly before the first bed. This pattern suggests that 1,1-DCE was being preferentially adsorbed in the first bed, displacing previously adsorbed 1,1-DCA [6].

REFERENCES

1. Record of Decision. U.S. Environmental Protection Agency, September 13, 1989.
2. Industrial Report. International Technology Corporation, August 1993 (unpublished).
3. Fact Sheet. U.S. Environmental Protection Agency. June 1994.
4. Various communications with Corporation. July 2 to August 15, 1997.
5. Groundwater Remedial Cost Analysis. U.S. Environmental Protection Agency, October 1994.
6. Semi-Annual NPDES Report for January - June 1987. International Technology Corporation, July 31, 1987.
7. Semi-Annual NPDES Report for July - December 1987. International Technology Corporation, January 29, 1988.
8. Semi-Annual NPDES Report for January - June 1988. International Technology Corporation, July 28, 1988.
9. Semi-Annual NPDES Report for January - June 1989. International Technology Corporation, July 28, 1989.
10. Semi-Annual NPDES Report for July - December 1989. International Technology Corporation, January 30, 1990.
11. Semi-Annual NPDES Report for January - June 1990. International Technology Corporation, July 30, 1990.
12. Semi-Annual NPDES Report for July - December 1990. International Technology Corporation, January 30, 1991.
13. Semi-Annual NPDES Report for January - June 1991. International Technology Corporation, July 30, 1991.
14. Semi-Annual NPDES Report for July - December 1993. International Technology Corporation, January 28, 1994.
15. Letter to CADTSC. International Technology Corporation, November 1993.

Analysis Preparation

This case study was prepared for the U.S. Environmental Protection Agency's Office of Solid Waste and Emergency Response, Technology Innovation Office. Assistance was provided by Eastern Research Group, Inc. and Tetra Tech EM, Inc. under EPA Contract No. 68-W4-0004.

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Pump and Treat of Contaminated Groundwater at the JMT Facility RCRA Site, Brockport, New York

Pump and Treat of Contaminated Groundwater at the JMT Facility RCRA Site, Brockport, New York

Site Name: JMT Facility RCRA Site (formerly Black & Decker RCRA Site)	**Contaminants:** Chlorinated solvents - Maximum concentrations detected in March 1988 were TCE (70,000 ug/L) and 1,2-DCE (23,000 ug/L)	**Period of Operation:** Status: Ongoing Report covers: 5/88 - 12/97
Location: Brockport, New York		**Cleanup Type:** Full-scale cleanup (interim results)
Vendor: Hydro Group, Inc. (1988-1997) 1011 Route 22 Bridgewater, NJ 08807 (908) 704-8882 O'Brien & Gere Operations, Inc. (1997-Present) 5000 Brittonfield Parkway Syracuse, NY 13221 (315) 437-8800	**Technology:** Pump and Treat - Groundwater is extracted using 1 well, located on site, at an average total pumping rate of 11.2 gpm - Extracted groundwater is treated with air stripping and discharged to a surface water under a SPDES permit - An interceptor drain was artificially created in the bedrock around the extraction well using controlled blasting techniques	**Cleanup Authority:** RCRA - Corrective Action
State Point of Contact: Larry Thomas New York State Department of Environmental Conservation (NYSDEC) 50 Wolf Road Albany, NY 12233-7252 (518) 457-9253 **Site Contact:** Paul William Hare Corporate Environmental Programs General Electric Company One Computer Drive South Albany, NY 12205 (518) 458-6613		**EPA Point of Contact:** Michael Infurna U.S. EPA Region 2 290 Broadway New York, NY 10007-1866 (212) 264-6150
Waste Source: Leaks from surface impoundments/ drying beds	**Type/Quantity of Media Treated:** Groundwater - 50.1 million gallons treated as of December 1997 - DNAPL suspected in groundwater at this site - Groundwater is found at 10 ft bgs - The extraction well is located in 1 aquifer; the geology at this site was reported as very complex - Hydraulic conductivity ranges from 0.65 to 0.93 ft/day	
Purpose/Significance of Application: RCRA corrective action site with relatively low groundwater flow; greater than 90% reduction in average concentrations of contaminants.		

Pump and Treat of Contaminated Groundwater at the JMT Facility RCRA Site, Brockport, New York (continued)

Regulatory Requirements/Cleanup Goals:
- Cleanup goals were set at state groundwater standards as follows: TCE (5 ug/L), cis-1,2-DCE (5 ug/L), TCA (5 ug/L), and vinyl chloride (2 ug/L).
- The cleanup goals must be met in the single recovery well at the site and in point-of-exposure wells, of which there are currently 17.
- A goal of the recovery system is to achieve hydraulic containment of the plume.

Results:
- Concentrations of contaminants decreased by more than 80% from 1987 to 1997, but remain above cleanup goals.
- Although contaminants have been detected in off-site wells, NYSDEC and the owner/operator have concluded that the plume had been contained and the off-site contamination was believed to be residual contamination prior to pump and treat. The addition of a new extraction well and a treatment system is currently being evaluated.
- From 1988 to 1996, the system removed 842 pounds of contaminants from the groundwater.

Cost:
- Estimated costs for pump and treat were $2,163,000 ($879,000 in capital and $1,284,000 in O&M), which correspond to $47 per 1,000 gallons of groundwater extracted and $2,569 per pound of contaminant removed.
- Building an enclosure for the treatment system was a substantial cost (about 23% of capital); however, the efficiency of the overall system has improved, especially in the winter months, and less time is needed for shutdown due to inclement weather.

Description:
The JMT Facility was operated as an appliance manufacturing facility by G.E. Company from 1949 to 1984 and by Black and Decker from 1984 to 1986. JMT Properties, Inc., is the current owner of the site and leases the facility to Kleen-Brite. Kleen-Brite uses the facility for packaging and distributing household products such as laundry detergent and bleach. G.E. and Black and Decker operated an on-site RCRA treatment, storage, and disposal facility (TSDF) under interim status. In 1984, routine sampling revealed elevated levels of halogenated VOCs in the groundwater at the site. In August 1987, Black and Decker closed the regulated units and, in early 1988, initiated a corrective measures program for groundwater. In 1987, Black and Decker submitted a RCRA Post-Closure Permit application to NYSDEC; the permit was issued in April 1994.

The groundwater extraction system consists of one recovery well installed in 1987 as an interceptor well at the leading edge of the plume; the well placement was designed to prevent additional contaminants from migrating off site. To increase the degree of hydraulic conductivity and the interconnection in the bedrock fractures in the extraction well area, an interceptor drain was artificially created in the bedrock around the extraction well. The drain was created using controlled blasting techniques and rubblizing the upper portion of the bedrock. Data indicate that the pump and treat system has reduced the contaminant concentrations in the plume, however concentrations in much of the plume remain above the cleanup goals.

SITE INFORMATION

Identifying Information:

JMT Facility RCRA Site (previously Black and Decker)

RCRIS #: NYD002221919

Treatment Application:

Type of Action: Corrective Action

Period of operation: 5/88 - Ongoing
(Monitoring and pumping data collected through December 1997)
(Mass removal data collected through 1996)

Quantity of material treated during application: 50.1 million gallons of groundwater

Background

Historical Activity that Generated Contamination at the Site: Appliance Manufacturing

Corresponding SIC Code: 3699 (appliance manufacturing)

Waste Management Practice That Contributed to Contamination: Leaks from surface impoundments/drying bed

Location: Brockport, New York

Facility Operations: [1, 2, 3]

- The JMT Facility (formerly the Black and Decker site) is located on 28.5 acres in a largely industrial area. Several industrial plants are nearby, and an inactive hazardous waste disposal site is adjacent to the western boundary, crossgradient to the site.
- The site was operated as an appliance manufacturing facility by G.E. Company from 1949-1984 and by Black and Decker from 1984-1986. JMT Properties, Inc. is the current owner of the site and leases the facility to Kleen-Brite. Kleen-Brite uses the facility for packaging and wholesale distributing of household products (*e.g.*, laundry detergent, bleach).
- G.E. and Black and Decker operated an on-site RCRA treatment, storage, and disposal facility (TSDF) under interim status. The solid waste management units (SWMUs) included six surface impoundments, one drying bed, and three waste storage areas, which were significant sources of contamination.
- In 1984, routine sampling revealed elevated levels of halogenated volatile organic compounds (VOCs) in the groundwater below the SWMUs. This discovery led to a site-wide groundwater quality assessment program as required by the 40 CFR 265.93 regulations for groundwater monitoring.
- In response to the findings of the groundwater assessment, Black and Decker closed the regulated units in August 1987, and initiated a corrective measures program for groundwater in early 1988. For source control, Black and Decker removed the uppermost soil/sludge, backfilled excavations, and established vegetative cover.
- In 1987, Black and Decker submitted a RCRA Post-Closure Permit application to NYSDEC. The permit was issued on April 4, 1994 and requires that the system continue to be operated, maintained, and monitored until certain termination criteria are met. The permit required an Off-Site Ground Water Investigation (OSGWI) which was presented in August 1996.

Regulatory Context:

- Site activities are conducted under provisions of the Resource Conservation and Recovery Act (RCRA) in 1976, as amended by the Hazardous and Solid Waste Amendments (HSWA) in 1984, and 40 CFR 264 and 265 Subpart A through H.

SITE INFORMATION (CONT.)

- A National Pollutant Discharge Elimination System (NPDES) permit was required to discharge treated groundwater to the New York State Barge Canal.

Groundwater Remedy Selection:
Groundwater extraction and treatment via air stripping was selected as the remedy for this site.

Site Logistics/Contacts

Site Lead: Owner/Operator

Oversight:
New York State Department of Environmental Conservation (NYSDEC)

Remedial Project Manager:
Michael Infurna
U.S. EPA Region 2
290 Broadway
New York, NY 10007-1866
(212) 264-6150

Site Contact:
Paul William Hare*
Corporate Environmental Programs
General Electric Company
One Computer Drive South
Albany, NY 12205
(518) 458-6613

State Contact:
Larry Thomas*
New York State Department of Environmental Conservation (NYSDEC)
50 Wolf Road
Albany, NY 12233-7252
(518)457-9253

Treatment System Vendor:
Hydro Group, Inc. (1988-1997)
1011 Route 22
Bridgewater, NJ 08807
(908)704-8882

O'Brien & Gere Operations, Inc. (1997-Present)
5000 Brittonfield Parkway
Syracuse, NY 13221
(315) 437-8800

Technical Advisors to the Site Management:
O'Brien & Gere Engineers, Inc.
19 Walker Way
Albany, New York 12205
(518) 452-9392

*Indicates primary contacts.

MATRIX DESCRIPTION

Matrix Identification

Type of Matrix Processed Through the Treatment System: Groundwater

Contaminant Characterization

Primary Contaminant Groups: Halogenated VOCs

- The contaminants of concern at the site are trichloroethylene (TCE), *cis*-1,2-dichloroethylene (*cis*-1,2-DCE), 1,1,1-trichloroethane (TCA), and vinyl chloride.
- The maximum concentration of TCE detected in March 1988 was 70,000 ug/L in well 23-B. The maximum concentration of

MATRIX SYSTEM DESCRIPTION (CONT.)

1,2-DCE detected during the same time was 23,000 ug/L in well 18-S. Vinyl chloride and 1,1,1-TCA have been detected sporadically.

- The presence of DNAPL was investigated during the RCRA Facility Investigation (RFI). No evidene of DNAPL was found as a result of this investigation.

- The initial contaminant plume, shown in Figure 1, was estimated to be 30 feet thick and to cover an 11-acre area. Contamination was found to have migrated downward though the overburden into the fractured bedrock. The resulting plume is migrating in a northwesterly direction consistent with groundwater flow [2]. Plume volume could not be estimated given the subsurface variability.

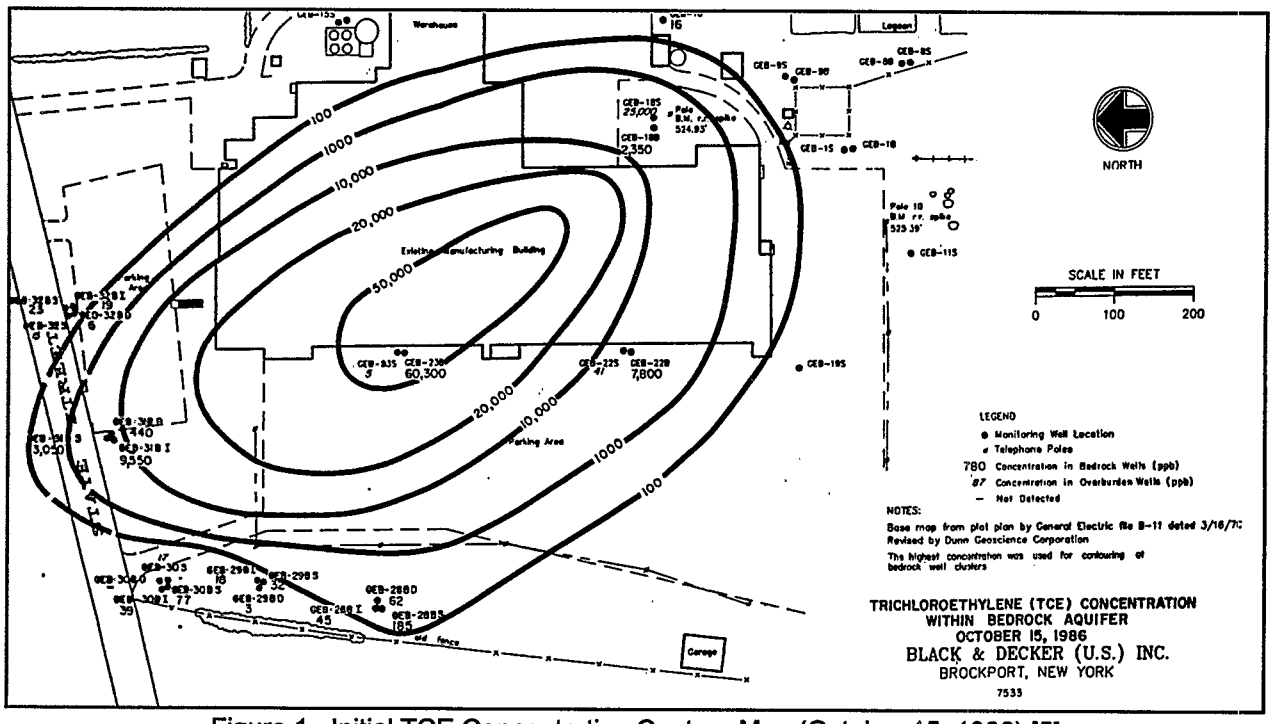

Figure 1. Initial TCE Concentration Contour Map (October 15, 1986) [5]

Matrix Characteristics Affecting Treatment Costs or Performance [2]

Hydrogeology:

Although subsurface materials at this site tend to function as a single hydrogeologic unit, due to differences in the geologic nature at this site of the materials, the site has been characterized as two units for EPA's remedial evaluation. The geology at this site is very complex, and the OSGWI has identified numerous hydrostratigraphic units. Information presented here is simplified for this discussion.

Unit 1	Overburden Aquifer	Silty fine to coarse sand and fine to coarse sandy silts with a little gravel and /or clay in places.
Unit 2	Bedrock Aquifer	Fractured sandstone interconnected to some degree with the overlying overburden materials.

MATRIX SYSTEM DESCRIPTION (CONT.)

The composition of both the overburden and bedrock units creates a complex environment for groundwater below this site. Groundwater flow is variable, less than 0.08 ft/day, and migration is very limited in the overburden aquifer. Groundwater flows along preferential pathways in the bedrock aquifer, complicating plume containment and monitoring. Furthermore, ambient water levels vary throughout the year to the extent that some of the overburden wells are dry for part of the year. On average, groundwater is encountered at 10 feet.

Matrix Characteristics Affecting Treatment Costs or Performance (Cont.)

Groundwater flows across the site in a northwesterly direction. The source areas are located in the central portion of the site. As the groundwater reaches the western side of the site it is captured in the fracture zone and extracted for treatment.

Tables 1 and 2 present technical aquifer information and technical well data, respectively.

Table 1: Technical Aquifer Information

Unit Name	Thickness (ft)	Conductivity (ft/day)	Average Velocity (ft/day)	Flow Direction
Overburden	5 - 20	0.93	0.0806	Northwest
Bedrock	150	0.65	0.078	Northwest

Source: [4]

TREATMENT SYSTEM DESCRIPTION

Primary Treatment Technology

Pump and treat with air stripping

Supplemental Treatment Technology

None

System Description and Operation

Table 2: Technical Well Data

Well Name	Unit Name	Depth (ft)	Yield (gal/day)
RW-1A	Bedrock Unit	40	16,150

Source: [3]

System Description [2, 3, 5]

- The groundwater extraction system consists of one recovery well (designated RW-1A) installed in 1987 as an interceptor well at the leading edge of the plume northwest of the former surface impoundments on the JMT facility, as listed in Table 2. The well placement was designed to prevent additional contaminants from migrating off site by achieving hydraulic containment [3].
- The initial plan for multiple conventional wells would not have been sufficient because of heterogeneity, as shown by

TREATMENT SYSTEM DESCRIPTION (CONT.)

pumping tests. The design engineers determined that one well placed at the toe of the plume in a blasted fractured zone would hydraulically contain the plume.

- To increase the degree of hydraulic conductivity and the interconnection in the bedrock fractures in the extraction well area, an interceptor drain was artificially created in the bedrock around the extraction well. Using controlled blasting techniques, a 300-foot long fracture zone was created in the upper 25 feet of the bedrock hydrogeologic unit, in effect "rubblizing" the upper portion of the bedrock. The blasted fracture zone was placed perpendicular to the direction of flow carrying the contaminant plume [2,3,5].

- The treatment system consists of a 57.5-foot packed-column air stripper tower with an internal diameter of 2.25 feet and a chemical feed system for addition of a sequestering agent to reduce bio-fouling. The tower is designed for a maximum flow of 100 gpm, and an air-to-water ratio of 75 to 1. The column was designed based upon 99.8% removal efficiency of TCE. Treated groundwater is discharged to the New York State Barge Canal under a SPDES permit [3].

- Two major modifications have been made to the system. In November 1995, an electrical and piping box was installed at the extraction well location, and a full-scale rehabilitation of the extraction well occurred during this same general time frame. In November 1996, an enclosure was constructed around the treatment system to provide heat and secondary containment.

- The groundwater quality is monitored quarterly in a core group of 15 wells and the extraction well. The discharge compliance monitoring for the treatment system is performed on a monthly basis as required by the SPDES permit.

System Operation [5, 6, 7-15]

- Quantity of groundwater pumped from the bedrock aquifer in gallons [5, 7-15]:

Year	Volume Pumped
1988	3,086,700
1989	4,865,000
1990	6,538,700
1991	4,222,300
1992	6,094,900
1993	7,054,800
1994	7,107,600
1995	3,787,100
1996	3,388,550
1997	3,924,750
Total	50,070,680

- As of December 1996, the treatment system was operational nearly 90% of the time. Shutdowns have been caused by periodic events, such as severe cold weather, ice storms, and lightning strikes. Downtime has also been influenced by rehabilitation, construction and maintenance activities [6].

- The air stripping media has only been changed once during the life of the treatment system in November 1995. A weak solution of nitric acid (5%) was used to remove scaling (bio-fouling) from the inside of the column and to loosen the packing [6]. Also in November 1995, a recovery well (RW-1A) rehabilitation was performed [13].

Operating Parameters Affecting Treatment Cost or Performance

The major operating parameter affecting cost or performance for this technology is the groundwater extraction rate. Table 3 presents the average extraction rate between 1988 and 1996, and the required performance parameters.

TREATMENT SYSTEM DESCRIPTION (CONT.)

Operating Parameters Affecting Treatment Cost or Performance (Cont.)

Table 3: Performance Parameters

Parameter	Value	
Average System Extraction Rate	11.2 gpm	
Performance Standard (Daily Maximum in SPDES permit)	TCE *cis*-1,2-DCE TCA Vinyl chloride	0.026 kg/day 0.079 kg/day 0.026 kg/day 0.132 kg/day
Remedial Goal (MCLs)	TCE *cis*-1,2-DCE TCA Vinyl chloride	5 µg/L 5 µg/L 5 µg/L 2 µg/L
Note: Average system rate was 11.2 gpm based on 46,145,650 gallons treated, system run time, and a 90% operational rate		

Source: [5, 7-15, 17]

Timeline

Table 4 presents a timeline for this corrective action project.

Table 4: Project Timeline

Start Date	End Date	Activity
1987	---	Remedial construction performed
1987	---	Artificial fracture created
5/88	---	P&T system placed into operation
4/94	---	Post-closure permit issued
10/94	1996	Installation of 40 off-site monitoring wells
8/96	---	Off-site groundwater investigation presented

Source: [2,16,17,18]

TREATMENT SYSTEM PERFORMANCE

Cleanup Goals/Standards

- Clean-up goals are set at New York State groundwater standards which are the Maximum Contaminant Levels (MCL) listed in Table 3 [17].

Additional Information on Goals

- The cleanup goals must be met in recovery well RW-1A [17]. The single compliance well is analyzed for Appendix IX constituents. However, termination criteria for the P&T system is also dependent on point-of-exposure wells, of which there are currently 17 [21].

TREATMENT SYSTEM PERFORMANCE (CONT.)

Treatment Performance Goals

- The goal of the treatment system is to reduce effluent contaminant concentrations to mass-based limits in order to meet SPDES permit requirements listed in Table 3 [2].
- The goal of the recovery system is to achieve hydraulic containment of the plume [6].

Performance Data Assessment [5, 6, 7-15, 18, 21]

For this discussion and Figures 3 and 5, total contaminant concentrations include TCE, 1,2-DCE, 1,1,1-TCA, and vinyl chloride.

- Figure 2 shows the trend in VOC concentrations detected in RW-1A from late 1987 to April 1988, before the system became operational, and from May 1988 through September 1997. As shown in this figure, concentrations of TCE declined 80% from 4,600 µg/L in December 1987 to 490 µg/L in September 1997. Concentrations of 1,2-DCE declined 91% from 1,600 µg/L in December 1987 to 140 µg/L in September 1997. Concentrations of contaminants remain above remedial goals [15].
- Groundwater monitoring results from May 1988 to December 1996 indicate that total contaminant concentrations have been reduced. Figure 3 illustrates changes in the average total contaminant concentrations in the groundwater over time. In the first year, average total contaminant concentrations declined 84% and average TCE concentrations dropped by a similar amount. Over the next six years, average total contaminant contamination declined by 80 percent [5, 7-15].
- In May 1996, the average concentration of TCE detected was 7 µg/L, while the maximum TCE concentration detected was 21 µg/L. Both the maximum and average concentrations are above the site cleanup levels.
- The use of blasting fractures to enhance conductivity in the fracture zone was an innovative approach to the challenges posed by the highly variable groundwater flow patterns at this site. Its effectiveness in enhancing the degree of conductivity and contaminant capture is demonstrated in Figure 4. In the first sampling episode after the zone was created in May 1987, TCE concentrations increased in wells GEB-31BD and GEB-32BI, both of which are directly downgradient of the fracture zone. However, as shown in the figure, these concentrations then decreased steadily in both wells [5, 7-11].
- During a 1994 -1996 post-closure investigation, contaminants were detected in off-site wells. However, the NYSDEC and the owner operator have concluded that the plume had been contained, and the off-site plume was believed to be residual contamination prior to pump-and-treat [21]. The addition of a new extraction well and a treatment system is currently being evaluated [16].
- The SPDES permit limitations have been met consistently since the permit was issued in May 1988 [6].
- Figure 5 presents the removal of contaminants through the treatment system annually from 1988 to 1996. During this time the P&T system removed approximately 842 pounds of contaminant mass from the groundwater [7, 18].
- The average system extraction rate is 11.2 gpm. Annual average pump rates have ranged from 8.2 gpm to a high of 13.5 gpm in 1994 [7,13].

TREATMENT SYSTEM PERFORMANCE (CONT.)

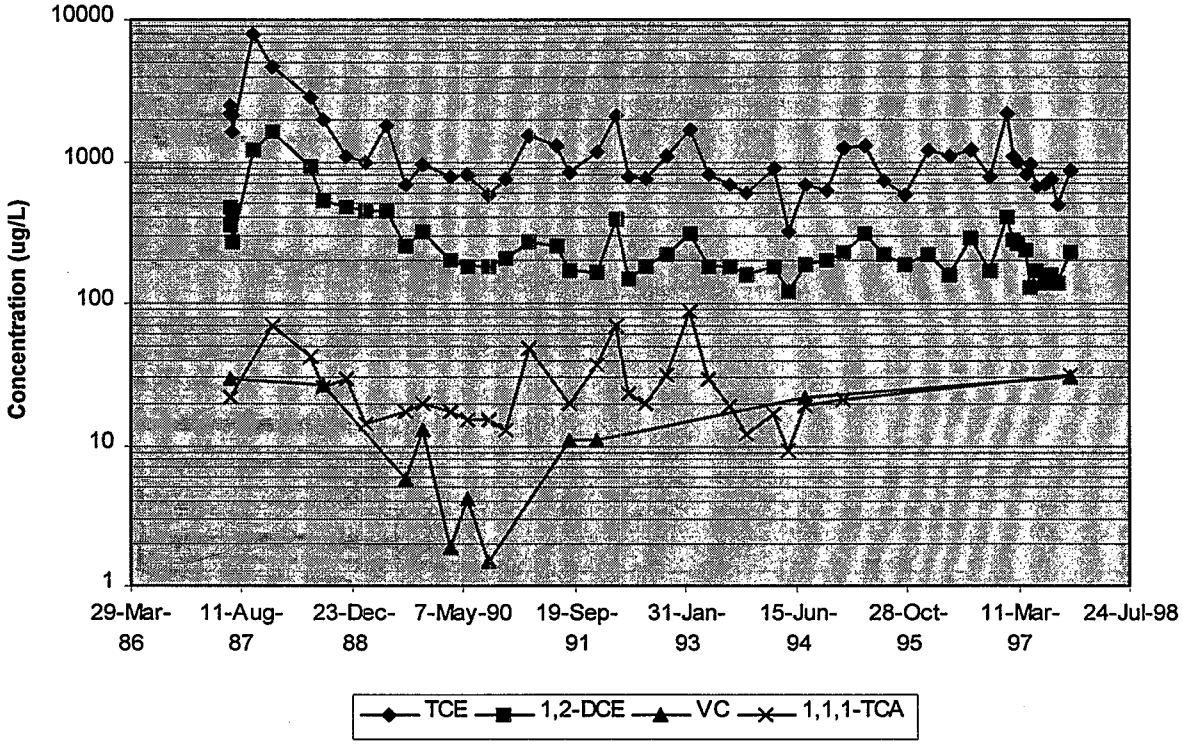

Figure 2. VOC Concentrations Detected in RW-1A (1987-1997) [5,7-15, 21]

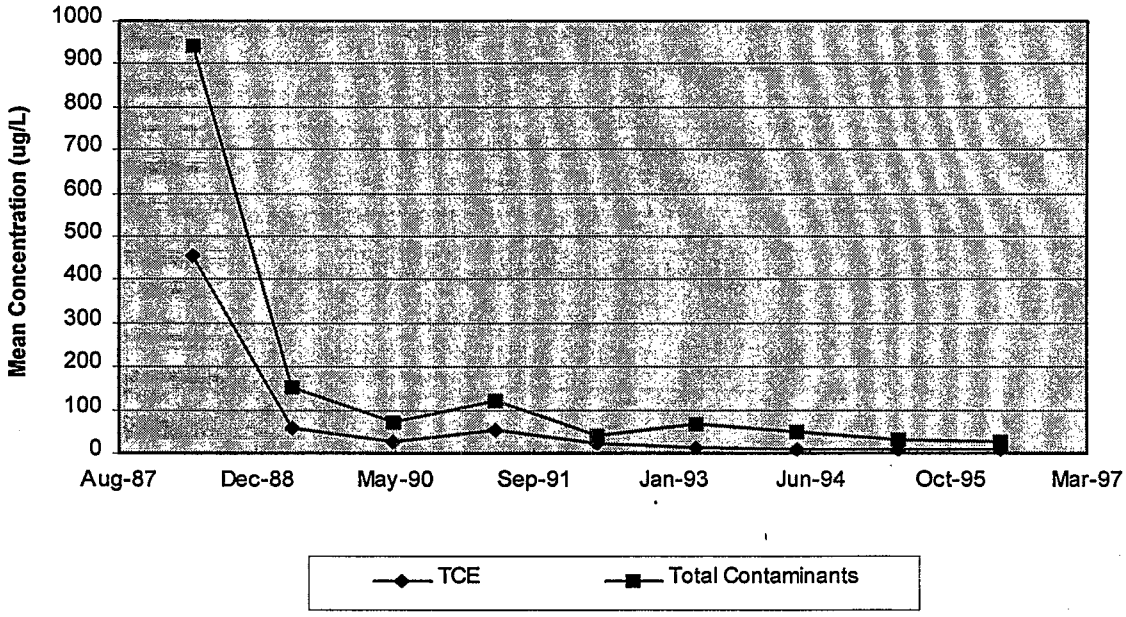

Figure 3. Average Groundwater Concentrations at the Toe of the Plume (1988-1996) [5, 7-15]

TREATMENT SYSTEM PERFORMANCE (CONT.)

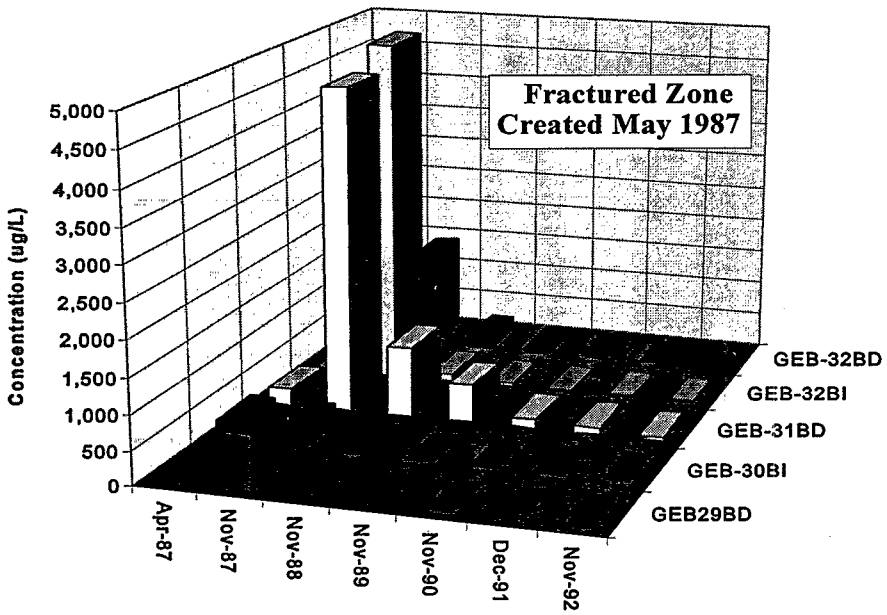

Figure 4. Well TCE Concentrations Near Fracture Zone [5, 7-11]

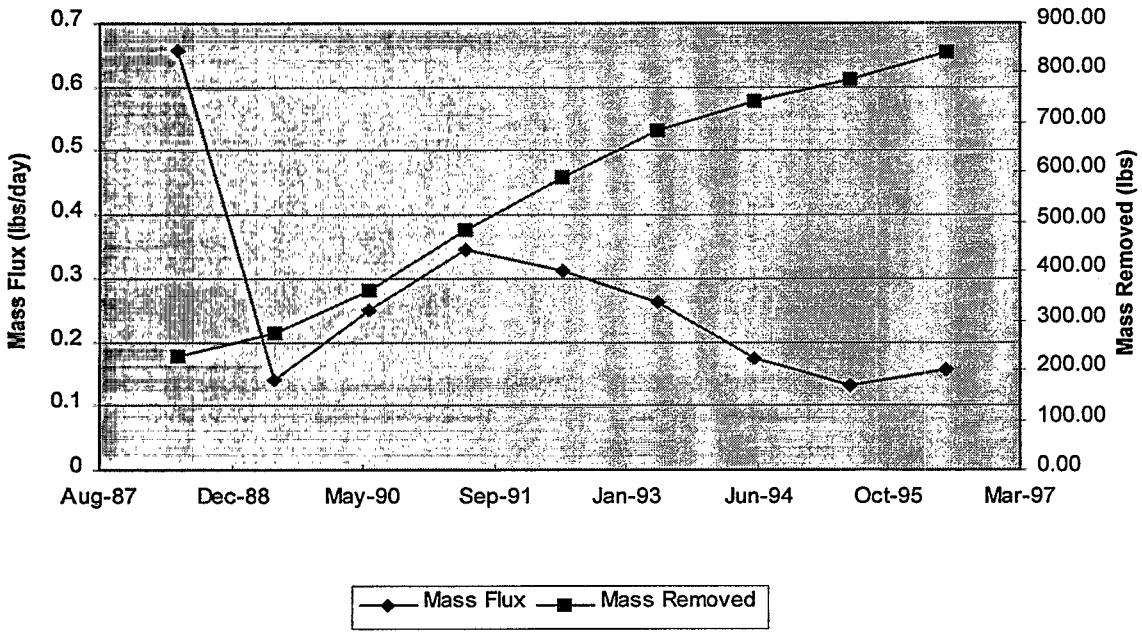

Figure 5. Mass Flux Rate and Cumulative Contaminant Removal (1988-1996) [7, 18]

TREATMENT SYSTEM PERFORMANCE (CONT.)

Performance Data Completeness

- Performance sampling for the treatment system is performed on a monthly basis. Data for the influent concentrations, effluent concentrations, and the system flow rate are available in the monthly SPDES Discharge Monitoring Reports (DMR). The analyses in Figure 2 are based on one month's data per year (June) collected from 1988 to 1996.
- Groundwater quality monitoring is performed during quarterly sampling events. A core group of 15 monitoring wells and the single recovery well are sampled for VOCs. Cyanide is monitored in the recovery well and 3 monitoring wells.
- A geometric mean was used for the average groundwater concentrations to represent the trend of contaminants in the groundwater at the toe of the plume. The second quarter monitoring event was used for annual data points plotted in Figure 3 of this report. A series of five well clusters throughout the plume, three wells in each cluster, has been used consistently to monitor the shallow, intermediate, and deep bedrock since 1988. A subset of five wells at the toe of the plume has been selected to document the effectiveness of the P&T system (i.e., GEB-28BS, GEB-29BD, GEB-30BI, GEB-31BI, GEB-32BI).

Performance Data Quality

The QA/QC program used throughout the corrective action met New York State requirements. All sample monitoring was performed using EPA-approved methods (SW-846 Methods 8010 and 9010), and the vendor did not note any exceptions to the QA/QC protocols unless otherwise noted.

TREATMENT SYSTEM COST

Procurement Process [6, 19]

G.E. contracted with Hydro Group, Inc. and its affiliate, Ground Water Associates, Inc., to construct and operate the remediation system, under the oversight of the NYSDEC. G.E. subsequently contracted with O'Brien & Gere Operations, Inc. for these services.

Cost Analysis

- Black and Decker and G.E. Company assumed all costs for investigation, design, construction, and operation of the treatment system at this site.

Capital Costs [6, 19]

Remedial Construction & Design	
Includes blasting of artificial fracture zone, pre- and post-blast pump tests, and construction of treatment system	$650,000
Enclosure building	$204,000
Piping and electrical enclosure at the extraction well - "hot-box"	$25,000
Total Site Cost	**$879,000**

Operating Costs [6, 19]

Annual Operation and Maintenance	
Includes all SPDES reporting, groundwater quality sampling, preparation of quarterly and annual reports, and maintenance costs	$150,000
Estimated Cumulative Total Operating Expenses (1987 to 1996)	**$1,284,000**

Cost Data Quality

The G.E. Company provided an estimate for actual capital costs, and an estimate of cumulative operating costs through 1997 [19].

OBSERVATIONS AND LESSONS LEARNED

- The total cost of treatment using the P&T system was $2,163,000, consisting of $879,000 in capital costs and $1,284,000 in estimated cumulative operating and maintenance costs through 1996 (assuming an average O&M cost of $150,000 per year) [6, 19]. According to the site contact, the cost of O&M has dropped significantly since 1988; largely because of more efficient O&M methods, decline in analytical service rates, upgrades, and less frequent non-routine maintenance requirements [6].
- Two modifications to the P&T system, enclosure of the treatment system and installation of a hot-box, resulted in an increase in capital costs totaling $229,000. Capital costs increased 35% over the original cost.
- The treatment system performance data indicate that approximately 842 pounds of contaminants were removed from the groundwater over 103 months at a cost of $2,569 per pound. As of the date of this report, the P&T system had not achieved cleanup goals [5, 7-15].
- Taking into account the cumulative cost of capital and operations and the volume of groundwater treated through 1996, the cost per 1,000 gallons treated was $47.
- Building an enclosure for the treatment system was a substantial cost. However, according to the site contact, the efficiency of the overall system has improved, especially in the winter months, and less time is needed for shutdown due to inclement weather. The cost-effectiveness of the enclosed building will be better determined in the future [21].
- Data indicate that the P&T system has reduced the contaminant concentration levels in the plume; however, contaminant concentrations in much of the plume remain above the established remedial goals [5, 7-15].
- Implementation of an artificially produced fracture zone in the bedrock was an innovative remedial alternative for this site. Through the use of controlled blasting, a selected zone of bedrock was transformed into a conduit which conveys groundwater to the single extraction well [20].
- Data from the RFI indicated that no significant amounts of DNAPL were present at the facility. The site engineer believes that the steady decline in contaminant concentrations in source areas is further evidence that no DNAPL contamination occurred at this site [6].

REFERENCES

1. Detailed Design for Treatment Enclosure, JMT Facility (EPA ID No. NYD002221919) Brockport, New York. General Electric Company Memorandum.
2. Evaluation of Ground Water Extraction Remedies: Phase II, Volume 2: Case Studies and Updates. U.S. Environmental Protection Agency. PB2-963346. February 1992.
3. Post Closure Permit Application, Part B. Appendix E-19: Treatment Facility Design. Hydrogroup. December 8, 1987.
4. Remedial System Performance Monitoring Plan, Black and Decker, Brockport, NY. Appendix E-26 of Post Closure Permit Application. Dunn Geoscience Corporation. January 11, 1989.

REFERENCES (CONT.)

5. RCRA Annual Groundwater Monitoring Report - 1987. Dunn Geoscience Corporation. March 1988.

6. Correspondence with Paul Hare, General Electric Company. June 2, 1997.

7. RCRA Annual Groundwater Monitoring Report - 1988. Dunn Geoscience Corporation. March 1989.

8. 1989 RCRA Annual Groundwater Monitoring Report. Dunn Geoscience Corporation. March 1990.

9. 1990 RCRA Annual Groundwater Monitoring Report. Dunn Geoscience Corporation. March 1991.

10. 1991 RCRA Annual Groundwater Monitoring Report. Dunn Geoscience Corporation. February 1992.

11. 1992 RCRA Annual Groundwater Monitoring Report. O'Brien & Gere Engineers, Inc. March 1993.

12. 1993 RCRA Annual Groundwater Monitoring Report. O'Brien & Gere Engineers, Inc. March 1994.

13. 1994 RCRA Annual Groundwater Monitoring Report. O'Brien & Gere Engineers, Inc. March 1995.

14. 1995 RCRA Annual Groundwater Monitoring Report. O'Brien & Gere Engineers, Inc. March 1996.

15. 1996 and 1997 RCRA Annual Groundwater Monitoring Reports. O'Brien & Gere Engineers, Inc. February 1997.

16. Off-Site Ground Water Investigation Report. O'Brien & Gere Engineers, Inc. August 1996.

17. RCRA Post Closure Permit. New York Department of Environmental Conservation. April 1994.

18. June SPDES Discharge Reports, Hydrogroup and O'Brien & Gere. June 1988-June 1996.

19. Personal communication with Lawrence Thomas, NYDEC. May 12-13, 1992.

20. Personal Communication with Paul Hare, General Electric Company. May 17, 1994.

21. Comments on draft report provided by Paul Hare, General Electric Company, and Larry Thomas, New York State Department of Environmental Conservation.

Analysis Preparation

This case study was prepared for the U.S. Environmental Protection Agency's Office of Solid Waste and Emergency Response, Technology Innovation Office. Assistance was provided by Eastern Research Group, Inc. and Tetra Tech EM Inc. under EPA Contract No. 68-W4-0004.

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Pump and Treat of Contaminated Groundwater at the Keefe Environmental Services Superfund Site, Epping, New Hampshire

Pump and Treat of Contaminated Groundwater at the Keefe Environmental Services Superfund Site, Epping, New Hampshire

Site Name: Keefe Environmental Services Superfund Site	**Contaminants:** Chlorinated solvents - Maximum concentrations included PCE (140 ug/L), TCE (210 ug/L), 1,1-DCE (1,200 ug/L) Volatiles- nonhalogenated - Maximum concentrations included benzene (160 ug/L)	**Period of Operation:** Status: Ongoing Report covers: 4/93 - 5/97
Location: Epping, New Hampshire		**Cleanup Type:** Full-scale cleanup (interim results)
Vendor: David Didian Woodward & Curran, Inc. (W&C) 41 Hutchins Drive Portland, ME 04101 (207) 774-2112	**Technology:** Pump and Treat - Groundwater is extracted using 5 wells, located off site, and 1 trench, located on site, at an average total pumping rate of 23.4 gpm - Extracted groundwater is treated with coagulation/flocculation and air stripping - Treated groundwater is discharged to the groundwater through an infiltration trench and spray irrigation system	**Cleanup Authority:** CERCLA Remedial - ROD Date: 3/21/88 - ESD Date: 6/90
State Point of Contact: Tom Andrews NHDES 6 Hazen Drive Concord, NH 03301 (603) 271-2910		**EPA Point of Contact:** Darryl Luce, RPM U.S. EPA Region 1 JFK Federal Building One Congress Street Boston, MA 02203 (617) 573-5767
Waste Source: Storage of drums and containers, unauthorized dumping, leaking lagoon	**Type/Quantity of Media Treated:** Groundwater - 46 million gallons treated as of May 1997 - Extraction wells are located in 2 aquifers, which are not influenced by a nearby surface water - Hydraulic conductivity ranges from 0.025 to 42.5 ft/day	
Purpose/Significance of Application: Performed optimization study after two years of operation; relatively low groundwater flow		

Regulatory Requirements/Cleanup Goals:
- Cleanup standards were established for the upper overburden and bedrock aquifers on site and the sand and gravel aquifer off site. These standards were required to have been met in all monitoring wells in the respective aquifers for two consecutive sampling rounds.
- Cleanup standards were identified for 1,2-DCA (5 ug/L), 1,2-DCE (7 ug/L), TCE (5 ug/L), PCE (5 ug/L), and benzene (5 ug/L).
- The treatment system was required to meet the cleanup goals for groundwater re-injected into the aquifer.
- The extraction system must capture and contain the contaminant plume.

Results:
- Average contaminant concentrations at the site have decreased 76% from April 1993 to October 1996. However, individual contaminant concentrations have not been reduced to below the cleanup goals.
- The P&T system has removed approximately 68 pounds of contaminants through February 1997.
- The treatment system has consistently met the performance standards established for this application.
- Plume containment has been achieved.

Pump and Treat of Contaminated Groundwater at the Keefe Environmental Services Superfund Site, Epping, New Hampshire (continued)

Cost:

- Actual cost data for this application show that approximately $2,408,000 ($1,582,539 in capital costs and $826,000 in O&M) were expended through May 1997, which correspond to $52 per 1,000 gallons of groundwater extracted and $35,000 per pound of contaminant removed.
- The mass removed through the treatment system may be significantly lower than the total mass extracted from the groundwater because of volatilization and other loses prior to the treatment plant; therefore, the cost per pound removed may be less than shown above.

Description:

Keefe Environmental Services operated from 1978 until 1981 as a spent solvent bulking, recovery, and reclamation facility. The facility consisted of drum storage areas, large bulk storage tanks, equipment shelters, a bulking area, and a 700,000-gallon, synthetically-lined waste lagoon. In 1979, a groundwater monitoring program began, and chlorinated solvents were detected. The site was added to the NPL in 1983 and a ROD was signed in March 1988. An ESD was issued in June 1990.

The current extraction system consists of four wells in the upper overburden aquifer, one well in the bedrock aquifer, and a collection trench. This extraction system was modified in 1995 (two years after startup) to optimize performance. Two wells were added and two others removed; locations for the new wells were selected to increase extraction rates. The treatment system consists of a coagulation/flocculation unit, an air stripping tower, and a vapor-phase carbon adsorption unit; the maximum design flow rate is 60 gpm. After four years of operation, the P&T system has reduced average contaminant concentrations within the plume and contained the plume from further migration. The site has not, however, met cleanup goals.

SITE INFORMATION

Identifying Information:

Keefe Environmental Services (KES) Superfund Site

CERCLIS #: NHD092059112

ROD Date: March 21, 1988

Treatment Application:

Type of Action: Remedial

Period of operation: April 1993 - Ongoing (Data collected through May 1997)

Quantity of material treated during application: As of May 1997, 46 million gallons of groundwater

Background

Historical Activity that Generated Contamination at the Site: Spent solvent bulking, recycling, and reclamation

Corresponding SIC Code: 7389A (Solvents Recovery)

Waste Management Practice That Contributed to Contamination: Storage of drums and containers, unauthorized dumping, leaking lagoon

Location: Epping, New Hampshire

Facility Operations: [1, 9]

- The 7.5-acre site was operated by KES from 1978 until 1981 as a spent solvent bulking, recovery, and reclamation facility.
- During its operation, the facility consisted of drum storage areas, large storage tanks, equipment shelters, a bulking area, and a 700,000-gallon, synthetically-lined waste lagoon.
- In 1980, KES abandoned the site because of financial constraints, leaving behind drums and storage tanks full of hazardous materials.
- In 1981, EPA took emergency response actions to remove hazardous materials that were stockpiled at the site. These materials presented an imminent hazard to human health and the environment [1].
- In 1982, EPA and NHDES expanded the groundwater monitoring program that was initiated in 1979. Chlorinated solvents have been detected in the groundwater since monitoring began.
- The site was added to the National Priorities List (NPL) in 1983.
- The Remedial Investigation (RI) performed in 1985 and 1986 found contaminants in the on-site soils and groundwater. This report will cover the groundwater contaminants only.

Regulatory Context: [1, 9]

- On March 19, 1986, the State of New Hampshire, the Town of Epping, and 127 settling PRPs entered into a Consent Decree.
- On March 21, 1988, EPA issued a Record of Decision (ROD) for the groundwater cleanup at this site.
- On June 8, 1990, EPA issued an Explanation of Significant Differences (ESD) for this site.
- Site activities are conducted under provisions of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980, as amended by the Superfund Amendments and Reauthorization Act (SARA) of 1986, §121, and the National Contingency Plan (NCP), 40 CFR 300.

Remedy Selection:

- Groundwater extraction and treatment via air stripping and carbon adsorption was selected as the remedy for this site based on treatability studies [1].
- The original design included soil vapor extraction (SVE) to remove contaminants from shallow soils that may act as a source zone. The remedy was amended in an ESD when additional sampling during remedial design found soil concentrations to be lower than found in the RI. SVE was not used at this site and no other source control measures were conducted or planned.

SITE INFORMATION (CONT.)

Site Logistics/Contacts

Site Lead: State

Oversight: EPA

Remedial Project Manager:
Darryl Luce
U.S. EPA Region I
John F. Kennedy Federal Building
One Congress Street
Boston, MA 02203
617-573-5767

State Contact:
Tom Andrews*
NHDES
6 Hazen Drive
Concord, NH 03301
603-271-2910

*Indicates primary contact

Operation and Maintenance (O&M) Contractor:
David Didian
Woodard & Curran Inc. (W&C)
41 Hutchins Drive
Portland, ME 04101
207-774-2112

Design Contractor:
Camp, Dresser & McKee, Inc (CDM)
Cambridge, MA 02142
617-252-8000

MATRIX DESCRIPTION

Matrix Identification

Type of Matrix Processed Through the Treatment System: Groundwater

Contaminant Characterization [1,7]

Primary Contaminant Groups: Halogenated volatile organic compounds

- Contaminants of concern include tetrachloroethylene (PCE), trichloroethylene (TCE), 1,1-dichloroethylene (1,1-DCE), 1,2-dichloroethane (1,2-DCA), and benzene.
- In 1990, maximum contaminant concentrations observed in the groundwater were PCE at 140 µg/L, TCE at 210 µg/L, 1,1-DCE at 1,200 µg/L, and benzene at 160 µg/L.
- By 1993, groundwater contaminants had migrated off site, and the size of the plume was estimated by site engineers to be 12 acres and 15 to 30 feet deep. The volume of contaminated groundwater was estimated to be 9.8 million gallons. Figure 1 presents a contour map of contaminant concentrations encountered at the site in 1993. No estimates of plume size before 1993 were provided in the available references.
- Contaminants are primarily found in the overburden material (Unit 2) which overlies the bedrock. Figure 1 shows concentration contours of total VOCs and 1,1,-DCE as high as 1,000 µg/L and 4,000 µg/L, respectively.

MATRIX DESCRIPTION (CONT.)

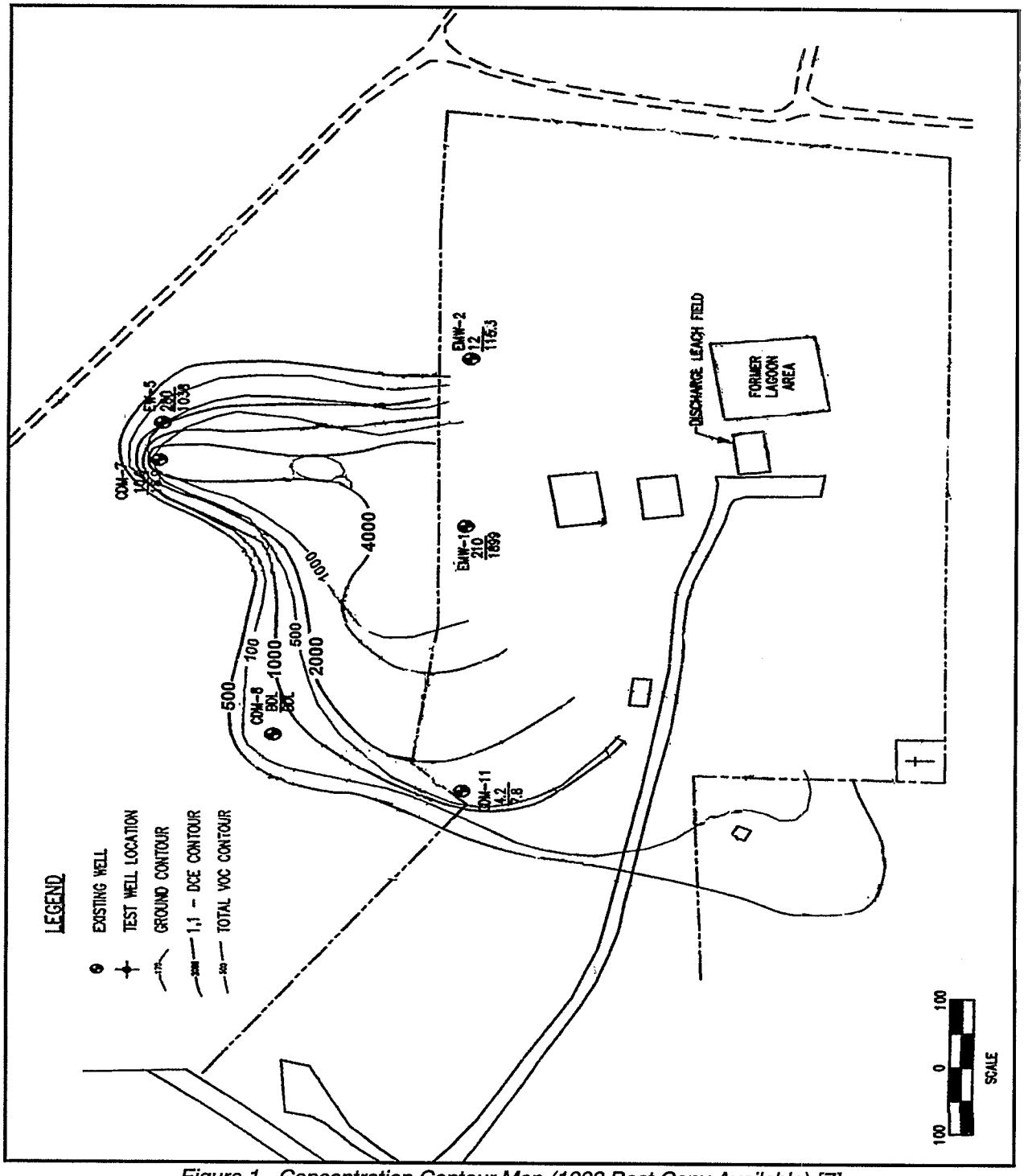

Figure 1. Concentration Contour Map (1993 Best Copy Available) [7]

MATRIX DESCRIPTION (CONT.)

Matrix Characteristics Affecting Treatment Costs or Performance

Hydrogeology: [5,6,7,8]

Three distinct hydrogeological units have been identified at this site.

Unit 1	Off site	Glacial sand and gravel outwash deposit consisting of stratified, silty, fine-to-medium sand and gravel that overlies the glacial till in lowlands adjacent to the site. The outwash is partially confined by a thin silty clay layer at the surface. This unit begins at the site boundaries.
Unit 2	On site	Upper overburden aquifer lacking sand lenses and consisting of glacial till. This unit is found on site and is overlain by Unit 1 off site.
Unit 3	Off site and On site	Fractured bedrock consisting of a muscovite schist. The bedrock is highly fractured throughout the upper 20 to 25 feet.

In Unit 2, groundwater flows radially away from the site toward the sand and gravel layer. Groundwater flow is determined by hydraulic conductivity and hydraulic gradient. Unit 2, composed of glacial till, is characterized by low hydraulic conductivity and high hydraulic gradient. The reverse situation occurs at the site boundary where the sand and gravel layer (Unit 1) overlies the glacial till. Unit 1 is present to the south and west of the site, and is the most conductive unit. Groundwater flows preferentially through this unit. Regionally, groundwater flow is to the west. The aquifer conductivity estimated for this site ranges from very high in the off-site sand and gravel unit to very low in the on-site glacial till.

Tables 1 and 2 provide technical aquifer information and well data, respectively.

Table 1. Technical Aquifer Information

Unit Name	Thickness (ft)	Conductivity (ft/day)	Average Groundwater Velocity (ft/day)	Flow Direction
Unit 1	0-30	42.5	0.033	Radial
Unit 2	20-125	0.025	0.033	Radial
Unit 3	50-120	NA	NA	NA

Source: [5,6]
NA - not applicable (fractured bedrock)

TREATMENT SYSTEM DESCRIPTION

Primary Treatment Technology

Pump and treat with air stripping

Supplemental Treatment Technology

Vapor-phase carbon adsorption, coagulation/flocculation

System Description and Operation

Table 2. Technical Well Data

Well Name	Unit Name	Depth (ft)	Yield (gal/day)
EW-1	Overburden	30	2,160 - 4,320
EW-2	Overburden	30	144 - 432
EW-3 (Not in service)	Overburden	30	NA
EW95-2 (New)	Overburden	30	11,520 - 14,400
EW95-7 (New)	Overburden	30	11,520 - 14,400
EW-5 (Not in service)	Overburden	30	NA
BEW	Bedrock	120	NA

Note: Average system rate is 33,700 gpd, based on the volume of water pumped since operations began and an operational rate of 95%. NA - no water currently pumped from these wells.

Source: [7,8]

System Description [7]

- The current extraction system consists of four wells in the upper overburden aquifer (Unit 1), one well in the bedrock aquifer (Unit 3), and a collection trench. The extraction wells are located off site, and the trench is located on site near the property boundary. This extraction system design was modified in 1995 (two years after remediation startup) to optimize performance. Two wells (EW95-2 and EW95-7) were added and two wells (EW-3 and EW-5) were removed from service. Locations for the two new wells were chosen to increase extraction rates. The bedrock well has been shut down since February 1995 because no contaminants were detected in this well.

- The extraction system design placed the wells off site and the collection trench on site at the property boundary to pull the plume towards the extraction network. Wells were placed off site because hydrogeologic conditions allowed for better pump rates and larger capture zones.

- The treatment system consists of a coagulation/flocculation unit, an air stripping tower, and a vapor-phase carbon adsorption unit. Maximum design flow rate is 60 gpm.

- The air stripper is 2.5 feet in diameter and 38 feet tall. A packing height of 30 feet with an air-to-water ratio of 50:1 is used to meet discharge requirements.

- The packing media is a 3.5-inch diameter polypropylene Tripac type.

- Effluent from the treatment system is discharged to the groundwater through an infiltration trench and a spray irrigation system. The spray irrigation system was implemented in June 1995 and operates when the temperature is above freezing.

TREATMENT SYSTEM DESCRIPTION (CONT.)

System Description and Operation (Cont.)

System Operation [3, 7, 8]

- The system began operating in April 1993. Below is the quantity of groundwater pumped from the aquifer in gallons (annual extraction rates not provided):

Total to Date	Well Location
5,159,000	EW-1
332,000	EW-2
2,445,000	EW95-2
5,150,000	EW95-7
8,838,000	Off-line wells*
23,756,000	Collection Trench
45,680,000	**Total**

*This includes the two removed wells and the inactive bedrock well.

- By 1995, contaminant concentrations in the extracted groundwater were reduced to less than 20 µg/L on average and mass flux to the treatment system was less than 0.01 lbs/day. As a result, the O&M contractor conducted an evaluation to optimize system performance. A calibrated groundwater model was used in the site evaluation [8]. The groundwater model for the Keefe site was created using MODFLOW, and PATH3D was used to estimate capture zones.
- As of May 1997, the treatment plant has been operational 97% of the time. Downtime is attributed to brownouts and routine maintenance [7].
- Air stripping media has not been changed to date, and the media has not required washing [3].
- Spent vapor-phase carbon was changed once in August 1996, at a cost of $5,000 [7]. This material was shipped off site by the vendor for regeneration.
- As a result of the optimization study in 1995, the installation of two new wells allowed two existing wells to be taken off line. The new wells, listed as EW-95-2 and EW-95-7 in Table 2, also were placed off site. Their locations were chosen, with the aid of the groundwater model, to increase groundwater extraction rates [8].

Operating Parameters Affecting Treatment Cost or Performance

The major operating parameter affecting cost or performance for this technology is the extraction rate. Table 3 presents the values measured for this and other performance parameters.

Table 3: Performance Parameters

Parameter	Value
Average Pump Rate	23.4 gpm
Performance Standard	Remedial Goals
Remedial Goals (aquifer and effluent)	Benzene 5 µg/L 1,2,-DCA 5 µg/L 1,1-DCE 7 µg/L TCE 5 µg/L PCE 5 µg/L

Source: [2]

TREATMENT SYSTEM DESCRIPTION (CONT.)

Timeline

Table 4 presents a timeline for this remedial project.

Table 4: Project Timeline

Start Date	End Date	Activity
3/88	---	ROD signed
6/90	---	ESD issued
9/90	11/91	Dates for design
6/92	4/93	Dates of construction
4/93	---	P&T system operations begun
---	9/93	Start-up and shake down process completed
6/95	---	P&T system optimized to increase pump rate and mass removed and shorten expected operating time requirement

Sources: [1,5,6]

TREATMENT SYSTEM PERFORMANCE

Cleanup Goals/Standards

Groundwater remediation must continue until all cleanup standards (listed in Table 3) have been attained in the upper overburden and bedrock aquifers on site and in the sand and gravel aquifer off site. These conditions must be met in all monitoring wells in the respective aquifers for two consecutive quarterly sampling rounds [9].

Additional Information on Goals

If cleanup goals are not met after 10 years of treatment, EPA and NHDES will reevaluate the appropriateness of the groundwater treatment system and/or cleanup standards [9].

Treatment Performance Goals [1]

- The treatment system effluent must meet the remedial goals for the groundwater since effluent is reinjected to the aquifer [7].
- As a secondary goal, the extraction system is designed to capture and contain the contaminant plume [7].

Performance Data Assessment [7,8]

For this report, total VOC concentration includes PCE, TCE, 1,1-DCE, 1,2-DCA and benzene.

- Average contaminant concentrations at this site have decreased 76% from April 1993 to October 1996. Groundwater monitoring results indicate that individual contaminant concentrations in the groundwater were not reduced below remedial goals.
- Figure 2 illustrates how the mean VOC concentration in the groundwater has changed over time. A geometric mean of the contaminant concentrations is used to indicate the trend within the entire plume. The data show that, overall, the mean decreased from 80 µg/L to 20 µg/L after a large decrease in the first year. The rate of concentration decrease has slowed over the last two years of operation.
- Figure 3 presents the removal of total VOCs through the treatment system annually from November 1993 to February 1997. During this time, the P&T system has removed approximately 68 pounds of contaminant mass. The extraction rate decreased from 0.13 lb/day to less than 0.04 lb/day during the first year of operation. During the next three years, the extraction rate remained nearly constant at 0.04 lb/day or less. The data show a gap where the system was shut down for modifications. The mass flux increased immediately after the new extraction wells were installed, but also shows steady decline over the next year of sampling.

TREATMENT SYSTEM PERFORMANCE (CONT.)

Performance Data Assessment (Cont.)

- According to the state contact, the mass removed through the treatment plant may be lower than the total mass extracted from the groundwater plume due to volatilization and other losses prior to the treatment plant.
- Based on Monthly Operating Reports, the treatment system effluent has consistently met the performance standards listed in Table 3.
- Prior to the 1995 system modifications, the contaminant plume was migrating off site. Based on a review of contaminant plume maps from 1995 and 1996, it appears that containment has been achieved since the extraction system was modified. The off site part of the plume has decreased in size, but still remains around wells EMW-3, CDM-IA, and CDM-10.
- Figure 4 presents total VOC concentrations in on-site monitoring wells Q1 and EMW-1. Both monitoring wells are located near the area of highest concentrations on site. The data in the figure indicate that elevated concentrations persist in the on-site groundwater. Concentrations in well EMW-1 have fluctuated between 100 µg/L and 3,200 µg/L. Concentrations in well Q1 have increased during the October 1996 sampling event after steadily decreasing in every sampling event prior. Overall, the concentrations in both wells are down from original levels. The reasons for the concentration fluctuations in monitoring well EMW-1 and the increase in Q1 are not known at this time.
- Figure 5 presents total VOC concentrations in monitoring wells CDM-9, CDM-10, and EMW-3. These wells are located off site in the contaminant plume. Contaminant concentrations have decreased in all three wells from startup to the October 1996 sampling event. As of October 1996, total VOC concentrations in monitoring wells CDM-9, CDM-10, and EMW-3 were 25 µg/L, 190 µg/L, and 480 µg/L, respectively.
- By May 1997, a total of 46 million gallons of groundwater were treated. Over the life of the system, the average flow rate was 23.4 gpm with a 97% operational rate. The site contact also reported that an additional 8 million gallons were treated during the remaining months of 1997.

Performance Data Completeness

- Performance sampling for the treatment system is conducted monthly. Data for influent concentration, effluent concentration, flow, chemical usage, and sludge production are available in monthly reports. Three monthly sampling events per year were used for Figure 3. These data were provided by the NHDES contact.
- Groundwater monitoring is performed semi-annually based on the monitoring program agreed to by EPA and the state. Data from 37 monitoring and extraction wells are available for these monitoring events. Eight groundwater sampling events were used for analyses performed in this report.
- Influent data and well data were provided by the NHDES contact. A geometric mean was used for average groundwater concentrations to represent the level of contaminants in the groundwater across the entire plume. Where concentrations were below detection limits, half of the detection limit was used for analysis of the data.
- Contaminant mass removal data were provided by the state contact.

Performance Data Quality

The QA/QC program used throughout the remedial action met the EPA and the State of New Hampshire requirements. All monitoring as performed using EPA-approved methods, and the vendor did not note any exceptions to the QA/QC protocols.

TREATMENT SYSTEM PERFORMANCE (CONT.)

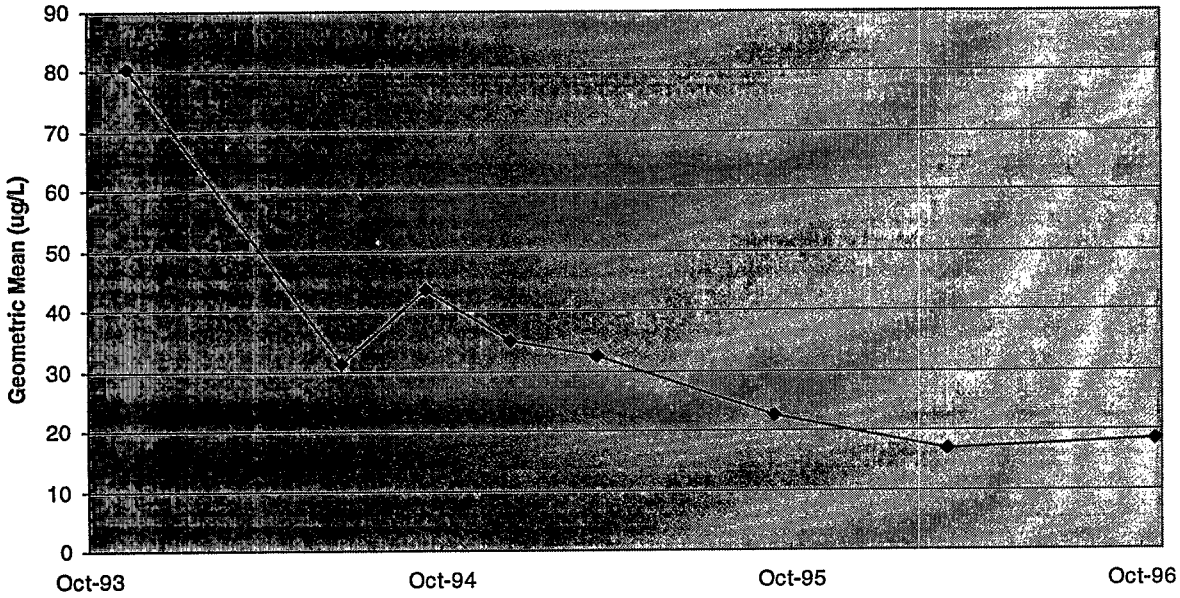

Figure 2. Average Groundwater Concentrations of Total VOCs (1993 to 1996) [7]

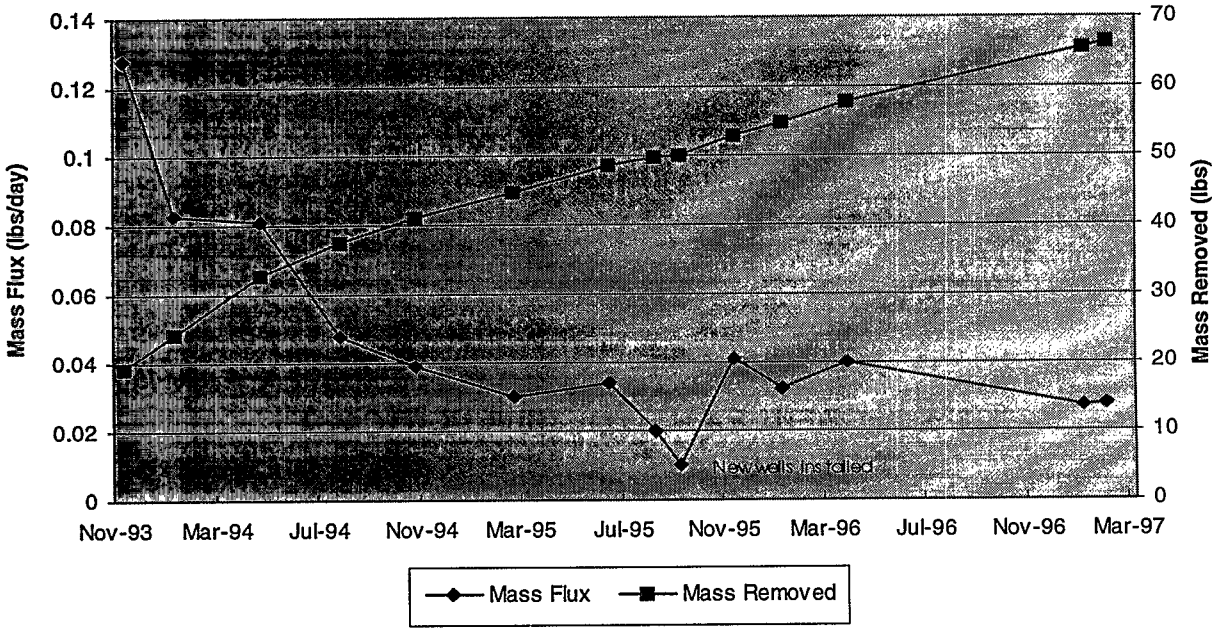

Figure 3. Mass Flux Rate and Cumulative Contaminant Removal for Total VOCs (12/93 - 2/97) [7]

TREATMENT SYSTEM PERFORMANCE (CONT.)

