EPA 542-R-98-011
September 1998

Remediation Case Studies:
Ex Situ Soil Treatment Technologies (Bioremediation, Solvent Extraction, Thermal Desorption)

Volume 7

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
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- Tennessee Valley Authority
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September 1998

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Compilation of this material has been funded wholly or in part by the U.S. Environmental Protection Agency under EPA Contract No. 68-W5-0055.

FOREWORD

This report is a collection of ten case studies of ex situ soil treatment technology 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 ex situ soil treatment technologies (Volume 7). The 10 case studies in this report include completed full-scale remediations and large-scale field demonstrations of bioremediation, solvent extraction, and thermal desorption. 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 ten applications of ex situ soil treatment technologies, including three applications of land treatment (bioremediation), one application of solvent extraction, and six applications of thermal desorption. Two of the land treatment applications were full-scale remediations of sites contaminated with polycyclic aromatic hydrocarbons (PAHs) and petroleum hydrocarbons, and one was a field demonstration at a site contaminated with pesticides. The solvent extraction application was a full-scale application to treat soil contaminated with PCBs. All six thermal desorption applications were full-scale, and involved treatment of soil contaminated with chlorinated solvents, petroleum hydrocarbons, PAHs, and pesticides. All case studies in this volume are for completed applications.

Table 1 provides a summary including information on technology used, contaminants and media treated, and project duration for the 10 ex situ soil treatment technology projects in this volume. This table also provides highlights about each application. Table 2 summarizes cost data, including information on quantity of media treated. In addition, Table 2 shows a calculated unit cost for some projects, and identifies key factors potentially affecting project cost. (The column showing the calculated unit costs for treatment provides a dollar value per unit of soil treated.) 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 incineration projects 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, moisture content, pH, total organic carbon, oil and grease or total petroleum hydrocarbons, field capacity, Btu value, halogen content, and metal content, and other site conditions.

Table 1. Summary of Remediation Case Studies: Ex Situ Soil Treatment Technologies (Bioremediation, Solvent Extraction, Thermal Desorption)

Site Name, State (Technology)	Principal Contaminants*						Media (Quantity Treated)	Project Duration	Highlights
	Chlorinated Solvents	BTEX and/or TPH	PAHs	Pesticides/Herbicides	Explosives	Metals			
Bioremediation									
Bonneville Power Administration Ross Complex, Operable Unit A, WA (Land Treatment)			●				Soil (2,300 yd^3)	11/94 - 1/96	Combination of bioremediation and enhancements used to land treat contaminated soil
Fort Greely, UST Soil Pile, AK (Land Treatment)		●					Soil (9,800 yd^3)	9/94 - 8/97	Application of land treatment to treat gasoline and diesel contaminated soil ex situ
Novartis Site, Ontario, Canada (Land Treatment)				●			Soil (200 tons)	3/96 - 9/97	Demonstrated the performance of the DARAMEND process for treating Metolachlor-contaminated soils
Solvent Extraction									
Sparrevohn Long Range Radar Station, AK (Solvent Extraction)							Soil (288 yd^3)	6/96 - 8/96	Application of an innovative technology to treat PCB-contaminated soil at a remote site in Alaska
Thermal Desorption									
FCX Washington Superfund Site, NC (Thermal Desorption)				●			Soil (13,591 yd^3)	3/95 - 3/96	Vacuum-enhanced low temperature thermal desorption used to treat pesticide-contaminated soil
Fort Lewis, Solvent Refined Coal Pilot Plant (SRCPP), WA (Thermal Desorption)			●				Soil (104,366 tons)	8/96 - 12/96	Thermal desorption of a relatively large amount of soil contaminated with PAHs

Table 1. Summary of Remediation Case Studies: Ex Situ Soil Treatment Technologies (Bioremediation, Solvent Extraction, Thermal Desorption) (continued)

Site Name, State (Technology)	Principal Contaminants*						Media (Quantity Treated)	Project Duration	Highlights
	Chlorinated Solvents	BTEX and/or TPH	PAHs	Pesticides/Herbicides	Explosives	Metals			
Naval Air Station Cecil Field, Site 17, OU 2, FL (Thermal Desorption)		●	●				Soil (11,768 tons)	6/95 - 9/25/95	Mobile thermal desorption unit used to treat soil contaminated with fuel and solvents
Port Moller Radio Relay Station, AK (Thermal Desorption)		●					Soil (9,500 yd^3)	6/95 - 8/95	Application of thermal desorption to treat sandy soil contaminated with diesel fuel at a remote site in Alaska
Re-Solve, Inc. Superfund Site, MA (Thermal Desorption)							Soil (36,200 yd^3)	6/93 - 12/94	Thermal desorption of PCB-contaminated soil
Waldick Aerospaces Devices Superfund Site, NJ (Thermal Desorption)	●	●				●	Soil (3,450 yd^3)	6/93 - 10/93	LTTD of soil contaminated with a wide range of organics

* Principal contaminants are one or more specific constituents within the groups shown that were identified during site investigations.

Table 2. Remediation Case Studies: Summary of Cost Data

Site Name, State (Technology)	Technology Cost ($)*	Quantity of Media Treated	Quantity of Contaminant Removed	Calculated Unit Cost for Treatment**	Key Factors Potentially Affecting Technology Costs***
Bioremediation					
Bonneville Power Administration Ross Complex, Operable Unit A, WA (Land Treatment)	Total: 1,082,859	2,300 yd^3	Not applicable	$470/$yd^3$	Costs were relatively high because this project involved researching rates of degradation under various enhancement techniques
Fort Greely, UST Soil Pile, AK (Land Treatment)	Total: $290,288	9,800 yd^3	Not applicable	$29.62/$yd^3$	Costs were higher than anticipated because treatment took twice as long as anticipated
Novartis Site, Ontario, Canada (Land Treatment)	Not provided	200 tons	Not applicable	Projected as $186/ton (Canadian dollars) for a full-scale application at this site	Factors for full-scale include site location (distance from material and climate), quantity of soil treated, initial concentrations of target compounds, applicable remediation criteria, and soil pretreatment requirements
Solvent Extraction					
Sparrevohn Long Range Radar Station, AK (Solvent Extraction)	Total: $828,179	288 yd^3	Not applicable	$780/$yd^3$	High transportation costs were incurred because this site was at a remote location and was accessible only by air
Thermal Desorption					
FCX Washington Superfund Site, NC (Thermal Desorption)	Total: $1,696,800	13,591 yd^3	Not applicable	$125/$yd^3$	One of the first applications of this vendor's technology at a full-scale; required several modifications during operation at this site
Fort Lewis, Solvent Refined Coal Pilot Plant (SRCPP), WA (Thermal Desorption)	Total (for entire RA): $7,100,000 Total (for treatment only): $tbd	104,366 tons	Not provided	$68/ton (for entire RA) $34/ton (for treatment only)	Unit costs were relatively low because of economies-of-scale

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 Unit Cost for Treatment**	Key Factors Potentially Affecting Technology Costs***
Naval Air Station Cecil Field, Site 17, OU 2, FL (Thermal Desorption)	Total: $1,946,122	11,768 tons	Not applicable	$165/ton	Site work and preparation including extensive storm water management lead to increased costs for this application
Port Moller Radio Relay Station, AK (Thermal Desorption)	Total: $3,325,000	9,500 yd^3	Not applicable	$350/$yd^3$	Mobilization and demobilization costs for this application were relatively high because of the remote site location
ReSolve, Inc. Superfund Site, MA (Thermal Desorption)	Total: $6,800,000	44,000 tons	Not applicable	$155/ton	Treatment of condensate from thermal desorber to meet strict water discharge limits required use of a multi-stage, on-site wastewater treatment system
Waldick Aerospaces Devices Superfund Site, NJ (Thermal Desorption)	Total (for entire RA): $4,995,159 Total (for treatment only): $2,017,361	3,450 yd^3	Not provided	$585/$yd^3$	Costs were higher because system was temporarily shut down because of non-compliance with air emission standard

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.

Ex Situ Soil Treatment Technologies
(Bioremediation, Solvent Extraction, Thermal Desorption)

Case Studies

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BIOREMEDIATION CASE STUDIES

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Land Treatment at the Bonneville Power Administration
Ross Complex, Operable Unit A, Wood Pole Storage Area
Vancouver, Washington

Land Treatment at the Bonneville Power Administration Ross Complex, Operable Unit A, Wood Pole Storage Area Vancouver, Washington

<table>
<tr><td>Site Name:
Bonneville Power Administration Ross Complex, Operable Unit A, Wood Pole Storage Area</td><td rowspan="2">Contaminants:
High molecular weight polycyclic aromatic hydrocarbons (HPAHs) and pentachlorophenol (PCP)
- HPAHs in soils during RI at levels up to 150 mg/kg (1,500 mg/kg in hot spots)
- PCP in soils during RI at levels up to 62 mg/kg (5,00 mg/kg in hot spots)</td><td>Period of Operation:
November 1994 - January 1996</td></tr>
<tr><td>Location:
Vancouver, Washington</td><td>Cleanup Type:
Full-scale
(EPRI also used this application for research)</td></tr>
<tr><td>Vendor:
Information not provided</td><td rowspan="2">Technology:
Land Treatment
- Four treatment beds (housed in a temporary tent); soil pretreated using a 0.25-inch vibrating screen
- Total of four treatment series - each series involved the four treatment beds used concurrently to test different combinations of enhancements (UV oxidation, peroxide addition, and ethanol addition) and bioremediation (nutrient addition)
- Mixing rate - weekly during treatment series 1; beds changed once every 84 days
- Residence time - average of 84 days
- Depths of lifts - 6 to 12 inches</td><td>Cleanup Authority:
CERCLA
- ROD signed: May 6, 1993</td></tr>
<tr><td>PRP Representative:
Tony Morrell
BPA Ross Complex
5411 Northeast Highway 99
Vancouver, WA 98663
(360) 418-2884

EPRI Representative:
Dr. Benjamin J. Mason
ETHURA
Electric Power Research Institute
9671 Monument Drive
Grants Pass, OR 97526-8782
(541) 471-1869</td><td>EPA Remedial Project Manager:
Nancy Harney
U.S. EPA Region 10
1200 6th Avenue
Seattle, WA 98101
(206) 553-6635</td></tr>
<tr><td>Waste Source: Drips and spills from wood preserving operations</td><td colspan="2" rowspan="2">Type/Quantity of Media Treated:
Soil - 2,300 cubic yards</td></tr>
<tr><td>Purpose/Significance of Application: Combination of bioremediation and enhancements used to land treat contaminated soil</td></tr>
<tr><td colspan="3">Regulatory Requirements/Cleanup Goals:
- The ROD specified primary target goals of 1 mg/kg for HPAH and 8 mg/kg for PCP.
- Because of concern about the ability to achieve the primary goal, the ROD included three alternatives (tiers) of cleanup goals. Tier 1: Enhanced land treatment - 1 mg/kg for HPAH; 8 mg/kg for PCP; Tier 2: Enhanced land treatment with installation of gravel cap on soil and institutional controls - 23 mg/kg for HPAH; 126 mg/kg for PCP; and Tier 3: Enhanced land treatment, with installation of multilayered cap on soil and institutional controls, greater than 23 mg/kg HPAH, greater than 126 mg/kg PCP.</td></tr>
</table>

Land Treatment at the Bonneville Power Administration Ross Complex, Operable Unit A, Wood Pole Storage Area Vancouver, Washington (continued)

Results:
- HPAH and PCP levels in soil were reduced by approximately 80 percent after treatment, and all soils met Tier 2 levels, at a minimum.
- Concentrations for the four treatment series ranged from 6.76 to 21.83 mg/kg for HPAHs and from 6.8 to 20.7 mg/kg for PCP.
- EPRI concluded that land treatment could not meet Tier 1 cleanup goals for all soil at the site.

Cost:
- Actual total cost of the project through November 1995 - $1,082,859 ($532,859 paid by BPA and $550,000 paid by EPRI). Includes costs for excavation, capital equipment, and operation and maintenance (O&M). Does not include cost for a gravel cap that was not completed until January 1996.
- The total cost of $1,082,859 corresponds to a unit cost of $470 per yd^3 for 2,300 yd^3 of soil treated.

Description:
The Bonneville Power Administration (BPA) owns and operates a power distribution center in Vancouver, Washington, known as the Ross Complex. The site, an active facility that BPA has operated since 1939 to distribute hydroelectric power throughout the Pacific Northwest, also has been used for research and testing, maintenance construction operations, and storage and handling of hazardous and nonhazardous waste. Operable Unit A (OU A) at the Ross complex consists of 21 contaminated areas, including the Wood Pole Storage Area. The Wood Pole Storage Area had been used to dry transmission line poles treated off site with pentachlorophenol (PCP) and creosote. The treated poles were transported to the site and placed on cross poles to dry. Contamination occurred when chemicals dripped from the poles onto the ground. A remedial investigation (RI) identified HPAHs (the sum of eight carcinogenic polycyclic aromatic hydrocarbons found in creosote) and PCP as the contaminants of concern. Under a ROD signed May 6, 1993, land treatment was selected as the remedy for the Wood Pole Storage Area. EPRI agreed to split the cost of the remediation in exchange for use of the project as a research tool to evaluate the rates of degradation under various bioremediation enhancement techniques.

The land treatment system consisted of a temporary treatment tent that housed four treatment beds. Contaminated soil first was passed through a 0.25-inch vibrating screen and then was placed in a treatment bed. Four treatment beds were used to concurrently test different bioremediation enhancement techniques including UV oxidation, peroxide addition, and ethanol addition, well as biodegradation (nutrient addition). Several combinations (configurations) of enhancements and biodegradation with nutrient addition were tested with the four test beds operated concurrently over a total of four different treatment series. All soils met Tier 2 levels; however, EPRI concluded that land treatment could not meet Tier 1 cleanup goals for all soil at the site. For this application, the performance of bioremediation with nutrient addition was found to be comparable to land treatment enhanced with hydrogen peroxide, ethanol, or UV light or with combinations of these enhancements. EPRI identified factors that could improve performance of UV-enhanced bioremediation for future applications, including: (1) using a higher-intensity UV light, (2) mixing soil more frequently, and (3) increasing the dissolution of contaminants to increase exposure to the UV rays. Initially, the nutrient solution was based on Alaska fish meal. However, test results showed that the microorganisms consumed the fish meal but did not degrade the contaminants of concern. A change was made to a new nutrient solution based of Miracle Gro™, a fertilizer containing nitrogen. EPRI noted that results improved when a relatively large volume of nutrient solution was maintained in the soils and that the treatment efficiency was relatively consistent throughout the year, independent of ambient temperature and precipitation.

Cost and Performance Summary Report
Land Treatment at the Bonneville Power Administration Ross Complex, Operable Unit A, Wood Pole Storage Area Vancouver, Washington

Summary Information [1, 2, 4, 6]

The Bonneville Power Administration (BPA) owns and operates a power distribution center in Vancouver, Washington, known as the Ross Complex. The site is an active facility that BPA has operated since 1939 to distribute hydroelectric power throughout the Pacific Northwest. The site also has been used for research and testing, maintenance construction operations, and storage and handling of hazardous and nonhazardous waste.

Operable Unit A (OU A) at the Ross complex consists of 21 contaminated areas, including the Wood Pole Storage Area. The Wood Pole Storage Area had been used to dry transmission line poles treated off site with pentachlorophenol (PCP) and creosote. The treated poles were transported to the site and placed on cross poles to dry. Contamination occurred when chemicals dripped from the poles onto the ground. A remedial investigation (RI) was performed at the Ross Complex in 1991. The RI identified high molecular weight polycyclic aromatic hydrocarbons (HPAHs) and PCP as the contaminants of concern. HPAHs consist of the sum of the eight carcinogenic polycyclic aromatic hydrocarbons that are found in creosote, specifically benz(a)anthracene, chrysene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, indeno(1,2,3-cd)pyrene, dibenz(a,h)anthracene, and benzo(g,h,i)perylene.

The RI identified concentrations ranging from nondetect (ND) to 150 milligrams per kilograms (mg/kg) for HPAHs and ND to 62 mg/kg for PCP. In hot spots at the site, where there were heavy deposits of wood preservatives, concentrations were reported as high as 5,000 mg/kg for HPAHs and 1,500 mg/kg for PCP. Following excavation of contaminated soil, average concentrations were identified as 35 and 33.9 mg/kg, respectively, in the excavated site soils.

Under a record of decision (ROD) signed May 6, 1993, land treatment was selected as the remedy for the Wood Pole Storage Area. BPA and the Electric Power Research Institute (EPRI) conducted remediation of the Wood Pole Storage Area from November 1994 through January 1996. EPRI agreed to split the cost of the remediation in exchange for use of the project as a research tool to evaluate the rates of degradation under various bioremediation enhancement techniques.

Approximately 2,300 cubic yards (yd^3) of material required treatment at this site. This amount consisted of 1,400 yd^3 from the pole storage areas and 900 yd^3 from the roadways. Of this material, 1,252 yd^3 were fines (material passing a 0.25-inch screen) and 1,048 yd^3 were gravel. Other materials at the site were identified in preliminary sampling as potentially requiring treatment. However results from additional sampling showed that treatment of these materials was not required.

CERCLIS ID Number:	WA1891406349
Lead:	Potentially Responsible Party

Timeline [3, 5]

May 6, 1993	ROD signed
November 1994 - January 1996	Land treatment conducted
September 23, 1996	Site deleted from National Priorities List (NPL)

Factors That Affected Cost or Performance of Treatment [6]

The table below lists the key matrix characteristics that affected the cost or performance of this technology and the values measured for each during site characterization.

Matrix Characteristics

Parameter	Value
Soil Classification:	Gravelly silt loam
Clay Content and/or Particle Size Distribution:	Gravel - 45.6%; Sand - 37%; Silt - 11%; Clay - 6.4%
Field Capacity:	25%
pH:	4.7

Treatment Technology Description [1, 2, 3, 4, 6]

The land treatment system implemented at the Wood Pole Storage Area consisted of a temporary treatment tent that housed four treatment beds. Contaminated soil first was passed through a 0.25-inch vibrating screen and then was placed in a treatment bed. According to EPRI, there were four series of treatment activities that each lasted an average of 84 days. Four treatment beds were used concurrently in each series of activities so that different treatment configurations could be tested. The four series of treatment activities, and the specific enhancements used in each of the beds, are shown below.

Treatment Series	Bed No.	Treatment Enhancement
1	1	UV (82 days)
1	2	Biodegradation (30 days), UV (30 days), and peroxide (22 days)
1	3	Biodegradation (30 days), peroxide (20 days), and biodegradation (32 days)
1	4	Biodegradation (82 days) - control bed
2	1	UV and ethanol (20%)
2	2	UV and ethanol (20%)
2	3	Biodegradation and ethanol (20%)
2	4	Biodegradation and ethanol (5%)
3	1	UV and ethanol (35%)
3	2	UV and ethanol (35%)
3	3	Biodegradation and ethanol (35%)
3	4	Biodegradation and ethanol (5%)
4	1	UV and ethanol (5%) - bed front 350 nm bulb; bed back 310 nm bulb
4	2	UV and ethanol (5%)
4	3	Biodegradation and ethanol (5%)
4	4	Biodegradation only

Treatment beds 1 and 2 were 27 ft by 17 ft and beds 3 and 4 were 34 ft by 17 ft. The volume of soil treated in each bed averaged 15 yd^3, with a range of 9.4 to 18.9 yd^3.

Biodegradation (land treatment) consisted of subterranean soil irrigation in each of the beds, with a nutrient solution added regularly. The nutrient solution was aerated by a pump that stirred the solution in a tank. Each of the four beds was sampled on an average of once every 11 days and analyzed using EPA Methods 8270 and 350, with sonification for extraction. Soils in each bed were mixed and replaced once every six weeks.

Initially, the nutrient solution was based on Alaska fish meal. However, test results showed that the microorganisms consumed the fish meal but did not degrade the contaminants of concern. A change was made to a new nutrient solution based on Miracle Grow™, a fertilizer containing nitrogen (31 percent by weight) and phosphorus (3 percent by weight) which EPRI typically had used for this technology. EPRI noted that results improved when a relatively large volume of nutrient solution was maintained in the soils and that the treatment efficiency was relatively consistent throughout the year, independent of ambient temperature and precipitation.

Listed below are the key operating parameters for each treatment series and the values measured for each.

Operating Parameters

Parameter	Value
Mixing Rate or Frequency:	Weekly during treatment series 1; beds changed once every 84 days
Depth of Lifts:	6 to 12 inches
Number of Lifts:	4
Moisture Content:	12%
pH:	4.7
Residence Time:	Average of 84 days
Temperature:	Ambient 47.2 +- 15.1 °F; Maximum 97 °F; Minimum 5 °F
Rate of Degradation (for each treatment scenario):	0.20 mg/kg/day
Enhancements:	Hydrogen peroxide (35%), UV light at 350 nm and 310 nm, and combinations of UV, hydrogen peroxide, and ethanol

Performance Information [1, 2, 3, 4, 6]

According to EPA, there was concern that it would be difficult to achieve the primary target goals of 1 mg/kg for HPAH and 8 mg/kg for PCP identified in the ROD. A decision was made to include alternative goals for the site, should the primary goals not be achieved. Therefore, the ROD specified three different levels (tiers) of cleanup goals. Tier 1 goals were the primary target goals; soil treated to those levels could be placed on site without further controls. Soil treated to the less stringent Tier 2 or Tier 3 goals could be placed on site, but additional controls would be required, as described below.

- Tier 1: Enhanced land treatment - 1 mg/kg for HPAH; 8 mg/kg for PCP
- Tier 2: Enhanced land treatment with installation of gravel cap on soil and institutional controls - 23 mg/kg for HPAH; 126 mg/kg for PCP
- Tier 3: Enhanced land treatment, with installation of multilayered cap on soil and institutional controls, greater than 23 mg/kg HPAH, greater than 126 mg/kg PCP

Analytical results from the four treatment beds within each treatment series were combined by EPRI and reported as one value. No quantitative analytical data were provided to evaluate the performance of individual treatment enhancements. EPRI also analyzed soil in a storage pile and a "biopile". The storage pile was the original stockpile of material that had been excavated from the Pole Yard. The biopile was a portion of the stored material (approximately 3 ft thick) that had shallow basins cut into the top; waste nutrient media was pumped into these basins and allowed to soak into the pile. Analytical data on the concentrations of HPAH and PCP in treated soils (four treatment series, storage pile, and biopile) are shown below.

[illegible]	HPAHs Initial (mg/kg)	HPAHs Final (mg/kg)	PCP Initial (mg/kg)	PCP Final (mg/kg)
1	15.43	15.08	25.17	20.70
2	34.48	21.83	41.75	18.05
3	16.14	11.71	20.39	18.15
4	10.03	6.76	13.59	6.80
Storage pile	37.16	10.03	35.76	13.59
Biopile	20.94	8.20	21.72	12.30

Soils from treatment series 1 were sampled again 120 days after the "final" samples were collected. In this additional sample, concentrations of HPAHs had decreased to 5.04 mg/kg and PCP to 9.64 mg/kg.

As these data illustrate, HPAH and PCP levels in soil were reduced by approximately 80 percent after treatment, and all soils met Tier 2 levels, at a minimum. After treatment, the average concentrations for the four treatment series ranged from 6.76 to 21.83 mg/kg for HPAHs and from 6.8 to 20.7 mg/kg for PCP. EPRI concluded that land treatment could not meet Tier 1 cleanup goals for all soil at the site.

Treated soils were placed in a storage cell located along the south fence line at the site and covered with approximately one foot of clean gravel. The area of the storage cell was less than one acre.

According to EPRI, the treatment enhancements achieved results that were similar to those for land treatment. Results of UV treatment demonstrated that only the top 1 to 10 millimeters (mm) of soil were affected by exposure to UV rays.

Performance Data Quality

Duplicate, split, and co-located samples were collected throughout the research effort. In addition, a random selection of samples were run using SW-846 Method 8270. EPRI reported that a comparison of the analytical results indicated that there was not a significant difference between the paired samples.

Cost Information [1, 2]

The ROD indicated that the remediation was projected to cost from $482,120 to $586,520 to achieve Tier 2 goals. In a summary of project costs, BPA reported the actual cost of the project to be $1,082,859 through November 1995 ($532,859 paid by BPA and $550,000 paid by EPRI). The total project cost consisted of costs for excavation, capital equipment, and operation and maintenance (O&M); no additional information was provided about the detailed components of the total project cost. In addition, no information was provided about the portion of the total project cost that was expended for testing and research. The total project cost reported may not be comprehensive because costs were reported only through November 1995, and the gravel cap was not completed until January 1996. The total cost of $1,082,859 corresponds to a unit cost of $470 per yd^3 for 2,300 yd^3 of soil treated.

Actual Project Costs

Cost Element	Cost ($ in 1995)
Excavation (of soil)	**Included in total**
Capital	**Included in total**
Operation & Maintenance	**Included in total**
Disposal of Residuals	**0**
Analytical (related to compliance monitoring, not technology performance)	**0**
Total Project Cost	**$1,082,859**

Observations and Lessons Learned [2, 3, 4, 5]

BPA completed remediation of the Wood Pole Storage Area in cooperation with EPRI. EPRI agreed to split the cost of the remediation in exchange for use of the project as a research tool to evaluate the rates of degradation under various bioremediation enhancement techniques. The PRP reported that overall project costs exceeded those projected in the ROD because additional activities were performed to support the research aspects of this application, including varying the treatment regimes to demonstrate variability in the rate of biodegradation.

For this application, the performance of land treatment was found to be comparable to land treatment enhanced with hydrogen peroxide, ethanol, or UV light or with combinations of these enhancements.

EPRI identified factors that could improve performance of UV-enhanced bioremediation for future applications, including: (1) using a higher-intensity UV light, (2) mixing soil more frequently, and (3) increasing the dissolution of contaminants to increase exposure to the UV rays. EPRI indicated that the Institute is considering obtaining a patent on the use of UV light as an enhancement to land treatment; no specific information was provided about the innovation to be submitted for a patent.

The vendor supporting EPRI initially used Alaska fish meal as the nutrient for this application because of the vendor's experience in the use of that approach to treat fuel spills. However, according to EPRI, the fish meal solution proved to be consumed quickly, and its use did not lead to sufficient biodegradation of the contaminants of concern.

Contact Information

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References

The following references were used in the preparation of this report.

1. EPA Region 10. 1993. *Final Record of Decision for Bonneville Power Administration, Ross Complex, Operable Unit A*. May 6.

2. Bonneville Power Administration. Not Dated. *Summary of Project Costs*.

3. EPA. 1997. Innovative Treatment Technologies Database, Annual Status Report (Eighth Edition). August.

4. Tetra Tech EM Inc. 1998. Record of Telephone Conversation Regarding Technology Performance of Land Treatment Application at BPA Ross Complex, OU A. Between Richard Weisman, Tetra Tech EM Inc., and Ben Mason, Electric Power Research Institute. June 9.

5. Tetra Tech EM Inc. 1998. Record of Telephone Conversation Regarding Availability of Data for BPA Ross Complex, OU A. Between Richard Weisman, Tetra Tech EM Inc., and Tony Morrell, Bonneville Power Administration. June 9.

6. Dr. Benjamin J. Mason, EPRI. 1998. Comments on Draft Cost and Performance Summary Report for Bonneville Power Administration. Provided by e-mail to Richard J. Weisman, Tetra Tech EM Inc. August 20.

Acknowledgments

This report was prepared for the U.S. Environmental Protection Agency's Office of Solid Waste and Emergency Response, Technology Innovation Office. Assistance was provided by Tetra Tech EM Inc. under EPA Contract No. 68-W5-0055.

Land Treatment of the UST Soil Piles at Fort Greely, Alaska

Land Treatment of the UST Soil Piles at Fort Greely, Alaska

Site Name: UST Soil Piles	**Contaminants:** Semivolatile and volatile nonhalogenated hydrocarbons - gasoline, diesel fuel, and BTEX components. Maximum contaminant concentrations of 3,000 mg/kg gasoline range organics, 1,200 mg/kg diesel range organics, and 20.2 mg/kg BTEX.	**Period of Operation:** Status: Complete Report covers: 9/94 through 8/97
Location: Fort Greely, Alaska		**Cleanup Type:** Remedial Action
Vendor: John Terwilliger Nugget Construction, Inc. 8726 Corbin Drive Anchorage, AK 99507 (907) 344-8365	**Technology:** Land Treatment - Stockpiled soil was washed and screened into stockpiles by particle size. - The small diameter soil was placed into windrows and tilled during summer months.	**Cleanup Authority:** Remedial Action under Alaska Department of Environmental Conservation UST Regulations
USACE Contact: Bernard T. Gagnon USACE - Alaska District P.O. Box 898 Anchorage, AK 99506-0898 (907) 753-5718		**Regulatory Point of Contact:** Rielle Markey Alaska Department of Environmental Conservation University Avenue Fairbanks, AK 99709 (907) 451-2117
Waste Source: Leaks from USTs and/or overfilling of USTs or ASTs	**Type/Quantity of Media Treated:** Soil - 11,939 yd^3 screened and washed - 9,800 yd^3 land treated	
Purpose/Significance of Application: Application of land treatment to treat gasoline and diesel contaminated soil ex situ		

Regulatory Requirements/Cleanup Goals:

- The goal of this remedial objective was to meet the ADEC Level A standards for UST-contaminated soils (as cited at 18 AAC 78.315) so that the soil could be used as final cover material for Landfill 7. The Level A standards are: DRO - 100 mg/kg, GRO - 50 mg/kg, benzene - 0.1 mg/kg, total BTEX - 10 mg/kg, and RRO - 2,000 mg/kg.

Land Treatment of the UST Soil Piles at Fort Greely, Alaska (continued)

Results:

- The concentrations of hydrocarbons in the contaminated UST soil stockpiles was reduced to below the ADEC Level A standards in two summers (with the exception of two samples that still contained DRO above the cleanup standard). The soil was used in the capping of the landfill.
- The average concentrations of contaminants indicate that the mass of DRO in the contaminated soil was reduced from 4,641 kg to 719 kg (approximately 85 percent), and the mass of GRO in the contaminated soil was reduced from 175 kg to nondetectable levels (approximately 100 percent) during the land treatment.
- Initial estimates, based on oxygen uptake measurements taken during a treatabililty study, showed that the remediation of the soil would take approximately 60 days of summer temperatures. The actual remediation took more than twice that long (July 1995 through July 1997).

Cost:

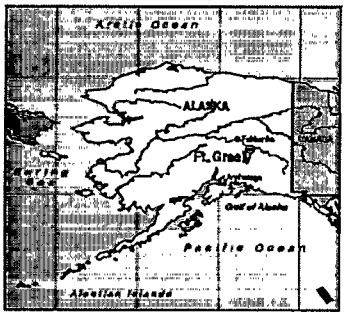
- The total cost of this remedial action was $696,171, consisting of $405,883 Phase I, soil screening and washing (including site preparation and mobilization) and $290,288 for Phase II, land treatment of soil.
- A total of 11,939 yd^3 of gasoline- and diesel-contaminated soil were processed in Phase I and 9,800 yd^3 (approximately 82 percent of the total volume) were treated in Phase II. The unit cost breakdown is: $34/$yd^3$ for Phase I, $29.62/$yd^3$ for Phase II, and $58.29/$yd^3$ for the total treatment.

Description:

The UST soil stockpiles are located at the 1970s landfill or "Landfill 7," located in the southeast sector of the U.S. Army Ft. Greely military facility. Ft. Greely is located approximately five miles south of Delta Junction, Alaska. The contaminated soil stockpiles were generated from the excavation of contaminated soil during a facility upgrade and site restoration activities at the Black Rapids Ski Area during the Summers of 1992 and 1993 and from the excavation of contaminated areas near buildings 602 and 606 at Ft. Greely in August 1991.

In the Fall of 1994 and Summer of 1995, Phase I of the remedial action was conducted, involving the screening and washing of the contaminated soil stockpiles and the completion of a biotreatability study on samples of the contaminated soil. The biotreatability study determined that the contaminated soil could be effectively treated via land treatment. In the Summer of 1995, the contaminated soil stockpiles were separated into windrows, to which nutrients and water were added. The windrows were tilled on a regular schedule during the summers of 1995 and 1996. Samples of the contaminated soil were collected at the end of each summer. In June 1997, closure samples were collected, which showed that the levels of contaminants in the soil had been reduced to below ADEC Level A cleanup standards in all but two of the samples. The soil was then used in the capping of Landfill 7.

SITE INFORMATION



IDENTIFYING INFORMATION

Site Name: UST Soil Stockpiles
Location: Ft. Greely, Alaska
Technology: Land Treatment
Type of Action: Remedial Action

TECHNOLOGY APPLICATION

Period of Operation: September 1994 - August 1997 (1,2)

Quantity of Material Treated During Application: 9,800 cubic yards (yd^3)

BACKGROUND

Site Background (1,2):

- The UST soil stockpiles are located at the 1970s landfill or "Landfill 7," located in the southeast sector of the U.S. Army Ft. Greely military facility. Ft. Greely is located approximately five miles south of Delta Junction, Alaska.
- The Black Rapids stockpile (BRS) of soil contaminated with diesel fuel was generated during upgrading of the facility and site restoration activities conducted at the Black Rapids Ski Area during the summers of 1992 and 1993.
- The small and large stockpiles of gasoline-contaminated soil (SGS and LGS) originated from the excavation of contaminated areas near buildings 602 and 606 at Ft. Greely in August 1991.

