COST AND PERFORMANCE REPORT

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

September 1998

Prepared by:

U.S. Environmental Protection Agency
Office of Solid Waste and Emergency Response
Technology Innovation Office

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.)

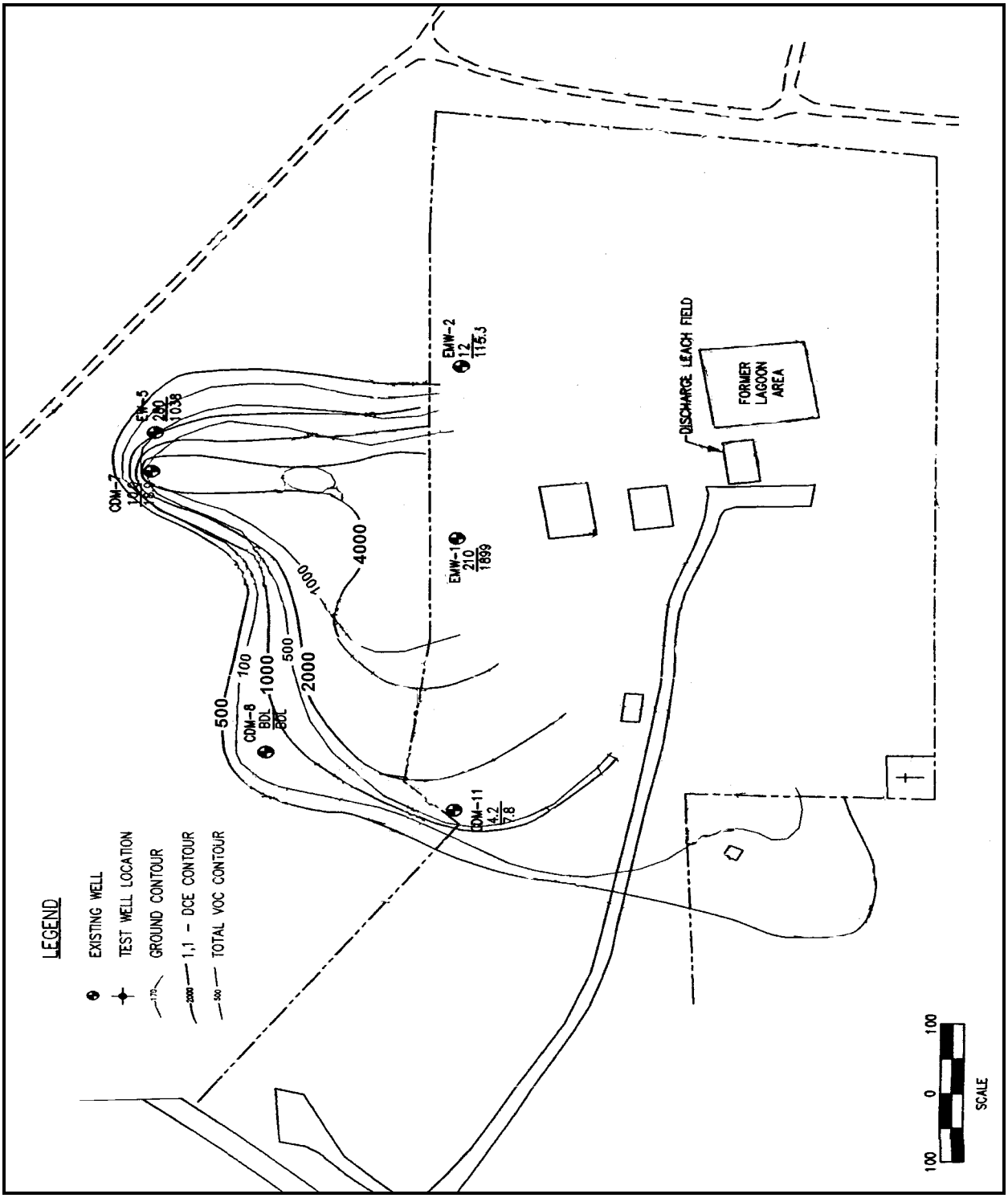

Figure 1. Concentration Contour Map (1993 Best Copy Available) [7]

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.)