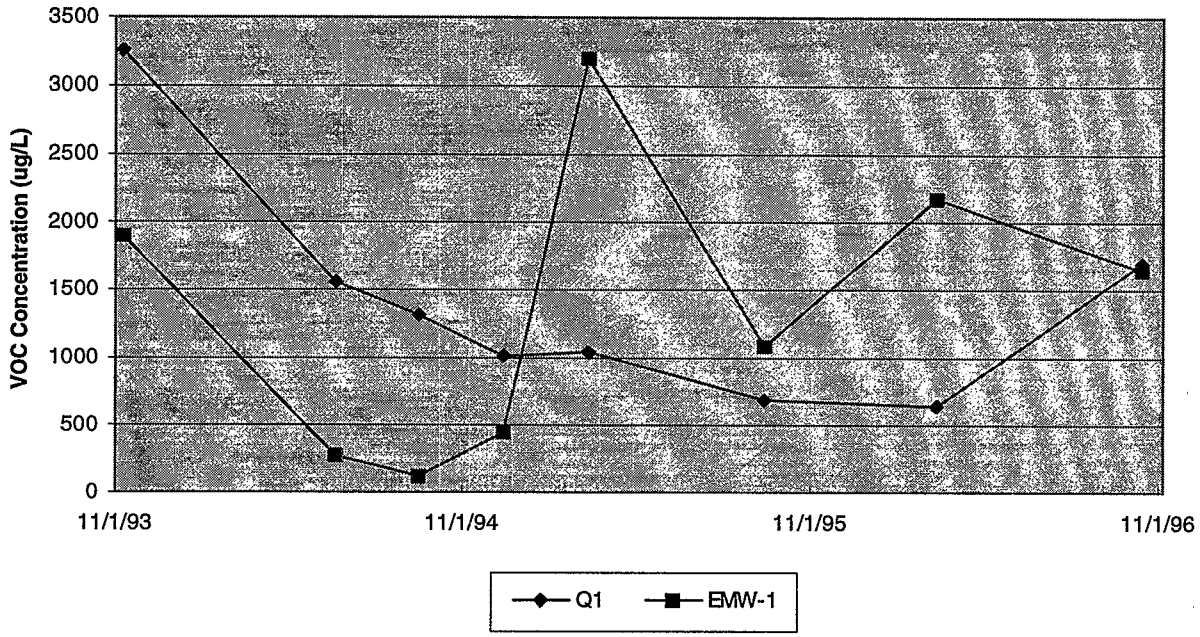

Figure 4. Total VOC Concentration in Two On-Site Wells (1993 - 1996) [7]

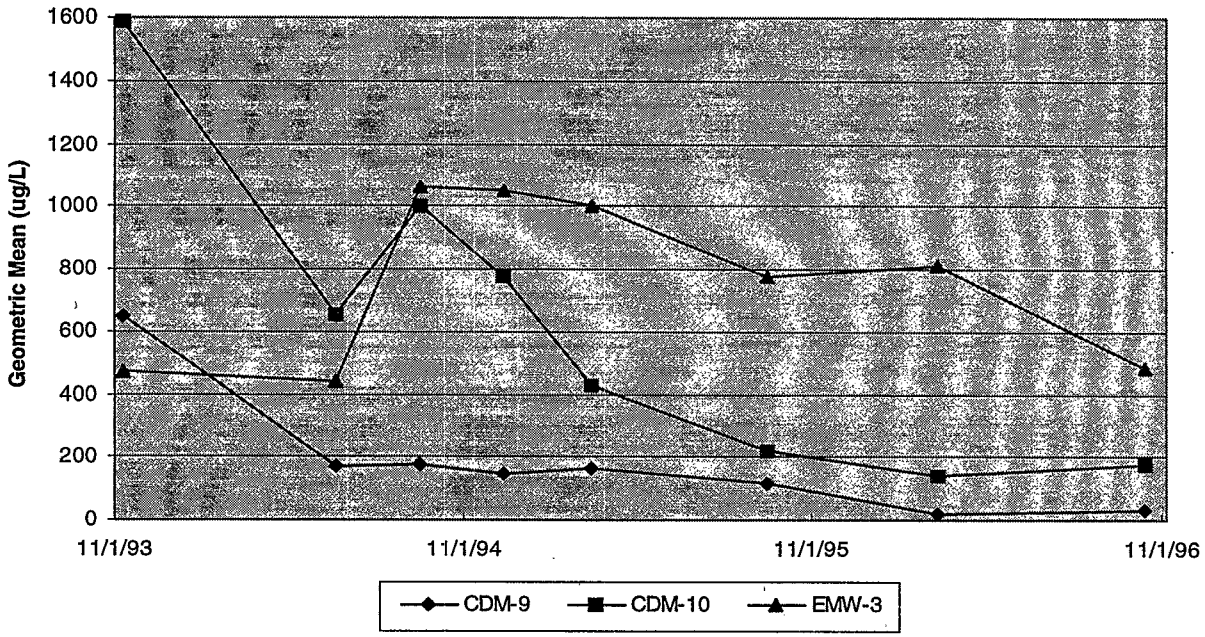

Figure 5. Total VOC Concentration in Three Off-Site Wells (1993 - 1996) [7]

TREATMENT SYSTEM COST

Procurement Process

The State of New Hampshire is the lead authority on this site. NHDES has contracted with Woodard & Corran (W&C) for operations and maintenance at the site.

Cost Analysis

All costs for design, construction, and operation of the treatment system at this site were borne by the Responsible Parties.

Capital Costs [7]

Remedial Construction	
Administration, Mobilization, and Demobilization	$306,494
Monitoring Wells	$8,000
Site Work	$215,000
Extraction System	$428,120
Treatment System	$624,925
Total Remedial Construction	**$1,582,539**

Operating Costs [7]

Annual Operation and Maintenance Cost (1993-1997)	
Labor	$497,000
Utilities	$73,973
Chemicals	$9,306
Repair and Maint.	$24,103
Nonroutine Maint.	$37,475
Sludge Disposal	$421
Analyses	$28,060
Office Supplies	$7,413
Subcontracts	$116,835
Safety, Training	$30,545
Other	$549
Total	**$825,680**

Other Costs [7]

Oversight	$558,299
Remedial Design	$863,334
Disposal of Hazardous Wastes	$50,000

Operating Data by Year

1993 - 1994	$285,000
1994 - 1995	$233,500
1995 - 1996	$230,600
1996 - 1997	$219,400

Cost Data Quality

Actual capital and operations and maintenance cost data are available from the state contact for this application.

OBSERVATIONS AND LESSONS LEARNED

- Total cost for the P&T system at the Keefe Environmental site through May 1997 was approximately $2,408,000 ($1,582,539 in capital costs and $826,000 in total operation and maintenance costs), which corresponds to $52 per 1,000 gallons and $35,000 per pound of contaminant removed. The mass removed through the treatment plant may be significantly lower than the total mass extracted from the groundwater plume due to volatilization and other losses prior to the treatment plant.

- The 1995-1996 system optimization study cost a total of $36,500. These costs were incurred in the operation and maintenance contract and are included under annual O&M costs [7].

- After four years of operation, the P&T system has reduced average contaminant concentrations within the plume and contained the plume from further migration. The site has not, however, met cleanup goals.

- In 1995, the system was reevaluated by the O&M contractor for this site. The reevaluation involved developing a groundwater model in conjunction with a test well program. The evaluation resulted in the installation of two replacement extraction wells. The new extraction wells increased extraction rates and increased mass flux to the treatment system. The increased extraction rates also resulted in more efficient plume capture [8].

- The reevaluation was prompted by the asymptotic decline of contaminant mass removed by the treatment system. To increase contaminant mass removal from the aquifer and decrease the required operating life of the system, additional wells were installed [8].

- Based on monitoring well data, the plume was not contained until a groundwater model was used to optimize the extraction well network by installing two new extraction wells in the overburden unit.

REFERENCES

1. Record of Decision, USEPA, Keefe Environmental Services, March 1988.
2. Monthly Operating Report (February 1997), Woodard & Curran, March 1997.
3. Monthly Operating Report (March 1997), Woodard & Curran, April 1997.
4. Draft Off-Site Hydrogeological Evaluation Report, Camp Dresser & McKee, Inc., March 1991.
5. Supplemental Remedial Investigation Report, Camp Dresser & McKee, Inc., December 1987.
6. Remedial Investigation Report, Tighe & Bond, 1982.
7. Correspondence with Mr. Tom Andrews, NHDES Representative. March 19, 1997.
8. Optimizing and Re-Evaluating Groundwater Extraction Systems Could Mean Early Shutdown, Carlson, Eric T., Environmental Technology, May/June 1996.
9. Declaration for the Explanation of Significant Differences, USEPA, Keefe Environmental Services, June 1990.

Analysis Preparation

This case study was prepared for the U.S. Environmental Protection Agency's Office of Solid Waste and Emergency Response, Technology Innovation Office. Assistance was provided by Eastern Research Group, Inc. and Tetra Tech EM Inc. under EPA Contract No. 68-W4-0004.

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Groundwater Pump and Treat and Soil Vapor Extraction at DOE's Lawrence Livermore National Laboratory Site 300, GSA OU

Groundwater Pump and Treat and Soil Vapor Extraction at DOE's Lawrence Livermore National Laboratory Site 300, GSA OU

Site Name: Lawrence Livermore National Laboratory (LLNL)Site 300 - General Services Area (GSA) Operable Unit (OU)	**Contaminants:** Volatile Organic Compounds: - Trichloroethene (TCE) - DNAPLs	**Period of Operation:** 6/91 - ongoing (Data reported through July 1997)
Location: Livermore, CA		**Cleanup Type:** Full-scale
Vendor/Consultants: Lockheed-Martin Energy Systems Inc. Oak Ridge, TN Weiss Associates Emeryville, CA	**Technology:** **Eastern GSA pump and treat (P&T)** - Three extraction wells - Treatment includes 5-micron particulate filter and three aqueous phase GAC units in series with a 50 gpm capacity **Central GSA pump and treat (P&T)** - 19 extraction wells - extract groundwater and soil vapor simultaneously - Treatment includes shallow tray air stripper (50 gpm); 5-micron particulate filter; two vapor-phase GAC units; air emissions stack housed in a portable treatment unit **Central GSA Soil Vapor Extraction (SVE)** - Seven extraction wells - 2-hp vacuum pump - Four vapor-phase GAC units in series	**Cleanup Authority:** CERCLA - Removal action - 1991 - ROD date: not provided
Additional Contacts: Michael G. Brown Deputy Director DOE/OAK Operations Office L-574 Lawrence Livermore National Laboratory Lawrence, CA 94551 (510) 423-7061 John P. Ziagos Site 300 Program Leader L-544 Lawrence Livermore National Laboratory Lawrence, CA 94551 (510) 422-5479		**Regulatory Point of Contact:** Information not provided
Waste Source: Waste buried in shallow trenches; disposal of wastewater in dry wells; leaks and spills	**Type/Quantity of Media Treated:** Through July 1997: Groundwater - a total of 93.8 million gallons of groundwater; 9.9 kg of VOC mass removed Soil - 399,000 cubic feet of soil vapor; 30.5 kg of VOC mass removed	
Purpose/Significance of Application: Combined use of groundwater pump and treat and SVE to remediate TCE and DNAPLs		

Groundwater Pump and Treat and Soil Vapor Extraction at DOE's Lawrence Livermore National Laboratory Site 300, GSA OU (continued)

Regulatory Requirements/Cleanup Goals:
- Groundwater - reduce VOC concentrations to MCLs in all contaminated groundwater including a cleanup goal of 5 ug/L for TCE. The discharge limit is 0.5 ug/L for total VOCs.
- Soil - soil vapor of 0.36 ppmv; soil vapor remediation will continue until: 1) it is demonstrated that VOC removal from the vadose zone is no longer technically or economically feasible and 2) the VOC inhalation risk inside Building 875 is adequately managed.

Results:
- Maximum TCE groundwater concentrations had been reduced from pre-remediation levels ranging from as high as 240,000 ug/L at the site to levels of 13 ug/L (eastern GSA) and 33 ug/L (central GSA) as of May 1997. These levels are above the cleanup goal of 5 ug/L.
- Maximum TCE soil vapor concentrations had been reduced from a pre-remediation level of 450 ppmv to 2 ppmv as of May 1997, above the cleanup goal of 0.36 ppmv.
- The discharge limits have been met while the system was operating.

Cost:
- Total cost for GSA OU - $36.6 million, including $6.2 million for the Eastern GSA P&T and $32.4 million for the Total Central GSA P&T and SVE systems. The costs include preconstruction and construction activities and post-construction O&M.

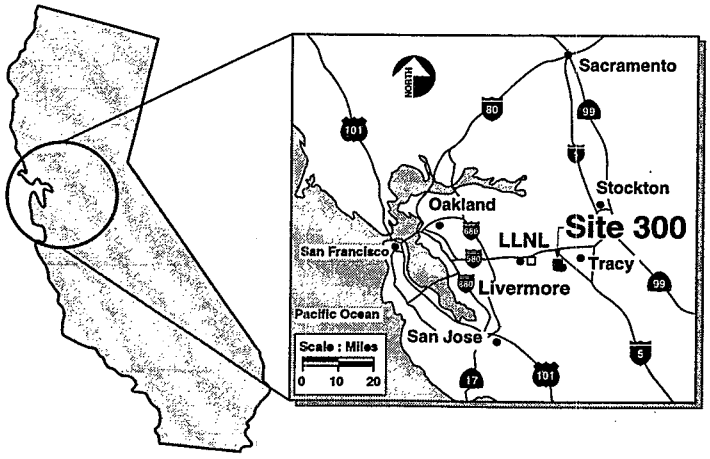
Description:
Lawrence Livermore National Laboratory Site 300 is a DOE experimental test facility located near Livermore California. Craft shops and equipment fabrication and repair facilities in the General Services Area (GSA) used solvents as degreasing agents. In the eastern portion of the GSA, craft shop debris was buried in shallow trenches. In the central portion, rinse waters from operations were disposed of in dry wells. The results of site investigations, begun in 1982, identified VOC contamination in the soil and groundwater. Groundwater TCE concentrations have been detected as high as 74 ug/L in the eastern GSA and 240,000 ug/L in the central GSA. Groundwater TCE plumes have been identified in both areas. The highest pre-remediation concentration of TCE in soil in the central GSA were 360,000 ug/L. Remediation began in 1991 as a removal action. A Record of Decision was signed moving the cleanup to the remedial phase.

The remedy at the eastern portion of the GSA, begun in 1991, involves groundwater extraction using three wells and treatment using carbon adsorption. The system originally used air sparging; however, as VOC concentrations in the groundwater decreased, air sparging was replaced with carbon adsorption. After six years of operation, the system has removed 5.1 kg of VOC mass, treated 93 million gallons of groundwater and reduced the maximum TCE concentration in groundwater to 13 ug/L. The remedy for the central portion of the GSA included both groundwater extraction and treatment and SVE. The groundwater system, operated since 1993, had 19 extraction wells and includes air stripping for vapors and carbon adsorption for treatment of groundwater. After four years of operation, the system has removed 4.8 kg of VOC mass, treated 787,000 gallons of groundwater, and reduced maximum TCE levels to 33 ug/L. The SVE system, operated since 1993, has removed 30.5 kg of VOC mass and reduced TCE concentrations in the soil vapor to 2 ppmv. Levels of VOC remained above the cleanup goals as of 1997. Cyclic pumping is used to maximize VOC mass removal efficiency from all three systems. Results of modeling used to predict the timeframe for cleanup indicated that the SVE system would require 10 years and groundwater extraction and treatment 55 years.

The total cost for the three technologies at the GSA OU as of 1997 is $36.6 million. This includes preconstruction and construction activities and post-construction O&M. The costs for the Eastern GSA P&T system is $6.2 million. The cost for the Central GSA P&T and SVE systems is $32.4 million.

1. SUMMARY

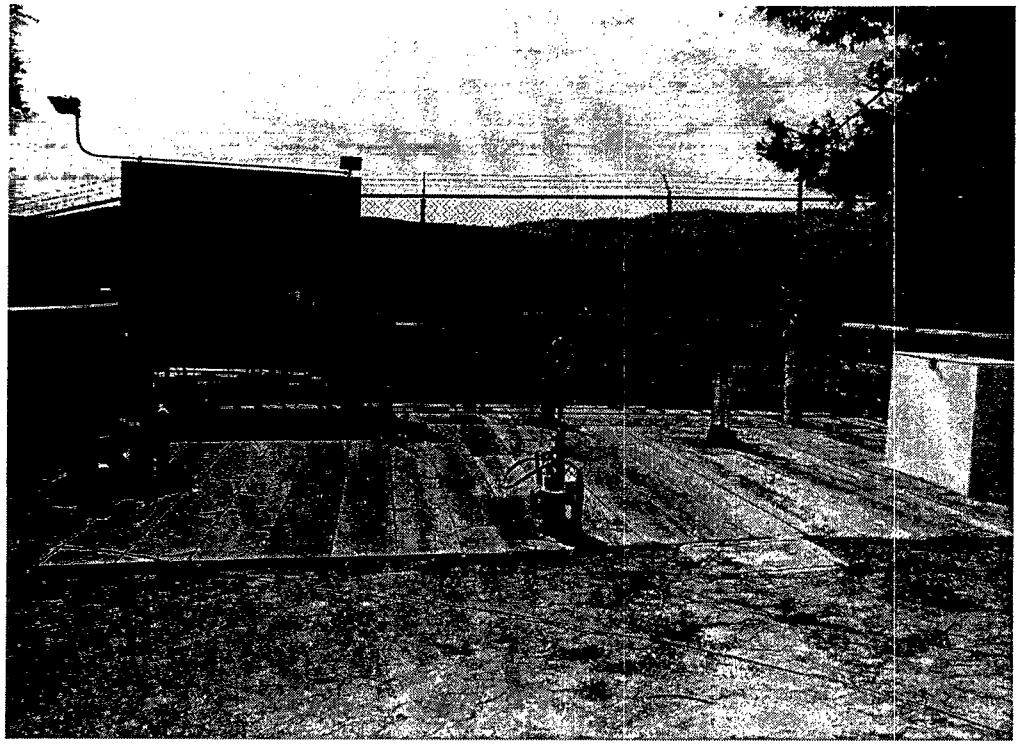
This report summarizes cost and performance data for ground water and soil vapor extraction and treatment at the General Services Area (GSA) Operable Unit (OU) at Lawrence Livermore National Laboratory (LLNL) Site 300. Solvents containing volatile organic compounds (VOCs), primarily trichloroethene (TCE), were released to the ground as a result of past activities in the craft shops and equipment fabrication and repair facilities.



Location of LLNL Site 300.

Remediation began in 1991 as a removal action under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). A Record of Decision (ROD) is in place (DOE, 1997), and the cleanup has moved into the remedial action phase. The ROD specifies Maximum Contaminant Levels (MCLs) as the ground water cleanup standards.

DOE/LLNL is currently operating two ground water extraction (GWE) wellfields and one soil vapor extraction (SVE) system. A total of 93 million gallons of ground water have been extracted and treated using air stripping or granular activated carbon (GAC). Approximately 40.4 kilograms of VOCs have been removed from the subsurface as of July 1997, most of which was TCE. In the eastern GSA, the primary objective of ground water extraction is to control migration of the contaminant plume. The length of the offsite TCE plume exceeding MCLs has been reduced from 4,500 to 200 feet, and the maximum ground water TCE concentration is now below 13 µg/L. At the central GSA, where the objective of the removal action is source control, maximum TCE concentration in ground water has been reduced from 240,000 µg/L to 10,000 µg/L. TCE concentration in extracted soil vapor has dropped from over 1,000 $ppm_{v/v}$ to 2 $ppm_{v/v}$. Future remedial actions will expand the extraction well field.



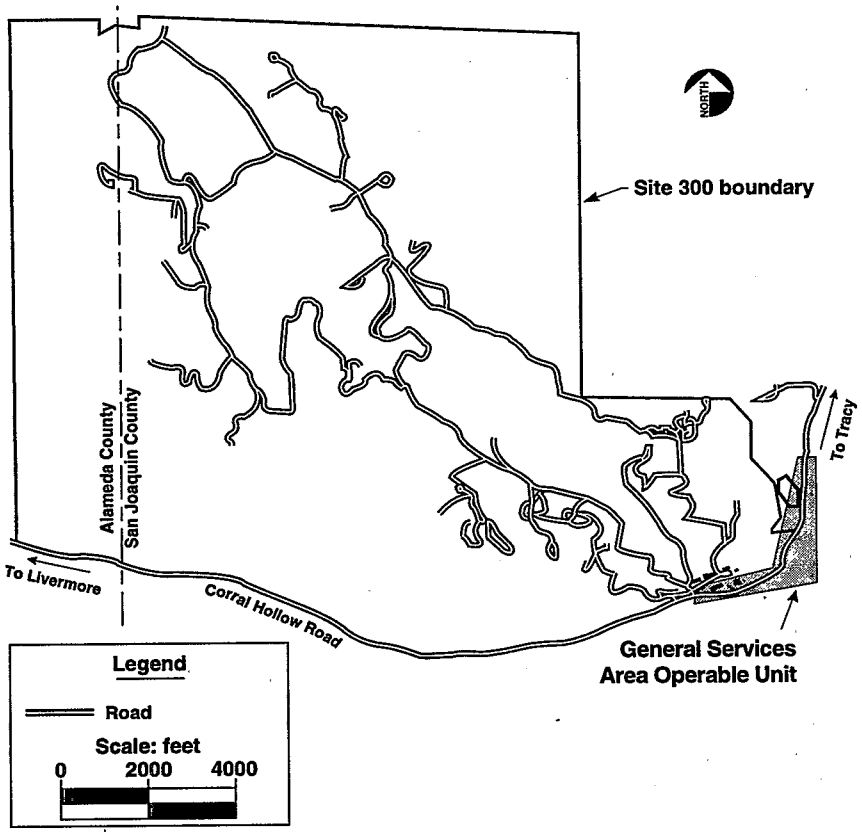
Central GSA extraction wells.

The total actual and projected costs for investigation and remediation in the GSA OU are estimated at $38.6M. Modeling predicts that to meet cleanup standards soil vapor extraction will need to continue for 10 years, and ground water extraction for 55 years.

2. SITE INFORMATION

Identifying Information

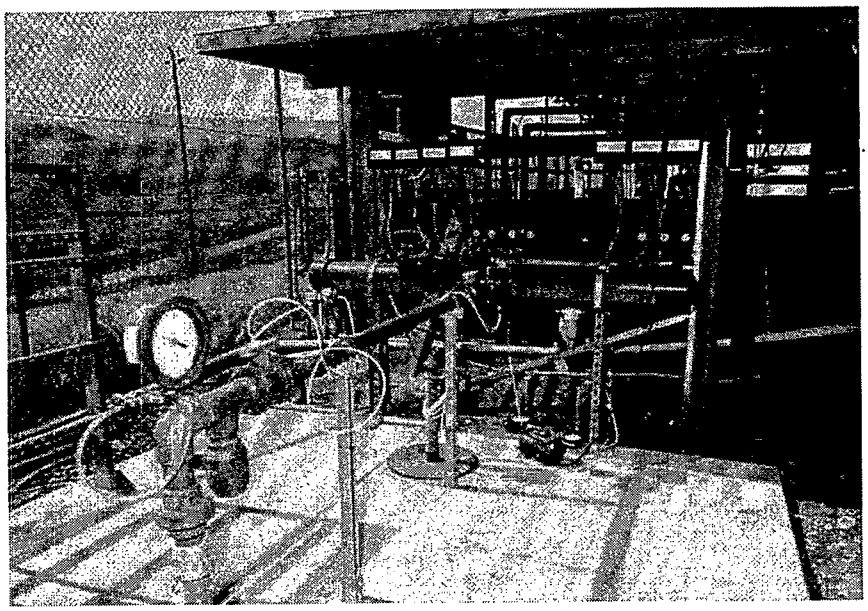
- Facility: Lawrence Livermore National Laboratory, Site 300.
- Operable Unit: General Services Area (OU 1).
- Regulatory Drivers: CERCLA, Record of Decision, Site 300 Federal Facility Agreement.
- Type of Action: Ground water and soil vapor extraction and treatment.
- Period of Operation: Ongoing since June 1991.



Location of the General Services Area Operable Unit at Site 300.

Technology Application

Prior to the ROD, DOE/LLNL used CERCLA removal actions to remediate VOCs in the subsurface through ground water and soil vapor extraction. Due to the success of these removal actions, the remedial action will continue this strategy and expand the extraction wellfield to 1) capture more contaminated ground water, 2) address additional source areas, and 3) shorten cleanup time.



Central GSA soil vapor extraction manifold.

Technology Application (cont.)

Remediation technology application in the GSA OU (July 1997).

Treatment system	Startup date (length of operation)	Volume of media treated	Mass of VOCs removed
Eastern GSA ground water	1991 (6 yrs)	93,000,000 gal of ground water	5.1 kg
Central GSA ground water	1993 (4 yrs)	787,000 gal of ground water	4.8 kg
Central GSA soil vapor	1994 (3 yrs)	399,000 cubic feet of soil vapor	30.5 kg
Total			40.4 kg

Site Background and History

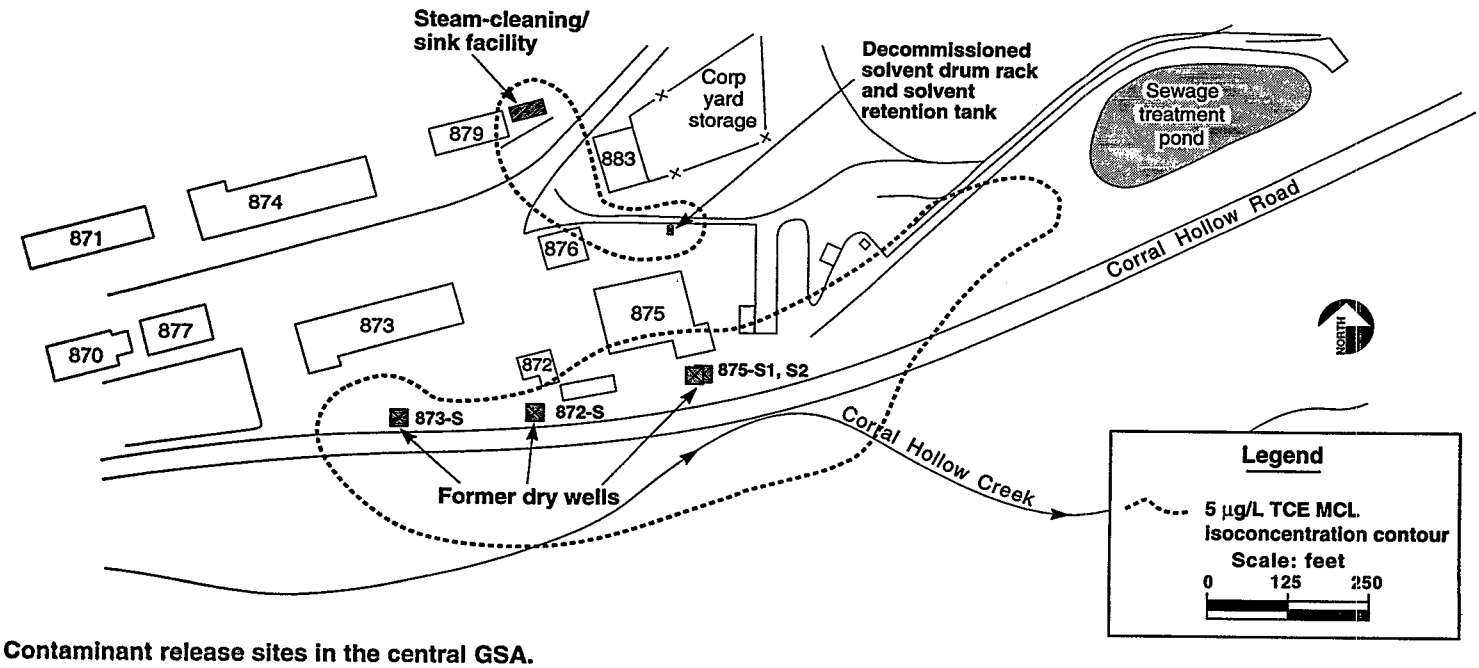
In the eastern GSA, craft shop debris containing TCE was buried in shallow trenches. Test pits were excavated and trace concentrations of VOCs found in soil and bedrock.

Solvents containing VOCs were commonly used in the central GSA craft shops as a degreasing agent. Rinse water from these operations were disposed in dry wells. The dry wells at the GSA typically were gravel-filled excavations about 3 to 4 feet deep and 2 feet across. Piping from floor drains in the shops led to the dry wells. All dry wells have been excavated.

Environmental investigations began in 1982. Almost 100 ground water monitor wells have been installed. Other site characterization methods include soil sampling, soil vapor surveys, hydraulic testing, colloidal borescope investigations, and geophysical surveys. These investigations identified six release sites, but central GSA dry wells 875-S1 and 875-S2 and the eastern GSA debris burial trench are the primary contributors to subsurface contamination.

Documents prepared for the GSA OU include the Site-Wide Remedial Investigation report (Webster-Scholten, 1994), a Feasibility Study (Rueth and Berry, 1995), a Proposed Plan (DOE, 1996), a Record of Decision (DOE, 1997), and a draft Remedial Design report (Rueth et al., 1997).

All releases in the GSA OU fall under SIC code 9631A.



Contaminant release sites in the central GSA.

Site Background and History (cont.)

Contaminant releases in the GSA.

Contaminant release site	Mechanism
Dry wells 875-S1 and 875-S2	Rinse water containing solvents from a parts dipping tank and steam cleaning/equipment washdown area in Building 875 was disposed during the 1960 and 1970s.
Dry well 872-S	Rinse water containing solvents from a cascade water spray area and equipment rinse down area in Building 872 was discharged during the 1960s and 1970s.
Dry well 873-S	Rinse water containing solvents from a paintbrush cleaning pad in Building 873 was discharged during the 1970s.
Decommissioned solvent drum rack and underground solvent retention tank	Solvent spills from a drum rack and tank occurred during 1970s and 1980s.
Building 879 steam-cleaning/sink facility	Waste water containing oil and grease and minor amounts of solvents was discharged to unlined drainage ditch during 1960s and 1970s.
Debris burial trenches	Craft shop debris contaminated with solvents was disposed in shallow trenches during the 1960s.

Site Contacts

Michael G. Brown
Deputy Director
Environmental Restoration Division
DOE/OAK Operations Office
L-574
Lawrence Livermore National Laboratory
Livermore, CA 94551
(510) 423-7061

John P. Ziagos
Site 300 Program Leader
L-544
Lawrence Livermore National Laboratory
Livermore, CA 94551
(510) 422-5479

3. MATRIX AND CONTAMINANT DESCRIPTION

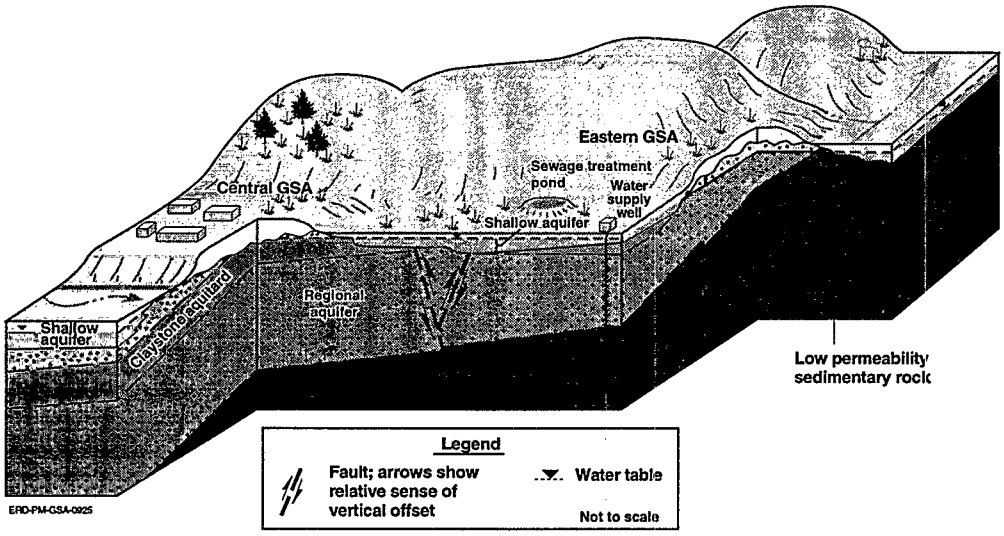
Matrix Identification

VOC-contaminated ground water and soil vapor are extracted from the subsurface and treated by the GSA remediation systems. VOCs have been detected in the vicinity of the dry wells 875-S1 and 875-S2 at concentrations indicative of Dense Non-Aqueous Phase Liquids (DNAPLs). High concentrations of VOCs have also been detected in soil vapor samples collected from the vicinity of these dry wells.

Hydrogeology

Eastern GSA: Depth to ground water is approximately 10 to 15 feet. Ground water flow in the alluvial valley fill (Qal) and shallow bedrock is eastward, turning north to follow the trend of the valley. Ground water flow velocity is estimated to be about 0.5 to 3 feet per day. This shallow aquifer is in hydraulic communication with the deeper regional aquifer ($Tnbs_1$).

Central GSA: Depth to water is approximately 10 to 20 feet. Ground water flow is south-southeast with an estimated flow velocity of 0.05 to 0.10 feet per day. The shallow aquifer occurs in terrace alluvium (Qt) and underlying fractured sandstone ($Tnbs_2$). Ground water in this aquifer is hydraulically isolated from the $Tnbs_1$ regional aquifer by a 60- to 80-foot-thick aquitard ($Tnsc_1$) in most of the central GSA. The shallow aquifer is also referred to as the Qt-$Tnsc_1$ hydrogeologic unit. The regional aquifer is encountered 35 to 145 feet below ground surface under confined to semi-confined conditions. Ground water flow in the regional aquifer is south-southeast at a velocity of 0.3 feet per day.



Conceptual hydrogeologic model of the GSA Operable Unit.

Contaminant Physical Properties

Contaminant physical properties.

Contaminant	Vapor pressure (mm Hg)	Henry's Law constant (atm-m^3/mol)	Density constant (g/cm^3)	Water solubility (mg/L)	Kow	Koc
Benzene	9.52E+01	5.40E-03	0.8680	1.75E+03	131.83	87.10
Bromodichloromethane	3.75E-01	1.60E-03	1.97	6.73E+03	123.03	74.13
Chloroform	1.60E+02	3.23E-03	1.4890	8.00E+03	79.43	43.65
1,1-Dichloroethene	5.91E+02	1.80E-02	1.2180	2.25E+03	69.18	64.57
trans-1,2-Dichloroethene	2.65E+02	7.20E-03	1.2565	6.30E+03	123.03	58.88
1,1,1-Trichloroethane	1.00E+02	1.62E-02	1.3390	1.55E+03	295.12	151.36
Tetrachloroethene	1.40E+01	1.53E-02	1.6227	1.50E+02	398.11	263.03
Trichloroethene	5.78E+01	9.10E-03	1.4642	1.10E+03	338.84	107.15

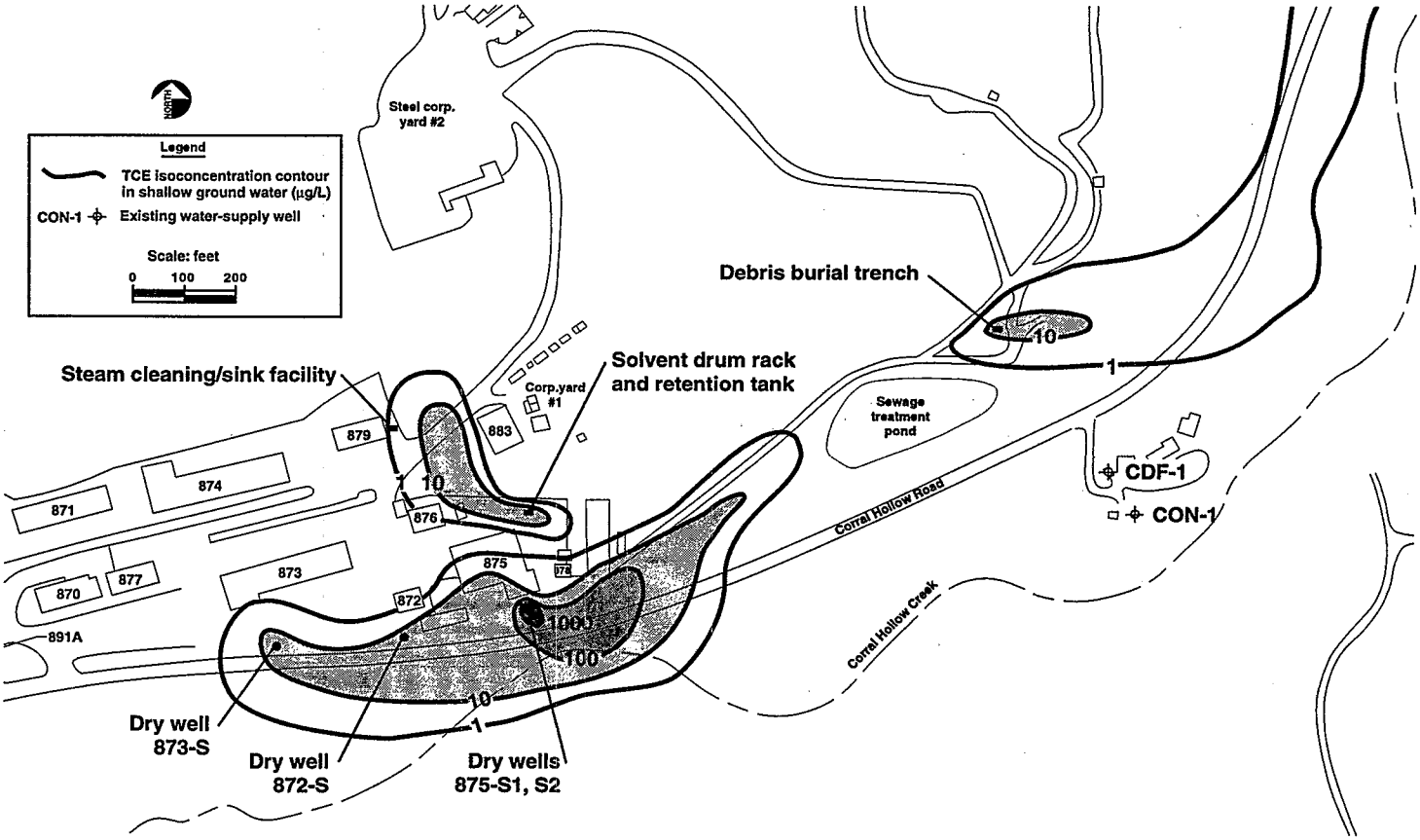
Vapor Pressure: The higher the vapor pressure, the more volatile.
Henry's Law Constant: Compounds with constants greater than 1E-3 readily volatilize from water; compounds with constants less than 1E-5 are not as volatile.
Density: Compounds with a density greater than 1 have a tendency to sink (i.e., DNAPLs); compounds with a density less than 1 have a tendency to float (i.e., LNAPLs).

Water Solubility: Highly soluble chemicals can be rapidly leached from wastes and soils and are mobile in ground water; the higher the value, the higher the solubility.
Octanol-Water Partition Coefficient (K_{ow}): Used in estimating the sorption of organic compounds on soils (high K_{ow} tends to adsorb more easily).
Organic Carbon Partition Coefficient (K_{oc}): Indicates the capacity for an organic chemical to adsorb to soil because organic carbon is responsible for nearly all adsorption in most soils (the higher the value, the more it adsorbs).

Nature and Extent of Contamination

In the eastern GSA, the highest TCE concentrations in ground water (up to 74 µg/L) occur in alluvium near the debris burial trench area release site. TCE has also been detected in the underlying bedrock regional aquifer at maximum concentrations of 62 µg/L. A ground water plume extends eastward from the debris burial trench area and has migrated northward in the Corral Hollow alluvium. Very low VOC concentrations (up to 0.19 mg/kg) have been detected in soil at the debris burial trenches.

In the central GSA, the highest pre-remediation TCE concentrations in soil or bedrock (up to 360,000 µg/kg) were detected below the Building 875 dry wells. TCE at concentrations up to 1,100 $ppm_{v/v}$ has also been reported in vadose zone soil vapor samples. A ground water plume, consisting primarily of TCE at historic concentrations up to 240,000 µg/L, extends into the Corral Hollow Creek alluvium. The bulk of contamination is present in the $Tnbs_2$ sandstone, approximately 35 feet below the surface. There is a smaller ground water plume with significantly lower TCE concentrations to the north associated with the drum storage rack and steam cleaning release sites.



Distribution of TCE in ground water (1997).

Matrix Characteristics

Matrix characteristics: ground water (Eastern GSA).

Matrix characteristic	Potential effects on cost or performance
Depth to ground water: 10 to 15 ft below ground surface (bgs)	The bulk of contamination is concentrated in the Qal, therefore extraction wells are relatively shallow. However, if pumping of source area in the Qal does not adequately remediate the underlying $Tnbs_1$, deeper extraction wells may be necessary.
Saturated thickness: Qal: 0 to 22 ft Total unit: 150 to 170 ft	
Hydraulic condition: Unconfined	None.
Hydraulic conductivity (K): 10^{-1} cm/sec (maximum)	High K results in high flow volume to treatment system. As a result, the VOC mass removal rate per volume of water treated is relatively low.
Ground water flow direction and gradient: E-NE to N with a gradient of 0.003 to 0.009	Strategic placement of extraction wells prevents further offsite migration of contaminated ground water.
Typical well yields: <0.5 to 50 gpm	Relatively high well yields necessitate continuous operation of treatment facility for hydraulic control.

Matrix characteristics: ground water (Central GSA).

Matrix characteristic	Potential effects on cost or performance
Qt-$Tnsc_1$ hydrogeologic unit (shallow aquifer)	
Depth to ground water: 20 to 30 ft bgs	The depth to ground water in this unit allows for the installation of relatively shallow extraction wells.
Saturated thickness: 80 ft	The bulk of contamination in this hydrogeologic unit is in the $Tnbs_2$ sandstone, which is approximately 18 to 25 ft thick.
Hydraulic condition: Unconfined	None.
Hydraulic conductivity: 10^{-3} to 10^{-4} cm/sec	The relatively low hydraulic conductivity in this unit has contributed to the limited migration of contaminants in ground water from the source areas.
Ground water flow direction and gradient: S-SE with a gradient of 0.04	Strategic placement of extraction wells prevents further offsite migration of contaminated ground water.
Typical well yields: <0.5 to 5 gpm	Low well yields from this unit necessitates batch treatment of contaminated ground water in the treatment facility.
Relationship to adjacent hydrogeologic units: Conformably overlies, but is hydraulically isolated from the $Tnbs_1$ regional aquifer except in the vicinity of the sewage treatment pond.	The $Tnsc_1$ confining layer, where present, prevents the migration of contaminants into the $Tnbs_1$ regional aquifer, eliminating the need for remediation of this aquifer in most of the central GSA.
$Tnbs_1$ regional aquifer	
Depth to ground water: 35 to 145 ft bgs	The contaminated portion of the $Tnbs_1$ is at a relatively shallow depth where this unit subcrops beneath the Qal to the east. Therefore, the planned extraction well for this unit will be relatively shallow.
Saturated thickness: 285 to 320 ft	
Hydraulic condition: Semi-confined to confined	The confined portion of this unit is uncontaminated and does not require remediation.
Hydraulic conductivity: 10^{-4} cm/sec	The relatively low hydraulic conductivity of this unit has limited the migration of contaminated ground water.
Ground water flow direction and gradient: S-SE with a gradient of 0.09	A downgradient $Tnbs_1$ reinjection well was included as part of the central GSA wellfield to help prevent further contaminant migration in this unit.
Typical well yields: <0.5 to 40 gpm	The central GSA treatment facility was designed to handle ground water pumped from one $Tnbs_1$ extraction well.
Relationship to adjacent hydrogeologic units: Conformably underlies, but is hydraulically isolated from the Qt-$Tnsc_1$ hydrogeologic unit in most of the central GSA.	Where the overlying $Tnsc_1$ confining layer is not present, contaminants have migrated into the $Tnbs_1$ aquifer resulting in the need for deeper extraction wells.

Matrix Characteristics (cont.)

Matrix characteristics: vadose zone soil or bedrock (Central GSA).

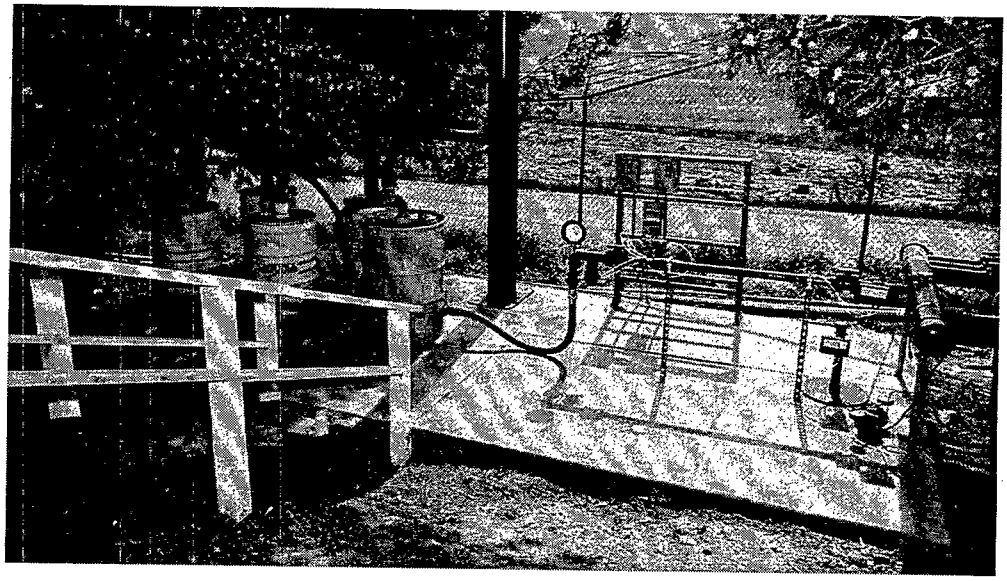
Matrix characteristic	Potential effects on cost or performance
$Tnbs_2$ sandstone	
Lithology: The $Tnbs_2$ sandstone, in which SVE is conducted, consists of a massive fine- to medium-grained sandstone with interbedded siltstone and claystone. Fractures have been observed in cores from this unit.	Although SVE is typically utilized in soil applications, combined SVE and GWE has proven more effective in remediating VOCs in the subsurface in the central GSA Building 875 dry well pad area than the use of GWE alone.
Range of Thickness: Approximately 25 ft thick in the vicinity of Building 875 where SVE efforts are concentrated.	SVE and GWE efforts are focused in the lower $Tnbs_2$ where the bulk of the contamination was identified.
Porosity: 0.36	Porosity of the $Tnbs_2$ bedrock was sufficient to implement SVE successfully.
Moisture Content: Saturated	This unit is purposely dewatering by ground water extraction so SVE can be used.

4. REMEDIATION SYSTEM DESCRIPTION

Treatment Technology Types

Treatment technology types.

Location	Soil/bedrock	Ground water
Eastern GSA	None	Extraction and ex situtreatment with aqueous-phase carbon adsorption
Central GSA	Soil vapor extraction with ex situvapor-phase carbon adsorption	Extraction and ex situtreatment with air stripping and vapor-phase carbon adsorption



Central GSA soil vapor treatment system.

Key Design Criteria

Eastern GSA Ground Water Extraction and Treatment System

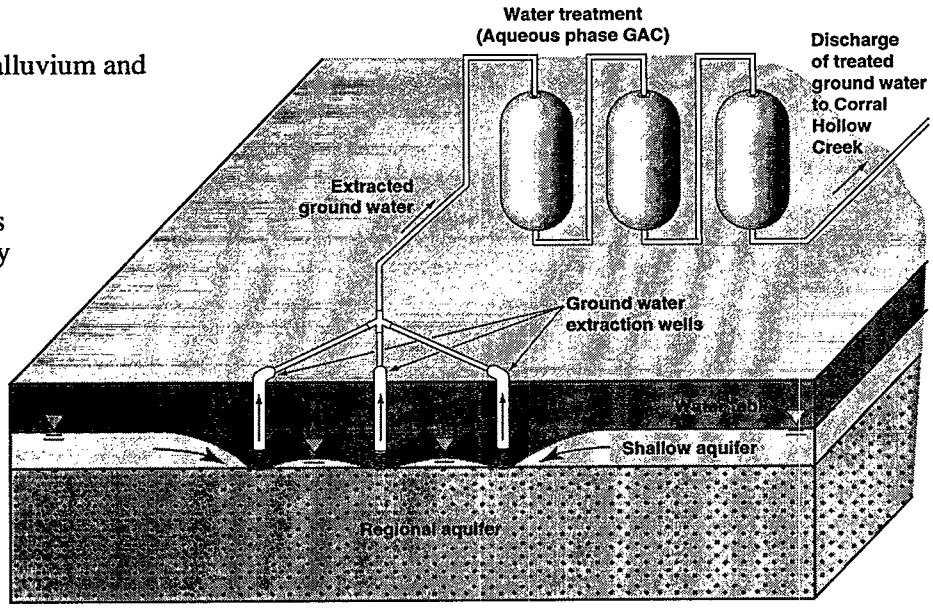
- Three extraction wells completed in the alluvium and shallow bedrock.
- Submersible electric pumps.
- Water distribution piping.
- 5-micron particulate filtration system.
- Three 1,000-lb aqueous-phase GAC units connected in series with a design capacity of 50 gpm.

Central GSA Ground Water Extraction and Treatment System

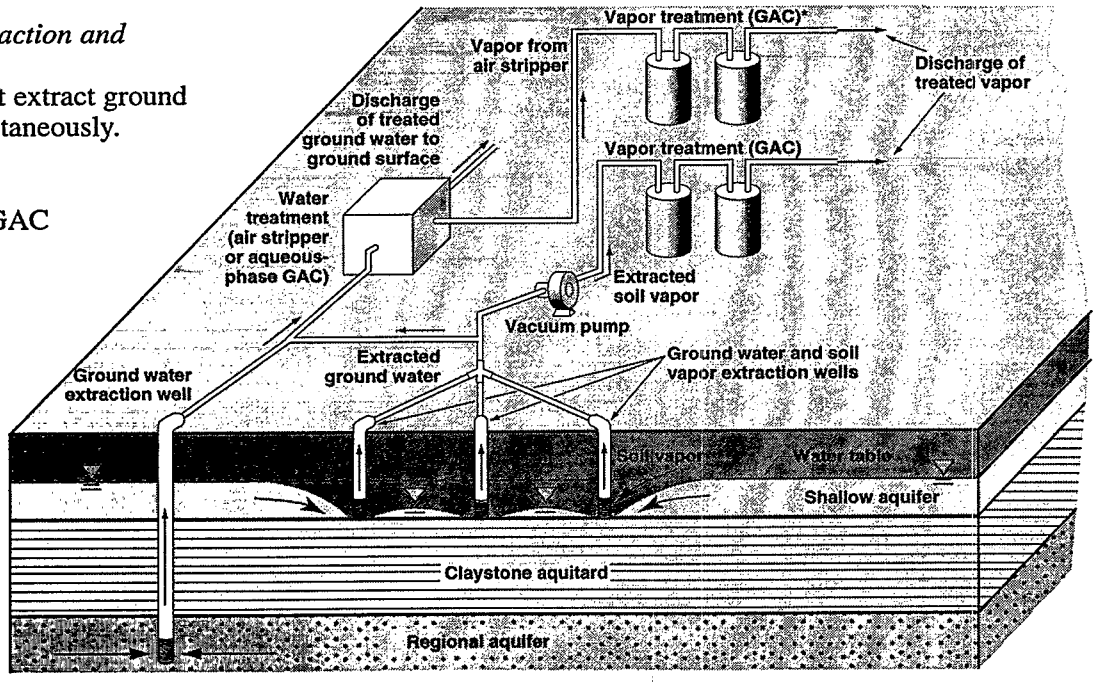
- Nineteen extraction wells completed in the alluvium, shallow bedrock, and regional aquifers.
- Submersible electric and pneumatic pumps.
- Water distribution piping.
- Shallow tray air stripper with a design capacity of 50 gpm, 5-micron particulate filter, two 140-lb vapor-phase GAC units, and air emissions stack housed in a Portable Treatment Unit (PTU).
- Pre- and post-treatment storage tanks.

Central GSA Soil Vapor Extraction and Treatment System

- Seven extraction wells that extract ground water and soil vapor simultaneously.
- Vapor distribution lines.
- 2-hp vacuum pump.
- Four 140-lb vapor-phase GAC units connected in series.
- Treated vapor discharge stack.



Schematic of the eastern GSA remediation system.



* Treatment of vapor from ground water treatment system is not necessary if aqueous-phase GAC is used.

Schematic of the central GSA remediation system.

Treatment System Operating Parameters

Eastern GSA GWE system.

Operating parameters	EGSA Ground water extraction and treatment system	Potential effects on cost or performance
Operating time	Continuous operation; 24 hrs/day, 7 days/wk	Continuous operation is more cost effective for contaminant mass removal at this time. Cyclic operation may be considered in the future to eliminate potential stagnation zones.
Pumping rate	45 gpm combined flow from 3 extraction wells	Modeling indicated that increasing the pumping rate and/or number of extraction wells did not significantly increase mass removal or enhance plume capture.
System throughput	45 gpm for a total monthly throughput of 1.5 to 2 million gallons	Combination of low flow rate and low influent VOC concentration allowed use of aqueous-phase GAC treatment technology.
pH	System influent: 7.5 System effluent: 8.1	NPDES permit discharge require 6.5<pH<8.5; significant increases in effluent pH could necessitate control measures.
VOC concentrations	System influent: 4 to 10 µg/L System effluent: <0.5 µg/L	Combination of low flow rate and low influent VOC concentration allowed use of aqueous-phase GAC treatment technology.
Mass removal rate	28 grams VOCs/month	Although the mass removal rate is low for the volume of ground water treated, monitoring data indicate a significant reduction in plume size as a result of this remediation strategy.

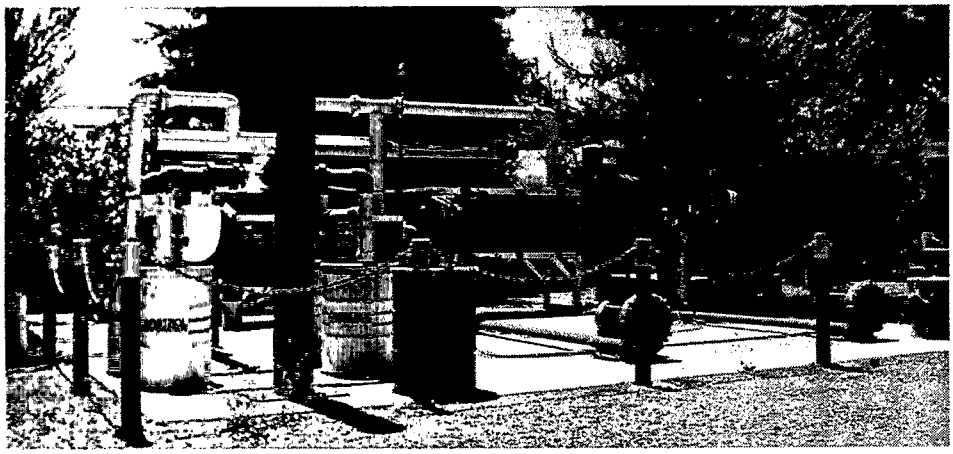
Central GSA GWE system.

Operating parameters	CGSA Ground water extraction and treatment system	Potential effects on cost or performance
Operating time	Continuous extraction. Batch treatment: approximately 10 to 20 days/month	Continuous extraction has resulted in dewatering of the bedrock, exposing a greater volume of contaminants to soil vapor extraction. This results in higher mass removal rates than could be achieved through GWE alone.
Pumping rate	0.3 gpm combined flow from 7 extraction wells. With expanded extraction wellfield: 15 gpm from 19 wells	Modeling indicated that increasing the pumping rate and/or number of extraction wells over that proposed in the Remedial Design document did not significantly increase mass removal or enhance plume capture.
System throughput	Currently 10 gpm during batch treatment for a total monthly throughput of approximately 1,000 gallons. With expanded extraction wellfield: up to 15 gpm	The ground water treatment system was designed to allow for increased capacity due to the planned wellfield expansion.
pH	System influent: 7.0 to 8.4 System effluent: 7.0 to 7.2	Substantive Requirements for waste discharge require 6.5<pH<8.5; significant increases in effluent pH could necessitate control measures.
Additives	Anti-scaling prevention agents: JP-7 or CO_2 pH control: CO_2, if necessary.	It has been necessary to inject anti-scaling agents to control scale buildup with the treatment system to prevent clogging of treatment units and discharge lines. Scale buildup could result in ineffective treatment and discharge limit violations.
VOC concentrations	System influent: 700 to 3,000 µg/L (seasonal variations) System effluent: <0.5 µg/L	The air stripping/vapor-phase GAC was determined to be effective in reducing VOC influent concentrations to meet discharge requirements. More innovative technologies will continue to be evaluated to identify more cost-effective remediation measures.
Air flow	Air stripper: 300 cfm Vapor-phase GAC: 450 cfm	Air flow rate in the air stripper was designed to establish the air-to-water mixing ratio necessary to reduce VOC concentrations to effluent limits.
Mass removal rate	Approximately 100 grams VOCs/month	Although the mass removal rate through ground water extraction is relatively low, the primary objective is to dewater the contaminated bedrock to maximize mass removal through SVE.

Treatment System Operating Parameters (cont.)

Central GSA SVE system.

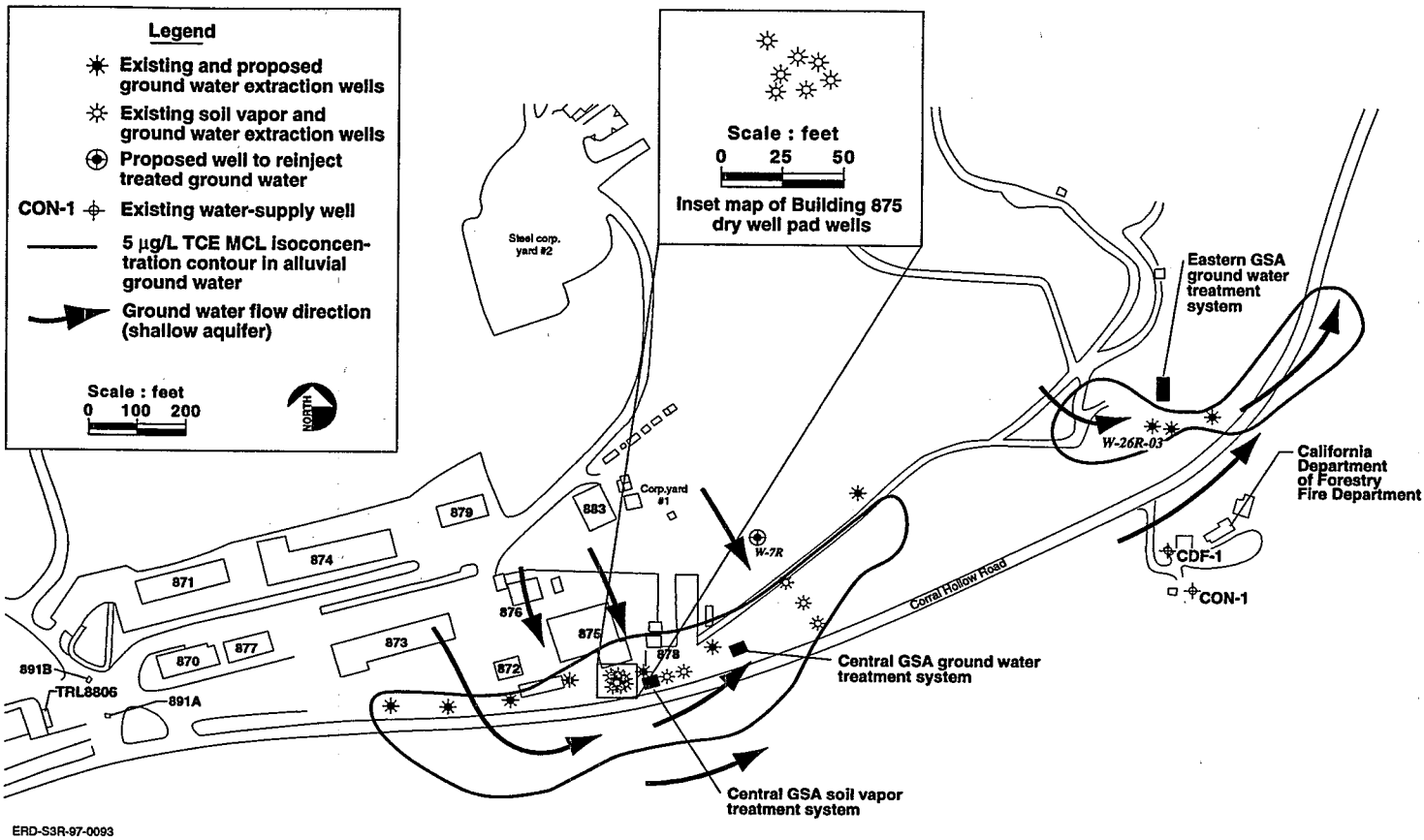
Operating parameters	CGSA Soil vapor extraction and treatment system	Potential effects on cost or performance
Operating time	Continuous extraction; cyclic operation may be utilized to maximize contaminant mass removal	In general, a higher mass removal rate is achieved through continuous operation of SVE; however, cyclic operation may be more cost-effective. Cyclic operation allows VOCs to reequilibrate in soil vapor possibly resulting in the same mass removal during shorter operating periods. In addition, cyclic operation can eliminate stagnation zones.
Extraction rate	Approximately 15 scfm	SVE testing indicated that more efficient mass removal was achieved using lower flow rates.
Moisture control	Water knockout drum	The water knockout drum was installed to reduce the moisture content in soil vapor prior to GAC treatment. A high moisture content in vapor can reduce the efficiency of vapor-phase GAC treatment.
VOC concentrations	System influent: 2 to 100 $ppm_{v/v}$ System effluent: <6 $ppm_{v/v}$	Although SVE has been effective in mass removal in the central GSA, more innovative technologies will continue to be evaluated to identify remediation measures which could significantly reduce cleanup time.
Air flow rate	15 scfm	See "Extraction Rate" discussion.
Mass removal rate	510 grams VOCs/month	SVE is a cost-effective method of remediating VOCs in the subsurface with a mass removal rate over 5 times that achieved through GWE.



Central GSA ground water treatment system (1993–1997).

Eastern GSA extraction wells and treatment system.

Treatment System Operating Parameters (cont.)



Existing and proposed extraction wells, reinjection well, and treatment systems.

GSA Treatment Facility Personnel Requirements

Each facility has a designated Facility Operator who has been trained in the safe and efficient operation of the treatment facility. To qualify as a Facility Operator, personnel must attend appropriate Facility Operator and Health and Safety training courses and undergo facility operation training in the field under the direction and supervision of a qualified Facility Operator. Total onsite Operation and Maintenance (O&M) personnel requirements for both the eastern and central GSA facilities average approximately 60 hours per month. These O&M activities include water and vapor facility compliance sampling, flow measurements, permit compliance documentation, daily inspections, GAC replacement, and well and treatment system maintenance.

5. REMEDIATION SYSTEM PERFORMANCE

Cleanup Objectives

- Reduce VOC concentrations in ground water to levels protective of human health and the environment.
- Reduce VOC concentrations in soil vapor to meet ground water cleanup standards.
- Mitigate VOC inhalation risk inside Building 875.

Cleanup Standards

Soil vapor remediation will continue until: 1) it is demonstrated that VOC removal from the vadose zone is no longer technically and/or economically feasible in order to meet ground water cleanup standards sooner, more cost effectively, and more reliably, and 2) the additive VOC inhalation risk inside Building 875 is adequately managed.

Ground water remediation will be conducted to reduce VOC concentrations to MCLs in all contaminated ground water. Modeling indicates that ground water cleanup standards should be reached in 10 years in the eastern GSA and in 55 years in the central GSA.

Ground water cleanup standards.

Contaminant of concern	EPA Cancer group [a]	Federal MCL (µg/L)	State MCL (µg/L)
Benzene	A	5	1
Bromodichloromethane	B2	100[b]	100[b]
Chloroform	B2	100[b]	100[b]
1,1-DCE	C	7	6
cis-1,2-DCE	D	70	6
PCE	B2-C	5	5
1,1,1-TCA	D	200	200
TCE	B2-C	5	5

[a]From Integrated Risk Information System (IRIS) database maintained by the U.S. Environmental Protection Agency: A = known carcinogen; B2 = probable carcinogen; C = possible carcinogen; D = noncarcinogen.
[b]Total trihalomethanes.

Criteria for Terminating Treatment System Operation

To monitor the progress of subsurface soil remediation, soil vapor concentrations will be monitored at dedicated soil vapor sampling points and at SVE wells through the life of remediation. The demonstration that the vadose zone cleanup has been achieved to the point that the remaining vadose zone VOC contaminants no longer cause concentrations in the leachate to exceed the aquifer cleanup levels will be made through contaminant fate and transport modeling, trend analysis, mass balance, or modeling. In addition, VOC concentrations in soil vapor will be monitored to ensure that the inhalation risk inside Building 875 is adequately managed.

As specified in the ROD, ground water cleanup in the GSA will continue until cleanup standards are achieved. Ground water will be monitored throughout the life of remediation to: 1) determine the effectiveness of the remedial action in achieving cleanup standards, 2) re-evaluate and improve the remediation plans, 3) determine when cleanup standards as stipulated in the ROD have been achieved, and 4) determine when active remediation should cease. When VOC concentrations in ground water are below negotiated cleanup standards, selected wells will be sampled for five years as part of post-closure monitoring. Remediation will be considered complete when contaminant concentrations remain below the cleanup standards for five years. If concentrations rise above cleanup standards, extraction will resume at the appropriate wells.

Monitoring

VOC concentrations in GSA ground water and soil vapor are monitored regularly to evaluate the performance of the remedial action in meeting cleanup standards.

Ground water sampling and analysis program.

Area	No. of wells sampled	Analyses conducted	Sampling frequency
Central GSA	54	EPA Method 601	Semi-annual
	2	EPA Method 601	Quarterly
	12	EPA Method 602	Annually
	2	Dissolved drinking water metals	Annually
	15	Dissolved drinking water metals	Every 2 years
QA/QC	14 (10% of total)	EPA Method 601 EPA Method 602 Dissolved drinking water metals	Annually
Eastern GSA	34	EPA Method 601	Semi-annually
	5	EPA Method 601	Quarterly
	2	EPA Method 601	Monthly
QA/QC	12	EPA Method 601	Annually

Remediation Plan

- The eastern and central GSA ground water extraction and treatment systems have been operating since 1991 and 1993, respectively, as CERCLA removal actions. Based on the performance evaluation and the progress of these removal actions in remediating ground water, the existing extraction and treatment systems will continue to be used as part of the long-term remedial action.