Waste Management Practices That Contributed to Contamination: Leaks from underground storage tanks (USTs) or overfilling of USTs or aboveground storage tanks (ASTs) (2)

Site Investigation (5):

- The diesel-contaminated soil in the Black Rapids area was identified during preconstruction sampling conducted in 1991 and in samples taken during construction excavation in 1992 and 1993. A report on the contractor's findings was submitted to the U.S. Army Corps of Engineers-Alaska District (USACE) in the summer of 1994.
- The extent of soil contamination in the area of buildings 602 and 606 at Ft. Greely was delineated and the contaminated soil excavated during a UST removal conducted in 1991 and 1992. The excavated soil was sampled between June 21 and 25, 1993 and the soil was determined to contain gasoline. Closure sampling for the excavations in the area of buildings 602 and 606 was conducted in May and June 1993.
- Soils excavated from the Black Rapids site were transported to Ft. Greely for treatment. Those soils were stockpiled and treated as part of the technology application discussed in this report.

SITE LOGISTICS/CONTACTS

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* Primary point of contact for this application.

MATRIX AND CONTAMINANT DESCRIPTION

MATRIX IDENTIFICATION

Soil (ex situ)

SITE STRATIGRAPHY (1)

- The subsurface consists of the capped 1970s Landfill, with groundwater at approximately 280 ft below ground surface.

CONTAMINANT CHARACTERIZATION

Semivolatile and volatile nonhalogenated hydrocarbons - gasoline and diesel fuel

CONTAMINANT PROPERTIES

Property	Gasoline	Diesel Fuel
Chemical Makeup	Paraffins, olefins, naphthenes, and aromatics	Unbranched paraffins
Flash Point	less than 50° F	110° to 190° F
Toxicity	High	High

MATRIX CHARACTERISTICS AFFECTING TREATMENT COST OR PERFORMANCE (1)

Parameter	Soil to Be Treated
Soil classification	Poorly graded sandy gravel with silt (GP-GM) and poorly graded gravel with sand (GP)
Particle Size Distribution	GP-GM (69% sand, 19% silt, 12% clay), GP(53.3% gravel, 40.9% sand, 5.8% fines)
Organic Matter	1.3% - 1.4%
Moisture Content	7.7 - 13.2% (solid dry weight)
pH	7.3 (average)
Ammonia - Nitrogen	2.1 - 5.46 milligrams per kilogram (mg/kg)
Nitrate - Nitrogen	2 - 13 mg/kg
Available Nitrogen	9.3 mg/kg (mean)
Available Phosphorus	6.4 mg/kg (mean)
Available Potassium	23 mg/kg (mean)
Cation Exchange Capacity	4.7 milliequivalents per 100 grams (mean)
Biological Oxygen Demand (BOD) (two-days at 20° C)	34.8 mg O_2/kg soil[1]
Field Capacity	15 - 16% moisture

[1] BOD was calculated on the basis of reported hydrocarbon degradation rate results. Those results were based on the two-day differential in pore space oxygen from a closed sample incubated at 20°C. The two-day BOD value included contributions from degradation of non-contaminant organic material, as well as the degradation of the contaminant.

TREATMENT SYSTEM DESCRIPTION

PRIMARY TREATMENT TYPE

Land treatment

SUPPLEMENTARY TREATMENT TECHNOLOGY TYPE

Screening (pretreatment)

TIMELINE (1,2)

Date	Activity
August 1991	Gasoline-contaminated soil from excavations near buildings 602 and 606 at Ft. Greely stockpiled at the Landfill 7 site
1992 to 1993	Diesel-contaminated soil from excavations at Black Rapids Ski Area stockpiled at the Landfill 7 site
September to October 1994	Phase I - Screening and washing of stockpiles and biotreatability study
July to September 1995	Completion of Phase I work; first season of Phase II work, land treatment of soil
June 1996 to August 1996	Second season of Phase II work
June 1997	Performance of closure sampling.
May 1998	Submittal of remedial action report (RAR)

TREATMENT SYSTEM (1,2,5)

- This application was conducted in two phases: Phase I, pretreatment of the stockpiled soil, and Phase II, land treatment of the contaminated soil.

Phase I - Screening and Washing of the Stockpiles

- Figure 1 shows the layout for the soil screening and washing equipment used in Phase I of this remediation effort.
- The soils from the site were screened and sorted into stockpiles by particle size (<1", 1" - 5", >5") and contaminant type—diesel and gasoline.
- According to the RAR, the stockpiles containing material of a diameter greater than 5" had no odor or visible contamination and were considered clean. Those stockpiles were not treated.
- For this project, ADEC extended the policy on oversized material to include all materials of a diameter greater than one inch that were free of odor or visible contamination. Therefore, the soils containing materials of a diameter of 1 inch to 5 inches were not treated. Those soils were spray- washed with a mixture of PES-31 (a proprietary additive containing a suspension of live cultured microorganisms preserved in a sterile solution with no nutrients) and water and left on site for use as final cover.

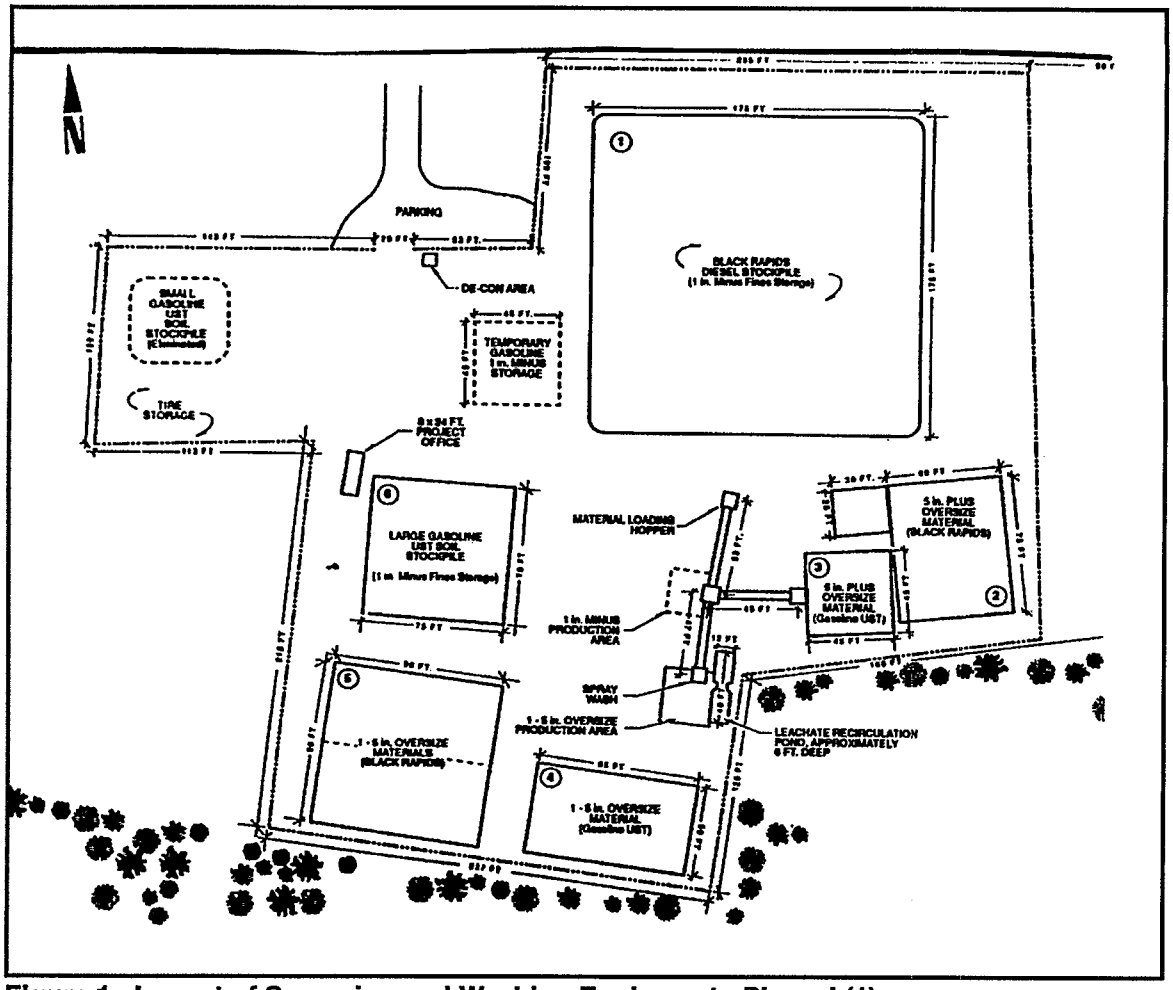

Figure 1. Layout of Screening and Washing Equipment - Phase I (1)

- The following table presents the volume of each of the soil stockpiles screened during Phase I by particle size, along with the volume of soil treated during Phase II.

Material Treated	Phase I Volume of Screened Stockpiles[1]	Phase II Volume of Treated Material[1]
Black Rapids Stockpiles - Diesel-Contaminated Soil		
1" minus	5,988 yd^3	5,988 yd^3
1" - 5" oversize	2,090 yd^3	—
5" plus	698 yd^3	—

Material Treated	Phase I Volume of Screened Stockpiles[1]	Phase II Volume of Treated Material[1]
Small and Large Stockpiles - Gasoline-Contaminated Soil		
1" minus	2,462 yd^3	2,462 yd^3
1" - 5" oversize	639 yd^3	—
5" plus	62 yd^3	—
Liner cover over stockpile liner (Estimated one-foot thick layer)		1,350 yd^3
Totals	11,939 yd^3	9,800 yd^3

Note: [1] Soil volumes based on measurements of stockpiles provided by Delta Survey Associates (1)

- A biotreatability analysis was performed on the one-inch minus soil segregated from the BRS, SGS, and LGS stockpiles and two background samples from the Black Rapids Ski Area soil. The average results are presented under the heading Matrix Characteristics Affecting Treatment Cost or Performance.
- In 1993 and 1994, hydrocarbon analyses were performed on samples from the BRS, SGS, and LGS soils. Samples were analyzed for gasoline range organics (GRO); diesel range organics (DRO); residual range organics (RRO); and benzene, toluene, ethylbenzene and xylene (BTEX). The results of those analyses are presented below by ranges of concentrations and average concentrations.

Soil	Date	Number of Samples	GRO (mg/kg)[1] Range/ Average[5]	DRO (mg/kg)[2] Range/ Average[5]	RRO (mg/kg)[3] Range/ Average[5]	BTEX (mg/kg)[4] Range/ Average[5]
BRS (1" minus)	10/94	5	ND(5) - 13/ 8.2	243-530/ 425	495 - 839/ 670	ND(0.025) - 0.34/0.23
BRS (1" - 2")	10/94	4	ND(5) - 7/ 5.5	ND(10) - 279/138	ND(40) - 58/ 45	ND(0.025) - 0.30/0.088
SGS/LGS (1" minus)	10/94	2	ND(5) - 84/ 44.5	162 - 1200/ 681.0	215 - 1420/ 818	ND(0.2) - 2.36/1.28
SGS/LGS (1" - 2")	10/94	2	—/ND(5)	15 - 44/30	118 - 362/ 240	—/ND(0.2)
SGS/LGS (before screening)	6/93	29	ND(1) - 3000/372			ND - 20.2[6]

Notes:

ND( ) Not detected in concentrations above the reported detection limit. The detection limit (shown in parentheses) was used in calculating averages for samples for which results were ND.

1 GRO by U.S. Environmental Protection Agency (EPA) Method 5030/8015 Modified

2 DRO by EPA Method 3540/8100 Modified

3 RRO analyzed as Total Petroleum Hydrocarbons (TPH) by EPA Method 418.1

4 BTEX by EPA Method 8020

5 Average concentration for all reported results. The higher of the results from any duplicate samples was used to calculate this average.

6 Calculation of the average concentration of BTEX was not possible because of high detection limits reported for several of the samples.

Phase II - Land Treatment (1, 2, 5)

- Soil at the Landfill 7 area totaling approximately 22,000 yd^3 was graded to accommodate the land treatment operations, and a stormwater control berm, a containment ditch, and a collection area were constructed to control stormwater runon and runoff.
- As described above, only soils from the BRS, SGS, and LGS stockpiles that had a particle size of one inch or less were included in the land treatment application. With a front-end loader, a dumptruck, and a dozer, the soil was placed on the graded area in uncompacted five-foot-high windrows (35 for the diesel contaminated soil and 8 for the gasoline contaminated soil). The rows were set approximately 20 feet apart. Figure 2 shows the configuration of the windrows.
- According to the ADEC, the contractor had designed the configuration of the windrows to allow the most efficient use of the tilling machine, to keep the GRO and the DRO soils separate, and to fit the configuration of the site.

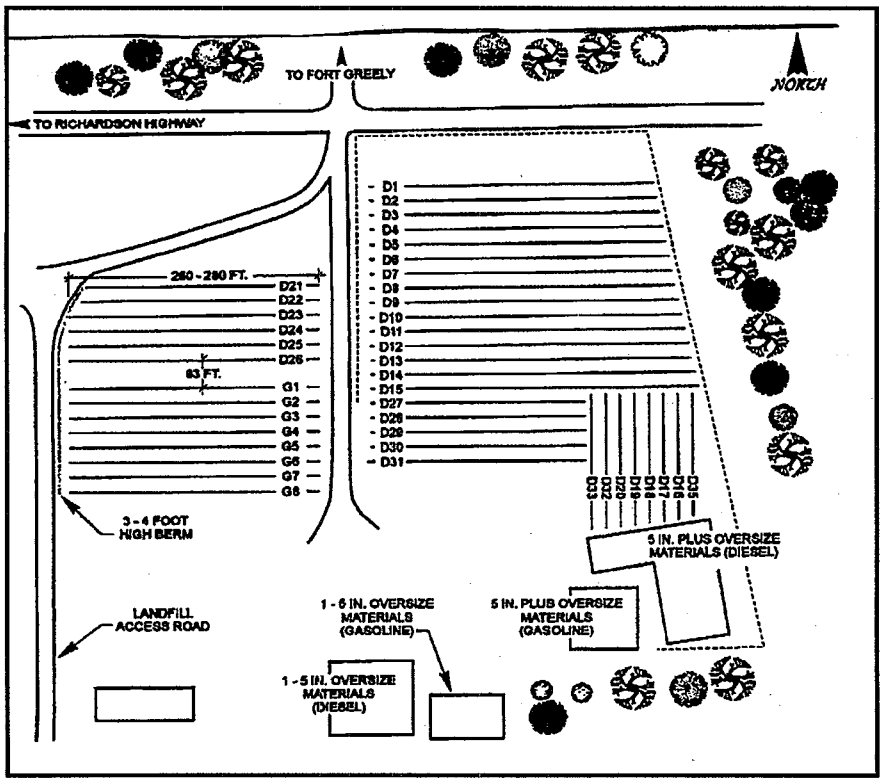

Figure 2. Layout of Windrows for Land Treatment Process: Phase II (2)

- With a scat rotary mixer-tiller, each windrow was tilled from bottom to top once each week during the summers of 1995 and 1996 (July through September in 1995 and June through August in 1996).
- The site work was conducted under a site-specific safety and health plan. The tilling machine was towed with a bobcat that had roll protection, and the operator wore a hard hat, steel-toed boots, and coveralls. Workers conducting sampling and testing wore level D personal protective equipment, which consisted of Tyvex coveralls, hard hat, protective boots, and Nitrile gloves.

OPERATING PARAMETERS AFFECTING TREATMENT COST OR PERFORMANCE (1, 2)

Parameter	Value
Mixing Rate/Frequency	Tilled weekly during the summers of 1995 and 1996 (July through September 1995 and June through August 1996)
Moisture Content	8 - 13% (soil dry weight)
pH	7.3 (average) initially
Residence Time	2 years (July 1995 - June 1997)
Temperature	52.5° F (mean summer)
Microbial Activity:	
- Oxygen Uptake Rate	17.4 mg O_2/kg soil/day
- CO_2 Evolution	Information not provided
- Hydrocarbon Degradation	5.0 mg hydrocarbon/kg soil/day
Nutrients and Other Amendments	Information not provided

TREATMENT SYSTEM PERFORMANCE

PERFORMANCE OBJECTIVES (1,2,5)

- The goal of this remedial action was to meet the ADEC Level A standards for UST-contaminated soils (as cited at 18 AAC 78.315) so that the soil could be used as final cover material for Landfill 7. The Level A standards are:

Parameter	Cleanup Level
DRO	100 mg/kg
GRO	50 mg/kg
Benzene	0.1 mg/kg
Total BTEX	10 mg/kg
RRO	2,000 mg/kg

TREATMENT PERFORMANCE DATA (2)

- Soil in the windrows was sampled in September 1995, August 1996, and June 1997. The frequency and analysis parameters presented below were used for the soil sampling.

Location	Date	Frequency	Parameters
Windrows of Gasoline-Contaminated Soil	September 1995, August 1996	- Two Samples for initial 100 yd^3 - One sample for each additional 100 yd^3 - Total of 30 samples per year	DRO, GRO, BTEX
	June 1997	- Two samples for initial 50 yd^3 - One sample for each additional 50 yd^3 - Total of 51 samples (plus 5 duplicates and 5 quality assurance/quality control QA/QC samples)	
Windrows of Diesel-Contaminated Soil	September 1995, August 1996	- Two samples for initial 100 yd^3 - One sample for each additional 300 yd^3 - Total of 26 samples per year	DRO
	June 1997	- Two samples for initial 50 yd^3 - One sample for each additional 150 yd^3 - Total of 42 samples (plus 5 duplicates and 5 QA samples)	
Beneath Liner of BRS	September 1995	- 31 samples from 30,625 ft^2 (plus 6 QA/QC samples)	DRO
Beneath Liner of SGS	September 1995	- Two samples from 2,025 ft^2 area (plus 2 QA/QC samples)	DRO, GRO, BTEX
Beneath Liner of LGS	September 1995	- Six samples from 5,700 ft^2 area (plus 2 QA/QC samples)	DRO, GRO, BTEX

- The results of the soil sampling in relation to ADEC's Level A cleanup standards are presented in the following table. Because concentrations of RRO in untreated soils were below the cleanup standard, no analyses of RRO were performed. Benzene was not reported separately from BTEX.

Location	Date	Number of Samples	DRO Mean Conc. (mg/kg)	DRO Number of Samples Exceeding Cleanup Standards	GRO Mean Conc. (mg/kg)	GRO Number of Samples Exceeding Cleanup Standards	BTEX Mean Conc. (mg/kg)	BTEX Number of Samples Exceeding Cleanup Standards
ADEC Level A Standards			100		50		10	
Gasoline-Contaminated Windrows	9/95	25	263	25	ND - 5	0	ND	0
	8/96	25	77	5	NS	NA	NS	NA
	6/97	51	71	1 (115 mg/kg)	ND	0	ND	0
Location	**Date**	**Number of Samples**	**DRO Mean Conc. (mg/kg)**	**DRO Number of Samples Exceeding Cleanup Standards**	**GRO Mean Conc. (mg/kg)**	**GRO Number of Samples Exceeding Cleanup Standards**	**BTEX Mean Conc. (mg/kg)**	**BTEX Number of Samples Exceeding Cleanup Standards**
Diesel-Contaminated Windrows	9/95	21	279	21	NS	NA	NS	NA
	8/96	21	93	8	NS	NA	NS	NA
	6/97	42	80	1 (140 mg/kg)	NS	NA	NS	NA
SGS/LGS Liner Areas	9/95	8	ND - 23	0	ND	0	ND	0
BRS Liner Areas	9/95	31	ND - 68	0	NS	NA	NS	NA

Notes:

ND - Not detected in concentrations above method detection limits

NS - Sample not analyzed for parameter

NA - Not applicable

- The final RAR for the site was completed in May 1998. The RAR was submitted to the ADEC, which concurred that the soil met cleanup objectives.

PERFORMANCE DATA ASSESSMENT

- Only the soil in the gasoline-contaminated windrows was analyzed for GRO and BTEX. The results of the analysis of samples collected in the September 1995 sampling showed that the concentrations of GRO and BTEX were below the cleanup standards in all 25 of the windrows sampled. Concentrations of GRO ranged from not detected to 5 mg/kg. BTEX was not detected.

- The soil in both the gasoline- and the diesel-contaminated windrows was analyzed for DRO. The results of the analysis of samples collected in June 1997 showed that concentrations of DRO were below the cleanup standard in all but one sample of each type of contaminated soil. The concentrations of DRO that exceeded the cleanup standard were 115 mg/kg for the gasoline-contaminated windrows and 140 mg/kg for the diesel-contaminated windrows. According to the USACE, those exceedances were statistically insignificant. (5)

- On the basis of the average concentrations of DRO and GRO in pretreatment (1994) and post-treatment (1997) soil, the mass of DRO in the soil was reduced from 4,641 to 719 kg, and the mass of GRO in the soil was reduced from 174 kg to nondetectable concentrations. The amounts of DRO and GRO destroyed during the land treatment phase of the remedial action are summarized as follows:

Source	Volume Treated (yd^3)	Average DRO (mg/kg)		Average GRO (mg/kg)		Contaminant Destroyed (kg)	
		1994[1]	1997[2]	1994[1]	1997[2]	DRO	GRO
BRS Soil	5,988	424.6	80	8.2	ND[5]	2,270	54
SGS/LGS Soil	2,462	681.0	71	44.5	ND[5]	1,652	121
Liner Cover Soil	1,350	0[4]	0[4]	0[4]	0[4]	0	0
Total	9,800	–	–	–	–	3,922	175

Notes:

1 1994 data from (1)

2 1997 data from (2)

3 Average soil density (1,100 kg/yd^3) based on average soil dry bulk density of 1.35 grams per cubic centimeter (g/cm^3) and water content of 8.6 percent (1)

4 Liner cover soil assumed to contain no contamination for purpose of material balance

5 All 1997 GRO analyses showed no detection; 0 mg/kg was used for this material balance

- Insufficient analytical data from the period before Phase I were available to determine the amount of contaminant destroyed in Phase I. The contractor estimated that at least 20 percent of the initial GRO volatilized during the soil screening process.

PERFORMANCE DATA QUALITY (2)

- QA/QC activities were conducted in accordance with specifications, requirements established in contract documents, and guidelines provided by the ADEC.
- Sampling was performed in accordance with the Sampling and Analysis Plan developed for this project in August, 1995, and approved by the USACE and the ADEC.
- QC samples were analyzed by the primary laboratory, and additional QA samples were sent to USACE QA laboratories, which provided the required 1997 government quality assurance report.
- The USACE chemical data quality report concluded that "...the data were sufficiently consistent and results were adequate to satisfy cleanup goals."

TREATMENT SYSTEM COST

PROCUREMENT PROCESS (5)

Procurement for this application was by indefinite delivery-type remedial action (IDTRA) contract. For this contract, only 8A contractors were evaluated. USACE solicited proposals for the contract, and the contractor was selected on the basis of technical qualifications to perform a variety of potential remedial actions. This application was issued as a delivery order against the contract; the contractor submitted a cost proposal for the work; and a firm, fixed price for the application was negotiated.

TREATMENT SYSTEM COST (4)

- The total cost of the Phase I and Phase II work was $696,171, broken down as follows.

Mobilization and preparatory work	$76,265
Site Work (Phase I screen and wash)	$329,618
Land treatment (Phase II)	$290,288
TOTAL	**$696,171**

REGULATORY/INSTITUTIONAL ISSUES

- This remedial action was conducted according to procedures set forth in ADEC's *Guidance Manual for Underground Storage Tank Regulations*, dated June 18, 1991 and in accordance with 18 AAC 78, UST regulations.

OBSERVATIONS AND LESSONS LEARNED

COST OBSERVATIONS AND LESSONS LEARNED

- The total cost of this remedial action was $696,171, consisting of $405,883 for Phase I, screening and washing (including site preparation and mobilization) and $290,288 for Phase II, land treatment.
- A total of 11,939 yd^3 of gasoline- and diesel-contaminated soil was processed in Phase I, and 9,800 yd^3 (82 percent of the total volume) were treated in Phase II. The unit cost breakdown is:

Phase I[1]	$34.00/$yd^3$
Phase II[2]	$29.62/$yd^3$
Total (w/ 82% of total volume being Land Treated)[3]	$58.29/$yd^3$

Notes:

1 Phase I unit cost for screening and washing of 11,939 yd^3 of stockpiled soil

2 Phase II unit cost for land treatment of 9,800 yd^3 of screened soil (one inch or less in diameter)

3 The total unit cost is the average cost of treatment of any given yd^3 of originally stockpiled soil (all of which was screened and washed and 82 percent of which was land treated).

PERFORMANCE OBSERVATIONS AND LESSONS LEARNED

- The average concentrations of contaminants indicate that the mass of DRO in the contaminated soil was reduced from 4,641 kg to 719 kg (approximately 85 percent), and the mass of GRO in the contaminated soil was reduced from 175 kg to nondetectable levels (approximately 100 percent) during Phase II (land treatment).
- Initial estimates, based on oxygen uptake measurements taken during the treatability study, showed that remediation of the soil would take approximately 60 days of summer temperatures. The actual remediation took more than twice that long (July 1995 through July 1997). That fact suggests that the rates of degradation of hydrocarbons for land treatment estimated from oxygen uptake analyses may require additional adjustment for site conditions, such as the noncontaminant organic composition of the soil or for maintenance factors for land treatment such as addition of nutrients.
- The concentrations of hydrocarbons in the contaminated soil from the SGS, LGS, and BRS stockpiles were reduced to levels below the ADEC Level A standards in two summers (with the exception of one sample each from the gasoline-contaminated windrows and the diesel-contaminated windrows that still contained DRO in concentrations above the cleanup standard). The treated soil was used in the capping of the landfill.
- The contractor concluded that use of PES-31 during the soil washing in Phase I was probably not necessary, but that the analytical scope of the analyses should have been increased to determine whether such was the case.

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1. Nugget Construction Company. 1994. Work Plan for Phase II, UST Soil Stockpile Bioremediation, Ft. Greely, Alaska. Prepared for USACE, Anchorage, Alaska. DACA85-94-D-0013, DO# 006. December.
2. Nugget Construction, Inc. 1998. Remedial Action Report, Phase II Landfarming Operation, UST Soil Stockpile Bioremediation; Ft. Greely, Alaska. Prepared for USACE, Ft. Wainwright, Alaska. DACA85-94-D-0013, DO# 0001. May.
3. USACE. 1994. Revised Statement of Work, Contaminated Soil Stockpiles, Characterization, Screening, Segregation, Ft. Greely, Alaska. DACA85-94-D-0013, DO0001. August.
4. USACE. 1996. Cost Data for Innovative Treatment Technologies, UST Soil Pile Bioremediation, Ft. Greely, Alaska.
5. USACE, Alaska District. 1998. Ft. Greeley UST Stockpile Pre-Draft Cost and Performance Report, Comments and Answers to Questions. September 11.

ACKNOWLEDGMENTS

This report was prepared for the U.S. Army Corps of Engineers under USACE Contract No. DACA45-96-D-0016, Delivery Order No. 12. Assistance was provided by Tetra Tech EM Inc. and Radian International LLC.

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Ex Situ Bioremediation at Novartis Site, Cambridge, Ontario

Ex Situ Bioremediation at Novartis Site, Cambridge, Ontario

Site Name: Novartis	**Contaminants:** Semivolatiles - halogenated - organic pesticides/herbicides, including Metolachlor, 2,4-D, Dinoseb, Atrizine - Metolachlor - initial concentrations as high as 170 mg/kg	**Period of Operation:** 3/96 - 9/97
Location: Cambridge, Ontario, Canada		**Cleanup Type:** Demonstration
Vendor: David Raymond, Project Manager Grace Bioremediation Technologies 3465 Semenyk Court Mississauga, Ontario Canada (905) 273-5374	**Technology:** Ex situ bioremediation of soils using the DARAMEND process - main treatment area, high Metolachlor test cell and static control cell - alternated aerobic and anaerobic conditions (10 cycles)	**Cleanup Authority:** Information not provided
Additional Contacts: Information not provided		**Regulatory Point of Contact:** Information not provided
Waste Source: Contamination resulting from formulating and warehousing pesticides and herbicides	**Type/Quantity of Media Treated:** Soil - 200 tons. Excavated from the site and stockpiled for treatment.	
Purpose/Significance of Application: Demonstrate the performance of the DARAMEND process for treating Metolachlor-contaminated soils		

Regulatory Requirements/Cleanup Goals:
Information on specific cleanup objectives was not included in this report. Performance and results are described in terms of reductions in concentrations of contaminants.

Results:
- Concentrations of Metolachlor in the main treatment cell were reduced from initial levels ranging from 48 to 84 mg/kg to below a detection level of 1.0 mg/kg. Concentrations in the high Metolachlor (HM) test cell were reduced from initial concentrations of 170 mg/kg to 38 mg/kg.
- Within the HM test cell, only the top 30 cm of a 60 cm deep cell were tilled during the demonstration. According to the vendor, effective treatment may not have occurred throughout the cell. A sample of the top 30 cm only of the HM test cell showed Metolachlor concentrations of 11.8 mg/kg.

Cost:
- No costs were reported for the demonstration.
- The vendor used data from the demonstration to estimate that the cost for treating the estimated 600 tons of contaminated soil that remained at the Novartis site would be $111,600 or $186/ton (in Canadian dollars).

Ex Situ Bioremediation at Novartis Site, Cambridge, Ontario (continued)

Description:
The Novartis site (formerly Ciba-Geigy), located in Cambridge, Ontario, has been used for the formulation and warehousing of agricultural chemicals since 1972. The site was contaminated with organochlorine pesticides and herbicides, with Metolachlor being the primary contaminant at the site. In 1996, Grace Bioremediation Technologies (Grace) conducted a pilot-scale demonstration of an ex situ bioremediation technology as part of a grant to complete the development of the DARAMEND bioremediation process. The grant was funded by the Ontario Ministry of Environment and Energy's Environmental Technologies Program, Environment Canada's Development and Demonstration of Site Remediation Technologies Program, and by Grace. The demonstration, conducted from March 1996 to September 1997, involved 200 tons of soil from the Novartis site that had been excavated and stockpiled. The soil was contaminated with Metolachlor, Dinoseb, Atrizine, and 2,4-D.

The ex situ treatment area included three cells - the main treatment cell (180 tons), the high Metolachlor (HM) test cell (10 tons), and a static control cell (10 tons). Soils were placed in the cells which were located within a greenhouse enclosure. The demonstration was designed to cycle between aerobic conditions and anaerobic conditions to promote the degradation of the contaminants. During the demonstration, the soil was subjected to a total of ten cycles. DARAMEND amendments and inorganic amendments (for example multivalent metal) were added to the soil. The soil was covered with a tarp during the anaerobic cycle and was tilled during the aerobic cycle. Data from the treated soil in the main treatment cell showed that concentrations of contaminants were reduced to below detection levels. Metolachlor was reduced from initial concentrations ranging from 48 to 84 mg/kg to below the detection limit of 1.0 mg/kg. Levels of Metolachlor within the HM cell were reduced from 170 mg/kg to 38 mg/kg. However, according to Grace, only the top 30 cm of the 60 cm deep cell were tilled during the demonstration such that the treatment was not effective throughout the entire cell. Data from the top 30 cm only of the HM cell showed that Metolachlor levels had been reduced to 11.8 mg/kg.

The projected cost to treat the remaining 600 tons of soil at the Novartis site using this technology was $111,600 or $186/ton in Canadian dollars. Grace noted that because these costs were based on the demonstration, which included extensive process monitoring and waste analysis costs, the projected cost for a full-scale application would be significantly less.

Cost and Performance Summary Report
Ex Situ Bioremediation of Soils at the Novartis Site, Cambridge, Ontario

Summary Information [1, 2, 3]

The Novartis site (formerly Ciba-Geigy) is located in Cambridge, Ontario. Since 1972, the site was used for formulating and warehousing of agricultural chemicals. Data obtained during characterization work performed by Ciba indicated that the site was contaminated with Metolachlor, a chlorinated herbicide.

In 1996, a pilot-scale demonstration of an ex situ bioremediation technology was conducted at the site by Grace Bioremediation Technologies (Grace) as part of a grant to complete development of the DARAMEND™ bioremediation process. The grant was funded by the Ontario Ministry of Environment and Energy's Environmental Technologies Program, Environment Canada's Development and Demonstration of Site Remediation Technologies Programs, and Grace.

The demonstration was conducted from March 1996 to September 1997. Approximately 200 tons of soil contaminated with Metolachlor were treated during this demonstration.

Timeline

February 6, 1996	Identified site for demonstration
February 23, 1996	Construction completed
Mar. 7, 1996 - Sept. 23, 1997	Demonstration conducted
September 23, 1997	Final samples collected

Factors that Affected Cost or Performance of Treatment [3, 4]

Matrix Characteristics

Listed below are the key matrix characteristics for this technology and the values measured for each.

Parameter	Value
Soil Classification:	Fine sandy loam
Clay Content and/or Particle Size Distribution:	59.6% sand, 37.5% silt, 2.9% clay
Moisture Content:	Varies*
pH:	7.8
Total Organic Carbon:	0.58%
Total Nitrogen:	< 0.01%
Available Phosphorus:	8 mg/kg

* Moisture content was 90% of water holding capacity during anoxic phase and 60% of water holding capacity during oxic phase.

Treatment Technology Description [1, 2, 3, 4]

The DARAMEND™ process is an ex situ soil bioremediation technology that has been modified by Grace to treat soils contaminated with chlorinated organics, such as organochlorine pesticides and herbicides that degrade slowly under aerobic conditions. The modified process uses organic and inorganic amendments to promote the activity of indigenous microorganisms in the soil to degrade contaminants. Microbial inoculation is not required. According to Grace, the technology has been applied to both ex situ and in situ treatment of soil. This report addresses the results of the ex situ demonstration at the Novartis site.

The treatment area included three treatment cells - the main treatment cell (Plot A), the high Metolachlor (HM) test cell (Plot B), and the static control cell (Plot C). The treatment area was lined with clay underlain with a high density polyethylene (HDPE) liner. The main treatment cell was designed to hold 180 tons of soil; the remaining cells were each designed to hold 10 tons of soil.

