Case Study Abstract

Soil Vapor Extraction System at Commencement Bay, South Tacoma Channel (Well 12A), Phase 2, Tacoma, Washington

<table>
<tr><td>Site Name:
Commencement Bay, South Tacoma Channel (Well 12A) Superfund Site</td><td rowspan="2">Contaminants:
Chlorinated Aliphatics
trans-1,2-Dichloroethene (DCE),
1,1,2,2-Tetrachloroethane (PCA),
1,1,2,2-Tetrachloroethene (PCE),
Trichloroethene (TCE)
- Average VOC concentrations in top 25 feet of soil ranged from 10 to 100 mg/kg
- Average PCA concentrations in soil borings ranged from 6,200 at 30 feet depth to over 19,000 mg/kg at 40 feet depth
- Approximately 571,000 lbs of VOCs present in unsaturated zone</td><td>Period of Operation:
Status: Ongoing
Report covers - 8/92 to 2/94</td></tr>
<tr><td>Location:
Tacoma, Washington</td><td>Cleanup Type:
Full-scale cleanup (Report documents demonstration phase)</td></tr>
<tr><td>Vendor:
Environmental Science & Engineering, Inc.</td><td rowspan="2">Technology:
Soil Vapor Extraction
- 22 wells used for vapor extraction, air inlet, and observation
- Vapor-phase carbon adsorption (GAC) used for treatment of extracted VOCs
- GAC beds regenerated on site with low pressure steam
- Design flow rate for extraction system of 3,000 standard cubic feet per minute (scfm)</td><td>Cleanup Authority:
CERCLA, Local Requirements
- ROD Date: 3/85</td></tr>
<tr><td>SIC Code:
2851 (Paints, Varnishes, Lacquers, Enamels, and Allied Products)</td><td>Point of Contact:
Phil Stoa
Remedial Project Manager
U.S. Army Corps of Engineers
Seattle District</td></tr>
<tr><td>Waste Source:
Storage - Drums; Other: Pour off from Processing Tanks</td><td colspan="2" rowspan="2">Type/Quantity of Media Treated:
Soil
- Volume of contaminated soil reported as 98,203 cubic yards, based on an area of 66,300 ft^2 and a depth of 40 ft
- Upper aquifer (50 ft thickness) consists of unconfined sand and gravel
- Surface soil permeability ranges from 2.8 to 3.6 x 10^{-3} cm/sec
- Separate liquid phases of VOCs in soil and groundwater suspected
- Tar-like compounds in soil suspected</td></tr>
<tr><td>Purpose/Significance of Application:
Application of soil vapor extraction with an on-site solvent recovery system; relatively large volume of contaminated soil; possible presence of separate liquid phases of VOCs and tar-like compounds in soil.</td></tr>
</table>

Case Study Abstract

Soil Vapor Extraction System at Commencement Bay, South Tacoma Channel (Well 12A), Phase 2, Tacoma, Washington (Continued)

Regulatory Requirements/Cleanup Goals:
- No specific cleanup goals identified in Record of Decision
- Local permit required for air emissions
- Performance objective for air treatment system set at 99% removal
- Air discharge limits specified as follows:

PCA	0.149 lbs/hr
PCE	0.095 lbs/hr
TCE	0.344 lbs/hr

Results:
- No results provided for quantity of contaminants removed during demonstration phase
- Computer modelling results show predicted removal rates for VOCs as a function of time
- Pilot-scale results indicated that 3 to 4 lbs/day/well of VOC could be removed from the upper 30 feet of soil
- No results provided for air emissions - treatment system removals or mass discharge rates
- Problems were experienced with the operation of the solvent recovery system
- Condensed mixed solvents formed an emulsion which did not readily separate from the water

Cost Factors:
Total Capital Cost - $5,313,973 (as of 5/94) (no breakdown of costs available)
Annual Operating Costs - $100,000 (estimated) (no breakdown of costs available)

Description:
The Commencement Bay site was used from 1927 to 1964 for waste oil recycling, paint and lacquer thinner manufacturing, and solvent reclamation and hundreds of drums of material were stored at the site. Leaks from these drums, as well as the dumping of wastes directly on the ground and overflows from the solvent and waste oil recycling tanks, resulted in contamination of the soil and groundwater at the site. The primary contaminants of concern at the site included DCE (trans-1,2-dichloroethylene), PCA (1,1,2,2-tetrachloroethane), PCE (1,1,2,2-tetrachloroethylene), and TCE (trichloroethylene). VOC soil concentrations range from 10 to 100 mg/L.