- The focus of the central GSA removal action has been source control at the Building 875 dry well release area. In the remedial action, the wellfield will be expanded to address additional contaminant releases and to capture much of the contaminated ground water. The estimated time to cleanup may be significantly reduced by the addition of strategically placed extraction wells and by using cyclic pumping to address stagnation zones that may develop in the subsurface.

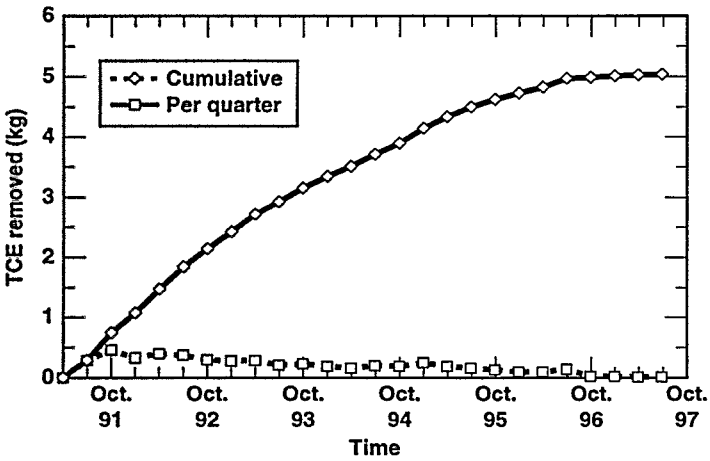
- In July 1994, soil vapor extraction for source control began in the central GSA Building 875 dry well area as part of a CERCLA removal action. Based on the performance evaluation and the progress of the removal action in remediating soil vapor in the central GSA, the existing soil vapor extraction and treatment system will continue to be used as part of the long-term remedial action.

- Ground water monitoring will be performed throughout the predicted 55 years of remediation or until ground water cleanup standards are met plus 5 years of post-remediation monitoring. Soil vapor concentrations will be monitored periodically from soil vapor extraction wells and soil vapor monitoring points during the predicted 10 years of SVE or until soil vapor cleanup standards are met.

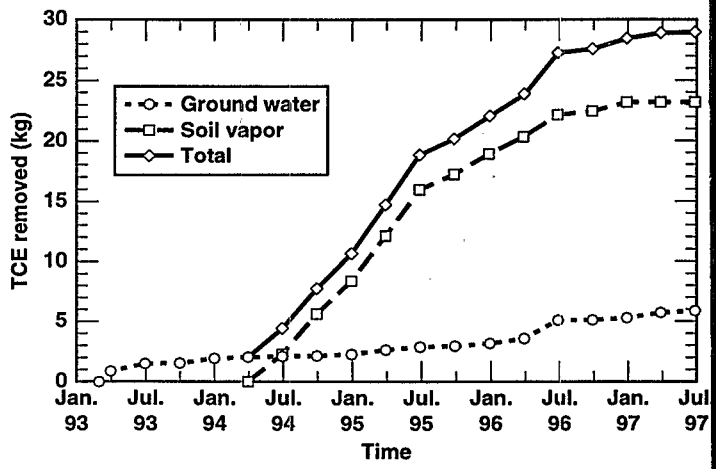
- Administrative controls will be implemented to prevent human exposure to contaminants, if necessary. These controls may include access restrictions and procedures for construction in areas where possible exposure to contaminated media may occur.

- Point-of-use (POU) treatment systems may be required at offsite water-supply wells if VOC concentrations in these wells exceed MCLs. The POU treatment system design consists of two gravity-flow aqueous-phase GAC canisters mounted on a double-containment skid.

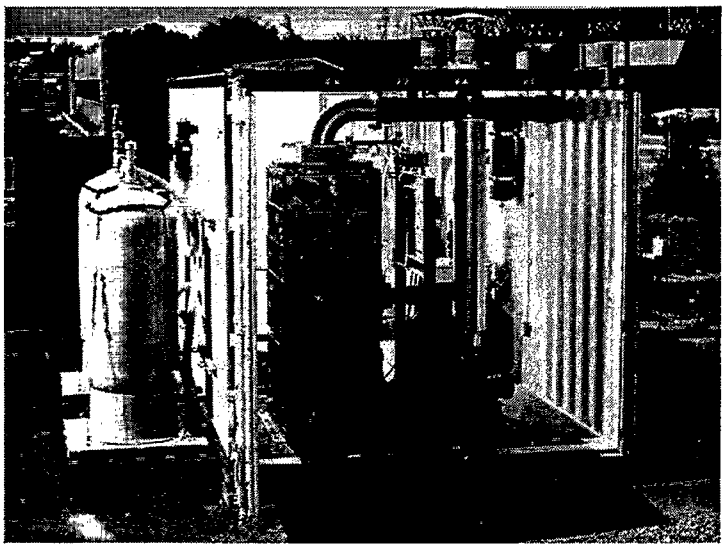
Remediation Plan (cont.)



Mass of TCE removed from ground water at the Eastern GSA.



Cumulative mass of TCE removed from ground water and so vapor at the Central GSA.



Central GSA Portable Treatment Unit (since 1997).

Treatment Facility Sampling and Analysis Program

Treatment facility sampling and analysis program.

Monitoring program	Type of samples collected	Sampling frequency	Analytical methodology	QA/QC
EGSA GWTS NPDES Permit	Influent/Effluent	Bi-monthly	EPA Method 601, TDS, pH	10% of total no. of samples collected
	Receiving Waters	Weekly when creek is flowing	EPA Method 601, pH, turbidity.	
CGSA GWTS Substantive Requirements	Influent/Effluent	Monthly	EPA Method 601 & 602, pH, spec. conduct.	10% of total no. of samples collected
CGSA SV Treatment System Air Discharge Permit	Effluent	Weekly	Monitored with an OVA.	OVA calibrated before each use

Quantity of Material Treated

Volume of contaminated media treated and mass of contaminants removed (July 1997).

Treatment system	Operation mode	Average flow rate	Volume treated to date	VOC mass removed to date
Eastern GSA GWTS	Continuous	45 gpm	93,000,000 gal	5.1 kg
Central GSA GWTS	Batch	12,000 gal/month	787,000 gal	4.8 kg
Central GSA SVTS	Continuous	15.3 scfm	399,000 cf	30.5 kg
				GSA Total: 40.4 kg

Quantity of Material Stored or Disposed

Approximately 1,100 lbs of VOC-laden GAC residual is generated by the central GSA treatment system annually. Based on contaminant concentration and flow rates, it is estimated that the 1,000-lb aqueous-phase GAC canisters from the eastern GSA ground water treatment system will need to be replaced approximately every two to three years. All spent GAC canisters are packaged, labeled for shipment, manifested, and temporarily stored onsite for up to 90 days before being transported offsite for regeneration or disposal.

Untreated and Treated Contaminant Concentrations

Contaminant concentrations prior to and during remediation.

Media	Area	Pre-remediation maximum TCE concentrations	Maximum TCE concentrations (May 1997)	Cleanup standards
Shallow ground water	Central GSA (Bldg. 875 dry well pad)	240,000 µg/L	10,000 µg/L	5 µg/L
Regional aquifer ground water	Central GSA (West of sewage treatment pond)	58 µg/L	33 µg/L	5 µg/L
Shallow ground water	Eastern GSA (Debris burial trench area)	74 µg/L	13 µg/L	5 µg/L
Soil/bedrock	Central GSA (Bldg. 975 dry well pad)	360 mg/kg	Not measured	Not applicable
Soil/bedrock	Eastern GSA (Debris burial trench area)	0.19 mg/kg	Not measured	Not applicable
Soil vapor	Central GSA (Bldg. 875 dry well pad)	450 $ppm_{v/v}$	2 $ppm_{v/v}$	0.36 $ppm_{v/v}$

Contamination concentration prior to and following treatment (May 1997).

Constituent	Discharge limits	Average untreated media concentration (treatment system influent)	Average treated media concentration (treatment system effluent)
CGSA ground water treatment system			
Total VOCs	Monthly median: 0.5 µg/L	1,500 µg/L	Monthly median: <0.5 µg/L
EGSA ground water treatment system			
Total VOCs	Monthly median: 0.5 µg/L	7 µg/L	Monthly median: <0.5 µg/L
CGSA soil vapor treatment system			
TCE	6 $ppm_{v/v}$	2 $ppm_{v/v}$	0 $ppm_{v/v}$

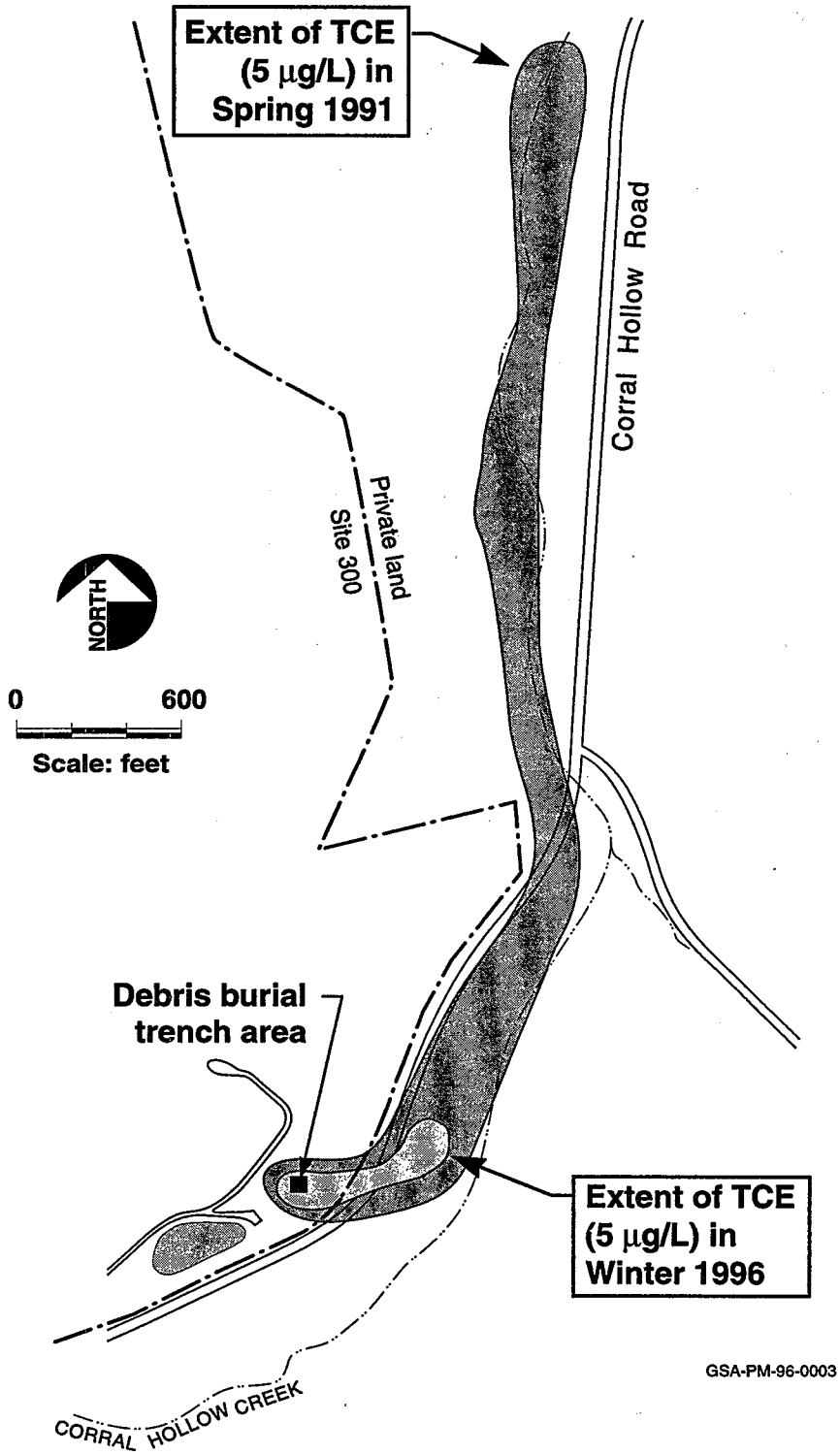
Comparison with Cleanup Objectives

After six years of ground water remediation in the eastern GSA, the maximum VOC concentrations in ground water have been reduced from a historical pre-remediation maximum of 74 µg/L to a maximum concentration of 13 µg/L as of second quarter 1997. Only five of the 42 monitor wells in the eastern GSA currently contain TCE in concentrations that exceed the cleanup standard of 5 µg/L. All other contaminants of concern in the eastern GSA have been remediated to below their respective cleanup standards (MCLs).

Prior to remediation of the eastern GSA VOC plume, the portion of the TCE plume in which concentrations exceed the cleanup standards for TCE (MCL of 5 µg/L) extended approximately 4,500 feet offsite. The TCE plume with concentrations exceeding the MCL now extends less than 200 feet from the site boundary.

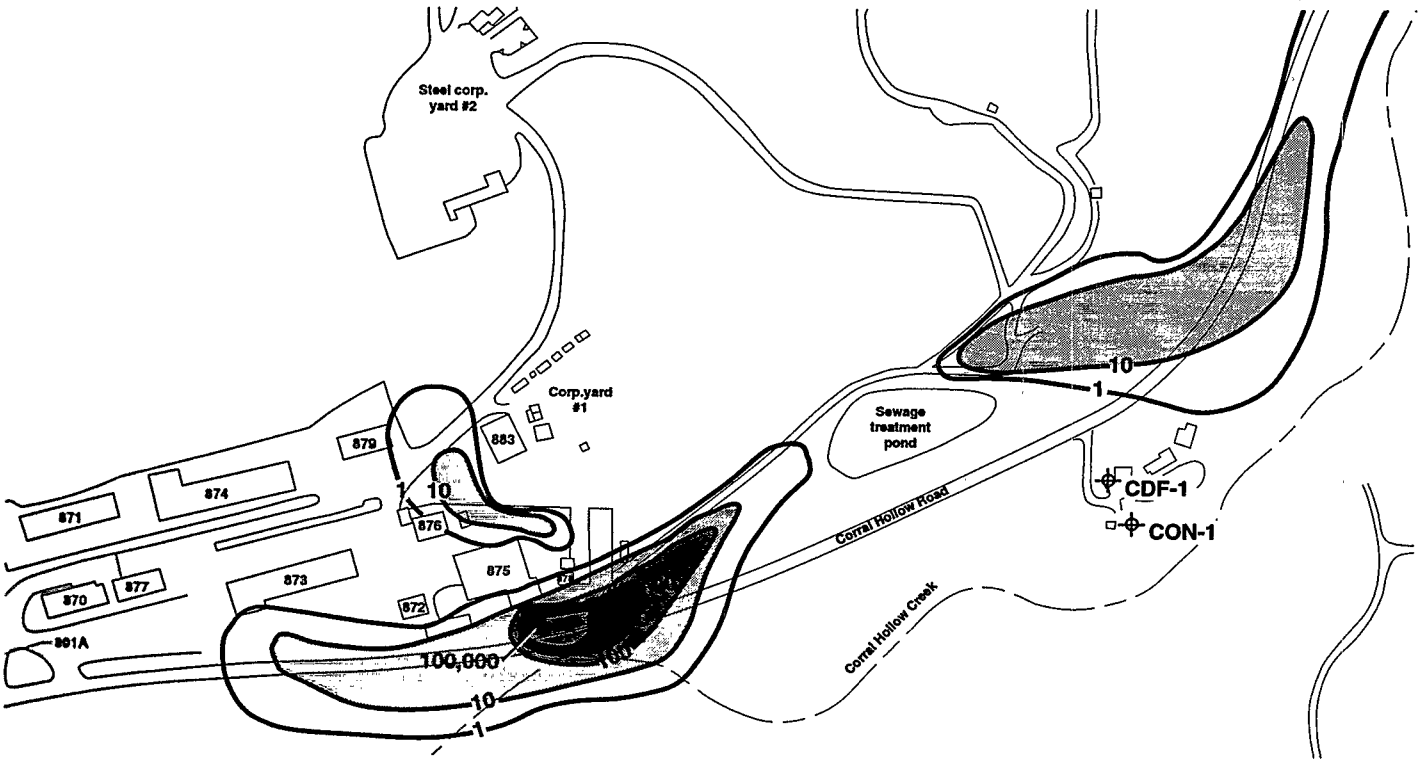
In the central GSA, maximum TCE concentrations detected in ground water prior to remediation were 240,000 µg/L. The maximum TCE concentration detected in ground water as of the fourth quarter of 1996, after approximately three years of source area remediation, was 10,000 µg/L. Of the eight VOCs identified as contaminants of concern in the central GSA, currently only TCE and PCE are detected in wells in concentrations which exceed the cleanup standards (MCLs). The actual mass removal achieved by the central GSA ground water treatment system is similar to the mass removal rate predicted by modeling.

Following two years of soil vapor extraction and treatment in the central GSA, TCE concentrations in soil vapor have been reduced from a pre-remediation concentration of 1,000 $ppm_{v/v}$ to 2 $ppm_{v/v}$.

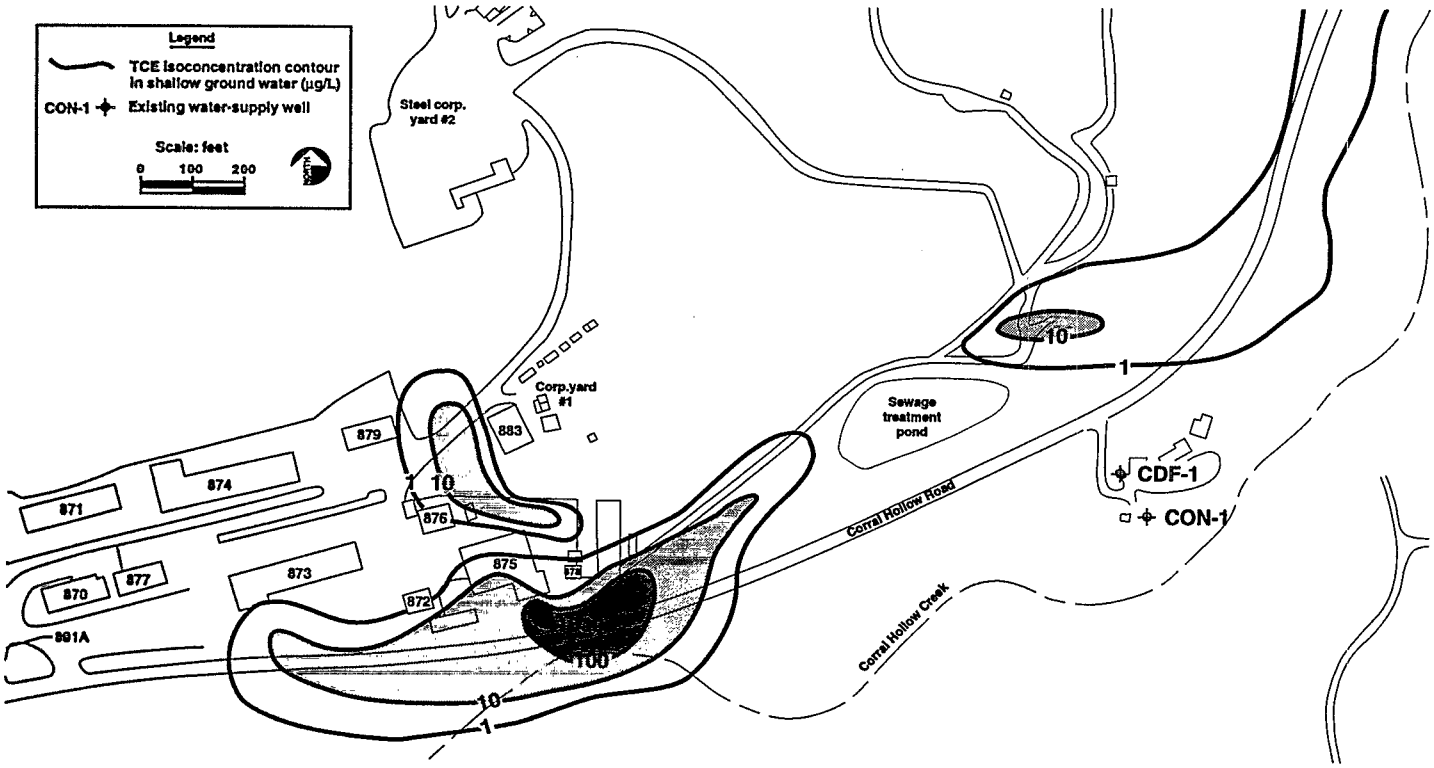


Eastern GSA pre-remediation and current plume configurations.

Comparison with Cleanup Objectives (cont.)

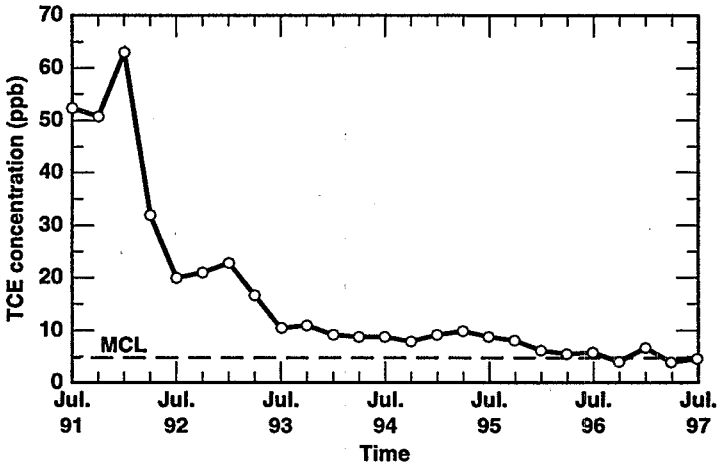


Distribution of TCE in ground water (1991).

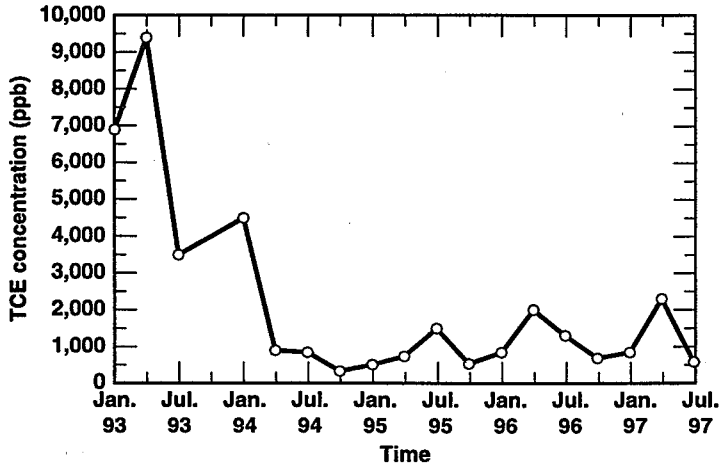


Distribution of TCE in ground water (1997).

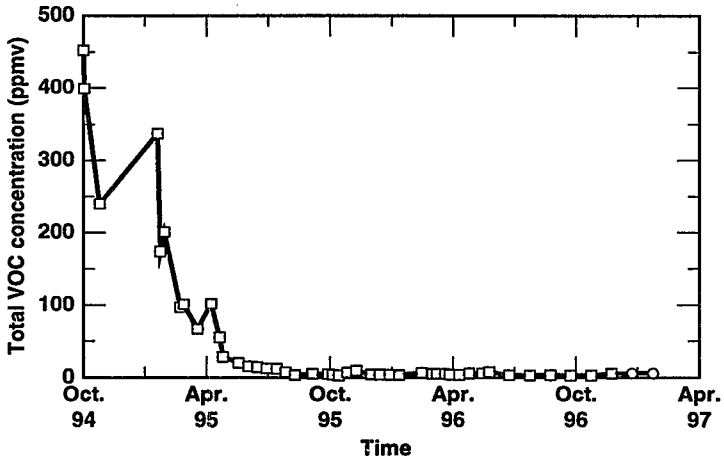
Comparison with Cleanup Objectives (cont.)



TCE concentration in ground water treatment system influent at the eastern GSA.



TCE concentration in ground water treatment system influent at the central GSA.



VOC concentration in soil vapor extraction system influent at the central GSA.

Risk Reduction

The GSA baseline risk assessment identified two exposure routes that could potentially result in unacceptable risk to the community and workers on site: 1) ingesting contaminated ground water, and 2) inhaling TCE vapor inside Building 875.

The calculated excess cancer risk for potential residential use of ground water in the vicinity of the eastern GSA debris burial trenches or at offsite wells is about 1 in 100,000 (10^{-5}). Existing offsite water-supply wells are monitored monthly for VOCs, however no VOCs have ever been detected in these wells at concentrations above MCLs. Water from these existing wells is used primarily for livestock watering and non-drinking water domestic purposes.

The excess cancer risk for use of ground water from a hypothetical well that could potentially be installed at the site boundary near Building 875 was calculated to be approximately 7 in 100 (7×10^{-2}). No water-supply wells currently exist at the site boundary location, and ground water in the area is not used for drinking water.

The excess human cancer risk from inhalation of TCE vapor inside Building 875 in the GSA was calculated to be 1 in 100,000 (10^{-5}). However, current VOC concentrations are likely lower due to ongoing soil vapor remediation.

6. COST SUMMARY

Assumptions

All preliminary activities and removal actions were conducted and associated costs incurred prior to the signing of the Final GSA ROD in February 1997. The worth of pre-1997 costs is based on the year incurred. The remaining activities presented are post-ROD with the exception of monitor well installation and removal action construction and operation and maintenance (O&M) costs.

Projected costs (post 1997) are present worth as estimated in the Feasibility Study and Remedial Design Documents. Costs presented for post-ROD remedial action activities have been calculated based on the projected life of the project. The total actual and projected investigation and remediation cost for the GSA Operable Unit is $38.6 M.

Cost Elements

Cost Elements for Eastern GSA.

General activity areas (WBS)	WBS 2nd level cost elements (WBS)	Cost items (WBS)	Costs ($K)	Subtotal ($K)
Preliminary/ Preconstruction Activities (32)	• RI/FS (32.02)	• Field Investigations (32.02.06) • Remedial Investigation - Data Evaluation (32.02.11) - Risk Assessment (32.02.12) - RI Document (32.02.13) • Feasibility Study: - Alternative Evaluation (32.02.14) - FS document (32.02.16) • Proposed Plan/ROD (32.02.03) • Sampling and Analysis (32.02.08)	545 437 430 92 215	1,845
	• Remedial Design (32.03)	• Removal Action Design (32.03.20) • Remedial Design Report (32.03.20)	9 117	
Construction Activities (33)	• Monitoring, Sampling, Testing, and Analysis (33.02)	• Monitor Well Installation/Soil Sampling (57 wells) (33.02.09, 33.02.06) • Ground Water Sampling and Analysis (33.02.05)	271 39	688
	• GW Collection and Control Construction (33.06) • Physical Treatment Construction (33.13)	• Removal Action Construction: GWE: - Air Stripping System Construction (33.13.07) - GAC-vapor systems (2) (33.13.19) - Extraction Wellfield Construction (33.06.01) • Remedial Action Construction: GWE: - GAC-Liquid System Construction (33.13.20)	173 205	
Post-Construction Operations and Maintenance (O&M): Removal Action (34)	• Monitoring, Sampling, Testing, and Analysis (34.02)	• Removal Action Monitoring, Sampling, Testing, and Analysis: - Air Monitoring (34.02.03) - Monitor Well O&M (34.02.04) - Ground Water/Treatment Facility Sampling (34.02.05) - Lab Chem. Analysis (34.02.09)	215	1,190
	• GW Collection and Control (34.06) • Physical Treatment O&M (34.13)	• Removal Action Ground Water Extraction and Treatment System O&M: - Extraction Well O&M (34.06.01) - Air Stripping System O&M (34.13.07) - Carbon Adsorption-Gas System O&M (34.13.19)	816	
	• Other: Treatment Facility Compliance Reporting (34.90)	• Removal Action TF Compliance Reporting (34.90.01)	159	
Post-Construction Operations and Maintenance (O&M): Remedial Action (34)	• Monitoring, Sampling, Testing, and Analysis (34.02)	Remedial Action Monitoring, Sampling, Testing, and Analysis: • Air Monitoring (34.02.03) • Monitor Well O&M (34.02.04) • GW/Facility Sampling (34.02.05) • Lab Chem. Analysis (34.02.09)	580	2,490
	• GW Collection and Control (34.06) • Gas/Vapor Collection and Control (34.07) • Physical Treatment O&M (34.13	• Remedial Action O&M - GWE: - Extraction/Injection O&M (34.06.01) - GAC-Liquid O&M (34.13.20)	1,600	
	• Other: Treatment Facility (TF) Compliance Reporting (34.90)	• Remedial Action Compliance (34.90.02)	310	
		Total Eastern GSA		$6,213K

Cost Elements (cont.)

Cost elements for Central GSA.

General activity areas (WBS)	WBS 2nd level cost elements (WBS)	Cost items (WBS)	Costs ($K)	Subtotal ($K)
Preliminary/ Preconstruction Activities (32)	• RI/FS (32.02)	• Field Investigations (32.02.06) • Remedial Investigation - Data Evaluation (32.02.11)/ Risk Assessment (32.02.12)/ RI Document (32.02.13) • Feasibility Study: - Alternative Evaluation (32.02.14) - FS document (32.02.16) • Proposed Plan/ROD (32.02.03) • Sampling and Analysis (32.02.08)	731 437 430 92 82	1,973
	• Remedial Design (32.03)	• Removal Action Design • Remedial Action Design (32.03.20)	75 126	
Construction Activities (33)	• Monitoring, Sampling, Testing, and Analysis (33.02)	• Monitor Well Installation/Soil Sampling (57 wells) (33.02.09, 33.02.06) • GW Sampling and Analysis (33.02.05)	374 55	1,987
	• GW Collection and Control Construction (33.06) • Air Pollution/Gas Collection and Control (33.07) • Physical Treatment Construction (33.13)	• Removal Action Construction (GWE) - Air Stripping System Construction (33.13.07) - GAC-vapor systems (2) (33.13.19) - Extraction Wellfield Construction (33.06.01) • Removal Action Construction(SVE) - GAC-vapor System (33.13.19) - SVE System (33.13.23) - Extraction Wellfield Construction (33.06.01) • Remedial Action Construction: 1) GWE: - Air Stripping System Construction (33.13.07) - GAC-vapor System Construction (33.13.19) 2) SVE: • Extraction wellfield expansion (33.06.01) • Extraction/Instrumentation - Equipment/Pipeline Construction (33.06.07)	506 123 296 347 286	
Post-Construction Operations and Maintenance (O&M): Removal Action (34)	• Monitoring, Sampling, Testing, and Analysis (34.02)	Removal Action Monitoring, Sampling, Testing, and Analysis: • Air Monitoring (34.02.03) • Monitor Well O&M (34.02.04) • GW/Treatment Facility Sampling (34.02.05) • Lab Chem. Analysis (34.02.09)	334	1,689
	• GW Collection and Control (34.06) • Gas/Vapor Collection and Control (34.07) • Physical Treatment O&M (34.13)	• Removal Action O&M (includes equipment and labor for TF and extraction wellfield O&M): - Extraction Well O&M (34.06.01) - Air Stripping System O&M (34.13.07) - GAC-vapor O&M (34.13.19) - SVE O&M (34.13.23)	883	
	• Other: Treatment Facility (TF) Compliance Reporting (34.90)	• Removal Action TF Compliance Reporting (34.90.01)	472	
Post-Construction Operations and Maintenance (O&M): Remedial Action (34)	• Monitoring, Sampling, Testing, and Analysis (34.02)	• Remedial Action Monitoring, Sampling, Testing, and Analysis: - Air Monitoring (34.02.03) - Monitor Well O&M (34.02.04) - Ground Water/Treatment Facility Sampling (34.02.05) - Lab Chem. Analysis (34.02.09)	10,230	26,790
	• GW Collection and Control (34.06) • Gas/Vapor Collection and Control (34.07) • Physical Treatment O&M (34.13)	• Remedial Action O&M - GWE - Extraction/Injection Wellfield O&M (34.06.01) - Air stripping System O&M (34.13.07) - Carbon Adsorption-Gas O&M (34.13.19) • Remedial Action O&M - SVE: - GAC-vapor O&M (34.13.19) - SVE System O&M (34.13.23)	12,375 1,050	
	• Other: Facility Compliance Reporting (34.90)	• Remedial Action TF Compliance Reporting (34.90.02)	3,135	
		Total Central GSA		$32,439K

7. REGULATORY

Regulatory agencies overseeing the GSA cleanup include the: 1) U.S. EPA, 2) Central Valley Regional Water Quality Control Board, and 3) California Department of Toxic Substances Control.

The driver for ground water cleanup is based on VOC concentrations in GSA ground water that exceed MCLs. Ground water in the GSA OU is considered a potential drinking water source by the state and federal regulatory agencies who require restoration of ground water to protect beneficial uses.

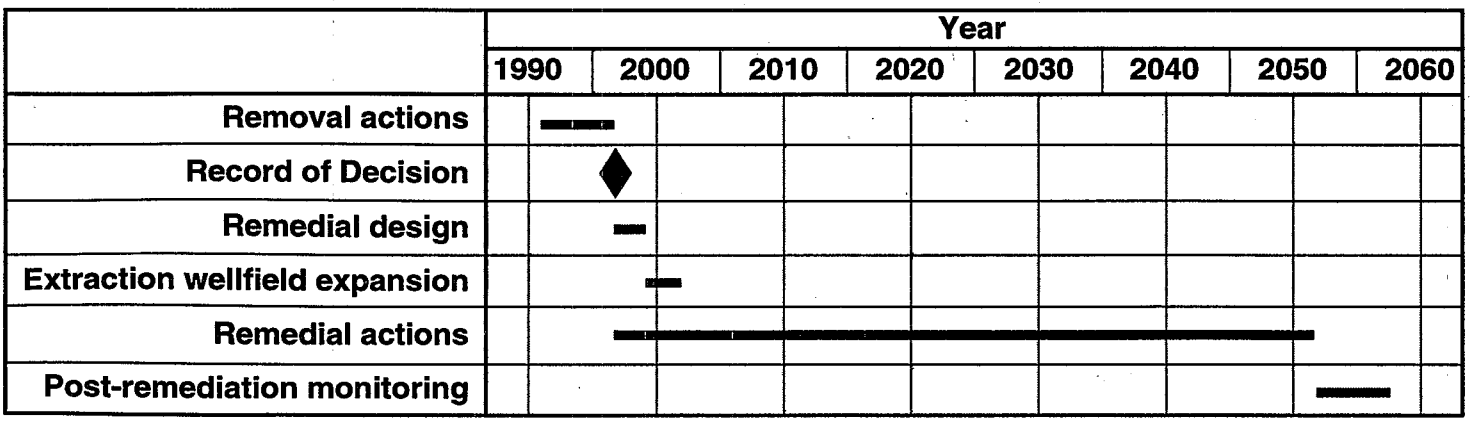
The driver for soil vapor cleanup is based on VOC concentrations in soil vapor in the central GSA Building 874 dry well pad area that are estimated to impact ground water in excess of drinking water standards and result in an inhalation risk inside Building 875 requiring risk management.

The state regulatory agency requires that discharges from the central and eastern GSA ground water treatment systems be treated for VOCs to meet a discharge limit of <0.5 µg/L VOCs. This standard is met by treating ground water with an air-stripping system in the central GSA and an aqueous-phase GAC system in the eastern GSA. The existing waste discharge permits and Record of Decision allow these treatment technologies to be readily supplemented by innovative treatment/destruction technologies if a more cost-effective method of treating contaminated ground water is identified. Treated water is discharged under a NPDES permit in the eastern GSA and under Substantive Requirements for Waste Discharge in the central GSA.

The local air regulatory agency requires that emissions to air from the central GSA soil vapor treatment system and ground water air-stripping system be treated for VOCs to meet a 6 $ppm_{v/v}$ discharge limit. Currently, this standard is met by treating emissions with vapor-phase GAC. The existing permit and Record of Decision allow the GAC to be readily supplemented by innovative treatment/destruction technologies if a more cost-effective method of treating contaminated vapor is identified.

In the GSA ROD, the state and federal regulatory agencies did not concur with the selection of MCLs as the cleanup standard for chloroform and bromodichloromethane because the MCL for total trihalomethanes is based on the economics of chlorinating a municipal water supply to remove pathogens and the agencies stated that the MCL did not adequately protect the beneficial uses of a drinking water source that has not been, and may not be, chlorinated. The modeling performed for the GSA Feasibility Study predicted that, in the course of remediating TCE to MCLs, chloroform and bromodichloromethane would be remediated to the taste and odor threshold levels desired by the regulatory agencies. However, the ROD states that if remediation does not show that cleanup of these compounds is proceeding as predicted, the cleanup standards for chloroform and bromodichloromethane will be revisited.

8. SCHEDULE



9. LESSONS LEARNED

Implementation Considerations

Soil vapor extraction and treatment in the central GSA Building 875 dry well pad area may continue past the 10 year estimated time to cleanup if it is demonstrated that it will expedite ground water cleanup in a cost-effective manner.

As VOC concentrations in ground water decreased in the eastern GSA, the air sparging system was replaced with aqueous-phase GAC. Using GAC will incur lower operation and maintenance costs and eliminated the need for an air discharge permit and associated compliance monitoring.

Carbonate scale buildup in both the central and eastern GSA treatment systems resulted in a reduction in treatment system efficiency and clogging of the discharge lines. To correct this problem, scale control agents (JP-7 and CO_2) are injected into the water stream. CO_2 injection can also be used to control the pH of the treatment system effluent to meet NPDES permit waste discharge requirements.

In the central GSA Building 875 dry well pad area, ground water extraction was used to dewater bedrock and create an "artificial" vadose zone. Simultaneous soil vapor and ground water extraction dramatically increased VOC mass removal rates from those obtained by ground water extraction alone.

Cyclic pumping (e.g. alternating periods when the extraction system is on and off) is used to maximize VOC mass removal efficiency from both ground water and soil vapor. During the pump-off cycles, VOCs desorb from solids into ground water and soil vapor, increasing the mass removal rate when the extraction system is turned back on. Cyclic pumping is also used to minimize or eliminate stagnation zones that develop due to competition between extraction wells.

The central GSA ground water treatment system is housed in a portable treatment unit (PTU). Using a PTU will: 1) prevent UV degradation of system components, 2) be significantly less costly than a permanent facility, and 3) allow the treatment system to be moved to another areas at LLNL if a more effective treatment technology is employed at the central GSA.

Technology Limitations

The ability to restore ground water to MCLs using active pumping is unlikely at many sites. If the stakeholders determine that extraction is technically and economically infeasible to reduce VOCs in ground water to the cleanup levels established in the ROD, the selected technologies may be re-evaluated. Low well yields (<0.5 gpm) in the central GSA may limit the effectiveness of pump and treat for ground water restoration and source control. Long-term ground water extraction in the central GSA Building 875 dry well pad area will be considered as a technique to enhance soil vapor extraction for the purposes of source removal.

Future Technology Selection Considerations

Innovative technologies will be considered for the GSA throughout the process of remediation to shorten cleanup time, improve cleanup efficiency, and reduce cost.

If technologies that enhance contaminant mobility are used (e.g. surfactants) it may be necessary to implement hydraulic controls near source areas to prevent further plume migration.

10. REFERENCES

Rueth, L., and T. Berry (1995), *Final Feasibility Study for the General Services Area Operable Unit, Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, CA (UCRL-AR-11380)

Rueth, L., R. Ferry, L. Green-Horner, and T. DeLorenzo (1997), *Draft Remedial Design Document for the General Services Area Operable Unit, Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, CA (UCRL-AR-127465 DR)

Webster-Scholten, C. P., Ed. (1994), *Final Site-Wide Remedial Investigation Report, Lawrence Livermore National Laboratory Site 300,* Lawrence Livermore National Laboratory, Livermore, CA (UCRL-AR-108131).

U. S. Department of Energy (1996), *The United States Department of Energy Presents the Proposed Plan for Remediation of the Lawrence Livermore National Laboratory Site 300 General Services Area*, Lawrence Livermore National Laboratory, Livermore, CA (UCRL-AR-122585)

U. S. Department of Energy (1997), *Final Record of Decision for the General Services Area Operable Unit Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, CA (UCRL-AR-124061)

11. VALIDATION

Signatories:

"This analysis accurately reflects the current performance and projected costs of the remediation."

Michael G. Brown
Deputy Director
Environmental Restoration Division
Oakland Operations Office
U. S. Department of Energy

John P. Ziagos
Site 300 Program Manager
Environmental Restoration Division
Lawrence Livermore National Laboratory

12. ACKNOWLEDGMENTS

This analysis was prepared by:

Weiss Associates
Emeryville, California
under Subcontract B319805
(R. Ferry, L. Rueth)

Lawrence Livermore National Laboratory
Environmental Restoration Division
Livermore, California
under Contract W-7405-Eng-48
(B. Clark, T. Dresser, K. Heyward)

HAZWRAP
Lockheed-Martin Energy Systems Inc.
Oak Ridge, Tennessee
(T. Ham)

DOE Headquarters
Washington, DC
(K. Angleberger)

Pump and Treat of Contaminated Groundwater at the Mystery Bridge at Hwy 20 Superfund Site, Dow/DSI Facility, Evansville, Wyoming

Pump and Treat of Contaminated Groundwater at the Mystery Bridge at Hwy 20 Superfund Site, Dow/DSI Facility, Evansville, Wyoming

<table>
<tr><td>Site Name:
Mystery Bridge at Hwy 20 Superfund Site, Dow/DSI Facility - Volatile Halogenated Organic (VHO) Plume</td><td rowspan="2">Contaminants:
Chlorinated solvents
- Maximum concentrations detected in September 1989 were trans-1,2-DCE (500 ug/L), TCE (430 ug/L), PCE (540 ug/L), and 1,1,1-TCA (500 ug/L)</td><td>Period of Operation:
Status: Ongoing
Report covers: March 1994 through October 1997</td></tr>
<tr><td>Location:
Evansville, Wyoming</td><td>Cleanup Type:
Full-scale cleanup (interim results)</td></tr>
<tr><td>Vendor:
Thomas J. Mueller, P.E.
Western Water Consultants, Inc.
611 Skyline Road
P.O. Box 4128
Laramie, WY 82071
(307) 742-0031</td><td rowspan="2">Technology:
Pump and Treat and Soil Vapor Extraction
- Groundwater is extracted using 3 wells, located on site, at an average total pumping rate of 103 gpm
- Extracted groundwater is treated with air stripping and reinjected using an infiltration trench with 600 ft of surface area
- SVE is used as a source control activity</td><td>Cleanup Authority:
CERCLA Remedial
- ROD Date: 9/24/90</td></tr>
<tr><td>State Point of Contact:
Don Fisher
Solid and Haz. Waste Div.
Wyoming Dept. of Environmental Quality
1222 W. 25th Street
Cheyenne, WY 82002
(307) 672-6457</td><td>EPA Point of Contact:
Lisa Reed Lloyd, RPM
U.S. EPA Region 8
999 18th Street, Suite 500
Denver, CO 80202-2466
(303) 312-6537</td></tr>
<tr><td>Waste Source:
Various contaminant releases, spills, and leaks</td><td colspan="2" rowspan="2">Type/Quantity of Media Treated:
Groundwater
- 192.8 million gallons treated as of December 1997
- Groundwater is found at 14-42 ft bgs
- Extraction wells are located in 1 aquifer at the site
- Hydraulic conductivity was reported as 340 ft/day</td></tr>
<tr><td>Purpose/Significance of Application:
Remedial strategy includes use of pump and treat for the on-site plume and natural attenuation for the off-site plume.</td></tr>
<tr><td colspan="3">Regulatory Requirements/Cleanup Goals:
- The remedial goal is to reduce the levels of contaminants in the on-site, up-gradient portion of the groundwater plume to below MCLs such that the remainder of the plume off site meets MCLs through natural attenuation within a reasonable time limit.
- Remedial goals were established for TCE (5 ug/L), PCE (5 ug/L), trans-1,2-DCE (100 ug/L), cis-1,2-DCE (70 ug/L), 1,1-DCE (7 ug/L), and 1,1,1-TCA (200 ug/L).</td></tr>
</table>

Pump and Treat of Contaminated Groundwater at the Mystery Bridge at Hwy 20 Superfund Site, Dow/DSI Facility, Evansville, Wyoming (continued)

Results:

- Contaminant concentrations in all wells have declined significantly, yet remain above MCLs. Concentrations of contaminants in three out of four source area wells fell below their respective MCLs in the last two sampling events in 1996; in the fourth well, the total contaminant concentration was 9.4 ug/L.
- Wells in the down-gradient portion of the plume declined from March 1993 to December 1996, but in at least one well (225 ft down-gradient of the site boundary) individual contaminant concentrations remain significantly above their respective MCLs.
- Approximately 21 pounds of contaminants have been removed from the groundwater at this site.

Cost:

- Actual costs for groundwater remediation were $918,000 ($305,000 in capital and $613,000 in O&M), which correspond to $5.65 per 1,000 gallons of groundwater extracted and $44,000 per pound of contaminant removed.

Description:

Since 1958, the Dow/DSI facility was used as a base for oil field service operations. Dow/DSI used mobile pumps, tanks, and other equipment to perform services for the oil and gas industry. It is believed that wash water from equipment cleaning operations contained chlorinated solvents. In addition, a tank at the site was used to store large volumes of toluene, which was used for cleaning purposes and oil well servicing activities. In 1986, residents complained of poor water and air quality. In response, EPA conducted an Expanded Site Investigation, which led to the discovery of contaminants in the groundwater. The site was placed on the NPL in August 1990 and a ROD was issued in September 1990.

The remedial strategy at this site was to actively treat the on-site groundwater plume using pump and treat with air stripping, and to allow natural attenuation to reduce contaminant levels in the off-site portion of the plume to levels below the MCLs. In four years of operation, contaminant concentrations in all wells have declined significantly, yet remain above MCLs.

SITE INFORMATION

Identifying Information:

Mystery Bridge at Hwy 20 Superfund Site
Dow/DSI facility - VHO Plume
Evansville, Wyoming

CERCLIS #: WYD981546005

ROD Date: September 24, 1990

Treatment Application:

Type of Action: Remedial

Period of operation: March 1994 - Ongoing (Performance data collected through October 1997)

Quantity of groundwater treated during application: 192.8 million gallons through December 1997

Background

Historical Activity that Generated Contamination at the Site: Oil and gas production enhancement

Corresponding SIC Code: 2911 (Oil and gas production enhancement)

Waste Management Practice That Contributed to Contamination: Various contaminant releases, spills, and leaks.

Operations: [1, 2]

- The Mystery Bridge Superfund site encompasses 400 acres, and is bordered on the north by the North Platte River, to the south by several industrial facilities, and to the east and west by the Brookhurst/ Mystery Bridge subdivision. The remedial action at the site addresses several groundwater contaminant plumes, emanating from several separate properties (KN Energy and Dow/DSI. Another source of contamination, from the Little America Refining Company, was not addressed as a remedial action for this site under CERCLA). The plumes contain different sets of contaminants, and each is being treated in a separate treatment system. This report addresses the remedial actions undertaken to address the plume originating from the Dow/DSI facility only.

- In 1986 residents complained of poor water and air quality. In response, EPA conducted an Expanded Site Investigation, which led to the original discovery of contaminants in the groundwater.

- The 23-acre Dow/DSI facility is situated along the Burlington Northern Railroad (BNRR) line, east of Evansville, WY. Since 1958, the site was used as a base for oil field service operations. Dow/DSI used mobile pumps, tanks, and other equipment to perform services for the oil and gas industry. It is believed that wash water from equipment cleaning operations contained chlorinated solvents. In addition, a large tank was located at the northern end of the site and was used to store large volumes of toluene, used for cleaning purposes and oil-well servicing activities.

- Releases were suspected from both the equipment cleaning activities and the toluene storage tank. Wash water from equipment cleaning operations flowed into a 1,000-gallon underground oil-water separator, located on the western portion of the site. Wash water from the oil-water separator sump seeped into the subsurface soils and the underlying groundwater. In addition, various spills and leaks were suspected to have occurred around the toluene storage tank, contaminating the subsurface soils in that area, as well.

- Beginning in January 1988, removal activities began at the Dow/DSI site, when approximately 440 cubic yards of contaminated soil were removed from the sump area and landfilled by Western Water Consultants (WWC). At the same time, the oil-water separator, an underground waste oil tank, and portions of the tile drain were removed by WWC. Soil vapor extraction (SVE) systems were installed in the sump and toluene storage areas to remove contaminants from subsurface soils. No further source control activities were performed.

SITE INFORMATION (CONT.)

Background (Cont.)

- The sump area SVE system consisted of two extraction wells and 80 feet of horizontal collector pipe. The extraction wells were installed to within two to four feet above the highest recorded water table level. The collector pipe was installed at a depth of five feet. From April to August 1988, approximately 334 pounds of volatile organic compounds (VOCs) were removed from the sump area [6].

- The toluene storage area SVE system consisted of two wells, installed to within two to four feet of the highest recorded water table level. From April to August 1988, approximately 6,000 pounds of VOCs were removed from the toluene storage area [6].

- In December 1987, an Administrative Order on Consent was issued to Dow/DSI (and KN Energy), requiring them to perform a remedial investigation/feasibility study (RI/FS). The RI/FS was completed in June 1990 and concluded that a plume of groundwater contaminated with volatile halogenated organic (VHO) compounds extended from the Dow/DSI facility to the North Platte River, approximately 0.5 mile downgradient. Another plume was identified originating from the KN Energy facility, but the RI/FS concluded that the two plumes had different sources, contained different compounds, and were not commingled.

- The site was placed on the National Priorities List (NPL) in August 1990.

Regulatory Context:

- On September 24, 1990, EPA issued a Record of Decision (ROD) for the groundwater operable unit. This operable unit covers the remedial activities at both the KN Energy and Dow/DSI facilities.

- A Consent Decree for the RI/FS was signed in 1988 between USEPA, Dow/DSI, and KN Energy.

- Site activities are conducted under provisions of: the Comprehensive Environmental Response, Compensation, and Liability Act of 1980, as amended by the Superfund Amendments and Reauthorization Act of 1986 (CERCLA/SARA) §121, the National Contingency Plan (NCP), 40 CFR 300; the Safe Drinking Water Act of 1974, as amended by 1984 reauthorization and amendments; Clean Air Act and 1990 Amendments; and the Resource Conservation and Recovery Act (RCRA) of 1976 and 1984 amendments.

Remedy Selection:

- Groundwater extraction and treatment in the on-site portion of the plume via air stripping was selected as the remedy for the Dow/DSI VHO plume at this site. Effluent was to be reinjected to the alluvial aquifer. Contamination in the off-site portion of the plume was to be eliminated through natural attenuation.

Site Logistics/Contacts

Site Lead: EPA-Lead

Oversight: State of Wyoming

Remedial Project Manager:
Lisa Reed Lloyd*
U.S. EPA Region 8
999 18th Street, Suite 500
Denver, CO 80202-2466
303-312-6537

* Indicates primary contacts

State Contact:
Don Fisher
Solid and Hazardous Waste Division
Wyoming Department of Environmental Quality
1222 W. 25th Street
Cheyenne, WY 82002
307-672-6457

Remedial Contractor:
Western Water Consultants, Inc.*
Thomas J. Mueller, P.E., Project Manager
611 Skyline Road
PO. Box 4128
Laramie, Wyoming 82071
307-742-0031

MATRIX DESCRIPTION

Matrix Identification

Type of Matrix Processed Through the Treatment System: Groundwater

Contaminant Characterization

Primary Contaminant Groups:
Halogenated volatile organic compounds

- The primary contaminants of concern at the site are 1,1-dichloroethene (1,1-DCE), *trans*-1,2-dichloroethene (*trans*-1,2-DCE), trichloroethene (TCE), tetrachloroethene (PCE), 1,1,1-trichloroethane (1,1,1-TCA), and 1,1-dichloroethane (1,1-DCA). Concentrations of toluene in the groundwater near the toluene storage tank did not justify it being considered a contaminant of concern [1].

- The maximum concentrations detected for the principal contaminants during the September 1989 sampling event included: (*trans*-1,2-DCE) 500 µg/L, (TCE) 430 µg/L, (PCE) 540 µg/L, and (1,1,1-TCA) 500 µg/L [1].

- To assess the likelihood that contaminants were present as nonaqueous phase liquids (NAPLs), samples were taken by WWC at discrete intervals in one well, which was screened across the aquifer. Relatively higher concentrations in samples taken at the top and bottom of the aquifer than those found in the central portion would have indicated the presence of NAPLs. No such evidence was found [2].

- Figure 1 shows that the VHO plume extends from the DSI facility through the subdivision in a northeast direction towards the North Platte River. The areal extent of the plume was estimated during the RI/FS to be approximately 135 acres and to contain 18,571,000 gallons of contaminated groundwater [1].

Matrix Characteristics Affecting Treatment Costs or Performance

Hydrogeology:

Groundwater moves across the site in a northeasterly direction towards the North Platte River. An alluvial aquifer is located in an erosional trough in the bedrock surface. The alluvial aquifer is composed of permeable, unconsolidated materials. The aquifer is bound on the northwestern and southeastern sides by subcrops of bedrock rising above the water table, limiting drainage from adjacent basins. Underlying the alluvium, the bedrock is composed of sandstone, interspersed with shale seams. Groundwater is found at an average depth of 35 feet below land surface, and flows at an average rate of 2.1 feet/day. A technical description of the alluvial aquifer is given below:

Alluvial Aquifer	The alluvial geology consists of 14.5 to 81 feet of quaternary alluvial floodplain and terrace deposits along the North Platte River and Elkhorn Creek. The upper 1.5 to 13 feet of the alluvial deposit is a surficial soil layer, which consists of a mixture of sandy silt and clayey silt. The remaining alluvium ranges in thickness from 13 to 68 feet (average thickness of 50 feet) and consists of well-sorted coarse to medium sand with little fine sand and trace amounts of silt and gravel. The depth to the groundwater in the alluvium ranges from 14 to 42 feet. The aquifer is underlain by non-water-bearing bedrock.

MATRIX DESCRIPTION (CONT.)

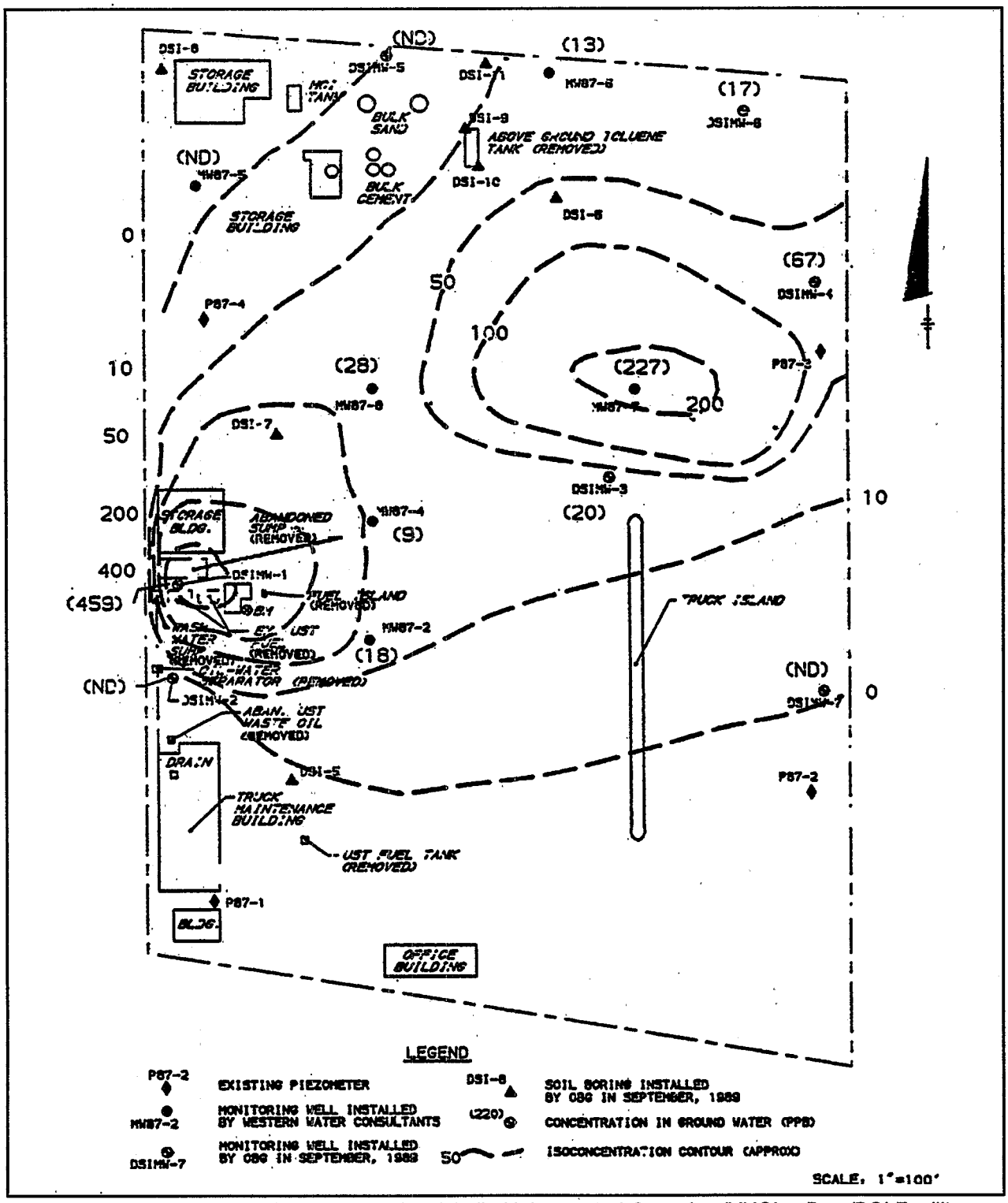


Figure 1. Concentration Contour Map for Volatile Halogenated Organics (VHO) - Dow/DSI Facility (July 1990) [1]

MATRIX DESCRIPTION (CONT.)

Matrix Characteristics Affecting Treatment Costs or Performance (Cont.)

Table 1 includes technical aquifer information.

Table 1. Technical Aquifer Information

Unit Name	Thickness (ft)	Conductivity (ft/day)	Average Velocity (ft/day)	Flow Direction
Alluvial Aquifer	14.5-81	340	2.12	Northeast

Source: [1]

TREATMENT SYSTEM DESCRIPTION

Primary Treatment Technology

Pump and treat with air stripping

Supplemental Treatment Technology

None

System Description and Operation

Table 2. Extraction Well Data

Well Name	Unit Name	Depth (ft)	Yield (gal/min)
XW93-1	Alluvium	40 - 45	25
XW93-2	Alluvium	40 - 45	50
XW93-3	Alluvium	40 - 45	25

Source: [2]

System Description

- The remedial approach at this site was to actively treat the on-site groundwater plume using pump and treat with air stripping, and to allow natural attenuation to reduce contaminant levels in the off-site portion of the plume to levels below MCLs [3].

- The extraction system consists of three wells placed along the eastern boundary of the Dow/DSI facility. Each well was designed to produce a minimum of 100 gpm. Based on groundwater modeling with Quikflow™, it was determined that a combined pump rate of 100 gpm would be sufficient to maintain hydraulic control over the plume, and not interfere with the pump and treat system at the nearby KN Energy facility. Each well was completed to bedrock and screened over the entire saturated zone [3].

- An infiltration gallery is used to reinject the treated groundwater. A design goal of the infiltration gallery was to minimize mounding at the point of infiltration. A site plan is included as Figure 2. The infiltration trench is 150 feet long, 4 feet wide, and 10 feet deep, for a total of 600 square feet of surface area. The trench has an infiltration capacity of 280 gpm. The bottom 5 feet is filled with washed gravel over a slotted PVC pipe. Another trench was constructed as a backup for when cleaning activities would shut down the primary trench [3].

- A particle trace test determined that the travel time between the infiltration gallery and the extraction wells was from 70 to 320 days. Based on this information, it was determined that approximately five pore volumes of water should be flushed through the center of the plume each year. Using

TREATMENT SYSTEM DESCRIPTION (CONT.)

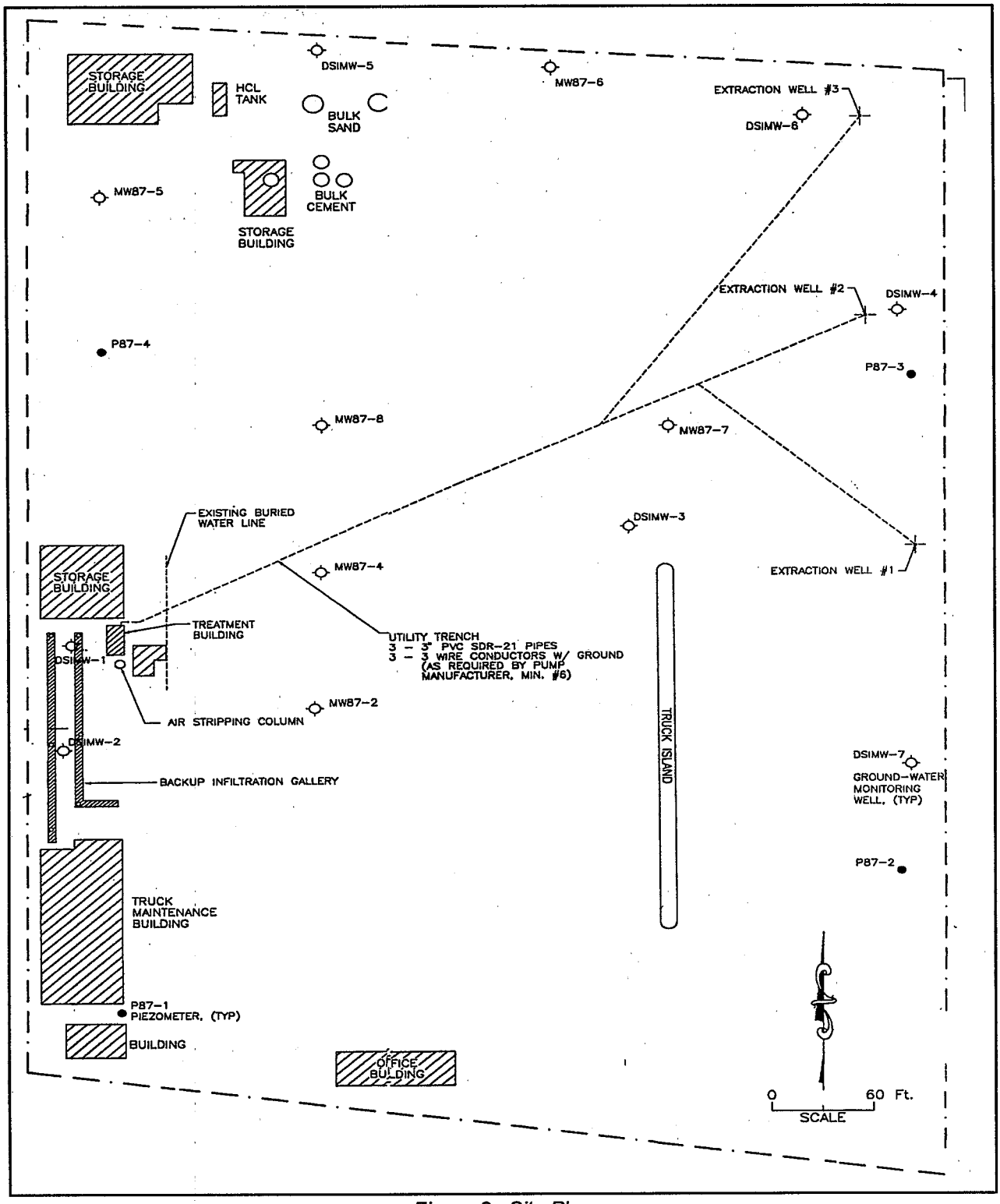


Figure 2. Site Plan

TREATMENT SYSTEM DESCRIPTION (CONT.)

System Description and Operation (Cont.)

retardation factors that range from 1.2 to 2.6, the site engineer estimated that TCE would be flushed through the system in a maximum of 0.5 to 1.5 years [3].

- The air stripper designed for this site has a column diameter of 2.5 feet, a packing height of 30 feet, and a maximum water loading rate of 150 gpm.

- Some design considerations were made based on shared experience with operating a pump and treat system at the KN Energy facility. For instance, the design called for a stripping column that would allow for rapid and easy removal, cleaning, and replacement of the stripping media. It was known, from the KN Energy system, that certain chemical species are likely to precipitate in the tower, fostering biological growth on the stripping media. As a result, the design specified that a chemical treatment system be included to add chelating agent for iron and manganese to inhibit such growth [3].

- Groundwater contamination and water levels are monitored in a network of 30 wells, placed both on and off site. All 30 wells are sampled quarterly for the seven primary contaminants of concern. Five wells, located off site along the Burlington Northern right-of-way and on a neighboring industrial property are monitored eight times per year for the seven primary contaminants of concern [4].

System Operation

- Remedial construction was completed on June 24, 1994; however, portions of the system were operating on a nearly continuous basis starting from March 28, 1994 [5].

- Quantity of groundwater pumped from aquifer in gallons by year [5]:

Year	Volume Pumped (gal)
1994	36,309,200 (missing data for 11/94)
1995	53,808,900
1996	55,472,300
1997	47,167,600
Total Volume through 1997	**192,758,000**

- The system has operated continuously from June 1994 to May 1998. The most persistent problems have been corrosion in the extraction wells and piping. All three extraction pumps have been taken out of service and cleaned. The reinjection pump also has been taken out of service for repairs. None of these events has led to a system shutdown or a loss of hydraulic control on the contaminant plume [5].

- Air stripping media has never been changed or cleaned. Annual inspections have revealed some build up of iron oxide, but not enough to require media cleaning or replacement.

- It was originally anticipated that cleanup of the site would take approximately six years. At this time, the downgradient portion of the plume appears to be ahead of schedule, i.e., it has achieved or is approaching the performance standards. The upgradient portion of the plume has not achieved the performance standards.

TREATMENT SYSTEM DESCRIPTION (CONT.)

Operating Parameters Affecting Treatment Cost or Performance

Table 3 presents operating parameters affecting cost or performance.

Table 3. Performance Parameters

Parameter	Value
Average Pump Rate	103 gpm
Performance Standard (µg/L)	Remedial Goals
Remedial Goal TCE PCE *trans*-DCE *cis*-DCE 1,1-DCE 1,1,1-TCA	(µg/L) 5 5 100 70 7 200
Note: Average pump rate was calculated as the average of monthly flow rates.	

Source: [4]

Timeline

Tale 4 presents a timeline for this remedial project.

Table 4. Project Timeline

Start Date	End Date	Activity
09/90	---	Record of Decision for OU1 signed by EPA
3/92	6/93	Remedial design completed
8/93	3/94	Remedial construction begun
---	6/94	Remedial construction complete
6/94	ongoing	Groundwater treatment operational

Source: [1, 2, 3, 5]

TREATMENT SYSTEM PERFORMANCE

Cleanup Goals/Standards

The goal of this remedy is to reduce the level of contaminants in the on-site upgradient portion of the groundwater plume to below MCLs, as shown in Table 3, such that the remainder of the plume off site meets MCLs through natural attenuation within a reasonable time limit [3].

Additional Information on Goals

The upgradient portion of the plume was defined as the on-site plume; the downgradient portion of the plume was defined as the off-site plume. Extensive groundwater modeling was used to determine that the cleanup time needed to achieve MCLs in the downgradient portion of the plume would be 6 to 14 years [3].

Treatment Performance Goals

The treatment system was designed to reduce contaminant levels in the influent to below MCLs for reinjection of the treated groundwater [3].

Performance Data Assessment [5,7,8]

For this report, total contaminants include TCE, PCE, 1,1,1-TCA, trans-, and cis-1,1-DCE.