A 204 ft. long by 30 ft. wide greenhouse structure was constructed over the treatment area. The arches for the greenhouse were placed every four ft. along its length and secured using concrete columns (18" by 48"). The greenhouse was covered with two layers of polyethylene, separated by forced air. The HM cell and the static control cell were constructed within the treatment area. Each cell was a rectangular wood-framed box open at the top, lined with a 40 mil HDPE.

Construction of the treatment area was completed in February 1996. A total of about 200 tons of soil were placed in the treatment area including drummed soil (about 15 cu. meters) and soil from excavation activities at Novartis. The demonstration was designed to cycle between anaerobic or "anoxic" conditions and aerobic or "oxic" conditions to promote reductive dechlorination and subsequent aerobic degradation of the chlorinated pesticides. From March 7, 1996, to September 23, 1997, the soil was subjected to a total of 10 complete aerobic and anaerobic cycles. For the anaerobic cycle, DARAMEND™ amendments and inorganic amendments (for example, multivalent metal) were added to the soil, the soil was irrigated, and then covered with a tarpaulin. For the aerobic cycle, the tarpaulin was removed and the soil was tilled twice a week. No amendments were added during the aerobic cycle in this application.

According to Grace, the demonstration was originally planned for 6 cycles. However, 10 cycles were used to compensate for initial delays in startup and slightly slower than anticipated

biodegradation rates. In addition, the HM cell was tilled using a hand operated rotary tiller because of the small cell size. As a result, Grace stated that tillage was effective in the top 30 cm rather than the full 60 cm plot depth (for the HM cell only).

Operating Parameters [4]

Parameter	Value
Mixing Rate or Frequency	Twice a week during aerobic cycle
Moisture Content	Refer to matrix characteristics
pH	Varies (6 -7.8)
Temperature	Ambient (>10 °C)
Rate of Degradation	19.4 ppm/month
Enhancement	Daramend™ (organic) and inorganic (multivalent metal)

Performance Information [1, 2, 3]

For sampling purposes, the main treatment cell was divided into five zones, and each zone was further divided into 20 equal subunits. Within each zone, five subunits were randomly selected for sampling during the course of the demonstration; these samples were composited for analysis. The HM and static control cells were not subdivided for sampling. Rather, for each sampling event, five samples were collected and composited from each of the cells.

Initial samples were collected prior to the start of treatment and analyzed for 2, 4-D, Dinoseb, Atrazine, and Metolachlor using a toxic organic (TO) Scan (EPA Method 625). Samples were also analyzed for soil physical/chemical properties, selected metals, and chloride. Samples to monitor treatment progress were collected on days 2, 7, 98, 208, 306, and 454 of the demonstration and screened for Metolachlor using a HPLC quick screening method (EPA Method SW846-8150). Final samples were collected on day 565 and analyzed in the same manner as the initial samples.

Table 1 presents the initial and final concentrations of these compounds by soil plot. Table 2 presents the progress sampling results for Metolachlor in soil by treatment area.

Table 1 - Initial and Final Concentrations of Target Compounds [3]

Plot		Initial Concentration (mg/kg)				Final Concentration (mg/kg)			
	Sample	2,4-D	Dinoseb	Atrizine	Metolachlor	2,4-D	Dinoseb	Atrizine	Metolachlor
A	Zone 1	(0.4)[1]	(0.4)	1.5	68	(1.0)	(1.0)	(1.5)	(1.0)
	Zone 2	(0.4)	(0.4)	4.7	84	(1.0)	(1.0)	(1.5)	(1.0)
	Zone 3	3.7	(0.4)	13.0	48	(1.0)	(1.0)	(1.5)	(1.0)
	Zone 4	2.8	(0.4)	17.0	54	(1.0)	(1.0)	(1.5)	(1.0)
	Zone 5	1.2	(0.4)	15.0	82	(1.0)	(1.0)	(1.5)	(1.0)
B	HM[2]	(0.4)	(0.4)	4.5	170	(1.0)	(1.0)	(1.5)	38
	HM[3]	-	-	-	-	(4.0)	(4.0)	(6.0)	11.8
C	Static control	(0.4)	(0.4)	1.0	37	2.3	(1.0)	3.9	56
	Untreated Material[4]	-	-	-	-	(1.0)	(1.0)	4.9	2.0

1 - Values in parenthesis represent MDL for compounds reported as non detectable
2 - Sample collected from entire 60 cm depth
3 - Sample collected from top 30 cm only
4 - Near berm around treatment area (uncontaminated soil)

Table 2 - Metolachlor Concentrations (mg/kg) [3]

Area	Initial	Day 2	Day 7	Day 28	Day 208	Day 306	Day 454	Day 565
Main Treatment cell[1]	67	72	65	53	27	14	3.1	ND
HM cell[2]	170	140	140	110	78	57	42	38
Static Control cell	37	NS	49	87	63	57	66	56

1- Average of 5 zones
2- Sample collected from entire 60 cm depth
NS- Not sampled
ND- Not detected (below 1.0 mg/kg)

The goal of the demonstration was to reduce the concentrations of the target organic compounds - 2, 4-D, Dinoseb, Atrizine, and Metolachlor in the treated soil (the principal target compound on which the system operation was optimized was Metolachlor). As shown in Table 1, Dinoseb was not detected in any of the initial or final samples. 2,4-D was reduced from initial concentrations as high as 3.7 mg/kg to below detection limits in Plots A and B. Atrizine was reduced from initial concentrations as high as 17.0 mg/kg to below detection limits in these plots.

As shown in Tables 1 and 2, the concentration of Metolachlor in the main treatment cell was reduced from initial levels ranging from 48 to 84 mg/kg (67 mg/kg average) to below the detection level of 1.0 mg/kg. This reduction was observed in all 5 sample zones. In the HM cell, concentrations of Metolachlor were reduced from 170 mg/kg to 38 mg/kg (a 78% reduction). According to Grace, because only the top 30 cm of soil were tilled in the HM cell (as described above), effective treatment may not have occurred throughout the cell. A final sample of the top 30 cm of the HM cell showed Metolachlor concentrations of 11.8 mg/kg, below the 38 mg/kg for the entire 60 cm sample. Metolachlor concentrations in the static control cell remained essentially unchanged (initial concentration of 37 mg/kg and a final concentration of 56 mg/kg).

Performance Data Quality [3]

According to Grace, split samples and field duplicates indicated that the data quality was generally good. The relative percent difference (RPD) was less than 20% for all progress samples. The RPD for the initial samples was high (100%). According to Grace, this high RPD was likely due to the relatively heterogeneous matrix following a single tillage event.

Cost Information [3, 4]

Specific cost information was not provided for the 200 ton demonstration. However, Grace used the results of the demonstration to project a cost of $111,600 or $186/ton (in Canadian dollars) for remediating the 600 tons of waste currently stored at the Novartis facility using DARAMEND™ bioremediation. (Based on an exchange rate of 0.65, this corresponds to a projected cost of $73,000 or $120/ton in U.S. dollars.) According to Grace, this cost was calculated by dividing the appropriate components of the project budget by the total mass of soil treated during the demonstration. Grace noted that while capital and startup costs (e.g., lease of tractor and permitting) would remain relatively constant regardless of scale, about one-third of the project budget was dedicated to items required for the demonstration (e.g., extensive process monitoring, supplemental waste analysis) that would not typically be required during commercial applications (these costs are not included in the projected costs shown above).

Grace also noted that a number of factors will affect the actual cost of using this technology on a full-scale basis at other sites. These include the site location (distance from source of equipment, supplies, and personnel, as well as climate), quantity of soil treated, initial concentrations of target compounds, applicable remediation criteria, monitoring requirements, soil pretreatment requirements, and personal protective equipment requirements. For example, Grace stated that a full-scale application involving treatment of 2,500 - 5,000 tons of waste would cost $80-125/ton (in Canadian dollars; $52-81/ton in U.S. dollars).

Observations and Lessons Learned

The modified DARAMEND™ process reduced the concentrations of Metolachlor in the main treatment cell by 99%, from initial concentrations of 67 mg/kg to below detection limits (1.0 mg/kg). Concentrations of this compound in the HM cell were reduced by 93% in the top 30 cm of soil that were tilled and by 78% in the entire 60 cm of soil in the cell. These results were achieved after 565 days of operation.

The lower reduction in the entire 60 cm depth of the HM cell was attributed by Grace to the fact that tillage was effective only to a depth of about 30 cm.

The use of alternating aerobic and anaeobic cycles appeared to promote biodegradation of chlorinated pesticides and herbicides without the use of microbial innoculum.

The time and number of cycles required for the demonstration was longer than planned. According to Grace, this was caused by initial delays in startup as well as low temperatures during the winter months that slowed biological activity.

Contact Information

For more information about this application, please contact:

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E-mail: david.raymond@grace.com

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The following references were used in the preparation of this report.

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3. Ex-situ Bioremediation of Soils Containing Metolachlor: Pilot-Scale Demonstration at Ciba-Geigy Facility, Cambridge, Ontario. Draft Final Report. Prepared by GRACE Bioremediation Technologies. February 1998.

4. Comments provided by David Raymond, Grace Bioremediation Technologies on Draft Cost and Performance Summary Report. October 7, 1998.

Acknowledgments

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

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SOLVENT EXTRACTION CASE STUDIES

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Solvent Extraction at the Sparrevohn Long Range Radar Station, Alaska

Solvent Extraction at the Sparrevohn Long Range Radar Station, Alaska

Site Name: Sparrevohn Long Range Radar Station	**Contaminants:** Semivolatile (halogenated) - PCBs. PCB concentrations in untreated soil analyzed during the treatability study ranged from 13 to 346 mg/kg, with an average concentration of 80 mg/kg.	**Period of Operation:** Status: Complete Report covers: 6/96 through 8/96
Location: Alaska		**Cleanup Type:** Indefinite Delivery Type Remedial Action
Vendor: Prime Contractor: Linder Construction 8220 Petersburg Street Anchorage, AK 99507 (907) 349-6222 Treatment Vendor: Terra Kleen Response Group Lanny D. Weimer 3630 Cornus Lane Ellicott City, MD 21042 (410) 750-0626	**Technology:** Solvent extraction - Stockpiled soil was treated in 85 yd^3 batches using solvent extraction in specially-constructed lined treatment cells. - The system was operated in a fill-and-drain mode, with 1 day/treatment cycle and 8 treatment cycles/batch. - The solvent was reclaimed on site through a molecular sieve, and burned on site after the treatment was completed. - Solvent extraction was chosen over thermal desorption and soil washing on the basis of cost-effectiveness and the relative logistics of mobilizing treatment equipment to the isolated site.	**Cleanup Authority:** Air Force Installation Restoration Program. The cleanup was negotiated by the Alaska Department of Environmental Conservation (ADEC) and target levels were agreed upon mutually by the Air Force and ADEC.
Additional Contacts: Bernard T. Gagnon U.S. Army Corps of Engineers, Alaska District P.O. Box 898 Anchorage, AK 99506-0898 (907) 753-5718 Air Force Project Manager: Patricia Striebich 611th CES/CEVR Elmendorf Air Force Base, AK 99506 (907) 552-4506		**State Point of Contact:** Ray Burger State of Alaska Department of Environmental Conservation Contaminated Sites Remediation Program 555 Cordova Street Anchorage, AK 99501 (907) 563-6529
Waste Source: Transformer storage, transformer maintenance, and drum storage	**Type/Quantity of Media Treated:** Soil - 288 yd^3 - Gravel with fines and likely little or no clay - Moisture content 9%	
Purpose/Significance of Application: Application of an innovative technology to treat PCB-contaminated soil at a remote site in Alaska.		

Solvent Extraction at the Sparrevohn Long Range Radar Station, Alaska (continued)

Regulatory Requirements/Cleanup Goals:
- A target cleanup level of 15 mg/kg for PCBs in soil was established for this application.
- The contractor was required to perform sampling of the soil at the surface and the bottom of each treatment cell.
- Concentrations of PCBs in the reclaimed solvent were required to be less than 2 mg/L before the solvent could be burned on site.

Results:
- Average concentrations of PCBs were reduced from 80 mg/kg in the untreated soil to 3.27 mg/kg after treatment.
- Concentrations of PCBs measured in samples from the tops and bottoms of each of the five batches of treated soil were reduced to below the 15 mg/kg target cleanup level.
- The concentrations of PCBs in treated soil varied among the batches by one order of magnitude. This variation was attributed to the variations in the concentrations of PCBs in the untreated soil.
- PCBs were not detected at concentrations above detection limits (0.1 mg/L) in the reclaimed solvent.
- Based on a mass balance, approximately 33.8 pounds of PCBs were transferred from the 441,000 kg of contaminated soil to 4,772 pounds of molecular sieve (used to reclaim the solvent), resulting in a contaminated material mass reduction of almost 100 to 1.

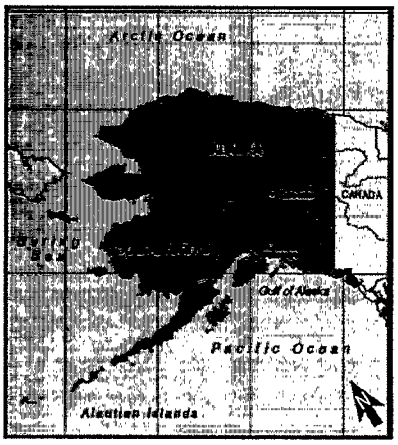
Cost:
- The total cost of this application was $828,179, including $602,530 for mobilization and demobilization, and $225,649 for the solvent extraction. This was less than one-half of the estimated cost of $1,908,545 to transfer all of the contaminated soil to the Defense Reutilization Marketing Office.
- The cost for solvent extraction corresponds to a unit cost of $780 per cubic yard of soil treated.
- Because of its remote location, the site was only accessible by air. Therefore, transportation costs for both mobilization and demobilization were a major factor in the overall cost of the project.

Description:
The Sparrevohn LRRS was constructed in 1952, and is one of ten Aircraft Control and Warning sites constructed as part of the air defense system in Alaska. The site is located approximately 200 miles west of Anchorage and is accessible only by air. It is currently operated by the Air Force as a Minimally Attended Radar facility and consists of a lower camp (elevation 1,700 feet) that includes support facilities and an upper camp (elevation 3,300 feet that houses radar equipment.

In 1986, PCB contamination was delineated at the site. In 1989, approximately 450 tons of PCB-contaminated soil from the lower camp were excavated and transported off site for disposal, and approximately 600 tons of PCB-contaminated soil from the upper camp were transported to the lower camp and stockpiled.

A treatability study was conducted on the stockpiled soil in 1995, and as a result of the study, the stockpiled soil was treated in batches using solvent extraction between June and August of 1996. Closure and site restoration activities at the site were completed in September 1996.

SITE INFORMATION



IDENTIFYING INFORMATION

Site Name: Sparrevohn Long Range Radar Station (LRRS)
Location: Alaska (approximately 200 miles west of Anchorage)
Technology: Solvent Extraction
Type of Action: Indefinite Delivery Type Remedial Action (IDTRA)

TECHNOLOGY APPLICATION (1)

Period of Operation: Treatability study - 1995; Full-scale operation - June through August 1996
Quantity of Material Treated During Application: 288 cubic yards of soil

BACKGROUND

Site Background (1, 2):

- Sparrevohn LRRS, constructed in 1952, was one of ten Aircraft Control and Warning (AC&W) sites constructed as part of the air defense system in Alaska. The Air Force currently operates the site as a Minimally Attended Radar (MAR) facility staffed by four people.
- The site is located approximately 200 miles west of Anchorage in the Sparrevohn Mountains and is accessible only by air. The site consists of a lower camp (elevation 1,700 feet) that includes support facilities and an upper camp (elevation 3,300 feet) that houses radar equipment.
- In June 1986, soil sampling for polychlorinated biphenyls (PCBs) was conducted at the lower camp in the vicinity of a former transformer pad and drum dump, and field screening for PCBs was conducted at the upper camp. In 1986, Sparrevohn and other bases were beginning to investigate possible PCB contamination in soil, and the sampling was conducted for those efforts to identify potential environmental problems at the bases.
- The results of the laboratory analyses of soils from the lower camp showed concentrations of PCBs ranging from 0.1 to 11,358 milligrams per kilogram (mg/kg); the results of field screening of the upper camp showed contamination with PCBs at concentrations above levels of concern.
- PCB test kits were used in conducting field screening. A positive result indicated that PCBs were present at or above a level of concern. At the time the screening was conducted, field test kits typically identified concentrations of PCBs at levels higher than 10 to 50 mg/kg as positive results (that is, the detection level). Information on the specific detection level for the PCB test kits used at Sparrevohn was not available.
- In 1989 contaminated soil at the lower camp was excavated and shipped off site for disposal; contaminated soil at the upper camp was excavated and transported to the lower camp, where it was stockpiled in a lined, diked containment area.

- Approximately 450 tons of PCB-contaminated soil were removed from the containment area, overpacked, and shipped off site.

- An estimated 600 tons of stockpiled PCB-contaminated soil remained at the site. According to USACE, concentrations of PCBs in the stockpiled soil were estimated at 5 to 500 mg/kg, based on information in manifests for material shipped from the site. No direct sampling of stockpiled soil at the site was performed at that time.

SIC Code: 9711 (National Security)

Waste Management Practice that Contributed to Contamination: Transformer storage, transformer maintenance, and drum storage.

Remedy Selection (1, 2):

- Several remedies were considered for treating the stockpiled PCB-contaminated soil, including thermal desorption, solvent extraction, and soil washing. Solvent extraction was selected over the other technologies on the basis of cost-effectiveness and the logistics of mobilizing on site. For example, solvent extraction was determined to require less equipment and less logistical support — fuel, water, and electricity — than the other technologies. On-site thermal destruction was not feasible because of the high costs of the mobilization and operation of a unit and the relatively low volume of contaminated soil to be treated. In addition, there was a concern that the use of thermal desorption would require that the system perform under stringent conditions to prevent the formation of dioxins and furans. Further, solvent extraction was expected to be more effective than soil washing.

- In addition to considering other technologies such as thermal desorption, soil washing, and solvent extraction, off-site disposal at the Defense Reutilization and Marketing Office (DRMO) at Elmendorf AFB in Anchorage, Alaska was considered. The cost of solvent extraction was found to be less than that of off-site disposal at DRMO. Disposal at DRMO was estimated to cost $0.76 per pound (approximately $3,080 per cubic yard), plus costs for mobilization and demobilization, for a total of $1,908,545. The negotiated cost of solvent extraction was less than half the estimated cost for disposal at DRMO (see the discussion under "Treatment System Costs").

SITE LOGISTICS/CONTACTS

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Treatment Vendor:
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Telephone: (410) 750-0626

*Primary point of contact for this application

MATRIX AND CONTAMINANT DESCRIPTION

MATRIX IDENTIFICATION

Soil (ex situ)

CONTAMINANT CHARACTERIZATION

Semivolatiles (halogenated) - PCBs (the specific PCB congeners or group of congeners was not identified.)

CONTAMINANT PROPERTIES

Property	PCBs
CAS No.	1336-36-3
Specific Gravity	1.3 to 1.8 at 60° F
Toxicity	High
Flammability	Low
Solubility	0.04 - 0.2 mg/L (in water @ 20° C)

NATURE AND EXTENT OF CONTAMINATION (1, 2)

- Only limited information is available about the nature and extent of contamination at Sparrevohn LRRS.
- Concentrations of PCBs in untreated stockpiled soil were measured as part of the treatability study. The results of eight composite samples showed PCB concentrations ranging form 13 to 346 mg/kg, with an average of 80 mg/kg.

MATRIX CHARACTERISTICS AFFECTING TREATMENT COST OR PERFORMANCE (1, 2)

- Listed below are the major matrix characteristics affecting cost or performance for this technology and the values measured for each parameter.

Parameter	Value
Soil Classification	Gravel with fines, GM or GP (based on observation)
Clay Content and/or Particle Size Distribution	Not quantified, but likely little or no clay
Hydraulic Conductivity/Water Permeability	Information not available
Contaminant Sorption/Soil Organic Content	Information not available
Lower Explosive Limit	Information not available
Presence of Emulsifying Agents	None
Moisture Content	9%

TREATMENT SYSTEM DESCRIPTION

PRIMARY TREATMENT TECHNOLOGY TYPES

Solvent extraction

SUPPLEMENTARY TREATMENT TECHNOLOGY TYPES

Post-treatment (solids): thermal destruction (residual solvent)

TREATMENT SYSTEM DESCRIPTION (1,3)

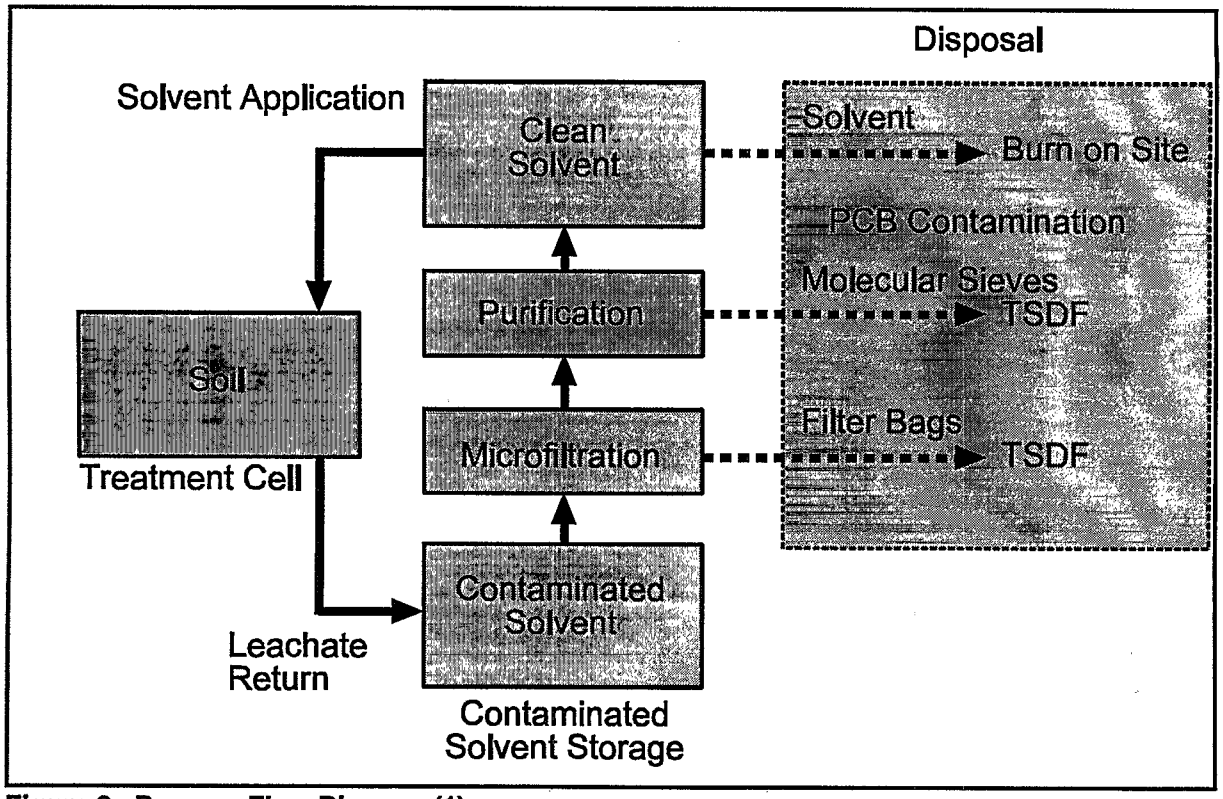

Figure 2. Process Flow Diagram (1)

Construction

- More than 200 tons of equipment and materials were mobilized to the site by air.
- Preliminary activities included construction of a contractor's camp, utilities, and cells for soil treatment and for clean and contaminated soil.
- The solvent extraction system used at Sparrevohn consisted of specially constructed soil treatment cells, storage cells for clean and contaminated solvent, solvent purification equipment (settling, 10-micron-bag filter, and molecular sieve purification stations), and associated process pumps and piping.
- The composition of the solvent used at Sparrevohn was proprietary business information, and was maintained by the treatment vendor. According to the contractor, the solvent is considered a non-hazardous and non-toxic substance.
- Soil treatment cells were constructed in the following steps: 1) the area of each cell was excavated to a depth of approximately two feet, 2) plywood sidewalls were erected on three sides of each cell, with one side left open to facilitate loading, 3) each cell's interior was lined with an impermeable membrane liner, 4) an underdrain system was installed to remove PCB-laden solvent, and 5) the cells were covered after loading to reduce evaporation of solvent and prevent rain from diluting the solvent.
- Five soil treatment cells were constructed, each with dimensions of 36 feet long, 16 feet wide, and 4 feet deep, a volume of approximately 85 cubic yards for each cell. Two additional cells of the same dimensions were constructed to store clean and contaminated solvent.

Operation

- The system operated in fill-and-drain mode. Contaminated soil was loaded into a soil treatment cell, and 3,000 to 4,000 gallons of clean solvent were pumped into the cell to immerse the soil in the solvent. Soil and solvent were held in the cell for one day to allow the PCBs to solubilize in the solvent.
- Contaminant-laden solvent was removed from the cells through the underdrain system, and transferred to the contaminated solvent cell. PCBs were removed from the solvent and concentrated in the molecular sieve medium, while cleaned solvent was collected in the clean solvent storage cell.
- The system treated the soil in batches, with each cell undergoing repeated cycles of fill and drain, until field screening, followed by confirmation sampling and laboratory analyses, showed that the concentration of PCBs in the soil was less than 15 mg/kg. Eight cycles of fill and drain were used for each soil treatment cell.
- At the conclusion of treatment, clean solvent was burned on site. The clean solvent was analyzed to determine that it contained concentrations of PCBs below 2 ppm, as required by the State.
- Solvent-consuming microbes and nutrients were added to the treated soil to promote biodegradation of residual solvent in the soil. According to the contractor, the solvent typically exhibited a half-life of approximately one or two days after such treatment.

OPERATING PARAMETERS AFFECTING TREATMENT COST OR PERFORMANCE (1)

Listed below are the major operating parameters affecting cost or performance for this technology and the values measured for each parameter.

Parameter	Value
Mixing Rate/Frequency	Not Applicable - Fill and drain operating mode
Moisture Content	9% (for all 5 treatment cells)
pH	Information not available
Pumping Time	Information not available
Residence Time/Number of Cycles	1 day/treatment cycle; 8 treatment cycles/batch
System Throughput	288 cubic yards in 5 batches
Temperature of Soil in Treatment Cells	Information not available
Additives and Dosage	Information not available

Closure

- Closure and site restoration activities included: dismantling the soil treatment cells (removing the roofs, puncturing the bottom liners, detaching the liners from the plywood sides, and removing the plywood sides); folding the liner edges over the top of the treated soil; adding a 12-millimeter liner on top of the treated soil; and placing clean soil (soil that had been excavated to construct the cells) over the liner to form a two-foot-thick cap. Remaining liner and piping were left in place with the treated soil. The closed cells were visible above grade as five smoothly graded, rectangular mounds. The molecular sieves and other project-derived wastes (that is, personal protective equipment (PPE) and liner material) were packed in drums and shipped off site for disposal at a facility approved by the U.S. Environmental Protection Agency (EPA). Molecular sieves were shipped to a treatment, storage, and disposal facility (TSDF) of Phillip Environmental and from there to Rollins Environmental for incineration. Additional PPE and stockpiled liner were turned in to the DRMO at Elmendorf Air Force Base for disposal. Solvent drums were crushed and sent to a metal recycler, and other debris were sent to a conventional municipal solid waste landfill in Anchorage, Alaska.

TREATMENT PLAN

- Planning and design of this project were conducted in the following three phases: 1) bench-scale treatability study of solvent extraction; 2) preparation of an engineering evaluation and cost analysis (EE/CA — see previous discussion under Remedy Selection), and 3) preparation of a delivery order (DO) to be issued to a previously selected IDTRA contractor for implementation of the selected remedy.

- The vendor of the solvent extraction process conducted the treatability study at the vendor's facilities, using a 5-gallon sample of PCB-contaminated soil.

- The study showed that concentrations of PCBs were reduced from 350 to less than 15 mg/kg through the application of seven cycles of fill and drain solvent extraction.

- The DO required that the contractor conduct sampling and testing (one sample per 50 cubic yards of soil before treatment); develop a work plan and other related plans; conduct treatment; and dispose of the stockpile of PCB-contaminated soil.

- The U.S. Army Corps of Engineers (USACE), Alaska District, the U.S. Air Force, and state regulators reviewed the plans. Major issues identified during the review included the nature of the solvent to be used, the confirmatory sampling protocol, and the method of disposal of the solvent at the completion of the project.

TIMELINE (1, 2)

Date	Activity
1952	Construction of Sparrevohn LRRS completed
June 1986	Soil sampling for PCBs conducted at lower and upper camps
1989 Construction Season	PCB-contaminated soils excavated at lower and upper camps, all soil from lower camp and some from upper camp shipped off site; and remaining soil from upper camp stockpiled on site
1995	Treatability study of solvent extraction process conducted
July 1995	Delivery order awarded
July 1995 to May 1996	Work plans prepared with approval in May 1996
May 28 to June 13, 1996	Materials and equipment mobilized to site
June 20 to August 12, 1996	Treatment, including confirmational sampling, conducted
August 12 to September 17, 1996	Closure and site restoration activities conducted

TREATMENT SYSTEM PERFORMANCE

PERFORMANCE OBJECTIVES (1, 2)

- A target cleanup level of 15 mg/kg for PCBs in soil was established for this application.

- The contractor was required to perform sampling of the soil at the surface (top) and the bottom of each treatment cell.

- Concentrations of PCBs in the clean solvent were required to be less than 2 mg/liter (mg/L) before the solvent could be burned on site.

TREATMENT PERFORMANCE DATA (1, 2)

- Table TPD-1 shows treatment performance data for each of the five soil treatment cells. Analyses were performed by both an immunoassay procedure and an analytical laboratory procedure (shown in Table TPD-1 as "composite"). The immunoassay procedure was used as a screening procedure to monitor the performance of the extraction system during operation. When screening data indicated that the soil had met the target cleanup level, additional samples were collected and shipped off site for analysis by the analytical laboratory procedure to confirm

that the cleanup level had been met. The detection limit for the screening was 10 mg/kg, and for the analytical laboratory was 0.36 mg/kg (the detection limit for the analytical laboratory varied slightly from analysis to analysis).

- Samples of treated soil were collected from both the top and the bottom of each treatment cell for analyses by the off-site laboratory using EPA Method 8080 (3). Originally, the contractor had recommended that samples be collected only from the tops of the cells. However, because of concerns that the solvent might mobilize the PCBs and that the PCBs might concentrate at the bottoms of the treatment cells, samples were collected at both the tops and the bottoms of the treatment cells to confirm that the target cleanup level had been met at both locations.

Table TPD-1. Solvent Extraction Treatment Performance Data, Sparrevohn LRRS [1]

Parameter	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5
PCB Concentration, mg/kg					
Untreated Soil (composite, average)*	80	80	80	80	80
Treated Soil (immunoassay procedure)	<10	<10	<10	<10	<10
Treated Soil (composite from top)	0.55	0.95	3.15	0.98	6.48
Treated Soil (composite from bottom)	0.68	0.99	2.19	8.84	7.88
Treated Soil (Average)			3.27		

* Concentration of 80 mg/kg in untreated soil, on the basis of average of results for eight individual composite samples, as follows: 346, 41, 13, 52, 59, 68, 40, and 28 mg/kg.

- PCBs were measured at levels below the detection limit (detection limit of 0.1 mg/L) in the regenerated (clean) solvent.

PERFORMANCE DATA ASSESSMENT

- The average concentration of PCBs was reduced from 80 mg/kg in untreated soil to 3.27 mg/kg in treated soil (96 percent reduction).

- The concentration of PCBs in treated soil was less than the soil target cleanup level (15 mg/kg) for all five treatment cells.

- The results of the immunoassay screening procedure indicated that the PCB concentrations in the treated soil had met the target cleanup level. The results of the screening were confirmed through off-site analysis which showed PCB concentrations in composite samples from both the top and the bottom of the treatment cells to be below the target cleanup levels.

- Samples were collected from both the top and the bottom of the treatment cells because of concerns that PCBs might concentrate at the bottom of the cells.

- The concentrations of PCBs in treated soil varied among the treatment cells by one order of magnitude (concentrations in composites from the tops of cells ranged from 0.55 to 6.48 mg/kg;

concentrations in composites from the bottoms of cells ranged from 0.68 to 8.84 mg/kg). This variation may be attributed to variations in the actual concentrations of PCBs in the untreated soil. While the average PCB concentration in untreated soil was 80 mg/kg, this was based on a composite of samples with PCB concentrations ranging from 13 mg/kg to 346 mg/kg.

- The concentration of PCBs in clean solvent was less than the concentration of 2 mg/L required by the state for burning the solvent on site. Therefore, spent solvent was burned in onsite burners and did not have to be transported off-site at the end of the application.

Material Balance: The concentration of PCBs in the soil before and after treatment and the weight of PCB extracted from the soil by the solvent and then accumulated in the molecular sieve are summarized below.

Media	Mass	PCB Concentration		Weight of PCB Transferred
		Before Treatment	After Treatment	
Soil	441,000 kg[1]	80 mg/kg	3.27 mg/kg	-33.8 kg
Molecular Sieve	4,772 kg	0 mg/kg	7,090 mg/kg[2]	+33.8 kg

Notes:
Residual solvent PCB concentration assumed to be 0 mg/kg for the purpose of material balance.
[1] Mass of soil based on 288 cubic yards at 125 pounds/cubic foot
[2] Concentration of PCBs in molecular sieve after treatment calculated as the weight of PCBs removed from the treated soil homogeneously distributed in the mass of the molecular sieve.