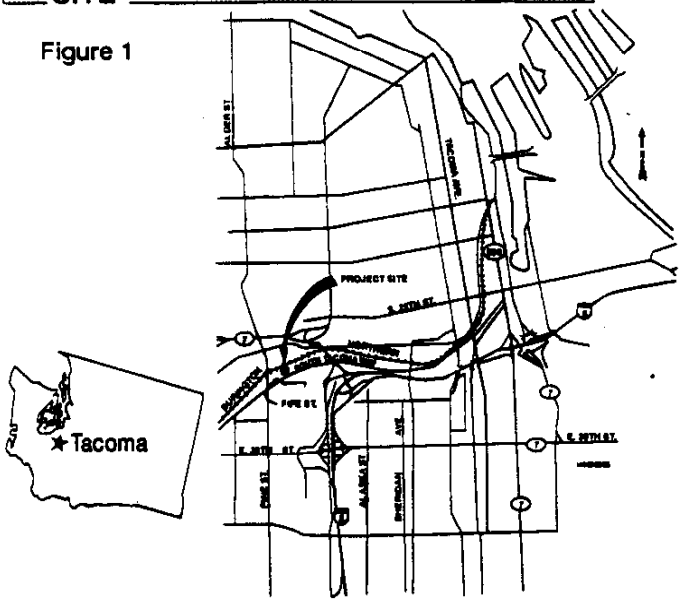
A full-scale SVE system was constructed in 1992. Operation testing of this system began in August 1992 and this report covers the demonstration phase of the project. The SVE system includes 22 vapor extraction wells. Granular activated carbon (GAC), used to treat extracted vapors, is regenerated on site using low pressure steam, which was subsequently condensed. The on-site solvent recovery system is used to separate VOCs from the condensate.

As of May 1994, the total capital costs and annual operating costs for this application were $5,313,973 and $99,810, respectively. While no performance data are available at this time, it was noted that the SVE system seems to be performing adequately. Several problems were experienced in the operation of the solvent recovery system. Condensed mixed solvents formed an emulsion which did not readily separate from the water. The report identifies a need to perform pilot testing of the solvent recovery system to ensure that separation of VOCs and water can be performed.

TECHNOLOGY APPLICATION ANALYSIS

SITE

Figure 1



TECHNOLOGY APPLICATION

This analysis covers the field application of in situ soil vapor extraction (SVE) to strip volatile organic compounds (VOCs) from a contaminated soil matrix and treat the extracted soil gases by vapor phase carbon adsorption. Operational testing began in August 1992 and is currently ongoing. This analysis covers performance through February 1994.

Groundwater at this site is being remediated through pump and treat which is not included in this analysis.

SITE CHARACTERISTICS

Site History/Release Characteristics

- During the period from 1927 to 1964 this site was used by National Oil and Paint for waste oil recycling, paint and lacquer thinner manufacturing, and solvent reclamation. The site was purchased by the Time Oil Company in 1964.
- The pre-1964 operations appear to have contributed to the site VOC contamination in several ways. First, the site was used to store hundreds of drums of potentially "useful" materials. Some of the stored drums leaked. Non-useable materials were dumped directly onto the ground. Second, during the recycling process for waste oil, solvents contained in the oil floated to the top of the processing tank and were poured off. Periodically, the tank holding the solvents overflowed onto the site.
- In 1981 chlorinated hydrocarbons were detected in groundwater samples from the city of Tacoma production well 12A.
- In 1983 a 5 tower air stripping system was built to treat well 12A water. In 1988 a pump and treatment system was installed near the contamination source to intercept and treat the groundwater plume.
- In accordance with the Record of Decision (ROD) signed in 1985, soils and solid waste materials were disposed of in an offsite Resource Conservation and Recovery Act (RCRA) approved facility. This waste material was contaminated with heavy metals (primarily lead),
- A pilot scale vapor extraction system was installed on site in 1985 and a full scale SVE was constructed in 1992. The full scale SVE began operation testing in 1992 and was scheduled for full operation in March 1994.