- Contaminant concentrations in all wells have declined significantly, yet remain above MCLs.
- Figure 3 presents the total contaminant concentrations from January 1993 to July 1997 in the wells located closest to the source area. From their initial levels, ranging from 20 µg/L to 70 µg/L, concentrations of all contaminants fell below their respective MCLs in three of four source area wells in the last two sampling events in 1996. In the fourth well, DSIMW-3, total contaminant concentration was 9.4 µg/L. Over time, concentrations of total contaminants have declined in a cyclical pattern, with concentrations spiking periodically, and then falling to levels gradually lower than in previous sampling events.
- Figure 4 presents concentrations of total contaminants detected in wells located near the site boundary, and at the edge of the extraction system capture zone, approximately mid-plume. During the October 1996 sampling event, concentrations of all contaminants were below their respective MCLs in two of four wells and had been at or below their respective MCLs in three of the last four sampling events. In the remaining two wells (DSIMW-4 and MKMW-1), which are both located near the plume centerline, total contaminant concentrations had declined by at least 62 percent from their initial levels, and were measured at 14 µg/L and 9.8 µg/L, respectively.
- Figure 5 shows total contaminant concentrations for the wells located in the downgradient portion of the plume, and which are beyond the hydraulic capture zone of the extraction system. These wells are installed in the downgradient portion of the plume, where, according to the ROD, natural attenuation should be acting to reduce contaminant levels. Total contaminant concentrations have declined in all wells. The sharpest declines were seen in wells EPA1-7 and EPA2-15, located approximately 225 feet downgradient of the site boundary. Total contaminant concentrations declined 72% and 86%, respectively in these two wells over the period from March 1993 to December 1996. Nonetheless, individual contaminants in EPA1-7 remain significantly above their respective MCLs, indicating that contaminants may be migrating past this point. However, concentrations in the wells directly downgradient of EPA1-7 have remained below MCLs since January 1995, suggesting that sufficient natural attenuation is occurring between the two wells [7].

TREATMENT SYSTEM PERFORMANCE (CONT.)

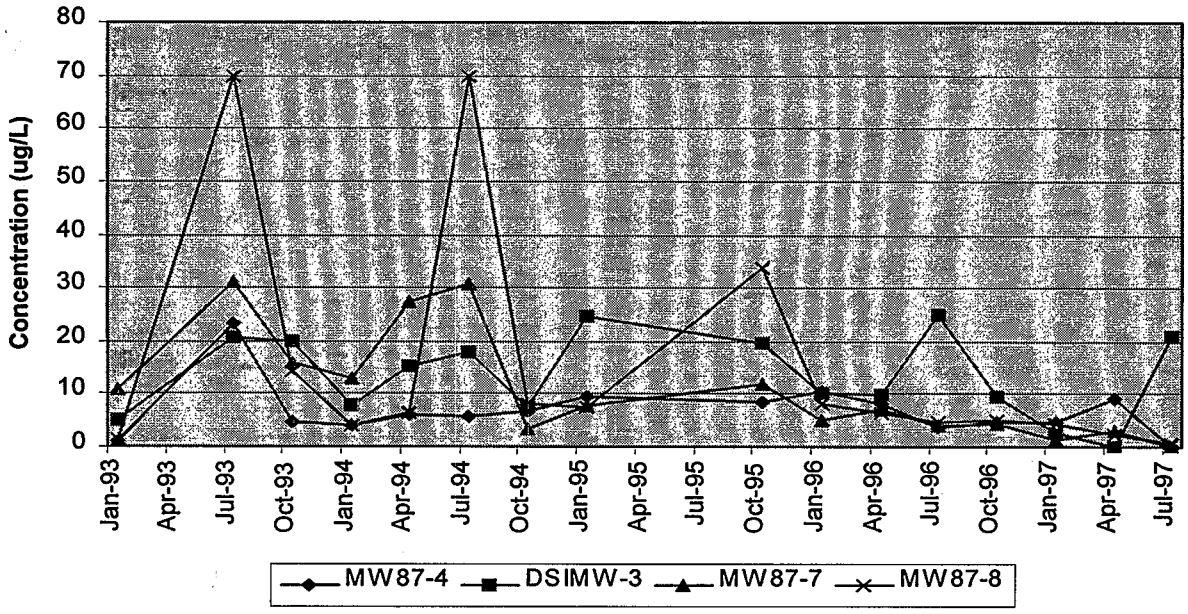


Figure 3. Total VOC Concentrations in Source Area Wells [5]

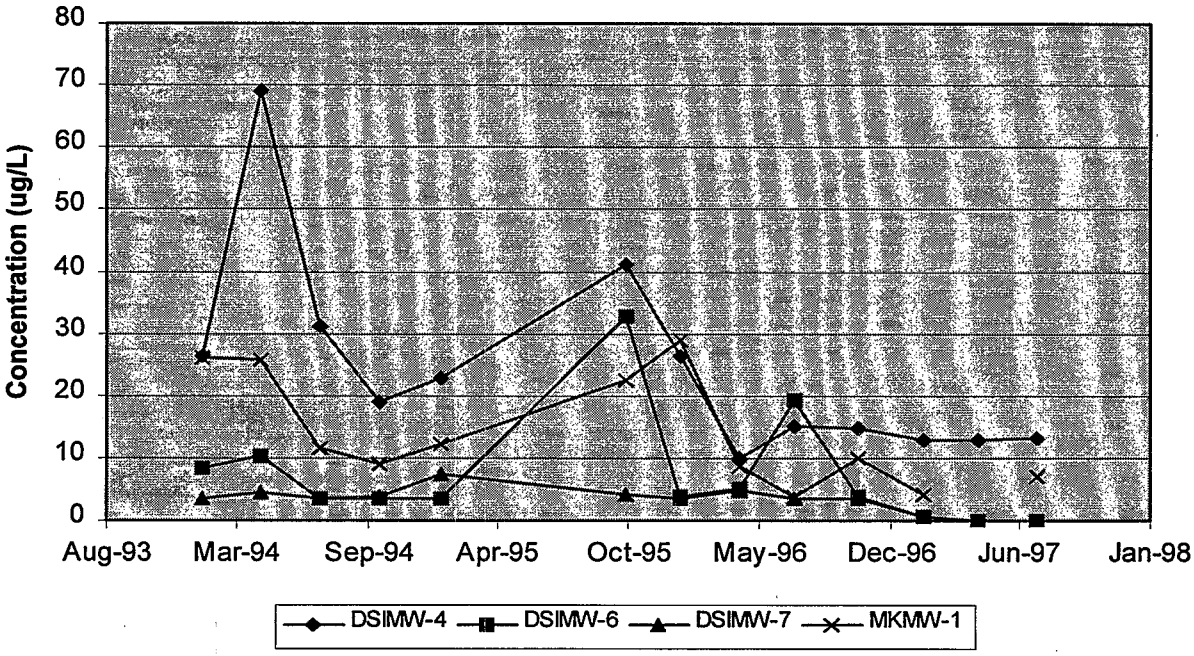


Figure 4. Total VOC Concentration in Mid-Plume Wells [1] [5]

[1]Discontinuous lines indicate that the well was not sampled on that date

TREATMENT SYSTEM PERFORMANCE (CONT.)

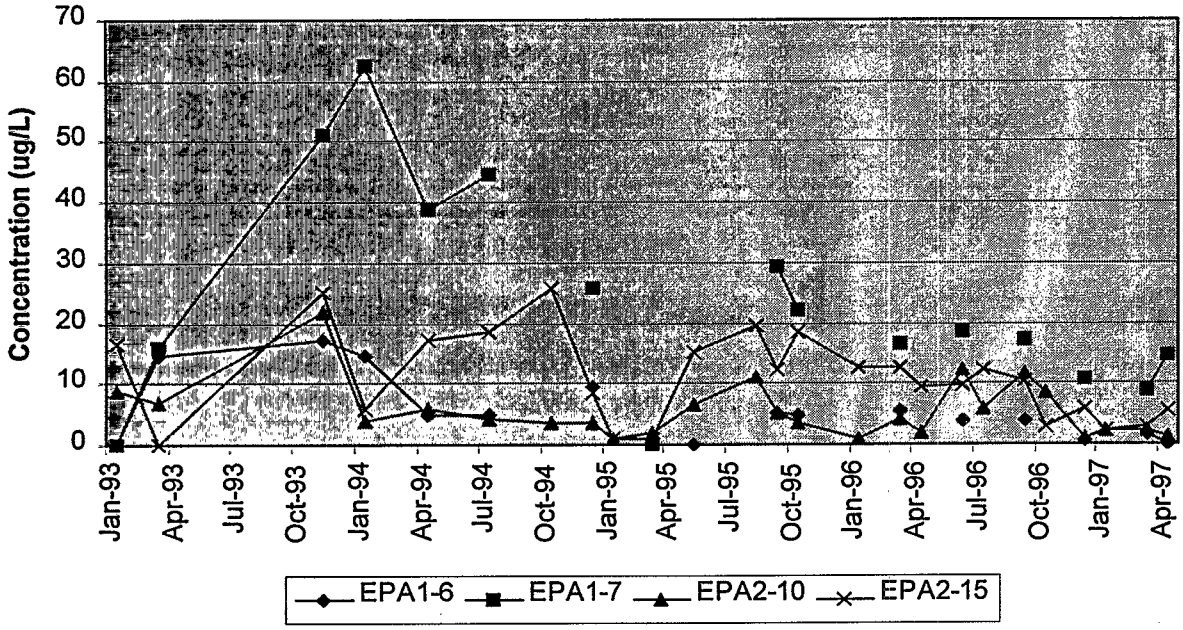


Figure 5. Total VOC Concentrations in Off-Site Downgradient Wells [1] [5]

[1]Discontinuous lines indicate that the well was not sampled on that date

Performance Data Assessment (Cont.)

- Monthly reports on the treatment system performance indicate that the treatment system has consistently reduced influent concentrations to levels below detection limits.

- Figure 6 reflects on the performance of the treatment system in removing volatile compounds in the influent stream. Figure 5 presents the cumulative mass removed and the mass per day removed in each of the three extraction wells from May 1994 through December 1996. Mass flux through the system, as measured by pounds of contaminant removed per day, has been unusually low for this type of site, and varied from 0.0088E-4 lbs/day to 0.03E-2 lbs/day. Since the beginning of system operations, the efficiency rate has remained close to 0.0073E-3 lbs/day. However, during the final quarter of 1995, this rate increased sharply. This increase follows a sharp increase in contaminant concentrations in many of the monitoring wells during the previous quarter.

- In three years of operation, the treatment system has removed less than 21 pounds of contaminants from the groundwater. Moreover, mass flux rates through the system are very low, reflecting the relatively low concentrations in the influent [5].

TREATMENT SYSTEM PERFORMANCE (CONT.)

Performance Data Completeness

- Quarterly data are available for concentrations of contaminants in the on-site groundwater from 27 monitoring wells and three extraction wells in monthly reports, and in spreadsheets delivered to the EPA RPM between reports. Twice-quarterly data are available for concentrations of contaminants in the off-site groundwater from five monitoring wells.
- Monthly data are available for the volume of groundwater treated by the system (missing November 1994).
- All available data were used in Figures 3 through 6.

Performance Data Quality

The QA/QC program used throughout the remedial action met the EPA and the State of Wyoming requirements. All monitoring is performed using EPA Method SW 8020, and the vendor did not note any exceptions to the QA/QC protocols [4].

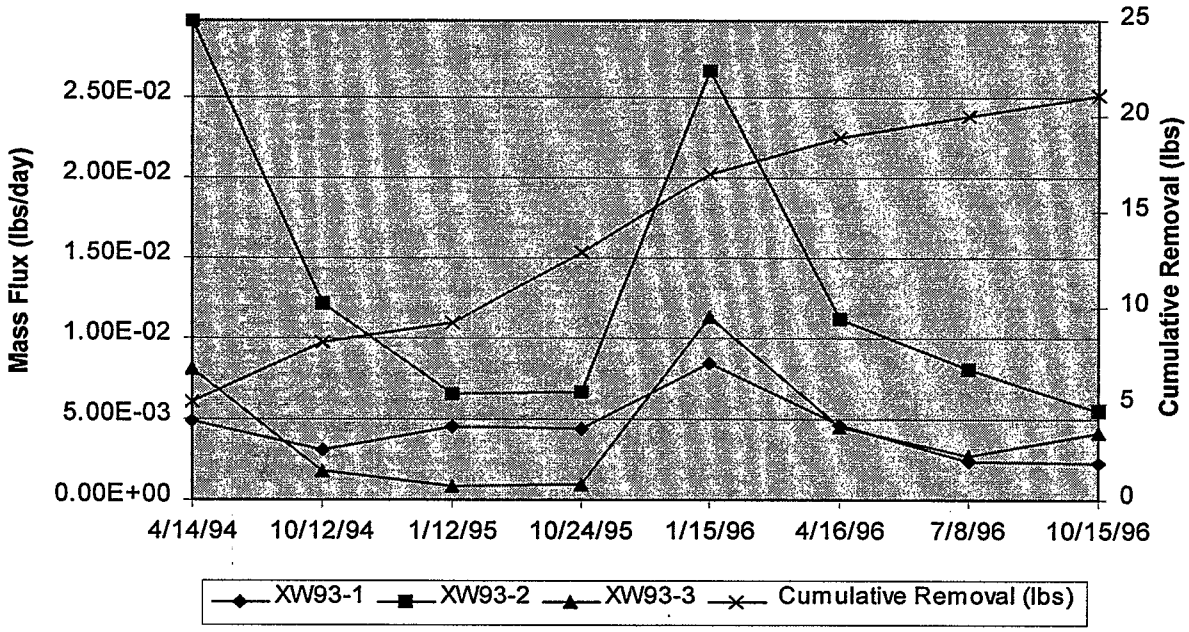


Figure 6. Mass Flux and Cumulative VOC Removal [5]

TREATMENT SYSTEM COST

Procurement Process

The PRP, Dow/DSI, contracted with Western Water Consultants, Inc. for engineering, design and oversight services at the facility.

Cost Analysis

- All costs for investigation, design, construction and operation of the treatment system at the site were borne by Dow/DSI.

Capital Costs [6]

Remedial Construction	$305,352

Operating Costs [6]

May 1994 through December 1987	$612,622

Other Costs [6]

Remedial Design	$257,692

Cost Data Quality

Actual costs for this site are available from the PRP.

OBSERVATIONS AND LESSONS LEARNED

- Concentrations of contaminants in the on-site portion of the plume have been reduced, largely to levels below their respective MCLs. The one exception is well DSIMW-3, where concentration levels remain above MCLs.
- Source removal activities were performed in 1988. With the source areas controlled, initial contaminant groundwater concentrations were relatively low and progress towards remedial goals has been realized by the date of this report.
- The total cost for groundwater remediation at this site through October 1997 was $918,000 ($305,000 in capital costs and $613,000 in operating costs) which corresponds to a unit cost of $5.65 per 1,000 gallons of groundwater treated and $44,000 per pound of contaminant removed.
- Site engineers indicated that it is likely that by the time the RI/FS was performed, further expansion of the plume had ceased. Site engineers reached this conclusion after taking into account the amount of time that the source may have been active and the relatively high mobility of chlorinated solvents in an aquifer of this type. A comparison of the plume geometries over the period 1988 to 1990 showed a slowing rate of growth. Based on this analysis, site engineers concluded that the plume had probably reached an equilibrium between the rate of transport and the rate of degradation by the time that the remedial system was constructed [2].

REFERENCES

1. U.S. Environmental Protection Agency. Record of Decision: Mystery Bridge at Highway 20. September 24, 1990.

2. Obrien & Gere. RI/FS Report: Mystery Bridge Road/Highway 20 Site, Natrona County, Wyoming. June 1990.

3. Western Water Consultants. Design Report for the Dow/DSI Ground-water Remediation System at the Brookhurst/Mystery Bridge Site. February 1993.

4. Western Water Consultants. Operation and Maintenance Plan for the Dow Chemical/Dowell Schlumberger Remedial Design and Remedial Action at the Brookhurst/Mystery Bridge Site. May 21, 1993.

5. Western Water Consultants. Monthly Progress Reports: August 1993 to April 1997. Various dates.

6. Correspondence with Brent Schindler, PRP Counsel, April 13, 1998.

7. Comments on draft report from Tom Mueller, Western Water Consultants, May 26, 1998.

8. Comments on draft report from Dennis Jaramillo, EPA Region VIII May 20, 1998.

Analysis Preparation

This case study was prepared for the U.S. Environmental Protection Agency's Office of Solid Waste and Emergency Response, Technology Innovation Office. Assistance was provided by Eastern Research Group, Inc. and Tetra Tech EM Inc. under EPA Contract No. 68-W4-0004.

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Groundwater Containment at Site LF-12, Offutt AFB, Nebraska

Groundwater Containment at Site LF-12, Offutt AFB, Nebraska

Site Name: Site LF-12, Offutt AFB	**Contaminants:** Volatile Organic Compounds (VOCs) - Levels of VOCs in soil vapor included 18 ppm acetone, 0.077 ppm toluene, and 0.031 ppm xylene - Contaminants in groundwater included 500 ppb TCE, 16,000 ppb DCE, 3.3 ppb chloroform, and 7 ppb bromodichloromethane	**Period of Operation:** Not available; system was operating in January 1997
Location: Nebraska		**Cleanup Type:** Full-scale cleanup
Vendor: Information not provided	**Technology:** Hydrualic containment consists of three recovery wells. The system operates at an average flow rate of 105 gpm. Groundwater is treated with air stripping and effluent is discharged to a local POTW.	**Cleanup Authority:** Installation Restoration Program
Additional Contacts: U.S. Air Force Air Combat Command		**Regulatory Point of Contact:** Information not provided
Waste Source: Disposal of refuse, waste solvents, and sewage sludge.	**Type/Quantity of Media Treated:** Groundwater - Quantity treated not provided. Groundwater is encountered between 9 and 18 feet below ground surface.	
Purpose/Significance of Application: Containment of groundwater using active pumping		
Regulatory Requirements/Cleanup Goals: Information on cleanup objectives was not included in this report.		
Results: Limited performance data are available for this application. The volume of contaminant removed as of January 1997 was 12.81 gallons. The average concentration of TCE in the extracted groundwater was 151 ppb.		
Cost: The capital cost for the system was $540,000. The O&M costs average $20,000 per year. Monthly O&M data were not provided.		

Groundwater Containment at Site LF-12, Offutt AFB, Nebraska (continued)

Description:
Site LF-12 is located at Landfill 4 at Offutt AFB in Nebraska. An estimated 40,000 cubic yards of refuse, waste solvents, and sewage sludge were disposed at Landfill 4, resulting in contamination of soil and groundwater at the site. Low levels of VOCs, including acetone, toluene, and xylene, were detected in the soil vapor. TCE (500 ppb), DCE (16,000 ppb), chloroform (3.3 ppb), and bromodichloromethane (7 ppb) were detected in the groundwater.

A hydraulic containment system was installed at the site, and was operating as of January 1997. Information on the start date for the system was not provided. The system consists of three recovery wells, and operates at an average flow rate of 105 gpm. Groundwater is treated with air stripping and effluent is discharged to a local POTW. Only limited cost and performance data are available for this application. The volume of contaminant removed as of January 1997 was 12.81 gallons. The average concentration of TCE in extracted groundwater was 151 ppb.

The capital cost for the system was $540,000, including design, labor, equipment, materials, and startup. O&M costs average $20,000 per year and include electrical, monitoring, equipment and materials, and operations. No data on actual monthly O&M costs were provided.

Groundwater Containment at Site LF-12, Offutt AFB

Site Background

This section focuses on the groundwater containment system located at Site LF-12 at Offutt AFB. Site LF-12 is located at Landfill 4 at Offutt AFB. A site map for LF-12 is included as Figure 47.

Contaminants in Soil

- An estimated 40,000 cubic yards of refuse, waste solvents, and sewage sludge were disposed of at the Landfill 4 (LF-12) before being covered.
- Low levels of VOCs present in the soil vapor (up to 18 ppm acetone, 0.077 ppm of toluene and 0.031 ppm of xylene).

Contaminants in Groundwater

- TCE, DCE, chloroform, and bromodichloromethane was detected in groundwater at concentrations of 500 ppb, 16,000 ppb, 3.3 ppb, and 7 ppb, respectively.

Lithology

- Landfill 4 (Site LF-12) is situated on an alluvial terrace. The fill overlies a 70 to 80 feet thick alluvial deposit. A 1 to 2 foot layer of clay lies on top of the alluvium, below the fill, which retards vertical migration of water. The alluvium rests on 5 to 10 feet of glacial till. Pennsylvania bedrock (limestone and shale) exists at 80 to 95 feet bgs.
- Depth to groundwater is 9 to 18 feet bgs.

Groundwater Containment System Details

- Hydraulic containment consists of three recovery wells (HF2C-PW1, LF4-PW3, and LF4-PW4).
- The system operates at an average groundwater flow rate 105 gpm.
- Groundwater is treated with air stripping and effluent is discharged to local POTW.

Total Capital Costs

- $540,000 (design, labor, equipment and materials, startup).

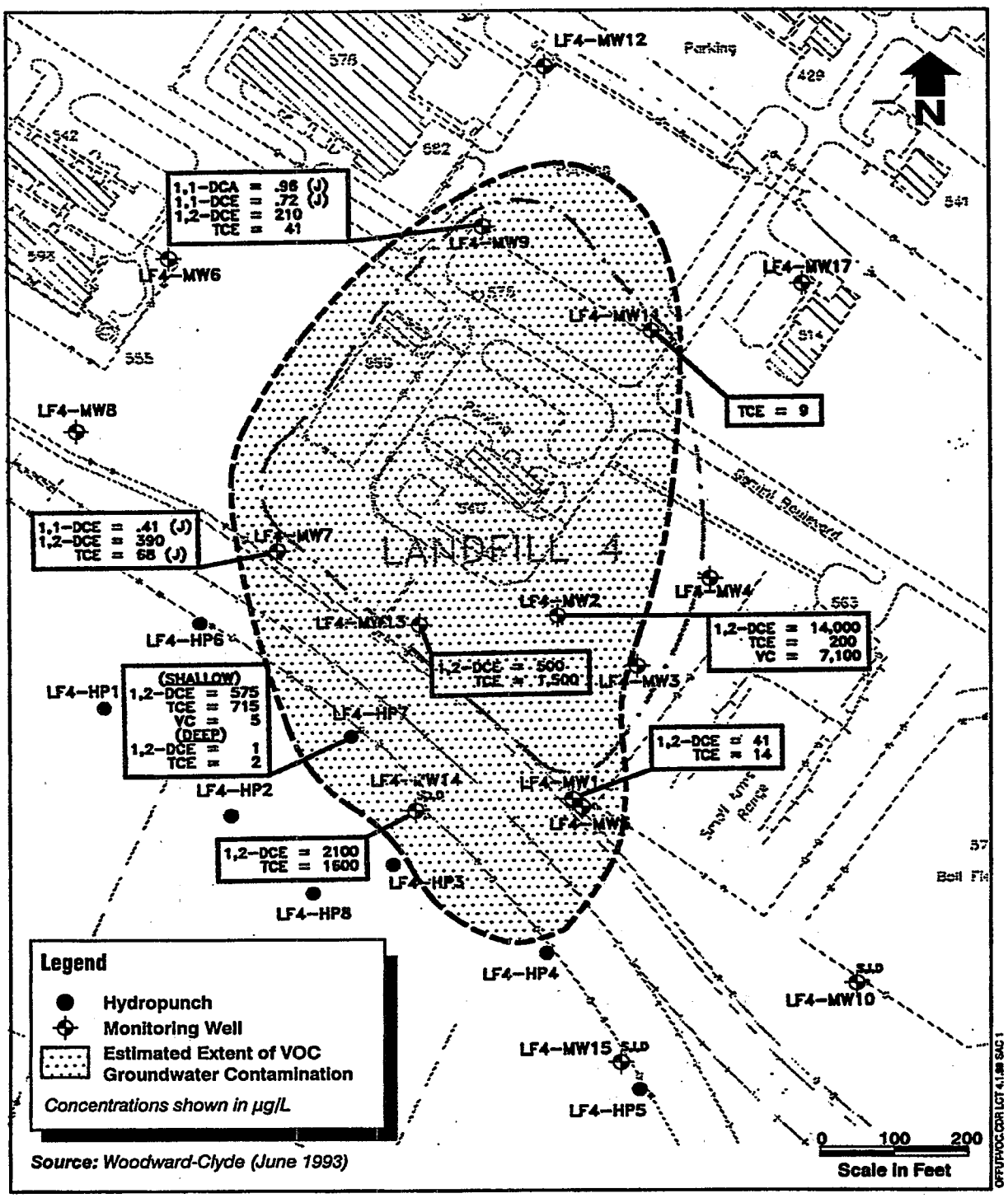
Total O&M Costs

- O&M costs average $20,000/year (electrical, monitoring, equipment and materials, operations).

Cost and Performance of Groundwater Containment at Site LF-12

The limited cost and performance data available for Site LF-12 at Offutt AFB is provided below:

- O&M costs average $20,000 per year.
- The average concentration of extracted groundwater was 151 ppb of TCE.
- The volume of contaminants removed as of January 1997 was 12.81 gallons.



Source: Woodward-Clyde (June 1993)

Figure 47. VOCs Detected in Groundwater at Landfill No. 4, Site LF-12, Offutt AFB

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Pump and Treat of Contaminated Groundwater at the Old Mill Superfund Site, Rock Creek, Ohio

Pump and Treat of Contaminated Groundwater at the Old Mill Superfund Site, Rock Creek, Ohio

Site Name:
Old Mill Superfund Site
(this site consists of two parcels of land - the Henfield property and the Kraus property)

Location:
Rock Creek, Ohio

Contaminants:
Chlorinated solvents
and volatiles - nonhalogenated
- Maximum concentrations detected in one plume (Henfield) were TCE (6,100 ug/L), PCE (300 ug/L), trans-1,2-DCE (460 ug/L0, and VC (14 ug/L)
- Maximum concentrations detected in other plume (Kraus) were ethylbenzene (19,000 ug/L) and xylenes (43,000 ug/L)

Period of Operation:
Status: Ongoing
Report covers: 9/89 - 7/97

Cleanup Type:
Full-scale cleanup (interim results)

Vendor:
Construction: Aptus Environmental Services, Inc.
Coffeyville, KS 67337
Operation & Maintenance:
Omprakash Patel
Roy F. Weston, Inc.
3 Hawthorn Pkwy, Suite 400
Vernon Hills, IL 60061-1450
(847) 918-4051

Technology:
Pump and Treat
- Groundwater is extracted using 3 wells and 5 trenches at an average total pumping rate of 3.1 gpm
- Extracted groundwater is treated with air stripping and carbon adsorption
- Treated groundwater is discharged to a surface water under a NPDES permit

Cleanup Authority:
CERCLA Remedial
- ROD Date: 8/7/85

State Point of Contact:
Mike Eberle
Ohio EPA
(216) 963-1126

EPA Point of Contact:
Ron Muraawski, RPM
U.S. EPA Region 5
77 W. Jackson Blvd.
Chicago, IL 60604-3590
(312) 886-2940

Waste Source:
Illegal waste disposal

Purpose/Significance of Application:
Relatively high unit cost, due to small quantity of groundwater extracted and low groundwater flow.

Type/Quantity of Media Treated:
Groundwater
- 13 million gallons treated as of 1997
- Groundwater is found at 5 ft bgs
- Extraction wells are located in 2 aquifers
- Hydraulic conductivity ranges from 0.22 to 1.25 ft/day

Regulatory Requirements/Cleanup Goals:
- Remedial goals were established for contaminants of concern that must be met throughout the site. These goals were based on achieving a carcinogenic risk level of 1×10^{-5}, and consist of 1,2-DCE (1.9 ug/L), TCE (15 ug/L), PCE (8.2 ug/L), and ethylbenzene (8,000 ug/L).
- Treatment system performance standards were established to meet NPDES permit requirements.
- The system was required to contain the plume and prevent off-site migration of contaminants.

Pump and Treat of Contaminated Groundwater at the Old Mill Superfund Site, Rock Creek, Ohio (continued)

Results:
- The 1997 annual sampling data indicate that the P&T system has contained the plume, but that contaminant concentrations in much of the plume remain above remedial goals. In addition, two hot spots remain problematic at this site, with TCE concentrations of 1,700 and 1,400 ug/L as of March 1997.
- The P&T system removed approximately 124 pounds of contaminants from 1990 to 1997.
- Treatment performance standards have been met consistently during this application.

Cost:
- Actual costs for the P&T system were approximately $3,236,000 ($1,596,000 in capital and $1,640,000 in O&M), which correspond to $250 per 1,000 gallons of groundwater extracted and $26,100 per pound of contaminant removed.
- The actual capital cost was approximately 22% higher than the original bid cost, due to a need to add collection trenches.

Description:
The Old Mill Superfund site includes two parcels of land, the Henfield and Kraus properties. The site was used for illegal disposal of drummed wastes for an undetermined number of years. In 1979, U.S. EPA and Ohio EPA found approximately 1,200 drums of waste including oils, resins, and PCBs on the Old Mill site. Drum and soil removal were completed in 1982 as a Superfund emergency removal action. Limited information is provided about site investigation activities, however, data are presented showing VOCs in the groundwater based on 1984 sampling data. The site was listed on the NPL in September 1983 and a ROD was signed in August 1985.

The P&T system has been designed to remediate plumes from both the Henfield and Kraus properties. The system consists of three deep recovery wells and five collection trenches. Extracted groundwater from both plumes is treated in one treatment plant, which consists of an 18-inch diameter air stripping tower and a granular activated carbon unit. In 1989 and 1994, the collection system was modified by adding collection trenches at the Kraus property needed to maintain containment. After eight years of P&T operation, the cleanup goals for this site have not been met. According to the RPM, the P&T system at this site does not appear to have the typical effect on groundwater contamination. New contaminants have been identified after the initial investigation and contaminant concentrations have increased at times during operations. The reasons for these events is not known at this time.

SITE INFORMATION

Identifying Information

Old Mill Superfund Site
Rock Creek, Ohio

CERCLIS #: OHD980510200

ROD Date: August 7, 1985

Treatment Application

Type of Action: Remedial

Period of operation: September 1989 - Ongoing
(Data collected through 1997)

Quantity of material treated during application: 13 million gallons of groundwater [9]

Background

Historical Activity that Generated Contamination at the Site: Illegal waste disposal

Corresponding SIC Code: NA

Waste Management Practice That Contributed to Contamination: NA

Location: Rock Creek, Ohio

Facility Operations: [4, 11]

- The Old Mill Superfund site includes two parcels of land, the Henfield property and the Kraus property. The Henfield property is approximately three acres in size, and the Kraus property is approximately 10 acres in size (see Figures 1 and 2). The two parcels are located across the road from each other, in a rural setting near the Village of Rock Creek, Ohio. The site was used for illegal disposal of drummed wastes for an undetermined number of years.

- In 1979, the U.S. EPA (EPA) and Ohio EPA (OEPA) found approximately 1,200 drums of waste including oils, resins, and PCBs on the Old Mill site. Drum and soil removal was completed in November 1982 as a Superfund emergency removal activity. The source removal actions at the Old Mill site included removal of drums containing hazardous materials, as well as excavation and off-site disposal of contaminated soil. Allowable Residual Contaminant (ARC) Criteria, or cleanup levels, were calculated to determine the concentrations of contaminants that could remain in the soil. No other contaminant sources, underground or above ground, were identified at the site.

- The site was listed on the National Priorities List (NPL) in September 1983.

- The Remedial Investigation (RI)/Feasibility Study (FS) was completed in 1984. An addendum to the RI was completed in 1985.

Regulatory Context:

- Site activities are conducted under provisions of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980, as amended by the Superfund Amendments and Reauthorization Act (SARA) of 1986, §121, and the National Contingency Plan (NCP), 40 CFR 300 [4].

- On August 7, 1985, the EPA issued a Record of Decision (ROD).

Remedy Selection:

- Extraction of groundwater and treatment via carbon filtration was selected as the remedy for contaminated groundwater at this site. Effluent is discharged to a local waterway. An air stripper and collection trench were added to the remedy during remedial design [4].

SITE INFORMATION (CONT.)

Site Logistics/Contacts

Site Lead: EPA

Remedial Project Manager:
Ron Murawski*
U.S. EPA Region 5
77 W. Jackson Blvd.
Chicago, IL 60604-3590
(312) 886-2940

State Contact:
Mike Eberle
Ohio EPA
216-963-1126

*Indicates primary contacts

Treatment System Vendor:
Aptus Environmental Services, Inc.
Coffeyville, KS 67337
(Construction Contractor)

Operations & Maintenance:
Omprakash Patel (Site Manager)*
Roy F. Weston, Inc.
Suite 400
3 Hawthorn Parkway
Vernon Hills, IL 60061-1450
(847) 918-4051

MATRIX DESCRIPTION

Matrix Identification

Type of Matrix Processed Through the Treatment System: Groundwater

Contaminant Characterization [1,10]

Primary Contaminant Groups: Volatile Organic Compounds (VOCs)

- Contaminants of concern at the site include TCE, PCE, *trans*-1,2-DCE, and VC. Phthalates also were detected at the site. However, since initial sampling, phthalate compounds have not been detected in groundwater.

- Two separate plumes (depicted in Figures 1 and 2) were identified at the site, one on the Kraus parcel and one on the Henfield parcel. The two plumes are not commingled and are located over 1,000 feet apart. As originally detected, the Henfield plume primarily consisted of halogenated VOCs and the Kraus plume consisted of benzene and xylene.

- The maximum contaminant concentrations detected on the Henfield parcel were TCE (6,100 µg/L), PCE (300 µg/L), *trans*-1,2-DCE (460 µg/L), and VC (14 µg/L). The maximum contaminant concentrations detected on the Kraus parcel were ethylbenzene (19,000 µg/L) and xylenes (43,000 µg/L). Halogenated compounds were not originally detected in the plume located on the Kraus parcel. However, during construction activities, TCE and *trans*-1,2-DCE were discovered in the soils and groundwater on the Kraus parcel, and continue to be the primary contaminants within that plume.

- The initial plume at the Henfield parcel extended 150 to 250 feet downgradient from the site. The areal extent of this plume was estimated during the remedial investigation to be 130,000 square feet. Based on a porosity of 30% and plume thickness of five feet, the volume of contaminated groundwater on the Henfield parcel was estimated for this report at 1.5 million gallons. Plume thickness was estimated based on the saturated thickness of the upper aquifer.

MATRIX DESCRIPTION (CONT.)

Contaminant Characterization (Cont.)

- The plume at the Kraus parcel was initially estimated to be 110,000 square feet in areal extent during the remedial investigation. Based on a porosity of 30% and a plume thickness of five feet, the volume of contaminated groundwater at the Kraus parcel was estimated for this report at 1.2 million gallons.
- Figures 1 and 2 depict total VOC contaminant contours for the Old Mill site (as detected during 1984 sampling events). Note the orientation of the figures for later discussion of groundwater characteristics.

Matrix Characteristics Affecting Treatment Costs or Performance

Hydrogeology: [1, 3, 10]

Two distinct hydrogeologic units have been identified beneath this site. Groundwater moves across the site at a relatively slow rate of 20 feet per year. The first hydrogeologic characterization depicted the site as primarily two interconnected soil groups. However, later findings during characterization efforts in 1985 showed that the site was actually two separate aquifers with an aquitard in between.

Groundwater is found at approximately five feet below ground surface. The majority of the groundwater contamination is found in the upper unit. Groundwater flow is to the west-southwest on the Henfield property and to the north-northwest on the Kraus property. Rock Creek is located approximately 500 feet south of the site. Tables 1 and 2 include technical aquifer information and well data, respectively.

Unit 1	Glacial till	The upper unit is approximately 10 feet thick and consists of silty glacial till. The aquifer is considered poor quality for domestic well supply. This unit is separated from the underlying shale unit by a low conductivity layer of a clayey till that acts as an effective aquitard. The clayey till is approximately five feet thick.
Unit 2	Weathered Shale	This lower unit is approximately 16 feet thick and consists of a weathered shale with evident vertical fractures. The porosity of this unit decreases with depth.

Table 1. Technical Aquifer Information

Unit Name	Thickness (ft)	Conductivity (ft/day)	Average Velocity (ft/day)	Flow Direction
Glacial Till (Henfield)	10	1.25	0.055	West-Southwest
Weathered Shale (Henfield)	16	0.22	NA	West
Glacial Till (Kraus)	10	1.25	0.055	North-Northwest
Weathered Shale (Kraus)	16	0.22	NA	North-Northwest

Source: [10]
NA - not available

MATRIX DESCRIPTION (CONT.)

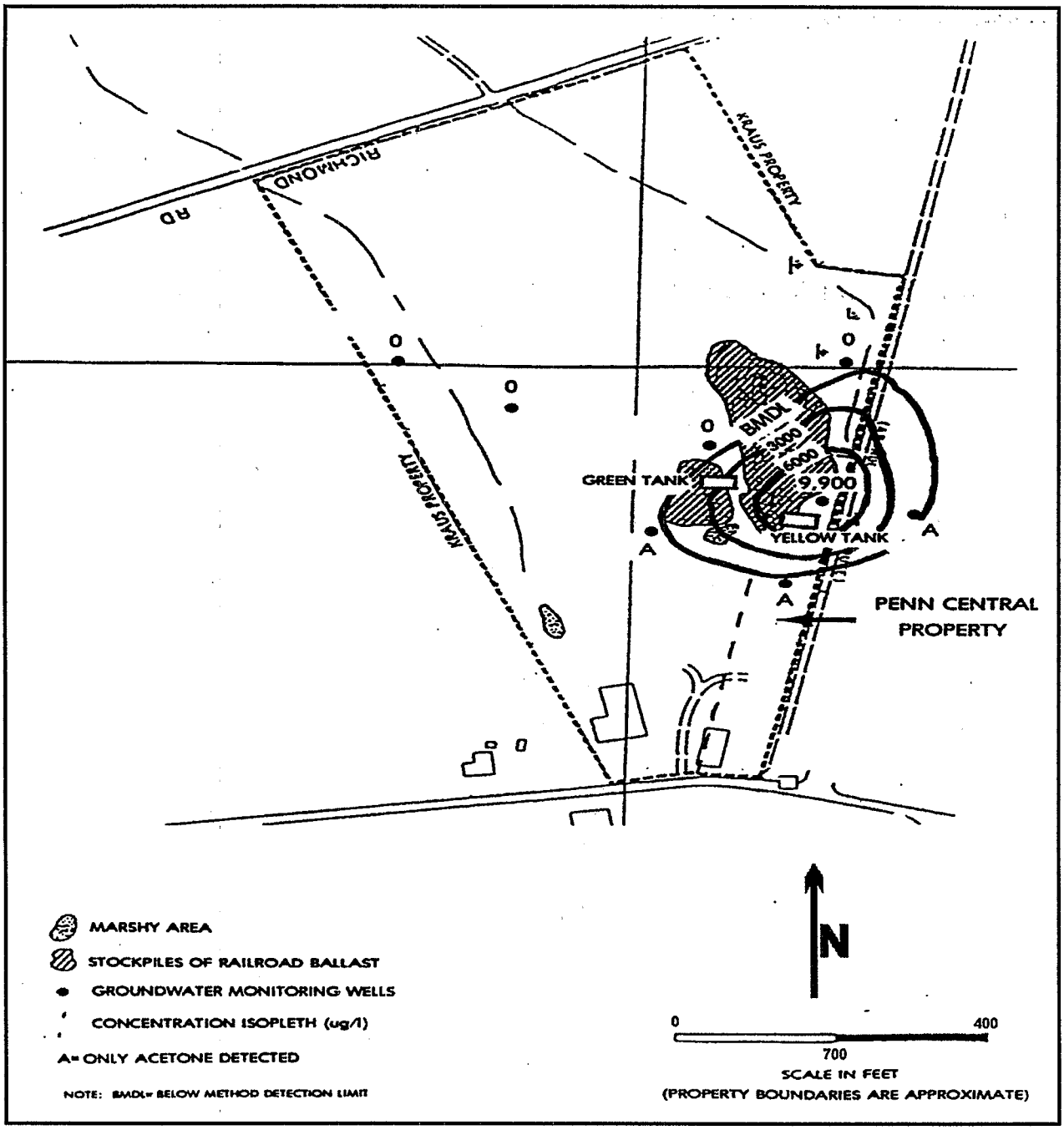

Figure 1. Total VOC Concentration Contour Map of the Kraus Property (1984) [1]

MATRIX DESCRIPTION (CONT.)

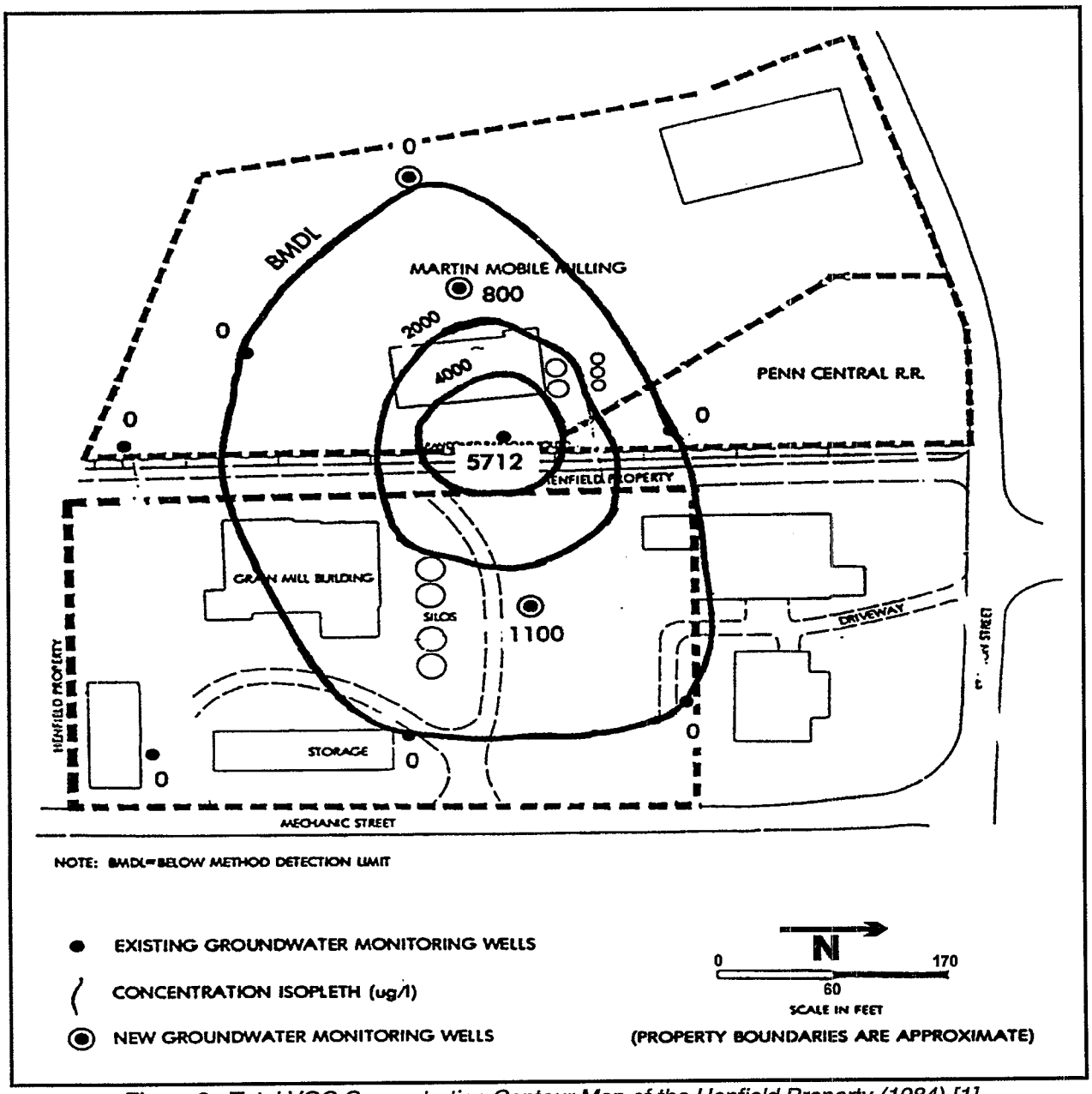

Figure 2. Total VOC Concentration Contour Map of the Henfield Property (1984) [1]

TREATMENT SYSTEM DESCRIPTION

Primary Treatment Technology

Pump and treat (P&T) with air stripping

Supplemental Treatment Technology

Carbon adsorption, particulate filters

System Description and Operation

Table 2. Technical Well Data

Extraction Well Name	Unit Name	Depth (ft)	Design Yield (gpd)
Martin Sump*	Glacial Till	7	1,000
Henfield Sump	Glacial Till	7	1,175
Kraus Sump-1	Glacial Till	7	1,000
Kraus Mod-2	Glacial Till	7	900
Kraus A-Sump	Glacial till	7	140
Henfield Well	Lower Aquifer	25	700
Kraus Well-1	Lower Aquifer	25	215
Kraus Well-2	Lower Aquifer	25	100

*The Martin Sump is located off site adjacent to the Henfield property in the downgradient part of the plume.
Source: [3]

System Description [3]

- The P&T system has been designed to remediate plumes from both parcels. The current extraction system for both plumes consists of three deep recovery wells to extract groundwater from the lower unit (lower aquifer) and five collection trenches to collect groundwater from the upper unit (glacial till). The collection trenches are seven feet deep and total 1,055 feet in linear length. The deep recovery wells are approximately 25 feet deep with a 10-foot screen interval set at the bottom. The extraction system was designed to remove a total of five gpm from the aquifer. The deep recovery wells were placed in the center of the plumes and the collection trenches at the toe of the plumes. Extracted water from both plumes is treated in one treatment plant.

- The part of the extraction system on the Kraus property required several modifications. The original extraction system consisted of two deep extraction wells and one collection trench. During construction, a new area of VOC-contaminated groundwater was discovered. Construction temporarily stopped while a revised design was configured. Once approved by EPA, a second collection trench was constructed approximately 200 feet downgradient of the first. This collection trench is 73 feet long and was placed to capture the newly detected groundwater contaminants.

- In 1993, the plume of TCE and 1,2-DCE on the Kraus property was observed downgradient of the second collection trench. As a result, a third collection trench was constructed on the Kraus property, and placed approximately 250 feet downgradient of the second trench. It is over 360 feet long and is situated to completely intercept the migrating plume. Two new monitoring wells were added to monitor groundwater downgradient of the third collection trench.

- During design of the treatment plant, a recycle line was incorporated to boost process flow from 5 gpm to 35 gpm through the stripping tower. This change allowed for more efficient blower sizing and stripping media selection.

- The initial, on-site treatment system consists of an 18-inch diameter air-stripping tower and two 1,000-pound granular

TREATMENT SYSTEM DESCRIPTION (CONT.)

System Description and Operation (Cont.)

activated carbon adsorption units in series. In March, 1997, the two carbon units were replaced by one 1,000-pound, granular activated carbon unit. Polypropylene saddle-type packing media are used in the stripping tower with a packing height of 14 feet.

- A groundwater monitoring system consisting of 18 wells on the Kraus property (including the two new wells), eight wells on the Henfield property, and eight total piezometers on both properties is used to track contaminant movement and groundwater flow.

- Effluent from the treatment system is discharged to Rock Creek under a NPDES permit. Rock Creek is located 500 feet south of the site.

System Operation [5-9,11]

- Quantity of groundwater pumped from aquifer by year:

	Volume Pumped (gal)	
Year	**Upper Unit**	**Lower Unit**
1990	1,377,424	495,777
1991	1,793,060	404,081
1992	1,186,225	269,540
1993	1,756,546	294,605
1994	1,235,491	327,780
1995	1,019,864	274,777
1996	1,455,491	277,132
1997	1,849,201	407,829

- The extraction network continues to extract groundwater from both the deep and shallow aquifers at a 20:80 ratio. Overall, groundwater extraction rates declined slightly during the first seven years of operation, then increased by 30 percent in the eighth year.

- The treatment train includes carbon filtration to remove any organic compounds, such as phthalates, that may remain in the effluent from the air stripper. The operating history of the treatment plant indicates that very little, if any, material enters the carbon treatment unit. As reported in each Annual Performance Report, the activated carbon may be under-utilized. A new carbon adsorption tank was installed in March 1997, replacing two existing tanks. No other carbon changes have occurred during the life of the system.

- The extraction network on both properties has worked well with no reported clogging problems. Pumps within wet wells associated with the collection trenches have reportedly worked properly.

- From March 1990 to September 1997, the system was 99% operational.

- Air stripper media has not required changing during this period of operation.

- Following the replacement of the old carbon units with a new carbon unit, the groundwater extraction rate increased significantly.

TREATMENT SYSTEM DESCRIPTION (CONT.)

Operating Parameters Affecting Treatment Cost or Performance

The major operating parameter affecting cost or performance for this technology is the extraction rate. Table 3 presents the value measured for this and other performance parameters.

Table 3. Performance Parameters

Parameter	Value	
Extraction Rate	Avg. = 3.1 gpm (2.46 - 4.18)	
Performance Standard (Effluent NPDES Limits)	PCE TCE TCA *trans*-1,2-DCE	4.1 µg/L 1.9 µg/L 3.8 µg/L 1.6 µg/L
Remedial Goals (Aquifer)	PCE TCE 1,2-DCE ethylbenzene	8.2 µg/L 15.0 µg/L 1.9 µg/L 8,000 µg/L
Note: The average system extraction rate was 4,500 gpd based on 13 million gallons of groundwater pumped and a 99% operation rate.		

Source: [3]

Timeline

Table 4 presents a timeline for this application.

Table 4. Timeline

Start Date	End Date	Activity
8/85	---	ROD signed
2/87	---	Changes made to the remedial design
6/87	6/89	Extraction and collection system constructed, and contaminated soils removed
3/89	6/89	Additional collection trench and deep extraction well added to Kraus collection system based on field sampling conditions during soils removal operations
9/89	---	Treatment system operations begun
4/94	7/94	Additional collection trench and monitoring wells added to the Kraus property

TREATMENT SYSTEM PERFORMANCE

Cleanup Goals/Standards

Specific cleanup criteria were established during the design phase by OEPA and EPA personnel. Table 3 includes goals for contaminants of concern. These goals must be met throughout the aquifer as measured in all on-site wells [4].

Additional Information on Goals

The cleanup goals for groundwater remediation at this site were based on achieving a 1×10^{-5} carcinogenic risk level [4].

TREATMENT SYSTEM PERFORMANCE (CONT.)

Treatment Performance Goals [3]

- To contain the contaminant plume and prevent off-site migration of contaminants.
- To reduce effluent contaminant concentrations to meet NPDES permit requirements.

Performance Data Assessment [5-13]

- The 1997 annual sampling data indicate that the P&T system has contained the plume; however, contaminant concentrations in much of the plume remain above established goals. Although additional collection trenches were required at the Kraus property, no contaminants have migrated off site. [9]
- After eight years of operation, levels of TCE and *trans*-1,2-DCE still exceed cleanup goals. Figures 3 and 4 show concentrations of TCE and 1,2-DCE in on-site sampling points on the Henfield Property. Figures 5 and 6 depict TCE and 1,2-DCE concentrations detected on the Kraus property. Concentrations in Figure 6 are an average of two wells in the deep aquifer.
- The 1993 annual performance report indicated that the plume of contaminants in the shallow aquifer had migrated past the second collection trench. As a result, an additional collection trench was added and appears to be providing adequate containment. No contaminants have migrated off site.
- The Henfield plume has been contained with the original collection trench and deep extraction well configuration. No contaminants have migrated downgradient of the Henfield site.
- Two hot spots in the vicinity of the Henfield sump and Kraus modified sump remain problematic at this site. As of March 1997, TCE concentrations in the Kraus modified sump and the Henfield sump were 1,400 µg/L and 1,700 µg/L, respectively.
- The maximum concentrations of contaminants in the groundwater during the July 1997 sampling event were TCE (1,700 µg/L), *trans*-1,2-DCE (730 µg/L), and PCE (93 µg/L).
- Figure 7 presents the removal of total contaminants through the treatment system from 1990 to 1997. The P&T system removed approximately 124 pounds of contaminant mass during this period.
- Due to increased concentrations of TCE and 1,1-DCE in the influent and increased flow through the treatment plant, the VOC mass loading to the treatment plant has increased in 1997.
- Groundwater level contour maps in annual reports indicate the deep extraction wells are creating an inward gradient over the affected areas. The collection trenches are also creating an inward gradient in their vicinity. Groundwater that naturally flows toward the trenches is collected.
- As noted earlier, the second goal of the treatment system is to remove contaminants from extracted groundwater to meet discharge requirements of the NPDES permit. Based on annual performance reports, discharge requirements have been met consistently. Phthalate compounds, which may require carbon treatment, have not been detected in influent or effluent sampling.
- Total contaminant removal rates reported in annual performance reports have fluctuated; however, the trend of the contaminant removal rate has declined exponentially from 0.08 lbs/day in July 1991 to 0.01 lbs/day in September 1996. However, the contaminant removal rate increased to 0.04 lbs/day in 1997.

TREATMENT SYSTEM PERFORMANCE (CONT.)

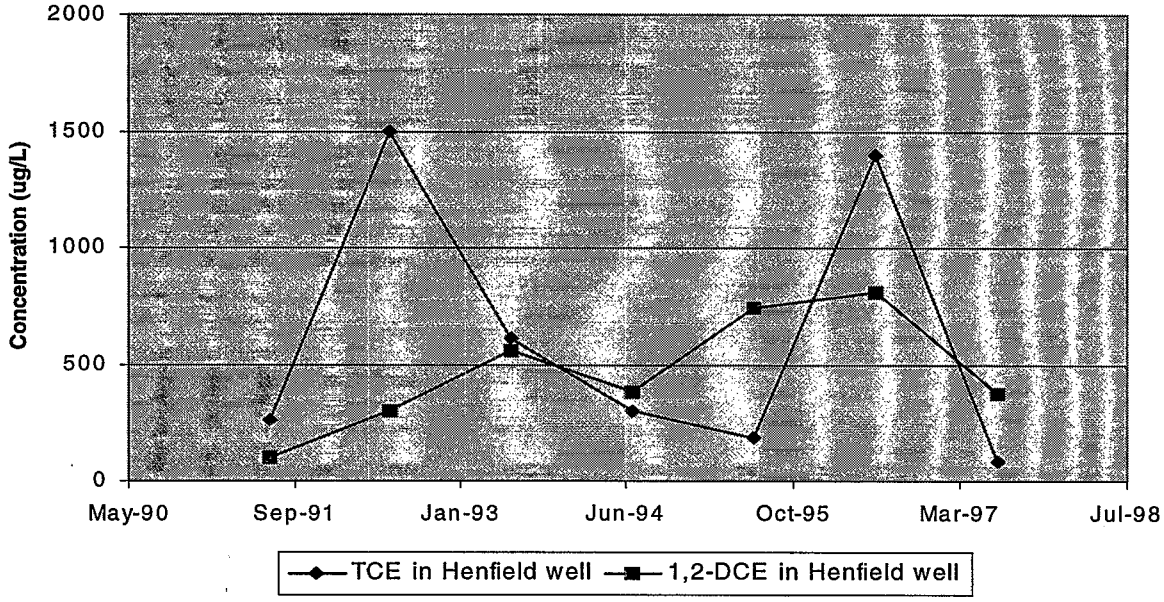

Figure 3. TCE and 1,2-DCE Concentrations on the Henfield Property (Deep Aquifer) (July 1991 - October 1996) [6-9,12]

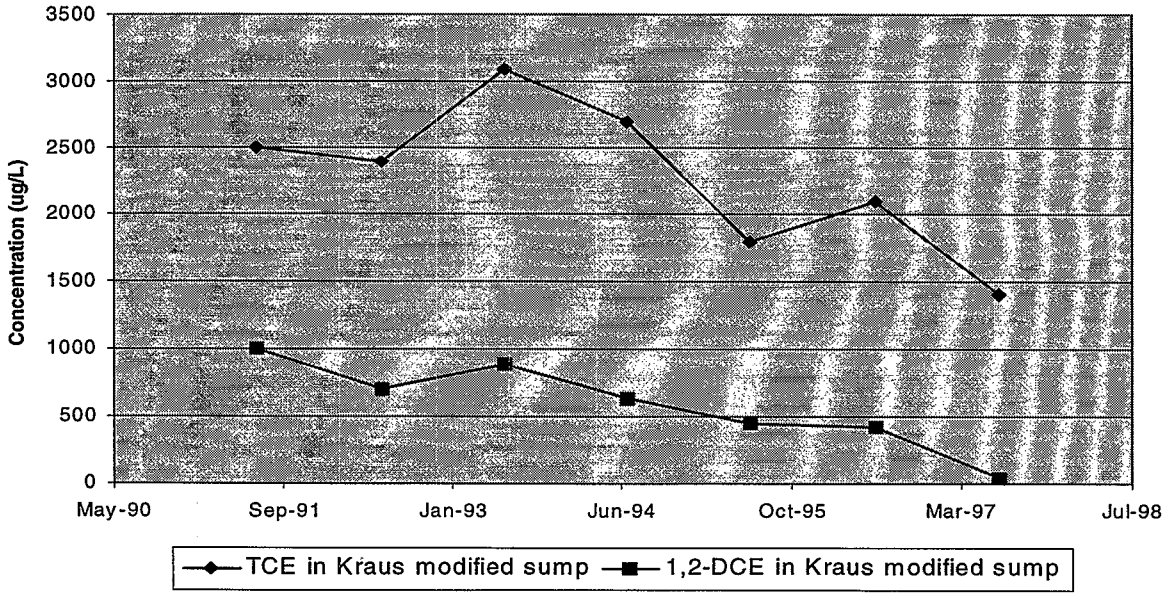

Figure 4. TCE and 1,2-DCE Concentrations on the Kraus Property (Shallow Aquifer) (July 1991 - July 1997) [6-9,12]

TREATMENT SYSTEM PERFORMANCE (CONT.)

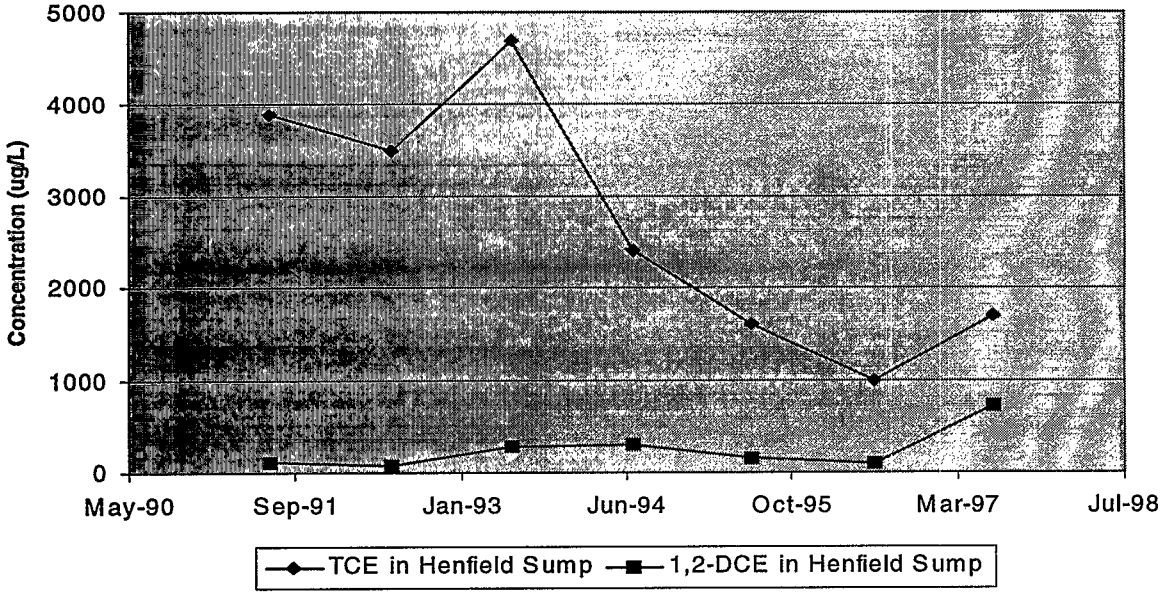

Figure 5. TCE and 1,2-DCE Concentrations on the Henfield Property (Shallow Aquifer) (July 1991 - July 1997) [6-9,12]

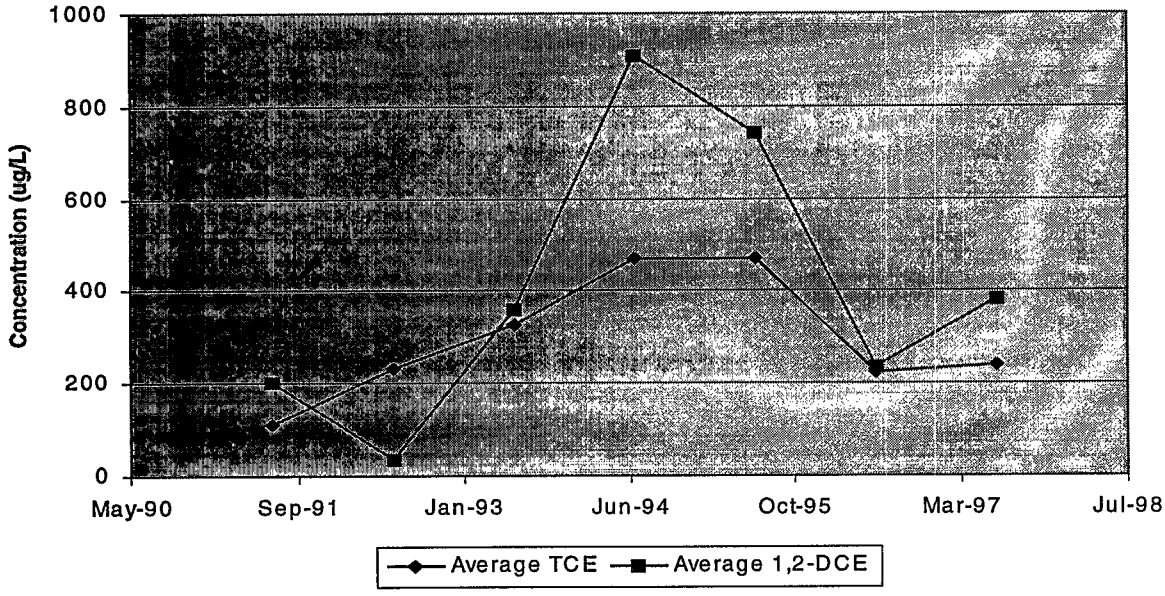

Figure 6. TCE and 1,2-DCE Concentrations on the Kraus Property (Deep Aquifer) (July 1991 - July 1997) [6-9,12]

TREATMENT SYSTEM PERFORMANCE (CONT.)

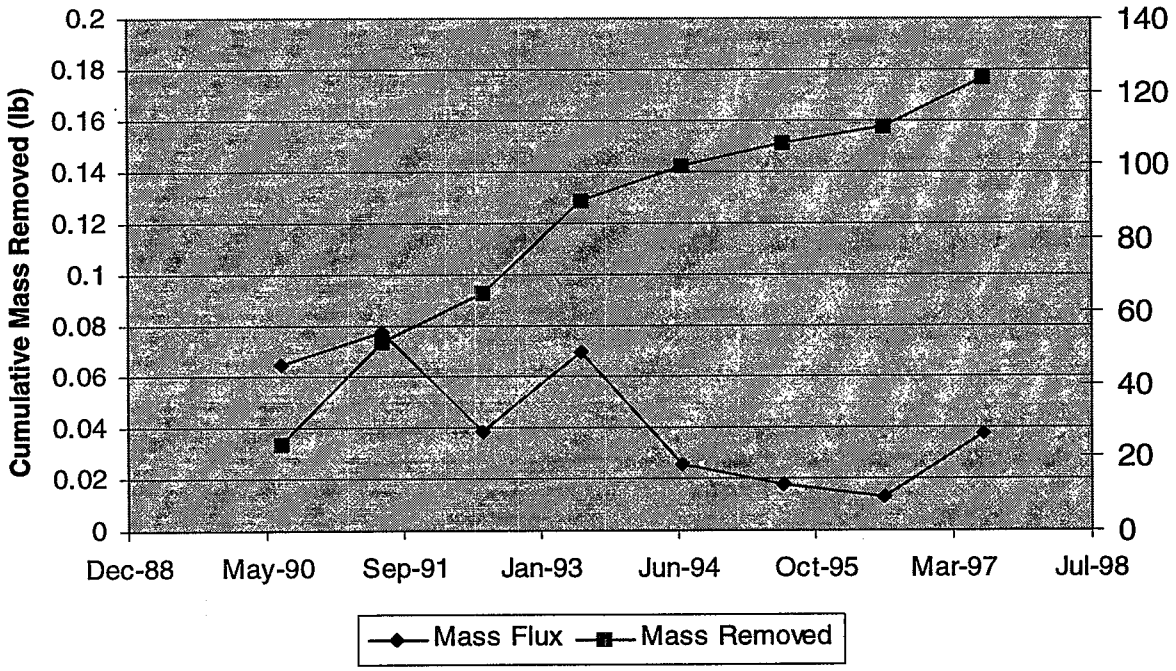

Figure 7. Mass Flux Rate and Cumulative Mass (TCE, 1,2-DCE, and PCE) Removal (1990 - 1997) [6-9,12]

Performance Data Completeness

- Performance data for influent, effluent, and groundwater concentrations are available quarterly from 1990.
- Contaminant mass removal and the volume of groundwater treated annually was provided in annual performance reports.
- Contaminant concentrations detected during annual sampling events were used for analyses performed in this report.

References 6 through 9 and 14 contain annual sampling data.

- When results were reported below detection limits, half of the detection limit was used for evaluation purposes.

Performance Data Quality

The QA/QC program used throughout the remedial action met the EPA and the State of Ohio requirements. All monitoring was performed using EPA-approved methods, and the vendor did not note any exceptions to the QA/QC protocols.

TREATMENT SYSTEM COST

Procurement Process

The U.S. Army Corps of Engineers (USACE) was responsible for oversight during construction activities. Woodward-Clyde was awarded the remedial design contract. The USACE contracted with Aptus Environmental to perform remedial action activities. Roy F. Weston is the operations and maintenance contractor for the treatment facility.

Cost Analysis

All costs for the investigation were borne by the U.S. EPA and OEPA. The U.S. EPA is responsible for O&M costs for the first 10 years, at which point the State of Ohio will assume responsibility.

Capital Costs [2]

Remedial Construction	
Monitoring Wells, Sampling	$138,000
Backfilling and Paving	$474,000
Groundwater Extraction System	$537,200
Groundwater Treatment Facility	$345,100
Additional collection trench, monitoring wells (1994)	$101,700
Total Remedial Construction	**$1,596,000**

Operating Costs [2]

Cumulative Operating Costs (1989-1996)	
Labor	$787,132
Utilities	$93,230
Analytical	$478,308
Maintenance	$22,568
Miscellaneous	$34,215
Report Preparation	$224,547
Total Operating Expenses	**$1,640,000**

Other Costs

Remedial Design	$954,235
Corps Oversight	$49,968

Cost Data Quality

Actual capital and operating cost data were provided by the U.S. EPA Remedial Project Manager (RPM), including a detailed breakdown of the cumulative operating costs included in this report.

OBSERVATIONS AND LESSONS LEARNED

- Collection trenches were added to improve plume containment. This modification resulted in an increase of $286,000 to total capital costs. $184,000 of this increase was included in the original remedial action costs; $102,000 was added in 1994.
- The total cost of treatment using the P&T system was $3,236,000, consisting of $1,596,000 in capital costs and $1,640,000 in cumulative operating costs through 1997. This corresponds to a cost of $26,100 per pound of contaminant removed and $250 per thousand gallons of groundwater treated.
- The actual capital cost for this project was approximately $286,000 more than the original bid cost. An additional $184,000 was required during initial construction activities and $102,000 was added in 1994. This represents a 22% increase in capital costs over the original bid cost.
- The average annual O&M cost, based on the first eight years of operation, was approximately $205,000 per year. This cost includes O&M costs, report preparation costs, analytical costs, and capital expenditure costs [13].
- After eight years of P&T operation and the removal of 124 pounds of contaminants

OBSERVATIONS AND LESSONS LEARNED (CONT.)

from the groundwater, the cleanup goals have not been met.

- In several wells, concentrations of contaminants have increased above initial levels. According to the RPM formerly assigned to the site, the reason for the increase in groundwater concentration is not known at this time; however, it potentially is due to precipitation increase or a subsurface source zone [2].