Removal Efficiencies: The PCB removal efficiency averaged 96 percent, on the basis of a comparison of an average concentration of PCBs in untreated soil of 80 mg/kg with an average concentration of PCBs in treated soil of 3.27 mg/kg.

PERFORMANCE DATA QUALITY (2)

- EPA Method 8080 was used by the laboratory to determine PCB concentrations in the soil and solvents

- The contractor wrote a SAP and a QAPP, which the USACE district, the Air Force, and the ADEC reviewed. Analytical data were reviewed internally by the district, and the USACE division laboratory wrote a chemical quality assurance report that validated the data. The report concluded that overall quality control was satisfactory.

TREATMENT SYSTEM COST

PROCUREMENT PROCESS

- The procurement was conducted under an indefinite delivery type remedial action contract. USACE solicited proposals for the contract, and the contractor was selected on the basis of technical qualifications to perform a variety of remedial actions that might be necessary. Only 8A contractors were evaluated for this contract.

- The contractor submitted a cost proposal for the project, which was issued as a delivery order (DO) against the contract. USACE required a minimum of three bids by any subcontractors in the contractor's proposal. In addition, in this case, USACE required that the contractor prepare a cost for shipment of contaminated soil to DRMO without treatment, for use in comparing costs. The contractor submitted its proposal for the work, and USACE negotiated a firm fixed-price contract for accomplishment of the work. The prime contractor had overall responsibility for the project, including the preparation of all project documents and subcontracting. The treatment subcontractor ran the treatment process and provided technical advice.

TREATMENT SYSTEM COST (1)

- Combination of mobilization and demobilization: $602,530
- Treatment - solvent extraction: $225,649
- The costs presented above are the negotiated costs for treatment (total of $828,179); they were compared with the costs of transfer to DRMO (total of $1,908,545, as discussed under the Treatment Plan section of this document).

COST SENSITIVITIES

- Because of its remote location, the site was accessible only by air. Therefore, transportation costs for both mobilization and demobilization were a major factor in the overall cost of the project.

- For mobilization, over 200 tons of equipment and materials were transported to the site by air.

- For demobilization, efforts were made to reduce the amount of material to be transported off site. For example, the technology achieved a reduction in mass of almost 100 to 1 (contaminants in 441,000 kg of soil transferred to 4,700 kg of molecular sieve) and excess solvent was incinerated on site rather than transported.

REGULATORY/INSTITUTIONAL ISSUES

- The project was managed by the Air Force (611th) under its Installation Restoration Program (IRP). The cleanup was negotiated with ADEC, and target cleanup levels were agreed upon mutually by the Air Force and ADEC. Contractor requirements were identified by examination of applicable codes, regulations, and guide specifications. Plans prepared by the contractor (work plan, SAP, QAPP, health and safety plan, and waste management plan) were reviewed by the USACE district, Air Force, and ADEC. (1,2)

OBSERVATIONS AND LESSONS LEARNED

COST OBSERVATIONS AND LESSONS LEARNED

- Solvent extraction of soil contaminated with PCBs at Sparrevohn LRRS cost $828,179 with a cost of $225,649 for activities directly attributed to treatment. This represents a unit cost of $780 per cubic yard of soil treated (288 cubic yards treated), for activities directly attributed to treatment.

- Because the location of the site was remote and the site was accessible only by air, the mobilization and demobilization costs of $602,530 were relatively high, compared with those costs for a similar operation in a more accessible location.

- Considering mobilization, demobilization, treatment, and disposal costs, solvent extraction was less than 50 percent as costly as off-site disposal through the DRMO (estimated at about $1.9 million).

- On-site thermal destruction of the clean solvent reduced the costs of the demobilization as the solvent did not have to be transported off site.

PERFORMANCE OBSERVATIONS AND LESSONS LEARNED

- Within a three month period (one construction season in Alaska), the solvent extraction system at Sparrevohn reduced the concentration of PCBs to less than the soil target cleanup level of 15 mg/kg for all five treatment cells.

- Solvent extraction reduced the average concentration of PCBs from 80 mg/kg in untreated soil to 3.27 mg/kg in treated soil, representing a 96 percent overall reduction.

- The immunoassay screening procedures used at Sparrevohn indicated that target cleanup goals had been met in the treated soil. In all five cases where the screening procedure indicated that the goals had been met, this was confirmed in the analyses performed by the off-site laboratory.

- A requirement to sample both the top and bottom of the treatment cells was added because of concerns that PCBs would concentrate at the bottom of the cells in this type of application.

- The solvent regeneration system used at Sparrevohn reduced PCB concentrations in the clean solvent to below detectable levels, thereby meeting the requirement for burning the clean solvent on site (below 2 mg/L). Because solvents could be burned on site, no solvent had to be transported off the site as part of the demobilization activities.

OTHER OBSERVATIONS AND LESSONS LEARNED

- The following additional observations and lessons learned were provided by the USACE project manager:

  - The performance of the solvent extraction technology is limited by fines, moisture, and organic content:

    - Treatment of contaminated soils having more than 15 percent clays or fines or high organic content is difficult because contaminants are strongly sorbed to the soil particles (soil particles also form tight aggregates that are difficult to break up).

    - Soils containing more than 20 percent moisture must be dried before treatment (excess water dilutes the solvent, reducing the solubility of the contaminant and transport efficiency).

    - Solvent extraction suppliers require a particle size analysis and information about moisture content, organic content, contaminant identification and concentration, and the target cleanup level to determine the number of wash cycles required and to estimate the cost of treatment.

- The treatment vendor indicated that the solvent extraction technology could be limited by soil moisture content. If the moisture content of treated soils exceeded 20 percent, a solvent dehydration unit would be required to recover or recycle the solvent.
- Solvent extraction vendors recommend a bench-scale treatability test to support the cost estimate.
- The process was flexible and rapid enough to allow additional soil to be treated midway through the project without delaying completion. For example, because of an error in measuring the stockpile of soil, an additional cell (approximately 50 cubic yards) was constructed midway through the project in treating the soil.

REFERENCES

1. Gagnon, Bernard T., P.E. Not dated. Solvent Extraction Treatment of PCB Contaminated Soil at Sparrevohn Long Range Radar Site, Alaska.
2. Gagnon, Bernard T., P.E. 1997. USACE - Alaska District, Comments and Responses on Pre-draft Report. December 2.
3. Berman, Michael H. 1998. Record of Telephone Conversation with Bernard Gagnon. June 19.

ACKNOWLEDGMENTS

This report was prepared for the U.S. Army Corps of Engineers under USACE Contract No. DACA45-96-D-0016, Delivery Order No. 12. Assistance was provided by Tetra Tech EM Inc. and Radian International LLC.

THERMAL DESORPTION CASE STUDIES

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Vacuum-Enhanced, Low Temperature Thermal Desorption at the FCX Washington Superfund Site Washington, North Carolina

Vacuum-Enhanced, Low Temperature Thermal Desorption at the FCX Washington Superfund Site
Washington, North Carolina

Site Name: FCX Washington Superfund Site	**Contaminants:** Pesticides - Aldrin, chlordane, DDT, DDE, DDD, dieldrin, heptachlor, heptachlor epoxide, methoxychlor, benzene hexachlorides	**Period of Operation:** March 1995 - March 1996
Location: Washington, North Carolina		**Cleanup Type:** Full-scale
Vendor: Nanette Orr McLaren/Hart Environmental Engineering Corporation Great Woods Park 800 South Main Street Mansfield, MA 02048 (508) 261-1515	**Technology:** Thermal Desorption - IRHV-200 vacuum-enhanced low temperature thermal desportion system - Four treatment chambers each equipped with 8 infrared heaters. At 1100°F, each heater produced 137,000 BTU/hr - Liquid seal vacuum pump used to create vacuum of 50 mmHg - High flow recirculation blower (6,000 acfm) - Air draw off recirculation stream (300 acfm) directed to air emissions control - Dry particulate filters, condensors, and carbon adsorption units - Residence time - 4 hr (batch process) - Soil temperatire - 350°F for a minimum of 5 minutes	**Cleanup Authority:** CERCLA Removal - Action memorandum date: 9/29/88
State Contact: Randy McElveen North Carolina DEHNR P.O. Box 27687 Raleigh, NC 27611 (919) 733-2801		**On-Scene Coordinator (OSC):** Paul Peronard EPA Region 4 345 Cortland Street, N.E. Atlanta, GA 30365 (404) 562-8767
Waste Source: Buried waste pesticides	**Type/Quantity of Media Treated:** Soil - 13,591 cubic yards	
Purpose/Significance of Application: Vacuum-enhanced low-temperature thermal desorption used to treat pesticide-contaminated soil		
Regulatory Requirements/Cleanup Goals: - Total pesticides - 1.0 mg/kg - For the demonstration, air emissions were to meet the EPA Region 4 Air Compliance Section standards for vented air emissions; no air emission standards were set for the full-scale operation.		
Results: - Treated soil met the cleanup goal of 1 mg/kg total pesticides. - A one-time stack air monitoring test was performed during the demonstration; all standards were met.		

Vacuum-Enhanced, Low Temperature Thermal Desorption at the FCX Washington Superfund Site
Washington, North Carolina (continued)

Cost:
- Total cost of $1,844,600 including $1,696,800 in costs directly associated with treatment.
- Based on 13,591 cubic yards of soil treated, the unit cost was $125 per cubic yard.

Description:
From 1945 to 1982, the Farmers Cooperative Exchange (FCX) operated a pesticide blending facility and warehouse where it packaged pesticides. The pesticides most frequently handled at the site were chlorinated organic pesticides including chlordane, methoxychlor, dichloro-diphenyl-trichloroethane (DDT), and 1,1-dichloro-2,2-bis(4-chlorophenyl) ethene (DDE). Various other chlorinated and nonchlorinated organic chemicals were used in mixing and blending of pesticides. Outdated or out-of-specification materials were buried in trenches on the FCX property. In 1985, the company filed for bankruptcy, and the building and warehouses were cleaned out. In 1986, the Fred Webb Grain Company (FWGC) purchased approximately 15 acres of the FCX property to be used to store grain under the federal government grain subsidy program. Subsequent investigations of the site performed by EPA and the state indicated that the site was contaminated with pesticides. The site was listed on the NPL in March 1989. The removal site investigation, performed in 1992, identified pesticide contamination in trenches at the site. Approximately 14,700 cubic yards of contaminated soil (total chlorinated pesticides above 1 ppm) were excavated and stock piled for on-site incineration. As a result of objections by the city to on-site incineration and in response to state issues regarding off-site disposal, EPA identified on-site thermal desorption as the remedy for the excavated contaminated soil at FCX.

Vacuum-enhanced, low temperature thermal desorption (LTTD) was used to treat the contaminated soil at the FCX site. The system operated under a vacuum of about 50 mm Hg and used an infrared heat source to desorb contaminants from the soil. By operating under a vacuum, the temperature required to desorb contaminants from the soil and the amount of oxygen present in the treatment chamber are lower than if the unit were operated under atmospheric conditions, helping to reduce the potential for formation of dioxins and furans. The model IRHV-200 mobile LTTD system used at the site included a treatment chamber, and emission control equipment including a dry particulate filter, condenser, and carbon adsorption unit. McLaren/Hart conducted two site demonstrations before full-scale operations began. The initial demonstration, conducted with a batch of clean soil, failed to heat the soil throughout. Several modification were made to the full-scale system to improve heat transfer. Samples of treated soil were collected for each 500-ton lot of soil (total of three lots). The results of the full-scale operation showed that the LTTD met the cleanup goal of 1 mg/kg total pesticides in each of the three lots. Data also showed that concentrations of dioxins and furans in the treated soil were less than in the untreated soil. McLaren/Hart used the results of the FCX application to identify a number of modifications and improvements to the LTTD system to further improve heat transfer rates and to decrease the overall length of the treatment cycles for other applications. A detailed summary of these improvements is included in the report.

SITE INFORMATION

Identifying Information:

FCX Washington Superfund Site
Washington, North Carolina

CERCLIS # NCD981475932

Action Memorandum Date:
September 29, 1988

Treatment Application:

Type of Action: Removal

EPA SITE Program Test Associated With Application? No

Period of Operation: March 1995 - March 1996

Quantity of Material Treated During Application: 13,591 cubic yards

Background

Waste Management Practice That Contributed to Contamination: Burial of outdated and out-of-specification mixed pesticides in trenches.

Site History [4, 5]:

From 1945 to 1982, the Farmers Cooperative Exchange (FCX) operated a pesticide blending facility and warehouse where it packaged pesticides. The pesticides most frequently handled at the site were chlorinated organic pesticides including chlordane, methoxychlor, dichloro-di-phenyltrichloroethane (DDT), and 1,1-dichloro-2,2-bis(4-chlorophenyl) ethene (DDE). Various other chlorinated and nonchlorinated organic chemicals were used in mixing and blending of pesticides. Outdated or out-of-specification materials were buried in trenches on the FCX property. In 1985, the company filed for bankruptcy, and the building and warehouses were cleaned out. In 1986, the Fred Webb Grain Company (FWGC) purchased approximately 15 acres of the FCX property to be used to store grain under the federal government grain subsidy program.

Subsequent investigations of the site performed by EPA and the state indicated that the site was contaminated with pesticides. In January 1989, EPA Region 4 initiated a removal action. Approximately 2,200 cubic yards of debris and soils contaminated with pesticides were excavated and disposed off site. The site was listed on the NPL in March 1989.

The removal site investigation, performed in 1992, identified pesticide contamination in trenches at the site. Approximately 14,700 cubic yards of contaminated soil (total chlorinated pesticides above 1 mg/kg) were excavated and stock piled for on-site incineration. As a result of objections by the city to the use of on-site incineration and in response to state issues regarding off-site disposal, EPA identified on-site thermal desorption as the remedy for the excavated contaminated soil at FCX.

Regulatory Context:

The removal action at the FCX site was performed under an action memorandum signed September 29, 1988. As a result of the issues identified above with respect to on-site incineration and off-site disposal, EPA made the decision to use on-site thermal desorption as the remedy.

In July 1994, the agency issued a request for proposal (RFP) for an on-site thermal desorption system to remove the contaminants from the soil. To support the selection of an on-site thermal desorption unit, the agency prepared technical specifications that included:

1. Elimination of oxygen within the unit (less than five percent) during treatment to reduce the potential for formation of dioxins and furans during thermal desorption

2. Recycling of the unit's air stream or use of a low-flow system to minimize the amount of gas discharged to the atmosphere

SITE INFORMATION (CONT.)

3. Exclusion of any type of device that allows combustion to take place in the presence of the contaminants

4. Use of a low-temperature condenser

5. Discharge flow of less than 500 actual cubic feet per minute (acfm), cooling of the emissions stream, and use of an indirect-fired system

Remedy Selection: On-site thermal desorption

Site Logistics/Contacts

Site Management: Fund Lead

Oversight: EPA

On-Scene Coordinator (OSC):
Paul Peronard*
EPA Region 4
345 Cortland Street, N.E.
Atlanta, GA 30365
Telephone: (404) 562-8767

State Contact:
Randy McElveen
North Carolina Department of Environment, Health, and Natural Resources, Superfund Station
P.O. Box 27687
Raleigh, NC 27611
Telephone: (919) 733-2801

ERCS Site Assessment Contractor:
Sara Legard
Four Seasons Industrial Services, Inc.
3107 South Elm-Eugene Street
P.O. Box 16590
Greensboro, NC 27416
Telephone: (910) 273-2718

Treatment System Vendor:
Nanette Orr
McLaren/Hart Environmental Engineering Corporation
Great Woods Park
800 South Main Street
Mansfield, MA 02048
Telephone: (508) 261-1515

* Primary point of contact for this application.

MATRIX DESCRIPTION

Matrix Identification

Type of Matrix Processed Through the Recovery System: Soil (ex situ)

Contaminant Characterization

Primary Contaminant Groups: Pesticides

Soil samples were collected from soil above the trench and inside the trench and analyzed for pesticides. Table 1 presents the results of analyses of soil samples.

Table 1: Contaminants and Concentrations in Soil [5]

Contaminant	Range (mg/kg)
Above the Trench	
Aldrin	27.0 - 1585.0
Chlordane	1.0 - 50.0
DDT	1.0 - 37.7
DDE	1.0 - 37.7
Mercury	0.0 - 28.0
In the Trench	
Chlordane	1.0 - 6629.0
DDD	1.0 - 500.0
DDT	1.0 - 19435.0
DDE	1.0 - 47.0
Dieldrin	1.0 - 47.0
Heptachlor	1.0 - 79.0
Heptachlor epoxide	1.0 - 79.0
Methoxychlor	1.0 - <130.0
Total benzene hexachlorides (BHC) (alpha BHC and gamma BHC)	1.0 - 189.0

MATRIX DESCRIPTION (CONT.)

Matrix Characteristics Affecting Treatment Cost or Performance

Table 2 presents the major characteristics of the matrix that affected the cost or performance of this technology and the values measured for each.

Table 2: Matrix Characteristics [11, 12]

Parameter	Value
Soil classification/ particle size distribution	Silty Sand (Augusta fine)
Moisture content	Less than 15 percent most of the time. Approximately 15 to 20 percent during final phase of project.
Oil and grease or total petroleum hydrocarbons (TPH)	Information not provided
Bulk density	Information not provided
Lower explosive limit	Information not provided

Soil was generally a silty sand that was fairly homogenous in nature and that required no processing before thermal treatment. Soil moisture had a significant effect on the length of the treatment cycle. Rate of transfer of heat was regulated primarily by the percentage of contained moisture. The average moisture content of the soil during most of the treatment program was less than 15 percent. During the final phase of treatment (December 1995 to March 1996), inclement weather increased the moisture content of the soil, which during that period was estimated to be between 15 to 20 percent, with an average of approximately 18 percent. The higher moisture content increased the length of the treatment cycle [11].

DESCRIPTION OF THE TREATMENT SYSTEM

Primary Treatment Technology

Vacuum-enhanced, low-temperature thermal desorption

Supplemental Treatment Technology Types:

Post-Treatment (Air): Dry particulate filter (DPF), condenser with chiller, carbon adsorption

Post-Treatment (Water): Reverse osmosis (R/O), carbon adsorption

System Description and Operation

System Description [1, 10, 12, 13]

Vacuum-enhanced, low temperature thermal desorption (LTTD) was used to treat the contaminated soil at the FCX site. Figure 1 shows the components of the model IRHV-200 mobile LTTD system used at the site, which consisted of a treatment chamber and emission control equipment including a dry particulate filter, condenser, and carbon adsorption unit.

The IRHV-200 LTTD system used infrared heat to desorb high-boiling point contaminants from the soil matrix and air to "strip" target contaminants from the soil matrix. The treatment chamber was operated under vacuum conditions to lower the effective boiling points of the target contaminants.

According to the vendor, by operating under a vacuum, the temperature required to desorb contaminants from the soil and the amount of oxygen present in the treatment chamber were lower than if the unit were operated under atmospheric condition. In addition, operating under low oxygen (anaerobic) conditions helped reduce the potential for formation of dioxins and furans.

A description of the major components of the system is presented below.

DESCRIPTION OF THE TREATMENT SYSTEM (CONT.)

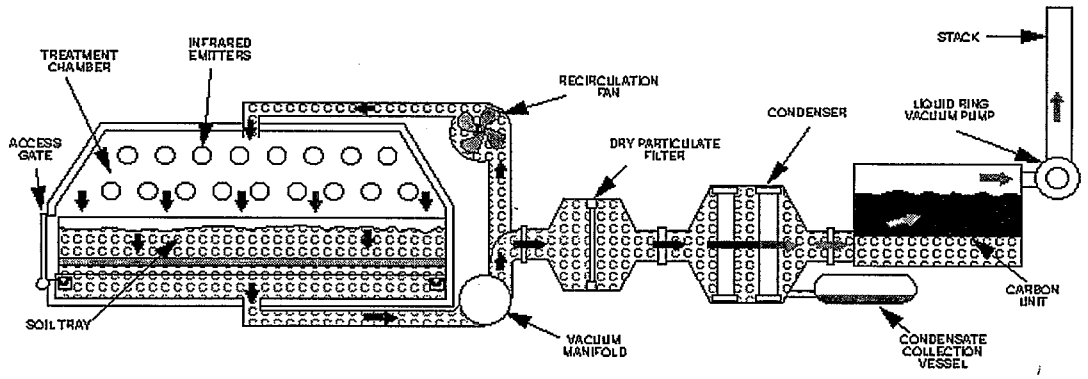

Figure 1. Major System Components of the IRHV-200

Four treatment chambers were used in this application. The treatment chamber was equipped with two bins, each measuring 8 feet wide by 8 feet long by 18 inches deep (2.5 cubic yards). Each bin was constructed of carbon steel sidewalls and a stainless steel, perforated base with 0.001" slots per square inch (46% open space) to allow for downward flow of air through the soil into two 4" x 20" air exhaust outlets centrally located in the base of each bin. Each bin was loaded with contaminated soil outside the chamber, placed into the treatment chamber by a wheel loader, and placed on top of the unit's internal support system inside the treatment chamber.

Eight individual infrared units arranged in parallel rows were used to generate infrared energy. During operation, thin-walled aluminized steel tubes were heated to approximately 1,100° F. At that temperature, each aluminized steel tube emitted energy in the infrared spectrum at the rate of approximately 137,500 British thermal units per hour (Btu/hr) for a total system output (infrared energy) of approximately 1.1 million Btu/hr. Generally, within 30 minutes, the surface of the soil was heated to over 250 °F with a goal of heating to a minimum of 350 °F

A liquid seal vacuum pump was used to create a vacuum of about 50 mmHg within each treatment chamber. As shown in Figure 1, each chamber was equipped with a high flow recirculation fan or blower, that was used to draw air through the soil in the treatment chamber to promote heat transfer. Air was drawn through outlets at the bottom of the chamber and returned to the chamber through air inlets at the top of the chamber. Air was drawn off of the recirculation air stream using the vacuum pump (rated at approximately 300 acfm) and directed to the emissions control system, as shown in Figure 1.

The dry particulate filters (DPFs) were in-line, static microfiltration elements (less than 10 microns) used to minimize the accumulation of particulates in the downstream air emission control equipment, such as condenser and carbon units and to control the release of smoke and particulates to the atmosphere. The DPFs were installed in the recirculation loop before the inlet for the primary condenser. The DPFs were designed to receive an air stream as high as 6,000 acfm at a maximum temperature of approximately 500°F.

DESCRIPTION OF THE TREATMENT SYSTEM (CONT.)

A primary condenser, installed between the treatment chamber and the vacuum pump, received an air stream at a flow rate of approximately 6,000 acfm (per treatment chamber) and a maximum temperature of approximately 400°F. The temperature of that air stream was reduced to approximately 40°F and passed through a velocity dissipator that functioned as a moisture separator to remove any residual water from the air stream. The majority of air exiting the primary condenser (5,400 acfm) was recirculated back into the treatment chambers (not shown on Figure 1). The balance of the air (600 acfm) was directed to the secondary condenser and carbon polishing system.

The temperature of the air stream was reduced to less than 32°F by the secondary condenser. Approximately 350 tons of chilling capacity was required at the FCX site. All condensate (water and contaminants) was transferred to a general collection vessel by a transfer pump. The condensable products were transferred from the collection tank to a 20,000-gallon Frac tank by an electrically powered transfer pump.

The air stream was passed through a vapor-phase carbon adsorption polishing system before it was discharged to the atmosphere. The system was charged with a single carbon adsorption unit that contained 2,000 pounds of activated carbon and was designed for mass flows as high as 100 acfm.

System Operation [1, 2, 3, 9, 10, 11, 12, 13]

McLaren/Hart conducted two site demonstrations before full-scale operations began. One hundred yd^3 of contaminated soil were treated during the demonstration program; analyses of total pesticides in the treated soil was performed for three lots. The initial demonstration, conducted with a batch of clean soil, failed to heat the soil throughout. Only the top 6 inches of 16 inches of soil in the treatment chamber reached 300° F. McLaren/Hart investigated several methods to improve the heat transfer. These included:

- Piping the exhaust gas from the propane unit through the bottom of the treatment chamber. However, this was not effective in increasing the temperature of the soil.
- Varying the depth of the soil in the treatment chamber. While this increased the rate of heat transfer, the throughput of the system was reduced.
- Adding a mechanical agitation system to increase the amount of heat transfer through the soil. A fan-type system was initially used. However, this turned the soil to powder after about an hour. The system was subsequently altered to use a hydraulically driven propeller for mechanical agitation.
- Adding an in-line blower to increase the air flow rate within the treatment chamber to 6,000 acfm and increasing the volume of air passing through the chamber, thereby improving the heat transfer through the soil.

As a result, the following design changes were made:

- The blower pump was increased in size from 30 to 300 hp.
- Mechanical agitations were added to the soil trays.
- A 6,000 acfm recirculation blower was added in-line after the primary condenser.
- Infrared heaters were added to the bottom of treatment chamber number four.

Full-scale operation started on April 26, 1995. Beginning in July of 1995, McLaren/Hart shut down the system for 3-4 hours per day as part of a power saver agreement with the local electric company. During September 1995, McLaren/Hart modified one of the treatment chambers by adding infrared heating tubes underneath the soil tray to help reduce the treatment time.

DESCRIPTION OF THE TREATMENT SYSTEM (CONT.)

When all of the soil reached the desired temperature of 350° F, the temperature was held at that level for five minutes. The treatment time was recorded, and the infrared heat source for the treatment chamber was deactivated manually. Before the heat source was deactivated, the vacuum pump remained operational for an additional 30 seconds to one minute to ensure that the chamber had been flushed of any fugitive emissions. The material bins then were removed from the treatment chamber. The treated soil was stockpiled and held until analytical data confirmed that it met cleanup levels.

The system was operated 24 hours/day for 7 days/week. The average treatment cycle was approximately 4.0 hours/treatment chamber. Each unit had a capacity of 6.0 hours/treatment chamber. With all four treatment units operational, the average treatment cycle was 6.0 tons/hr.

In total, McLaren/Hart treated 13,591 cubic yards of contaminated soil. After the results of analysis of post-treatment confirmatory soil samples were received, the treated soil was transported outside the treatment zone and stockpiled for eventual beneficial reuse by the city of Washington, North Carolina.

At the FCX site, all condensate generated was collected in a 20,000-gallon Frac tank. The condensate was treated by:

1. A phase separator
2. An iron-selective sand filter
3. A reverse osmosis unit (selective membrane)
4. A granular activated carbon polishing unit

The rated capacity of the system was approximately five gpm, with a discharge water quality of less than 10 ppb of hazardous organic compounds. The treated water was used to rehydrate the treated soil. Approximately 450,000 gallons of condensate (water and contaminants) were collected and treated at the site, resulting in the generation of thirty-three 55-gallon drums of pesticides and three 55-gallon drums of carbon from the water treatment system that required disposal at an off-site facility permitted under RCRA.

Operating Parameters Affecting Treatment Cost or Performance [1, 12]

Table 3 presents the major operating parameters that affected cost or performance of the technology and the values measured for each.

Table 3: Operating Parameters [1, 12]

Parameter	Value
Vacuum condition in treatment chamber	50 mm Hg
Energy output of total system (infrared energy)	1.1 million Btu/hr
Air flow rate for treatment chamber	300 acfm (6,000 acfm for recirculated air stream)
Temperature of infrared source	1,100° F
Total cooling capacity of chiller	350 tons
Flow rate for reverse osmosis system	1 to 4 gpm
Mass flow for carbon adsorption polishing system	Maximum 100 acfm
Residence time	4 hours/chamber (5 minutes at minimum of 350 °F)
System throughput	6 tons/hr
Soil temperature	350 - 400 °F

DESCRIPTION OF THE TREATMENT SYSTEM (CONT.)

Timeline

Table 4: Timeline [2, 3, 4, 5, 6, 7, 8, 12]

Start Date	End Date	Activity
March 31, 1989	---	The site was listed on the NPL.
September 29, 1988	---	Action memorandum signed.
1992	---	On the basis of the results of the RI, ERRB initiated excavation of 13,000 cubic yards of soil.
July 1994	---	EPA Region 4 issued an RFP for thermal desorption of 14,700 cubic yards of soil contaminated with pesticides.
November 28, 1994	---	Site mobilization began.
January 25, 1995	---	Using a batch of clean soil, the contractor conducted an initial site demonstration of the low-temperature, vacuum-enhanced thermal desorption unit.
February 1, 1995	---	The LTTDS system was 95 percent completed following modifications to increase uniform heating of soil and to operate the system under conditions specified in the contract.
March 16, 1995	---	The contractor was given approval by the OSC to conduct a second site demonstration program for treatment of contaminated soil by the LTTDS system after the system was modified to increase heat transfer through the soil.
March 20, 1995	April 20, 1995	The contractor completed treatment of 105 cubic yards of contaminated soil before a contract deadline of March 30, 1995.
April 26, 1995	March 12, 1996	The contractor conducted full-scale operation of the unit, treating approximately 13,591 cubic yards of contaminated soil in warehouses and stockpiled.
March 18, 1996	March 21, 1996	The LTTDS equipment was demobilized from the site.
August 30, 1996	---	The contractor submitted a final report on the project.

TREATMENT SYSTEM PERFORMANCE

Cleanup Goals/Standards [6]

The cleanup goal for the site was 1.0 mg/kg of total pesticides (per EPA method 8080 for organochloride pesticides and polychlorinated biphenyls [PCB]).

To confirm that the cleanup goals had been achieved, three independent grab samples were to be taken each day or from each 500-ton lot. Each of the three samples was to show concentrations below 1.0 mg/kg of total pesticides before the lot was to be considered treated successfully.

No permit was required to vent the carrier gas from the treatment system because the contaminants were expected to have negligible vapor pressures at 32 °F. An upper limit of approximately 150 mg/kg for total hydrocarbons was established for emissions for the carbon polishing system during full-scale operation.

Table 5 shows the standards the EPA Region 4 Air Compliance Section developed for the release of the vented carrier gas during the demonstration. A one-time stack air monitoring test was performed during the demonstration program. Three sample trains were obtained during the stack sampling and analyzed for volatile organic compounds, total pesticides, dioxins, furans, particulates, moisture, and volume of gas.

Table 5: Standards for Vented Air Emissions for Demonstration [6]

Compound	Maximum Concentration mg/dscm
Aldrin	0.25
Chlordane	0.5
DDT	1.0
Dieldrin	0.25
Heptachlor	0.5
Lindane	0.5
Methoxychlor	30.0

Performance Data and Data Assessment [12, 13]

Table 6 presents results of analyses of soil for the demonstration program. Results indicated that the LTTD met the cleanup goal of 1 mg/kg total pesticides in each of three lots. Data also showed that concentrations of dioxins or furans (toxicity equivalent) in the treated soil were less than in the untreated soil.

The results of the analyses of stack samples from the demonstration (Table 7) indicated that the concentrations for pesticides were below the EPA standards, as specified in Table 5. Dioxin and furan (toxicity equivalent) were reported at 1.180 x 10^{-9} mg/dcsm.

Table 8 shows post-treatment analytical data for full-scale operations. All samples of treated soil met the cleanup goal of 1.0 mg/kg total pesticides. The table shows the concentrations of total pesticides for the three composite samples for each of 43 stockpiles.

Emissions from the exhaust stack met the standards for discharges of total hydrocarbons from all four treatment chambers. The average FID reading for total hydrocarbon emissions ranged from 2.8 mg/kg to 142.7 mg/kg.

A total of 13,591 cubic yards of soils were treated. Less than one percent of soil required retreatment.

Performance Data Quality

The quality assurance and quality control (QA/QC) program conducted throughout the remedial action met the requirements of both EPA and the state of North Carolina. Methods approved by EPA were used in performing all monitoring. Results of all laboratory analysis were submitted with a Level III data quality package; results of analyses are on file with EPA Region 4 (Contract No. 68-54-4003). All soil analysis was performed by laboratories approved by EPA Region 4 (Kiber Environmental Services in Atlanta, Georgia, and Southern Testing in Wilson, North Carolina).

TREATMENT SYSTEM PERFORMANCE (CONT.)

Table 6: Analytical Results of Soil Analysis for the Demonstration Program [12]

Contaminant	Lot	Pre-treatment concentration (mg/kg)	Post-treatment concentration (mg/kg)
Total Pesticides[1]	1 2 3	3226.0 57.2 57.7	0.0252 0.0292 0.187
Dioxins/furan (expressed as 2,3,7,8-TCDD toxicity equivalent)[2]	Composite sample from lots 1, 2, and 3	0.193×10^{-3}	0.0085×10^{-3}
Semivolatiles	Composite sample from lots 1, 2, and 3	0.571	Not available
RCRA metals Arsenic Barium Chromium Lead	Composite sample from lots 1, 2, and 3	 8.5 11.0 3.1 4.0	Not available

Table 7: Results of Analysis of Emissions for the Demonstration Program [12]

Compound	Concentration (mg/dscm)	Mass Rate (lb/hr)
Particulate	0.035×10^{-3}	0.001
Dioxin and furan (expressed as 2,3,7,8-TCDD toxicity equivalent)	1.180×10^{-9}	1.40×10^{-11}
Semivolatiles	3.108×10^{-6}	1.345×10^{-4}
VOCs	2.202	1.125×10^{-3}
PCBs	1.236×10^{-4}	8.47×10^{-8}
Total Pesticides	6.744×10^{-3}	1.565×10^{-6}
Aldrin	0.083×10^{-3}	5.65×10^{-8}
Chlordane	0.115×10^{-3}	7.90×10^{-8}
DDT	$< 0.032 \times 10^{-3}$	$< 2.16 \times 10^{-8}$
Dieldrin	0.039×10^{-3}	2.64×10^{-8}
Heptachlor	0.016×10^{-3}	1.12×10^{-8}
Methoxychlor	$< 0.158 \times 10^{-3}$	$< 10.8 \times 10^{-8}$

1 Total pesticides consisted of alpha-BHC, gamma-BHC, dieldrin, endrin, 4,4'-DDD, 4,4'-DDT, aldrin, heptachlor epoxide, 4,4'-DDE, alpha-chlordane, gamma-chlordane, and toxaphene. Lot 1 contained 56 mg/kg of 4,4'-DDD and 3,170 mg/kg of toxaphene.