Contaminants of Concern

- The VOCs of greatest concern in the soil and groundwater are the following chlorinated hydrocarbons:

  DCE (trans-1,2-dichloroethylene)

  PCA (1,1,2,2-tetrachloroethane)

  PCE (1,1,2,2-tetrachloroethylene)

  TCE (trichloroethylene)

Contaminant Properties

Properties of contaminants focused upon during remediation are:

Property at 1 atm	Units	DCE	PCA	PCE	TCE
Empirical Formula		$C_2H_2Cl_2$	$C_2H_2Cl_4$	C_2Cl_4	C_2HCl_3
Density	g/cm^3	1.257	1.586	1.6311	1.462
Melting Point	°C	-50	-43.8	-22.4	-84.8
Vapor Pressure @ 25°C	mm Hg	331	419	77	
Henry's Law Constant	$(atm)(m^3)$	$5.32X10^{-3}$	$3.81X10^{-4}$	$2.87X10^{-2}$	$1.17X10^{-2}$
Water Solubility	mg/l	600	2,900	150	1,100
Log Octanol-Water Partition Coefficient;	log K_{ow}	1.48	2.39	2.53	2.53
Organic Carbon Partition Coefficient; Koc, L/kg	118	364	126		

Nature & Extent of Contamination

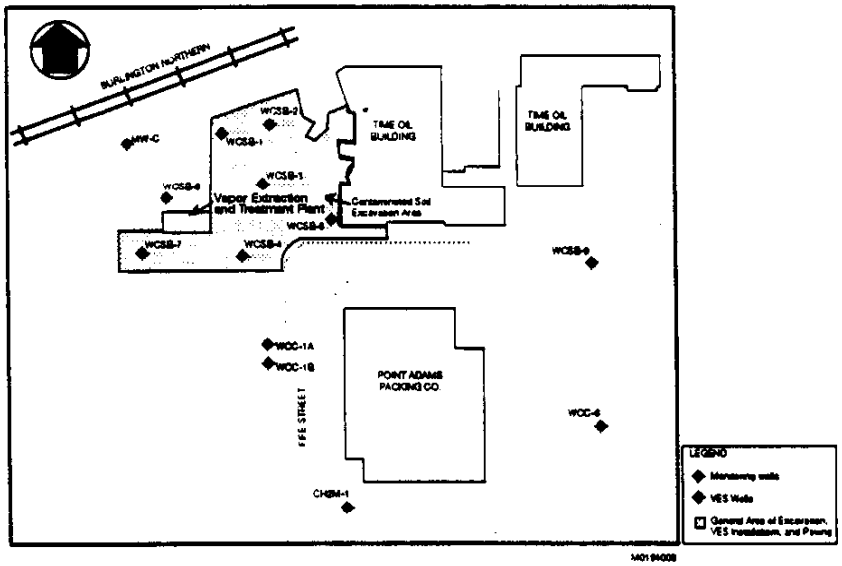
- About 20% or the contamination is in the top 32.5 feet, and the remaining 80% is in the 32.5 to 40 feet depth interval.
- The volume of contaminated soil is (66,287 ft2 X 40 ft deep =) 2,651,480 ft3.
- For the VOCs, there may be separate liquid phases of these compounds or miscible solutions between them in both the soil and groundwater.
- Free phase estimates are 3,734 pounds of PCE; 126,112 pounds of TCE; and 209,115 pounds of PCA.
- Tar like compounds (motor oil residues) may be present that will retard the extraction of PCA, PCE, and TCE by providing adsorptive layers in the soil. Tar like compounds will not be significantly extracted by the Soil Aeration System.
- With one exception, average VOC soil concentrations in the top 25 feet ranged from 10 to 100 mg/L along with significant quantities of semivolatile compounds.
- There are about 571,000 pounds of VOCs in the unsaturated zone.