- According to the RPM, the P&T system at this site does not appear to have the typical effect on groundwater contamination. New contaminants have been identified after the initial investigation and contaminant concentrations have increased at times during operations. The reasons for these events is not known at this time [2].

- A dual-stage carbon adsorption system was built into the treatment system to handle the anticipated levels of semivolatiles in the influent; however, the levels in the influent stream have not been above detection limits since operations began. Consequently, the activated carbon units have not been utilized as intended and may not have been necessary [11].

REFERENCES

1. Remedial Investigation Report for Old Mill, CH2M Hill, 1984.
2. Correspondence with Remedial Project Manager. U.S. EPA Region V, May 7, 1997.
3. Remedial Action Report, U.S. Army Corps of Engineers, 1990.
4. Superfund Record of Decision, U.S. EPA, 1985.
5. Eighth Quarterly Evaluation Report, Roy F. Weston, Inc., 1993.
6. Third Annual Performance Evaluation Report, Roy F. Weston, Inc., 1993.
7. Fourth Annual Performance Evaluation Report, Roy F. Weston, Inc., 1994.
8. Fifth Annual Performance Evaluation Report, Roy F. Weston, Inc., 1995.
9. Sixth Annual Performance Evaluation Report, Roy F. Weston, Inc., 1996.
10. Addendum to the Remedial Investigation Report, CH2M Hill, 1985.
11. Five Year Review, U.S. EPA, 1996.
12. Seventh Annual Performance Evaluation Report, Roy F. Weston, Inc., April 1998
13. Comments on the April 14, 1998 Preliminary Draft Cost and Performance Report, Ron Murawski and Omprakash Patel, May 18, 1998.

Analysis Preparation

This case study was prepared for the U.S. Environmental Protection Agency's Office of Solid Waste and Emergency Response, Technology Innovation Office. Assistance was provided by Eastern Research Group, Inc. and Tetra Tech EM Inc. under EPA Contract No. 68-W4-0004.

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Pump and Treat of Contaminated Groundwater at the SCRDI Dixiana Superfund Site, Cayce, South Carolina

Pump and Treat of Contaminated Groundwater at the SCRDI Dixiana Superfund Site, Cayce, South Carolina

<table>
<tr><td>Site Name:
SCRDI Dixiana Superfund Site</td><td rowspan="2">Contaminants:
Chlorinated solvents
- Maximum concentrations detected during intial investigations were PCE (600 ug/L), TCE (130 ug/L), 1,1,1-TCA (560 ug/L), 1,1-DCE (470 ug/L), and 1,1,1,2-PCA (25 ug/L)</td><td>Period of Operation:
Status: Ongoing
Report covers: 8/92 - 3/97</td></tr>
<tr><td>Location:
Cayce, South Carolina</td><td>Cleanup Type:
Full-scale cleanup (interim results)</td></tr>
<tr><td>Vendor:
EPA Contractor: Ebasco Services, Inc.
PRP Project Coordinator: de maximis, Inc.
PRP contractor: S&ME, Inc.
PRP Operations Contractor: O&M, Inc.</td><td rowspan="2">Technology:
Pump and Treat
- Groundwater is extracted using 15 wells and a 300-ft shallow extraction trench, at an average total pumping rate of 40 gpm
- Extracted groundwater is treated with air stripping and discharged to a POTW</td><td>Cleanup Authority:
CERCLA Remedial
- ROD Date: 9/26/86</td></tr>
<tr><td>State Point of Contact:
Yanqing Mo
South Carolina DHEC
Bureau of Hazardous and Solid Waste
2600 Bull Street
Columbia, SC 29201</td><td>EPA Point of Contact:
Yvonne Jones, RPM
U.S. EPA Region 4
345 Courtland St., N.E.
Atlanta, GA 30365
(404) 562-8793</td></tr>
<tr><td>Waste Source:
Spills from poor waste handling practices, leaking drums</td><td colspan="2" rowspan="2">Type/Quantity of Media Treated
Groundwater
- 20.6 million gallons treated as of March 1997
- Groundwater is found at 14 ft bgs
- Extraction wells are located in 4 aquifers, and all 4 aquifers are contaminated
- Hydraulic conductivity ranges from 5 to 45 ft/day</td></tr>
<tr><td>Purpose/Significance of Application:
Remediation at a site with complex hydrogeology, consisting of eight distinct hydrogeological units.</td></tr>
<tr><td colspan="3">Regulatory Requirements/Cleanup Goals:
- Reduce the concentration of contaminants in the groundwater to primary drinking water standards or maximum contaminant levels (MCLs).
- Cleanup goals were established for 1,1,1-TCA (200 ug/L),TCE (5 ug/L), 1,1,2-TCA (5 ug/L), PCE (5 ug/L), 1,1,2,2-TCA (5 ug/L), 1,1-DCE (7 ug/L), chloroform (100 ug/L), carbon tetrachloride (5 ug/L), benzene (5 ug/L), and dichloromethane (5 ug/L)
- A secondary goal is to hydraulically contain the migration of contaminants in the groundwater.</td></tr>
</table>

Pump and Treat of Contaminated Groundwater at the SCRDI Dixiana Superfund Site, Cayce, South Carolina (continued)

Results:

- Groundwater monitoring results indicate that contaminant concentrations have not been reduced to below cleanup goals. Concentrations in the well with the highest concentration, however, have been reduced by approximately 81% since 1992.
- The plume was not contained from 1992 until November 1995. Hydrodynamic control of the plume has been maintained since November 1995.
- The P&T system has removed approximately 7 pounds of contaminants from the groundwater from 1992 to 1996.

Cost:

- Actual costs during the EPA-lead portion of the P&T system operation were approximately $1,439,700 ($1,189,700 in capital and $250,000 in O&M), which correspond to $464 per 1,000 gallons of groundwater extracted and $200,000 per pound of contaminant removed.
- Costs for the PRP-lead portion of the operation were $294,000 for capital and $180,000 for O&M.

Description:

South Carolina Recycling and Disposal Inc (SCRDI) operated this site as an industrial waste storage facility until 1978. The starting date of operations at this facility is not known. Waste materials stored on site included solvents, phenols, specialty chemicals, hydrogen peroxide, and pyridine. In 1978, SCRDI applied for a waste management permit from the South Carolina Department of Health and Environmental Control (SCDHEC). After a site visit, the permit was denied because of poor waste management practices, such as materials stored in leaking containers, drums stored in exposed conditions, and improper waste handling procedures. In June 1980, SCDHEC implemented a preliminary groundwater study to determine the extent of subsurface contamination. Analytical results from this study indicated that halogenated organic and metal contamination was found on site. The site was placed on the NPL in August 1982 and a ROD was signed in September 1986.

Two distinct remedial systems have operated at this site; one operated from August 1992 to June 1994 (EPA-lead portion), and the other from November 1995 to present (PRP-lead portion). A Supplemental Site Investigation (SSI) was performed in 1994 and a remedial system optimization study was performed in 1995; as a result the system was modified to include 15 extraction wells, a 300 ft shallow collection trench, and a shallow stacked tray air stripper.

The EPA portion of this application was based on RI results which did not accurately characterize the site. Based on these results, wells were screened in two lower groundwater units, but not in an upper, contaminated unit. In addition, during the EPA portion, wells were screened across two units, which allowed contaminants to migrate from one unit to the other, previously uncontaminated unit.

SITE INFORMATION

Identifying Information

SCRDI Dixiana Superfund Site
Cayce, South Carolina

CERCLIS #: SCD980711394

ROD Date: September 26, 1986

Treatment Application

Type of Action: Remedial

Period of operation: 8/92 - Ongoing (Data collected through March 1997)

Quantity of material treated during application: 20.6 million gallons of groundwater through March 1997

Background [7]

Historical Activity that Generated Contamination at the Site: Industrial waste storage

Corresponding SIC Code: NA

Waste Management Practice That Contributed to Contamination: Spills from poor waste handling practices, leaking drums

Location: Cayce, SC

Facility Operations:

- South Carolina Recycling and Disposal, Inc. (SCRDI) operated this site as an industrial waste storage facility until 1978. The starting date of operations at the site is not known. Waste materials stored on site included solvents, phenols, specialty chemicals, hydrogen peroxide, and pyridine.
- In 1978, SCRDI applied for a waste management permit from the South Carolina Department of Health and Environmental Control (SCDHEC). After a site visit, the permit was denied because of poor waste management practices, such as materials stored in leaking containers, drums stored in exposed conditions, and improper waste handling procedures.
- A suit was filed by SCDHEC against SCRDI for its waste management practices. As a result of this suit, SCRDI removed over 70 drums of waste and visibly contaminated soils were removed by SCRDI between September 1978 and June 1980. No other source control actions were performed at the site.
- In June 1980, SCDHEC implemented a preliminary groundwater study to determine the extent of subsurface contamination. Analytical results from this study indicated a potentially serious health concern from halogenated organic and metal contamination found on site. SCDHEC advised owners of affected residential wells to seek alternative water sources, and recommended a more detailed groundwater investigation.
- Groundwater contamination was confirmed during a detailed site investigation completed by SCDHEC in August 1982.
- The site was placed on the National Priorities List (NPL) in September 1983.
- A remedial investigation (RI) was completed in October 1985. The RI provided detailed information about the organic and metal contaminants found on site. The feasibility study (FS) was completed in September 1986.
- A Record of Decision (ROD) was issued in September 1986 for groundwater remediation. An Explanation of Significant Differences (ESD) was issued in 1991. The ESD documents specific modifications to the discharge point and treatment system.
- S&ME Inc., a PRP contractor, conducted an additional hydrogeologic study in 1994. The report, entitled Supplemental Site Investigation (SSI) Report provided new information about the hydrogeology of the site.

SITE INFORMATION (CONT.)

Background (Cont.)

- The remedial action for this site was managed by SCDHEC and EPA through June 1994. Remedial activities ceased in June 1994 because the EPA ARCS contract was canceled. EPA identified and named responsible parties in a Unilateral Administrative Order (UAO) issued in February 1995. As a result, the site changed from a fund-lead to a PRP-lead site. A new PRP contractor was hired and remedial activities resumed in November 1995.

Regulatory Context:

- On September 26, 1986, a ROD was signed for groundwater remediation at this site.
- Site activities are conducted under provisions of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980, as amended by the Superfund Amendments and Reauthorization Act (SARA) of 1986, §121, and the National Contingency Plan (NCP), 40 CFR 300.

Remedy Selection: Extraction and treatment of groundwater via air stripping was selected as the remedy for this site.

Site Logistics/Contacts

Site Lead: EPA-lead from August 1992 through June 1994; PRP-lead from November 1995 to present

Oversight: EPA

Remedial Project Manager:
Yvonne Jones*
U.S. EPA Region IV
345 Courtland Street, N.E.
Atlanta, Georgia 30365
404-562-8793

*Indicates primary contact

State Contact:
Yanqing Mo
South Carolina Department of Health and Environmental Control
Bureau of Hazardous and Solid Waste
2600 Bull Street
Columbia, S.C. 29201

Treatment System Vendor:
Ebasco Services, Inc. (EPA Contractor)
Waste Abatement Technology (WATEC)
de maximis, Inc. (PRP project coordinator)
S&ME, Inc. (PRP contractor)
O&M, Inc. (PRP operations contractor)

MATRIX DESCRIPTION

Matrix Identification

Type of Matrix Processed Through the Treatment System: Groundwater

Contaminant Characterization [4, 10]

Primary Contaminant Groups: Halogenated volatile organic compounds (VOC) and metals

- The primary contaminants of concern are perchloroethylene (PCE), trichloroethylene (TCE), 1,1-dichloroethylene (1,1-DCE), 1,1,1-trichloroethane (1,1,1-TCA) and 1,1,1,2-perchloroethane (1,1,1,2-PCA).
- The maximum concentrations detected during initial investigations were PCE (600 µg/L), TCE (130 µg/L), 1,1,1-TCA (560

MATRIX DESCRIPTION (CONT.)

Contaminant Characterization (Cont.)

µg/L), 1,1-DCE (470 µg/L), and 1,1,1,2-PCA (25 µg/L).

- According to the RI report, the areal extent of the plume in 1982 was 80,000 square feet and it extended to a depth of 40 feet. The volume of the plume detected at the site was initially estimated to be 4.8 million gallons. A 1994 groundwater study found the plume to be 204,000 square feet in areal and approximately 12.2 million gallons. According to the study report, the plume increased in size partly because the plume was not contained during the first two years of operation. The increase in size also is attributed to a more accurate estimate of the plume location, since the 1994 estimate reflects a better understanding of the site hydrogeology [10].
- Figure 1 illustrates contaminant distribution detected during the 1994 site investigation.
- In 1982, contaminants were suspected to be located primarily within Units C and D beneath the site. Subsequent groundwater evaluations performed in 1994 revealed multiple sand zones (see Hydrogeology), all contaminated.

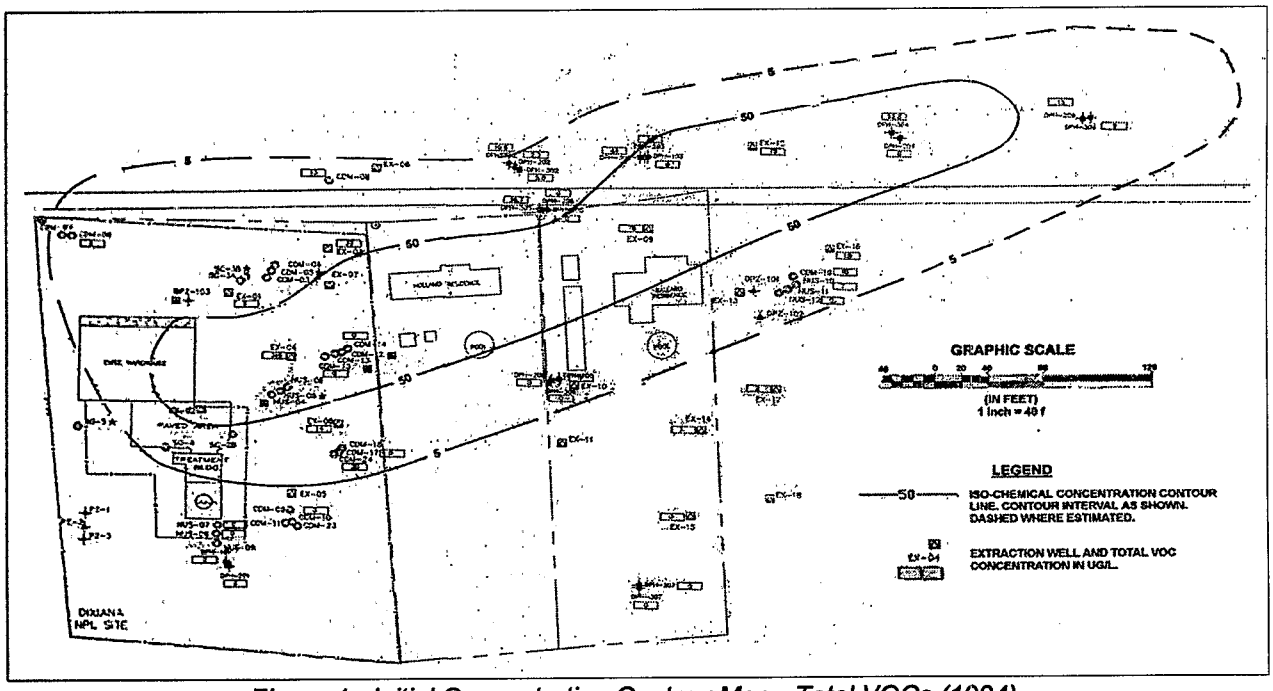

Figure 1. Initial Concentration Contour Map - Total VOCs (1994)

MATRIX DESCRIPTION (CONT.)

Matrix Characteristics Affecting Treatment Costs or Performance

Hydrogeology [4,10]:

Eight distinct soil layers have been identified within the upper 100 feet of soils beneath the SCRDI Dixiana site. These units are labeled A through H. Five water-bearing units (A,C,D,F, and H) have been identified; Units B, E, and G are semiconfining layers. The water table begins approximately 14 feet below ground surface. Groundwater flows in an easterly direction in the upper unconfined aquifer (Unit A). Groundwater flows in a southeasterly direction in Units C, D, F, and H.

The original site characterization data collected in 1984 and 1985 identified Unit C as the uppermost water-bearing region. Units C and D are hydraulically connected and were suspected of containing the majority of the groundwater contamination. In the 1994 investigation, Unit A was identified as the uppermost aquifer and samples revealed that most groundwater contaminants were present in this unit. The original remedial design was based on the early site characterization data. As a result, no extraction wells were placed in Unit A. Because the thickness of Unit D was overestimated in many areas in the early study, many of the extraction wells placed in Unit D were actually screened across both Units D and F. The wells with screened intervals across both units presented a pathway for contaminants to migrate from Unit D into Unit F, which was previously uncontaminated.

Unit A Undifferentiated sands, silts, clays
Unit B Kaolinitic clays
Unit C Undifferentiated sands, silts, clays
Unit D Sands, silty sands
Unit E Kaolinitic clays
Unit F Sands, clayey sands, discontinuous clay layers
Unit G Kaolinitic clays
Unit H Sands, silty sands, clayey sands

Tables 1 and 2 include technical aquifer information and extraction well data, respectively. The extraction wells are discussed in the following section.

Table 1. Technical Aquifer Information

Unit Name	Thickness (ft)	Conductivity (ft/day)	Average Velocity (ft/day)	Flow Direction
A	10-15	10	0.6	East
C	7-10	10	0.8	Southeast
D	7-9	10	0.8	Southeast
F	10-15	45	NC	Southeast
H	50-70	5	NC	NC

NC - Not Characterized
Source: [10]

TREATMENT SYSTEM DESCRIPTION

Primary Treatment Technology

Pump and treat with air stripping

Supplemental Treatment Technology

Pyrolox metal media filtration

System Description and Operation [6, 11, 12]

Table 2. Technical Well Data

Well Name	Unit Name	Depth (ft)	Design Yield (gal/min)
7 Extraction Wells	C/D	18-35	3-10
1 Extraction Well	C	13-26	3-10
7 Extraction Wells	D	24-35	3-10
Recovery Trench	A	10-12	NA

Note: Table represents current conditions. Average system rate for Phases I and II was 4 gpm. Average system rate since November 1995 has been 40 gpm. NA = Not Available

Source: [11]

System Description:

- Two distinct remedial systems have operated at this site; one operated from August 1992 to June 1994, and the second from November 1995 to present. A supplemental site investigation (SSI) was performed in 1994, and a remedial system optimization study was performed in 1995. As a result, the remedial system operated by PRPs (November 1995 to present) was modified from the EPA system (August 1992 to June 1994) to optimize performance.

- From August 1992 to June 1994, 20 extraction wells were pumped to remove groundwater from Units C and D and Unit F (through the hydraulic connection with Unit D). Eight of the extraction wells were located in areas of higher contaminant concentrations; the remaining wells were located on the periphery of the plume.

- The treatment system that operated from August 1992 until June 1994 consisted of an 18,000-gallon equalization tank, a pyrolox metal media filter unit, and a packed-column air stripper.

- Under the PRP-lead, the pump and treat (P&T) system was modified to consist of 15 extraction wells (five taken off line), a 300-foot shallow collection trench, and a shallow stacked tray air stripper. The revised extraction system was designed to collect groundwater from contaminated Units A,C, and D. Total extraction rate for this system has averaged 40 gpm.

- The pre-1995 treatment system was replaced in October 1995; the modified system became operational in November 1995. The equalization tank is no longer used in the modified system.

- Effluent from both systems has been discharged to the City of Cayce municipal treatment plant under a wastewater discharge permit.

System Operation:

- Quantity of groundwater pumped from the aquifer in gallons:

Year	Volume Pumped (gallons)	Unit Name
1992-1994	3.1 million	C,D,F
1995-1997	17.5 million	A,C,D

TREATMENT SYSTEM DESCRIPTION (CONT.)

System Description and Operation (Cont.)

- From August 1992 to June 1994, the site was operational approximately 80% of the time. Downtime was due to power failures from lightning strikes and scaling within process piping.

- From November 1995 through March 1997, the remedial system has been operational nearly 98% of the time. The modified system was designed to operate continuously without full-time staff on site. A remote sensing and control system was installed, which allows personnel to check and modify system operations from off-site locations.

- The EPA groundwater remediation program (1992-1994) was designed to be performed in two phases lasting 270 days (Phase I) and 321 days (Phase II), respectively. During Phase I, eight on-site wells within the more contaminated part of the plume were to be pumped at 1.5 gpm each, and 12 off-site wells were to be pumped at 0.17 gpm each. During Phase II, after on-site groundwater was remediated, the on-site wells would not be pumped, and the off-site wells would be pumped at either 0.5 or 0.9 gpm each.

- Based on a site modeling evaluation completed with Phase I data, the pumping rates for Phase II were revised. On-site wells would continue to be pumped at 1.5 gpm and eight off-site wells would be shut off. The remaining four off-site wells would continue pumping at 0.17 gpm each.

- The modified extraction well system designed by the PRPs consists of 15 extraction wells including eight existing wells, four replacement wells, and three new wells.

- The four wells that were replaced were hydraulically connecting Units D and F. The old wells were properly closed and replaced with new wells at the same location, but screened in Units C and D only.

- Three new well locations were picked to optimize hydraulic containment and mass recovery. The locations were chosen based on information from the 1994 SSI.

- Six of the 15 extraction wells are located in the central part of the plume. These wells are pumped at approximately 4 to 6 gpm. The remaining wells are pumped at 1 to 2 gpm.

- A shallow recovery system (SRS) was also installed to collect groundwater from Unit A. This system has reportedly contributed approximately 6 gpm. The SRS consists of 300 feet of trenches that intercept the shallow groundwater plume to a depth of 12 feet.

- The new extraction system was designed to optimize recovery from Units C and D, while eliminating the cross-contamination of Unit F. The extraction rate has been increased by a factor of 10, and the groundwater plume is being contained.

- A shallow stacked tray air stripper was chosen to replace the tall packed column air stripper because the newer models of stacked tray air strippers are more economical to operate and maintain [12].

- The QuickFlow™ Analytical Ground-Water Flow Model developed by Geraghty & Miller was used during optimization of the modified extraction well systems [12].

- From 1992 to 1994, air stripping media was changed on one occasion when it became clogged and ineffective.

- Since 1995, no air stripping media has been utilized in the on-site treatment system; therefore, downtime from changeouts has not occurred.

TREATMENT SYSTEM DESCRIPTION (CONT.)

Operating Parameters Affecting Cost or Performance

The major operating parameter affecting cost or performance for this technology is the extraction rate. Table 3 presents the value measured for this and other performance parameters.

Table 3: Performance Parameters

Parameter	Value	
Extraction Rate	4 gpm (92-94); 40 gpm (95-97)	
Maximum Daily Flow	86,000 gallons	
Performance Standard (Effluent)	Temp.	140 °F
	pH	6-9 units
	Dichloromethane	1.58 mg/L
	Carbon tetrachloride	5.07 mg/L
	1,1-Dichloroethane	29.13 mg/L
	1,1,1-TCA	2.60 mg/L
	TCE	6.48 mg/L
	PCE	1.21 mg/L
	Chloroform	1.78 mg/L
	1,1,2-TCA	13.54 mg/L
	1,1,2,2-TCA	3.46 mg/L
	1,1-DCE	1.67 mg/L
Remedial Goals (aquifer)	1,1,1-TCA	200 µg/L
	TCE	5 µg/L
	1,1,2-TCA	5 µg/L
	PCE	5 µg/L
	1,1,2,2-TCA	5 µg/L
	1,1-DCE	7 µg/L
	Chloroform	100 µg/L
	Carbon tetrachloride	5 µg/L
	Benzene	5 µg/L
	Dichloromethane	5 µg/L

Source: [5, 6, 7, 12]

Timeline

Table 4 presents a timeline for this remedial project.

Table 4: Project Timeline

Start Date	End Date	Activity
9/86	---	Record of Decision signed
---	9/88	Remedial design completed
10/90	7/91	P&T system constructed
7/91	---	ESD issued
	6/92	Sewer line completed to City of Cayce POTW
8/92	7/93	Phase I performed
7/93	6/94	Phase II performed
6/94	---	Remedial activities stopped; EPA and PRPs enter into negotiations; UAO issued, changing site to PRP-lead
10/94	---	Supplemental Site Investigation performed
6/95	10/95	P&T system modified by PRPs
11/95	ongoing	Modified P&T system restarted

Source: [6, 8, 10]

TREATMENT SYSTEM PERFORMANCE

Cleanup Goals/Standards [5, 6, 7, 12]

- The goal of this remedy is to reduce the concentration of contaminants in the groundwater to primary drinking water standards or maximum contaminant levels (MCL). These standards are applied throughout the aquifer as measured in all wells installed on and off site. Table 3 contains specific clean-up criteria.

Additional Information on Goals

- A secondary goal of this remedy is to hydraulically control the migration of contaminants in the groundwater to eliminate further spreading of contaminants downgradient of the site.

Treatment Performance Goals [5, 6, 7, 12]

- The treatment system must reduce contaminant levels in the treated water to meet discharge requirements imposed by the local POTW. These requirements are stipulated in the discharge permit with the City of Cayce POTW and are also included in Table 3.

Performance Data Assessment [7, 8, 9, 10]

For this report, total contaminants includes PCE, 1,1-DCE, and 1,1,1-TCA.

- From 1992 to 1997, groundwater monitoring results indicate that contaminant concentrations have not been reduced to below cleanup goals. To illustrate how total contaminant concentrations have changed from 1992 to 1997, Figure 2 presents data from wells NUS-04 and CDM-13 in the central part of the plume. Well NUS-04 and CDM-13 are the only wells that were sampled consistently from 1992 to 1997. Total contaminant concentrations in well NUS-04 have been reduced by approximately 81% since 1992.

- From 1992 until November 1995, the plume was not contained, as was determined during a SSI performed in October 1994. Sampling revealed that groundwater contaminants in Units C and D had migrated more than 300 feet downgradient of the most downgradient extraction well. The total plume size at that time was estimated to be 204,000 square feet. The initial plume size was estimated to be 80,000 square feet. According to the SSI, the increase was attributed to both the loss of plume containment and increased accuracy in the estimate of the plume size.

- Water level data collected in quarterly reports indicate that hydrodynamic control of the plume has been maintained since November 1995. Only one off-site well, DMW 202, shows contaminant concentrations above detection limits.

- A total of 20.6 million gallons of groundwater was treated from 1992 to 1997. Taking into account the hours of system operation, the calculated daily average treatment rate was 4 gpm during EPA-lead operation and 40 gpm during PRP-lead operation. The remedial system was shut down from June 1994 through November 1995.

- As shown in Figure 3, the P&T system has removed approximately seven pounds of contaminant mass from 1992 to 1996. Figures 4, 5, and 6 show PCE, TCE, and 1,1-DCE concentrations, respectively, for NUS-04 and CDM-13.

- PCE concentrations in Figure 4 begin at 2,500 µg/L and 1,100 µg/L for wells NUS-04 and CDM-13, respectively. PCE concentrations in NUS-04 decline to 500 µg/L, but spike above 3,000 µg/L on two occasions. PCE concentrations in CDM-13 decline to 64 µg/L, but then rebound to 500 in the December 1993 sampling.

TREATMENT SYSTEM PERFORMANCE (CONT.)

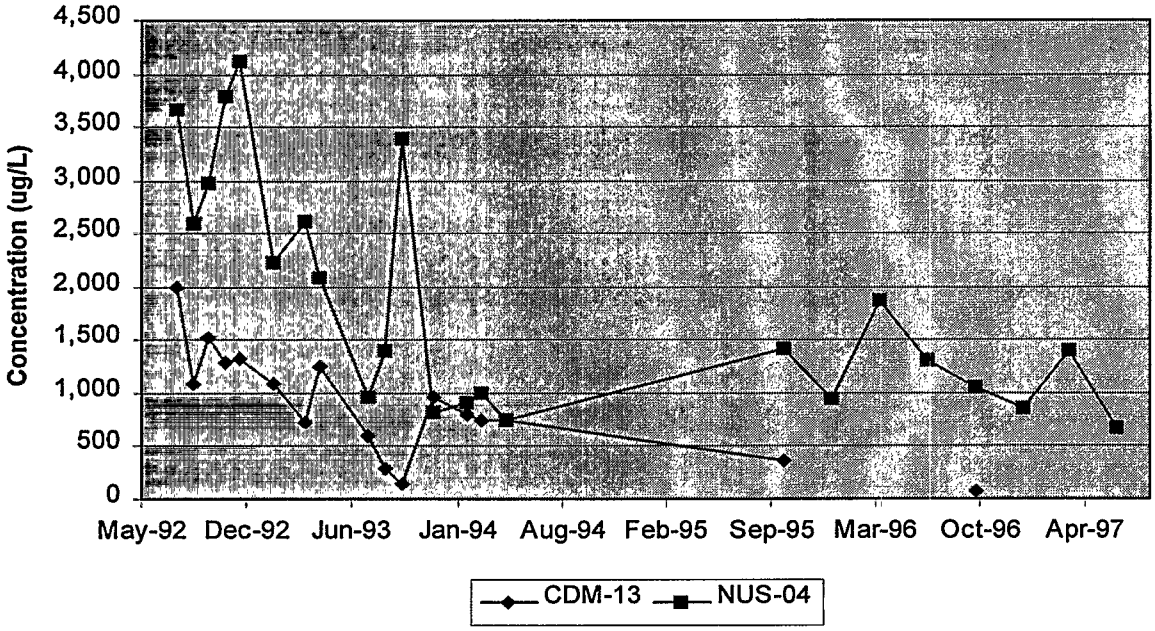

Figure 2. Total Contaminant Concentrations in Groundwater (August 1992 - July 1997) [2,7,8,12]

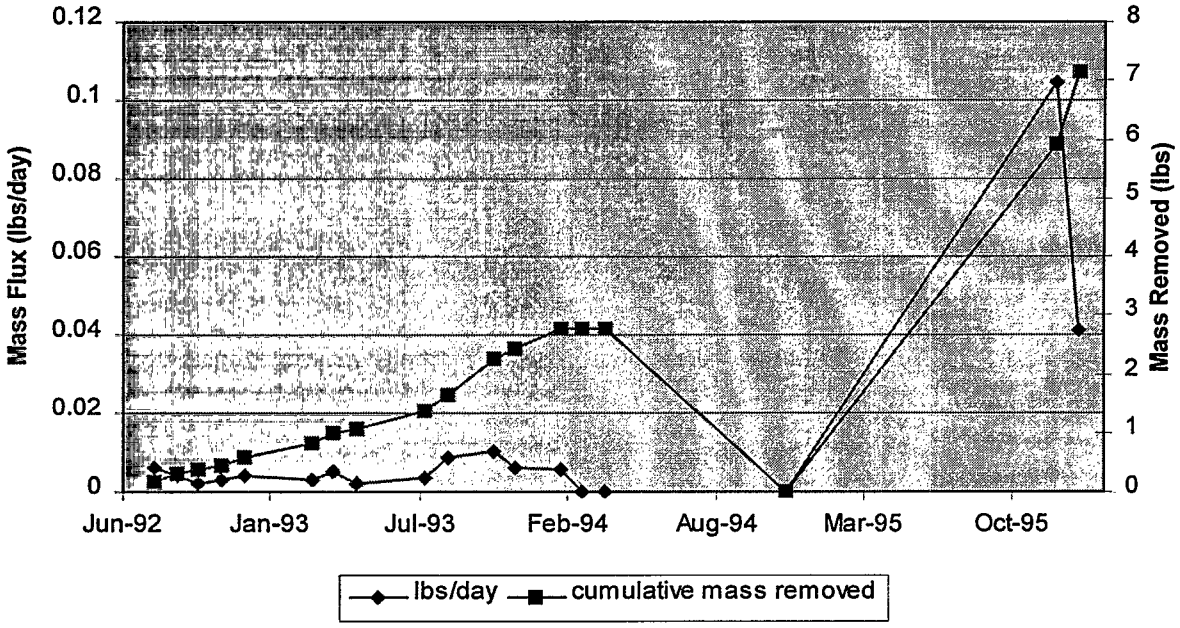

Figure 3. Total Contaminant Mass Flux and Cumulative Mass Removal (August 1992 - January 1996) [2,7,8]

TREATMENT SYSTEM PERFORMANCE (CONT.)

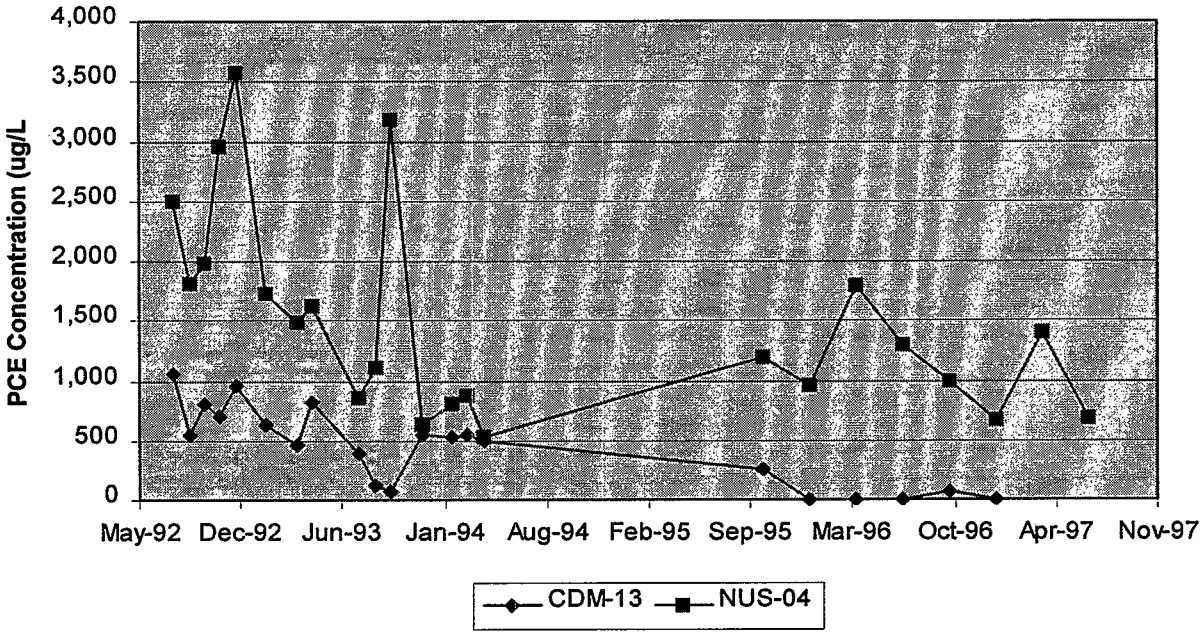

Figure 4. PCE Concentrations (1992 - 1997) [2,7,8,12]

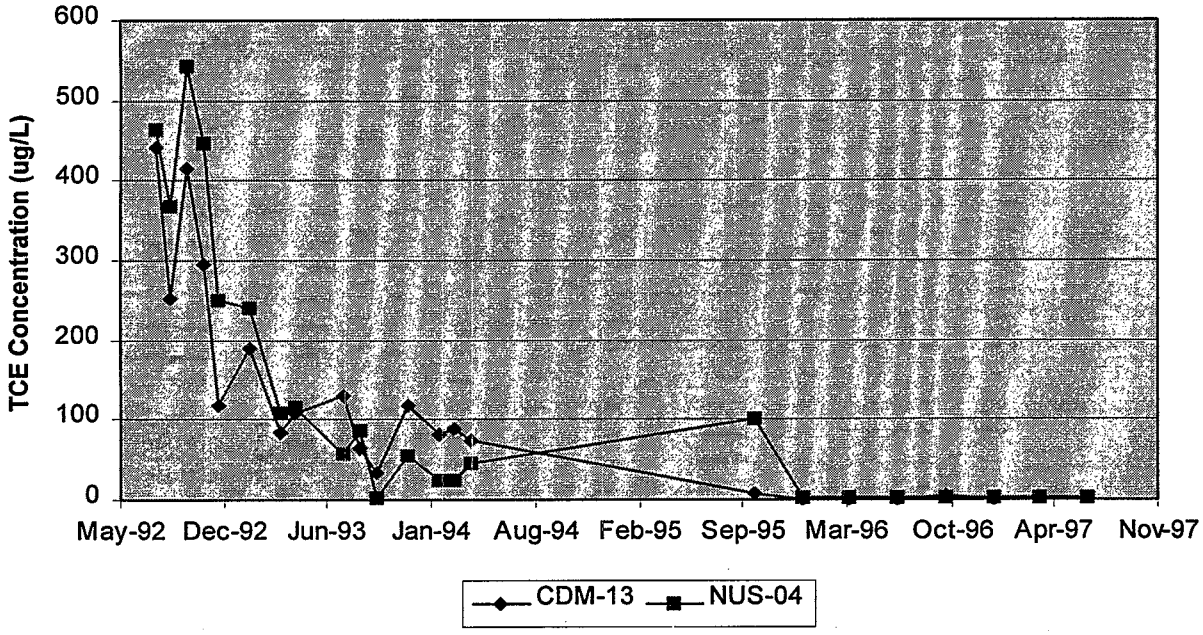

Figure 5. TCE Concentrations (1992 - 1997) [2,7,8,12]

TREATMENT SYSTEM PERFORMANCE (CONT.)

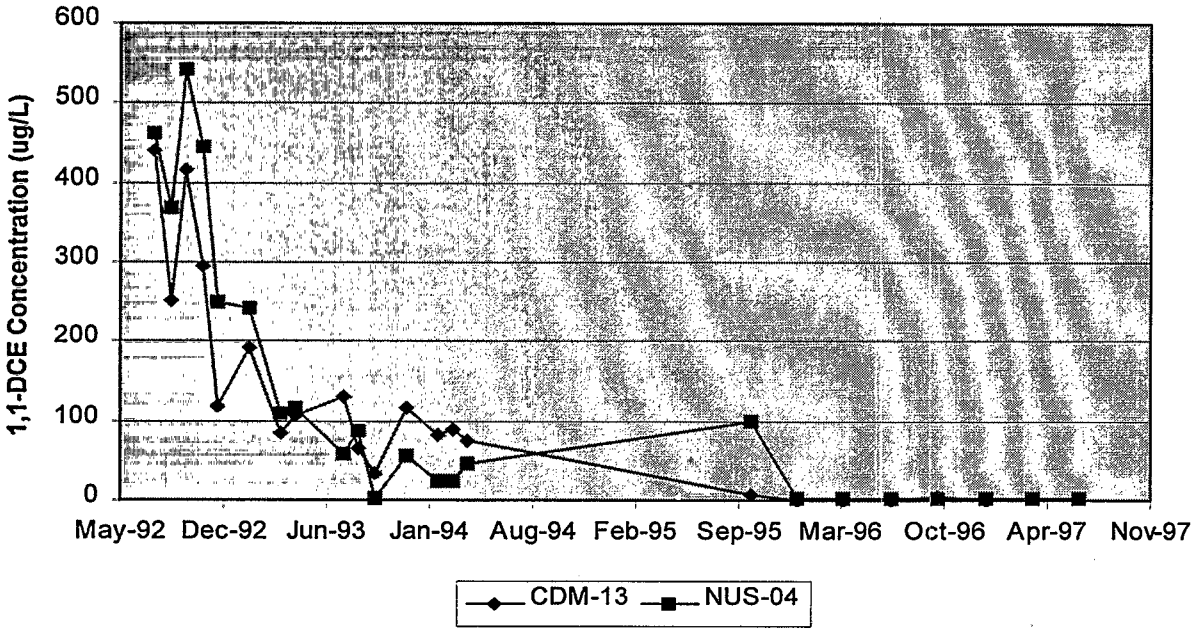

Figure 6. 1,1-DCE Concentrations (1992 - 1997) [2,7,8,12]

Performance Data Assessment (Cont.)

- In Figure 5, TCE concentrations in wells NUS-04 and CDM-13 follow similar patterns, beginning near 450 µg/L and declining to approximately 75 µg/L. In October 1996, TCE concentrations were 2 and 6 µg/L, respectively.

- As shown in Figure 6, 1,1-DCE concentrations in NUS-04 and CDM-13 begin at 675 µg/L and 425 µg/L, respectively. Concentrations in NUS-04 are reduced to 30 µg/L and in CDM-13 to 74 µg/L before the system is shut down. In October 1995, concentrations in NUS-04 increased to 150 µg/L, but declined below detection limits by July 1997.

- During Phase I and II operations, all effluent limitations were met with one exception. PCE and 1,1,1-TCA were detected at 5.9 and 7.7 µg/L, respectively, in effluent samples collected during December 1992. The treatment system was shut down and the air stripper packing was replaced after it was determined that the original material had become clogged and ineffective. The system was restarted and all effluent limitations were met during the remainder of Phases I and II.

- Review of the treatment system influent and effluent data from November 1995 through March 1997 indicate that the treatment system is compliant with SCDHEC air discharge requirements and wastewater discharge permit for the City of Cayce POTW.

TREATMENT SYSTEM PERFORMANCE (CONT.)

Performance Data Completeness

- During Phases I and II, monitoring wells were sampled monthly according to the Performance Standards Verification Monitoring (PSVM) plan. During PRP management, a set of seven sampling points were monitored quarterly. Two of the seven wells were the same during both PRP and EPA operation periods.
- Influent and effluent samples are collected on a monthly basis. Data are reported to the City of Cayce to comply with the wastewater discharge permit. Data from 1992 to 1994, December 1995, and January 1996 were available for mass removal calculations in this report.
- Contaminant mass removal was determined from system influent measurements, along with treatment data from 1992 through January 1996. The PRPs have not collected influent data; therefore, mass removal can be calculated only through January 1996.
- Sample collection procedures are documented in the PSVM plan.

Performance Data Quality

The QA/QC program used throughout the remedial action met the EPA and the State of South Carolina requirements. All monitoring was performed using EPA-approved methods, and the vendor did not note any exceptions to the QA/QC protocols.

TREATMENT SYSTEM COST

Procurement Process

Until the 1995 UAO, the U.S. EPA was the lead agency for this site and SCDHEC was the support agency. Ebasco was the EPA ARCS contractor responsible for remedial action activities until 1994. Currently, the site is a PRP-lead site with Solutia, Lucent Technologies, and Therm-O-Disc named as primary responsible parties. de maximis, Inc. is currently the primary contractor for the PRP group.

Cost Analysis

All costs for investigation, design, construction and operation of the treatment system at this site were borne by the PRPs.

TREATMENT SYSTEM COST (CONT.)

Capital Costs for EPA-Lead Operation [5]

Remedial Construction	
Mobilization and Preparatory Work	$103,000
Groundwater Extraction Wells	$267,000
Groundwater Treatment System Installation	$474,000
Facilities Construction	$214,000
Analytical	$7,100
Mobilization/Demobilization of Lab Services	$3,800
Demobilization	$120,800
Total Remedial Construction	**$1,189,700**

Costs for PRP-Lead Operation

Upgrade from Stripping Tower, New Extraction Wells, and Collection Trench	$294,000
PRP O&M Costs (total through March 1997)*	$180,000

Operating Costs for EPA-Lead Operation [5]

Significant Operations	$35,000
Influent/Effluent Analysis	$70,000
Periodic Maintenance	$125,000
POTW	$20,000
Total Annual Operating Expense	**$250,000**

Other Costs for EPA-Lead Operation [5]

Project Planning	$334,668
Intermediate Design	$58,600
Final Design	$88,013
Closeout	$4,978
Technical Assistance	$27,823
Corps Oversight	$17,080
Total Design	$531,161
EPA Oversight	$9,627
State Oversight	$123,377

*Estimated O&M cost for PRP activities is less than $100,000/year.

Cost Data Quality

Actual cost data are available from the EPA Region IV Remedial Project Manager (RPM).

OBSERVATIONS AND LESSONS LEARNED

- Actual costs incurred during the EPA-lead operation of the P&T system were approximately $1,439,700 ($1,189,700 in capital costs and $250,000 in operating and maintenance costs), which corresponds to $200,000 per pound of contaminants removed and $464 per 1,000 gallons of groundwater. Mass removed and the volume of groundwater treated under PRP management were not included in unit calculations.
- After 35 months of operation, the contaminant concentrations in the well with the highest concentrations (NUS-04), have been reduced by 81%. However, containment concentrations remain above the cleanup goals.
- The treatment system has met the SCDHEC air discharge requirements and, with one exception in December 1992, has operated in compliance with effluent limitations. The exceedance was attributed to air stripper packing becoming clogged; after the packing was replaced, there were no additional exceedances.
- According to the RPM, the pumping schedule set for this site during the original EPA design anticipated total site restoration within less than two years [5].
- As a result of the initial RI, which did not accurately characterize the site, initial extraction wells were screened across Units D and F, which allowed contaminants from the upper contaminated Unit (D) to flow into the lower, previously uncontaminated Unit (F). These wells were subsequently closed to eliminate the source of contaminants for the lower zone. New

TREATMENT SYSTEM COST (CONT.)

wells were completed with screened intervals entirely within Units C and D [10].

- In the 1994 supplemental site investigation, the upper sandy Unit A, was determined to be the most highly contaminated unit beneath this site. Initial characterization data failed to identify this, and initial design parameters did not include groundwater recovery from this unit. Until November 1995, the contaminant plume in this unit migrated off site unimpeded. The modified extraction system was designed to prevent further migration of the plume in this unit as well as all groundwater contamination [10].
- When the ARCS contract that Ebasco operated under was terminated, no groundwater was extracted from June 1994 until November 1995. The stop in operations led to plume loss during this period [5].
- In 1994 and 1995, after a supplemental site investigation was completed by the PRPs, the extraction well configuration was redesigned and a collection trench was added to the recovery system. This effort was required to contain the groundwater plume that was escaping the groundwater recovery system up until that time.
- The air stripping tower was leased to EPA by Ebasco for use at this site. When Ebasco was replaced by the PRP contractor, de maximis, a new stacked tray air stripper was purchased. The cost of upgrading to the stacked tray air stripper, as well as reconfiguring the extraction wells and adding the collection trench, was approximately $294,000.

REFERENCES

1. Ebasco Environmental. Operational Status Report for March 1994.
2. Ebasco Environmental. Phase II Operations Evaluation, May 1994.
3. Ebasco Environmental. Phase I Operations Evaluation, July 1993.
4. NUS. Remedial Investigation Report for SCRDI Dixiana, 1986.
5. Correspondence with Remedial Project Manager. U.S. Environmental Protection Agency/Region 4, January 16, 1998.
6. U.S. Environmental Protection Agency. Remedial Action Report for the SCRDI Dixiana Site, December 1993.
7. Superfund Record of Decision: SCRDI Dixiana, 1986.
8. Site Monitoring Report, August 1 through October 31, 1996. O&M, Inc., November 1996.
9. O&M, Inc. Site Monitoring Report, November 1 through March 31, 1997, April 1997.
10. S&ME, Inc. Supplemental Site Investigation Report, November 1994.
11. U.S. Environmental Protection Agency. Five Year Report for the SCRDI Dixiana Superfund Site, September 1995.
12. Comments on draft Cost and Performance Report, May 1998. U.S. EPA Region 4 and de maximis, Inc., May 31, 1998.

Analysis Preparation

This case study was prepared for the U.S. Environmental Protection Agency's Office of Solid Waste and Emergency Response, Technology Innovation Office. Assistance was provided by Eastern Research Group, Inc. and Tetra Tech EM Inc. under EPA Contract No. 68-W4-0004.

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Groundwater Containment at Site OT-16B, Shaw AFB, South Carolina

Groundwater Containment at Site OT-16B, Shaw AFB, South Carolina

Site Name: Site OT-16B, Shaw AFB	**Contaminants:** Organic Compounds - Chlorinated Solvents: - Trichloroethene (TCE) - Tetrachloroethene (PCE) - one plume contains PCE and TCE; one plume contains TCE only	**Period of Operation:** 2/95 - 12/96
Location: South Carolina		**Cleanup Type:** Full-scale cleanup
Vendor: IT Corporation	**Technology:** Hydrualic containment through active pumping. One recovery well.	**Cleanup Authority:** Installation Restoration Program
Additional Contacts: U.S. Air Force Air Combat Command		**Regulatory Point of Contact:** Information not provided
Waste Source: Fuel Spill	**Type/Quantity of Media Treated:** Groundwater and free product - A total of 40.5 gallons of PCE and TCE were removed during this interim action.	
Purpose/Significance of Application: Groundwater containment of chlorinated solvents using active pumping.		

Regulatory Requirements/Cleanup Goals:
The operational objective of the interim action was to achieve hydraulic containment of the plume and to operate as efficiently as possible over a relatively long period of time.

Results:
- Data on whether plume containment was achieved was not available. Therefore, the report presents results in terms of the efficiency of the contaminant that has been removed by the system through August 1997.
- A total of 40.5 gallons of TCE and PCE (14.2 gallons TCE and 26.3 gallons PCE) were removed during the interim action. Monthly removal rates ranged from 0.16 gallons to 4.85 gallons of contaminant.

Cost:
The capital cost for the interim groundwater containment system was $1,960,000. The total cumulative O&M costs from February 1995 through August 1997 were about $50,000. Monthly O&M costs ranged up to $10,436. The average O&M cost per gallon of contaminant removed was $1,512.

Groundwater Containment at Site OT-16B, Shaw AFB, South Carolina (continued)

Description:
Site OT-16B , located at the Shaw AFB in South Carolina, is part of Operable Unit 2 at the site. The groundwater at Site OT-16B is contaminated with volatile organic compounds (VOCs) and two contaminant plumes were identified in the Upper Black Creek Aquifer at the site. One plume contained TCE and PCE ; the other contained TCE only. As part of an interim action at the site, a system was installed to provide hydraulic containment of these contaminant plumes through active pumping. The interim action system consisted of one recovery well which was operated from February 1995 through December 1996.

Data on whether the plumes had been contained was not available. Therefore, the performance data presented in the report focuses on the efficiency of contaminant removal by the system. Performance and cost data were provided from system startup in February 1995 through August 1997. During this time, a total of 40.5 gallons of TCE and PCE were removed from the groundwater, with monthly removal rates ranging from 0.16 gallons to 4.85 gallons. The total O&M costs through August 1997 was about $50,000. The average O&M cost per unit of contaminant removed was $1,512.

Groundwater Containment at Site OT-16B, Shaw AFB

Site Background

This section focuses on the interim action groundwater containment system located at OT-16B, Shaw AFB. Site OT-16B is part of OU2 at Shaw AFB. A site map for OT-16B with TCE groundwater contamination is included as Figure 32.

Contaminants in Groundwater

- The principal groundwater contaminants in the Upper Black Creek Aquifer at the site are trichloroethene (TCE), and tetrachloroethene (PCE).
- The Black Creek Aquifer contains two plumes: one plume contains PCE and TCE, the other plume contains only TCE.

Lithology

- The Upper Black Creek Aquifer, at Site OT-16B, consists of clays, silts, silty sand, and clayey sand.

Groundwater Containment System Details

- Hydraulic containment through active pumping.
- The interim action system consisted of one recovery well (2BEX-01).
- Following operation of this interim action system, a full-scale remedial action began in January 1998 with the installation and operation of three extraction wells located within and at the edge of the groundwater plume.

Operation Period

- The interim action groundwater system was started in February 1995 and was operated through December 1996.

Total Capital Costs

- The estimated capital costs for the interim action groundwater system was $1,960,000.

Total O&M Costs

- Total cumulative costs from February 1995 through August 1996 were $36,000.

Cost and Performance of Groundwater Containment at Site OT-16B

Groundwater Containment of Dissolved Contaminants Operational Objectives

Groundwater containment systems are most often used to protect downgradient areas threatened by a containment plume. The objective of groundwater containment for dissolved phase contaminants is to operate efficiently over a relatively long period of time. The emphasis of dissolved phase groundwater containment is whether containment was cost effectively achieved, not mass removal.

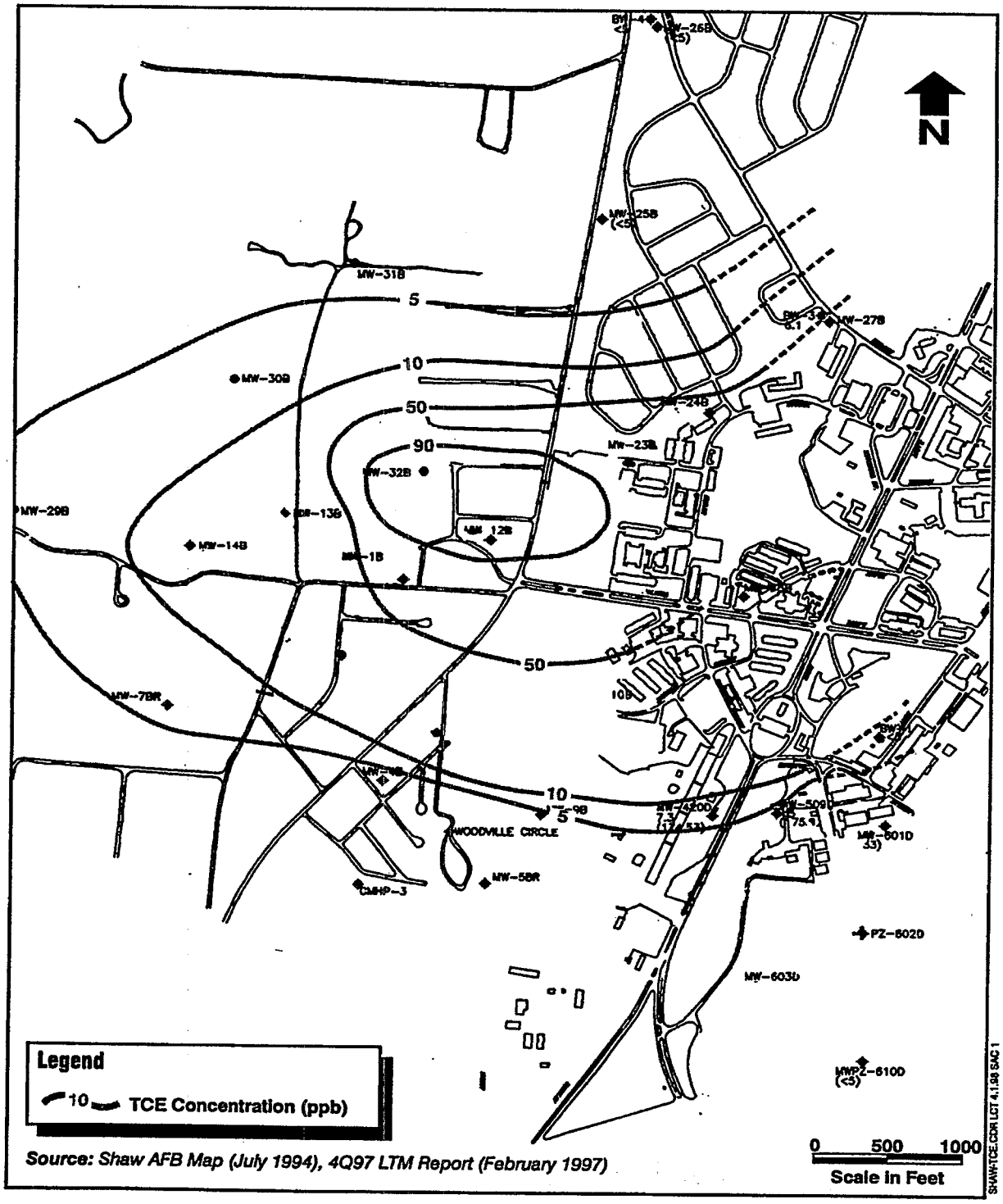
Data on whether groundwater containment is being achieved at each site is not available. Therefore, this report will only present the efficiency of contaminant removal for groundwater containment sites. However, each dissolved phase site should be evaluated to determine if the plume is cost effectively being contained.

Cost for Operation

Figure 33 illustrates curves of the O&M costs for the interim action groundwater containment system at Site OT-16B. The monthly O&M costs range from $0 to $10,437. Total O&M costs after 2.5 years of operation were $51,000.

Contaminant Removal

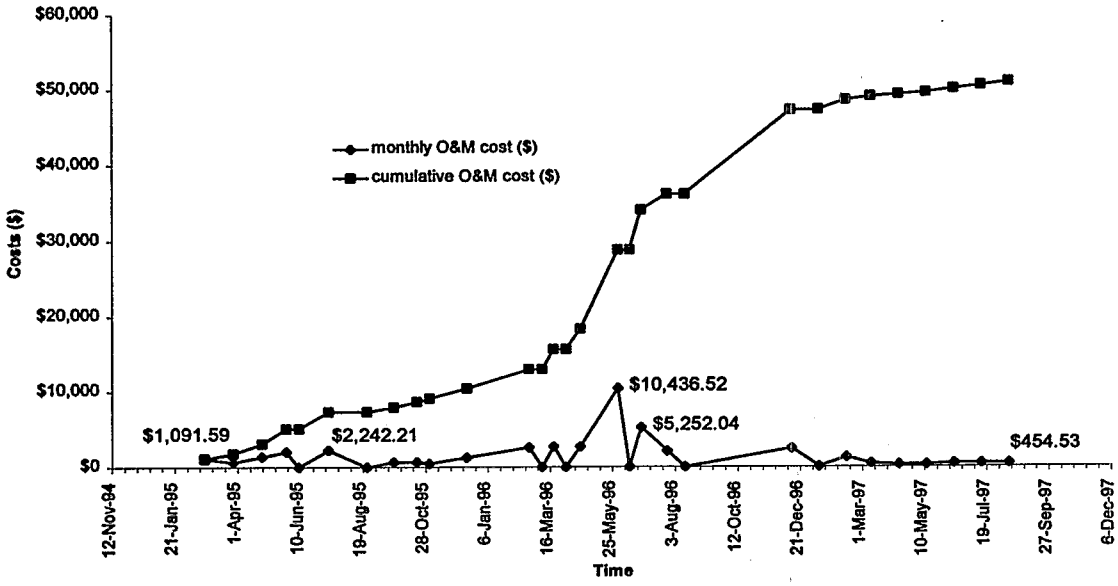
Figure 34 illustrates the removal rates of dissolved PCE and TCE at the interim action groundwater containment system at



Source: Shaw AFB Map (July 1994), 4Q97 LTM Report (February 1997)

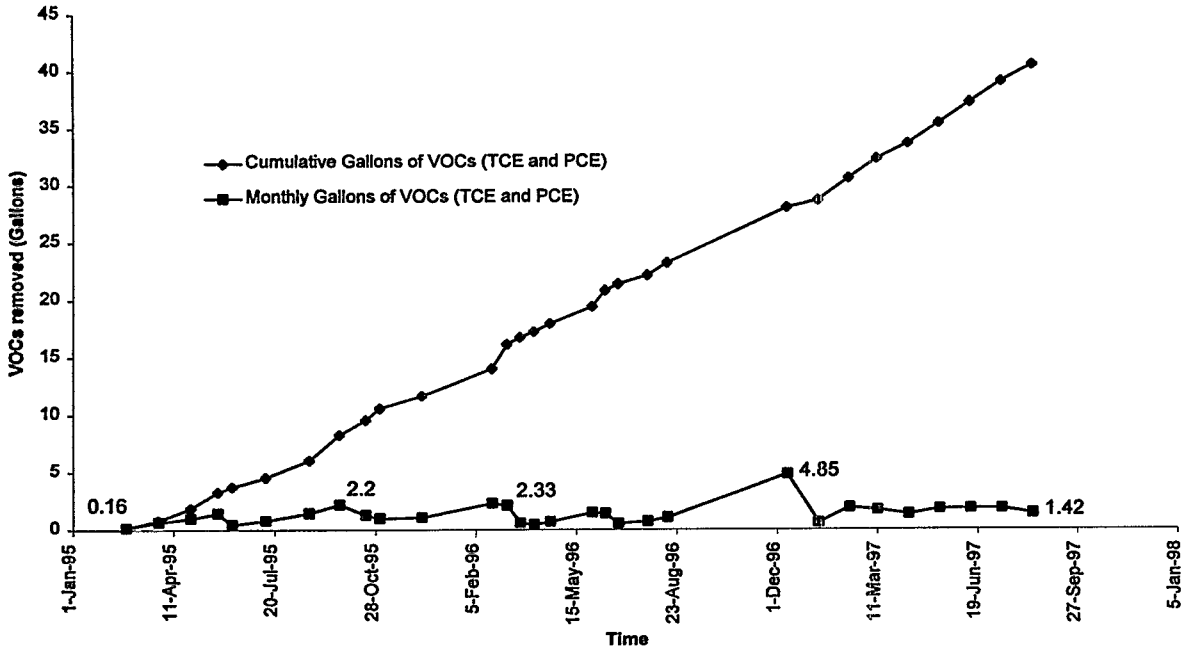
Figure 32. TCE Isoconcentrations in the Black Creek Aquifer at OU2, Site OT-16B, Shaw AFB

Figure 33
Monthly and Cumulative O&M Costs vs. Time
Dissolved TCE and PCE
Site OT-16B, Shaw AFB



Rawot16b.xls; O&M costs new

Figure 34
Monthly & Cumulative VOC Removal vs. Time
Dissolved TCE and PCE
Site OT-16B, Shaw AFB



Rawot16b.xls; Vol. vs. time

Site OT-16B. Monthly removal rates of dissolved PCE and TCE product ranged from 0.16 to 4.85 gallons. Total contaminant removal after 2.5 years of operation was 40.5 gallons of PCE and TCE. In August 1997, the curve representing the cumulative removal rate had not yet begun to flatten, indicating that the removal rate was still adequate for this system's performance and it was meeting its operational objectives. This system was expanded to a full-scale system in January 1998.

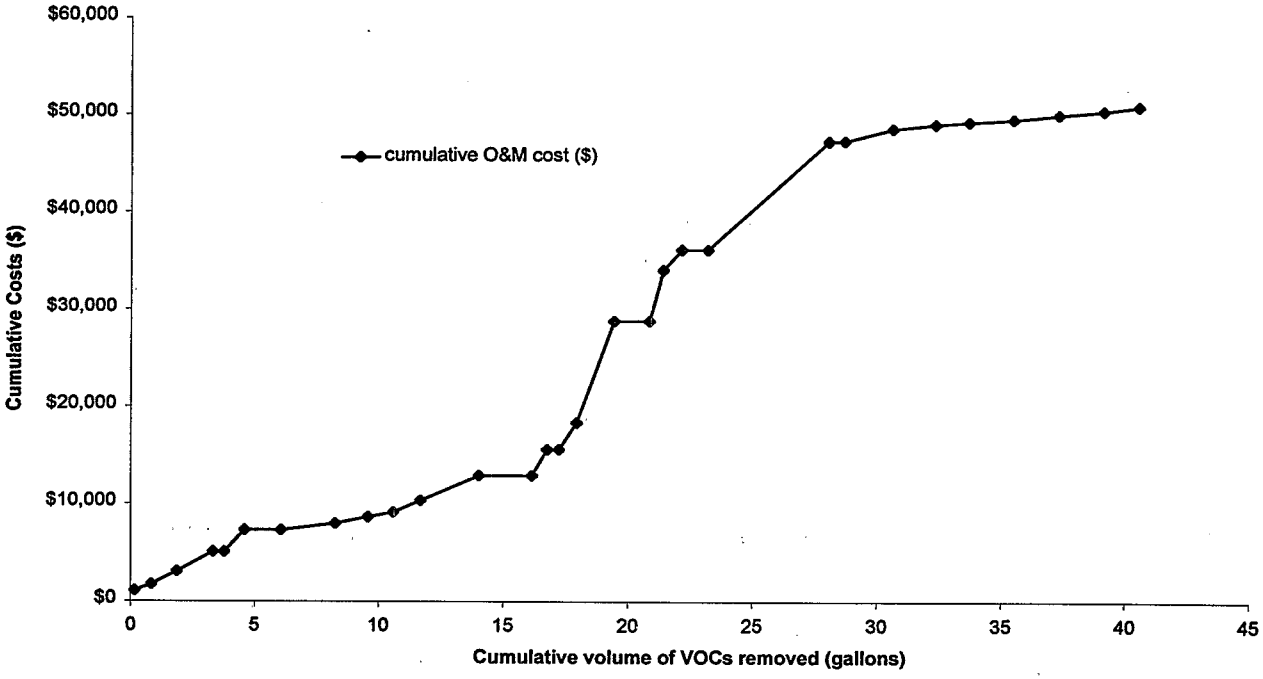
Correlation of Costs and Contaminant Removal

Figures 35 and 36 illustrate the relationship between the O&M costs and the removal rates for the interim action groundwater containment system at Site OT-16B.

Figure 35 illustrates the cumulative O&M cost relative to the cumulative contaminant removal. As of August 1997, the curve had not steepened. In August 1997, this groundwater containment system was operating efficiently for this system's performance and was meeting its operational objectives.

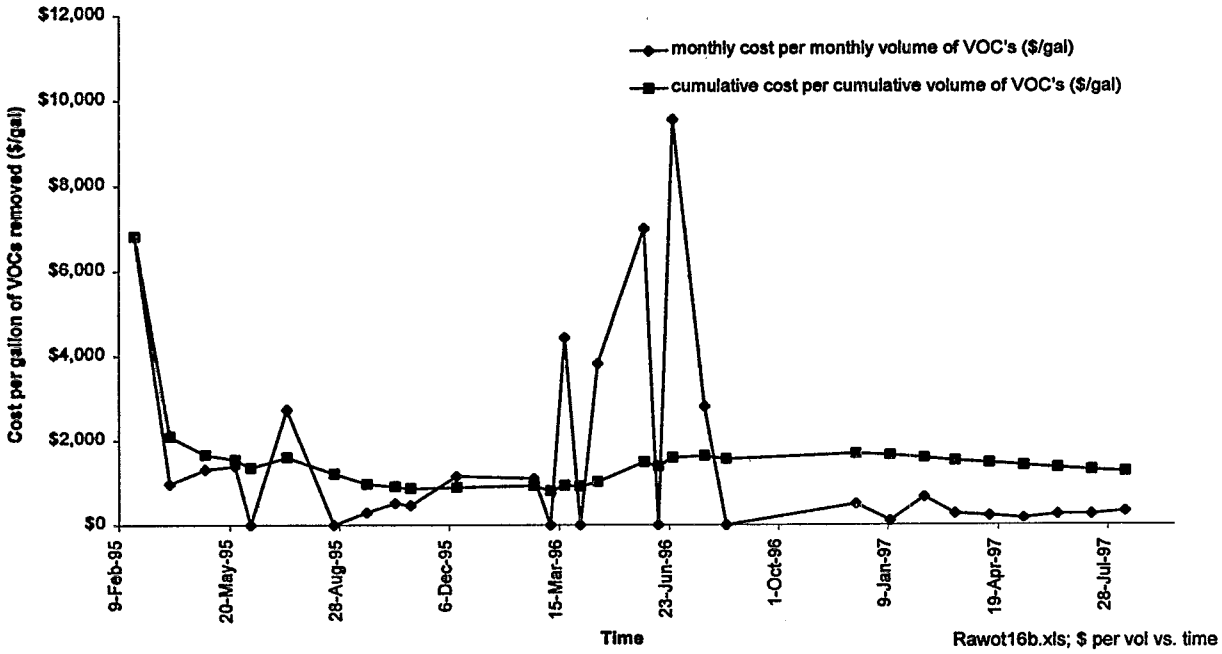
Figure 36 illustrates curves of the monthly and cumulative cost per unit of contaminant removal relative to the operation time of the technology. The monthly curve illustrates the cost per gallon of dissolved TCE and PCE removal in each month. The cumulative curve illustrates that the average cost per unit of contaminant removal was $1,512/gallon of TCE and PCE after 2.5 years of operation time.