2 Total dioxin concentration was expressed as 2,3,7,8-TCDD toxicity equivalent. The pretreatment concentration of total dioxin was 0.193×10^{-3} mg/kg. Individual concentrations of dioxin before treatment were 7.14×10^{-3} mg/kg of 1,2,3,4,6,7,8-HPCDD and 122×10^{-3} mg/kg of 1,2,3,4,6,7,8,9-OCDD. The post-treatment concentration of total dioxin was 0.0085×10^{-3} mg/kg. Individual concentrations of dioxin after treatment were 0.36×10^{-3} mg/kg of 1,2,3,4,6,7,8-HPCDD and 4.88×10^{-3} mg/kg of 1,2,3,4,6,7,8,9-OCDD.

TREATMENT SYSTEM PERFORMANCE (CONT.)

Table 8: Summary Log of Post-Treatment Analyses [13]

Treatment stockpile no.	Cleanup goal (mg/kg)	Concentration of total pesticides in composite[1] sample 1 (mg/kg)	Concentration of total pesticides in composite[1] sample 2 (mg/kg)	Concentration of total pesticides in composite[1] sample 3 (mg/kg)	Average FID reading for total hydrocarbons (mg/kg)
1	1.0	0.019	0.095	0.071	30.9
2	1.0	0.30	0.044	0.037	51.1
3	1.0	0.129	0.132	0.149	53.6
4	1.0	0.099	0.103	0.093	61.2
5	1.0	0.275	0.250	0.287	142.7
6	1.0	0.197	0.235	0.156	54.9
7	1.0	BQL	BQL	BQL	78.5
8	1.0	BQL	BQL	BQL	48.6
9	1.0	BQL	BQL	BQL	16.5
10	1.0	0.006	0.006	0.150	3.2
11	1.0	BQL	BQL	BQL	3.1
12	1.0	0.015	0.043	0.051	13.80
13	1.0	BQL	BQL	BQL	14.30
14	1.0	BQL	BQL	BQL	34.7
15	1.0	BQL	BQL	BQL	8.3
16	1.0	0.004	0.017	BQL	9.8
17	1.0	0.036	0.034	0.038	8.3
18	1.0	0.028	0.037	0.044	7.7
19	1.0	0.006	0.012	0.071	8.3
20	1.0	0.139	0.097	BQL	5.5
21	1.0	0.018	0.086	0.110	6.0
22	1.0	0.012	0.035	0.032	7.0
23	1.0	0.065	0.023	0.039	6.8
24	1.0	0.070	0.060	0.030	6.6

TREATMENT SYSTEM PERFORMANCE (CONT.)

Table 8 (continued): Summary Log of Post-Treatment Analyses [13]

Treatment stockpile no.	Cleanup goal (mg/kg)	Concentration of total pesticides in composite[1] sample 1 (mg/kg)	Concentration of total pesticides in composite[1] sample 2 (mg/kg)	Concentration of total pesticides in composite[1] sample 3 (mg/kg)	Average FID reading for total hydrocarbons (mg/kg)
25	1.0	0.160	0.190	0.170	6.6
26	1.0	0.063	0.072	0.083	6.2
27	1.0	0.110	0.043	0.110	5.2
28	1.0	0.027	0.061	0.172	6.1
29	1.0	0.131	0.075	0.213	7.6
30	1.0	0.090	0.019	0.075	6.8
31	1.0	0.112	0.091	0.081	8.0
32	1.0	0.102	0.034	0.082	7.2
33	1.0	0.040	0.086	0.045	8.3
34	1.0	BQL	BQL	BQL	6.7
35	1.0	BQL	BQL	BQL	5.4
36	1.0	0.036	BQL	BQL	6.3
37	1.0	0.032	0.180	0.080	6.3
38	1.0	0.765	0.998	0.539	5.4
39	1.0	BQL	BQL	BQL	7.0
40	1.0	BQL	BQL	BQL	7.5
41	1.0	0.030	BQL	BQL	4.7
42	1.0	BQL	BQL	BQL	4.3
43	1.0	0.039	0.008	BQL	2.8

[1] Independent composite sample was taken from each 500-ton lot.

Cost of the Treatment System

Procurement Process

The lead agency for the site was EPA Region 4. A lump sum contract for $1,247,000 was issued to McLaren/Hart on September 16, 1994 for the remediation of approximately 14,700 cubic yards of soil.

Initial oversight was performed by EPA Region 4. After successful completion of the demonstration program, and at the midpoint of full-scale treatment operations, EPA Region 4 contracted with the U.S. Coast Guard for daily oversight.

Costs [9]

Table 9 presents the costs reported by the vendor for the thermal desorption application at the FCX Washington Superfund site. Costs incurred to implement modifications of the system necessary to improve the heat transfer rate are presented as equipment costs.

Table 9: Summary of Costs [12]

Cost Element	Cost ($ in 1996)
Excavation (of soil)	**Included with capital costs**
Capital	
Mobilization/Demobilization	
- Mobilization of equipment	65,000
- Site closure and demobilization	20,000
Site Work/Preparation	
- Site preparation (permits not required)	15,000
Equipment and Appurtenances	
- Equipment modifications/rentals	907,200
Start-up and Testing	
- Performance evaluation	30,000
Capital Subtotal	**1,037,000**

COST OF THE TREATMENT SYSTEM (CONT.)

Table 9 (continued): Summary of Costs [12]

Cost Element	Cost ($ in 1996)
Operation and Maintenance	
Direct Labor	
- Labor	453,000
- Subcontractors	75,600
Direct Materials (includes utility and fuel costs)	
- Utilities	150,000
Health and Safety	
- Miscellaneous and health and safety	71,000
Analytical (related to technology performance, not compliance monitoring)	
- Treatment verification	40,000
O&M Subtotal	**789,600**
Disposal of Residuals	
- Waste disposal	18,000
Analytical (related to compliance monitoring, not technology performance)	**Included under O&M**
Total Project Cost	**1,844,600**
Other	
- EPA oversight (estimated at 480 days at $500)	240,000

The total reported cost for this application, without oversight was $1,844,800, including $1,696,800 for costs directly associated with treatment. Based on treating 13,591 cubic yards of soil, this corresponds to a unit cost of $125 per cubic yard.

However, the contract was issued as a fixed-price (lump sum) contract for $1,247,000. While the costs incurred by the vendor were $1,844,800, EPA paid only the $1,247,000 amount. The cost overrun of $597,800 was borne by the contractor.

The primary reason for the contractor's cost overruns was the extended treatment cycle required because of limitations in the convective heat transfer rate in the treatment chamber at elevated vacuum pressures. All costs for modifications of the system to improve the heat transfer were borne by McLaren/Hart.

Quality Of Cost Data

Costs included in this report are estimates provided by McLaren/Hart.

OBSERVATIONS AND LESSONS LEARNED

Cost Observations and Lessons Learned

McLaren/Hart stated that the initial system design could have been improved and conduct of more treatability studies at the start of the cleanup phase would have resulted in an improved initial system design that would have required fewer modifications during full-scale operation.

The OSC indicated that McLaren/Hart considered the cost overrun a research and development cost for optimizing its technology.

Performance Observations and Lessons Learned

The results of the demonstration indicated that the LTTD system could achieve the specified cleanup goal of 1.0 mg/kg total pesticides for the contaminated soil at the FCX site. The results of a one-time stack test met the EPA Region 4 standards for vented air emissions.

One of the objectives of operating the system under vacuum was to allow treatment to occur at lower soil temperatures and under low oxygen conditions to reduce the potential of formation of dioxins and furans. Data on stack emissions from the demonstration showed a very low mass rate for dioxin and furans of 1.4×10^{-11} lb/hr.

For the full-scale application, the cleanup goals were met for the 43 stockpiles of soil treated (13,591 cubic yards). Less than one percent of the soil required retreatment.

Other Observations and Lessons Learned [2, 3, 10, 13, 14]

After the application of LTTD at the FCX site, McLaren/Hart made a number of modifications to the system. These included:

- Increasing the size of the infrared units from 137,500 BTU/hr to 1.5 million BTU/hr.
- Replacing the thin-walled aluminized steel heating elements with heavier gauge cast iron to reduce metal fatigue and to improve heat transfer rate which allows for shorter treatment cycles.
- Eliminating the primary condenser in the recirculation loop. McLaren/Hart determined that there was no benefit to removing water and contaminants from the air stream prior to recirculation to the treatment chamber. In addition, McLaren/Hart found that without the primary condenser, the heat capacity of the air stream was higher, reducing energy use.

McLaren/Hart determined that continuous operation of the IRHV-200 system at elevated vacuums was not cost-effective. Rather, significant improvement in treatment cycle times was achieved by "ramping" to the desired treatment temperature initially under low-vacuum conditions (2 to 4 inches Hg). Once the target treatment temperature is achieved, full vacuum is applied to the treatment chamber to attain 50 mm Hg of pressure. This procedure reduced the overall length of the treatment cycle.

McLaren/Hart reported using the modified IRHV-200 system and revised operating parameters to successfully treat contaminated soil at other sites, including soils contaminated with pesticides and mercury.

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2. Farmers Cooperative Exchange, Inc. (FCX). 1995. Pollution Reports (POL RPT) to U.S. Environmental Protection Agency (EPA). February 2 through September 19.

3. FCX. 1995. Weekly POL RPTs to U.S. Coast Guard. March 23 through September 13.

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5. EPA Region 4. 1991. Action Memorandum Regarding Request for increase in the Removal Action Ceiling and Exemption from the $2 Million Limit at the FCX Pesticide Site, Washington, North Carolina. From Greer C. Tidwell, Regional Administrator. To Don R. Clay, Assistant Administrator for Solid Waste. October 16.

6. EPA Region 4. 1994. Award Contract to McLaren/Hart Environmental Engineering Corporation. September 16.

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10. McLaren/Hart. 1997. Memorandum Regarding Questions about FCX. From Ed Walsh. To Tom Sinski, Tetra Tech EM Inc. (Tetra Tech). September 5.

11. McLaren/Hart. 1997. Memorandum Regarding Questions About FCX. From Ed Walsh. To Tom Sinski, Tetra Tech. June 9.

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13. McLaren/Hart. 1997. Memorandum Regarding FCX Cost and Performance Report. From Nicole A. Ihlenfeld. To Tom Sinski, Tetra Tech. June 9.

14. McLaren/Hart, Inc. 1996. Final Report Farmers Cooperative Exchange, Washington, North Carolina, EPA Contract No. 68-54-4003. August 30.

Preparation of the Analysis

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 Tetra Tech EM Inc. under EPA Contract No. 68-W4-0004.

Thermal Desorption at the Solvent Refined Coal Pilot Plant, Ft. Lewis, Washington

Thermal Desorption at the Solvent Refined Coal Pilot Plant, Ft. Lewis, Washington

Site Name:
Solvent Refined Coal Pilot Plant (SRCPP)

Location:
Ft. Lewis, Washington

Contaminants:
Semivolatile (nonhalogenated) - polycyclic aromatic hydrocarbons (PAHs). PAHs were detected throughout the SRCPP, with individual PAH concentrations as high as 410 mg/kg, and typically not exceeding 2 mg/kg.

Period of Operation:
Status: Complete
Report covers: August through December 1996

Cleanup Type:
Remedial Action
ROD Date: October 15, 1993

Vendor:
Melody Allen
Dames & Moore, Inc.
2025 First Avenue, Suite 500
Seattle, Washington 98121
(206)728-0744

Technology:
Thermal Desorption
- Soil was pre-screened using a1 ½ -inch bar screen.
- Pre-screened soil was fed to the direct-fired, rotary kiln-type thermal desorption unit.
- Soil was treated at nominally 700-750°F with a throughput of 50-150 tons per hour.
- Off-gas was treated with a baghouse and recycled to the desorber or thermally oxidized and discharged to the atmosphere.

Cleanup Authority:
Conducted under a federal facilities agreement among the EPA, the U.S. Army, Ft. Lewis, and the State of Washington Department of Ecology

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CENWS-PM-HW
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EPA Point of Contact:
Bob Kievit
Remedial Project Manager
U.S. EPA, Region 10
Washington Operations Office
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Lacey, Washington 98503
Telephone: (360) 753-9014

Waste Source:
Leaks and spills

Purpose/Significance of Application:
Thermal desorption of a relatively-large amount of soil contaminated with PAHs.

Type/Quantity of Media Treated:
Soil
- 104,336 tons of soil were treated during this application, including 2,200 tons during the field demonstration.
- Soil was classified as various sand and gravel.
- Moisture content was 4%.

Regulatory Requirements/Cleanup Goals:
- Cleanup levels for this application were 1 mg/kg for the sum of the concentrations for seven carcinogenic PAHs (based on the Record of Decision) and 200 mg/kg for both diesel range and oil range fuel hydrocarbons (based on the Ft. Lewis base management).
- The PAH cleanup level was derived from Washington State Model Toxics Control Act Method B cleanup levels for ingestion of soil containing carcinogenic PAHs.
- Air emission limits for this application were established by the Puget Sound Air Pollution Control Agency as performance standards limiting the acceptable physical operating parameters for the baghouse and thermal oxidizer.

Thermal Desorption at the Solvent Refined Coal Pilot Plant, Ft. Lewis, Washington (continued)

Results:

- The LTTD system used at the SRCPP achieved soil cleanup levels and air emission standards during the treatment of the contaminated soil at a desorber temperature generally between 700 and 750°F.
- During the field demonstration test, the system treated soil contaminated with total carcinogenic PAHs at levels ranging from 0.6 mg/kg to 4.2 mg/kg to less than the 1.0 mg/kg cleanup level established for this application.
- During full operation of the LTTD system, samples of treated soil had concentrations of total carcinogenic PAHs ranging from below detection limit to 0.44 mg/kg.

Cost:

- The total cost for this application was approximately $7,100,000. The unit cost for thermal desorption treatment of contaminated soil was approximately $34 per ton treated, and for the entire RA was approximately $68 per ton treated.
- The original bid for this application was approximately $3,500,000. There were 23 modifications to the bid, resulting in a final cost that was approximately twice the original. Modifications included such items as an increase in the quantity of soil requiring treatment and additional site work.

Description:

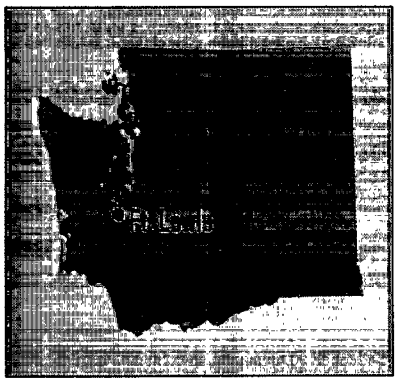
The SRCPP occupies approximately 25 acres between Sequalitchew Lake and Hammer Marsh on North Ft. Lewis, approximately 12 miles south of the city of Tacoma, Washington. It was operated from 1974 to 1981 as a production and research facility that worked to develop a solvent extraction process to derive petroleum hydrocarbon products from coal via operations such as heat extraction and thermal cracking. Soil at the SRCPP was contaminated by leaks and spills of process materials that occurred during operations at the plant.

On the basis of the remedial investigation and pre-remediation surface soil chemistry survey, 17 areas were identified for excavation of contaminated soil. The thermal desorption system used to treat the soil consisted of a rotary thermal desorber with a baghouse and a thermal oxidizer for off-gas treatment.

Approximately 104,000 tons of contaminated soil were treated during a field demonstration test and full-scale operation of the system. Samples of treated soil had total concentrations of carcinogenic PAHs ranging from below detection limits to 0.44 mg/kg.

SITE INFORMATION

IDENTIFYING INFORMATION



Site Name: Solvent Refined Coal Pilot Plant (SRCPP)
Location: Ft. Lewis, Washington
Technology: Thermal Desorption
Type of Action: Remedial
ROD Date: October 15, 1993

TECHNOLOGY APPLICATION (1)

Period of Operation: August through December 1996 (11)
Quantity of Material Treated During Application: 104,336 tons of soil were treated during the application, including 2,200 tons during the field demonstration. (4)

BACKGROUND

Site Background (6, 7):

- Ft. Lewis is located approximately 12 miles south of the city of Tacoma, Washington; the 86,000-acre fort is divided by I-5 into North Ft. Lewis and main Ft. Lewis. The SRCPP occupies an area of approximately 25 acres between Sequalitchew Lake and Hamer Marsh on North Ft. Lewis.
- The SRCPP was operated from 1974 to 1981 as a production and research facility that worked to develop a solvent extraction process to derive petroleum hydrocarbon products from coal. Operations conducted at the SRCPP included heat extraction and thermal cracking.
- Treated liquid wastes from the process were sent to an unlined wastewater lagoon adjacent to the site. Surface runoff was collected and discharged at two points, one north and one south of the facility; the runoff later was redirected and sent to an wastewater treatment plant on site.
- Raw materials used in the process included coal, coal-derived organic liquids, water, and hydrogen gas; the process also required the use of catalysts.
- By-products of the process included such liquids as phenols, gasoline, kerosene, and fuel oil and such gases as hydrogen sulfide, carbon monoxide, carbon dioxide, and methane.
- Soil at the SRCPP was contaminated by leaks and spills of process materials that occurred during operations at the plant.

SIC Code: 9711 (National Security)

Waste Management Practice that Contributed to Contamination: Leaks and spills

Site Investigation (6, 7):

- From 1993 to 1994, a remedial investigation (RI) was performed at the SRCPP to identify potential effects on soil, groundwater, surface water, and sediments in Sequalitchew Lake and Hamer Marsh.

- Soil contamination was investigated by drilling 23 borings and excavating 20 test pits within and in the vicinity of the SRCPP. In addition, one hand auger boring was installed in a former wastewater treatment area. Soil samples were collected from each exploration and analyzed for volatile organic compounds (VOC), semivolatile organic compounds (SVOC), and metals. Table RI-1 summarizes the results of analyses of soil samples collected during the RI for VOCs, SVOCs, and metals, in terms of concentration ranges measured and frequencies of detection.

- The RI found that VOCs, SVOCs, and metals characteristic of SRCPP operations (metals from coal and catalysts) were present in soils at the site. In addition, it concluded that the distribution of contaminants beneath the SRCPP was highly variable and discontinuous in nature. Polycyclic aromatic hydrocarbons (PAH) were detected throughout the SRCPP, with average individual PAH concentrations of PAH typically not exceeding 2 mg/kg.

- Table RI-1 shows that the relatively lowest frequency of detection was that for VOCs (detected in fewer than 20 of 85 samples), while the frequency of detection of PAHs and metals was relatively greater.

Table RI-1. Results of Analysis of Soil Samples Collected During the RI (6)

Detected Analyte	Concentration Range (mg/kg)	Frequency of Detection[b]
VOCs:		
Benzene	<0.052-0.30	1/85
Chloroform	<0.054-0.3	2/85
Ethylbenzene	<0.052-12	8/85
2--Hexanone	<0.052-11	1/85
Tetrachloroethene	<0.052-0.98	17/85
1,1,1-Trichloroethane	<0.052-0.20	1/85
Trichloroethene	<0.052-0.12	2/85
Toluene	<0.052-5.2	13/85
Total Xylenes	<0.052-34	15/85
SVOCs--PAHs:		
Acenaphthene	<0.18-69	30/159
Acenaphthylene	<0.18-1.05	8/159
Anthracene	<0.18-30	41/159
Benzo(a)anthracene	<0.18-12	42/159
Benzo(b)fluoranthene	<0.18-17	53/159
Benzo(k)fluoranthene	<0.18-5.3	33/159
Benzo(g,h,i)perylene	<0.18-5.7	48/159
Benzo(a)pyrene	<0.18-8.8	48/159
Chrysene	<0.18-19	54/159
Dibenzo(a,h)anthracene	<0.18-1.2	14/159
Dibenzofuran	<0.18-99	43/159
Fluoranthene	<0.18-130	61/159
Fluorene	<0.18-84	37/159
Indeno(1,2,3-cd)pyrene	<0.18-3.3	43/159
2-Methylnaphthalene	<0.18-270	40/159
Naphthalene	<0.18-290	32/159
Phenanthrene	<0.18-410	73/159
Pyrene	<0.18-79	69/159

Table RI-1. Results of Analysis of Soil Samples Collected During the RI (6) (continued)

Detected Analyte	Concentration Range (mg/kg)	Frequency of Detection[b]
SVOCs--Others:		
Aniline	0.11 J-1.4	1/159
Benzoic Acid	<5.3-0.49 J	1/159
Bis (2-ethylhexyl)phthalate	0.041 J-19	8/159
Di-n-octylphthalate	<0.18-0.15 J	1/159
2,6-Dinitrotoluene	<0.18-0.52	NR
4,6-Dinitro-2-methyl phenol	<0.91-0.95 J	1/159
N-Nitrosodimethylamine	<0.18-0.14 J	1/159
Phenol	<0.18-1.2	5/159
2-Methyl phenol	<0.18-0.41 J[a]	1/159
4-Methyl phenol	<0.18-0.575 J	7/159
2,4-Dimethylphenol	<0.18-0.36 J	8/159
Total Metals:		
Antimony	<0.26-3.25	7/69
Arsenic	0.78-12	69/69
Barium	22-84	69/69
Beryllium	<0.26-0.52	10/69
Cadmium	<0.26-2.5	5/69
Chromium	3.8-19	69/69
Copper	8-1700	69/69
Iron	6200-37000	69/69
Lead	<1.54-120	69/69
Manganese	110-500	69/69
Mercury	<0.10-0.11	1/69
Nickel	6.7-26	69/69
Selenium	<0.16-0.90	3/69
Silver	<0.26-1.5	11/69
Zinc	13-220	69/69

Notes:
[a] All measured values are below method reporting limit (MRL)
[b] Frequency of detection is calculated as the number of samples that exhibit detections divided by the total number of samples taken.
J Estimated concentration
NR Not reported

- On the basis of the results of the RI, 11 zones were identified (Areas A through K), where contaminated soil was to be excavated. Figure 1 shows those areas. Figure 1 also shows the originally planned vertical extent of excavation for each of those areas and the planned locations of confirmatory samples in each of the areas. Sample frequency was based on the results of pre-excavation sampling used to designate each area as hot, moderate, or cool.

- Dames & Moore performed a pre-remediation surface soil chemical survey in September 1995 to determine whether additional areas of soil contamination were present outside the area covered by the original soil excavation plan. In total, 173 surficial soil samples were taken from outside the original soil excavation area. The results of analysis of those samples supported the inclusion of six additional areas (Areas L through Q) in the excavation plan. Figure 1 also shows those areas.

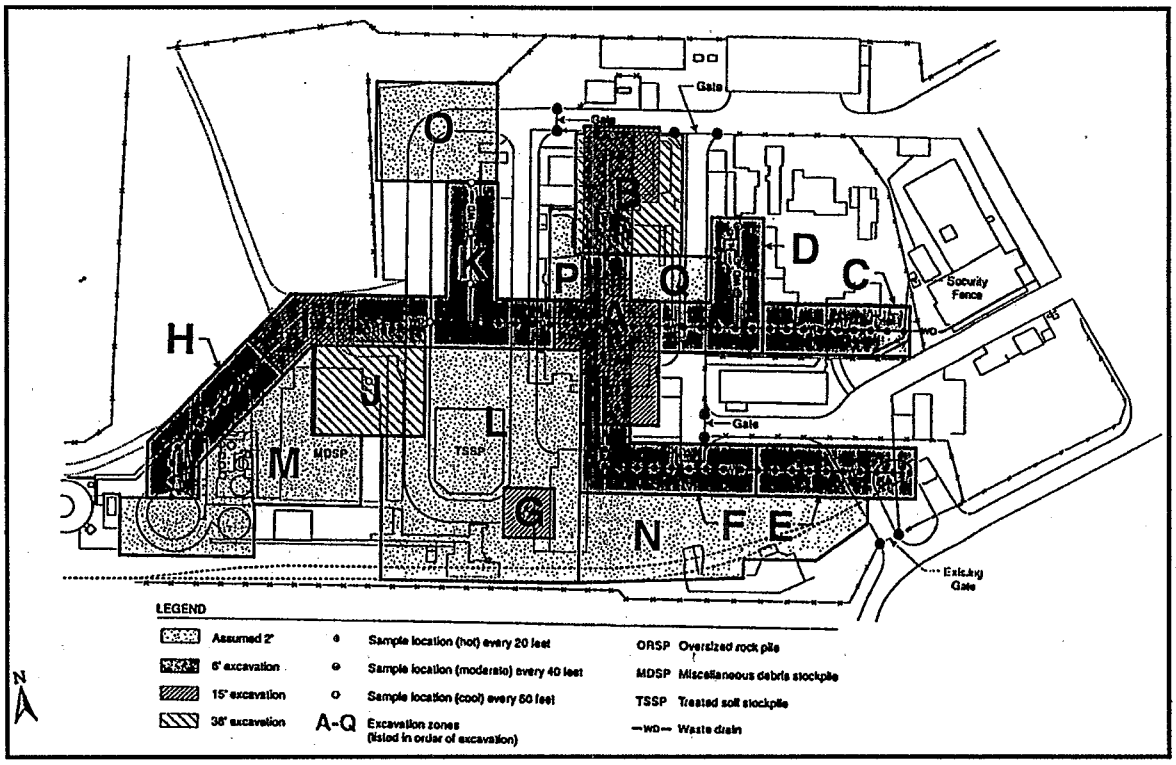


Figure 1. Soil Excavation Zones [11]

SITE LOGISTICS/CONTACTS

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MATRIX AND CONTAMINANT DESCRIPTION

MATRIX IDENTIFICATION

Soil (ex situ)

CONTAMINANT CHARACTERIZATION (6)

- Semivolatiles (Nonhalogenated) - carcinogenic polycyclic aromatic hydrocarbons (cPAH), metals
- Seven cPAHs and arsenic, were identified as contaminants concern in soil at the SRCPP. The seven cPAHS were: benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, chrysene, dibenzo(a,h)anthracene, and indeno(1,2,3-cd)pyrene.
- The substances were identified as contaminants of concern on the basis of their occurrence and distribution in the soil and a risk-based screening approach. Under the screening approach, an estimate was made of the potential that given constituents would affect groundwater adversely if pavements at the site were removed. The estimate showed that the cPAHs would affect groundwater adversely, while the arsenic would not. Therefore, although arsenic was identified as a contaminant of concern, no remedial action for arsenic was found to be necessary.

CONTAMINANT PROPERTIES (9)

Contaminant	Chemical Formula	Molecular Weight (g/mole)	Boiling Point (°C at 1 atm)	Melting Point (°C at 1 atm)
Benzo(a)anthracene	$C_{18}H_{12}$	228.29	425	160.7
Benzo(b)fluoranthene	$C_{20}H_{12}$	252.32	480	168
Benzo(k)fluoranthene	$C_{20}H_{12}$	252.32	480	217
Benzo(a)pyrene	$C_{20}H_{12}$	252.32	310-312	179-179.3
Chrysene	$C_{18}H_{12}$	228.29	448	255-256
Dibenzo(a,h)anthraene	$C_{22}H_{14}$	278.35	535	266
Indeno(1,2,3-cd)pyrene	$C_{22}H_{12}$	276.35	530	162.5-164

MATRIX CHARACTERISTICS AFFECTING TREATMENT COST OR PERFORMANCE (6, 10, 13)

Parameter	Value
Soil Classification	Various sand and gravel
Clay Content/Particle Site Distribution	Information not available
Soil Plasticity	Information not available
Moisture Content	4%
Total Petroleum Hydrocarbons	Not Detected - 8200 mg/kg
Presence of Alkaline Metal Salts	Information not available
Lower Explosive Limit	Information not available

TREATMENT SYSTEM DESCRIPTION

PRIMARY TREATMENT TECHNOLOGY

Thermal desorption

SUPPLEMENTARY TREATMENT TECHNOLOGIES

Pre-treatment (soil): screening

Post-treatment (off-gas): baghouse and thermal oxidizer

TIMELINE (8, 11)

Date	Activity
1974 - 1981	SRCPP operated as a production and research facility.
1993 - 1994	Remedial investigation was conducted.
September 1995	Pre-remediation surface soil chemistry survey was conducted.
May - December 1996	Contaminated soil was excavated and post-excavation sampling conducted.
June 1996	Field demonstration test of size sorting was conducted.
August 5 - 9, 1996	Equipment startup was performed.
August 12 - 14, 1996	Field demonstration test of soil treatment was performed.
August 15 - December 9, 1996	Full-production thermal desorption treatment was performed.
December 1996 - March 1997	Post-remediation confirmation sampling was conducted.
December 15, 1997	Final Chemical Reports 2 and 3 were submitted.

TREATMENT SYSTEM SCHEMATIC AND TECHNOLOGY DESCRIPTION AND OPERATION (8, 11)

Construction

- The low-temperature thermal desorption (LTTD) system used in this application was supplied by Midwest Soil Remediation, of Elgin, Illinois. The system consisted of a rotary thermal desorber system rated at 64 million British Thermal Units per hour (MM BTU), a baghouse rated at 48,000 actual cubic feet per minute (acfm), and a thermal oxidizer rated at 74 MM BTU/hr.

- The LTTD system was a direct-fired unit, in that the rotary kiln heated the soil through direct contact between the oil-fired burner exhaust and the soil.

Operation

- Figure 2 is a schematic diagram of the process flow for soil and gases in the LTTD system. As Figure 2 shows, soil entered the system through a primary feeder (hopper) and passed through a screen (1 1/2-inches) and a belt weigh scale before it was conveyed to the rotary desorber. Treated soil went through a thermal dust conductor and soil cooler before exiting through a stacking conveyor onto piles of soil.

- A combustion burner fed hot gases countercurrent to the flow of soil through the desorber. Gases from the desorber passed through a baghouse and were recycled to the desorber or thermally oxidized and discharged to the atmosphere through a stack.

- Several post-excavation soil samples showed evidence that soil containing cPAHs at concentrations above cleanup levels were being left in place at the site. However, a sitewide statistical analysis of the final post-excavation soil samples indicated that the 95 percent upper confidence limit for the concentration of cPAHs at the bottom of all of the excavations was 0.55 mg/kg, a concentration that was below the 1.0 mg/kg cleanup level. (See the discussion of cleanup levels under Performance Objectives.)

System Monitoring Requirements (11)

Parameter Monitored	Frequency	Operating Parameters
Soil temperature in thermal desorber	Twice per hour during field demonstration test and once per hour thereafter	700 to 750°F
Pressure drop in baghouse		3.5 - 7.5 inches WC
Temperature of the thermal oxidizer		Higher than 1600°F

Closure

- From December 1996 through March 1997, 57 confirmatory surface soil samples were collected from areas of the site at which site remediation activities had been carried out to confirm that previously uncontaminated surface soil had not been contaminated during the remedial action (RA). Several additional contaminated areas were excavated to a depth at which concentrations of cPAH were found to be below the cleanup standard. Soil excavated at that time was disposed of at an offsite landfill.

- In May, June, and November 1996 groundwater samples were collected from five monitoring wells. In all three rounds of sampling, cPAH and total petroleum hydrocarbons (TPH) were measured at levels below detection limits and results for metals were similar to the data collected during the 1993-94 Remedial Investigation/Feasibility Study (RI/FS). On the basis of these data, the contractor concluded that groundwater had not been affected by site remediation activities.

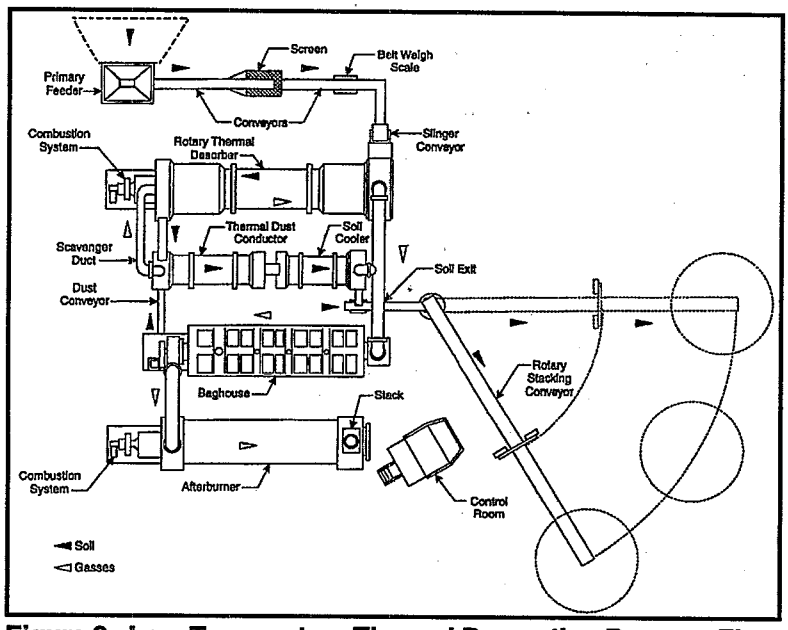

Figure 2. Low-Temperature Thermal Desorption Process Flow Diagram (8)

- On the basis of the results of post-excavation and closure sampling, the contractor determined that a total of six areas of soil containing cPAHs at concentrations above cleanup standards remained in place. Three of those areas were considered to be "*de minimus*" because of the extent of excavation performed in each area. The other three areas remained in place at the site under the direction of the USACE. The contractor stated that those three areas likely will require remediation in the future to attain cleanup levels that are appropriate to the residential use identified in the future land use scenario for the site.