Contaminant Locations and Geologic Profiles

Remedial investigation field activities at the site found the following concentrations:

Contaminant	Water from Well 12A Concentration, ppb
DCE	30 to 100
PCA	17 to 300
PCE	1.6 to 5.4
TCE	54 to 130

Figure 2



LOCATION OF EXCAVATION AREA AND TREATMENT SYSTEMS

- DCE was detected (0.11 mg/kg soil) at only one site: the top 5 feet at WCSB 9, about 270 feet from the center of contamination.
- With the exception of the 40 foot depth of WCSB 5, TCE was only occasionally detected at other WCSBs, and then only at concentrations of less than 10 mg/kg.
- With the exceptions of WCSB 4 and 5, PCA concentrations were less than 180 mg/kg except for one surface (0.5 foot depth) contamination at WCSB 7 where the concentration was 475 mg/kg.
- At WCSB 4 and 5, average PCA concentrations dropped from a maximum of 161 mg/kg at 5 feet depth down to 6 mg/kg at a depth of 20 feet.
- The average PCA concentrations in WCSB 4 and 5 increase from 6,200 mg/kg at 30 feet depth to over 19,000 mg/kg at a depth of 40 feet. The corresponding TCE concentration at 40 feet was 25,000 mg/kg for WCSB 5.
- The bulk of the contamination is centered at WCSB 4 & 5 (at the 30 to 40 foot depth) which are only 88 feet apart.
- It appears that the bulk of the contamination is in an area that is less than 50 feet from a line drawn between WCSB 4 & 5.

- Most of the contamination appears to be centered in an area of about (100 X 188 =) 18,800 ft2, and in a volume of about (15 X 18,800 =) 282,000 ft^3 of soil.
- All of the contaminants of concern are DNAPLs. Clearly they have had time to pass through 40 feet of soil (leaving relatively low residual concentrations in the top 20 feet) and have passed downward through the water table.
- All of the contaminants of concern have a solubility in water of 150 mg/l (PCE) or more (up to 2,900 mg/l for PCA).

Hydrogeologic Units

There are 2 hydrogeologic aquifers.

- The upper aquifer (unconfined sand and gravel) is 50 feet thick (depth to the water table is about 36 feet).
- The upper aquifer is separated from the lower aquifer by a 40 foot thick dense glacial till aquitard.
- The lower aquifer is not contaminated.
- The area suspected of groundwater contamination is in the upper aquifer and covers about 100 acres and is bounded by the city water well field on the south, the Burlington Northern Railroad on the north, and Interstate 5 on the East.

Site Conditions

• Average Air Temperature	38°F (Jan.) to 65°F (July)
• Precipitation	
-Annual Average	38. in.
-December Average	6.3 in.
-July Average	0.8 in.
• Snowfall, Annual Average	14. in.
• Relative humidity, Average	65% to 85%
• Wind Speed, Average	10 mph

- The vadose zone thickness (depth to groundwater) varies from 33 to 40 feet.
- The groundwater gradient is about 0.05%, falling to the north-northeast.

Key Soil or Key Aquifer Characteristics

Property	Units	Range or value
Porosity	%	30
Particle density	g/cm3	2.65
Soil bulk density	g/cm3	1.86
Surface soil permeability	cm/sec	2.8 to 3.6 X 10-3
Depth to groundwater	feet	36
Aquifer thickness	feet	50
Water Saturated thickness	feet	10 to 17

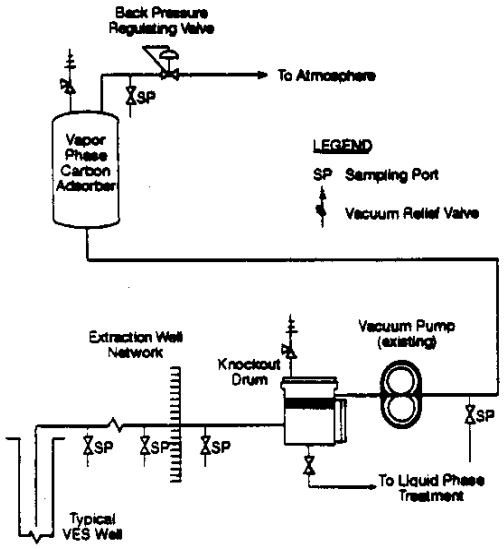
TREATMENT SYSTEM

The selected remedial action includes:

- Use of soil vapor extraction (vacuum applied via extraction wells that extend to the groundwater) to remove much of the remaining contamination in the soil. Other wells serve as air inlet wells and also extend to the groundwater.
- Paving of the ground surface above the area of influence of the SVE to minimize short circuiting of air flow from the surface and to promote deeper horizontal air flows in order to maximize VOC removal.
- The extracted vapor stream (vacuum pump discharge) is forced through a vapor phase carbon absorber where 99% of the VOCs are removed.
- The cleaned vapor stream is discharged to the atmosphere.
- The GAC beds are regenerated with low pressure steam to remove the VOCs.
- The steam and VOCs are condensed and the VOC separated from the water by decanting.