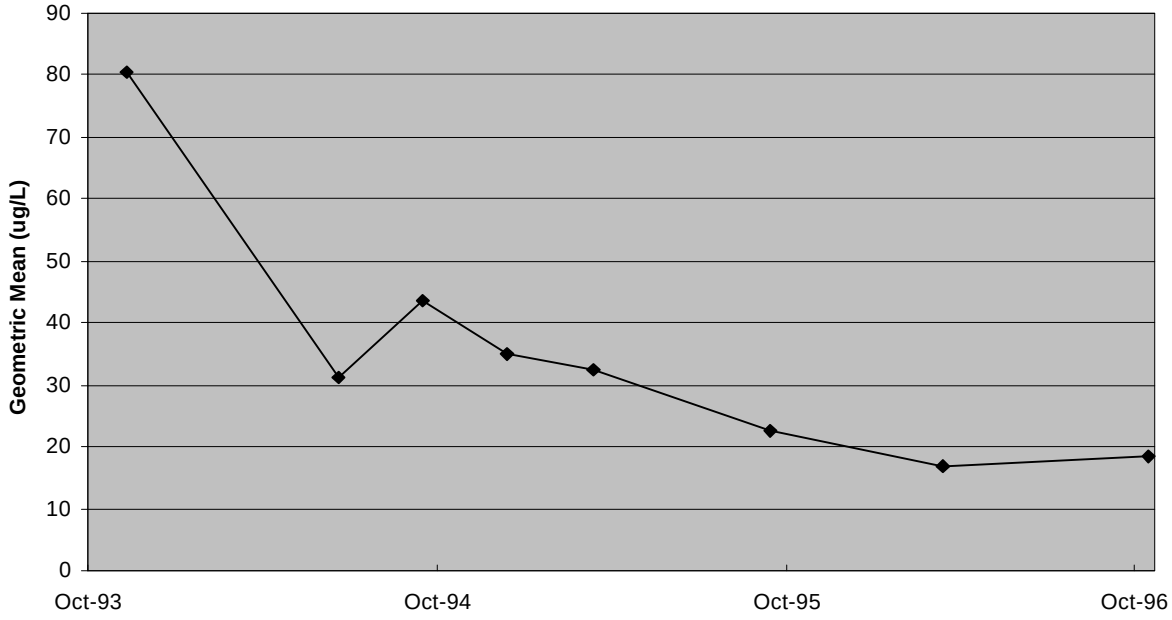

Figure 2. Average Groundwater Concentrations of Total VOCs (1993 to 1996) [7]

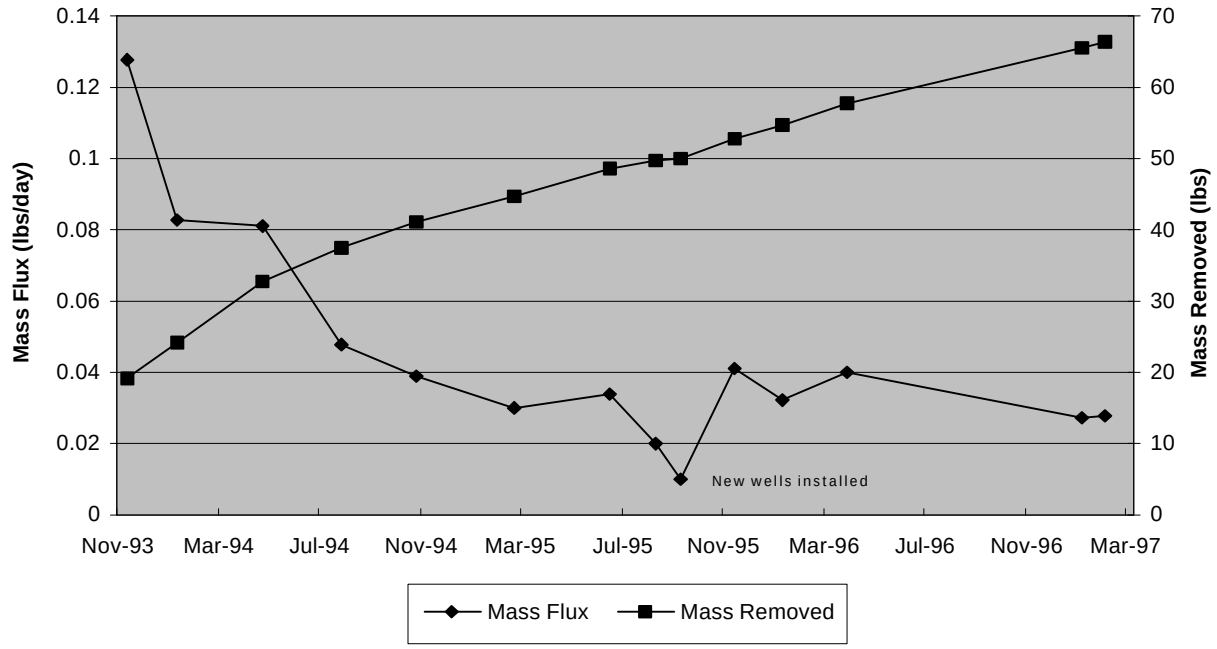

Figure 3. Mass Flux Rate and Cumulative Contaminant Removal for Total VOCs (12/93 - 2/97) [7]

TREATMENT SYSTEM PERFORMANCE (CONT.)