OPERATING PARAMETERS AFFECTING TREATMENT COST OR PERFORMANCE (8)

Parameter	Value
Residence Time	Information not available
System Throughput	Approximately 50 to 150 tons per hour
Temperature (of thermal desorber)	Approximately 700 to 750°F
Drum Pressure (of thermal desorber)	-0.05 to -0.9 inches WC
Baghouse Inlet Temperature	205 to 323°F
Baghouse Outlet Temperature	190 to 301°F
Baghouse Pressure Change	1.6 to 7.6 inches WC
Thermal Oxidizer Temperature	956 to 1,813°F

TREATMENT SYSTEM PERFORMANCE

PERFORMANCE OBJECTIVES

- Table CL-1 summarizes the cleanup levels established for treated soil in this application, and the sources of the cleanup levels.

Table CL-1. Summary of Cleanup Levels for Treated Soil at the SRCPP (6)

Contaminant	Cleanup Level (mg/kg)	Source of Cleanup Level
Benzo(a)anthracene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Benzo(a)pyrene, chrysene, Dibenzo(a,h)anthracene, Indeno(1,2,3-cd)pyrene	1.0 for the sum of the concentrations for all seven cPAHs	Record of Decision (12)
Fuel hydrocarbons - diesel range (referred to as TPH-diesel)	200	Ft. Lewis base management (6)
Fuel hydrocarbons - oil range (referred to as TPH-oil)	200	Ft. Lewis base management (6)

- The cleanup level identified for this application was the sum of the concentrations for all seven cPAHs, and were derived from Washington State Model Toxics Control Act (MTCA) Method B cleanup levels for ingestion of soil containing cPAHs. The slope factor and MCL for benzo(a)pyrene was used in calculating cleanup levels for all cPAHs; consequently, cleanup levels are identical for all of cPAHs are the same. The Method B cleanup level represents a one-in-one million risk for each cPAH, producing an aggregate risk of seven in one million. (10)

- Air emission limits for this application were established by the Puget Sound Air Pollution Control Agency (PSAPCA). The PSAPCA identified the following limits (8):
  - Pressure drop across baghouse: 3.5 to 7.5 inches WC
  - Minimum temperature in thermal oxidizer: 1,600°F
  - Maximum exhaust stack opacity: 5 percent
  - Maximum exhaust stack emissions of particulate matter: 0.02 grains per dry standard cubic foot (gr/dscf)
  - Maximum exhaust stack emissions of cPAHs: 0.04 pounds per hour

TREATMENT PERFORMANCE DATA (8,11)

- For the field demonstration test, treatment was conducted for three days, with each day consisting of one eight-hour shift. Composite samples were collected as soil was fed into the LTTD unit and as soil exited from the LTTD unit. Each composite sample consisted of individual grab samples taken at approximately one-half hour intervals; collection of the exit samples began one-half hour later than collection of feed samples. Samples were composited at the one-hour, four-hour, and eight-hour intervals. In addition, two field duplicate samples were collected for quality control purposes.

- Table TPD-1 summarizes the results of analysis of the samples collected during the field demonstration test, in concentrations of individual cPAHs and total concentrations of cPAHs.

Table TPD-1. Treatment Performance Data from Field Demonstration Test - mg/kg (8)

Sample/Contaminant			Benzo(a)anthracene	Benzo(b)fluoranthene	Benzo(k)fluoranthene	Benzo(a)pyrene	Chrysene	Dibenz(a,h)anthracene	Indeno(1,2,3-cd)pyrene	Total cPAH
Soil Cleanup Level										1.0
Sample ID	Laboratory ID	Date Collected								
FFDT11	58664-01	8/12/96	0.62	0.59	0.13	0.42	0.83	0.035 U	0.17	2.8
FFDT41	58664-02	8/12/96	0.52	0.64	0.034 U	0.48	0.61	0.034 U	0.21	2.5
FFDT81	58664-03	8/12/96	0.56	0.63	0.068	0.54	0.67	0.035 U	0.23	2.7
EXFDT11	58664-04	8/12/96	0.027 J	0.042	0.033 U	0.022 J	0.043	0.033 U	0.033 U	0.13
EXFDT112	58664-05	8/12/96	0.034 J	0.066	0.035 U	0.035	0.063	0.035 U	0.035 U	0.20
EXFDT41	58664-06	8/12/96	0.038	0.059	0.035 U	0.032 J	0.048	0.035 U	0.035 U	0.18
EXFDT81	58664-07	8/12/96	0.059	0.083	0.035 U	0.047	0.074	0.035 U	0.035 U	0.26
FFDT12	58696-01	8/13/96	0.43	0.45	0.10	0.42	0.54	0.032 J	0.14	2.1
FFDT42	58696-02	8/13/96	1.20	0.67	0.21	0.55	1.20	0.040	0.28	4.2
FFDT82	58696-03	8/13/96	0.47	0.40	0.065	0.320	0.54	0.029 J	0.15	2.0
EXFDT12	58696-04	8/13/96	0.035 U	0.035 U	0.035 U	0.035 U	0.024 J	0.035 U	0.035 U	0.024
EXFDT42	58696-05	8/13/96	0.033 J	0.050	0.036 U	0.027 J	0.061	0.036 U	0.036 U	0.17
EXFDT82	58696-06	8/13/96	0.028 J	0.037	0.034 U	0.020 J	0.029 J	0.034 U	0.034 U	0.11
FFDT13	58726-01	8/14/96	0.13	0.13	0.041	0.099	0.17	0.035 U	0.029 J	0.60
FFDT43	58726-02	8/14/96	0.31	0.29	0.11	0.26	0.41	0.034 U	0.097	1.5
FFDT83	58726-03	8/14/96	0.36	0.33	0.064	0.25	0.47	0.034 U	0.099	1.6
EXFDT13	58726-04	8/14/96	0.017 J	0.033 U	0.033 U	0.033 U	0.026 J	0.033 U	0.033 U	0.043
EXFDT43	58726-05	8/14/96	0.032 J	0.037	0.034 U	0.034 U	0.046	0.034 U	0.034 U	0.12
EXFDT83	58726-06	8/14/96	0.025 J	0.035 U	0.035 U	0.035 U	0.037	0.035 U	0.035 U	0.062
EXFDT832	58726-07	8/14/96	0.030 J	0.032 J	0.034 U	0.034 U	0.043	0.034 U	0.034 U	0.11

J = Analyte was analyzed for and positively identified, but the associated numerical value is an estimated quantity.
U = Analyte was analyzed for but not detected.

Sample EXFDT112 is the field duplicate of EXFDT11. Sample EXFDT832 is the field duplicate of EXFDT83.
Sample Prefixes: FFDT - Feed sample from the field demonstration test collected before soil entered the LTTD unit.
EXFDT - Exit sample from the field demonstration test of soil leaving the LTTD.

- As Table TPD-1 shows, feed samples from the field demonstration test had total concentrations of cPAHs ranging from 0.6 mg/kg to 4.2 mg/kg, with eight of nine samples measured at a concentration higher than 1.0 mg/kg. Exit samples had total concentrations of cPAHs ranging from 0.024 mg/kg to 0.26 mg/kg, less than the 1.0 mg/kg cleanup level established for this application. The average concentration of total cPAH in the feed samples was 2.2 mg/kg, and the average in the exit samples was 0.13 mg/kg.

- The field demonstration test determined that a screen size of one and one-half inches was the most appropriate screen size for sorting coarse material (oversize) from soil to be treated. That screen size was found to produce oversize material that had concentration of cPAHs of less than 1.0 mg/kg, and a concentration of TPH of less than 200 mg/kg.

- Each day during full production, a composite of three discrete soil samples from the treated soil exiting the cooler was taken and analyzed for cPAHs. No pre-treatment samples of the soil were taken during full production. According to the contractor's report, the results of analysis of the treated soil indicated that the treated soil had concentrations of cPAHs below the 1.0 mg/kg cleanup level. This was based on an analysis of 93 sample of tested soil. The results ranged from below detection limits to 0.44 mg/kg.

- No data from analyses of the treated soil for concentrations of fuel hydrocarbons were available.

- The air emissions testing during the operation test of the LTTD systems showed that average emissions of particulate matter were 0.017 gr/dscf, and that no emissions of cPAHs were detected at or above the specified reporting limits, corresponding to a calculated emission rate of less than 0.0003 pounds per hour. In addition, the opacity measured during the test was zero percent. The system generally met the requirements of PSAPCA for pressure drop across the baghouse and for minimum temperature in the thermal oxidizer. According to the contractor, the air emission results met the requirements established by PSAPCA for this application.

Material Balance: No quantitative material balance was completed for this application because of the limited amount of matched performance data on untreated and treated soil.

Links to Operating Conditions: The LTTD system was found to meet the cleanup levels established for this application, operating at a temperature of 700 to 750°F with a system throughput of 50 to 150 tons/hr.

Removal Efficiencies: An average removal efficiency of 94 percent for cPAHs was calculated for the field demonstration test phase of this application on the bases of an average concentration of cPAHs in the feed samples of 2.2 mg/kg and an average in the exit samples of 0.13 mg/kg.

PERFORMANCE DATA QUALITY (6,7,8,11)

- The contract specifications for this application required the use of Environmental Protection Agency SW-846 Method 8270 for analysis of SVOCs in soil. That method uses gas chromatography and mass spectroscopy (GC/MS). The contract required GC/MS for quantification of cPAHs and required that measured values be based on a 95 percent upper confidence limit on the mean. Post-excavation sampling indicated that the 95 percent upper confidence limit was 0.55 mg/kg.

- The contract required that a minimum detection limit of 0.1 mg/kg be achieved for each of the cPAHs that were identified as contaminants of concern and that the contractor refine the analytical methodology as needed to meet the data quality objectives for this application. This criterion was satisfied, except in the case of some samples submitted to the QA laboratory.

- Fuel hydrocarbons were analyzed by the Washington State Department of Ecology Diesel Method Modified, rather than the EPA SW-846 Method 8015 (extended), with a minimum detection limit of 50 mg/kg.

- Analytical laboratories used during this application were: Pace Laboratory; Analytical Resources, Inc. (ARI); Sound Analytical Services, Inc.; and AMTest Air Quality LLC.

- Air emission source testing included collection of samples at sample port and traverse point locations (EPA Test Method 1) and testing for velocity and volumetric flow rate (EPA Test Method 2); molecular weight (fixed gas composition)(EPA Test Method 3); stack gas moisture (EPA Test Method 4); particulate emissions (EPA Test Method 5); sulfur dioxide (EPA Test Method 6C); nitrogen oxides (EPA Test Method 7E); opacity (EPA Test Method 9); and total hydrocarbons and VOCs (EPA Test Method 25A). Air emissions of PAHs were analyzed by EPA SW-846 Method 0010.

- QA/QC procedures used in this application included review of holding times and use of blanks, surrogates, matrix spikes, matrix spike duplicates, field duplicates, laboratory control samples, field duplicate samples, and split samples.

- According to the contractor's report, procedures for monitoring dust, organic vapor, and noise set forth in the health and safety plan were followed.

TREATMENT PLAN (7, 8, 11)

- The ROD for this application specified that contaminated soil at the site would be treated with thermal desorption or soil washing. Thermal desorption was selected for this application, on the bases of the results of a treatability study.

- The prime contractor for this application developed a remedial action management plan (RAMP) in August 1995. The RAMP described health and safety requirements and included the contractor's quality control plan, chemical data management plan, the environmental protection and stormwater plan, the soil treatment plan, the materials handling plan, the waste management plan, the demolition and decontamination plan, and the site demobilization and restoration plan.

- This application was completed in three phases: (1) pre-remediation activities, (2) remediation at full production, and (3) confirmation of closure. The pre-remediation phase included a surface-soil chemical survey and a field demonstration test of thermal desorption. The full-production phase included thermal desorption treatment of the majority of soil, as well as continued sampling and testing of groundwater and storm water; aboveground demolition; and disposal of investigation-derived wastes and the wastes that were sent off site. The confirmation of closure phase included a return visit to the site to identify areas that might have remained contaminated with cPAHs.

- The field demonstration test involved identifying the appropriate screen size for sorting coarse material (oversize) from the soil to be treated, and treating "highly contaminated" (soil known through sampling to contain high concentrations of cPAHs and TPH), as well as collecting and analyzing samples of soil from the feed point and exit point of the LTTD unit and associated testing for stack emissions.

- Before the field demonstration test was conducted, the equipment was started so that the system's mechanical components could be adjusted and the operating parameters set.

TREATMENT SYSTEM COST

PROCUREMENT PROCESS (3, 7)

- USACE, through its Seattle, Washington District office, administered the remediation activities at the SRCPP. Dames & Moore was selected as the prime contractor for this activity under USACE Contract No. DACA67-95-C-0062.
- USACE received seven bids for this application, ranging in cost from $3,513,349 to $5,426,030. The Dames & Moore bid was the lowest of the seven.

TREATMENT SYSTEM COST (6)

- The original bid submitted by Dames & Moore for this application was $3,513,349 and included the first six items (with subitems) shown in Table C-1. As Table C-1 shows, the cost of thermal desorption treatment of the first 37,000 tons of soil was projected to be $1,261,700, or $34.10 per ton of soil treated.
- For this application, 23 modifications were identified, covering such items as an increase in the quantity of additional soil treated from 15,000 to 67,336 tons; excavation of contaminated soil from the area in which the LTTD unit was to be set up; and demolition of a railroad spur at that location. To reflect the 23 modifications, the cost for this contract was revised to a total cost of $7,100,467.

Table C-1. Summary of Original Bid and Actual Costs (4, 6)

ITEM NO.	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE ($)	AMOUNT ($)
0001	Design and Management Plan and Reporting	1	Job	Lump Sum	196,670
0002	Excavation and Size Separation of Soil				
0002A	Excavation of first 40,000 Cubic Yards (yd^3)	40,000	(yd^3)	7.08	283,200
0002B	Excavation of next 10,000 Cubic Yards (yd^3)	10,000	(yd^3)	7.08	70,800
0003	Treatment of Contaminated Soil				
0003A	Treatment of first 37,000 Tons	37,000	tons	34.10	1,261,700
0003B	Treatment of next 15,000 Tons	15,000	tons	33.72	505,800
0004	Soil Excavation and Stockpiling	4,000	(yd^3)	3.24	12,960
0005	Field and Laboratory Chemical And Analytical Testing of Soils				
0005A	First 1,200 tests	1,200	each	145.64	174,768
0005B	Next 300 tests	300	each	145.64	43,692
0006	Demolition and Site Work	1	Job	Lump Sum	963,759
			TOTAL	$3,513,349	

- As of August 12, 1998, approved payment of $7,094,767.23 in costs for this application, including $3,532,270 for thermal desorption treatment of 104,336 tons of soil. All items are paid in full.

REGULATORY/INSTITUTIONAL ISSUES

- The remedial activity at the SRCPP was conducted under a federal facilities agreement (FFA) among EPA, the U.S. Army, Ft. Lewis, and the State of Washington Department of Ecology. The ROD prepared for this application describes requirements for excavation and remediation of contaminated soil, monitoring of the groundwater of the upper aquifer, and maintenance of institutional controls at the SRCPP. (6,7,12)

- Under the FFA, the U.S. Army was designated the lead agency, with approval by EPA and concurrence by the state. (12)

OBSERVATIONS AND LESSONS LEARNED

COST OBSERVATIONS AND LESSONS LEARNED

- The total cost for this application was approximately $7,100,000. The unit cost for thermal desorption treatment of contaminated soil was approximately $34 per ton treated, and for the entire RA was approximately $68 per ton treated.

- The original bid for this application was approximately $3,500,000. There were 23 modifications to the bid, resulting in a final cost that was approximately twice the original. Modifications included such items as an increase in the quantity of soil requiring treatment and additional site work.

PERFORMANCE OBSERVATIONS AND LESSONS LEARNED

- The LTTD system used at the SRCPP achieved soil cleanup levels and air emission standards during the treatment of approximately 104,000 tons of contaminated soil from August through December 1996 at a desorber temperature generally between 700 and 750 °F.

- During the field demonstration test, the system treated soil contaminated with total cPAHs at levels ranging from 0.6 mg/kg to 4.2 mg/kg to less than the 1.0 mg/kg cleanup level established for this application. The average concentration in the feed samples was 2.2 mg/kg, and the average in the exit samples was 0.15 mg/kg.

- During full operation of the LTTD system, samples of treated soil had total concentrations of cPAHs ranging from below detection limit to 0.44 mg/kg.

OTHER OBSERVATIONS AND LESSONS LEARNED

- The field demonstration test determined that a screen size of one and one-half inches was the most appropriate screen size for sorting coarse material (oversize) from the soil to be treated. That screen size was found to produce oversize material that had a concentration of cPAHs of less than 1.0 mg/kg and a concentration of TPH of less than 200 mg/kg.

REFERENCES

1. Project summary sheet, prepared by USACE-Omaha, July 1997.

2. Treatability Study Engineering Report, Solvent-Refined Coal Pilot Plant, Fort Lewis Military Reservation, Fort Lewis, Washington, Volume III, Appendices J through M, Hart Crowser, for U.S. Army Corps of Engineers, Contract No. DACA67-93-D-1004, Delivery Order No. 18, October 4, 1994, J-3933-18.

3. Abstract of Offers - Construction, Solicitation Number DACA67-95-B-0047, May 2, 1995.

4. Payment Estimate - Contract Performance, Contract No. DACA67-95-C-0062, USACE-Seattle District, May 23, 1997.

5. USACE, Cost Estimate, Project SRCPPR: SRCPP Soil Remediation, DACA67-95-R-0015, March 3, 1995.

6. USACE Contract Specifications, Solvent Refined Coal Pilot Plant (SRCPP) Soil Remediation, Fort Lewis, WA, DACA67-95-C-0062, May 2, 1995 (and subsequent modifications).

7. Final Remedial Action Management Plan, Solvent Refined Coal Pilot Plant Soil Remediation, Fort Lewis, Washington, Dames & Moore, Inc., for USACE Contract #DACA67-95-C-0062, November 8, 1995.

8. Draft Chemical Report 1, Solvent Refined Coal Pilot Plant Soil Remediation, Fort Lewis, Washington, Dames & Moore, Inc., for USACE Contract #DACA67-95-C-0062, November 8, 1996.

9. CRC Handbook of Chemistry and Physics, 1st Student Edition, CRC Press, 1988.

10. Final Feasibility Study Report, Landfill 4 and Solvent Refined Coal Pilot Plant, Fort Lewis, Washington, Applied Geotechnology, for USACE-Seattle District, May 1993.

11. Final Chemical Reports 2 and 3, Solvent Refined Coal Pilot Plant, Fort Lewis, Washington, Dames & Moore, Inc., for USACE Contract #DACA67-95-C-0062, December 15, 1997.

12. Record of Decision for Landfill 4 and the Solvent Refined Coal Pilot Plant, Fort Lewis Military Reservation, Washington, October 15, 1993.

13. Record of Telephone Conversation with Kira Lynch, USACE, Berman, Michael H., September 14, 1998.

ACKNOWLEDGEMENTS

This report was prepared for the U.S. Army Corps of Engineers under USACE Contract No. DACA45-96-D-0016, Delivery Order No. 12. Assistance was provided by Tetra Tech EM Inc. and Radian International LLC.

Thermal Desorption at Naval Air Station Cecil Field, Site 17, OU 2
Jacksonville, Florida

Thermal Desorption at Naval Air Station Cecil Field, Site 17, OU 2
Jacksonville, Florida

<table>
<tr><td>Site Name:
Naval Air Station Cecil Field, Site 17, OU 2</td><td rowspan="2">Contaminants:
Petroleum products and chlorinated solvents
- BTEX
- 1,2-dichlorobenzene as high as 18 mg/kg
- Napthalene as high as 19 mg/kg
- 2-methylnapthalene as high as 47 mg/kg</td><td>Period of Operation:
June 19 to September 25, 1995</td></tr>
<tr><td>Location:
Jacksonville, Florida</td><td>Cleanup Type:
Full-scale</td></tr>
<tr><td>Vendor:
Dustcoating, Inc.
Maple Plain, Minnesota</td><td rowspan="2">Technology:
Thermal Desorption:
- Mobile propane-fired Gencor Model 232 rotary drum dryer modified to thermally process contaminated soil
- 60-inch-diameter-by-20-foot-long rotary dryer with burner (direct-fired), a primary collector baghouse, and an afterburner system
- Nominal system throughput - 25-50 tons/hour; actual system throughput - 17 tons/hour.
- Soil temperature - 825°F
- Average residence time - 3.5 minutes
- Afterburner temperature - 1,500°F with a retention time of approximately two seconds</td><td>Cleanup Authority:
CERCLA
- Interim ROD dated September 30, 1994</td></tr>
<tr><td>Navy Point of Contact:
Mark Davidson
Southern Division, Naval Facilities Engineering Command
North Charleston, SC 29419-9010
(843) 820-5526</td><td>EPA Remedial Project Manager:
Debbie Vaughn-Wright
U.S. EPA Region 4
61 Forsyth Street, SW
Atlanta, GA 30303-3104
(404) 562-8539</td></tr>
<tr><td>Waste Source: Disposal of waste fuel and oil</td><td colspan="2" rowspan="2">Type/Quantity of Media Treated:
Soil - 11,768 tons</td></tr>
<tr><td>Purpose/Significance of Application: Mobile thermal desorption unit used to treat soil contaminated with fuel and solvents</td></tr>
<tr><td colspan="3">Regulatory Requirements/Cleanup Goals:
- Total recoverable petroleum hydrocarbon (TRPH) level of 50 mg/kg provided that total polycyclic aromatic hydrocarbons (PAH) were less than 1 mg/kg and total volatile organic hydrocarbons were less than 50 mg/kg.
- Particulate emissions of 0.04 grains per dry standard cubic foot (gr/dscf)</td></tr>
<tr><td colspan="3">Results:
- 110 of 115 post-treatment samples met the cleanup goal of 50 mg/kg TRPH after one pass.
- For the five post-treatment samples that did not meet the cleanup goal, the five batches of soil (724.5 tons, or approximately 6% of the total) were re-treated. All samples of the re-treated soil met the cleanup goals.</td></tr>
</table>

Thermal Desorption at Naval Air Station Cecil Field, Site 17, OU 2 Jacksonville, Florida (continued)

Cost:
- The total cost for the application was $1,946,122.
- This represents a unit cost of $165 per ton of soil treated for treatment of 11,768 tons of contaminated soil.

Description:
Naval Air Station (NAS) Cecil Field, established in 1941, provides facilities, services, and material support for the operation and maintenance of naval weapons, aircraft, and other units of the operating forces. NAS Cecil Field includes several operable units (OU) and contaminated sites, including Site 17 in OU2. Site 17 reportedly was used for two or three years during the late 1960s and early 1970s for the disposal of waste fuel and oil, possibly including oil contaminated with solvents and paints. Soil at Site 17 was found to be contaminated with petroleum products and chlorinated solvents. In September 1994, EPA signed an interim Record of Decision (ROD) for Site 17 specifying that soil be excavated and treated by thermal desorption.

The thermal desorption unit used at Site 17 was a mobile unit provided by Dustcoating, Inc. of Maple Plain, Minnesota. The unit, a propane-fired Gencor Model 232 rotary drum dryer modified to thermally process contaminated soil, consisted of a 60-inch-diameter-by-20-foot-long rotary dryer with burner (direct-fired), a primary collector baghouse, and an afterburner system. The nominal system throughput for this unit was 25-50 tons/hour; the actual system throughput during this application was 17 tons/hour. The desorber treated contaminated soil at approximately 825°F with an average residence time of 3.5 minutes. An afterburner operated at a temperature of at least 1,500°F with a retention time of approximately two seconds to destroy organic compounds in the off-gas. A total of 115 post-treatment soil samples were collected and analyzed. All but five of these samples met the cleanup goal after the first pass. The five samples were retreated and all met the cleanup goal. According to the EPA RPM, no specific operational problems were identified as causing the failure to meet the cleanup goals on the first pass; however, the contractor suspects that this was caused by elevated levels of moisture in the soil.

Cost and Performance Summary Report: Thermal Desorption at Naval Air Station Cecil Field, Site 17, OU 2 Jacksonville, Florida

Summary Information [1, 2, 4, 6]

Naval Air Station (NAS) Cecil Field, established in 1941, provides facilities, services, and material support for the operation and maintenance of naval weapons, aircraft, and other units of the operating forces. NAS Cecil Field's responsibilities have included operation of fuel storage facilities, performance of aircraft maintenance, maintenance and operation of engine repair facilities and test cells for turbojet engines, and support for special weapons systems. NAS Cecil Field, recently identified for closure under the Base Realignment and Closure (BRAC) program, is located 14 miles southwest of Jacksonville, Florida, primarily in Duval County.

NAS Cecil Field includes several operable units (OU) and contaminated sites, including Site 17 in OU 2. Site 17 reportedly was used for two or three years during the late 1960s and early 1970s for the disposal of waste fuel and oil, possibly including oil contaminated with solvents and paints. The wastes were transported to the site in small tank trucks, bowsers, and 55-gallon drums, and emptied into a pit approximately 50 feet in diameter and 3 to 4 feet deep. While in the pit, the wastes either evaporated or percolated into the ground.

Soil at Site 17 was found to be contaminated with petroleum products and chlorinated solvents. Specific contaminants identified in the soil at Site 17 included benzene, toluene, ethylbenzene, and xylenes (BTEX) and methylene chloride. During a 1991 remedial investigation, methylene chloride was detected in soil borings at concentrations as high as 58 milligrams per kilogram (mg/kg). During a 1995 feasibility study, volatile organic compounds (VOCs), semivolatiles, and inorganics were detected in both surface and subsurface soil samples. In subsurface soil samples, BTEX constituents were detected as high as 14 mg/kg for xylenes. In addition, a number of semivolatiles were detected in the subsurface, including 1,2-dichlorobenzene as high as 18 mg/kg, napthalene as high as 19 mg/kg, and 2-methylnapthalene as high as 47 mg/kg.

In September 1994, EPA signed an interim Record of Decision (ROD) for Site 17. The ROD specified that soil at Site 17 be excavated and treated by thermal desorption.

A total of 11,768 tons of contaminated soil was excavated from Site 17 and treated on site by a thermal desorption system. The period of performance for the thermal desorption treatment was June 19 to September 25, 1995. During that three-month period, the desorber had a cumulative run time of approximately 800 hours.

CERCLIS ID Number:	FL5170022474
Lead:	Southern Division, Naval Facilities Engineering Command

Timeline [2]

September 30, 1994	Interim ROD signed
January 1, 1995	Contractor mobilizes to the site
April 13, 1995	Contractor begins to excavate and stockpile contaminated soil
June 19 - September 25, 1995	Thermal desorption system operated
October 23, 1995	Contractor hydromulches Site 17
October 27, 1995	Final site inspection conducted

Factors That Affected Cost or Performance of Treatment [4, 6]

Listed below are the key matrix characteristics for this technology and the values measured for each during site characterization.

Matrix Characteristics

Parameter	Value
Soil Classification:	Sand and silty sand
Clay Content and/or Particle Size Distribution:	2% medium sand, 88% fine sand, 10% silt and clay (typical site soils)
Moisture Content:	20% (average natural moisture content)
pH:	Not available
Oil and Grease:	Not available
Bulk Density:	90 lbs/ft^3 for dry site soils
Lower Explosive Limit:	Not available

Treatment Technology Description [1, 2, 6]

The thermal desorption unit used at Site 17 was a mobile unit provided by Dustcoating, Inc. of Maple Plain, Minnesota. The unit, a propane-fired Gencor Model 232 rotary drum dryer modified to thermally process contaminated soil, was mounted on two trailers. The unit consisted of a 60-inch-diameter-by-20-foot-long rotary dryer with burner (direct-fired), a primary collector baghouse, and an afterburner system. The nominal system throughput for this unit was 25-50 tons/hour; the actual system throughput during this application was 17 tons/hour. The desorber treated contaminated soil at approximately 825°F with an average residence time of 3.5 minutes. An afterburner operated at a temperature of at least 1,500°F with a retention time of approximately two seconds to destroy organic compounds in the off-gas.

Before treatment in the desorber, soil was excavated from the disposal pit from four to eight feet below ground surface and stockpiled on a 30-millimeter (mil) high-density polyethylene (HDPE) liner. The liner was configured so that contaminated water excavated with the soil, including entrained groundwater, would flow back into the pit at Site 17, thereby reducing the moisture content in the soil before the soil was transferred to the desorber unit. The stockpiled soil also was covered with a plastic liner to protect the soil from rainfall and to direct storm water into the pit at Site 17. The water that collected in the pit at Site 17 was transported through a pipe to the wastewater treatment facility (WWTF) at Cecil Field for treatment.

After treatment, the excavation at Site 17 was backfilled with both treated and clean soil, and the site was graded for proper drainage. At the completion of grading, all areas that had been disturbed were re-seeded. Solid wastes generated as part of the application, such as personal protective equipment (PPE), plastic sheeting material, and construction material and debris, were placed in roll-off bins and transported off site to a landfill permitted under RCRA Subtitle D. A final site inspection was conducted on October 27, 1995.

Listed below are the key operating parameters for this technology and the values measured for each.

Operating Parameters

Operating Parameter	Value
Residence Time:	3.5 minutes
System Throughput:	17 tons/hour
Soil Temperature:	825 °F

Performance Information [2, 3, 6]

Operation of the thermal desorption unit was permitted by the state of Florida under Permit No. 31-16-0345-01. The permit included conditions for particulate emissions of 0.04 grains per dry standard cubic foot (gr/dscf). In addition, the Florida Administrative Code (FAC) required the collection and analysis of samples of soil collected before treatment and samples of soil collected after treatment, with analysis of those samples for total recoverable petroleum hydrocarbons (TRPH), volatile organic halocarbons (VOH), volatile organic aromatic compounds, and total metals. Analyses of metals were required to comply with the FAC concentration limits for Soil Thermal Treatment Facilities.

According to the EPA Remedial Project Manager (RPM), the cleanup goal identified for soil at Site 17 was a TRPH level of 50 mg/kg provided that total polycyclic aromatic hydrocarbons (PAH) were less than 1 mg/kg and total VOHs were less than 50 mg/kg.

At Site 17, 21 pre-treatment soil samples from the soil stockpiles and 115 post-treatment soil samples were collected and analyzed. However, results from specific samples were not provided.

Throughout the system operation, post-treatment soil samples were collected hourly and composited over an eight-operational-hour (maximum) time interval. Five post-treatment samples did

not meet the cleanup goal of 50 mg/kg TRPH. As a result, five batches of soil (724.5 tons, or approximately 6% of the total) required re-treatment. All samples of the re-treated soil met the cleanup goals. According to the EPA RPM, no specific operational problems were identified as causing the failure to meet the cleanup goals on the first pass; however, the contractor suspects that this was caused by elevated levels of moisture in the soil.

A comparison of material input and output from the desorber was not completed because matched untreated/treated soil samples were not collected. Untreated (i.e., before-treatment) samples were collected from soil stockpiles and treated (i.e., post-treatment) samples were composited from the material exiting the desorber.

The thermal desorption unit was tested for particulate emissions on July 12, 1995 (3 weeks after startup), and was found to have emissions greater than the permitted limit of 0.04 gr/dscf (the actual emission level was not provided). This circumstance was believed to be the result of a pinhole leak in one of the bags in the primary collector baghouse. The bag was repaired, and when the unit was tested again on August 3, 1995, it met the emission limit, with an actual emission of 0.005 gr/dscf.

Performance Data Quality [2]

Quality assurance/quality control (QA/QC) activities for this application included use of EPA-approved test methods. Methods 8020, 9073, and 8010 were used for analysis of pre-burn and post-burn samples. The Response Action Contract (RAC) contractor noted that the subcontract for the laboratory that performed analyses at the beginning of this application, Geological Environmental and Oceanographic Services, Inc. (GEOS), was terminated because of QA problems (these problems were not specified). Environmental Conservation Laboratories performed the remainder of the analyses; no problems were noted about the work performed by this organization.

Cost Information [2, 6]

The original award cost for remedial activities at Site 17 was $1,539,689. However, four changes in scope increased the total cost to $1,946,122. The changes covered activities associated with site work and preparation, and included relocation of the thermal desorption unit at Cecil Field; addition of a water pipeline to transport water to the Cecil Field WWTF; addition of water filtration equipment; and addition of other water management equipment. No additional detail was provided on the specific elements included under equipment and appurtenances.

The Navy requested relocation of the unit to Site 3, which required clearing, grading, installation of a water disposal system and a liner. A water pipeline was installed from Site 3 to the WWTF to allow storm water overflow from Site 3 to be pumped to the WWTF. A second pipeline was added to allow clean water from the WWTF to be pumped to Site 3. Both pipelines were 3-inch HDPE fusion-welded pipes. Water filtration equipment, including in-line sand filters, a bag filter, a cyclone, and larger capacity pumps were installed to control Total Suspended Solids (TSS). Increased quantities of storm water and groundwater from Site 3 and Site 17 had resulted in TSS concentrations above acceptable levels at the WWTF. Additional water management equipment was required to handle increased storm water runoff and groundwater levels that resulted from excessive precipitation. Temporary measures included installation of FRAC tanks for Site 17 water storage, and construction of a berm around the Site 17 excavation perimeter to contain storm water. As a result of a hurricane threat, the Site 17 excavation was backfilled on an expedited and emergency overtime basis.

As shown below, a detailed breakdown of project costs was not provided. For example, information was not provided on the portion of the total project cost that was expended for excavation of soil or disposal of treatment residuals. The total cost of $1,946,122 represents a unit cost of $165 per ton of soil treated for treatment of 11,768 tons of contaminated soil at Site 17.