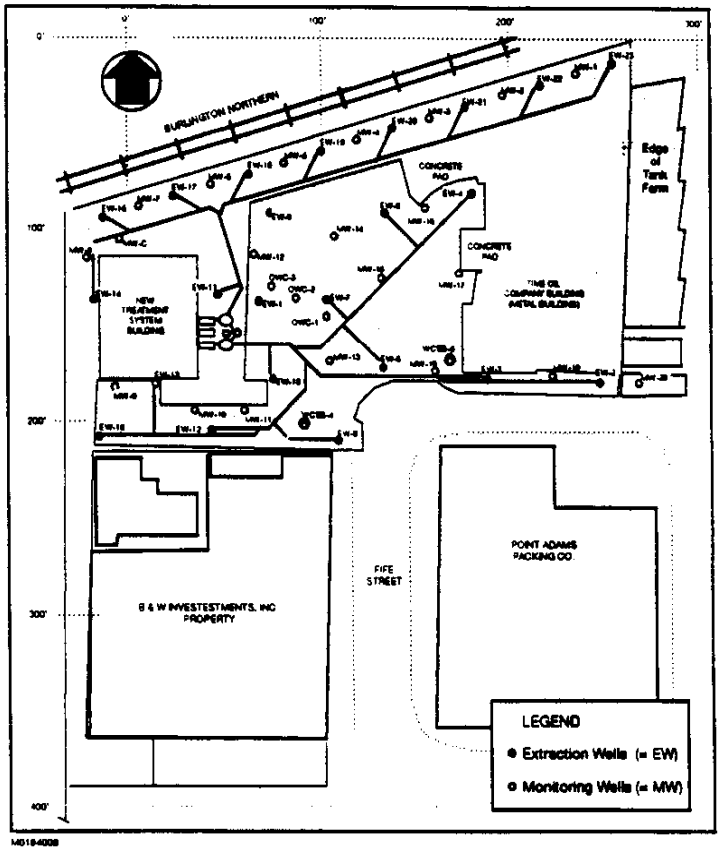
Overall Process Schematic

Figure 3



Process Flow Diagram for Soil Vapor Extraction and Treatment System.

Figure 4



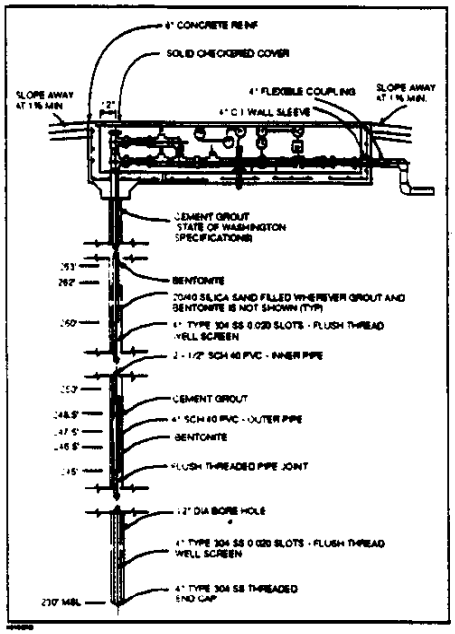
EXTRACTION/MONITORING WELL NETWORK

Extraction Well Network

- The pilot-scale VES showed that 3 to 4 pounds/(day)(well) of VOCs could be removed from the soil in the upper 30 feet.
- Full-scale VES contains 22 wells. Each well can act either as a vapor extraction well, an air inlet well, or as an observation well.