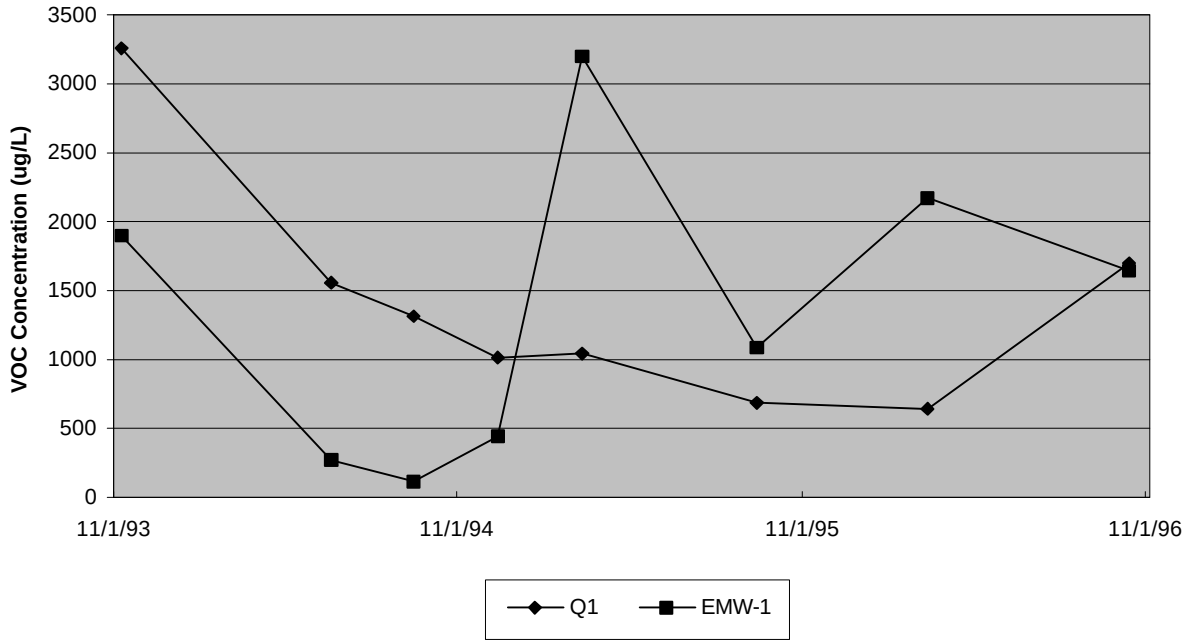

Figure 4. Total VOC Concentration in Two On-Site Wells (1993 - 1996) [7]

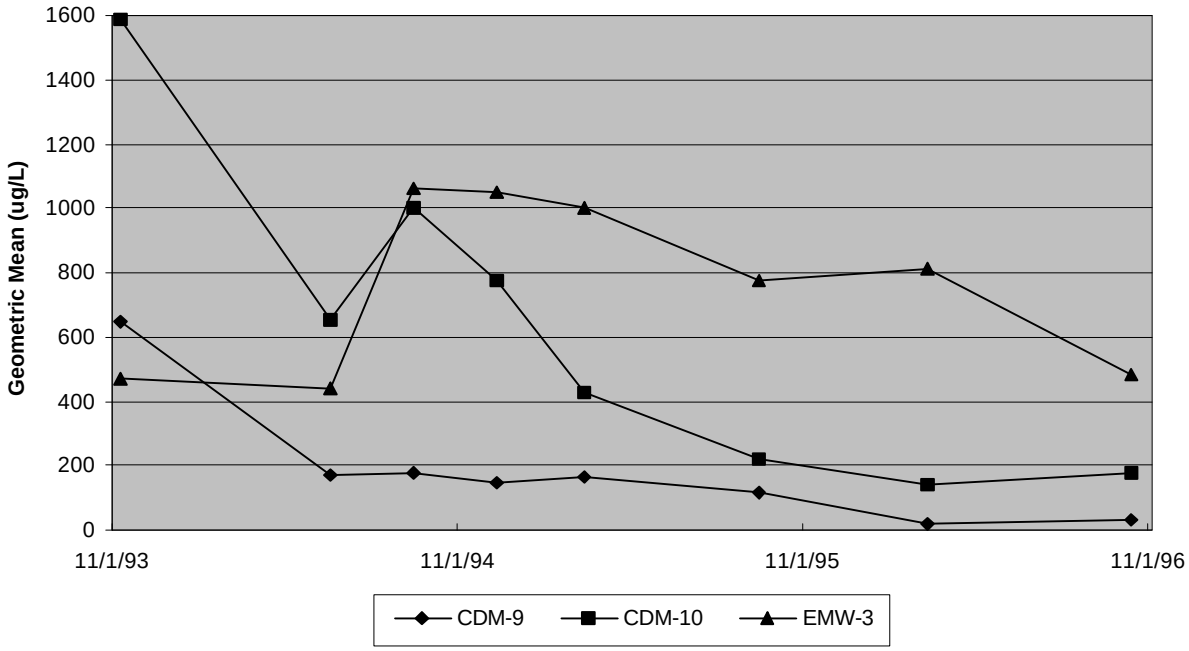

Figure 5. Total VOC Concentration in Three Off-Site Wells (1993 - 1996) [7]

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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