In addition, the vendor of the thermal desorption treatment for this application has filed a lawsuit seeking to recover an additional $500,000 in costs allegedly resulting from unanticipated down time that was not caused by the treatment vendor. No additional information on the status of the lawsuit was provided.

Actual Project Costs

Cost Element	Cost ($ in 1995)
Excavation (of soil)	**Included in total**
Capital	
Site Work and Preparation	
- Locate thermal unit to Site 3	150,000
- Pipeline, Site 3 to WWTF	15,127
- Water filtration equipment	11,526
- Water management - FRAC tanks, pipeline from Site 17 to Site 3 sump, berm around Site 17, backfill/hurricane preparation	229,780
Equipment and Appurtenances	1,539,689
Capital Subtotal	**1,946,122**
Operation & Maintenance	**Included with capital**
Disposal of Residuals	**Included with capital**
Analytical (related to compliance monitoring, not technology performance)	**0**
Total Project Cost	**1,946,122**

Observations and Lessons Learned [1, 2, 6]

Several innovations were incorporated into this remedial activity. According to the RAC contractor (Bechtel Environmental, Inc.), 24-hour operations were conducted to help meet tight schedules, an innovative design for the stockpile area was used to provide cost savings, and Bechtel used one of its subsidiaries (Bechtel Leasing, Inc.) to provide much of the equipment to the Navy at a lower cost than otherwise would have been available. In addition, Bechtel worked with the Navy to minimize disturbance of wetlands adjacent to the remediated area, and to ensure that the remedial work did not interfere with flight operations at the base.

The effort involved in managing storm water at the site was more extensive than had been estimated. Several measures (discussed in the cost section) were taken to control storm water, resulting in an increase in costs of about $250,000. The Navy decided before September 1994 that a storm water management plan was not necessary for the site. During the remedial activity, storm water collected within the bermed area at Site 17 and created a "lake" at the excavation. According to personnel at Cecil Field and at Bechtel, that condition could have been avoided if treated soil had been used as backfill in the excavation at Site 17 as soon as the soil had been determined acceptable for use as backfill. In addition, on two occasions, storm water discharges from Site 17 to the NAS Cecil Field WWTP caused the WWTP to exceed its limits under the National Pollutant Discharge Elimination System (NPDES) for biochemical oxygen demand.

According to the EPA RPM, conducting operations 24-hours a day was the most efficient way to operate since it takes approximately four hours to bring the unit up to operating temperature from a cold start.

The vendor of the thermal desorption technology mobilized on this site before completing all necessary paperwork and permits and notifications required by the state of Florida. In addition, in its first stack test, the desorption unit failed to meet the particulate limit established for the application. According to the Navy's contractor, those events delayed the application of the thermal desorption unit and temporarily ceased operation of the technology.

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References

The following references were used in the preparation of this report.

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6. Deborah A. Vaughn-Wright, Regional Project Manager, EPA Region 4. 1998. Letter to Richard Weisman, Tetra Tech. Response to Request for Additional Information, Naval Air Station Cecil Field, Site 17, OU 2. April 14.

Acknowledgments

This report was prepared for the U.S. Environmental Protection Agency's Office of Solid Waste and Emergency Response, Technology Innovation Office. Assistance was provided by Tetra Tech EM Inc. under EPA Contract No. 68-W5-0055.

Thermal Desorption at the Port Moller Radio Relay Station, Port Moller, Alaska

Thermal Desorption at the Port Moller Radio Relay Station, Port Moller, Alaska

Site Name: Port Moller Radio Relay Station	**Contaminants:** Volatiles (nonhalogenated) - BTEX and Petroleum Hydrocarbons - GRO, DRO, and total recoverable petroleum hydrocarbons (TRPH). Maximum contaminant concentrations were 300,000 mg/kg TRPH and 11,000 mg/kg DRO.	**Period of Operation:** Status: Complete Report covers: 6/95 through 8/95
Location: Port Moller, Alaska		**Cleanup Type:** Remedial Action
Vendor: Frederick Paine, Anderson Excavating and Wrecking Co. 1824 South 20th Street Omaha, NE 68108 (402)345-8811	**Technology:** Thermal Desorption - Soil was pre-screened using a two-inch bar screen. - Pre-screened soil was fed to the on-site, direct-fired thermal desorption unit. - Soil was treated at nominally 500°F with a throughput of 40-60 tons per hour. - Off-gas was treated with a baghouse and afterburner. - Treated soil was used as backfill on site.	**Cleanup Authority:** Managed under the Formerly Used Defense Sites Program and the Installation Restoration Program, with USACE serving as lead agency. USACE solicited review comments, as appropriate, from the U.S. Air Force and ADEC
USACE Contact: Bernard T. Gagnon USACE, Alaska District P.O. Box 898 Anchorage, AK 99506-0898 (907)753-5718		**State Point of Contact:** John Halverson, State of Alaska Department of Environmental Conservation, Contaminated Site Program 555 Cordova Street Anchorage, AK 99501 (907)563-6529
Waste Source: Oil spills (contamination was located primarily in an outfall ditch connected to a floor drain inside a building, near USTs and ASTs, and at drum and warehouse areas)	**Type/Quantity of Media Treated:** Soil - 9,500 yd^3 of soil was treated - Approximately 10% of soil was clayey silt; remainder was sand or sand with gravel - Moisture content 11%	
Purpose/Significance of Application: Application of thermal desorption to treat sandy soil contaminated with diesel fuel at a remote site in Alaska.		
Regulatory Requirements/Cleanup Goals: - Cleanup goals for this application were based on the results of negotiations with ADEC. They consisted of the following cleanup goals: DRO (200 mg/kg), GRO (200 mg/kg), TRPH (200 mg/kg), BTEX (15 mg/kg). - An air quality permit issued by the State of Alaska required air emissions to meet the following limits: particulate matter (<0.05 gr/dscf), and carbon monoxide (< 100 ppmv and 2.39 lbs/hr).		

Thermal Desorption at the Port Moller Radio Relay Station, Port Moller, Alaska (continued)

Results:
- The thermal desorption unit at Port Moller achieved the cleanup goals after three months of operation.
- Of the 118 treated soil samples analyzed, 115 (97 percent) achieved the cleanup goals after one pass through the desorption unit. The three samples that did not achieve the cleanup goals after one pass were treated at relatively low soil temperatures (less than 400 °F). Those soil samples were retreated and subsequently achieved the cleanup goals.
- Air emissions testing was conducted at the site, but no data were available for review. However, analytical data from an application similar to that at Port Moller met the state's requirements for air emissions.

Cost:
- USACE Alaska Division used an innovative approach to procuring a remediation contractor for this application. That approach was based on the use of unit prices established by the government for specific activities associated with the remediation and solicitation of bids as a percentage of the unit prices.
- The actual cost of thermal desorption of contaminated soil at Port Moller was $3,325,000 (for activities directly attributed to treatment), or $350 per yd^3 of soil treated (9,500 yd^3 treated).

Description:
The Port Moller Radio Relay Station (RRS) was constructed in the late 1950s and served as a communication link between Cold Bay and Port Heiden, Alaska. Until 1969, a Defense Early Warning line facility and the White Alice Communication System facility were co-located at the site. From 1969 to 1978, the site functioned as a RRS, and the site was abandoned in 1978. The site consists of the White Alice facility (buildings and antenna) located on a plateau at an elevation of 1,000 feet, and a fuel storage and supply facility located on the shoreline at the foot of the slope leading to the plateau.

In 1994, the USACE demolished the buildings, removed the fuel tanks, constructed a landfill for the disposal of debris, installed monitoring wells, identified areas of soil contamination, and seeded the landfill and other disturbed areas. In addition, a treatability study was conducted on contaminated soil from the site to determine the relative effectiveness of treatment using thermal desorption, soil washing, and bioremediation. Thermal desorption was chosen for the full-scale site remediation based on the results of the treatability study.
The contractor mobilized the remediation equipment to Port Moller in May 1994. Approximately 9,500 yd^3 of contaminated soil were treated using an oil-fired portable thermal desorption unit, which had a rated capacity of 70 tons per hour. The soil was treated in three months of operation and the treated soil was used as backfill to grade the site.

The total cost for treatment of contaminated soil at Port Moller was $3,919,736, which includes $3,325,000 for treatment and almost $600,000 for mobilization and demobilization, due to the remote location of the site.

SITE INFORMATION

IDENTIFYING INFORMATION

Site Name: Port Moller Radio Relay Station (RRS)
Location: Port Moller, Alaska
Technology: Thermal Desorption
Type of Action: Remedial

TECHNOLOGY APPLICATION (1)

Period of Operation: Treatability study - 1994; full-scale operation - June through August 1995
Quantity of Material Treated During Application: 9,500 cubic yards of soil

BACKGROUND

SIC Code: 9711 (National Security)

Waste Management Practice that Contributed to Contamination: Oil spills (contamination was located primarily in an outfall ditch connected to a floor drain inside a building, near underground storage tanks [UST] and aboveground storage tanks [AST], and at drum and warehouse areas).

Site Background (14, 15):

- The Port Moller Radio Relay Station (RRS) (also referred to as the U.S. Air Force White Alice RRS, or the White Alice Communications System (WACS) site) was constructed in the late 1950s and served as a communication link between Cold Bay and Port Heiden, Alaska.
- Until 1969 a Defense Early Warning (DEW) line facility and White Alice facility were co-located at the site. From 1969 to 1978, the site functioned as an RRS. In November 1978, the site was abandoned.
- The site consists of the White Alice facility (buildings and antenna) located on a plateau at an elevation of 1,000 feet, and a fuel storage and supply facility located on the shoreline at the foot of the slope leading to the plateau.
- The site is located approximately 500 miles southwest of Anchorage on the Alaska Peninsula and is accessible only by air or water.
- In 1994, the U.S. Army Corps of Engineers (USACE) performed the following environmental remediation work at Port Moller: demolition of buildings, removal of fuel tanks, construction of a landfill for disposal of debris, installation of monitoring wells, exploration and sampling of soil and water to identify areas of contamination, and seeding of the landfill containing demolition debris and of other disturbed areas.

Remedy Selection

- Thermal desorption was selected for the application on the basis of the results of a treatability study and an engineering cost analysis. A treatability study was performed for ex situ bioremediation; that technology was found to be not feasible. A cost analysis showed that on-

site thermal desorption was less expensive than off-site thermal treatment; for that reason, on-site thermal desorption was selected as the remedy for the application.

Site Investigation (14):

- A site investigation was performed from May to August, 1994. Sampling performed at 10 distinct areas at Port Moller consisted of testing for soil type, depth to groundwater, and concentrations of hydrocarbons in soil and groundwater. Chemical analysis was performed for diesel range organics (DRO); gasoline range organics (GRO); benzene, toluene, ethylbenzene, and xylenes (BTEX); total petroleum hydrocarbons (TPH); and volatile organic compounds (VOC).

- Sampling results showed that DROs were present at 3 of the 10 areas in concentrations greater than 2,000 milligrams per kilogram (mg/kg), and in 2 additional areas in concentrations higher than 200 mg/kg.

- On the basis of the results of the sampling, the 10 areas were scored against matrices identified by the Alaska Department of Environmental Conservation (ADEC), which included a quantitative analysis based on depth to subsurface water, mean annual precipitation, soil type, potential receptors, and volume of contaminated soil. Scores for the 10 areas ranged from 20 to 36 under the ADEC matrices, with 3 of the 10 areas scoring in the range of 27 to 36. These scores were used in the process of setting cleanup goals - see discussion below under performance objectives.

SITE LOGISTICS/CONTACTS

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MATRIX AND CONTAMINANT DESCRIPTION

MATRIX IDENTIFICATION

Soil (ex situ)

CONTAMINANT CHARACTERIZATION

Volatiles (nonhalogenated) - GRO and BTEX
Semivolatiles (nonhalogenated) - DRO and total recoverable petroleum hydrocarbons (TRPH)

CONTAMINANT PROPERTIES

- GRO, DRO, Residual Range Organics (RRO), and TRPH are indicator parameters that refer to a range of hydrocarbons and are defined by ADEC as follows:
  - GRO - hydrocarbons in the range of C_6 - C_{10} (flash point -50°F)
  - DRO - hydrocarbons in the range of C_{10} - C_{28} (flash point 110° to 190°F)
  - RRO - hydrocarbons as C_{28} and greater (flash point > 190°F)
  - TRPH - hydrocarbons as the sum of DRO, GRO, and RRO
- Properties of the contaminants are provided below for BTEX.

Property	Benzene	Toluene	Ethylbenzene	Xylenes
Chemical Formula	C_6H_6	$C_6H_5CH_3$	$C_6H_5C_2H_5$	$C_6H_{4(}(CH_3)_2$
Moleular Weight	78.11	92.14	106.17	106.17
Specific Gravity (at 20° C)	0.88	0.87	0.87	0.86 - 0.88
Vapor Pressure (mm Hg at 70° F)	79.4	23.2	10.4	5 - 9
Boiling Point (°C at 760 mg Hg)	80.1	110.6	136.2	138.3 - 144.4
Octanol-Water Partition Coefficient (K_{ow})	132	537	1,100	1,830

CHARACTERISTICS OF UNTREATED SOIL

- Based on the results of ADEC's scoring (see site investigation), soil was excavated from five areas at Port Moller for treatment by thermal desorption. Table C-1 shows the quantity of soil excavated, soil characteristics, and maximum level of contamination found in each of the five areas.

Table C-1. Characteristics of Untreated Soil [1]

Area	Soil Quantity Excavated (cubic yards)	Soil Characteristics	Maximum Level of Contamination
Outfall Ditch	1,000	A	300,000 mg/kg TRPH (1994 Investigation)
Antennas 1 and 3	600	B	6,700 mg/kg DRO (1994 Investigation)
Warehouse	1,100	C	8,400 mg/kg DRO (1995 Excavation)
Tank Rack	1,300	D	2,400 mg/kg DRO (1994 Investigation)
Tank Farm	5,500	E	11,000 mg/kg DRO (1994 Investigation)
TOTAL	**9,500**		

A - Clayey silt with subangular rocks and cobbles, moderately to strongly cohesive.
B - Sand (from backfill).
C - Sand with small amounts of gravel
D - Sand with small amounts of gravel
E - Sand (primarily)

MATRIX CHARACTERISTICS AFFECTING TREATMENT COST OR PERFORMANCE

Listed below are the major matrix characteristics affecting cost of performance for this technology and the values measured for each parameter.

Parameter	Value
Soil Classification	See Table C-1
Clay Content or Particle Size Distribution	Information not available
Soil Plasticity	Information not available
Moisture Content	11 % by mass (3)
Oil & Grease or Total Petroleum Hydrocarbons	See Table C-1
Presence of Alkaline Metal Salts	Information not available
Lower Explosive Limit	Information not available

- The soil at Port Moller is characterized as either lowland or upland. The lowland area (warehouse, tank rack, and tank farm) is a flat outwash plain of glacial sand and minor gravel that has been reworked by shoreline wave action. Typically, those deposits have little or no silt, and the sands tend to be of larger grain sizes. The upland area (outfall ditch and antennas 1 and 3) is a substantial glacial moraine, which forms the 1,000-foot plateau, and is an undifferentiated mix of silt, often with minor clay, and coarse gravel, often with large, subangular rocks. Only small amounts of sand are present in the upland area.

TREATMENT SYSTEM DESCRIPTION

PRIMARY TREATMENT TECHNOLOGY

Thermal desorption

SUPPLEMENTARY TREATMENT TECHNOLOGIES

Post-treatment (off-gas): oxidizer and baghouse

TIMELINE (1)

Date	Activity
1950s	Construction of Port Moller RRS was completed.
1950s to 1969	Port Moller functioned as a DEW line.
1969 to 1978	Port Moller functioned as an RRS.
November 1978	The site was abandoned.
1994 (months not specified)	Anderson Excavating and Wrecking Co. (Anderson) performed the following environmental remediation work at Port Moller: demolition of buildings, removal of fuel tanks, construction of a landfill for disposal of debris, installation of monitoring wells, exploration, and sampling of soil and water to identify areas of contamination, and seeding of landfill containing demolition debris and other disturbed areas (note that seeding was not successful).
May 1994 to August 1994	Anderson performed a site investigation, including sampling and analysis of soil and groundwater.
1994 (month not specified)	Enviros, Inc. conducted a treatability study on soil from Port Moller.
April 1995	Anderson submitted a chemical data report related to the environmental remediation activities conducted in 1994.
May 1995	Anderson mobilized to the site to implement the thermal desorption technology.
June 28, 1995 to August 24, 1995	Treatment of contaminated soil by thermal desorption was conducted.
August 1995	USACE reseeded areas that had been seeded unsuccessfully.
January 1996	Anderson Excavating and Wrecking submitted a final report on site remediation and restoration activities at Port Moller.

TREATMENT SYSTEM SCHEMATIC AND TECHNOLOGY DESCRIPTION AND OPERATION (1,2,16)

Mobilization

- In May 1994, the contractor mobilized equipment to Port Moller. The equipment included a drill rig, a compressor, asbestos abatement equipment, oil recovery equipment, excavators, loaders, trucks, generators, all-terrain vehicles (ATV), and miscellaneous support equipment required for self-sufficiency at a remote site in Alaska.

Construction

- The thermal desorption system used at Port Moller consisted of an oil-fired portable treatment unit, including a 40,000,000-British thermal unit (Btu)/hour rotary kiln (direct-fired burner and afterburner Model No. P-830H0), a 28,000,000-BTU/hour oxidizer, and a 450-filter baghouse (Model No. P1533BH). The unit was custom designed to handle the wide variety of soils to be remediated at Port Moller. The unit had a rated capacity of 70 tons per hour and was manufactured by Tarmac, Inc., of Kansas City, Missouri.

Operation

- Soil was fed to the desorber continuously after prescreening; a two-inch bar screen was used to remove oversize material. A conveyor belt with a built-in scale was used to feed the soil. After treatment in the desorber, soil was cooled by a water quench and transferred to a stockpile for clean soil. Off-gasses from the desorber were treated in a baghouse and high temperature afterburner before they were discharged to the atmosphere. Particulate matter collected in the baghouse was mixed with treated soil in the clean soil stockpile.

- Soil from the outfall ditch area was a highly cohesive clayey silt and was found to be difficult to treat separately from other soil. Some of the soil was saturated with petroleum oil lubricants (POL) at concentrations as high as 300,000 mg/kg. At times, the soil was too oily to travel up the conveyor belt that fed the treatment unit. The vendor revised the plan of operation to address that problem by blending highly contaminated soil from the outfall ditch with sandy soil from the tank rack and warehouse areas at a ratio of one part outfall ditch soil to three parts tank rack and warehouse area soil (one part clayey silt to three parts sandy soil). This soil blending was performed before treatment as a means of controlling temperatures in the rotary kiln. The vendor noted that a critical factor for controlling temperatures was maintaining an even flow of uniformly mixed soil into the unit.

- Moisture content of the soil also was found to affect operating temperatures. To address that concern, the vendor covered the soil stockpile with a tarp during heavy rains. The references available provide no additional information about the range of moisture content in the untreated soil or of the effect of elevated moisture content on the temperature of soil in the rotary kiln.

- For the major portion of the time during which the system was operated, soil temperatures in the thermal desorption unit ranged from 500 to 1,200°F (initial operations took place at temperatures in the range of 400 to 500°F).

- At times, soil temperatures were less than 500°F. This occurred when unusually wet or fine-grained soil, or soil having an elevated concentration of contaminants, was introduced into the unit. The lower soil temperatures, which occurred primarily at the beginning of the application, were minimized after the vendor began mixing soil from different areas at the site.

- During treatment of highly contaminated soil (estimated to be over 100,000 mg/kg), the vendor reported that because combustible vapors were being desorbed from the soil in quantities sufficient to sustain the oxidizer's operation, the external fuel supply to the oxidizer could be "virtually shut off."

- During the operation of the unit, particulate matter, carbon monoxide (CO), and oxygen (O_2) levels in the exhaust gas from the oxidizer were monitored continuously and recorded. No analytical data on the results of this monitoring were included with available references.

- Water was obtained from an infiltration trench near the treatment unit and was used to cool the soil and control dust.

- Approximately 9,500 cubic yards of excavated soil were treated at Port Moller.

- The references available provide no information about the percentage of time the system was operational.

OPERATING PARAMETERS AFFECTING TREATMENT COST OR PERFORMANCE (1, 16)

Listed below are the major operating parameters affecting cost or performance for this technology and the values measured for each parameter.

Parameter	Value
Residence Time	Information not available
System Throughput	40-60 tons per hour at 10% moisture
Soil Temperature	500 to 1200°F (see text)

Closure

- After treatment, soil was used to backfill and contour the tank rack, warehouse, and tank farm excavations. In 1994, the USACE attempted to revegetate (seed) the landfill containing demolition debris and other disturbed areas at Port Moller with a mix of red fescues, rye grass, and Kentucky bluegrass. This initial seeding was not successful. In August 1995, after thermal desorption had been completed, USACE reseeded the areas with a different seed mix. Grass was growing vigorously in all areas within three weeks of the reseeding. The seed mix used in 1995, recommended by the Plant Materials Center in Palmer, Alaska, consisted of bering hair grass, arctared red fescue, and Gruening alpine bluegrass. The seed was spread with 20-20-10 (N-K-P) fertilizer at 12.5 pounds per 1,000 square feet. The Plant Materials Center recommended this mixture for soil at Port Moller having a pH ranging from 5.2 to 5.9.

- Seven acres at Port Moller were reseeded: the warehouse and tank rack area (one acre); the tank farm and operations area (one acre); and the landfill, an abandoned road to the reservoir, the outfall ditch, and the antenna area (5 acres).

TREATMENT PLAN (3)

- In 1994, Enviros, Inc. performed a treatability study of three remediation technologies using soil collected from the diesel tank farm, the gasoline and diesel tank area, and the waste drain outfall. The treatability study was performed to evaluate the effectiveness, at a bench scale, of thermal desorption, soil washing, and bioremediation. In addition, the treatability study provided a detailed soil characterization, including specific gravity, hydrocarbon speciation, pH, nutrients and microorganisms present, particle size distribution, and soil classification. Thermal desorption was tested on three soil samples representing different concentrations of hydrocarbons in the untreated soil. The results of the treatability study showed that, of the three technologies tested, thermal desorption achieved the lowest concentration of hydrocarbons (measured by EPA Method 418.1 Modified) in the treated soil (220 mg/kg at 750°F). The results of treatment of the three soil samples by thermal desorption are summarized below by treatment temperature.

Table TS-1. Results of Treatability Study of Thermal Desorption [3]

Treatment Temperature	Concentration of Hydrocarbons (mg/kg, dry weight)		
	Sample #1	Sample #2	Sample #3
No treatment	4,000	11,600	205,000
225°F	1,100	2,500	193,000
450°F	280	920	185,000
750°F	60	190	220

- In its recommendations, the vendor of the treatability study noted that soil treated by thermal desorption met the required cleanup levels for the site and that the performance of thermal desorption was not as dependent on site conditions (for example, relatively short summer season and inclement weather) as soil washing or bioremediation.

TREATMENT SYSTEM PERFORMANCE

PERFORMANCE OBJECTIVES (2)

- The cleanup goals for the application were based on the results of negotiations with ADEC.
- The negotiated cleanup goals for the application consist of the following:

  DRO - 200 mg/kg
  GRO - 200 mg/kg
  TRPH - 200 mg/kg
  BTEX - 15 mg/kg

- ADEC first proposed Matrix Level A cleanup criteria that include a concentration of DRO of 100 mg/kg. However, during the negotiation, it was agreed that the cleanup goal for DRO be increased from 100 to 200 mg/kg. USACE Alaska District indicated that the application of that criterion would ensure that the site would be restored to levels that are environmentally acceptable, at considerable cost savings to the government over application of the Level A

criterion. USACE Alaska District had estimated that the additional testing and slower production needed to meet a cleanup goal of 100 mg/kg for DRO would have increased the project cost by 48 percent.

- The air quality permit issued by the state of Alaska required that the emissions meet the following limits: particulate matter, 0.05 grains per dry standard cubic foot (gr/dscf); and CO, 100 parts per million volume (ppmv) and 2.39 pounds per hour.

TREATMENT PERFORMANCE DATA AND ASSESSMENT (1, 16)

- Table TPD-1 summarizes the results of analyses of samples collected during the operation of the thermal desorption system at Port Moller. Listing the results by specific sample numbers and groups of sample numbers, the table shows sampling date, soil temperature, and results of analysis for before- and after-treatment for DRO, GRO, TRPH, and BTEX. At Port Moller, 118 samples of treated soil were collected. Samples were collected at a frequency of one per 50 tons for the first 250 tons, one per 100 tons for the next 4,000 tons (approximately), and one per 200 tons for the remaining 5,000 tons (approximately).

- Matching samples of untreated soil were available for only 8 of the 118 samples of treated soil (those samples were mostly those collected at lower soil temperatures - e.g., 350 to 400°F). In the case of soil temperatures shown as more than (>) or less than (<) a certain value, the references available do not indicate the exact soil temperature.

- Only three samples of after-treatment soil contained concentrations of contaminants higher than the applicable cleanup goals (samples 253, 258, and 277). For sample 253, collected at a soil temperature of <350°F, the concentration of DRO was 210 mg/kg, and the concentration of TRPH was 242 mg/kg. For sample 277, collected at a soil temperature of 350°F, the concentration of DRO was 258 mg/kg, and the concentration of TRPH was not reported. Both of the samples were treated again in the desorber at higher temperatures and subsequently achieved the cleanup goals.

- For sample 258, collected at a soil temperature of >500°F, the concentration of DRO was 122 mg/kg, and the concentration of TRPH was 206 mg/kg. The concentration of TRPH was 3 percent higher than the applicable cleanup goal; however, according to USACE, the sample was not retreated, probably because the TRPH concentration was relatively close to the cleanup level (206 versus 200 mg/kg), and because it was believed that the difference was within the range of error for the analytical method used.

Table TPD-1. Thermal Desorption Treatment Performance Data, Port Moller [1]

Sample No. (95PMS R-)	Date	Soil Temperature (°F)	Before Treatment (mg/kg)				After Treatment (mg/kg) (Cleanup Goal)			
			DRO	GRO	TRPH	BTEX	DRO (200)	GRO (200)	TRPH (200)	BTEX (15)
191/192	6/28/95	>400	564	6	NR	0.06	45	ND	NR	ND
193/194	6/29/95	>400	735	22	NR	0.43	45	ND	NR	ND
195/196	6/29/95	>400	546	5	NR	ND	132	ND	NR	ND
197/198	6/29/95	>400	5,590	NR	6,800	NR	150	NR	120	NR
199/200	6/29/95	>400	6,500	NR	6,800	NR	122	ND	87	ND
201/202	6/29/95	>400	487	NR	NR	NR	49	ND	NR	ND
203/204	6/30/95	750	6,340	NR	10,700	NR	41	NR	74	NR
207-210, 212-216	6/30-7/2/95	400 to >400	NR	NR	NR	NR	12-112	ND	ND-94	ND
217-252	7/2-7/19/95	>500	NR	NR	NR	NR	23-160	ND-23	26-175	ND
253	7/20/95	<350	NR	NR	NR	NR	210	ND	242	ND
254-275	7/20-8/2/95	>500 to 550	NR	NR	NR	NR	23-140	NR	54-206	NR
276/277	8/2/95	350	1,080	NR	NR	NR	258	NR	NR	NR
283-430	8/3 - 8/24/95	>600 to 1,200	NR	NR	NR	NR	ND-160	NR	ND-178	NR

Laboratory testing methods were not available
NR = Not reported.
ND = Not detected; detection limit not provided.

- While data on the actual air emissions from the Port Moller application were not available, the RPM provided emissions data for a similar application show that actual emissions were: particulate matter, 0.0046 gr/dscf; CO, 0.29 ppmv; and CO, 0.016 pounds per hour. According to the RPM, this similar application met the state's requirements for air emissions.

Material Balance: No quantitative material balance was completed for this application because of the limited amount of performance data available from matched samples of untreated and treated soil.

Links to Operating Conditions: The data provided in Table TPD-1 show the link between soil temperature and treatment performance. As the data show, when soil temperatures were lower than 400°F concentrations of contaminants in the treated soil were higher than the limits established as the cleanup goals for DRO and TRPH.

Removal Efficiencies: No quantitative analysis of removal efficiencies could be completed for the application because of the limited amount of performance data available from matched samples of untreated and treated soil.

PERFORMANCE DATA QUALITY

- The sampling and analysis program conducted at Port Moller included use of quality control procedures, such as quality assurance (QA) and quality control (QC) samples. The vendor noted no exceptions to QA or QC procedures for the application.

TREATMENT SYSTEM COST

PROCUREMENT PROCESS

- USACE, through its Richardson Resident Engineer (RRE) Office in Anchorage, Alaska, administered the environmental remediation activities at Port Moller. Anderson performed the environmental remediation activities in support of the RRE under USACE Contract No. DACA-94-D-0003. (1)

- USACE Alaska District used an indefinite quantity, unit price, delivery order-type contract to procure a contractor for the application. The contract included a 10-page list of unit prices that covered all work items to be needed at the site, ranging from equipment mobilization to individual analytical tests. The prices were established by staff of USACE Alaska District. The contract was advertised through a request for proposals (RFP), and bidders were instructed to submit separate items addressing technical qualifications and costs. For costs, the bidders were instructed to submit bids as a percentage of the government-established unit prices. USACE Alaska District received five proposals, with bids ranging from 89 to 105 percent of the unit prices. Anderson was selected on the basis of five rating factors that ranked bidders by technical expertise and cost. Anderson's bid included a cost of 93.9 percent of the government-established unit prices. (2)

- USACE Alaska District used the contracting approach described above to address its concerns about the difficulty of accurately defining the quantity of contaminated soil for a thermal desorption project. Under the contract developed by USACE Alaska District, the contractor was required to determine the extent of contamination during the site investigation phase of the work in 1994 and use the unit prices in the contract to determine the total cost to USACE for treating contaminated soil.

TREATMENT SYSTEM COST (2, 7)

- The environmental remediation activities at Port Moller were conducted under three delivery orders (DO). DO 1, under which work was performed in 1994, included mobilization and demobilization, operation of a contractor's camp, testing, site delineation, removal and closure of underground and aboveground storage tanks, asbestos abatement, general demolition, and landfilling; costs under DO 1 were $4,043,463.

- DO 2, under which work was performed in 1994, included sampling, testing, excavation, hauling, and stockpiling of contaminated soil; treatability studies; and revegetation; costs under DO 2 were $415,175.

- DO 3, under which work was performed in 1995, included mobilization and demobilization; operation of a contractor's camp; operation by the contractor of a field laboratory, including sampling and testing; and thermal treatment of soil contaminated with POL; costs under DO 3 were $3,919,736.

- The costs of DO 3 (thermal desorption activities) were categorized according to an interagency remedial action work breakdown structure (WBS) that includes specific cost elements for before-treatment activities, cost elements for activities directly attributed to treatment, and cost elements for after-treatment activities. Under the WBS, the costs for DO 3 were categorized as shown in Table C-1.

Table C-1. Summary of Costs for Thermal Desorption Activities at Port Moller, Alaska, Categorized According to the WBS (7)

Activity	Cost ($)	Comment
Mobilization and demobilization	594,038	Before- and after-treatment activities
Contractor's camp	31,590	Before-treatment activity
Operation by the contractor of a field laboratory	37,033	Before-treatment activity
Thermal treatment of soil contaminated with POL	3,325,000	Activity directly attributed to treatment

COST SENSITIVITIES

- As discussed above, the costs of thermal desorption at Port Moller were affected by the cleanup goals established by ADEC, the concentrations of contaminants in the soil, the moisture content of the soil, and the quantity of soil to be treated. The references available provide no additional information about specific factors of the application that affected costs.

- In addition, because of the remote location of the site, mobilization and demobilization costs were relatively high.

REGULATORY/INSTITUTIONAL ISSUES

- This project was managed under the Formerly Used Defense Sites (FUDS) Program and the Installation Restoration Program (IRP), with USACE serving as lead agency. In that role, USACE solicited review comments, as appropriate, from the U.S. Air Force and ADEC.

OBSERVATIONS AND LESSONS LEARNED

COST OBSERVATIONS AND LESSONS LEARNED

- USACE Alaska District took an innovative approach to procuring a remediation contractor for the application. That approach was based on the use of unit prices established by the government for specific activities associated with the remediation and solicitation of bids as a percentage of the unit prices.

- USACE Alaska District developed an innovative contract based on the use of unit prices to provide flexibility in determining the total cost to the government of remediating contaminated soil at Port Moller. For a thermal desorption project, it is difficult to estimate accurately the quantity of contaminated soil to be treated. For the Port Moller contract, costs were based on the use of unit prices. The contractor was required to determine the quantity of contaminated soil during the site investigation phase of the work and use the unit prices in the contract to determine the total cost to USACE for treating the contaminated soil. USACE Alaska District indicated that that approach required close coordination between the government and the contractor and saved years of time that otherwise would have been spent delineating the contaminated areas at the site.

- The actual cost of the thermal desorption of soil contaminated with POL at Port Moller was $3,325,000 (for activities directly attributed to treatment), or $350 per cubic yard of soil treated (9,500 cubic yards treated).

PERFORMANCE OBSERVATIONS AND LESSONS LEARNED

- The thermal desorption unit used at Port Moller achieved the cleanup goals after three months of operation. Untreated soil contained concentrations of DRO as high as 6,500 mg/kg, and concentrations of TRPH as high as 10,700 mg/kg. Concentrations of DRO in treated soil were less than 200 mg/kg, for soil treated at temperatures of 400 to 1,200°F.