System Closeup

Figure 5



EXTRACTION WELL DETAIL

Key Design Criteria

- Design flow rate for the VES was 3,000 scfm (136 scfm/well).
- TCE was the design component for the first 900 days and PCA was the design component for the next 900 days.
- The product of design flow rate (scfm) times half life* was taken to be a constant for a given contaminant at this site.
- Half lives used for 3,000 scfm were:

PCA	296 days
PCE	47 days
TCE	50 days

- For a given contaminant, the initial solvent removal rate (lb/day) is directly proportional to the air flow rate (cfm).
- Influent loading rate for the air treatment system:

Compound	Influent loading rate, lb/hr
PCE	9.46
PCA	14.89
TCE	34.42
Water	136.5
Air	13,930

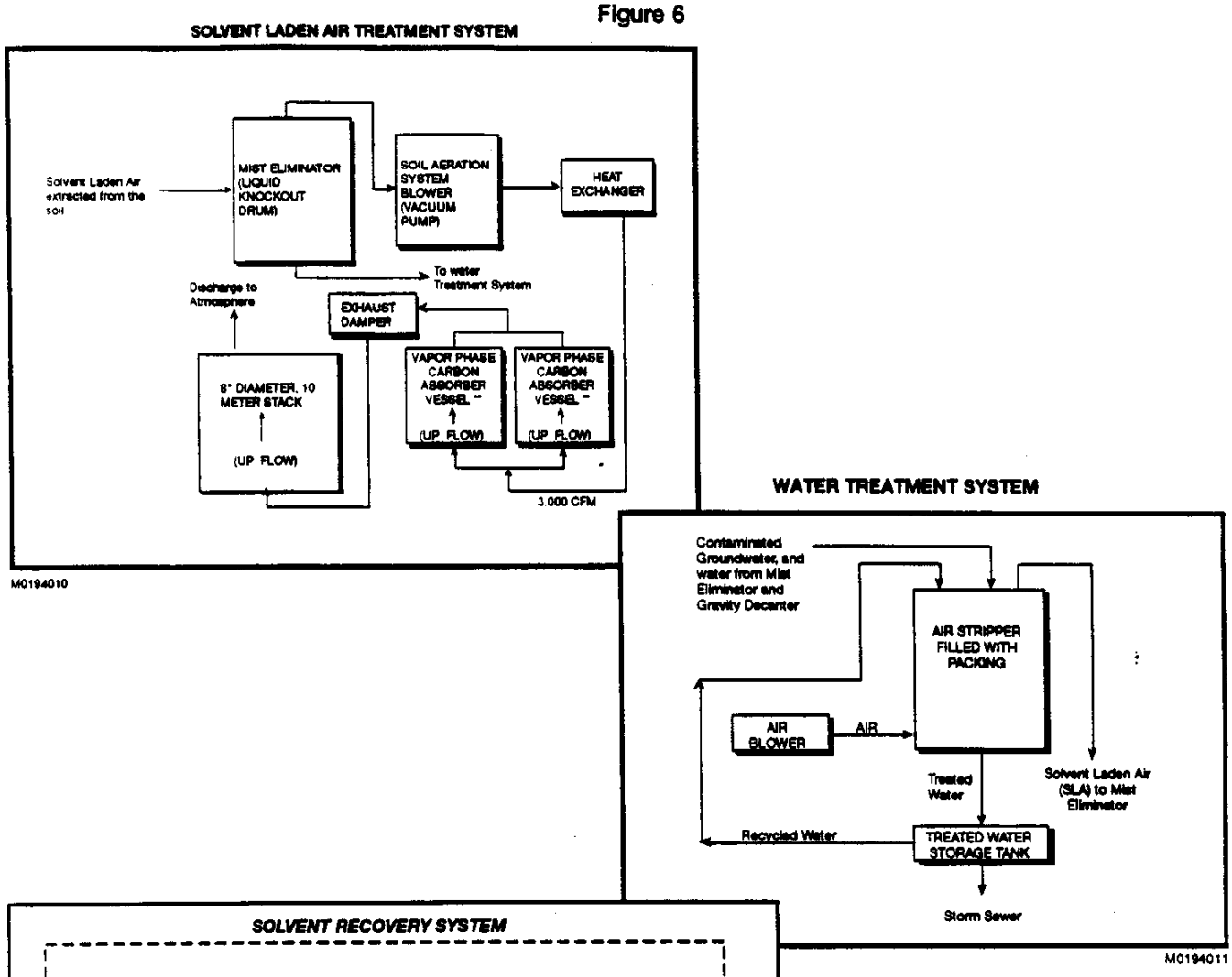
- Total allowable air treatment system pressure drop: 2 psi @ 3,000 scfm
- The water treatment system must be able to treat 51 gallons per hour of condensate from the gas treatment system mist eliminator (liquid knockout drum).
- The adsorption capacity of granular activated carbon (GAC) for PCA is given by the equation:

  mg PCA adsorbed/g GAC = 12.8(mg/L of PCA in water)0.613

* *The half life for a given contaminant is the time required for half of the original amount to be removed from the unsaturated zone.*