Figure 35
Cumulative O&M Costs vs. Cumulative VOCs Removed
Dissolved TCE and PCE
Site OT-16B, Shaw AFB



Rawot16b.xls; $ per vol

Figure 36
Monthly & Cumulative Cost per gallon of VOCs Removed vs. Time
Dissolved TCE and PCE
Site OT-16B, Shaw AFB



APPENDIX A

Detailed Cost and Performance Data Table

Dissolved Phase VOC Recovery Pumping
Site OT-16B
Shaw Air Force Base

Date of Contaminant Removal	Cumulative mass of TCE removed (kg)	Cumulative mass of TCE removed (lb)	Cumulative mass of PCE removed (kg)	Cumulative mass of PCE removed (lb)	Cumulative mass of VOCs (TCE and PCE) (kg)	Cumulative mass of VOCs (TCE and PCE) (lbs)	Cumulative Gallons of TCE	Cumulative Gallons of PCE	Cumulative Gallons of VOCs (TCE and PCE)	Monthly Gallons of VOCs (TCE and PCE)	monthly O&M cost ($)	cumulative O&M cost ($)	monthly cost per monthly volume of VOC's ($/gal)	cumulative cost per cumulative volume of VOC's ($/gal)	cumulative cost per total cumulative mass ($/kg)	cumulative cost per total cumulative mass ($/lb)
23-Feb-95	0.25	0.551155	0.48	1.0582176	0.73	1.6093726	0.1	0.06	0.16	0.16	1,091.59	1,091.59	6,822.44	6,822.44	1,495.33	678.27053
27-Mar-95	1.17	2.5794054	1.6	3.527392	2.77	6.1067974	0.45	0.38	0.83	0.67	647.45	1,739.04	966.34	2,095.23	627.81	284.7712
28-Apr-95	2.39	5.2690418	3.46	7.6279852	5.85	12.897027	0.92	0.94	1.86	1.03	1,346.82	3,085.86	1,307.59	1,659.06	527.50	239.2691
25-May-95	3.47	7.6500314	5	11.0231	8.47	18.6731314	1.34	1.97	3.31	1.45	2,013.44	5,099.30	1,388.58	1,540.57	602.04	273.08221
8-Jun-95	4.17	9.1932654	6.18	13.624552	10.35	22.817817	1.61	2.16	3.77	0.46	0.00	5,099.30	0.00	1,352.60	492.69	223.47887
11-Jul-95	5.01	11.045146	7.56	16.666927	12.57	27.7120734	1.93	2.66	4.59	0.82	2,242.21	7,341.51	2,734.40	1,599.46	584.05	264.92099
23-Aug-95	7.28	16.049634	11.57	25.507453	18.85	41.557087	2.81	3.25	6.06	1.47	0.00	7,341.51	0.00	1,211.47	389.47	176.66084
22-Sep-95	8.52	18.783362	13.57	29.916693	22.09	48.7000558	3.28	4.98	8.26	2.2	653.01	7,994.52	296.82	967.86	361.91	164.15833
18-Oct-95	9.68	21.340722	15.45	34.061379	25.13	55.4021006	3.73	5.84	9.57	1.31	669.94	8,664.46	511.40	905.38	344.79	156.39227
1-Nov-95	10.26	22.619401	16.37	36.089629	26.63	58.7090306	3.95	6.64	10.59	1.02	473.22	9,137.68	463.94	862.86	343.13	155.64352
13-Dec-95	12.03	26.521579	19.11	42.130288	31.14	68.6518668	4.64	7.04	11.68	1.09	1,258.16	10,395.84	1,154.28	890.05	333.84	151.42837
21-Feb-96	15.01	33.091346	23.53	51.874709	38.54	84.9660548	5.79	8.22	14.01	2.33	2,563.59	12,959.43	1,100.25	925.01	336.26	152.52479
7-Mar-96	15.65	34.502303	24.49	53.991144	40.14	88.4934468	6.03	10.11	16.14	2.13	0.00	12,959.43	0.00	802.94	322.86	146.44508
20-Mar-96	16.12	35.538474	25.24	55.644609	41.36	91.1830832	6.22	10.53	16.75	0.61	2,707.48	15,666.91	4,438.49	935.34	378.79	171.81816
3-Apr-96	16.51	36.398276	25.87	57.033519	42.38	93.4317956	6.37	10.85	17.22	0.47	0.00	15,666.91	0.00	909.81	369.68	167.68285
19-Apr-96	17.65	38.911543	27.61	60.869558	45.26	99.7811012	6.81	11.12	17.93	0.71	2,712.79	18,379.70	3,820.83	1,025.08	406.09	184.20021
31-May-96	19.58	43.16646	30.4	67.020448	49.98	110.1869076	7.55	11.87	19.42	1.49	#####	28,816.22	7,004.38	1,483.84	576.56	261.52127
13-Jun-96	20.15	44.423093	31.04	68.431405	51.19	112.8544978	7.77	13.07	20.84	1.42	0.00	28,816.22	0.00	1,382.74	562.93	255.33958
26-Jun-96	20.88	46.032466	31.97	70.481701	52.85	116.514167	8.05	13.34	21.39	0.55	5,252.04	34,068.26	9,549.16	1,592.72	644.62	292.39586
25-Jul-96	21.77	47.994577	33.47	73.788631	55.24	121.7832088	8.39	13.74	22.13	0.74	2,073.37	36,141.63	2,801.85	1,633.15	654.27	296.77022
14-Aug-96	22.88	50.441706	35.15	77.492393	58.03	127.9340986	8.82	14.38	23.2	1.07	0.00	36,141.63	0.00	1,557.83	622.81	282.50193
11-Dec-96	23.88	52.646326	36.45	80.358399	60.33	133.0047246	10.38	17.67	28.05	4.85	2,431.05	47,269.96	501.25	1,685.20	783.52	355.40061
11-Jan-97	24.64	54.321837	37.24	82.100049	61.88	136.4218856	10.67	18.01	28.68	0.63	62.70	47,332.66	99.52	1,650.37	764.91	346.95797
11-Feb-97	26.94	59.392463	39.62	87.347044	66.56	146.7395072	11.56	19.04	30.6	1.92	1,265.12	48,597.78	658.92	1,588.16	730.13	331.18402
11-Mar-97	28.8	63.493056	41.99	92.571994	70.79	156.0650498	12.27	20.05	32.32	1.72	458.04	49,055.82	266.30	1,517.82	692.98	314.32931
11-Apr-97	29.8	65.697676	44.17	97.378065	73.97	163.0757414	12.66	20.99	33.65	1.33	287.48	49,343.30	216.15	1,466.37	667.07	302.57903
12-May-97	30.8	67.902296	47.44	104.58717	78.24	172.4894688	13.05	22.39	35.44	1.79	287.48	49,630.78	160.60	1,400.42	634.34	287.73223
12-Jun-97	31.8	70.106916	50.77	111.92856	82.57	182.0354734	13.43	23.83	37.26	1.82	454.53	50,085.31	249.74	1,344.21	606.58	275.14038
13-Jul-97	32.8	72.311536	54.1	119.26994	86.9	191.581478	13.82	25.26	39.08	1.82	454.53	50,539.84	249.74	1,293.24	581.59	263.80337
13-Aug-97	33.8	74.516156	56.53	124.62717	90.33	199.1433246	14.2	26.3	40.5	1.42	454.53	50,994.37	320.09	1,259.12	564.53	256.06869

Groundwater Containment at
Sites SD-29 and ST-30, Shaw AFB, South Carolina

Groundwater Containment at Sites SD-29 and ST-30, Shaw AFB, South Carolina

Site Name: Sites SD-29 and ST-30, Shaw AFB	**Contaminants:** Petroleum Hydrocarbons, Free Product (JP-4 fuel), Chlorinated Solvents - estimated 60 gallons of JP-4 fuel spilled at SD-29; total petroleum hydrocarbon levels up to 592 ppm in soil at ST-30 - Free product in groundwater at both sites	**Period of Operation:** 3/95 - 2/96
Location: South Carolina		**Cleanup Type:** Full-scale
Vendor: IT Corporation	**Technology:** Interim action free product recovery systems at SD-29 and ST-30. The systems used pneumatic products skimmer pumps until 1/96. At that time, passive skimmer bailers were placed in the wells to reduce operating costs. Contaminated groundwater was treated using an air stripper.	**Cleanup Authority:** Installation Restoration Program
Additional Contacts: U.S. Air Force Air Combat Command		**Regulatory Point of Contact:** Information not provided
Waste Source: Fuel spill and leaking supply line	**Type/Quantity of Media Treated:** Groundwater and free product - A total of 102 gallons of free product were recovered	
Purpose/Significance of Application: Interim action to recover free product from groundwater		

Regulatory Requirements/Cleanup Goals:
The operational objective of the interim action free product source removal was to remove liquid-phase contamination as quickly and cost-effectively as possible to prevent continued contamination of surrounding soil and groundwater.

Results:
- A total of 102 gallons of free-phase JP-4 fuel was recovered during the year the system was operated (97 gallons from ST-30 and 5 gallons from SD-29). Monthly removal rates ranged from 0 to 50 gallons of free product. By October 1995, the removal rates had decreased to below 5 gallons/month. By February 1996, the removal rate had become negligible and the system was shut down.

Cost:
The capital cost for the SD-29 groundwater containment system was $394,000. Data on the capital cost for the ST-30 system were not available.
Data on O&M costs were reported as a total for both systems. The total cumulative cost for the SD-29 and ST-30 was $17,000. Monthly O&M costs ranged from $0 to $6,021. In January 1996, after removal rates had decreased, passive bailers were installed in the wells to reduce operating costs. The operating cost for February 1996 was $500.
The average O&M cost was $166/gallon of JP-4 recovered.

Groundwater Containment at Sites SD-29 and ST-30, Shaw AFB, South Carolina (continued)

Description:
Sites SD-29 and ST-30 at Shaw AFB, located in South Carolina, were the locations of soil and groundwater contamination as a result of leaks and spills of JP-4 fuel. An estimated 60 gallons of JP-4 fuel were spilled at site SD-29 when an oil/water separator pump failed. Eighty tons of soil were excavated from the site. In addition, the groundwater was determined to be contaminated with free phase JP-4 fuel, dissolved fuel components, and dissolved chlorinated solvents. A leaking jet fuel supply line was the source of contamination at the ST-30 site. Free phase JP-4 fuel was identified in the groundwater. Interim action groundwater containment systems were installed to remove free product and prevent continued contamination of surrounding soil and groundwater. The systems were operated from March 1995 through February 1996.

The groundwater containment systems included pneumatic product skimmer pumps to recover free product. These pumps were used until January 1996, when the removal rate has decreased and the system was evaluated to determine if operating costs could be reduced. Passive skimmer bailers were then installed to reduce operating costs. The system was shut down in February 1996, after the removal rates had remained negligible for several months. During the year of operation, a total of 102 gallons of JP-4 was recovered - 97 gallons from ST-30 and 5 gallons from SD-29. Monthly removal rates ranged from 0 to 50 gallons per month.

The total capital cost for the SD-29 system was $394,000. No data on capital costs were available for the ST-30 system. Data on O&M costs were reported as a total for the SD-29 and ST-30 systems. The total cumulative costs for the year of operation was $17,000. Monthly O&M costs ranged from $0 to $6,021. The operating cost for February 1996 was $500. The average O&M cost per unit of contaminant removed was $166/gallon of JP-4.

Groundwater Containment at Sites SD-29 and ST-30, Shaw AFB

Site Background on Site SD-29

This section focuses on the interim action groundwater containment system located at Site SD-29, Shaw AFB. A site map for SD-29 is included as Figure 25.

Contaminants in Soil

- In January 1992, sixty gallons of JP-4 jet fuel was spilled when a pump failed at an oil/water separator located at the site.
- Eighty tons of contaminated soil was excavated.
- Further investigation indicated that the soil at the site was contaminated with volatile organic compounds (VOCs), with contaminant concentrations increasing with sample depth.

Contaminants in Groundwater

- Free product JP-4 jet fuel, dissolved fuel components, and dissolved chlorinated solvents have been identified in the groundwater.

Lithology/Hydogeology

- Sands and silts.
- Groundwater is found in a shallow water table aquifer and the Upper Black Creek Aquifer.

Groundwater Containment System Details

- Interim action JP-4 free product recovery system.
- Pneumatic product skimmer pumps were used from March 1995 through January 1996.
- Passive skimmer bailers were placed in wells in January 1996.
- Approximately 5 gallons of JP-4 was recovered during its year of operation.
- Contaminated groundwater was treated with an air stripper.
- An Interim Corrective Measure, consisting of three extraction wells, has been designed and is being implemented to address the mobile JP-4, dissolved fuel, and dissolved chlorinated solvent plumes. The target pump rate is 1 to 2 gpm.

Operation Period

- The interim action system began operation in March 1995 and was operated through February 1996.
- The interim action system was shut down when product recovery became negligible.

Total Capital Costs

- The estimated capital costs for the SD-29 interim action groundwater containment system was $394,000.

Total O&M Costs

- See below.

Site Background on Site ST-30

This section focuses on the interim action groundwater containment system located at Site ST-30, Shaw AFB. A site map for ST-30 is included as Figure 26.

Contaminants in Soil

- Soil was contaminated with JP-4 jet fuel by a leaking jet fuel supply line.
- TPH concentrations ranged from 87 to 592 ppm.

Contaminants in Groundwater

- Free product JP-4 jet fuel was identified on groundwater.

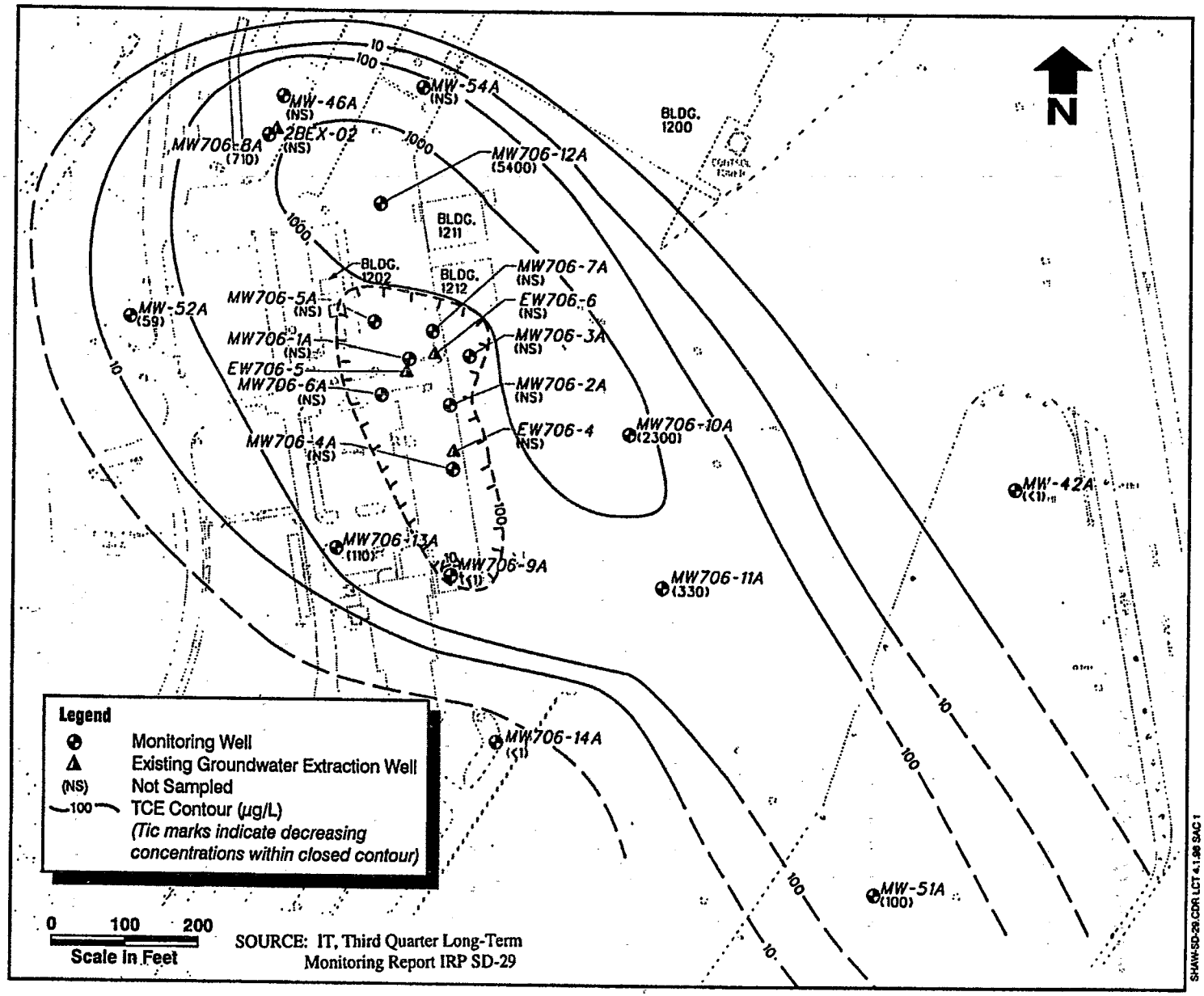


Figure 25. Location of Site SD-29 Oil/Water Separator, Shaw AFB

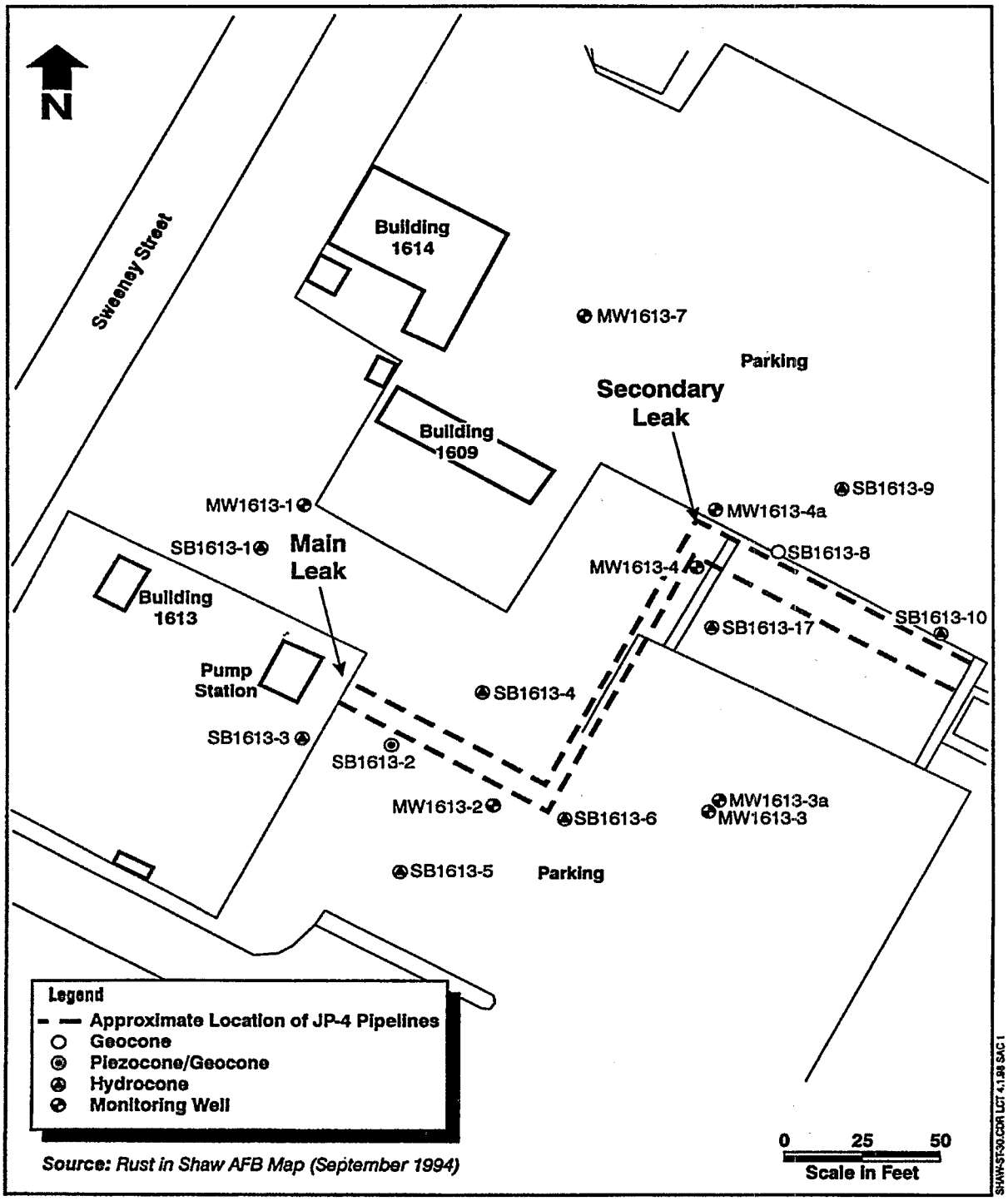


Figure 26. Location of Leaking Fuel Line, Site ST-30, Shaw AFB

Lithology

- Predominantly interlayered poorly graded, well graded, and clayey coarse to fine grain sands.

Groundwater Containment System Details

- In March 1995, an interim action free product recovery system was installed to remove free-phase JP-4.
- Contaminated groundwater was treated with an air stripper.
- Approximately 97 gallons of JP-4 was recovered during its year of operation.
- Pneumatic product skimmer pumps were used from March 1995 through January 1996.
- Passive skimmer bailers were installed in January 1996 and are checked monthly.
- There are currently no remedial activities or monitoring at ST-30.

Operation Period

- The interim action system was operated from March 1995 through February 1996.
- The interim action system was shut down when recovery of JP-4 became negligible.

Total Capital Costs

- Data not available.

Total O&M Costs – Sites SD-29 and ST-30

- Total cumulative costs for the SD-29 and ST-30 interim action free product recovery system were $17,000 from March 1995 through February 1996.

Cost and Performance of Groundwater Containment at Sites SD-29 and ST-30

Groundwater Containment with Free Product Source Removal Operational Objectives

The objective of free product source removal is typically to remove liquid-phase contamination as quickly and cost-effectively as possible to prevent continued contamination of surrounding soil and groundwater. The emphasis for free product removal is that the mass of contaminants is cost effectively removed.

Cost for Operation

Figure 27 illustrates curves of O&M costs for the interim action groundwater containment systems at Sites SD-29 and ST-30. The monthly O&M costs ranged from $0 to $6,021. Total O&M costs after one year of operation were $17,000.

Contaminant Removal

Figures 28 and 29 illustrate curves of the removal rates of JP-4 free product for the interim action groundwater containment system at Sites SD-29 and ST-30. Monthly removal rates of JP-4 free product ranged from 0 to 50 gallons. Total contaminant removal after one year of operation was 102 gallons of JP-4 free product. By October 1995, both curves representing the cumulative removal rate had flattened, indicating that the removal rates were negligible and a system evaluation for reducing operating cost was warranted. In January 1996 passive skimmer bailers were installed in the recovery wells. The interim action systems were shut down in February 1996 as recovery was negligible and the system was no longer able to meet the operation objectives.

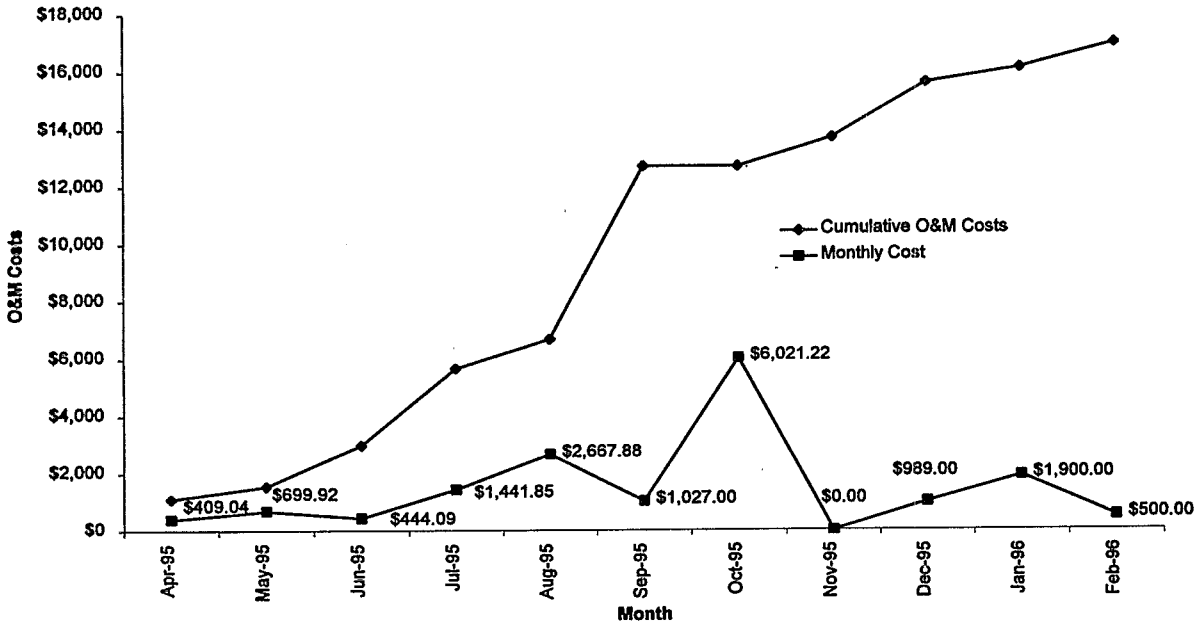
Correlation of Costs and Contaminant Removal

Figures 30 and 31 illustrate the relationship between the O&M costs and the JP-4 recovery of the interim action groundwater containment system at Sites SD-29 and ST-30.

Figure 30 illustrates the cumulative O&M cost relative to the cumulative contaminant removal. During October 1995, the curve had become vertical where the cost per unit of contaminant removal rose exponentially. In January 1996, to reduce cost, passive skimmer bailers were installed in the recovery wells. The system was shut down in February 1996 as recovery was negligible and the system was no longer able to meet the operation objectives.

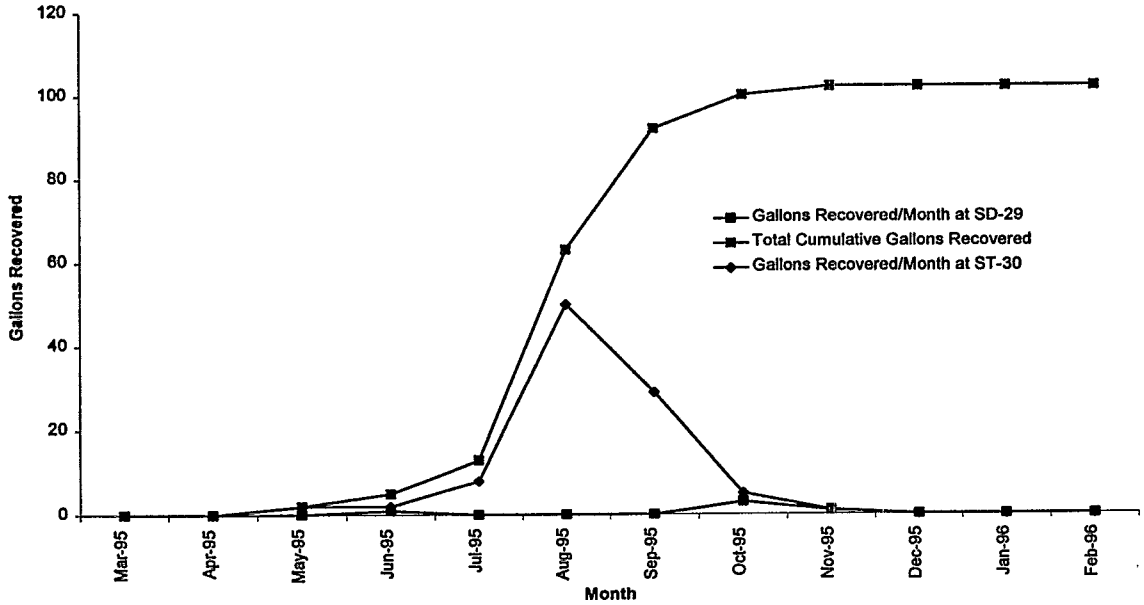
Figure 31 illustrates curves of the monthly and cumulative cost per unit of contaminant removal over the operation time of the systems. The monthly curve illustrates the cost per gallon of JP-4 removal in each month. The cumulative curve illustrates that the average cost per unit of contaminant removal was $166/gallon of JP-4 after one year of operation.

Figure 27
Cumulative and Monthy O&M Costs vs. Time
Sites SD-29 and ST-30, Shaw AFB



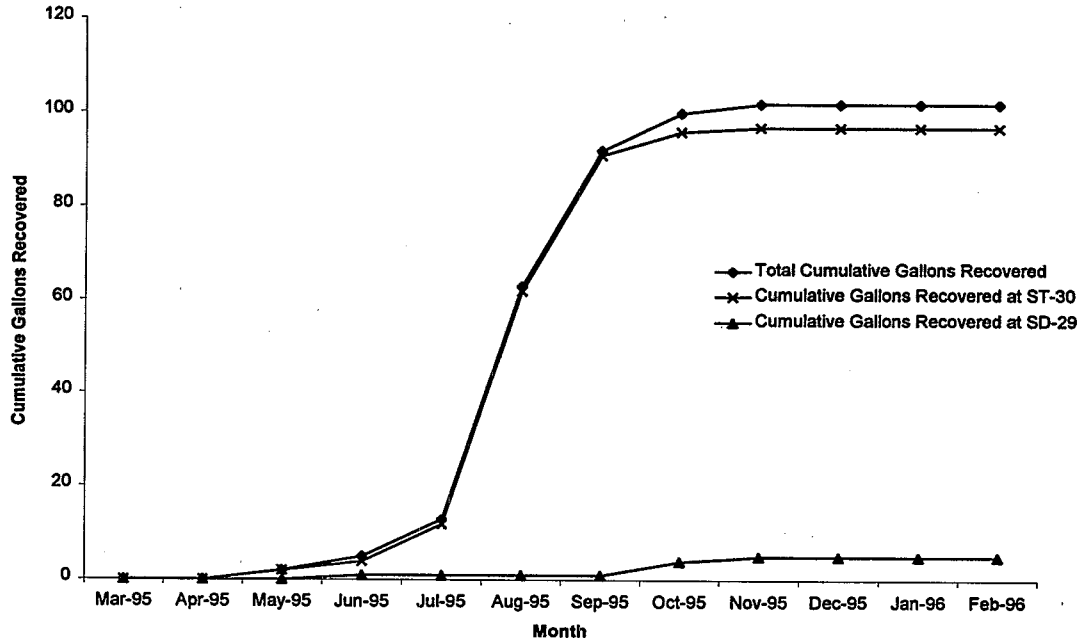
Shaw2930.xls; Cumulative and Monthly Costs

Figure 28
Monthly JP-4 Free Product Recovered at Sites SD-29 and ST-30 and Cumulative Gallons Recovered, Shaw AFB



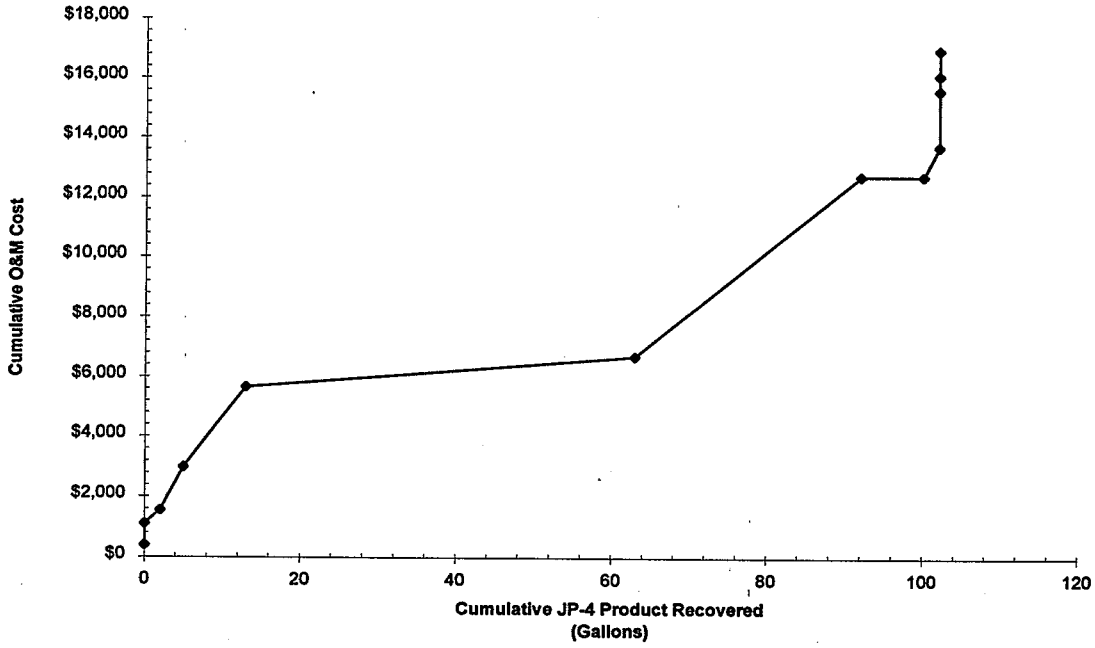
Shaw2930.xls; Monthly Gallons Recovered

Figure 29
Cumulative JP-4 Free Product Recovered
Site SD-29 and ST-30, Shaw AFB



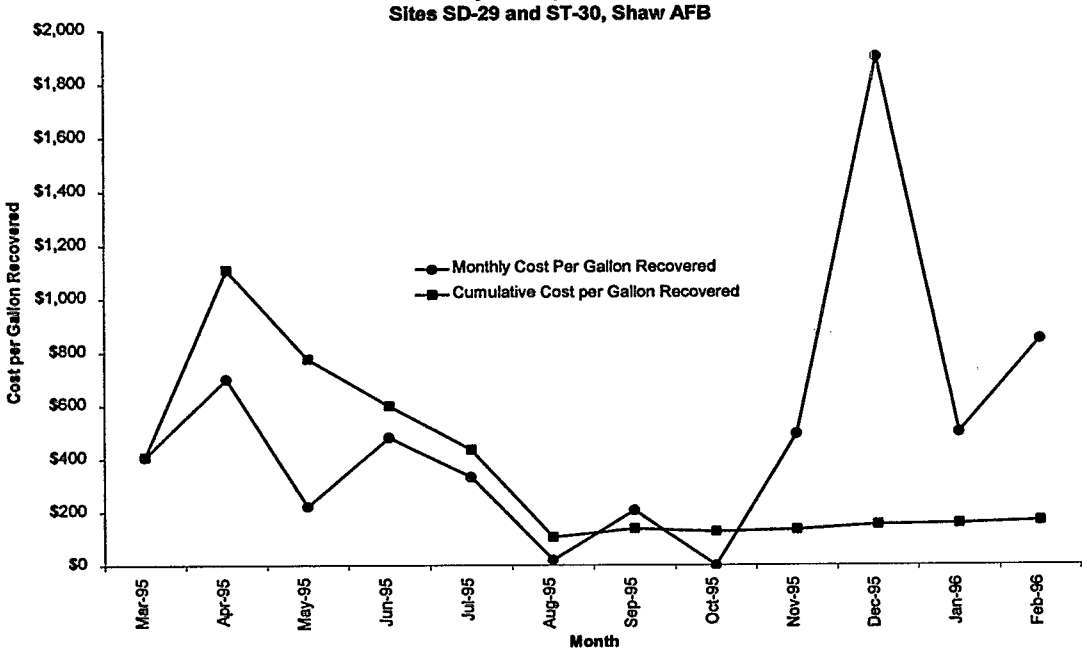
Shaw2930.xls; Cumulative Gallons Recovered

Figure 30
Cumulative O&M Costs per Cumulative JP-4 Product Recovered
Sites SD-29 and ST-30, Shaw AFB



Shaw2930.xls; Cumulative Cost & Gallons

Figure 31
Cumulative and Monthly Costs per Gallon Recovered vs. Time
Sites SD-29 and ST-30, Shaw AFB



Shaw2930.xls; Cost Per Gallon

APPENDIX A

Detailed Cost and Performance Data Tables

JP-4 Free Product Recovery
Sites SD-29 and ST-30
Shaw Air Force Base

Cost Per Gallon For Free Product Recovery Interim Remedial Action System At IRP Sites SD-29 and ST-30 O&M Cost

Month	Gallons Recovered/Month	Total Cumulative Gallons Recovered	Monthly Cost	Cumulative O&M Costs	Monthly Cost Per Gallon Recovered	Cumulative Cost per Gallon Recovered
Mar-95	0	0	$409.04	$409.04	$409.04	$409.04
Apr-95	0	0	$699.92	$1,108.96	$699.92	$1,108.96
May-95	2	2	$444.09	$1,553.05	$222.05	$776.53
Jun-95	3	5	$1,441.85	$2,994.90	$480.62	$598.98
Jul-95	8	13	$2,667.88	$5,662.78	$333.49	$435.60
Aug-95	50	63	$1,027.00	$6,689.78	$20.54	$106.19
Sep-95	29	92	$6,021.22	$12,711.00	$207.63	$138.16
Oct-95	8	100	$0.00	$12,711.00	$0.00	$127.11
Nov-95	2	102	$989.00	$13,700.00	$494.50	$134.31
Dec-95	0	102	$1,900.00	$15,600.00	$1,900.00	$152.94
Jan-96	0	102	$500.00	$16,100.00	$500.00	$157.84
Feb-96	0	102	$850.00	$16,950.00	$850.00	$166.18

Free Product Recovery
Remedial Action System
IRP Site SD-29, Building 1202

Month	Gallons Recovered/Month at SD-29	Cumulative Gallons Recovered at SD-29
Mar-95	0	0
Apr-95	0	0
May-95	0	0
Jun-95	1	1
Jul-95	0	1
Aug-95	0	1
Sep-95	0	1
Oct-95	3	4
Nov-95	1	5
Dec-95	0	5
Jan-96	0	5
Feb-96	0	5

Free Product Recovery Interim
Remedial Action System
Operable Unit 1, IRP Site ST-30

Month	Gallons Recovered/Month at ST-30	Cumulative Gallons Recovered at ST-30
Mar-95	0	0
Apr-95	0	0
May-95	2	2
Jun-95	2	4
Jul-95	8	12
Aug-95	50	62
Sep-95	29	91
Oct-95	5	96
Nov-95	1	97
Dec-95	0	97
Jan-96	0	97
Feb-96	0	97

Pump and Treat of Contaminated Groundwater at the Solid State Circuits Superfund Site, Republic, Missouri

Pump and Treat of Contaminated Groundwater at the Solid State Circuits Superfund Site, Republic, Missouri

Site Name:
Solid State Circuits Superfund Site

Location:
Republic, Missouri

Contaminants:
Chlorinated solvents
- Contaminants of greatest concern at this site are TCE, 1,1-DCA, 1,1-DCE, methylene chloride, 1,1,1-TCA, and vinyl chloride
- Maximum concentration of TCE was 290,000 ug/L

Period of Operation:
Status: Ongoing
Report covers: 1993 - 3/97

Cleanup Type:
Full-scale cleanup (interim results)

Vendor:
Steve Chatman
Chatman & Associates
647 Massachusetts Ave., Ste. 211
Lawrence, KS 66044-2250
(785) 843-1006

Technology:
Pump and Treat
- Groundwater is extracted using 7 wells, 4 located on site and 3 located off site, at an average total pumping rate of 34 gpm
- Three wells have depths of 90 ft bgs, two wells of approximately 300 ft bgs, one of 600 ft bgs, and one of 985 ft bgs
- Groundwater extracted from on-site wells is treated with air stripping and discharged to a POTW
- Groundwater extracted from off-site wells is discharged without treatment to a POTW

Cleanup Authority:
CERCLA Remedial
- ROD Date: 9/27/89

EPA Point of Contact:
Steve Auchterlonie, RPM
U.S. EPA Region 7
726 Minnesota Avenue
Kansas City, KS 66101
(913) 551-7778

State Point of Contact:
Candice Hamil
Missouri Dept. Of Nat. Resources
205 Jefferson Ave., P.O. Box 176
Jefferson City, MO 65101
(314) 751-3176 or (800) 334-6946

Facility Engineer:
Greg Vierkant
Lucent Technologies
2101 West Chesterfield Blvd.
Suite C100-110
Springfield, MO 65807-8672
(417) 882-2211

Waste Source:
Storage of stripper and plating wastes in sump pit

Purpose/Significance of Application:
Groundwater characterized as a leaky artesian system occurring in a karst formation.

Type/Quantity of Media Treated:
Groundwater
- 257 million gallons treated as of March 1997
- DNAPL suspected in groundwater on site
- Extraction wells are located in 3 aquifers, which are influenced by a nearby surface water
- Groundwater is characterized as a leaky artesian system occurring in karst formations, with three units identified at the site
- Hydraulic conductivity ranges from <0.01 to 1.62 ft/day

Regulatory Requirements/Cleanup Goals:
- The remedial goals for this site are to reduce the TCE concentration in groundwater to 5 ug/L and maintain hydraulic control over the groundwater contaminant plume.
- Performance goals were that TCE levels in individual discharge points to the POTW were below 200 ug/L, and that average water levels and pump rates from specific wells be within specified ranges; these latter requirements were to ensure hydraulic containment.

Pump and Treat of Contaminated Groundwater at the Solid State Circuits Superfund Site, Republic, Missouri (continued)

Results:
- TCE concentrations in some of the wells have decreased from 1987 to 1996, and are below the cleanup goal in one well, however, TCE concentrations in most wells remain well above the cleanup goal.
- From March 1988 through March 1997, 2,754 pounds of TCE were removed from the groundwater.
- Plume containment has been achieved for this site.

Cost:
- Actual costs for the P&T system were approximately $2,510,400 ($893,700 in capital and $1,616,700 in O&M), which correspond to $10 per 1,000 gallons of groundwater extracted and $913 per pound of contaminant removed.
- The capital costs do not include the costs for installation of the four deeper wells; these costs were accounted for as part of the RI/FS and are not included in the total cost shown above.

Description:
From 1968 through November 1973, Solid State Circuits manufactured circuit boards and used TCE as a cleaning solvent in portions of its manufacturing process. Since 1973, the site was occupied by a number of tenants, including Micrographics, Inc., a photographic processing firm. In November 1979, a fire partially destroyed the building, and the debris was pushed into the basement under the remaining portion of the building. In June 1982, the Missouri Department of Natural Resources collected samples of water from the city's three municipal wells and detected elevated concentrations of TCE in one well located 500 ft from the site. In 1984, MDNR investigated the site and found elevated levels of TCE in the fill dirt and rubble from the basement, in a 540 ft deep well in the basement, and in shallow groundwater outside the building. The site was placed on the NPL in June 1986 and a ROD was signed in September 1989.

The groundwater is characterized as a leaky artesian system occurring in karst formations, with three units identified at the site, with shallow and deep bedrock zones extending up to 1,500 ft bgs. The groundwater extraction system consists of seven wells, one of which is a municipal well. Extracted groundwater is treated using air stripping. After nine years of operation, cleanup goals for TCE have not been achieved. Site operators are evaluating innovative technologies to enhance the remedial effort, such as air sparging using a horizontal well.

SITE INFORMATION

Identifying Information:

Solid State Circuits (SSC) Superfund Site
Republic, Missouri

CERCLIS #: MOD9808854111

ROD Date: September 27, 1989

Treatment Application:

Type of Action: Remedial

Period of operation: 1993 - Ongoing (Data collected through March 1997.)

Quantity of material treated during application: 257,149,396 gallons of groundwater as of March 1997.

Background

Historical Activity that Generated Contamination at the Site: Manufacturing of printed circuit boards

Corresponding SIC Code: 3571 (Electronic Computers)

Waste Management Practice That Contributed to Contamination: Storage of stripper and plating wastes in sump pit in the basement.

Facility Operations [1,2]:

- The site is located in the town of Republic, Missouri and occupies a lot that is approximately 0.5 acres in a primarily urban area.

- The site operated as Solid State Circuits (SSC) from 1968 through November 1973. During this time, SSC manufactured circuit boards and used trichloroethene (TCE) as a cleaning solvent in portions of its manufacturing process. Since that date, the site was occupied by a number of tenants, including Micrographics, Inc., a photographic processing firm, and a factory outlet store. In November 1979, a fire partially destroyed the building, and the debris was pushed into the basement under the remaining portion of the building.

- In June 1982, the Missouri Department of Natural Resources (MDNR) collected samples from of Republic's three municipal wells for analysis of volatile organic compounds as part of EPA's National Synthetic Organic Chemical Survey. Elevated concentrations of TCE were detected in one municipal well, located 500 feet from the former SSC site. Periodic sampling in the three municipal wells over the next three years consistently revealed elevated TCE concentrations in the well closest to the site; no TCE was detected in two other municipal wells nor in two additional wells installed by the City of Republic since the start of the RI/FS.

- In 1984, MDNR investigated the former manufacturing facility in an attempt to identify the source of contamination in the municipal well. Samples of soils and debris from pipes and sumps in the basement, as well as from a 540-foot deep well found in the basement, were collected. Elevated levels of TCE were found in the fill dirt and rubble excavated from the basement, in the basement well, and in the shallow groundwater outside of the building.

- In 1984, MDNR removed 75 to 150 cubic yards of TCE-contaminated soils from the basement and recased the upper 40 feet of the basement well in the hopes of using it as an extraction well. The well yield was very low and the well was plugged per state regulations. In 1985, EPA excavated and removed an additional 1,400 cubic yards of contaminated soil from within and below the basement.

- In June 1987, SSC began the Remedial Investigation/Feasibility Study. Between June and December 1987, a number of activities were performed, including a

SITE INFORMATION (CONT.)

Background (Cont.)

survey of the sewer system and private wells in the area. Monitoring wells were installed and a dual-tower air stripper was installed to treat groundwater pumped from on-site extraction wells.

- The site was placed on the National Priorities List (NPL) on June 10,1986.

Regulatory Context:

- The Record of Decision was signed on September 27, 1989.
- The EPA, MDNR, and SSC signed a Consent Decree in July 1990, requiring SSC to conduct design, construction, and operations activities for the groundwater cleanup under DNR supervision. The Consent Decree was entered in May 1991.
- Site activities are conducted under provisions of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA) §121, and the National Contingency Plan (NCP), 40 CFR 300.

Groundwater Remedy Selection: An expansion of the existing system of groundwater extraction and treatment via air stripping was selected as the remedy for this site as the most cost-effective approach.

Site Logistics/Contacts

Site Lead: State

Oversight: EPA

Remedial Project Manager:
Steve Auchterlonie
U.S. EPA Region 7
726 Minnesota Avenue
Kansas City, KS 66101
(913) 551-7778

State Contact:
Candice Hamil*
Missouri Department of Natural Resources(MDNR)
205 Jefferson Avenue
P.O. Box 176
Jefferson City, MO 65101
(314) 751-3176 or (800) 334-6946

*Indicates primary contacts

Treatment System Operator:
Steve Chatman*
Chatman & Associates
647 Massachusetts St., Ste. 211
Lawrence, KS 66044-2250
(785) 843-1006

Facility Engineer:
Greg Vierkant*
Lucent Technologies
2101 West Chesterfield Blvd.,
Suite C100-110
Springfield, MO 65807-8672
(417) 882-2211

MATRIX DESCRIPTION

Matrix Identification

Type of Matrix Processed Through the Treatment System: Groundwater

Contaminant Characterization [2]

Primary Contaminant Groups: Volatile Organic Compounds

- Contaminants of greatest concern at the site are 1,1-dichloroethane (1,1-DCA), 1,1-dichloroethylene (1,1-DCE), *trans*-1,1-dichloroethylene (*trans*-1,1-DCE), methylene chloride, 1,1,1-trichloroethane (TCA), trichloroethylene (TCE), and vinyl chloride. TCE was reported at concentrations several orders of magnitude greater than the contaminant with the next largest concentration.

- TCE contamination was found during the RI/FS in the three groundwater units beneath the site at both on- and off-site locations. Maximum TCE concentrations detected in the surficial, or Unconsolidated Fractured Shallow Bedrock (UFSB), unit ranged from 300 µg/L near Highway 60 (approximately 1,000 feet downgradient) to 40,000 µg/L on site. The on-site maximum concentration in the intermediate, or Unfractured Shallow Bedrock (SBR), unit was 290,000 µg/L, and the highest concentrations in this unit were found between 150 and 300 feet below ground surface (bgs). The maximum on-site concentration of TCE found in the deep, or Deep Bedrock (DBR), unit was 18,000 µg/L, with the highest concentration found between 400 and 500 feet bgs.

- Significant effort has been expended to detect dense, nonaqueous phase liquid (DNAPL) at this site. No direct physical, chemical, or visual evidence has been reported from the site. Nevertheless, concentrations of TCE found during the RI are well above 1 percent of solubility, and high concentrations persist in localized extraction wells, two indicators of subsurface source zones.

- Figures 1 through 3 show the TCE plumes in each groundwater unit, respectively, in 1989. The plume in the surficial unit is controlled by a fracture zone, and, in 1989, contamination was restricted to a narrow area less than 50 feet wide, 10 feet deep, and extending approximately 1,500 feet downgradient. The plume in the intermediate unit had not migrated far from the point of release and was estimated to be no greater than 100 feet in length with highest concentrations found between 150 and 300 feet bgs. In the deep unit, the plume was estimated to extend 785 feet downgradient and to be 500 feet wide. The initial volumes of contaminated groundwater contained in the three units were estimated in 1989 to be 15 million, 790,000, and 42 million gallons, respectively.

MATRIX DESCRIPTION (CONT.)

Matrix Characteristics Affecting Treatment Costs or Performance

Hydrogeology [2]:

The groundwater system at the SSC site is characterized as a leaky artesian system occurring in karst formations with shallow bedrock and deep bedrock zones separated by a semiconfining shale layer. Groundwater flow is vertical as well as lateral. There is an interconnection between the fracture zone in the UFSB and nearby Robert Spring/Shuyler Creek but no contamination has been detected in the spring or the creek [2]. There are three principal units in the groundwater system.

Unit 1	USFB	Unconsolidated material formed of reddish-brown clay interspersed with a layer of weathered coarse crystalline limestone. Water yield is low and aquifer is not a significant source of drinking water
Unit 2	SBR	Consolidated limestone formations with fractures that can significantly impact flow velocity and direction. It is interconnected to some degree with the overlying overburden materials.
Unit 3	DBR	Confined aquifer composed of dolomite and sandstone formations. This is the principal drinking water source in the area.

Tables 1 and 2 present technical aquifer information and technical well data, respectively. A discussion of extraction wells is included in the next section.

Table 1. Technical Aquifer Information

Unit Name	Thickness (ft)	Conductivity (ft/day)	Average Velocity (ft/day)	Flow Direction
UFSB	1 - 15	0.0000001 - 0.01	Not Available	Consistent with surface water flow
SBR	250 - 300	0.023	0.0009	Southeast
DBR	1,000 - 1,500	1.62	0.43	Southeast

Source: [2]

MATRIX DESCRIPTION (CONT.)

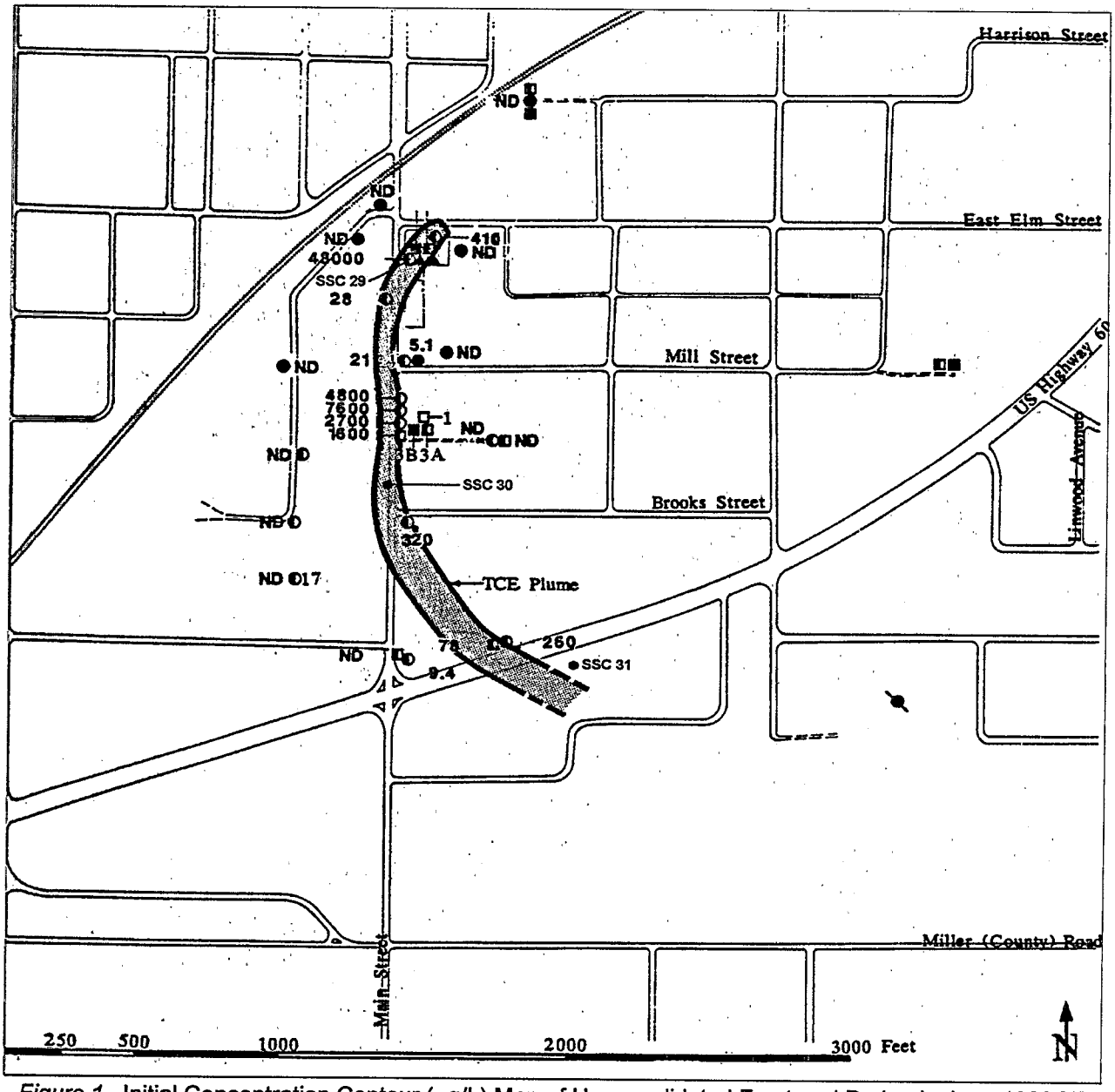


Figure 1. Initial Concentration Contour (μg/L) Map of Unconsolidated Fractured Bedrock, June 1989 [1]

MATRIX DESCRIPTION (CONT.)

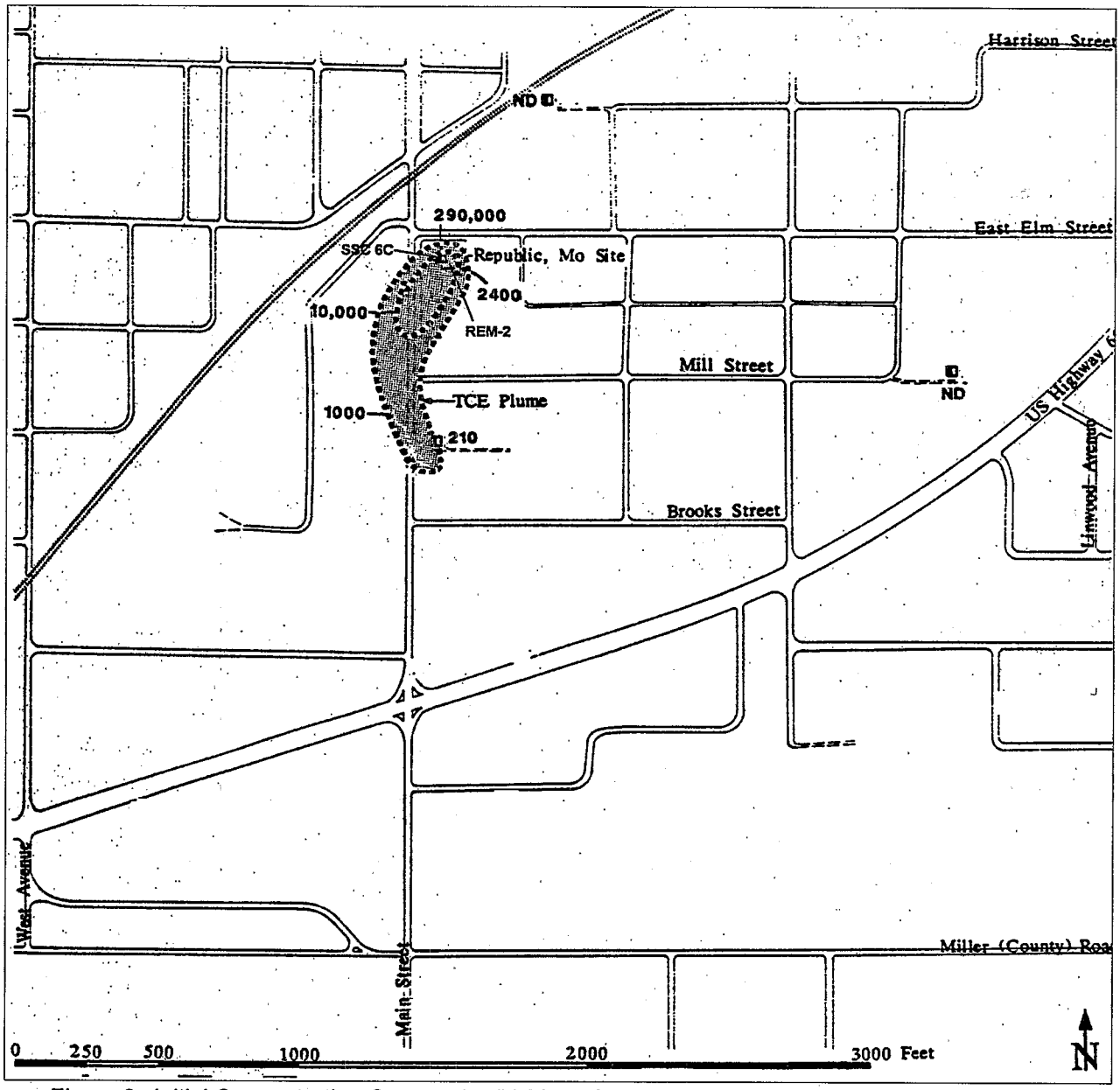


Figure 2. Initial Concentration Contour (μg/L) Map of Unfractured Shallow Bedrock, June 1989 [1]

MATRIX DESCRIPTION (CONT.)

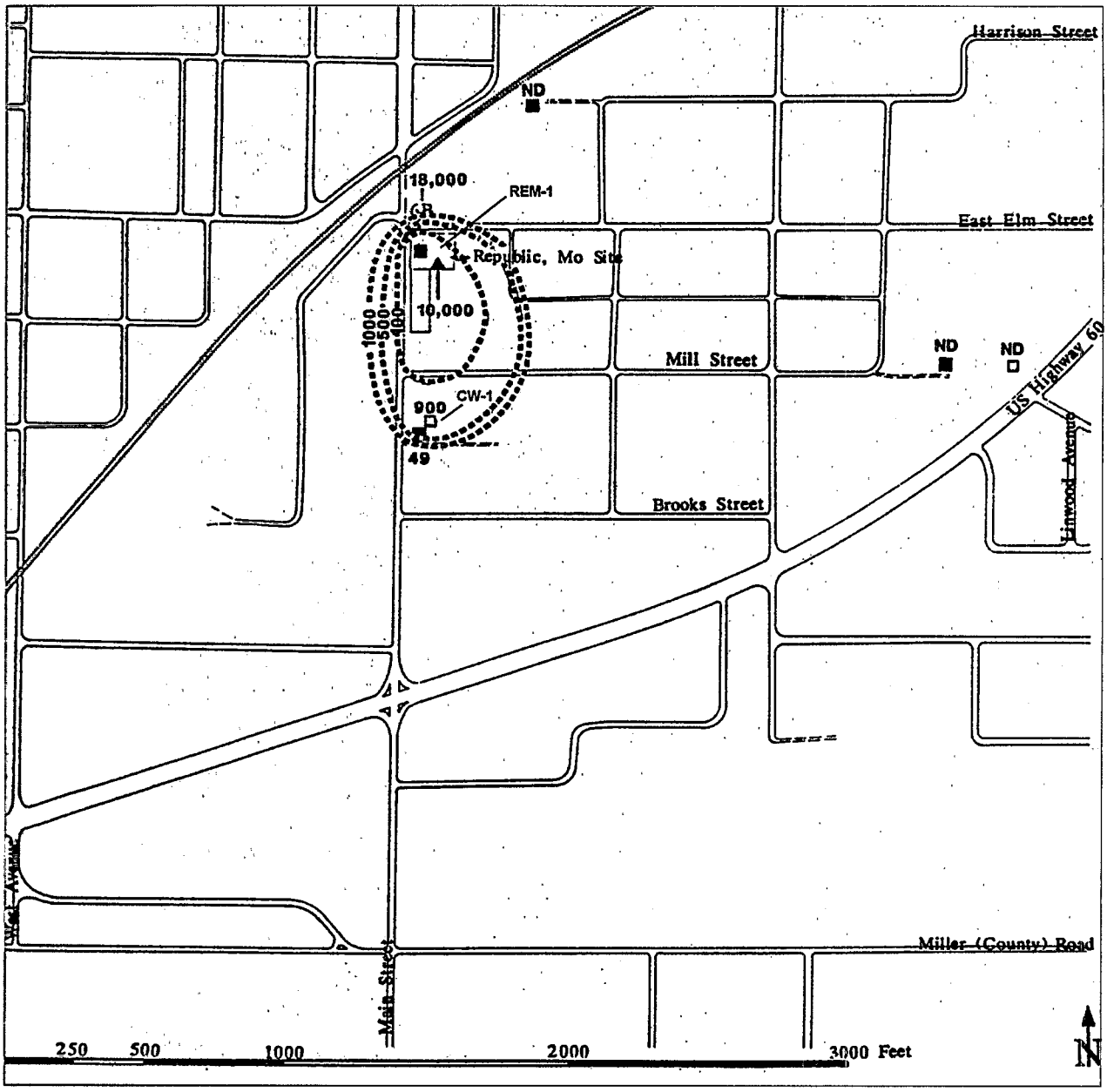


Figure 3. Initial Concentration Contour (μg/L) Map of Deep Bedrock, June 1989 [2]

TREATMENT SYSTEM DESCRIPTION

Primary Treatment Technology

Pump and treat with air stripping

Supplemental Treatment Technology

None

System Description and Operation [2, 3]

Table 2. Technical Well Data

Well Name	Unit Name	Depth (ft)	Ave. Yield (gal/min)
SSC-29	UFSB	90	1-3
SSC-30	UFSB	90	1.2-7
SSC-31	UFSB	90	1.8-17.4
SSC-6C	SBR	283	0.3-1.6
REM-2	SBR	331	.01-.42
CW-1	DBR	985	65
REM-1	DBR	600	55

Note: Average system yield is 49,493 gallons per day, taking into account the system operational time from 1993 to 1996.

Source: [2, 3]

- The groundwater extraction system at this site was installed in phases from 1987 to 1993. The initial system consisted of four on-site wells. Two were installed in the SBR unit and one in the DBR unit; the existing Municipal Well CW-1, which was contaminated with TCE, is the fourth well. In 1993, three additional wells were installed in UFSB, along the off-site portion of the plume.

- The extraction wells in each of the three hydrologic units are operated differently to ensure that hydraulic containment of the plume in that unit is maintained.

- UFSB wells are operated continuously to maintain an annual rolling average water level between 5 to 20 feet above the bottom of the well. The SBR wells are operated intermittently to maintain a level between 25 to 50 feet above the well bottom, with both wells pumping for a limited period every day. The DBR wells operate continuously.

- The on-site wells and SSC-30 discharge to the treatment system while the off-site wells discharge directly to the public sewer line where it is carried to and treated at the POTW. If the levels exceed discharge standards, the groundwater is routed to the air stripper for treatment. Monitors are installed at the points of discharge to selectively shut off when the discharge standard is violated [3].

- The state required pipes carrying extracted water with TCE concentrations levels greater than 100 ppb to be constructed of double-walled PVC, while lines carrying less contaminated water can be single-walled [3].

- Groundwater with TCE concentrations that exceed 200 µg/L is treated in a treatment system consisting of an equalization tank and two stripper towers set in a series [3].

TREATMENT SYSTEM DESCRIPTION (CONT.)

System Description and Operation (Cont.)

- The equalization tank holds 960 gallons and serves to regulate the flow of water from the extraction wells that are pumping at different rates and frequencies [3].

- The two 23-foot air stripping towers are plumbed in series, each having an internal diameter of 37.25 inches. The towers are packed with PVC packing to a height of 13.5 feet. Air and groundwater are sent through the tower at a ratio of 750 to 1, respectively, and have a design flow rate of 150 to 175 gpm. Treated groundwater is then discharged to the local POTW. Effluent is monitored once every 90 days to ensure that discharge standards are being met [3, 4, 5].

- Air emissions from the stripping towers were monitored during the Pilot Program, conducted from October 1991 to January 1992. Emission levels remained below the state air standards, and no treatment of air emissions is required [3].

- The extraction and treatment system operations are monitored and controlled by a specialized software package. The software tracks and monitors system parameters, such as individual well pump rates and water levels, and water levels in the sanitary sewer. A telecommunications component of the software permits users to access the system from off-site locations with a modem. The software can control well pump rates to maintain the rolling average extraction levels required by the Consent Decree. The software also monitors the leak detectors installed along the pipelines and can turn off specific wells in the event of a leak. A meteorological station feeds external temperature and precipitation data to the software system to identify freezing or high water conditions that might affect treatment system operations [10].

- According to the PRP contractor, the integrated hardware and software data acquisition and control system results in significant cost savings for the project. Total estimated savings are at least $25,000 per year.

- Groundwater quality is monitored in all seven extraction wells and 13 monitoring wells. As of January 1996, the chemical monitoring frequency was reduced to annual. The UFSB unit has eight monitoring points, and the SBR and DBR units have six each. All wells are monitored quarterly for TCE. Groundwater levels are monitored daily, averaged, and reported as annual rolling averages on a quarterly basis. The Consent Decree specified that certain water levels above the well bottom must be maintained in the UFSB and SBR units to ensure hydraulic containment [6].

System Operation [2, 4, 5, 7]

- The total quantity of groundwater pumped from each unit is given below [7]:

	Volume Pumped (gallons)			
Year	**UFSB**	**SBR**	**DBR**	**All Units**
Pre-1993	Not available	Not available	123,563,609	123,563,609
1993	825,416	70,910	47,587,620	48,483,946
1994	3,058,415	107,200	39,727,669	42,893,284
1995	3,633,828	138,770	19,626,360	23,398,958
1996	3,505,324	115,756	9,468,533	13,089,613
March 1997	1,584,276	66,310	4,069,400	5,719,986
Total	12,607,259	498,946	244,043,191	257,149,396

- As of March 1997, the treatment system has been operational approximately 95% of the time. The majority of downtime is for routine maintenance of the pumps and the strippers. A small amount of downtime is due to updates to the software control system, and seasonal high water levels in the sanitary sewer that prevent discharge to the POTW [4, 5].

TREATMENT SYSTEM DESCRIPTION (CONT.)

System Description and Operation (Cont.)

- Pumping of contaminated groundwater began during the RI/FS in 1987. At that time, groundwater was extracted from CW-1 and treated in a rented air stripper (which was purchased in December 1987). Over the next two years, three additional wells were installed on site to provide influent to the air stripper. In late 1990, the air stripper was re-conditioned with new packing and piping. In 1993, three wells were installed in the off-site fracture zone. The effluent from these wells is discharged directly to the sanitary sewer [2, 5].

- The treatment system was shut down several times prior to 1994 because of freezing water in the strippers. During the first quarter of 1994, the stripper blowers were changed to link to the transfer pumps. This change allowed the blowers to operate only when there was water in the stripping towers. Since the switch, there has not been a freezing problem [5].

- Air stripping media has not been changed since operations began. The towers are cleaned twice in the summer with sodium hyperchlorite to prevent biofouling [10].

- The site operators have begun evaluating the feasibility of adding innovative technology to improve the efficiency of the remedial action. Soil vapor extraction and air sparging are two technologies currently under review, both for their efficacy in reducing concentrations in soils and groundwater and for their ability to stimulate bioremediation [4, 5]. At the time of this report, no decisions had been made. Currently, the site operators are installing a 485-foot horizontal well beneath Main Street and above the Main Street fracture.