The Treatment System

Figure 6



PERFORMANCE

Performance Objectives

- Clean up soil to the extent possible. (Specific goals were not set in the ROD or the construction documents).
- Achieve air treatment system removal of 99%.
- Achieve discharge limits for air of:

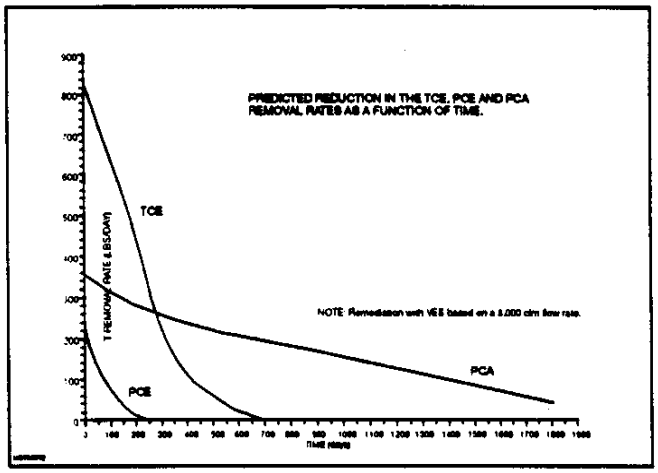
Compound	lb/hr
PCA	0.149
PCE	0.095
TCE	0.344

Treatment Plan

- An analysis was performed to estimate the amount of contaminants that can be removed daily from the unsaturated soil at various air flow rates and from this the capacity of the soil ventilation system was determined.
- A 3000 scfm soil vapor extraction (SVE), GAC gas treatment, and solvent recovery system was installed.
- The design life of the SVE system is 30 years.

Operational Performance

Figure 7



System Downtime

Currently (May 1994), the SVE system is in an extended startup due to problems with solvent recovery system. As a result, periods of system downtime occur frequently.

Treatment Performance

Effects on Plume

- Predictions made by the model used prior to operation of the soil aeration system estimated extraction efficiencies of 1 to 2% for the ethylenes (TCE and PCE), while the efficiency for PCA was estimated to be 2 to 7%.

Contaminants versus Time at the Treatment Plant Influent

- Data for this performance parameter was not available.

Total Pounds Contaminants Removed

- Data for this performance parameter was not available.

Performance Assessment

- The system is still in the demonstration phase.
- The SVE process seems to be performing adequately.
- It is necessary to size, place and tune the wells to optimize the performance of the system.
- The solvent recovery system is experiencing problems. The condensed mixed solvents form an emulsion which does not readily separate from the water.

COST

Calculations showed that on site regeneration of carbon adsorption beds (with steam) would reduce the total cost of this alternative from $4,657,000 to $944,050 for 5 years of operation. This was estimated to be the most cost effective alternative for treatment of the air removed by the gas collection system. Incineration was estimated at $1,439,200.

Capital Costs

Total Capital Costs (as of 5 May 1994)	$5,313,973
Annual Capital Cost (see above)	$99,810*

* Estimated

REGULATORY/INSTITUTIONAL ISSUES

- Highly contaminated surface soils were transported to a RCRA subtitle C landfill facility for treatment/disposal
- ARARs include RCRA, Clean Air Act regulations (for emissions of VOCs), the Clean Water Act, and the Safe Drinking Water Act (there are no drinking water standards for the contaminants present in Well 12A).
- A permit was required by local authorities for the air treatment facilities.
- If groundwater from Well 12A is to be used for drinking water, then it must be treated to the 10^{-6} risk level for the contaminants present. Otherwise, in order to be consistent with 40 CFR 264, Subpart F, groundwater corrective action is required until the concentration of hazardous constituents complies with one of the following:
  - Maximum Contaminant Levels (MCLs - where designated for particular substances)
  - Alternate Concentration Limits (ACLs - that provide adequate protection of public health and the environment or background).
- NPL site.
- Performance objective of the air treatment system: 99% removal.
- Discharge limits for air:

Compound	lb/hr
PCA	0.149
PCE	0.095
TCE	0.344

SCHEDULE

- The specification for the soil aeration system (reference 4), dated April 1991, states that installation of equipment shall be completed within 360 days of notice to proceed.
- No schedule showing the issuance of the notice to proceed was given.
- No schedule for the progress of the operating phase was given.

Date		
9/84	Approve Remedial Action & Initiate Negotiation with PRPs	
	Negotiation Successful	**Negotiation Unsuccessful**
3/85	Sign EDD, Consent 106 AO	Unilateral 106 AO effective
	Sign ROD, IAG	
2/85	Design Initiated by PRPs	Design Initiated by EPA
5/85	Construction Procurement by PRPs	
9/85		Construction Procurement by EPA
7/85	Construction Initiated by PRPs	
10/85	Construction Completed by PRPs	Construction Initiated by EPA

LESSONS LEARNED

The solvent recovery system, using low pressure steam to strip the VOCs from the GAC is too complex and very operator intensive.

Implementation Considerations

- Pilot testing of the solvent recovery system should be performed to ensure that a proper separation of solvent VOCs and water can be performed.
- Total capital costs estimated in the ROD was $1,590,000 and O&M costs were estimated to be an additional $50,000/year. Actual capital costs are more than $5,300,000 with annual operating costs currently estimated at nearly $100,000.
- Well head vaults, if used, should probably be traffic-rated.

Future Technology Selection Considerations

The liquid phase solvent recovery system was evaluated to be more cost effective than incineration — $944,050 for steam vs $1,439,200 for incineration (see the Cost Section). Any future technology selection should consider the complexity of this process, the cost of addition operator involvement, as well as the difficulties in separating product from water by the solvent decanting system during the process selection process.

SOURCES

Major Sources For Each Section

Site Characteristics:	2, 6, and 9
Treatment System:	3, 4, 5, and 6
Performance:	Source #s
Cost:	7
Regulatory/Institutional Issues:	1, 3, 4, and 5
Schedule:	1
Lessons Learned:	1, 3, and 4

Chronological List of Sources and Additional References

1. EPA Superfund Record of Decision: South Tacoma Channel-Well 12A, WA, EPA/ROD/R10-85/OO4, May, 1985.
2. Revised Remedial Design Report, South Tacoma Channel Well 12A, by Woodward-Clyde Consultants for U.S. Army Corps of Engineers, Superfund Branch, Kansas City, Missouri District, April 17, 1987.
3. 100% Final Design Analysis, South Tacoma Channel Well 12-A, by Environmental Science & Engineering, Inc. for U.S. Army Corps of Engineers, Kansas City, Missouri, April, 1991.
4. Specifications for Soil Aeration System, South Tacoma Channel Well 12A, Phase 2, U.S. Army Corps of Engineers, Kansas City District, April, 1991.
5. Soil Aeration System, South Tacoma Channel Well 12-A, Phase 2, Operation and Maintenance Manual, by Environmental Science & Engineering, Inc. for U.S. Army Engineering District, Kansas City Corps of Engineers, April, 1991.
6. Soil Aeration System, South Tacoma Channel Well 12-A, Phase 2 (drawings), by Environmental Science & Engineering, Inc. for U.S. Army Corps of Engineers, Kansas City District, June 10, 1991.
7. Letter from Philip N. Stoa, EPA Coordinator, Construction Division, Construction Services Branch, Seattle District, Corps of Engineers, December 15, 1993.
8. RREL Treatability Data Base, Version 4.0, EPA, November 15, 1991.
9. Climates of the States, by the National Oceanic and Atmospheric Administration, US Department of Commerce, published by the Water Information Center, 1974.
10. Fax from Bill Brooker, U.S. Army Corps of Engineers, Fort Lewis Area Office, dated 5/10/94.

ANALYSIS PREPARATION

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REVIEW

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