Operating Parameters Affecting Treatment Cost or Performance

The major operating parameter affecting cost or performance for this technology is the pumping rate. Table 3 presents the values measured for this and other operating parameters.

Table 3. Operating Parameters

Parameter	Value
Range of Treatment System Pumping Rates	19-105 gpm
Performance Standard	Discharge from any one point not to exceed 200 µg/L TCE
Remedial Goal	TCE 5 µg/l

Source: [1,3,7]

TREATMENT SYSTEM PERFORMANCE (CONT.)

Timeline

Table 4 presents a timeline for this remedial project.

Table 4. Project Timeline

Start Date	End Date	Activity
1987	1989	RI/FS and interim groundwater treatment conducted
Sept 1989	—	ROD issued
1991	1992	Remedial design performed
1993	—	UFSB off-site wells installed
Jan 1993	—	System operation began
Jan 1993	—	Quarterly monitoring begins
Sept 1993	—	Additional UFSB extraction well, SSC-31, installed
1995	—	Water sampling in municipal distribution reduced to biannual; chemical monitoring reduced to semiannual
Jan 1996	—	Chemical monitoring reduced to annual

Source: [6]

TREATMENT SYSTEM PERFORMANCE

Cleanup Goals/Standards [1]

The remedial goals for this site are to reduce the TCE concentration in groundwater to 5 µg/L and maintain hydraulic control over the groundwater plume. These goals must be met throughout all affected aquifers.

Treatment Performance Goals [6]

Performance goals for the system were delineated in the Consent Decree and were formulated in terms of required pump rates and water levels to ensure hydraulic containment of the plume. Specific goals were:

- To ensure that TCE levels in individual discharge points to the POTW are below 200 µg/L.
- To maintain an average water level above well bottom in UFSB wells of 5 to 20 feet.
- To maintain an average water level above well bottom in SBR wells of 25 to 50 feet.
- To maintain an average annual pump rate from the DBR wells of 75 gpm.
- Total sewer discharge cannot exceed 200 gpm from all sewer discharge locations.

Performance Data Assessment

- No contaminants have been detected in downgradient monitoring wells nor in Robert Spring since 1993 when the UFSB wells were installed, and plume containment appears to have been achieved [7].
- Contaminant removal through the air stripper is shown in Figure 4. From March 1988 through March 1997, 2,754 lbs of TCE were removed from the groundwater. Two periods of increased removal were noted.

TREATMENT SYSTEM PERFORMANCE (CONT.)

Performance Data Assessment (Cont.)

In the first quarter of 1989, the two SBR wells were installed, and mass flux increased from less than 2 lb/day to 5.3 lb/day. By the following quarter, it had returned to its previous level. When the UFSB wells were installed in early 1993, the mass removal rate rose abruptly from less than 2 lb/day to 4.8 lb/day, and reached 25.1 lb/day by the final quarter of 1993. However, by the end of the first quarter of 1994, the rate of removal had returned to less than 2 lb/day [7].

- Figure 5 illustrates changes in the TCE concentrations found in the DBR wells over time. Groundwater monitoring results indicate that contaminant concentrations in one DBR well have been reduced below treatment goals. TCE concentrations in CW-1, located at the toe of the DBR plume, have declined steadily, and, as of April 1993, have remained below detection limits. Contaminant levels in REM-1, located in the source area, were high in 1987 (4,758 µg/L), and had dropped to approximately 100 µg/L in the last quarter of 1996 [7, 8]. Additionally, the reduction in concentrations in REM-1 demonstrates the pathway contributing contaminants into the DBR has been shut off and concentrations near the source have been reduced by a factor of 40 [11].

- The data in Figure 6 show the change in TCE concentrations in the on-site SBR wells. Concentrations have declined regularly in well REM-2 from 1987 through 1996, they have varied in SCC-6C, going through cycles over the period [7, 8].

- Figures 7 through 9 present changes in TCE concentrations in three different areas of the UFSB plume: the source, mid-plume, and the toe. As shown in Figure 5, TCE concentrations in the source area have clearly declined in both wells since 1987. The largest decline was seen in SSC-11, which dropped from 31,067 µg/L in 1987 to 3,200 µg/L at the end of 1996. Contamination levels at mid-plume have not reduced appreciably from their levels in 1993, and have increased significantly in SSC-20. However, a 1987 sampling event found a level of 66,560 µg/L in that well; therefore, despite the rise in TCE concentrations in this well from 1993 to 1996, the level of TCE in SSC-20 in the final quarter of 1996 was substantially lower than the 1987 level. At the toe of the plume, TCE concentrations have declined to less than 50 µg/L in wells SSC-31, SSC-26, and SSC-27 [7, 8].

TREATMENT SYSTEM PERFORMANCE (CONT.)

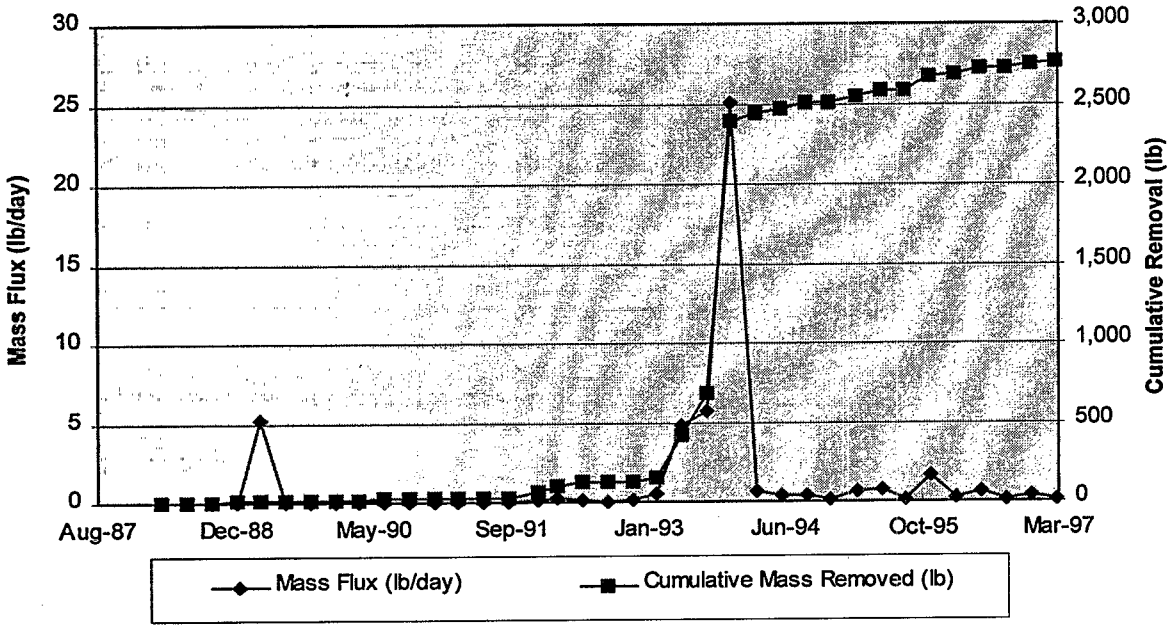


Figure 4. Mass Flux Rate and Cumulative Total Contaminant Removal from March 1988 to March 1997 [7]

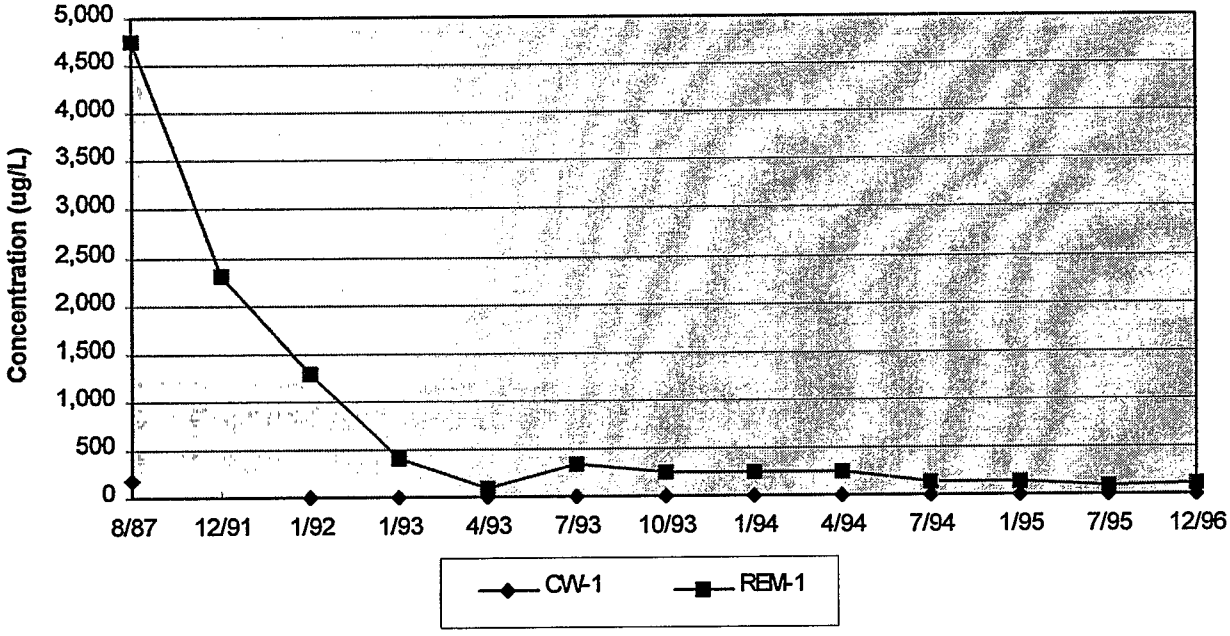


Figure 5. TCE Groundwater Concentrations in DBR Wells, August 1987 to December 1996 [7]

TREATMENT SYSTEM PERFORMANCE (CONT.)

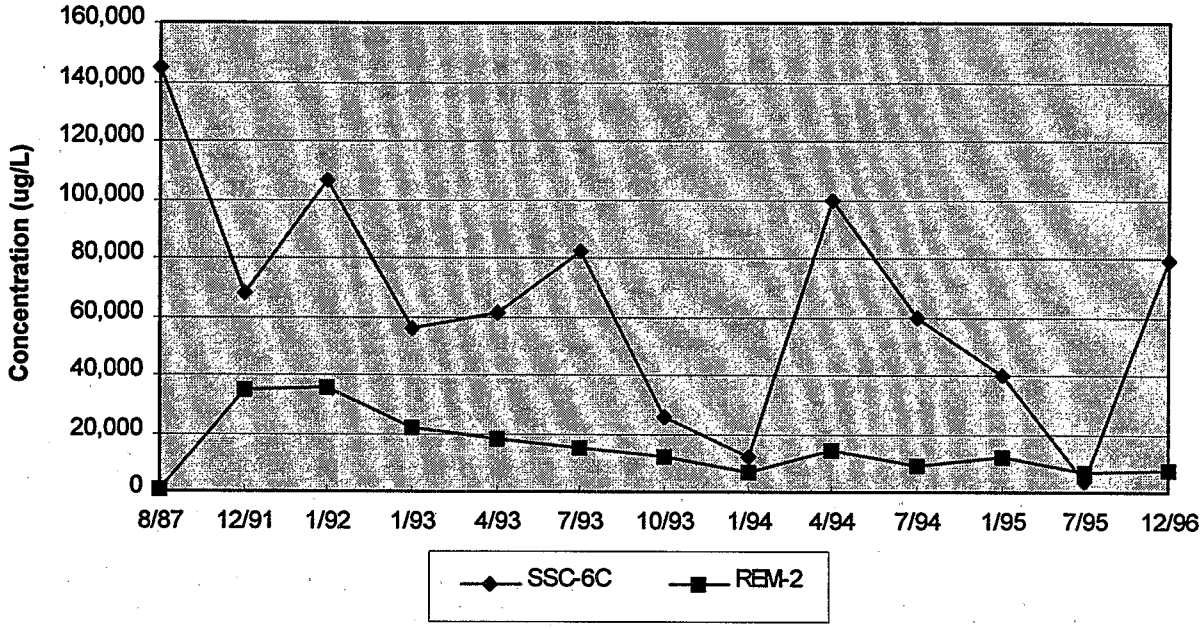


Figure 6. TCE Groundwater Concentrations in SBR Wells, August 1987 to December 1996 [7]

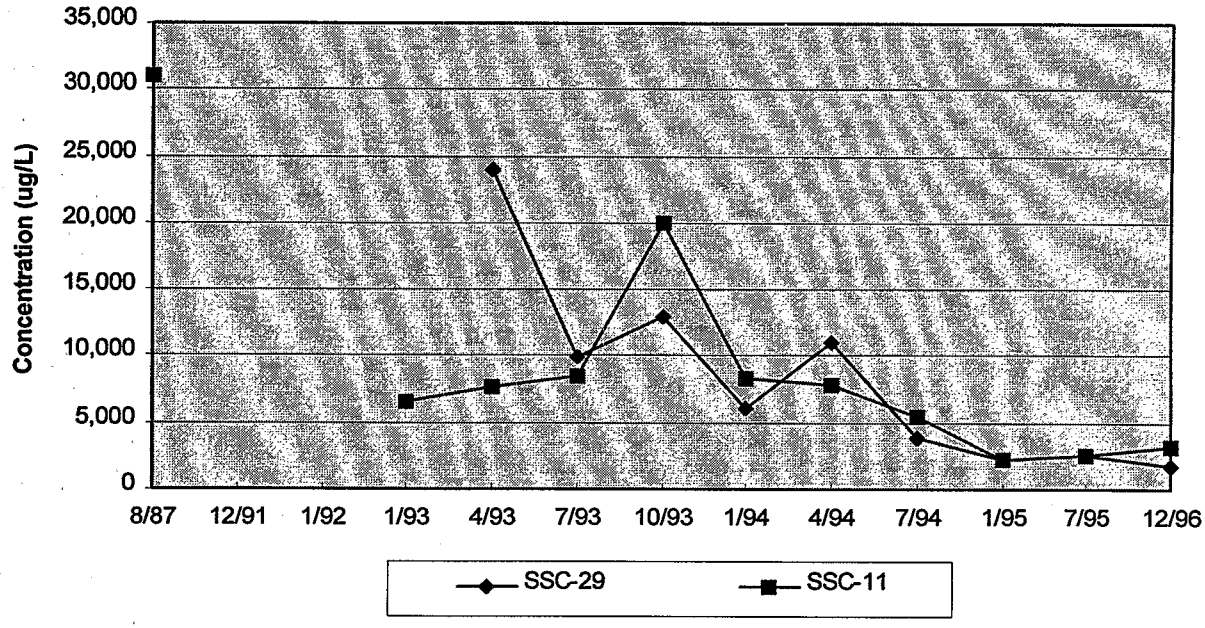


Figure 7. TCE Groundwater Concentrations in UFSB Wells (Source Area), August 1987 to December 1996 [7]

TREATMENT SYSTEM PERFORMANCE (CONT.)

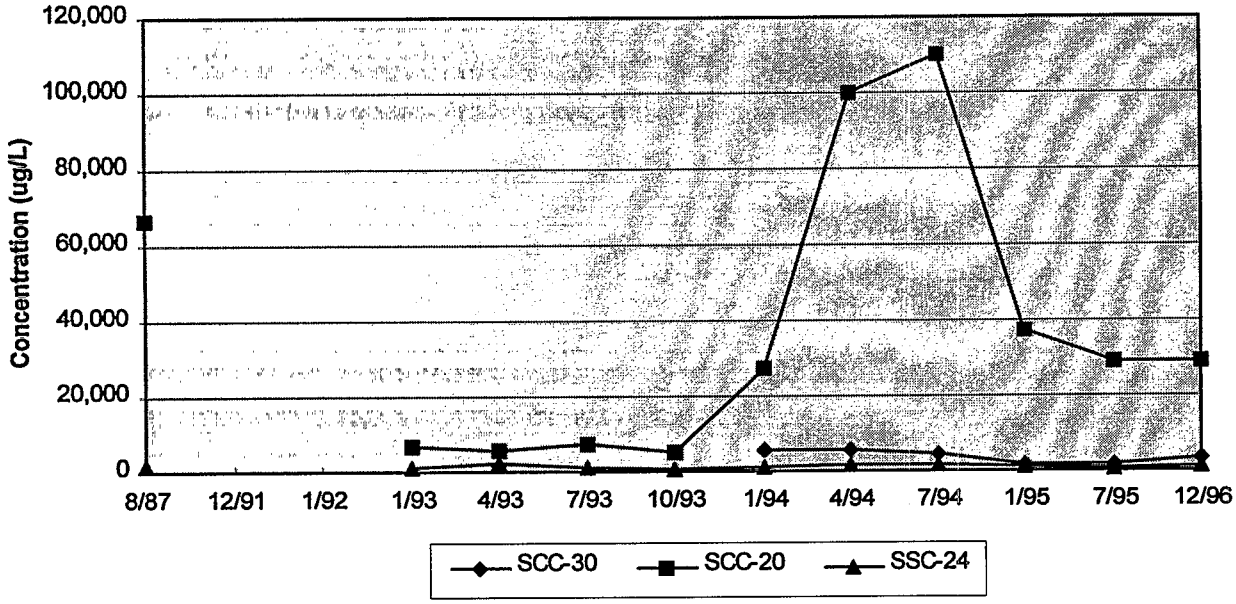


Figure 8. TCE Groundwater Concentrations in UFSB Wells (Mid-Plume Area), August 1987 to December 1996 [7]

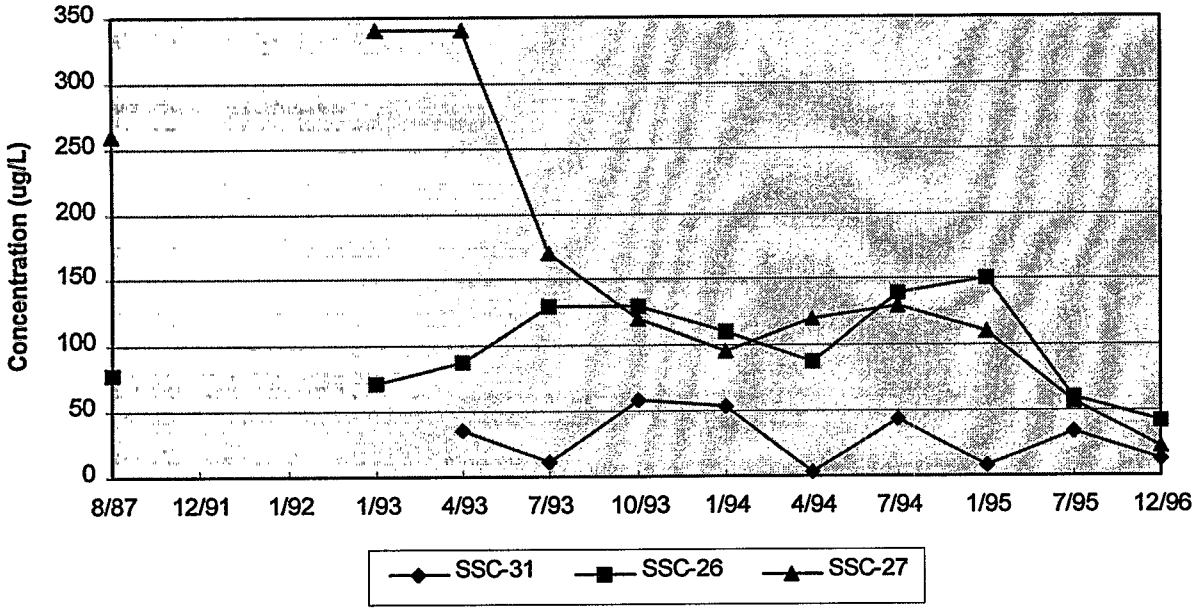


Figure 9. TCE Groundwater Concentrations in UFSB Wells (Toe Area), August 1987 to December 1996 [7]

TREATMENT SYSTEM PERFORMANCE (CONT.)

Performance Data Completeness

- Performance monitoring data are only available for TCE because it is one to three orders of magnitude greater than other constituents and this was chosen as the indicator compound to be monitored. Furthermore, the amount of TCE removed by the POTW is not available. Therefore, the estimated mass removed through the air stripper represents an underestimate of total contamination removed during this remedial action.

- Air stripper influent monitoring data, collected quarterly, are available from January 1993 to the final quarter of 1996; these data were used in Figure 4. To generate data for the period from 1987 to 1993, sporadic monitoring in wells, CW-1 and REM-1 were combined with monthly pumping volumes to generate estimates of contaminant removal in these two wells over this period.

- Groundwater quality was monitored in all wells on a quarterly basis from January 1993 to January 1996. At that time, the monitoring frequency was changed to semi-annual. Data in Figures 5 to 9 represent all available data for the wells shown.

Performance Data Quality

The QA/QC program used throughout the remedial action met the EPA and the State of Missouri requirements. All monitoring was performed using EPA Method 8010, as set out in the Consent Decree, and the site operator did not note any exceptions to the QA/QC protocols. [10]

TREATMENT SYSTEM COST

Procurement Process

Solids States Circuits, and later the Missouri Remedial Action Corporation (MRAC), a company founded by the PRPs at this site (other sites as well), have contracted with a series of companies to construct and operate the remedial system at this site. Presently, the system is being operated by Chatman Associates of Lawrence, Kansas.

Cost Analysis

All costs for design, construction and operation of the treatment system at this site were borne by MRAC.

TREATMENT SYSTEM COST (CONT.)

Capital Costs [6]

Remedial Construction	
Engineering and Site Management	$57,329
DBR/SBR Extraction Wells	Not Available
UFSB Extraction Wells and Piping	$786,085
Air Stripper	
Rental/Purchase	$49,290
Rehabilitation	$40,266
Total Remedial Construction	**$893,666**

Operating Costs [6]

Project Management	$386,000
Data Management	$134,000
Monitoring/Analysis	$282,000
Utilities	$370,700
Periodic Maintenance	$146,600
Reporting	$152,400
Other	$145,600
Cumulative Operating Cost through 6/30/97	$1,616,700

Annual Operating Costs

1992	$104,121.69
1993	$431,410.13
1994	$264,246.69
1995	$272,721.17
1996	$215,832.75
1997	$255,390.00
	$1,543,722.43

Other Costs [6]

Remedial Design	Not Available
EPA/DNR Oversight	$243,771

Cost Sensitivities

- There were no significant changes to the construction scope of work that increased the capital cost by more than 10 percent [5].
- There have been no significant events that have increased or decreased the cost of operations more than was expected [4].

Cost Data Quality

Actual capital and operations and maintenance cost data are available from the responsible party for this application. Limited information on the items included in the total capital costs was provided. The individual costs of remedial design and the installation of the DBR and SBR wells were not available because they were tracked as part of the RI/FS [5].

OBSERVATIONS AND LESSONS LEARNED

- According to the PRP contractor, the remedy, as operated, has eliminated groundwater pathways to human populations and the environment; ensured that municipal water supply operations are not impacted; ensured safe operation of the remediation system during times of high sewer flow; ensured minimal human exposure; and kept annual O&M manpower costs to less than half of what was originally projected. In addition, the PRP contractor noted that the pumping rate for wells in the DBR unit was reduced 80 percent (from 75 gpm to 15 gpm) [11].

OBSERVATIONS AND LESSONS LEARNED (CONT.)

- Project management costs for both construction and operations were about 6 percent of the respective totals. If periodic reporting is included, the percentage rises to 18 percent. This is a relatively low percentage for project management, which can be attributed, in part, to the active role played by the MRAC engineer. [6]

- Total cost for the remedial action at this site were $2,510,400 ($1,616,700 in O&M costs and $893,700 in construction costs) which corresponds to $913 per pound of contaminant removed and $10 per 1,000 gallons treated.

- TCE concentrations in some of the wells have decreased from 1987 to 1996, and are below the cleanup goal in one well; however, TCE concentrations in most wells remain well above the cleanup goal.

- Contaminant removal rates through this system have been relatively low, less than two pounds of contaminant per day, on average. This low rate is largely due to the hydrogeology of the site, which is dominated by tight clay materials and solution-weathered limestone. In both materials, contaminants are difficult to remove [5].

- TCE levels in CW-1, the first well to be contaminated, declined rapidly after the original extraction system came online. The site engineer stated that pumping in CW-1 prior to the RI had established groundwater flow paths that drew contamination from the basement dry well towards CW-1. Once the source removal actions were complete, the dissolved contamination remaining between the source area and CW-1 defined a narrow path that was rapidly remediated by pumping CW-1 [5].

- The site engineer believes that DNAPL is not likely to be present at the site. No DNAPL has ever been identified, despite several extensive groundwater assessments. However, concentrations in several wells remain high, and in some wells are presently higher than 1 percent of the solubility limit for TCE.

- To enhance the remedial effort, site operators are evaluating innovative technologies at the time of this report. They are considering installing an air sparging system using a horizontal well in the fracture zone of the UFSB. Placement of the horizontal well along the fracture zone would force the groundwater pressure gradients towards the SBF extraction wells in the highest part of the plume, enhancing VOC removal from the groundwater in that stage of the plume. The well would be designed and constructed for two other uses: as a nutrient injection well to enhance natural bioremediation in the fracture system, and as an air sparging well.

- According to the site engineer, institutional constraints that restricted the operator's ability to use reinjection at this site may have increased the time required for site remediation more than any other single factor [11].

REFERENCES

1. Record of Decision for Solid States Circuits, Republic, MO, U.S. Environmental Protection Agency. July 1989.

2. Remedial Investigation Report for the Republic, Missouri Site, Geraghty & Miller. June 1989.

3. Remedial Design Report for the Republic, Missouri Site, McLaren/Hart Environmental Engineering Corporation. October 1992

4. Communications with Chatman Associates. June 18, 1997.

5. Communications with Greg Vierkant, Lucent Technologies, June 24-25, 1997.

6. Five Year Review Report, Solid States Circuits, Republic, Missouri, Missouri Department of Natural Resources. September 1996.

7. Electronic Spreadsheet for Remedial Costs. MRAC, Inc. 1993-1997.

8. Electronic Spreadsheet for System Operation. Missouri Remedial Action Corporation, Inc. 1993-1997.

9. 1996 Annual Report for the Republic Missouri Site. Chatman and Associates, Inc. January 1997.

10. Supplemental Shallow Ground-Water Investigation Tasks: Remedial Investigation/Feasibility Study. Geraghty & Miller, Inc. April 1988.

11. Correspondence from Steve Chatman, Chatman & Associates, Inc., June 23, 1998.

Analysis Preparation

This case study was prepared for the U.S. Environmental Protection Agency's Office of Solid Waste and Emergency Response, Technology Innovation Office. Assistance was provided by Eastern Research Group, Inc. and Tetra Tech EM Inc. under EPA Contract No. 68-W4-0004.

Pump and Treat of Contaminated Groundwater at the Sol Lynn/Industrial Transformers Superfund Site, Houston, Texas

Pump and Treat of Contaminated Groundwater at the Sol Lynn/Industrial Transformers Superfund Site, Houston, Texas

Site Name: Sol Lynn/Industrial Transformers Superfund Site	**Contaminants:** Chlorinated solvents - Maximum concentration of TCE detected in 1988 was 1,200 mg/L	**Period of Operation:** Status: Ongoing Report covers: 10/93 - 10/96
Location: Houston, Texas		**Cleanup Type:** Full-scale cleanup (interim results)
Vendor: Clearwater Systems, Inc. P.O. Box 822 New Caney, TX 77357 (713) 399-1980 **Installation, Startup, and Operation Subcontractor:** Maxim Technologies, Inc.	**Technology:** Pump and Treat - Groundwater is extracted using 12 wells at an average total pumping rate of 8 gpm - Extracted groundwater is treated with filtration (for iron), pH adjustment, air stripping, carbon adsorption, and filtration - Treated groundwater is reinjected through 14 wells	**Cleanup Authority:** CERCLA Remedial - ROD Date: 9/23/88
State Point of Contact: James Sher TNRCC, Mail Code 144 12100 Park Circle Austin, TX 78753 (512) 239-2444 **Site Management:** John Kovski Radian International LLC 9801 Westheimer, Suite 500 Houston, TX 77042 (713) 914-6426		**EPA Point of Contact:** Ernest R. Franke, RPM U.S. EPA Region 6 1445 Ross Ave., Suite 1200 Dallas, TX 75202-2733 (214) 665-8521
Waste Source: Disposal of punctured trichloroethene drums on the ground surface	**Type/Quantity of Media Treated:** Groundwater - 13 million gallons treated as of October 1996 - DNAPL was suspected in groundwater at this site - Groundwater is found at 20-25 ft bgs - Extraction wells are located in 3 aquifers - Hydraulic conductivity ranges from 0.14 to 25.5 ft/day	
Purpose/Significance of Application: Relatively high unit cost for treatment, due to high capital costs and small quantity of groundwater extracted.		
Regulatory Requirements/Cleanup Goals: - A remedial goal was established for TCE of 5 ug/L, based on the maximum contaminant level, that must be met throughout all affected aquifers. - A goal for the extraction system is hydraulic containment of the plume.		

Pump and Treat of Contaminated Groundwater at the Sol Lynn/Industrial Transformers Superfund Site, Houston, Texas (continued)

Results:

- From 1994 to 1996, concentrations of contaminants were reduced in some wells, but remain above the cleanup goal in the silty, shallow, and intermediate zone wells. In some shallow zone wells, concentrations have increased to higher than 1,000 ug/L over this period. Through 1996, approximately 4,960 pounds of contaminants have been removed from the groundwater. Further plume delineation was being performed at the time of this report.
- Hydraulic containment of the plume has not been achieved, according to the TNRCC manager.

Cost:

- Actual costs for pump and treat were $2,547,387 ($2,104,910 in capital and $442,477 in O&M), which correspond to $196 per 1,000 gallons of groundwater extracted and $514 per pound of contaminant removed.

Description:

Sol Lynn owned and operated this site as Industrial Transformers, a scrap metal and electrical transformer reclamation facility, from 1971 through 1978. Sol Lynn then leased the property to Ken James, who operated the site as Sila King, Inc., a chemical supply business, in 1979 and 1980. During the fall of 1971, the city of Houston Water Pollution Control Division discovered that workers at Industrial Transformers poured oil out of electrical transformers onto the ground during transformer dismantling. In 1981, reports of strong odors originating from the site were brought to the attention of the Texas Department of Water Resources. Upon inspection, approximately 75 punctured drums were found scattered about the property. A remedial investigation conducted from 1984 through 1991 showed elevated levels of PCBs in surficial soils and TCE in shallow soils and groundwater, and that the plume had migrated off site. The Sol Lynn/Industrial Transformer site was listed on the NPL in March 1989 and a ROD was signed in September 1988.

The extraction system used at this site consists of 12 wells - five wells in the silty zone, six wells in the shallow sand zone, and one well in a lower, intermediate aquifer. Eight of the 12 wells are located across the centerline of the plume along the site's northern boundary. This placement serves to intercept contaminated groundwater as it moves across the site and to draw back the off-site plume. As of 1996, concentrations of contaminants were reduced in some wells, but remain above the cleanup goal in the silty, shallow, and intermediate zone wells. Although remediation is not complete, the site engineers shut down the extraction system in October 1996. Extraction well pipes were leaking and fouled, and the extraction system lost plume containment. Currently, the site is being reevaluated. Aquifer usage, alternative remedial actions, and plume boundaries are being examined.

SITE INFORMATION

Identifying Information:

Sol Lynn/Industrial Transformers Superfund Site
Houston, Texas

CERCLIS #: TXD980973327

ROD Date: September 23, 1988

Treatment Application:

Type of Action: Remedial

Period of operation: October 1993 - October 1996
(Performance data collected through October 1996)

Quantity of material treated during application: 13 million gallons of contaminated groundwater.

Background

Historical Activity that Generated Contamination at the Site: Chemical recycling and supply

Corresponding SIC Code: 2869

Waste Management Practice That Contributed to Contamination: Disposal of punctured trichloroethylene drums on the ground surface

Location: Houston, Texas

Facility Operations: [1, 2, 3, 4, 5]

- Mr. Sol Lynn owned and operated the site as Industrial Transformers, a scrap metal and electrical transformer reclamation facility, from 1971 through 1978. Sol Lynn then leased the 3/4-acre property to Ken James, who operated the site as Sila King, Inc., a chemical supply business, in 1979 and 1980 [1,2].
- The first documented investigation of this site took place during the fall of 1971 when the City of Houston Water Pollution Control Division discovered that workers at Industrial Transformers poured oil out of electrical transformers onto the ground during transformer dismantling. In 1981, strong odors originating from the site were brought to the attention of the Texas Department of Water Resources, the predecessor of the Texas Water Commission (TWC). Upon inspection, approximately 75 drums were found scattered about the property. Most of the drums, labeled "Trichloroethylene" (TCE), were empty and had puncture holes [2].
- A remedial investigation (RI) and feasibility study was performed from December 26, 1984 through February 21, 1991. Remedial design was performed from June 22, 1989 through August 26, 1992 [2].
- The results of the RI showed elevated levels of polychlorinated biphenyl (PCB) in surficial soils and TCE in shallow soils and groundwater [3]. The RI also showed that the plume had migrated off site [3].
- An unidentified silty water-bearing unit was discovered and investigated in 1991, concurrent with groundwater remedial design activities. Groundwater samples taken in this zone as part of a Field Investigation of the Silty Zone Report revealed high concentrations of TCE, the highest of which was 1,200 mg/L [4].
- Approximately 2,400 cubic yards of soil, which included all soils with PCB contamination of 25 mg/kg or greater, were excavated and treated in a dechlorination unit for source control in late 1992. Treated soils were disposed of in an off-site landfill [5].
- The Sol Lynn/Industrial Transformer Superfund Site was listed on the National Priorities List (NPL) March 31, 1989 [1].

SITE INFORMATION (CONT.)

Background (Cont.)

Regulatory Context:

- A Record of Decision (ROD) was signed for this site on September 23, 1988.
- Site activities are conducted under provisions of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980, as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA) §121, and the National Contingency Plan (NCP), 40 CFR 300.

Groundwater Remedy Selection:

- The selected groundwater remedy for this site is extraction and treatment via air stripping and carbon adsorption. Air stripper exhaust is treated through vapor-phase carbon adsorption to meet Texas air quality criteria.

Site Logistics/Contacts

Site Lead: State

Oversight: EPA

Remedial Project Manager:
Ernest R. Franke
U.S. EPA Region 6
1445 Ross Ave., Ste. 1200
Dallas, TX 75202-2733
(214) 665-8521

State Contact:
James Sher*
Texas Natural Resources Conservation Commission (TNRCC), Mail Code 144
12100 Park Circle
Austin, Texas 78753
Phone: (512) 239-2444
FAX: (512) 239-2450

*Indicates primary contacts

Installation, Startup, and Operation Subcontractor:
Maxim Technologies, Inc.
(previously named Huntingdon Engineering and Environmental, Inc. and Southwest Laboratories, Inc.)

Treatment System Vendor:
Clearwater Systems, Inc.
P.O. Box 822
New Caney, Texas 77357
(713) 399-1980

Site Management:
John Kovski*
Radian International LLC
(formerly Radian Corporation)
9801 Westheimer, Ste. 500
Houston, TX 77042
(713) 914-6426

MATRIX DESCRIPTION

Matrix Identification

Type of Matrix Processed Through the Treatment System: Groundwater

MATRIX DESCRIPTION (CONT.)

Contaminant Characterization [3, 4, 20]

Primary Contaminant Groups: Halogenated volatile organic compounds

- The on-site groundwater is contaminated with TCE. In 1988, during the remedial investigation site sampling of the shallow and intermediate aquifer zones, the maximum concentration of TCE detected in groundwater on site was 600 mg/L. An off-site maximum TCE concentration of 790 mg/L also was detected during this sampling episode [3]. During the field investigation of the silty zone, the maximum concentration of TCE detected in the groundwater was 1,200 mg/L [4].
- While free product was not observed, according to the Silty Zone Investigation report, the high dissolved concentrations of TCE detected at the site suggest that residual TCE product, a dense non-aqueous phase liquid (DNAPL), exists in the aquifer material. This residual TCE is most likely adsorbed in the interstitial spaces of the aquifer matrix, rather than pooled as a free-phase DNAPL at the base of the zone [4].
- The EPA Region 6 Fact Sheet reports that 4.2 million gallons of groundwater are contaminated with site wastes; groundwater contamination in the 90-foot zone has not been determined [2]. Figures 1 and 2 are contour maps which depict the silty and shallow sand zone groundwater contamination during design sampling episodes [3, 4].

Matrix Characteristics Affecting Treatment Costs or Performance

Hydrogeology [2,3,4, 8]:

Groundwater is found at this site in two distinct zones -- the Upper Aquifer and the Lower Aquifer. The Upper Aquifer is composed of two units: a discontinuous perched zone, called the Silty Zone (Unit 1), and the Shallow Sand Zone (Unit 2). Neither serves as a known supply of drinking water. The groundwater flows in a northwesterly to westerly direction and is encountered at approximately 20 to 25 feet below land surface. Both aquifers are composed of similarly sandy material, resulting in relatively homogeneous flow conditions. The three water-bearing units are described below:

Unit 1	Silty Zone	A layer of silty clay with low yield. This unit is not continuous across the site.
Unit 2	Shallow Sand Zone	A layer of water-bearing sand with sand content varying from 50% to 70 percent. This unit is underlain by a stiff clay layer. Investigations in March 1998 revealed an additional sandy layer beneath this layer. No further characterization was available on the newly discovered sand layer.
Unit 3	Intermediate Aquifer	A layer of water-bearing sand that is underlain by a thick clay layer.

MATRIX DESCRIPTION (CONT.)

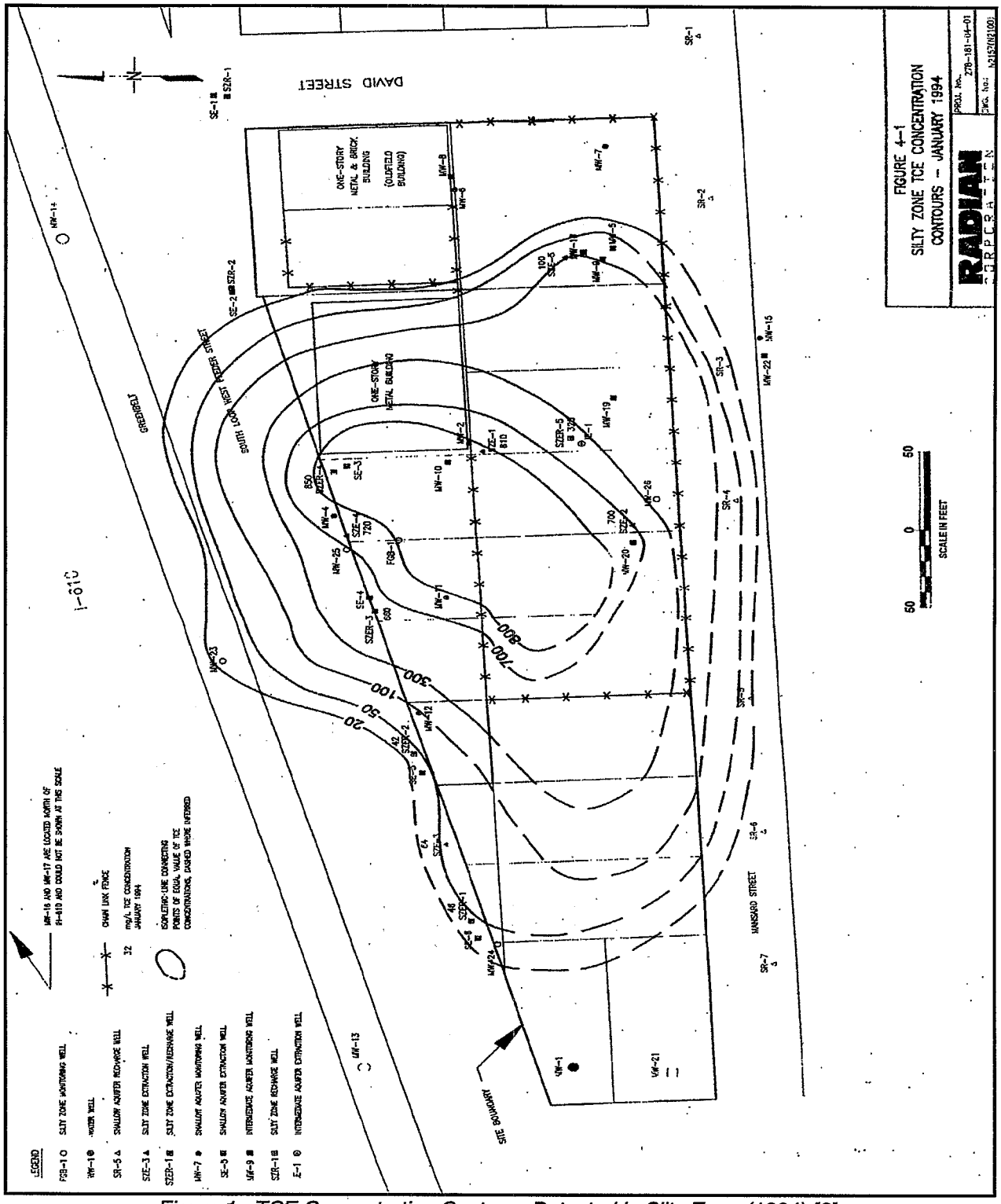


Figure 1. TCE Concentration Contours Detected in Silty Zone (1994) [3]
(Best Copy Available)

MATRIX DESCRIPTION (CONT.)

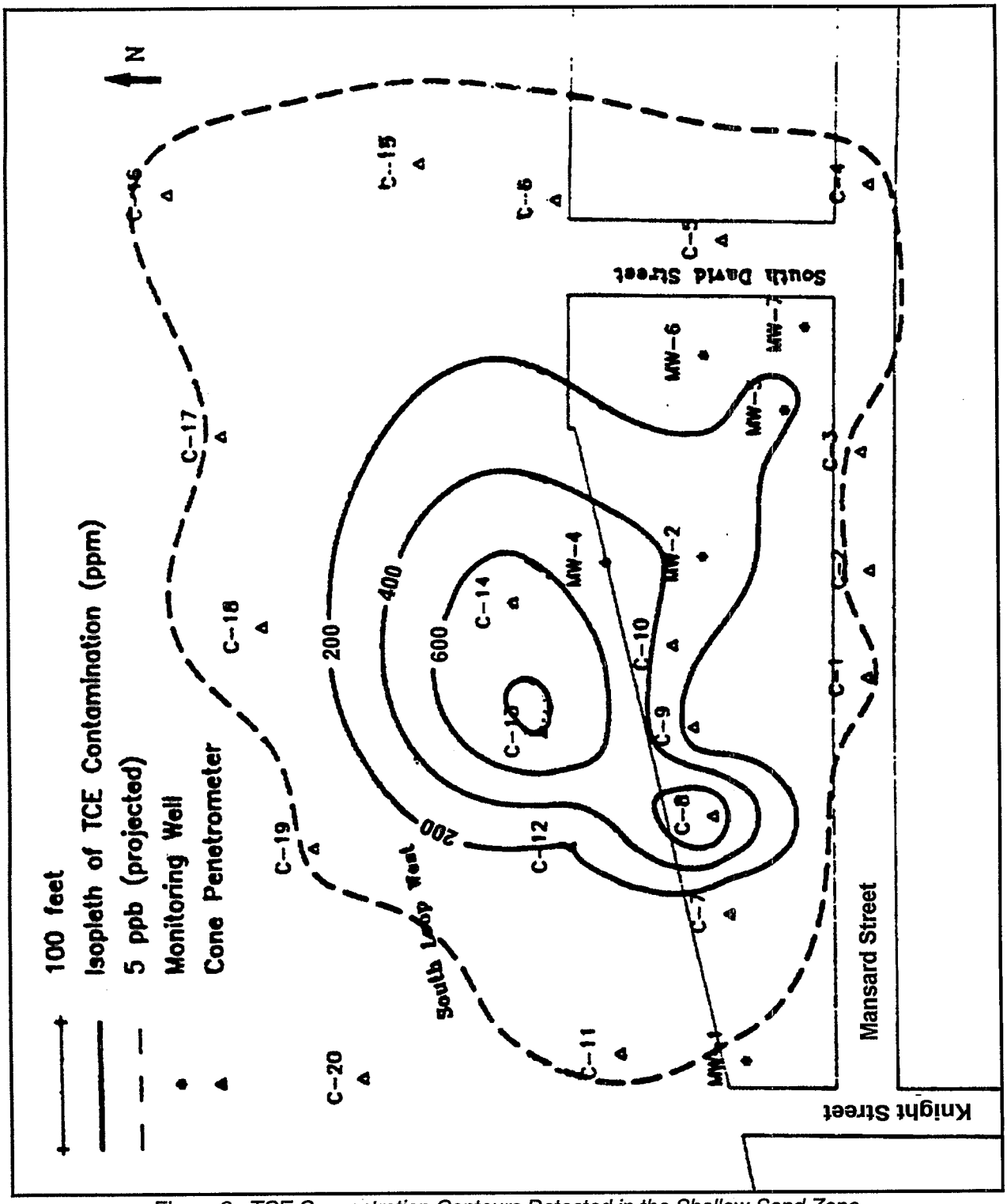


Figure 2. TCE Concentration Contours Detected in the Shallow Sand Zone (February 1991, Best Copy Available) [3]

MATRIX DESCRIPTION (CONT.)

Tables 1 and 2 provide technical aquifer information and extraction well data, respectively.

Table 1. Technical Aquifer Information

Unit Name	Average Depth (ft)	Thickness (ft)	Conductivity (ft/day)	Average Velocity (ft/year)	Flow Direction
Silty Zone	20	5-10	3.8	10.5	Northwest
Shallow Sand Zone	35	2-12	25.5	106	Northwest
Intermediate Aquifer	80	11	0.14	NA	West

NA - The average velocity of the groundwater in the lower aquifer is not available.
Source: [2]

TREATMENT SYSTEM DESCRIPTION

Primary Treatment Technology

Pump and treat with air stripping and liquid-phase carbon adsorption

Supplemental Treatment Technology

Vapor-phase carbon adsorption

System Description and Operation [3, 4, 20]

Table 2. Extraction Well Data

Well Name	Unit Name	Depth (ft)	Design Yield (gal/min)
SZE-1 through SZE-5	silty zone	25	0.5-5.0
SZR-1 through SZR-2	silty zone	25	0.5-5.0
SZER-1 through SZER-5	silty zone	25	0.5-5.0
SE-1 through SE-6	shallow sand zone	40	3-10
SR-1 through SR-7	shallow sand zone	40	3-10
IE 1	intermediate aquifer	92	3-10

Note: Extraction well designations end in "E," recharge well designations end in "R."

Source: [2]

TREATMENT SYSTEM DESCRIPTION (CONT.)

System Description and Operation (Cont.)

System Description [6]

- The recovery system is designed to maintain hydraulic control over the contaminant plume. The system includes five wells in the silty zone, six wells in the shallow sand zone, and one well in the lower aquifer, as listed in Table 2. Eight of the 12 wells are located across the centerline of the plume along the site's northern boundary. This placement serves to intercept contaminated groundwater as it moves across the site and to draw back the off-site plume. The remaining extraction wells in the upper aquifer are installed in the silty zone along or near the center line of the plume. The single extraction well installed in the intermediate aquifer is placed near the center of the plume.

- A groundwater model, MODFLOW, was used to identify well placement and extraction rates. The possibility of ground settlement as a result of dewatering in the silty zone supported the use of a groundwater model for well placement and designing extraction rates.

- Groundwater treatment consists of air stripping and carbon polishing. To minimize fouling in the air stripper packing, an iron filter and pH adjustment unit were installed up stream of the air stripper. The iron filter consists of two parallel tanks filled with Pyrolox media. Hydrochloric acid is added to lower the pH to inhibit the formation of mineral salts in the stripper.

- The 15 foot high, 36 inch diameter air stripper tower is filled with polypropylene packing. The air stripper removes the majority of the volatile organic contaminants in the water.

- After air stripping, liquid-phase carbon absorption is used to remove the remaining volatile and nonvolatile organic contaminants in the water. Two activated carbon adsorption columns are operated in series; each contains 80 cubic feet of activated carbon.

- Filters remove suspended solids above 0.45 micron size from the treated groundwater prior to recharge or on-site release.

- The secondary treatment system consists of activated carbon adsorption of the volatile organic contaminants in the off gas from the air stripper. Two activated carbon columns are operated in series; each holds 60 cubic feet of activated carbon.

- The groundwater reinjection system consists of 14 recharge wells, seven wells in the silty zone and seven wells in the shallow sand zone. Groundwater was designed to be reinjected at approximately 60 gpm, which is consistent with the design extraction rate.

- The groundwater monitoring system consists of 20 monitoring wells: five wells in the silty zone, eight wells in the shallow sand zone, and seven wells in the intermediate zone.

System Operation [12, 14, 19, 20]

- Quantity of groundwater pumped from aquifer in gallons:

Volume Pumped (gallons)

Year	Silty Zone	Shallow Aquifer	Intermediate Aquifer
1993	Not available	Not available	Not available
1994	347,962	630,791	2,858,755
1995	744,024	3,955,502	7,576,419
1996	113,880	1,559,517	2,256,088

Source: [14]

- The remedial action strategy at this site employed a two-phase approach. During Phase I, groundwater was extracted from the silty and intermediate zones. Treated groundwater was discharged to the local publicly owned treatment works (POTW). This pumping strategy was intended to reduce or eliminate contamination migration from the silty zone into the shallow zone. The Phase II pumping strategy shifted extraction to the shallow and the

TREATMENT SYSTEM DESCRIPTION (CONT.)

System Description and Operation [3, 4, 20]

intermediate zones. Treated groundwater was recharged through seven silty zone and seven shallow zone wells [4]. The decision to start Phase II operations was made based on evaluation of the contamination levels and the groundwater levels in the silty zone. The reduction in contamination levels from Phase I operations had leveled off and further reductions in the groundwater level would be unproductive [19].

- As of March 1996, the site engineer reported that system had been approximately 69% operational. More recent information on operational status was not available [12].
- The RI did not identify contamination in the Silty Zone. As a result, construction and design were altered after the later investigation of the silty zone found contamination.
- During operation, site engineers were unable to achieve design extraction rates, and pumping rates were low.
- Although remediation is not complete, the site engineers shut down the extraction system in October 1996. Extraction well pipes were leaking and fouled, and the extraction system lost plume containment.
- Currently, the site is being reevaluated. Aquifer usage, alternative remedial actions, and plume boundaries are being examined. The redesign for the piping system and electrical distribution system was completed in January 1998 and the bid was opened in April 1998 [20].

Operating Parameters Affecting Treatment Cost or Performance

The groundwater extraction rate is the major operating parameter affecting cost or performance for this technology. Table 3 presents the values for all performance parameters.

Table 3: Performance Parameters

Parameter	Value
Average Pump Rate	8 gpm*
Effluent Performance Standard (POTW and Recharge)	TCE (5 ppb)
Cleanup Goal	TCE (5 ppb)
Air Emission Limit	TCE (0.4 lbs/hr)

Source: [1,6]
*Based on 13 million gallons of groundwater pumped and a 69% operation rate over three years.

TREATMENT SYSTEM DESCRIPTION (CONT.)

Timeline

Table 4 presents a timeline for this remedial project.

Table 4: Project Timeline

Start Date	End Date	Activity
9/23/88	---	Record of Decision approved
6/22/89	8/26/92	Design of remediation system
8/92	10/93	Remedial construction
10/8/93	---	Begin Phase I Remedial Operations
10/12/94	---	Begin Phase II Remedial Operations
10/96	ongoing	Site shutdown for redesign

Source: [1, 2, 11]

TREATMENT SYSTEM PERFORMANCE

Cleanup Goals/Standards [1]

The remedial goal for TCE in the groundwater is the maximum concentration limit (MCL) of 5 µg/L, set under the Safe Drinking Water Act. This goal must be met throughout all aquifers.

Treatment Performance Goals [3, 4]

- The goal of the extraction system is hydraulic containment of the plume.
- The performance goal for the treatment system is to meet the effluent standard of 5 ppb for TCE in recharge.
- The air emission limit from the vapor phase carbon filter is 0.4 lbs/hr, or 30 ppmv, for TCE as measured at the vent stack.

Performance Data Assessment [8, 14, 15, 16, 19, 20]

- After two years of operation, concentrations of TCE in most areas of the plume remained above remedial goals; overall concentrations in the lower aquifer have been below goals but exceeded goals on a periodic basis [15].
- Figure 3 shows TCE concentrations in the silty zone wells from August 1994 to October 1996. These data show that average TCE concentrations in the silty zone declined in all wells. However, the decline varied from well to well, and by October 1996, TCE levels in the silty zone still exceeded 100,000 µg/L in two of these wells. In three wells, concentrations had dropped below 70,000 µg/L, with the lowest concentration recorded at 32,650 µg/L [15].
- Figure 4 presents TCE concentrations in shallow sand zone wells over the same period. During the first three months of Phase II operations (beginning October 1994) TCE concentrations rose in four of the five wells, including rapid increases in SE-3 and SE-4. In December 1994,

concentrations in SE-4 had risen to more than 500,000 µg/L. However, by late 1995 and early 1996, a discernable downward trend emerged. By October 1996, concentrations in the two shallow zone wells with the highest levels of TCE remained in excess of 200,000 µg/L while concentrations in SE-1 and SE-2 were 136 µg/L and 2,920 µg/L, respectively [15].

- Figure 5 shows TCE concentrations in the single intermediate aquifer well from August 1994 to October 1996. Over much of this period, TCE concentrations remained below the remedial goal of 5 µg/L, with the exception of short periods in the late summer of 1994 and 1996, when concentrations increased to 34 µg/L and 72 µg/L, respectively [14].

- Concentrations of contaminants increased in the lower aquifer and the newly discovered sandy layer after pumping began, indicating connectivity between the shallow zone and these layers.

- Hydraulic containment of the plume has not been achieved, according to the TNRCC manager [16].

- Influent concentrations of TCE were consistently reduced by the treatment system to levels below the 5 µg/L remedial goal [15].

- Concentrations of TCE in air emissions have not exceeded the 0.4 lb/hr limit specified in the air permit during remedial operations [16].

- Figure 6 presents the removal of contaminants through the treatment system from 1993 to 1996. Over this period, the pump and treat system has removed approximately 4,960 pounds of contaminant mass from the groundwater [8]. Contaminant removal rates reported in annual performance reports have fluctuated; however, the trend of the contaminant removal rate declines from 7.1 lbs/day in July 1995 to 1.8 lbs/day in October 1996 [8].

- From 1993 to 1996, a total of 13 million gallons of groundwater were treated. Taking into account the hours of system operation, the average treatment rate is 12,000 gpd [8].

Performance Data Completeness

- Contaminant mass removal information is available in monthly reports for the period December 1993 through October 1996. Figure 6 incorporates these data.

- Water level measurements and influent concentrations were collected on a biweekly basis over the period from December 1993 through October 1996.

- Groundwater concentration data were available for all extraction wells and five silty zone recharge wells for the period August 1994 through October 1996. These data were used to calculate the three-month rolling averages shown in Figures 3 through 6. A rolling average was used to smooth out for graphical purposes the extreme variation present in the monthly data.

Performance Data Quality

The QA/QC program used throughout the remedial action met the EPA and the State of Texas requirements. All monitoring was performed using EPA-approved methods, and the vendor did not note any exceptions to the QA/QC protocols.

TREATMENT SYSTEM PERFORMANCE (CONT.)

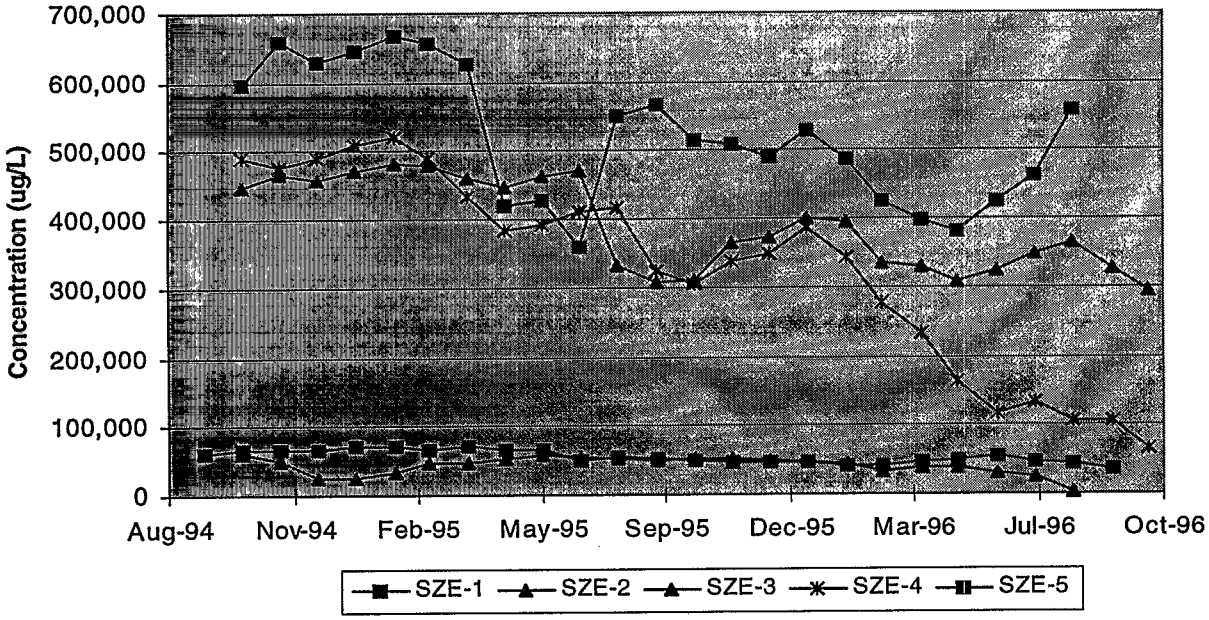


Figure 3. TCE Concentrations in Silty Zone Wells (August 1994 - October 1996) [15]

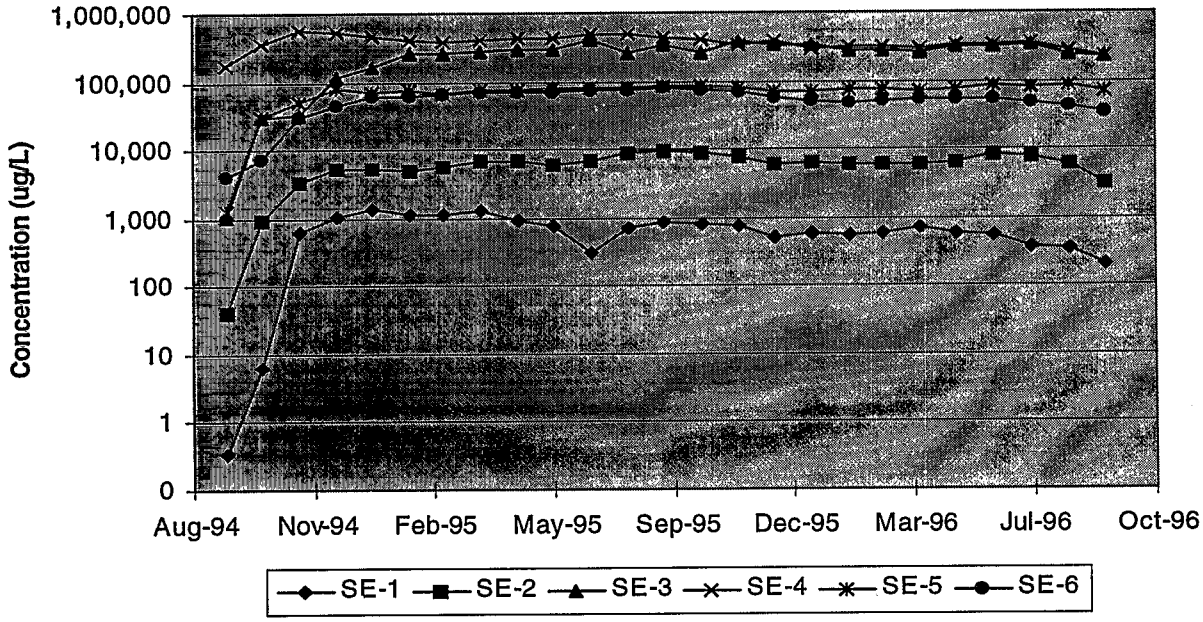


Figure 4. TCE Concentrations in Shallow Zone Wells (August 1994 - October 1996) [15]

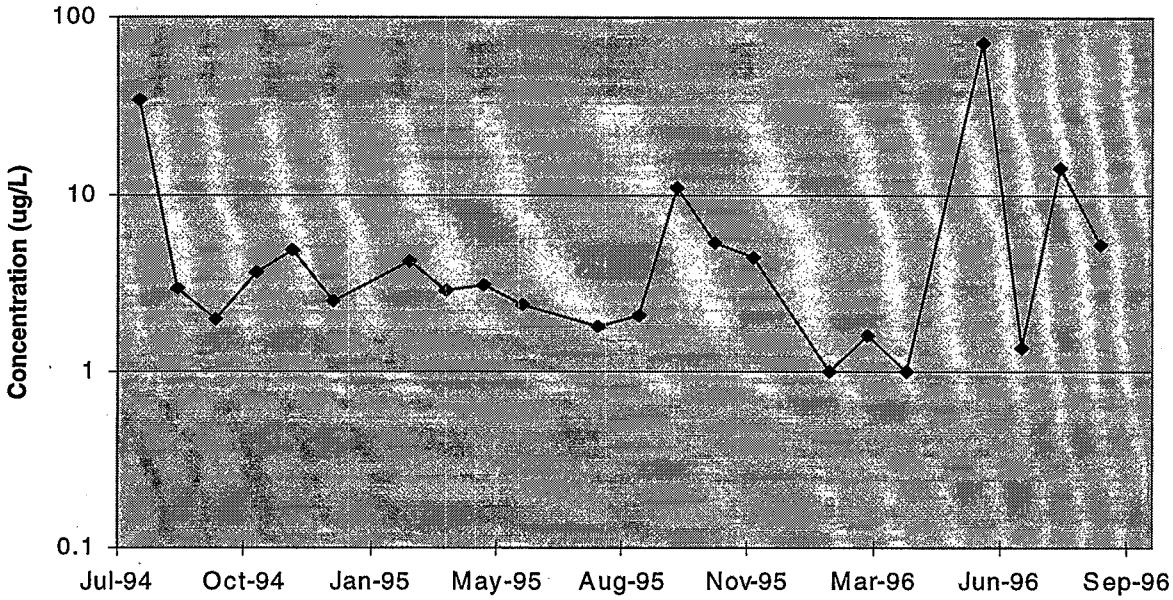


Figure 5. TCE Concentrations in Intermediate Zone Wells (August 1994 - September 1996) {15}

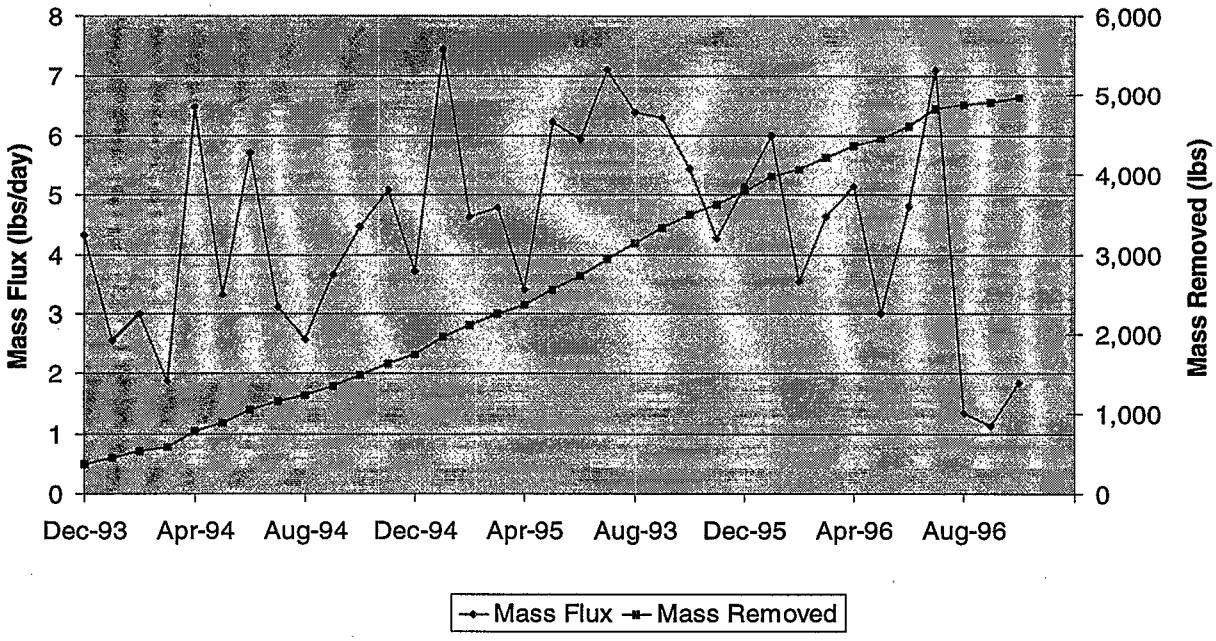


Figure 6. Mass Flux Rate and Cumulative Containment Removal (December 1993 - October 1996) [15]

TREATMENT SYSTEM COST

Procurement Process

Texas Natural Resource Conservation Commission is the lead at this site. Radian International LLC (formerly Radian Corporation) is responsible for oversight of the Sol Lynn site. Maxim Technologies, Inc., was the installation, startup, and operation contractor through April 1997. (Maxim Technologies, Inc. was previously operated as Huntingdon Engineering and Environmental, Inc. and as Southwest Laboratories, Inc.)

Cost Analysis

All costs for investigation design, construction and operation of the treatment system at this site were shared by EPA and the TNRCC.

Capital Costs [9,11,14]

Remedial Construction	
Mobilization and Preparatory Work	$351,275
Monitoring, Sampling, Analysis	$8,759
Fences, Gates, etc.	$26,106
Groundwater Collection and Control	$712,971
Treatment System	$359,526
Site Security	$58,941
Construction Management and Engineering	$348,446
Other	$238,886
Total Remedial Construction	**$2,104,910**

Operating Costs [14]

1993 Operations and Maintenance Costs	$59,443
1994 Operating and Maintenance Costs	$173,517
1995 Operating and Maintenance Costs	$123,511
1996 Operating and Maintenance Costs	$86,006
Total Cumulative Operating Costs	**$442,477**

Other Costs [10]

Remedial Investigation	**$750,030**
Remedial Design	
Design	$490,490
Analytical	$7,016
TNRCC Review	$4,300
Technical Support	$102,452
Total Design	**$614,305**
EPA Oversight	$114,446

Cost Data Quality

Actual capital and operations and maintenance cost data are available from TNRCC and Radian International for this application.

OBSERVATIONS AND LESSONS LEARNED

- Total actual cost to date for the pump and treat system at the Sol Lynn/Industrial Transformers site was $2,547,387 ($2,104,910 in capital and $442,477 in operations and maintenance), which corresponds to $196 per 1,000 gallons of groundwater treated and $514 per pound of contaminant removed [14].
- The treatment system has removed 4,960 pounds of volatile organic compounds from the groundwater over three years. However, after two years of pump and treat system operation at Sol Lynn, TCE concentrations remain above the remedial goal of 5 µg/L. Data from the silty and the shallow sand zones show concentrations above 100,000 µg/L. While TCE concentrations in the intermediate aquifer have generally remained below the remedial goal, concentrations increased above the goal during the summer of 1996 [15].

OBSERVATIONS AND LESSONS LEARNED (CONT.)

- Monthly sampling in monitoring wells downgradient of the capture zone showed an increase in TCE concentrations in groundwater after August 1996, indicating that the plume had extended beyond the capture zone. Therefore, the system was shut down in October 1996 for redesign. System redesign was completed in January 1998. Further plume delineation was being performed at the time of this report [15, 16].
- The site characterization performed during the RI did not identify silty zone contamination. As a result, problems were encountered with the original design. The design and construction had to be modified after the Remedial Design was completed [2].

REFERENCES

1. Record of Decision, U.S. Environmental Protection Agency, September 1988.
2. ITS Remedial Action Interim Report, Volume 1. Radian Corporation. February 1995.
3. Feasibility Study Report Phase II. Radian Corporation. 1994.
4. Field Investigation of the Silty Zone Report. Radian Corporation. 1992.
5. Industrial Transformer Site Remedial Design Report - Volume II: Soil Dechlorination Treatment. ENSR Consulting and Engineering, June 1991.
6. Operation & Maintenance Manual. Huntingdon Engineering & Environmental, Inc. February 1995.
7. Industrial Transformer Superfund Site Remedial Action Oversight Contract Monthly Status Reports, Radian Corporation. October 1993 - September 1995, November 1995 - January 1996, March 1996.
8. Remedial Action Oversight Contract Annual Status Reports. Radian Corporation. 1994-1996.
9. Change Order #15. TNRCC. April, 1997.
10. Remedial Design Phase Invoice History. Radian Corporation. 1989-1991.
11. Groundwater Remedial Oversight Invoice History. Radian Corporation. 1992-1994.
12. Personal Communication with James Sher, TNRCC, June 17, 1997.
13. Personal Communication with John Kovski, Radian Corporation, June 3, 1997.
14. Remedial Action Invoice History. Southwest Labs Environmental Services. January 1993-August 1993.
15. Monthly Reports. Radian Corporation. August 1994 to November 1996.
16. Personal Communication with James Sher, TNRCC. April 11, 1997.
17. Personal Communication with James Sher, TNRCC. November 20, 1997.
18. Sol Lynn Site Facts Sheet, EPA Region 6. March 31, 1998.
19. Comments on draft report provided by John Kovski, Radian International LLC, June 1998.
20. Comments on draft report provided by James Sher, TNRCC, June 1998.

Analysis Preparation

This case study was prepared for the U.S. Environmental Protection Agency's Office of Solid Waste and Emergency Response, Technology Innovation Office. Assistance was provided by Eastern Research Group, Inc. and Tetra Tech EM, Inc. under EPA Contract No. 68-W4-0004.

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Pump and Treat of Contaminated Groundwater with Containment Wall at the Solvent Recovery Services of New England, Inc. Superfund Site Southington, Connecticut

Pump and Treat of Contaminated Groundwater with Containment Wall at the Solvent Recovery Services of New England, Inc. Superfund Site Southington, Connecticut

<table>
<tr><td>Site Name:
Solvent Recovery Services of New England, Inc. Superfund Site</td><td rowspan="2">Contaminants:
Chlorinated solvents; semivolatiles - nonhalogenated; PCBs; and heavy metals
- Maximum concentrations detected in 1991 included TCE (41,000 ug/L), cis-1,2-DCE (110,000 ug/L), 1,1,1-TCA (320,000 ug/L), PCBs (85 ug/L), barium (3,510 ug/L), cadmium (76.9 ug/L), chromium (111 ug/L), lead (175 ug/L), and manganese (37,200 ug/L)</td><td>Period of Operation:
Status: Ongoing
Report covers: July 1995 through June 1998</td></tr>
<tr><td>Location:
Southington, Connecticut</td><td>Cleanup Type:
Full-scale cleanup (interim results)</td></tr>
<tr><td>Vendor:
NTCRA 1 Design Contractor:
Blasland, Bouck, & Lee, Inc (BBL)
Syracuse, NY
NTCRA 1 Const. Contractor:
BBL Environmental Services
NTCRA 1 Operations Contractor:
Handex of New England
PRP Oversight Contractor:
de maximis, Inc.
Bruce Thompson
PRP Project Manager
37 Carver Circle
Simsbury, CT 06070
(860) 651-1196</td><td rowspan="2">Technology:
Pump and Treat and Vertical Barrier Wall
- Groundwater is extracted using 12 wells at an average total pumping rate of 20 gpm
- Extracted groundwater is treated with addition of chemical (caustic), clarification, filtration, UV/oxidation, and activated carbon
- Treated groundwater is discharged to a surface water
- A sheet pile wall, 700 ft long, is located at the downgradient portion of the plume</td><td>Cleanup Authority:
CERCLA Removal
- Non-Time Critical Removal Action Memorandum: 4/1/93</td></tr>
<tr><td>State Point of Contact:
Mark Beskind
Connecticut Department of Environmental Protection
79 Elm Street
Hartford, CT 06106-5127
(860) 424-3018</td><td>EPA Point of Contact:
Karen Lumino, RPM
U.S. EPA Region 1
JFK Federal Building
One Congress Street
Boston, MA 02203
(617) 573-9635</td></tr>
<tr><td>Waste Source:
Waste lagoons, open pit incineration, incineration residuals handling, drum storage</td><td colspan="2" rowspan="2">Type/Quantity of Media Treated:
Groundwater
- 32.5 million gallons treated as of June 1998
- DNAPL was observed in several monitoring wells on site
- Depth to groundwater was not provided for this site
- Extraction wells are located in 2 aquifers, which are both heterogeneous and anisotropic
- Hydraulic conductivity ranges from 0.023 to 300 ft/day</td></tr>
<tr><td>Purpose/Significance of Application:
UV/oxidation has been effective at treating water contaminated with pure phase contaminants, including a mix of VOCs, PCBs, and metals.</td></tr>
</table>

Pump and Treat and Containment of Contaminated Groundwater at the Solvent Recovery Services of New England, Inc. Superfund Site Southington, Connecticut (continued)

Regulatory Requirements/Cleanup Goals:

- No cleanup goals or standards have been established as of the time of this report. A ROD is expected to be finalized in 1999, at which time cleanup standards will be set. The ROD is expected to incorporate a waiver of groundwater standards within the NAPL zone due to technical impracticability.
- A primary goal of the extraction system is to prevent migration of all contaminated overburden groundwater from the operations area at the site.

Results:

- Contaminant levels within the containment wall have not been reduced as DNAPL continues to dissolve into the aqueous phase.
- During the past three years, containment of the plume has been maintained the majority of the time, and wells down-gradient of the plume have not had increased contaminant levels. Containment was lost less than four days over the three years of operation.
- From July 1995 to July 1997, approximately 4,344 pounds of VOCs have been removed from the groundwater.

Cost:

- Actual costs for pump and treat were $5,556,900 ($4,339,600 in capital and $1,217,300 in O&M), which correspond to $265 per 1,000 gallons of groundwater extracted and $1,280 per pound of contaminant removed.
- Expedited review of design documents helped to minimize costs for this application.

Description:

Solvent Recovery Services of New England, Inc. (SRS) reclaimed spent industrial solvents for reuse or blending from 1955 until March 1991. Chemicals from site activities and process sludge were disposed of in two on-site unlined lagoons from 1955 until 1967, when they were closed. For several years thereafter, wastes were burned in an open pit incinerator at the southeastern corner of the operations area, and incinerator ash was used as fill at the facility. Operating practices for handling of spent solvents resulted in spills and leaks to the soils. From 1980 to 1982, EPA conducted numerous investigations of the SRS site. The site was placed on the NPL in September 1983 and a non-time critical removal action memorandum was signed in April 1993.

The groundwater containment system consists of 12 extraction wells and a down-gradient steel sheet pile wall that extends to the bedrock. Eleven wells are located along the interior of the wall, and one well is located in the center of the containment area. Containment of the plume has been maintained 98% of the time over a three year period. UV/oxidation has been effective at treating water contaminated with pure phase contaminants, including a mix of VOCs, PCBs, and metals, to levels that meet state discharge standards.

SITE INFORMATION

Identifying Information:

Solvent Recovery Services of New England, Inc. Site
Southington, Connecticut

CERCLIS #: CTD009717604

ROD Date: Scheduled for September 1999

Non-Time Critical Removal Action Memorandum: April 1, 1993

Treatment Application:

Type of Action: Removal

Period of operation: July 19, 1995 - Ongoing (Performance data collected through July 1997; data on volume treated collected through June 1998)

Quantity of groundwater treated during application: 32.5 million gallons through June 30, 1998

Background

Historical Activity that Generated Contamination at the Site: Solvents recovery

Corresponding SIC Code: 7389A (Solvents Recovery)

Waste Management Practice That Contributed to Contamination: Waste lagoons, open pit incineration, incineration residuals handling, drum storage

Facility Operations [1,2,3,7]:

- This case study presents information on Phase 1 of the Non-Time Critical Removal Action (NTCRA) performed at the Solvent Recovery Services of New England, Inc. (SRS) Site. The final RI Report was submitted in June 1998. The Record of Decision (ROD) will be prepared by September 1999.
- The 2.5-acre site is located in a suburban area bordered by commercial, agricultural, and residential properties. Included in the area potentially affected by the SRS plume is the SRS facility operations area, an adjoining property, and the Town of Southington wellfield.
- SRS reclaimed spent industrial solvents for reuse or blending from 1955 until March 1991. Chemicals from site activities and process sludge were disposed of in two on-site unlined lagoons from 1955 until 1967, when they were closed. The lagoon contents were drained and disposed of off site. The lagoons were then backfilled with clean soil.
- For several years thereafter, wastes were burned in an open pit incinerator at the southeastern corner of the operations area, and incinerator ash was used as fill at the facility. Practices used for waste handling, transferring, and storing of spent solvents and fuels in drums and tanks resulted in spills and leaks to the soils.
- From 1980 to 1982, EPA conducted numerous investigations of the SRS site during the evaluation process for the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) National Priorities List (NPL). Further investigations were performed from 1980 through 1990 under the purview of Resource Conservation and Recovery Act (RCRA). The site was placed on the NPL on September 8, 1983.
- In 1983, SRS entered into a Consent Decree with EPA which required changes to solvent handling procedures, spill control measures, paving of the operations area, fire protection measures, and the installation of a system to recover groundwater.
- The groundwater recovery system, named the On-site Interceptor System (OIS), included 25 recovery wells but no monitoring wells. The OIS extracted groundwater, treated it in an air stripper, and discharged it to the Quinnipiac River. EPA reviewed OIS performance in 1993. The OIS was found to be ineffective in preventing off-site migration of contaminated overburden groundwater. The OIS unit was shut down in 1994 when EPA made the decision that NTCRA 1 was needed.

SITE INFORMATION (CONT.)

Background (Cont.)

- SRS disposed of remaining on-site sludges from tanks, concrete dikes, and drums during shutdown cleanup from January 25 to March 26, 1991.

- In 1992, EPA removed PCB-containing sediments from a drainage ditch as part of a Time-Critical Removal Action. From January through February 1994, EPA conducted a Time-Critical Removal Action to dispose of drums, pails, and other containers with residual laboratory chemicals off site.

- The NTCRA 1 Action Memorandum was signed by the Region 1 Regional Administrator on April 1, 1993, and addresses the performance of soil studies and the extraction and treatment of the groundwater in the overburden aquifer to contain the plume.

- On October 4, 1994, EPA entered into an Administrative Order of Consent (AOC) for NTCRA 1 with greater than 1,600 Potentially Responsible Parties (PRPs). A 1994 de minimis settlement reduced the number of active PRPs to 360. NTCRA 1 was the only action addressed in the first AOC. EPA entered into a second AOC for NTCRA 2 and to complete the RI/FS and perform a TI Evaluation with the PRPs on February 6, 1997, with an effective date of five days after signature.

- NTCRA 1 pre-design investigation work was initiated in September 1994, and included installation of four initial recovery wells, four overburden piezometers and four bedrock piezometers. The 100% Design was submitted in December 1994, and construction occurred from February 1995 to July 1995, with system start-up in July 1995. This report addresses only the groundwater activities performed under NTCRA 1.

Regulatory Context:

- Remedial activities in the overburden aquifer are being performed under NTCRA 1, as an interim remedy.

- Site activities are managed under CERCLA, as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA) §121, and the National Contingency Plan (NCP), 40 CFR 300.

Remedy Selection: Groundwater containment is currently being conducted under a two-phase Non-Time Critical Removal Action (NTCRA 1 and NTCRA 2). NTCRA 1 was mandated to minimize migration of contaminated groundwater in the overburden aquifer. NTCRA 2 was mandated to minimize migration of contamination in the bedrock aquifer. Under NTCRA 1, contaminated groundwater is pumped from the overburden aquifer containment system, treated by ultra violet light (UV) oxidation, and discharged to the Quinnipiac River. Containment is also provided by a downgradient sheet pile wall. NTCRA 2 will extend the groundwater extraction system into the bedrock aquifer and will use the same treatment technology [1].

SITE INFORMATION (CONT.)

Site Logistics/Contacts

Site Lead: PRP

Oversight: EPA

Remedial Project Manager:
Karen Lumino*
U.S. EPA Region I
John F. Kennedy Federal Building
One Congress Street
Boston, MA 02203
(617) 573-9635

State Contact:
Mark Beskind*
Connecticut Department of Environmental Protection
PERD
79 Elm Street
Hartford, CT 06106-5127
(860) 424-3018

*Indicates primary contacts

Treatment System Vendor(s):
PRP Oversight Contractor: de maximis, Inc.
Bruce Thompson*
PRPs Project Manager
37 Carver Circle
Simsbury, CT 06070
(860) 651-1196

Treatment System Vendor:
NTCRA 1 Design Contractor: Blasland, Bouck, & Lee, Inc. (BBL), Syracuse, NY
NTCRA 1 Construction Contractor: BBL Environmental Services
NTCRA 1 Operations Contractor: Handex of New England

MATRIX DESCRIPTION

Matrix Identification

Type of Matrix Processed Through the Treatment System: Groundwater

Contaminant Characterization [1,3,4,7]

Primary Contaminant Groups: Volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), polychlorinated biphenyls (PCBs), and metals.

- The contaminants of concern at the site include VOCs, SVOCs, PCBs, and metals. Refer to Attachment A for a complete list and range of contaminants detected in the groundwater during sampling in 1991. VOCs are the most prevalent contaminants.
- As shown in Attachment A, sampling events performed in 1991 detected concentrations of trichloroethlene (TCE) at 30,000 µg/L, *cis*-1,2-dichloroethylene (*cis*-1,2-DCE) at 110,000 µg/L, 1,1,1-trichloroethane (1,1,1-TCA) at 78,000 µg/L, as well as other VOCs in the overburden aquifer. The same sampling events detected TCE concentrations of 41,000 µg/L, *cis*-1,2-DCE at 5,300 µg/L, 1,1,1-TCA at 320,000 µg/L, as well as other VOCs in the bedrock aquifer.
- PCBs and metals were also detected at levels of concern. PCBs were detected at concentrations up to 85 µg/L in 1991. Barium (3,510 µg/L), cadmium (76.9 µg/L), chromium (111 µg/L), lead (175 µg/L), and manganese (37,200 µg/L) all had maximum concentrations of concern.

MATRIX DESCRIPTION (CONT.)

Contaminant Characterization (Cont.)

- From 1994 to 1995, Blasland, Bouck, and Lee, Inc. (BBL) constructed the NTCRA 1 system. During construction, dense nonaqueous phase liquid (DNAPL) was found in samples from monitoring wells and in the soil from the bottom of some wells. DNAPL has been visually observed in samples from both aquifers. The DNAPL was analyzed and found to contain primarily TCE, perchloroethylene (PCE), and toluene, with additional VOCs at smaller fractions.

- DNAPL is present in both the overburden and bedrock aquifers. Figures 1, 2, and 3 illustrate the contaminant plume distribution in the upper, middle, and lower layers of the overburden aquifer, respectively, based on November 1996 to February 1997 data. Figures 4 and 5 illustrate the contaminant plume distribution in the shallow and deep layers of the bedrock aquifer, respectively, based on November 1996 to February 1997 data .

- Figures 1, 2, and 3 show that the contaminant plume in the overburden covered the on-site operations area and migrated downgradient east, offsite, to the Quinnipiac River. The 1998 RI data modified the plume delineation shown in Figures 1 and 2, and the northern extent of the plume was decreased.

- Figures 4 and 5 show that the contaminant plume in shallow bedrock covered the operations area and migrated south and east to the Quinnipiac River.

- An estimate of the volume of the plume was not provided in the available reference material. An estimate could not be developed because of the complexity of the hydrogeology at the site. However, the 1998 RI by BBL estimated the volume of actual DNAPL in the aquifer at up to 900,000 gallons. The recovery of DNAPL is discussed in the System Operations section.

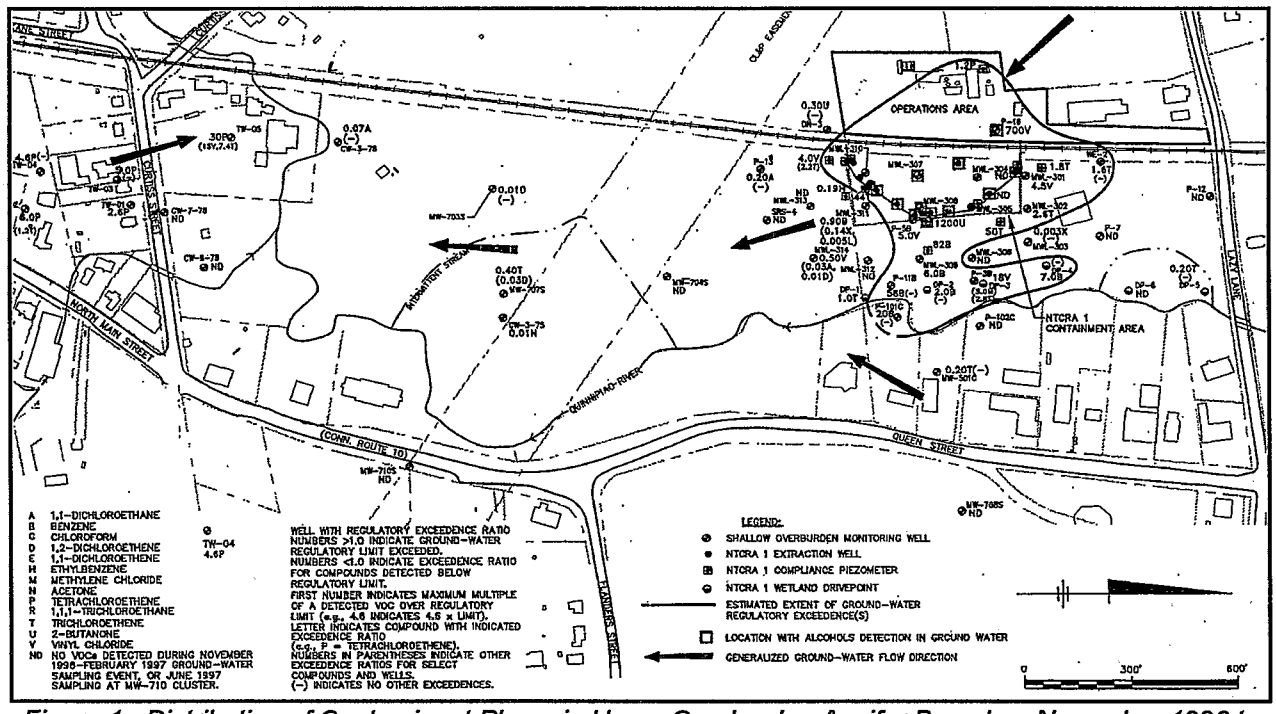

Figure 1. Distribution of Contaminant Plume in Upper Overburden Aquifer Based on November 1996 to February 1997 Sampling Data [3]

MATRIX DESCRIPTION (CONT.)

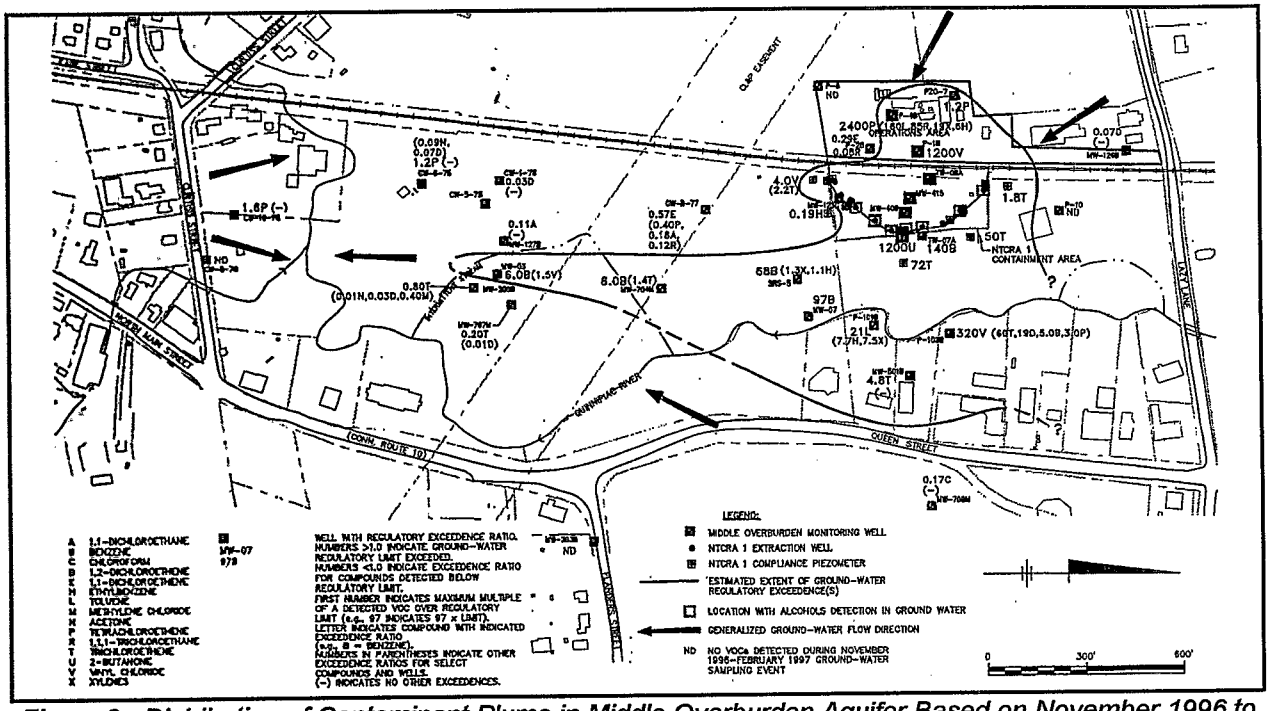

Figure 2. Distribution of Contaminant Plume in Middle Overburden Aquifer Based on November 1996 to February 1997 Sampling Data [3]

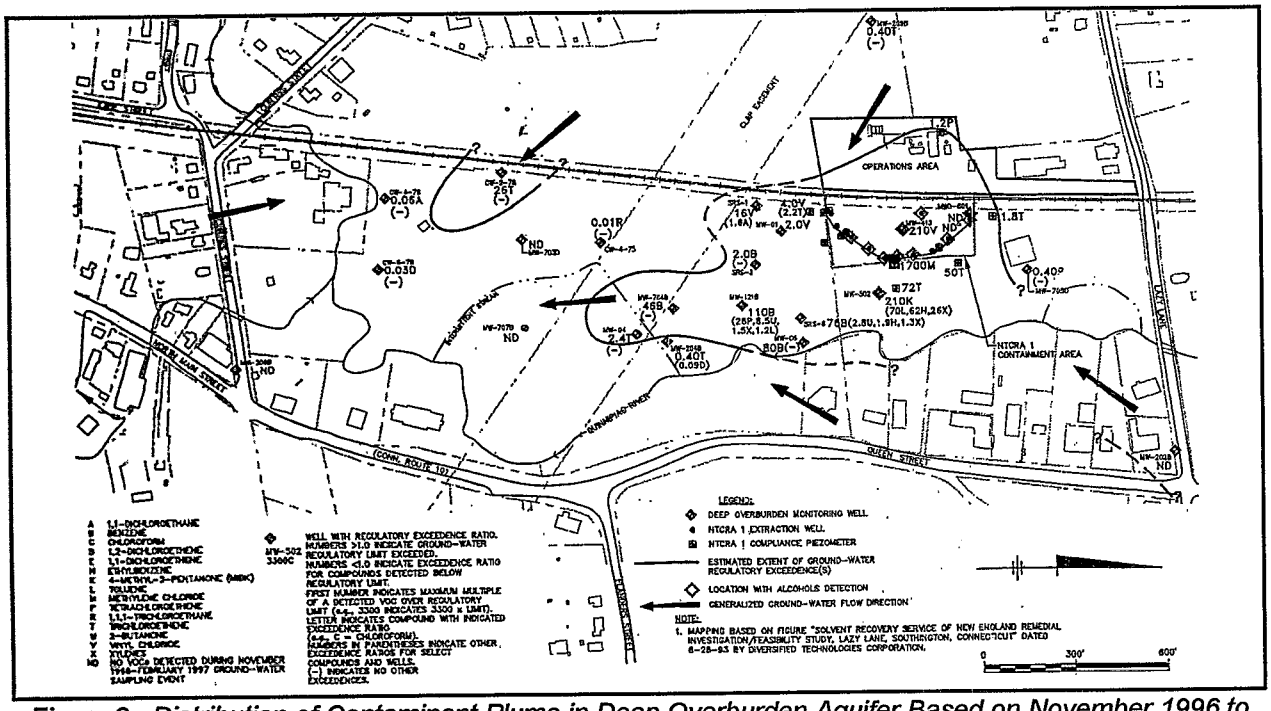

Figure 3. Distribution of Contaminant Plume in Deep Overburden Aquifer Based on November 1996 to February 1997 Sampling Data [3]

MATRIX DESCRIPTION (CONT.)

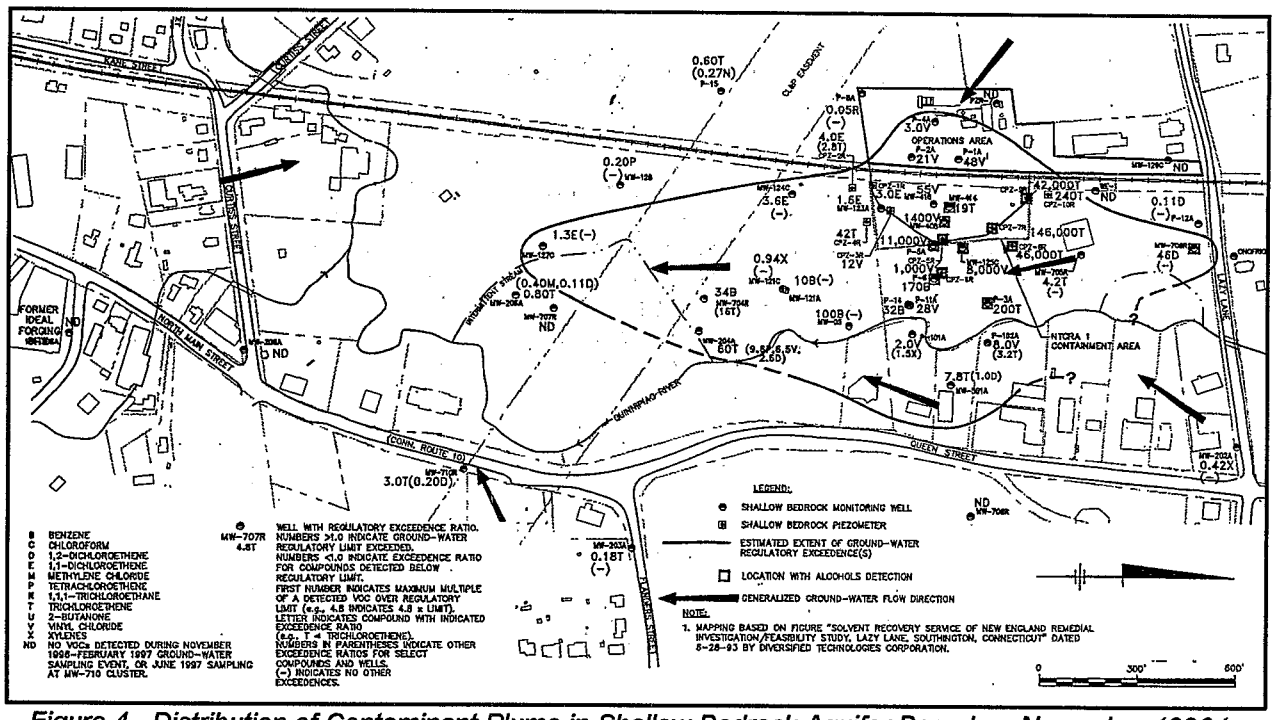

Figure 4. Distribution of Contaminant Plume in Shallow Bedrock Aquifer Based on November 1996 to February 1997 Sampling Data [3]

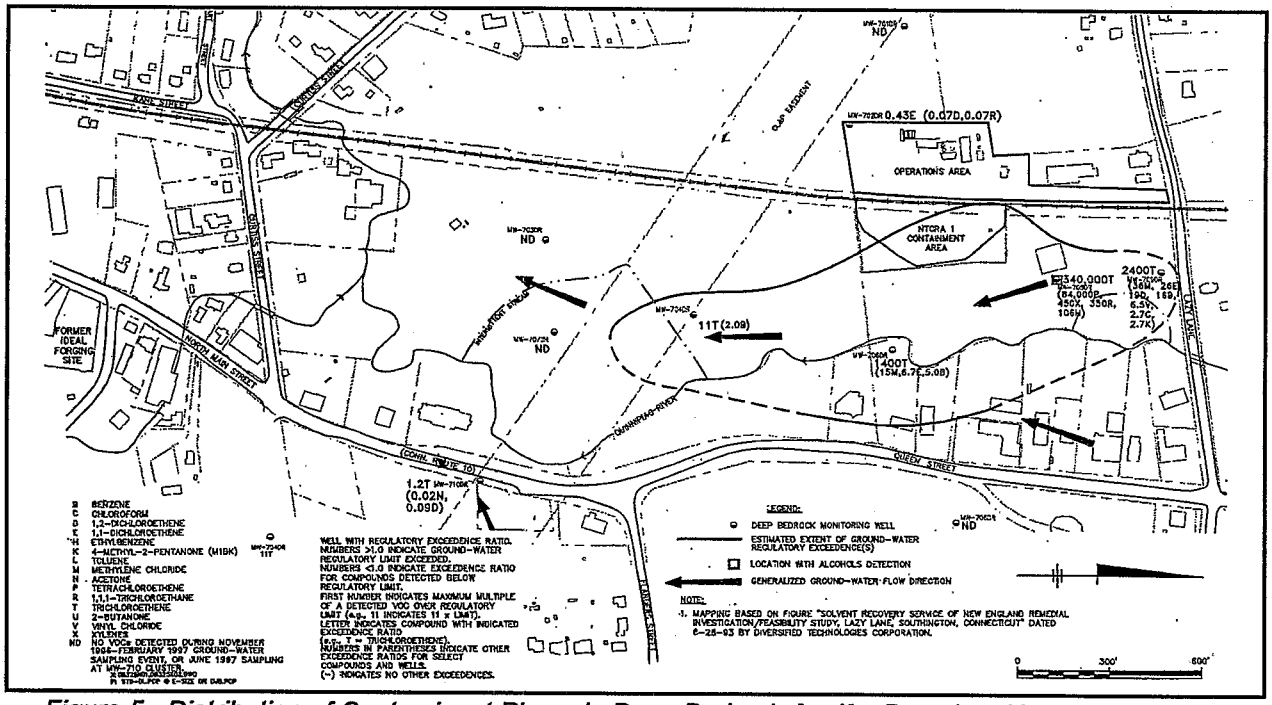

Figure 5. Distribution of Contaminant Plume in Deep Bedrock Aquifer Based on November 1996 to February 1997 Sampling Data [3]

MATRIX DESCRIPTION (CONT.)

Matrix Characteristics Affecting Treatment Costs or Performance

Hydrogeology [3,7]:

The geology of the study region consists of Pleistocene glacial deposits overlying the Upper Triassic New Haven Arkose bedrock ("red bed"). Wisconsin-age glaciation partly eroded and smoothed the bedrock hills, depositing the principle unconsolidated overburden units throughout the region. The hydrogeology at the site is complex. For the purposes of this report, the hydrogeology can be grossly characterized as two units: the overburden and the bedrock. Hydraulic conductivity in both aquifers is heterogeneous and anisotropic. Hydraulic conductivities have been measured to range over three orders of magnitude in the overburden and five orders of magnitude in the bedrock. Regional groundwater flow is towards the Quinnipiac River, from both sides of the river.

Overburden Unit	The overburden unit was divided into three layers for characterization purposes: shallow overburden, middle overburden, and deep overburden. These layers do not necessarily correspond to separate hydrostratigraphic units. The shallow overburden is glacial outwash, a mix of reddish-brown silty sand and gravel interbedded with layers of silt and sorted sand and gravel. The middle overburden is unstratified reddish-brown clay, silt, sand, gravel, cobbles, and boulders, but also includes discontinuous sandy seams. The deep layer is basal till, primarily coarse-grained sand and gravel with cobbles and boulders. In some areas at the site, fill overlies the overburden. The thickness of the overburden unit varies from 10 to 40 feet and decreases towards the river.
Bedrock Unit	The bedrock unit is severely weathered in the top 5 feet and is more competent but still highly fractured and permeable 5 to 30 feet below ground surface. As the bedrock dips towards the river, depth from ground surface to bedrock increases.

Groundwater at the site flows towards the Quinnipiac River from both sides; however, south of the site, the river discharges to the overburden aquifer. This flow pattern implies a circulation common to Connecticut hydrology. The groundwater at the site flows east, but regionally groundwater flow direction varies. The overburden aquifer is a water-bearing unit, but is not used for drinking water because of poor water quality. The bedrock fractures contain groundwater but connectivity of the fractures is undetermined.

Tables 1 and 2 present technical aquifer information and well data, respectively.

Table 1. Technical Aquifer Information

Unit Name	Thickness (ft)	Conductivity (ft/day)	Solute Velocity (ft/day)	Flow Direction
Overburden	10 - 40	0.2 - 300[1]	2.3[2]	East[3]
Bedrock	Not Characterized	0.35[1]	Not Available	Not Characterized

1 Conductivity is highly variable because of heterogeneity and anisotropy. Bedrock hydraulic conductivity is the bulk conductivity
2 Solute velocities varied from 0.00 ft/day for PCBs and naphthalene to 2.30 ft/day for methanol.
3 At the site, groundwater flows east. Regionally, groundwater flows to the Quinnipiac River from both sides.
Source: [3]

TREATMENT SYSTEM DESCRIPTION

Primary Treatment Technology

Pump and treat (P&T) with UV oxidation

Supplemental Treatment Technology

Metals precipitation and liquid phase carbon adsorption

System Description and Operation [3,4,7]

Table 2. Technical Well Data

Well Name	Unit Name	Screened Interval (feet below ground surface)
RW-1	Overburden	14.5 - 27
RW-2	Overburden	19 - 31.5
RW-3	Overburden	18 - 28
RW-4	Overburden	9.9 - 21
RW-5	Overburden	10.21 - 20.21
RW-6	Overburden	10.14 - 20.14
RW-7	Overburden	8.58 - 18.58
RW-8	Overburden	11 - 26
RW-9	Overburden	10.81 - 30.81
RW-10	Overburden	8.27 - 33.27
RW-11	Overburden	8.84 - 23.84
RW-12	Overburden	12.5 - 27.5
MWD-601	Overburden	21.4 - 26.4

Source: [1]

System Description

- The groundwater containment system consists of 12 extraction wells and a downgradient steel sheet pile wall that extends to the bedrock.
- The extraction wells are placed according to locations determined by computer modeling, using MODFLOW to optimize containment. MODFLOW showed that because of low hydraulic conductivity, containment could not be achieved by recovery wells alone; therefore, a sheet pile wall was installed.
- The sheet pile wall is shaped in a horseshoe in the downgradient portion of the plume. It is approximately 700 feet long and extends vertically to the bedrock.
- Eleven wells are located along the interior of the sheet pile wall, with one in the center of the containment area. Water is pumped from the wells to a transfer pipe leading to the groundwater treatment system.
- The recovery wells are 8" diameter stainless steel screens, installed into 14" diameter boreholes. Each recovery well incorporated a 2' stainless steel sump at the base of the screen, in anticipation of DNAPL mobilization towards the wells.
- Influent water is pumped through the treatment train illustrated in Figure 6. A metals pretreatment system is the first treatment step. This is primarily a gravity-flow system designed to operate at a flow rate of up to 100 gpm and to remove inorganics (primarily iron and suspended solids). The metals pretreatment system consists of a 10,000-gallon flow equalization tank followed by a 1,000-gallon clarifier feed tank. Caustic soda is added to the clarifier feed tank to adjust the pH from approximately 7.0 to 9.0. Water from the clarifier feed tank flows first to a flash-mix chamber (not shown) where polymer is added; next to a slow-mix chamber (not shown) where flocculation occurs; and then

TREATMENT SYSTEM DESCRIPTION (CONT.)

System Description and Operation (Cont.)

to an inclined-plate clarifier where solids settle out. Effluent from the clarifier flows by gravity to a sand filter and then to a 3,000-gallon oxidation feed tank. Sulfuric acid is added to the oxygen feed tank to reduce the pH from approximately 9.0 to 7.0. The water is then pumped through the UV oxidation treatment system.

- The treated groundwater from the metals pretreatment system is pumped to the enhanced oxidation treatment system, which consists of two independent oxidation chambers. Each is designed to accommodate a flow rate of 50 gpm, for a total flow of 100 gpm. The enhanced oxidation treatment system removes organic compounds using high-powered UV lamps that emit UV radiation through a quartz sleeve into the water stream. Simultaneously, an oxidizing agent, hydrogen peroxide, is added and forms oxidizing radicals that destroy the organic compounds contained in the water.

- The UV oxidation treatment system discharges treated water into a 3,000-gallon granular activated carbon (GAC) feed tank and is pumped through two liquid-phase GAC units connected in a series. Each liquid-phase GAC unit consists of two skid-mounted liquid-phase GAC vessels connected in parallel. The first GAC unit removes organic compounds that may remain in the water following treatment in the enhanced oxidation treatment system. The treated water then flows through a second GAC unit designed to remove any residual peroxide. Treated effluent is discharged to the Quinnipiac River.

- The equalization tank, clarifier feed tank, flash mix chamber, slow mix chamber, inclined plate clarifier, sludge thickener tank, sludge dewatering press, filter press, sand filter, and oxidation feed tank are all vented to a vapor-phase carbon adsorption treatment system.

- The sludge from the bottom of the clarifier is pumped to a sludge thickener tank and then to a sludge-dewatering filter press. A portion of the sludge from the bottom of the clarifier is recycled back to the flash mix chamber to enhance precipitation and flocculation in the clarifier. The filter press uses the compaction pressure of the sludge pump to dewater sludge into filter cakes consisting of 25 to 60 percent solids. The filter cake is dropped into two collection hoppers and transferred into containers for off-site disposal. Supernatant from the sludge thickener, filtrate from the filter press, backwash from the sand filter, and water collected in the building sump and filter press room sump are directed back to the equalization tank.

- The groundwater levels at the downgradient end of the site are monitored continuously to verify containment. There are 12 monitoring wells just upgradient of the sheet pile wall and 12 monitoring wells downgradient of the sheet pile wall. An inward vertical gradient of 0.3 foot must be maintained between the wells upgradient and downgradient of the wall to demonstrate that containment is being maintained. One pair of wells is equipped with a datalogger, which is programmed to notify site operators by telephone if the 0.3-foot gradient is not maintained.

System Operation

- Approximately 32.5 million gallons of water have been treated from July 1995 to June 30, 1998. From July 1995 through 1997, approximately 21 million gallons of water were treated.

- The site has been operational 100% of the time. As described in System Description, pumping must be continuous to meet the 0.3-foot inward gradient requirement.

TREATMENT SYSTEM DESCRIPTION (CONT.)

System Description and Operation (Cont.)

- The system has a 100 gpm capacity, but has averaged at 20 gpm. The initial MODFLOW modeling predicted the need for a steady-state pumping rate of 20 gpm. The system was designed to treat a higher flow in anticipation of eventual expansion.

- The 0.3-foot inward gradient was lost in one pair of compliance piezometers on June 25-28, 1996. The event lasted less than one day. Failure of a recovery pump caused the temporary loss of containment. Recovery wells are now redeveloped at least once per year, at which time the pump heads are removed and serviced (cleaned).

- In August, January, and February 11, 1998, containment was lost for less than one day due to power outages. In December 1996, containment was lost because of CAC backpressure. All of these losses were quickly mitigated.

- Containment was also lost at one pair of compliance piezometers located in the extreme south end of the system several times in May 1998. Extremely heavy rainfall events, coupled with artesian conditions in the bedrock aquifer and slight fouling in a recovery well pump, caused the loss. The pump head was replaced with a higher capacity unit (16 gpm replaced an 8 gpm head), which restored containment.

- Operations and maintenance efforts depend largely on pump rate and influent contaminant concentrations, because the largest cost is the electrical power required by the UV oxidation system. O&M optimization has focused on energy management, which has included reducing electrical power demand by staggering pump and UV oxidation cycling, changes in electrical rates paid (based on the reduced demands), and tailoring the number of UV bulbs in operation (each bulb "on" accounts for roughly $1,000 per month in power cost). Also, although DNAPL was observed in some wells, no corrosion has been observed in any NTCRA 1 wells. One PVC monitoring well was observed to have been affected by DNAPL, and it was abandoned.

- Recovery wells are surged and redeveloped annually, due to fouling of the well screens. The recovery well pumps are also pulled and cleansed as part of the maintenance procedure. Most of the recovery well level controls need to be cleaned on a weekly basis to remove biological fouling. Routine preventive maintenance (redevelopment) has minimized operational issues.

- According to the PRP oversight contractor, in May 1998, the gravel access road across the NTCRA 1 containment area was relocated to the west of the sheetpile wall and 1,000 poplar trees were planted within the containment area. The PRP oversight contractor stated that this "phytoremediation pilot study" is predicted to achieve the NTCRA 1 containment requirements during the growing season within three to five years, which may allow shut down of the NTCRA 1 system over a portion of each year. No additional information on the pilot study was provided [7].

- In addition, the PRP oversight contractor indicated that, as part of the FS work, the PRPs have contracted with the University of Connecticut to perform a bench-scale treatability study of the potential effectiveness of Fenton's Reagent in treating NTCRA 1 influent. If appropriate, a pilot scale demonstration will be implemented [7].

TREATMENT SYSTEM DESCRIPTION (CONT.)

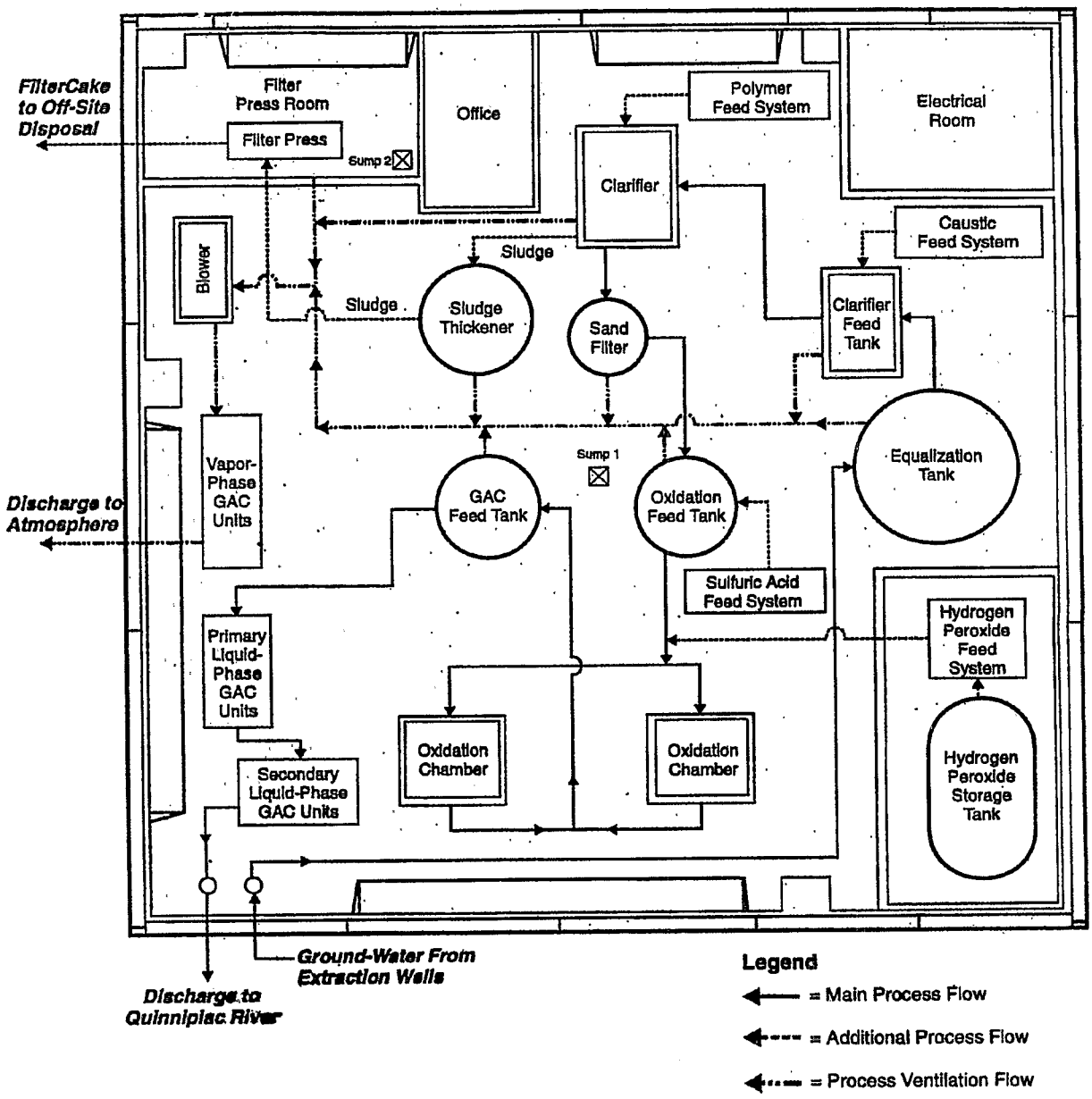

Figure 6. Treatment System Schematic [1]

TREATMENT SYSTEM DESCRIPTION (CONT.)

Operating Parameters Affecting Treatment Cost or Performance

One major operating parameter affecting cost or performance for this technology is the flow rate. Values for this and other performance parameters are presented in Table 3.

Table 3: Performance Parameters

Parameter	Value
Average Pump Rate	20 gpm
Performance Standard (Effluent)	See Attachment B
Remedial Goal (Aquifer)	NA*

*NA - This action is a removal action and remedial goals do not apply as discussed in the Cleanup Goals section.
Source: [1,3]

Timeline

A timeline for this remedial project is shown in Table 4.

Table 4: Project Timeline

Start Date	End Date	Activity
1980	1993	RCRA investigations
9/83	—	Site placed on NPL, OIS constructed
1991	—	SRS closed
1991	—	EPA issues UAO which mandates two NTCRAs
1994	—	EPA begins Remedial Investigation
4/95	—	NTCRA 1 written and approved
7/19/95	—	Begin operation of NTCRA1

Source: [1]

TREATMENT SYSTEM PERFORMANCE

Cleanup Goals/Standards

No cleanup goals or standards have been established at this time. A ROD will be finalized in 1999, at which time cleanup standards will be set. The ROD is expected to incorporate a waiver of groundwater standards within the NAPL Zone due to technical impracticability.

Additional Information on Goals

None

Treatment Performance Goals

- The primary goal of the extraction system is to prevent migration of all contaminated overburden groundwater from the operations area of the site.
- The primary goal for the treatment system is to reduce contaminant concentrations in the effluent to the substantive requirement levels Discharge Limits listed in Attachment B, set by the Connecticut Department of Environmental Protection.

TREATMENT SYSTEM PERFORMANCE (CONT.)

Performance Data Assessment [1,3,7]

For the purpose of this analysis, total contaminants includes the contaminants listed in Attachment A. Total VOCs includes those contaminants listed under VOCs in Attachment A.

- Mass removed and influent contaminant concentrations are expressed in terms of total VOCs because the level of total VOCs is high compared with levels of other contaminants. During operation of NTCRA 1, monitoring was performed for VOCs and PCBs. Dioxins and furans are monitored quarterly, with none detected to date.
- As discussed in System Description and Operation, an inward hydraulic gradient of 0.3 feet must be maintained to show hydraulic plume containment. Overall containment has been lost less than four days out of the three years of operation, resulting in a 98% operation rate. Furthermore, water quality sampling data in wells downgradient of the plume have not had increased contaminant levels.
- There are 230 monitoring wells associated with the SRSNE Site, up, down and side gradient of the NTCRA 1 system. These wells were sampled as part of the RI field work, and the data was interpreted to produce the RI plume figures. Wells in the vicinity of the NTCRA 1 system are gauged on a weekly basis. Contaminant levels within the wall have not reduced as DNAPL continues to dissolve into the aqueous phase.
- Influent concentrations of VOCs to the treatment system were 10,000 µg/L in July 1997. Effluent standards have been met throughout system operation. Refer to Attachment B for a list of the most recent effluent monitoring results.
- Influent from the overburden aquifer has been found to have VOC contaminant concentrations ranging from 9,750 to 63,800 µg/L. Figure 7 shows the temporal change in total VOC concentrations in the influent, as calculated by BBL. The average influent concentration from August 1995 through July 1997 has decreased but fluctuations are seen throughout the operation.
- The cumulative mass of dissolved VOCs removed from July 26, 1995 to July 2, 1997 was approximately 4,344 lbs (1,970 kg). Figure 8, also calculated by BBL, illustrates incremental mass removal and cumulative mass removal over time. The incremental removal has fluctuated over the two years of operation, with an average removal rate of 5.95 lb/day (2.7 kg/day).
- Historically, DNAPL has been concentrated in RW-5. Approximately two liters of DNAPL were recovered from RW-5 per week from August 1995 to October 1995. RW-5 is now gauged weekly for DNAPL, but no recovery has occurred since Spring 1996. A total of approximately 20 liters of DNAPL was recovered, which apparently depleted the "pool" intercepted and mobilized by pumping at RW-5.

Performance Data Completeness [1,3,7]

- Performance Data regarding plume containment were provided in the Innovative Technology Data Questionnaire, from EPA Region I. Graphs of performance data in Figures 7 and 8 regarding mass removed and VOC influent concentrations were provided in the RI.

Performance Data Quality

The QA/QC program used throughout the remedial action met the EPA and the State of Connecticut requirements. All monitoring was performed using EPA-approved methods, and the vendor did not note any exceptions to the QA/QC protocols.

TREATMENT SYSTEM PERFORMANCE (CONT.)

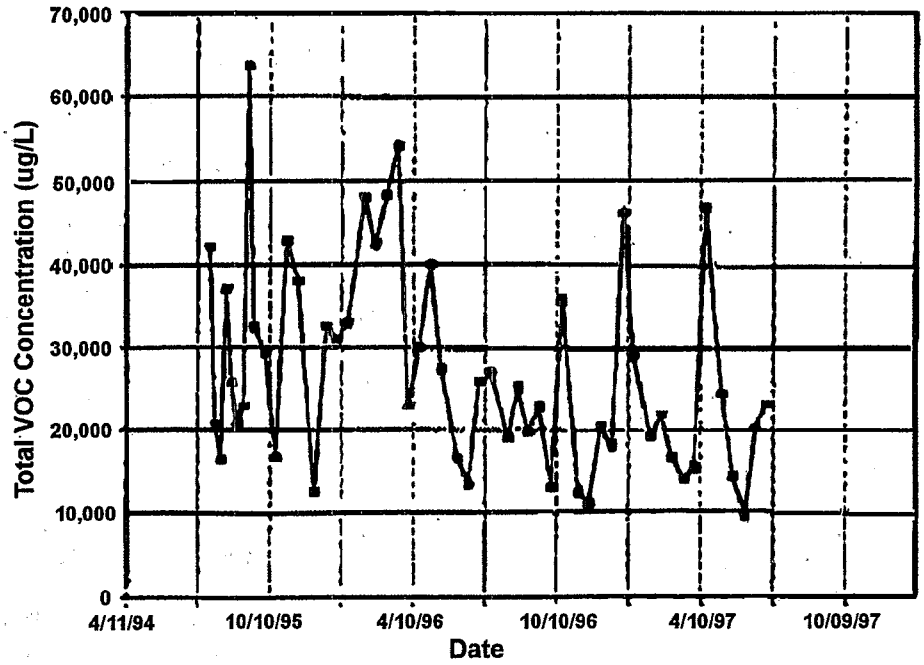

Figure 7. NTCRA 1 Influent Total VOC Concentrations [3]

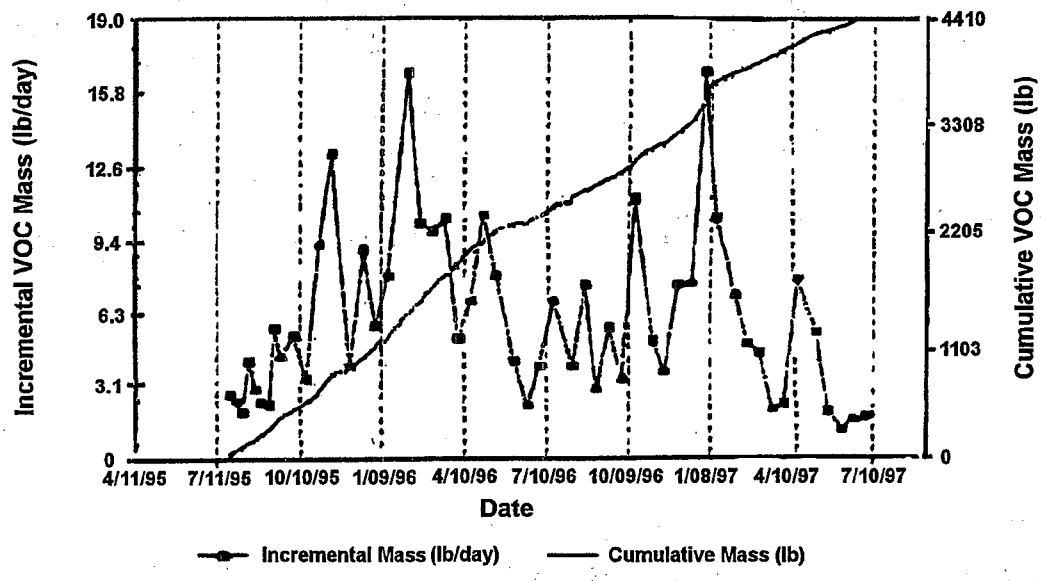

Figure 8. NTCRA 1 Total VOC Mass Removal Summary [3]

TREATMENT SYSTEM COST

Procurement Process

The PRPs contracted with de maximis to manage the remediation and with Handex to operate the system. EPA and the State of Connecticut oversee the site.

Cost Analysis

All costs for remediation at this site are borne by the PRPs.

Capital Costs [1]

Construction Management	$135,200
Deliverables	$17,650
Construction Management	$138,900
Engineering Services	$562,150
Site Work (sheet pile wall, site grading, foundation work)	$1,211,702
Recovery Wells and Piezometers	$254,235
Electrical Work	$330,612
Mechanical Work	$273,900
Prefab Building (80' x 80' building)	$207,185
UV/OX Units	$732,250
Metals Pretreatment System	$388,355
Granular Activated Carbon Systems	$87,450
Total Site Construction	**$4,339,589**

Operating Costs [1]

Start-up	$54,800
Operations & Maintenance (first two months)	$67,930
July 1995 - July 1996	$634,386
July 1996 - July 1997	$460,224
Total O&M	**$1,217,340**

Other Costs [1]

Pre-Design Investigation	$135,400
Design	$21,700
Project Management	$26,200
Bedrock Modeling	$31,400
DNAPL Response Activities	$16,500

Cost Data Quality

Cost data were supplied by the PRP representative, de maximis, Inc. The reported Construction, Design, and Operating Costs provided by de maximis were actual costs incurred.

OBSERVATIONS AND LESSONS LEARNED

- The cost for groundwater treatment at SRS from 1995 to 1997 was $5,556,900 ($4,339,600 in capital costs and $1,217,300 in Operating Costs), which corresponds to $265 per 1,000 gallons treated and $1,280 per lb of contaminant removed (based on 21 million gallons of water treated and 4,344 lbs of contaminants removed through 1997).
- The NTCRA 1 project was designed, approved, and constructed in nine months by eliminating redundant reviews of the design document. The design was written in one step, avoiding the 30%, 60%, 95%, and 100% reviews typically required. The expedited review helped minimize costs [4].
- After two years of operation, the groundwater pump and treat system at SRS has removed approximately 4,300 lbs of VOCs. Effluent standards have been met throughout the system operation.
- Containment has been maintained 98% of the time. Containment has been lost for a total of less than four days. Water quality sampling data from wells downgradient of the plume have not showed an increase in contaminant levels.

OBSERVATIONS AND LESSONS LEARNED (CONT.)

- UV oxidation treatment is effective at treating water contaminated with pure phase contaminants to levels that meet the State of Connecticut standards. The mix of contaminants (VOCs, PCBs, and metals) makes treatment difficult. High (pure-phase) VOC levels would require a large stripper or series of strippers. In addition, several of the influent contaminants (including ketones and alcohols) are not amenable to air-stripping, and the public was sensitive to potential air emissions from air stripping. Unlike GAC, UV oxidation allows treatment of contaminants with no residual solids. In addition, considering the concentrations of contaminants, GAC would have required frequent regeneration. UV oxidation is thus an ideal alternative for treatment when the matrix of contaminants includes high levels of VOCs, in addition to metals and PCBs [1,7].

- DNAPL has been identified at this site. Residual DNAPL acts as a constant source for a dissolved plume to form. DNAPL presence is one cause of fluctuation in total VOC concentrations in the influent. Because of the complex hydrogeology and the DNAPL, a Technical Impracticability (TI) waiver will be applied for [4].

- According to the remedial contractor, DNAPL characterization has been discovered to follow Raoult's Law, with physical data to demonstrate the empirical relation. Mobile DNAPL was found in an overburden well installed during NTCRA 1 construction. Both the DNAPL and supernatant groundwater were sampled and characterized, which allowed effective solubility limits to be empirically demonstrated. The results correlated closely with effective solubility limits predicted using Raoult's Law. DNAPL was also encountered in a bedrock monitoring well installed during the RI. Similar sampling, analysis and correlation was performed. SRS remedial contractors and the PRP representative are finalizing this finding in a future publication [7].

REFERENCES

1. Innovative Technology Questionnaire, Solvent Recovery Service of New England, Inc. Site, Southington, Connecticut, EPA Region 1, undated.

2. Solvents Recovery Service of New England, Superfund Facts Sheet, EPA Region 1, undated.

3. Draft Remedial Investigation, provided by de maximis, Inc. Undated.

4. Correspondence with Mr. Bruce Thompson, de maximis, Inc. December 22, 1997.

5. Non-Time Critical Removal Action No. 1, Ground-water Containment and Treatment System Operations Plan, Solvent Recovery Service of New England, Inc. Superfund Site, Blasland, Bouck & Lee, Inc., June 1995.

6. Correspondence with Mr. John Smaldone, U.S. EPA Region 1, November 11, 1997, December 18, 1997, and December 23, 1997.

7. Comments on draft report provided by Bruce Thompson, de maximis, Inc., July and August 1998.

Analysis Preparation

This case study was prepared for the U.S. Environmental Protection Agency's Office of Solid Waste and Emergency Response, Technology Innovation Office. Assistance was provided by Eastern Research Group, Inc. and Tetra Tech EM Inc. under EPA Contract No. 68-W4-0004.

ATTACHMENT A
CONTAMINANTS DETECTED IN THE GROUNDWATER DURING 1991 SAMPLING

VOLATILE ORGANIC COMPOUNDS	CONCENTRATION				Connecticut Department of Health Safe Drinking Water Standards (ug/l)
	OVERBURDEN GW		BEDROCK GW		
	MIN ug/l	MAX ug/l	MIN ug/l	MAX ug/l	
Methylene Chloride					
Vinyl Chloride	360 J S,F	620 J S,F	8 J S,F	110 J S,F	2
Chloroethane		1100 J		2 J	
Acetone	R	R	R	R	
2-Butanone (MEK)	R	R	R	R	1,000
1,1-Dichloroethene	320 J S,F	15,000 J	190 J S,F	2,300 J S,F	7
1,1-Dichloroethane	290 J	5500 J	94.5 J	940 J	
trans-1,2-dichloroethene				0.8 J	
cis-1,2-Dichloroethene	2,500 J F	110,000 J F	275 J F	5,300 J F	
1,2-Dichloroethane		940 J S,F		1.3 J S	1
1,1,1-Trichloroethane	24,000 J	78,000 J	17,000 J	320,000 J	200
Carbon Tetrachloride	290 J S,F	9,100 J S,F	69.5 J S,F	2,000 J S,F	5
1,2-Dichloropropane				0.7 J	5
Trichloroethene	26,000 J	30,000 J	14 J S,F	41,000 J	5
1,1,2-Trichloroethane				4.7 J	
Benzene		610 J S,F		1.9 J S	1
4-Methyl-2-pentanone (MIBK)		22,000 J	22.5	2,100 J	
trans-1,3-Dichloropropene				390 J S	10
Tetrachloroethene		2,000 J S,F	4.6 J	6,400 J S,F	5
1,1,1,2-Tetrachloroethane				1.8 J	
Toluene		81,000 J		150,000 J	1,000
Ethylbenzene	870 J F	60,000 J F	51 J	740 J F	
Styrene		49,000 J F	9.7 J		
Xylene (total)				43.5 J	
Isopropylbenzene		1,200 J		1 J	
a-propylbenzene				0.8 J	
1,3,5-Trimethylbenzene				1 J	
1,2,4-Trimethylbenzene		950 J	2.6 J	710 J	

Notes:
(+) = The sample was averaged with its field duplicate
J = Value is estimated
R = Value was rejected
S = Exceeds Connecticut DHS Standards
F = Exceeds Federal MCLs
MEK = Methyl Ethyl Ketone
MIBK = Methyl Isobutyl Ketone
Shading denotes exceeds Federal MCLs

ATTACHMENT A (Continued)
CONTAMINANTS DETECTED IN THE GROUNDWATER DURING 1991 SAMPLING
(Page 2)

SEMIVOLATILE ORGANIC COMPOUNDS	CONCENTRATION				Connecticut Department of Health Safe Drinking Water Standards (ug/l)
	OVERBURDEN GW		BEDROCK GW		
	MIN ug/l	MAX ug/l	MIN ug/l	MAX ug/l	
Phenol	22	4,200		14	
1,3-Dichlorobenzene				2 J	
1,4-Dichlorobenzene				10	75
1,2-Dichlorobenzene		30			
2-Methylphenol	14	83	12	16	
4-Methylphenol	14	100	4 J	13	
Isophorone		8 J	2 J	9 J	
2,4-Dimethylphenol	7 J	11		2 J	
Naphthalene	3 J	44	2 J	3 J	
4-Chloro-3-Methylphenol		16			
2-Methylnaphthalene		3 J			
Dimethyl Phthalate	2 J	17			
Phenanthrene		10 J			
DI-N-Butylphthalate	1 J	52 J		3 J	
Butylbenzylphthalate	9 J	63 J			
Bis(2-ethyl hexyl)phthlate		11,000			
Di-N-Octylphthalate		26 J			

PESTICIDES/PCB COMPOUNDS	OVERBURDEN GW		BEDROCK GW		Treatment Performance Standards (CT DHS) STDS (ug/l)
	MIN ug/l	MAX ug/l	MIN ug/l	MAX ug/l	
Aroclor 1254				13 S,F	1
Aroclor 1260		85 S,F			1

Notes: (+) = The sample was averaged with its field duplicate
J = Value is estimated
Shading denotes exceeds Federal MCLs

S = Exceeds Connecticut DHS Standards
F = Exceeds Federal MCLs

Source: [1]

ATTACHMENT A (Continued)
CONTAMINANTS DETECTED IN THE GROUNDWATER DURING 1991 SAMPLING
(Page 3)

METALS	CONCENTRATION					Connecticut Department of Health Safe Drinking Water Standards (ug/l)
	OVERBURDEN GW			BEDROCK GW		
	FILT. SAMP. (ug/l)	MIN ug/l	MAX ug/l	MIN ug/l	MAX ug/l	
Aluminum	35.6	12,200	51,700	906	91,300	
Arsenic	2.0 J	5.0	21.0	4.0 J	8.0 J	50
Barium	280	604	3,510 J	106	2,690 J	1,000
Beryllium		1.1 J	5.4 J	1.9 J	8.54 J	
Cadmium		2.6 J	76.9 S,F		4.25 J	5
Calcium	65,100	37,100	349,000	41,850 J	140,000	
Chromium		51.2 S	111 S,F	114 J S,F	176 S, F	50
Cobalt	52.4	19.6	140	10.4	267.5 J	
Copper	10.4	44.1 J	324	5.6	1,460 J	1,000
Iron	7,350	39,100	84,400	1,930	99,850 J	
Lead		28.0 J	175 S,F	5.3	50.0 J S,F	15
Magnesium	3,360	9,540	25,700	1,490	33,400	
Manganese	6,720 S	7,610 S	37,200 S	45.5	4,000 J	5,000
Mercury			0.35 J			2
Nickel		32.4 J	84.3	101	102.2 J	
Potassium		5,940	14,000 J	12,465 J	19,600 J	
Sodium	12,600	10,100	105,000 J	6,320	16,910 J	20,000
Vanadium		38.1 J	114	32.8	152	
Zinc	47.6 J	66.2	151	393 J	893	

Notes:
(+) = The sample was averaged with its field duplicate
J = Value is estimated
R = Value was rejected
S = Exceeds Connecticut DHS Standards
F = Exceeds Federal MCLs
Shading denotes exceeds Federal MCLs

Source: [1]

ATTACHMENT B
EFFLUENT STANDARDS SET BY THE CONNECTICUT DEPARTMENT OF HEALTH

Parameter	Substantive Requirement Discharge Limit (mg/L)	Most Recent Effluent Concentration (6/17/98) (mg/L)
A. ORGANIC PARAMETERS		
Volatile Organic Compounds		
Trichloroethene	0.973	<0.002 JB
Tetrachloroethene	0.106	<0.005
Toluene	4.0	0.022
Ethylbenzene	1.0	0.003 J
Xylenes, Total	0.50	0.003 J
Vinyl chloride	4.50	0.27
1,1-Dichloroethene	0.06	0.007
Tetrahydrofuran	0.50	0.14 J
1,2-Dichloroethene*	5.0	0.915
1,2-Dichloroethane	0.25	0.008
1,1,1-Trichloroethane	4.0	0.12
1,1,2-Trichloroethane	0.25	<0.005
Methylene chloride	15.0	0.230 B
Styrene	0.50	<0.005
Alcohols		
Ethanol	20.0	<5
Methanol	30.0	<5
2-Butanol (sec-Butanol)	10.0	<5
2-Propanol (Isopropanol)	10.0	<5
Ketones		
Acetone	35.0	N/A
2-Butanone (Methyl Ethyl Ketone)	10.0	N/A
4-Methyl-2-pentanone (Methyl Isobutyl Ketone)	2.0	N/A
B. INORGANIC PARAMETERS		
Metals		
Copper, Total	15.8 g/day	1.98
Iron, Total	5.0	1.68
Lead, Total	3.2 g/day	0.4
Nickel, Total	0.5	<0.040
Zinc, Total	40.3 g/day	1.99
Other		
Total Suspended Solids (TSS)	30.0	<4.0
Peroxide	1.0	0
pH (SU)	1.0	0
Dioxins/Furans	NL	NS
Total PCBs	NL	NS

NOTES:
mg/L = Milligrams per liter unless otherwise noted.
SU = standard units
J = denotes an estimated value less than the Laboratory's Practical Quantitation Level
B = parameter detected in the laboratory method blank
NL = no limited specified
NS = not sampled (total PCBs analysis required monthly; dioxin/furan analysis required quarterly)
ND = parameter not detected at analytical method detection limit
* = 1,2-Dichloroethene represents cis and trans 1,2-Dichloroethene
N/A = As of July 6, 1998 the results for these analytes had not been provided by Katahdin Analytical Services