- Of the 118 soil samples, 115 (97 percent) achieved the cleanup goals after one pass through the desorption unit. The three samples that did not achieve the cleanup goal after one pass were treated at relatively low soil temperatures (less than 400°F). Those samples were retreated and subsequently achieved the cleanup goals.

- Air emissions testing was conducted at this site (17), but no data were available for review. However, analytical data from an application similar to that at Port Moller met the state's requirements for air emissions.

OTHER OBSERVATIONS AND LESSONS LEARNED

- The USACE Construction Branch Chief responsible for the Port Moller thermal desorption application identified the following lessons learned related to thermal treatment of soil contaminated with POL through the experiences gained at Port Moller (2):

Topic Area	Lessons Learned
Characteristics of the matrix	• Uniformity is essential in the feed material. Blend soil aggressively to avoid clumps of peat and clay and remove rocks. Disperse pockets of extremely highly contaminated soil to avoid flare-ups in the plant. • Take measures to decrease the moisture content of the stockpile. Keep the stockpile compact in areal extent. Cover the stockpile. Work from a building or structure if possible, especially in high winds and heavy rain.
Skills of the contractor and government oversight personnel	• During operation of the system, experienced, skilled personnel, including the plant operator, the feed operator, and the millwright, must monitor the system. • An experienced geologist must manage field screening for excavation, collecting samples of feed material and remediated soil for certification of remediation. Rigorous management of field screening during excavation to ensure proper segregation of contaminated and clean layers of soil is a crucial element in maintaining cost control and requires diligent oversight by the government. • The contractor must establish a strong support network of suppliers, including the plant manufacturer, emissions control equipment manufacturer, the air emissions consultant, and personnel of general equipment parts service centers. • The complexity of the electronic control equipment requires very specialized technical support personnel, including an electrician, an electrical engineer, a computer programmer, and an air emissions technician. The technical consultants must be available instantly to respond to equipment failures and must be prepared to travel to the plant to troubleshoot the equipment and perform repairs.
Quality control and standard operating procedures (SOP)	• Rigorous QC and supervision of materials handling to avoid costly mistakes is important. Remediated soil must be stockpiled according to a well-designed plan to avoid the need to move it more than necessary before it is approved for backfilling. • The contractor must demonstrate to the government that it has established a rigorous SOP for maintenance of equipment. Failure to check high-wear points, fines-accumulation points, fuel supply, and other features of the plant otherwise would cause costly breakdowns and delays. • The contractor must establish a procedure for handling material that, for a variety of reasons, must be reprocessed. Designate a location for stockpiling such material, which could include cobbles that are screened out before the contaminated soil enters the dryer unit. If lumps of clay, peat, or asphalt enter the coarse-screened stockpile, the material must be rescreened at the contractor's expense. If remediated soil fails to meet the cleanup criteria established by ADEC, it must be retreated. Failure to address the need to retreat some material in advance will cause delays.

Topic Area	Lessons Learned
Analytical requirements	• The support of an analytical laboratory is essential. Regulators are likely to recommend sampling every 50 tons of processed soil. If the system is performing properly, it is advisable to notify regulators that a greater increment, such as 250 tons, will be used. USACE must take the initiative to maintain control of cost and technical aspects of projects. Further, excessive-sampling overtaxes the laboratory's production capacity and diminishes its ability to provide rapid turnaround when necessary
Air quality	• Compliance with the requirements of an air emissions permit requires sophisticated combustion control equipment, as well as dependable air monitoring equipment for continuous monitoring of emissions. It is essential a consultant be available under contract to monitor emissions and oversee quarterly reporting to ADEC's Air Quality Program. • Access to USACE HTRW CX is an essential resource for USACE resident office managers. Thermal desorption remediation equipment is complicated and must meet strict air emissions criteria. Mr. Ed Mead of CEMRD-ET-HE reviewed requirements and provided copies of relevant U.S. Environmental Protection Agency (USEPA) publications and assisted in calculating air emissions for reporting to ADEC.
Payment procedures	• The government and the contractor must establish the procedure for measurement for payment that will be used. To do so requires continual measurement of the quantity, density, and weight of the soil. The typical form of measurement for process equipment is the use of a calibrated belt scale. Belt scales require frequent calibration checks by the contractor and witnessed by a representative of the government. To avoid confrontations during the project, the procedure must be simple and clearly understood by both parties. Since all equipment has limitations and failures occur, a backup procedure for measurement for payment is necessary. To minimize the risks to both parties, it must be agreed in advance that the government and the contractor will maintain a system of multiple checks, independent measurement of all excavations and of all stockpiles of segregated, contaminated, and remediated soil. Frequent calculations of mass balance should be performed to ensure that parties are in agreement.

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ACKNOWLEDGEMENTS

This report was prepared for the U.S. Army Corps of Engineers under USACE Contract No. DACA45-96-D-0016, Delivery Order No. 12. Assistance was provided by Tetra Tech EM Inc. and Radian International LLC.

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Thermal Desorption at the Re-Solve, Inc. Superfund Site
North Dartmouth, Massachusetts

Thermal Desorption at the Re-Solve, Inc. Superfund Site
North Dartmouth, Massachusetts

Site Name: Re-Solve, Inc. Superfund Site	**Contaminants:** PCBs and Volatile Organic Compounds (VOCs)	**Period of Operation:** June 1993 - December 1994
Location: North Dartmouth, Massachusetts		**Cleanup Type:** Full-scale
Vendor: Gary Duke RUST Remedial Services, Inc. 200 Horizon Center Blvd. Trenton, New Jersey 08691-1904 (609) 588-6373	**Technology:** Thermal Desorption - X*TRAX™ Model 200 - thermal separation system, gas treatment system, and liquid storage and processing system - Dryer feed rate - 120 tons/day - Dryer temperature - 500 to 1100°F - Treated soil temperature - 700 to 750°F (average 732°F) - Residence time - 2 hours - Condensate water generated by the system was treated in the on-site multi-stage treatment system (oxidation; flocculation and sedimentation; filtration; air stripping; liquid-phase carbon adsorption; vapor-phase carbon adsorption)	**Cleanup Authority:** CERCLA - ROD date: 9/24/87 - ESD date: 6/11/93
State Contact: Nikki Korkatti Project Manager Massachusetts Department of Environmental Protection Bureau of Waste Site Cleanup One Winter Street, 5th Floor Boston, Massachusetts 02108 Telephone: (617) 574-6840		**EPA Remedial Project Manager:** Joseph LeMay EPA Region 1 John F. Kennedy Federal Building, Room 2203 Boston, Massachusetts 02203 (617) 573-9622
Waste Source: Disposal of waste in lagoons	**Type/Quantity of Media Treated:** Soil - 36,200 cubic yards (44,000 tons)	
Purpose/Significance of Application: Thermal desorption of PCB-contaminated soil		

Regulatory Requirements/Cleanup Goals:
- The ROD specified a cleanup level of 25 mg/kg for PCBs in soil.
- Process vent emission rate was limited to 0.38 lb/hr of total hydrocarbons (THC).
- Perimeter air monitoring was required for VOCs and dust during excavation; if action levels were exceeded, excavation was to be stopped and control measures implemented.
- Effluent was required to meet daily and monthly limits for VOCs, PCBs, and metals.

Results:
- The treated soil met the cleanup goal of 25 mg/kg PCBs, with concentrations ranging from 0.59 mg/kg to 21 mg/kg.
- Greater than 99% of the soil met the cleanup goal after one pass through the treatment system; only 0.5 percent required retreatment.
- The process vent emissions met the air emission standard; THC emissions ranged from 0.002 to 0.296 lb/hr.
- Treated water generally met the effluent standards. For the few exceedances, the vendor determined that the concentrations would not be higher than the concentration used in developing a discharge permit; however, information was not provided on any actions by the state as a result of the exceedances.

Thermal Desorption at the Re-Solve, Inc. Superfund Site North Dartmouth, Massachusetts (continued)

Cost:
- Total cost to treat the soil - $6,800,000; corresponding to a unit cost of $155/ton (44,000 tons treated).

Description:
Re-Solve operated a waste chemical reclamation facility in North Dartmouth, Massachusetts from 1956 until 1980. Hazardous materials handled at the site included polychlorinated biphenyls (PCBs), solvents, waste oils, organic liquids and solids, acids, alkalies, and inorganic liquids and solids. On December 23, 1980, the state accepted Re-Solve's offer to surrender its disposal license, on the condition that all hazardous waste be removed from the site. In late 1981, Re-Solve removed drums and other debris, including buildings, from the site; however, contents of four on-site lagoons and a cooling pond and the residue from an oil spreading operation were not removed. The site was placed on the the National Priorities List (NPL) in September 1983. The results of the Remedial Investigation indicated that soil and groundwater at the site were contaminated with PCBs and other compounds. In response to a 1983 ROD, soil contaminated with PCBs was excavated and shipped off-site for disposal. However, the results of additional investigations conducted to evaluate the effectiveness of the remedial action indicated that extensive PCB contamination remained in areas beyond the remediated lagoons, cooling pond, and oil spreading area. A second ROD for the site, signed in September 1987, called for excavation of additional contaminated soil and treatment by thermal desorption and dechlorination (DECHLOR). However, the results of a pilot-scale demonstration of the DECHLOR process indicated that the process would not be cost-effective or economically feasible on a full-scale basis. In June 1993, EPA issued an ESD to remove the DECHLOR process from the full-scale treatment system and specify the treatment of the concentrated oil contaminated with PCBs that was recovered in the X*TRAX™ system at an off-site incinerator permitted under the Toxic Substances Control Act (TSCA).

The X*TRAX™ Model 200 system consisted of three main components - thermal separation system, gas treatment system, and liquid storage and processing system. In the thermal separation system, contaminated solids were fed into a propane-fired rotary dryer, and heated indirectly to volatilize the moisture and organic contaminants; the dryer consisted of a long steel cylinder rotating inside of a furnace. The moisture, contaminants, and a small amount of dust were swept continuously from the dryer to the gas treatment system by a nitrogen carrier gas. The gas treatment system removed moisture and contaminants from the carrier gas and reconditioned the gas before recycling it to the dryer. Materials that accumulated within and later exited the system were considered residues of treatment. All treated soil met the cleanup goal of 25 mg/kg for PCBs. Greater than 99 percent of the soil met the cleanup goal after the first pass, with only 0.5 percent of the soil requiring retreatment.

SITE INFORMATION

Identifying Information

Re-Solve, Inc. (Re-Solve), Superfund Site, Operable Unit (OU) 2
North Dartmouth, Massachusetts

CERCLIS No. MAD980520621

ROD Date: September 24, 1987; Explanation of Significant Differences (ESD), June 11, 1993

Treatment Application

Type of Action: Remedial

EPA SITE Program Test Associated With Application? Yes (see Reference 2 for additional information about the Superfund Innovative Technology Evaluation (SITE) demonstration)

Period of Operation: June 21, 1993 to December 21, 1994

Quantity of Material Treated During Application: 36,200 cubic yards (yd^3) of soil and sediment

Background

Waste Management Practice That Contributed to Contamination: On-site disposal of hazardous wastes

Site History: Re-Solve operated a waste chemical reclamation facility in North Dartmouth, Massachusetts from 1956 until 1980. Hazardous materials handled at the site included polychlorinated biphenyls (PCBs), solvents, waste oils, organic liquids and solids, acids, alkalies, and inorganic liquids and solids.

In 1974, the Massachusetts Division of Water Pollution Control issued Re-Solve a license to collect and dispose of hazardous waste. On December 23, 1980, the Massachusetts Division of Hazardous Waste accepted Re-Solve's offer to surrender its disposal license, on the condition that all hazardous waste be removed from the site. In late 1981, Re-Solve removed drums and other debris, including buildings, from the site. The contents of four on-site lagoons and a cooling pond and the residue from an oil spreading operation were not removed.

In December 1982, the site was proposed for inclusion on the National Priorities List (NPL) and was placed on the NPL on September 8, 1983.

Regulatory Context [1, 2]

In Fall 1982, the U.S. Environmental Protection Agency (EPA) conducted a remedial investigation and feasibility study (RI/FS) to assess the extent of contamination at the site. The RI/FS included sampling of soil, groundwater, lagoon wastes, and sediment. An initial record of decision (ROD) for the site was signed on July 1, 1983. The remedial action specified in that ROD called for excavation and off-site disposal of approximately 15,000 yd^3 of soil contaminated with PCBs from the four lagoons, the cooling pond, and the oil spreading area. In 1985, EPA's contractor, the U.S. Army Corps of Engineers (USACE), completed excavation and off-site disposal of that material, referred to as OU 1. Additional investigations conducted to evaluate the effectiveness of the remedial action indicated that extensive PCB contamination remained in areas beyond the remediated lagoons, cooling pond, and oil spreading area.

A supplemental RI/FS was performed from September 1983 to June 1987 to assess the extent of contamination that had migrated beyond the remediated areas and the boundaries of the site, including contamination of both soil and groundwater. A second ROD for the site, signed on September 24, 1987, called for excavation of an additional 22,500 yd^3 of soil contaminated with PCBs and 3,000 yd^3 of contaminated sediment, followed by treatment of that material by a thermal desorptions and dechlorination and management of migration (MOM) for groundwater treatment. The contaminated soil and sediment were referred to as OU 2, and the groundwater was referred to as OU 3.

In 1987, the responsible parties (RP) formed the Re-Solve Site Group and assumed responsibility for site remediation. A mixed funding consent decree, signed on May 31,1989, required that EPA reimburse the RPs

SITE INFORMATION (CONT.)

approximately 30 percent of the reasonable remedial action costs, not to exceed a cap of $6.9 million. In 1991, the Re-Solve Site Group contracted with RUST Remedial Services, Inc. (RUST) to treat the contaminated soil and sediment with RUST's patented X*TRAX™ thermal desorption unit, followed by its DECHLOR process to dechlorinate the PCBs.

In 1992, RUST conducted a pilot-scale demonstration of the DECHLOR process under the EPA SITE Program. Although during the pilot-scale demonstration, the DECHLOR process was successful in treating the concentrated PCB oil generated by the X*TRAX™ thermal desorber, the applications analysis report for the technology demonstration indicated that the process would not be cost-effective or economically feasible on a full-scale basis, primarily because the addition of reagents during the DECHLOR process would lead to an increase in the volume of process residues (oil) requiring subsequent treatment. Consequently, on June 11, 1993, EPA issued an ESD to remove the DECHLOR process from the full-scale treatment system and specify the treatment of the concentrated oil contaminated with PCBs that was recovered in the X*TRAX™ system at an off-site incinerator permitted under the Toxic Substances Control Act (TSCA).

The thermal desorption application at OU 2 is the subject of this report. The excavation and off-site disposal (OU 1), and groundwater treatment (OU 3) are not addressed.

Remedy Selection:

For OU 2, the selected remedy consisted of the excavation and treatment of soils and sediments contaminated with PCBs by thermal desorption, followed by off-site incineration of concentrated PCB oil recovered by the thermal desorber.

Site Logistics/Contacts

Site Management: RP lead

Oversight: Federal

Remedial Project Manager:
Joseph LeMay
EPA Region 1
John F. Kennedy Federal Building, Room 2203
Boston, Massachusetts 02203
Telephone: (617) 573-9622

State Contact:
Nikki Korkatti
Project Manager
Massachusetts Department of Environmental Protection
Bureau of Waste Site Cleanup
One Winter Street, 5th Floor
Boston, Massachusetts 02108
Telephone: (617) 574-6840

Treatment System Vendor:
Gary Duke
RUST Remedial Services, Inc.
200 Horizon Center Blvd.
Trenton, New Jersey 08691-1904
Telephone: (609) 588-6373

MATRIX DESCRIPTION

Matrix Identification

Type of Matrix Processed Through the Treatment System: Soils and sediments

Contaminant Characterization [2, 3]

Primary Contaminant Groups: PCBs; volatile organic compounds (VOCs).

The Applications Analysis Report (AAR) prepared following the SITE demonstration for the technology indicated that Aroclors 1242 and 1252 were the primary PCB congeners at the site, and that PCBs were present in untreated soils at concentrations of more than 240 mg/kg.

Only limited data are available on the concentrations of VOCs in the soil at this site. Elevated levels of methylene chloride, 2-butanone (MEK), trans-1,2-dichloroethene, trichloroethene (TCE), 4-methyl-2-pentanone, tetrachloroethene (PCE), and toluene were found in the lagoon soil. Elevated levels of various organics, particularly acetone and MEK were found in soil at the cooling pond area.

MATRIX DESCRIPTION (CONT.)

The concentrations of PCBs in lagoon soil were in the range of 500 milligrams per kilogram (mg/kg). Relatively high levels of total VOCs (2,666 mg/kg) also were found in this area.

Matrix Characteristics That Affected Treatment Cost or Performance [2]

Table 1 presents the major characteristics of the matrix that affected cost or performance of this technology and the values measured for each.

Table 1: Matrix Characteristics [2]

Parameter	Value
Soil moisture content	8.9 percent
Soil classification and particle size distribution	Granular and sandy with moderate silt content and a very low clay content; classified in the A-2-4 group according to the American Society for Testing and Materials (ASTM) soil classification system
Oil & grease or total petroleum hydrocarbons (TPH)	Information not provided
Bulk density	Calculated as 1.2 tons/yd^3
Lower explosive limit	Information not provided

TREATMENT SYSTEM DESCRIPTION

Primary Treatment Technology

Thermal desorption

Supplemental Treatment Technology

Post-treatment (air): filtration and carbon adsorption

System Description and Operation [1, 2, 4]

System Description

In the X*TRAX™ system, soils containing organic contaminants were heated indirectly in an inert atmosphere, driving off the water and organic contaminants as vapor and leaving the dry solids behind. The vaporized contaminants then were condensed and collected as liquids. Figure 1 shows a material flow diagram for the X*TRAX™ process.

The mobile X*TRAX™ Model 200 full-scale system used at the Re-Solve site consisted of three semitrailers, one control room trailer, eight equipment skids, and various pieces of movable equipment. All skids and trailers that contained liquids had containment curbs for spill control. An area of approximately 125 by 145 feet was required for the equipment. Mobilization time totaled 11 weeks because it was necessary to construct a concrete slab at the site.

The X*TRAX™ Model 200 system had three main components: (1) the thermal separation system, (2) the gas treatment system, and (3) the liquid storage and processing system. In the thermal separation system, contaminated solids were fed into a propane-fired rotary dryer, and heated indirectly to volatilize the moisture and organic contaminants; the dryer consisted of a long steel cylinder rotating inside of a furnace. The moisture, contaminants, and a small amount of dust were swept continuously from the dryer to the gas treatment system by a nitrogen carrier gas. The gas treatment system removed moisture and contaminants from the carrier gas and reconditioned the gas before recycling it to the dryer. Materials that accumulated within and later exited the system were considered residues of treatment. They included water, organic liquids, and dust collected by the eductor scrubber, and water and organic liquids collected by the primary and secondary condensers.

System Operation

Figure 2 shows the equipment layout for the X*TRAX™ Model 200 and identifies the specific equipment associated with the thermal separation, gas treatment, and liquid storage and processing systems. The thermal separation system consisted of a vibratory screener, a feeder, a rotary dryer, product conveyors, and a product cooler.

Before treatment in the X*TRAX™ unit, contaminated soil was passed through a vibratory screener to separate materials that were one inch or less in diameter from those having diameters greater than one inch. That

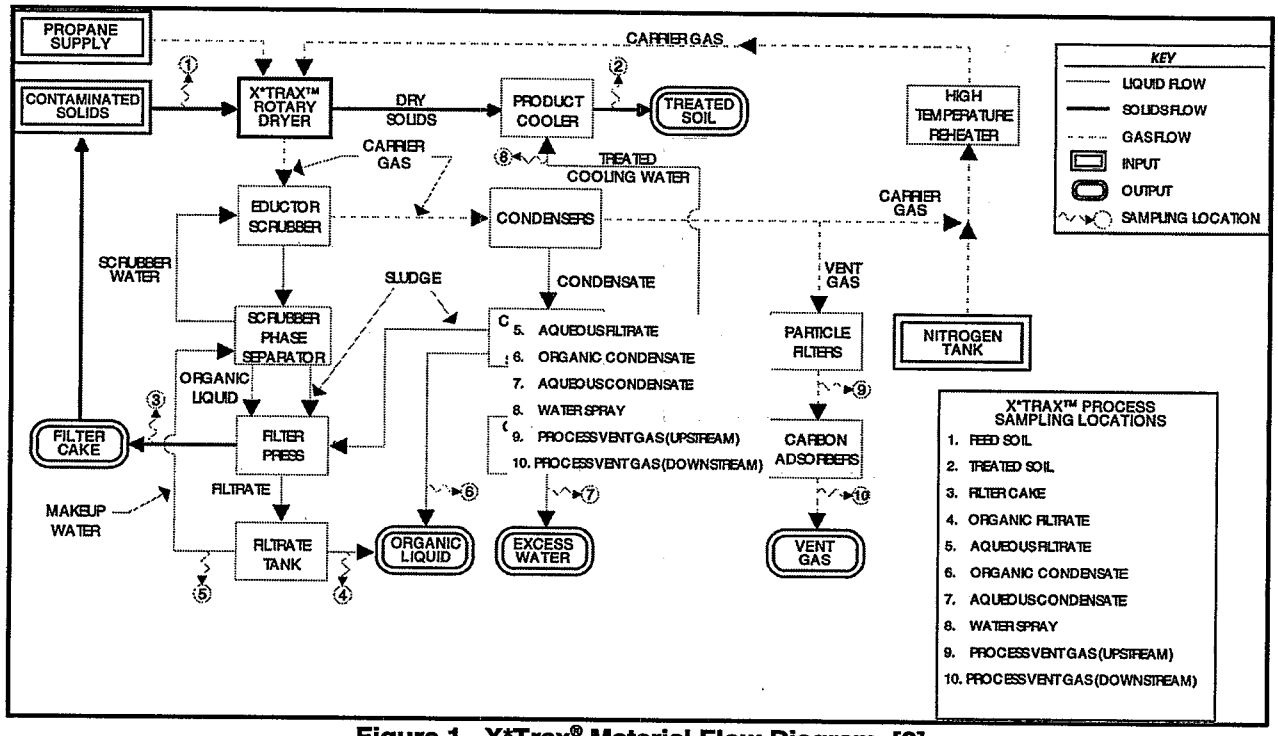

Figure 1. X*Trax® Material Flow Diagram [2]

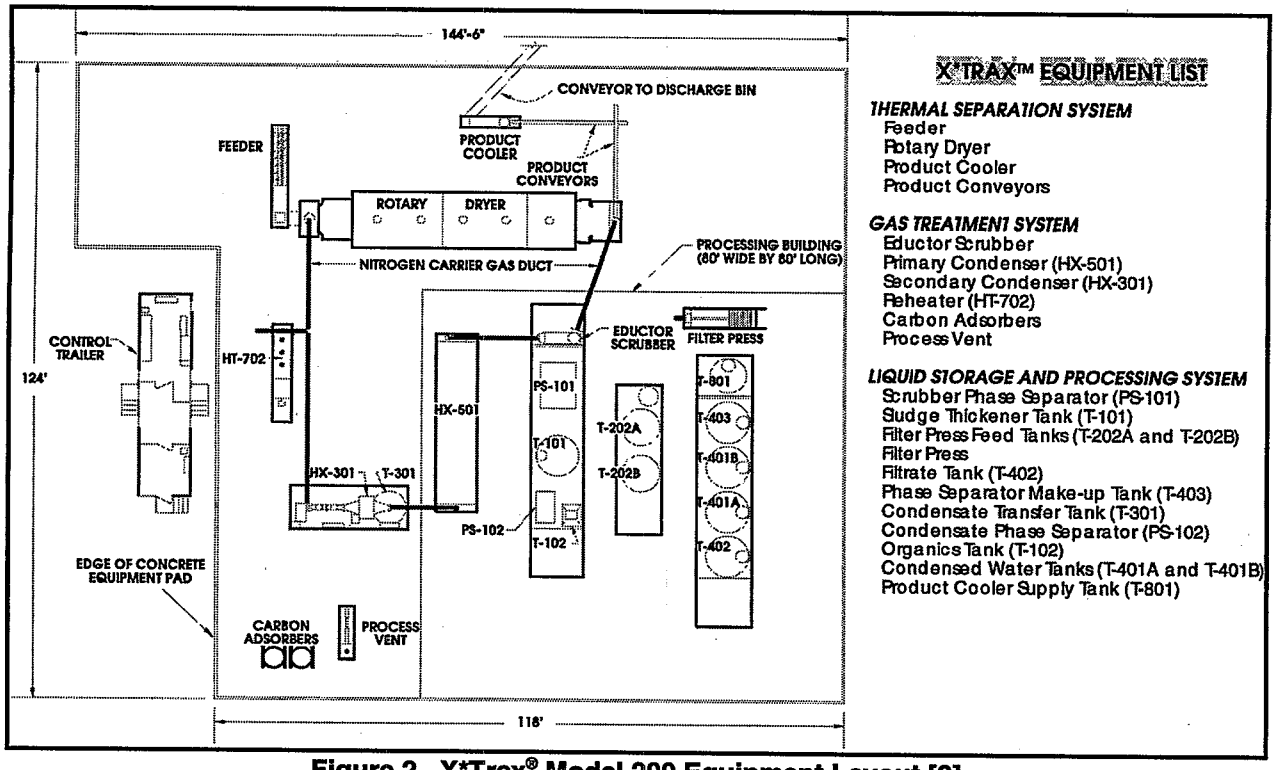

Figure 2. X*Trax® Model 200 Equipment Layout [2]

TREATMENT SYSTEM DESCRIPTION (CONTINUED)

operation was required to ensure that soil passing through the X*TRAX™ unit was small enough to be treated without causing a malfunction of the unit. Feed material typically was delivered to the vibratory screener by a front-end loader or similar equipment. The inclined and horizontal conveyors then moved the feed material from the screener to the rotary dryer (thermal separator) at a regulated rate. The X*TRAX™ system was equipped with an automatic waste feed cutoff feature. When certain operating parameters exceed specified control limits, the inclined conveyor automatically shut down, effectively stopping the flow of contaminated solids to the dryer. Table 2 presents the conditions that would cause the automatic waste feed cutoff feature to operate.

Table 2:
List of Conditions for Operations of Automatic Waste Feed Cutoff [4]

ITEM	CONDITION
Carrier gas stream	High oxygen concentration (greater than 7 percent)
Dryer internal gas pressure	High pressure (greater than 2" water column (WC) for 60 seconds)
Primary heat exchanger, HX-501	High differential pressure across exchanger*
Secondary heat exchanger, HX-302	High outlet temperature*
Recirculation blower	Low outlet pressure*
Dryer cylinder	Loss of rotation
Product handling equipment (for example, cooler mixer, double flap valve, or product conveyors)	Stoppage

* Value will depend on selected operating conditions.

The rotary dryer was a 42-foot-long steel cylinder with a diameter of 90 inches that rotated inside a furnace heated by burning either propane or natural gas fuel. The dryer was divided into five separate heating zones to enhance temperature control, and was positioned at an incline, slightly higher at the inlet. As the dryer rotated, the feed material tumbled slowly and gradually moved to the lower end of the dryer.

The furnace supplied heat through the dryer wall to vaporize water and organic contaminants from the feed material as it moved through the dryer. Because the heating was indirect, contaminated solids in the dryer were isolated completely from combustion gases in the furnace.

The dryer operated under a slightly negative pressure to prevent any waste or waste by-products from leaking out of the system. Moisture and organic vapors released from the contaminated solids were swept continuously out of the dryer by the nitrogen carrier gas. The carrier gas had a flow rate ranging from 700 to 900 cubic feet per minutes (cfm) during the pilot test. With experience, this was reduced to about 400 cfm during full-scale operations. About 5 to 10 percent of the carrier gas was replaced continuously with fresh nitrogen gas to maintain a low oxygen concentration (less than 4 percent) and prevent combustion from occurring in the dryer. The X*TRAX™ system was equipped with a high-level alarm that sounded if the oxygen concentration of the carrier gas exceeded 4 percent. If the oxygen concentration increased to 7 percent, a second high-level alarm would sound, the automatic waste feed would cut off, and additional nitrogen would be introduced directly into the rotary dryer.

The primary process control parameter that RUST used to determine the degree of contaminant removal in the dryer was the temperature of the treated soil. This parameter was controlled by adjusting the feed rate, furnace temperature, and residence time of materials in the dryer (which is a function of cylinder rotation speed and angle of inclination).

Two enclosed screw conveyors moved the treated solids from the discharge end of the dryer to the product cooler. The product cooler

TREATMENT SYSTEM DESCRIPTION (CONT.)

was a horizontal, continuous mixer with a spray tower mounted above the solids inlet. As dry, treated solids entered the product cooler, they were sprayed with water to lower the temperature and reduce dust emissions. The solids then were mixed as they passed through the product cooler. The wet, cool solids exiting the product cooler dropped onto an inclined belt conveyor that carried the material to a soil discharge bin. A full discharge bin constituted a treatment batch and contained approximately 180 tons (150 yd^3) of soil. A total of 250 batches were treated during the remedial action.

The rotary dryer produced decontaminated soil and off-gases. Each batch of treated soil from the X*TRAX™ unit was monitored for PCBs to ensure that the treatment criterion of 25 mg/kg had been achieved before the soil was returned to the site for backfilling. Materials that were shown to have concentrations of PCB higher than 25 mg/kg were retreated in the X*TRAX™ system; one treatment batch (approximately 0.5 percent of soil treated) required reprocessing. Treated soil and sediments were backfilled on site and covered with 18 inches of gravel.

The carrier gas was passed through two condensers in series. The primary condenser typically cooled the carrier gas to near-room temperature. Most of the water vapor, as well as organic compounds of low and intermediate volatility, was condensed. The resulting liquid then flowed under gravity to the condensate transfer tank. The carrier gas then passed through the secondary condenser, where its temperature was reduced to 40° F, condensing the remaining water vapor and organic constituents. A mist eliminator located immediately downstream of the secondary condenser was used to remove remaining moisture entrained in the carrier-gas stream. Liquids from both the secondary condenser and the mist eliminator, if any, flowed under gravity to the condensate transfer tank. After the organic contaminants and water vapor were removed, most of the carrier gas was recycled to the rotary dryer. However, 5 to 10 percent of the carrier gas was discharged continuously to the atmosphere as process vent gas. This process vent gas was treated with an air pollution control (APC) system that consisted of a 10-micron particle filter, a high-efficiency particulate air (HEPA) filter, three carbon adsorption units, and a power vent blower. The carbon unit included, in series, a 150-pound (lb) guard bed, a 1,000-lb main adsorber, and a 150-lb backup bed. The remedial design/remedial action (RD/RA) statement of work called for the carbon adsorber to be replaced before the daily emission rate exceeded 0.38 pounds per hour (lb/hr) of total hydrocarbons (THC); however, according to the final remedial action report, emissions never exceeded 0.296 lb/hr.

A phase separator was used to separate liquid condensate into aqueous (water) and organic phases. The recovered organic condensate was shipped to an incinerator permitted under TSCA. The recovered water initially was used to cool the treated soils and sediments (product). Later, because some high concentrations of organic substances and particulates were detected in the water, it was discharged to the on-site water treatment system (WTS), and the treated water from the WTS was used to cool the product.

The WTS was constructed on site to treat groundwater extracted at the site, groundwater removed during the dewatering operations associated with excavation, surface water from storm events, decontamination water, and excess water condensate generated by the X*TRAX™ system. The WTS consisted of the following treatment units: oxidation using potassium permanganate, flocculation and sedimentation, green-sand filtration, sludge filter pressing, air stripping, liquid-phase carbon adsorption, and vapor-phase carbon adsoprtion.

The vapor-phase carbon units of the WTS were changed once in the summer of 1993 and once in the summer of 1994. An aerobic biological fixed-film aqueous treatment system was installed in the WTS to remove acetone from the condensate because acetone was not removed efficiently by air stripping or carbon adsorption. The flocculation/sedimentation, ultrafiltration, and biological treatment systems were added during full-scale operation to treat organic constituents and particulates in the water condensate.

TREATMENT SYSTEM DESCRIPTION (CONT.)

In this application, the X*TRAX™ unit treated 36,200 yd^3 of soils and sediments contaminated with PCBs, consisting of 36,000 yd^3 soils and 200 yd^3 of sediments.

The full-scale WTS was designed for a maximum flow rate of 150 gallons per minute (gpm). However, during this application, it operated at continuous flow rates that ranged from 100 to 120 gpm.

Operating Parameters Affecting Treatment Cost or Performance [2]

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

Table 3: Operating Parameters [2]

Parameter	Value
Dryer feed rate	120 tons per day for entire project, including downtime (154 tons per day was the maximum daily feed rate)
Dryer cylinder shell temperature	500 to 1100° F
Temperature of treated soil	700 to 750° F; with an average of 732° F
Residence time of solids	2 hours for soil temperature of 732° F
Recirculation rate of carrier gas	700 to 900 cfm during pilot test, reduced to 400 cfm during full-scale operations
System throughput	Calculated as 80 tons per day average reflects intermittent operation due mainly to excess moisture in untreated soils from inclement weather

Timeline

Table 4: Timeline [1]

Start Date	End Date	Activity
12/30/82	-	Site was placed on NPL
07/01/83	-	First ROD was signed by EPA Regional Administrator, requiring the removal of PCB-contaminated soil from four on-site lagoons, a cooling pond, and an oil spreading area
09/08/83	-	Site was placed on NPL
09/83	06/87	Supplemental RI/FS was performed to assess the extent of contamination that had migrated beyond the remediated areas and the boundaries of the site
-	9/85	USACE completed removal of approximately 15,000 yd^3 of highly contaminated PCB soils for disposal off site.
09/24/87	-	Second ROD was signed by EPA Regional Administrator, requiring source control (soil-sediment treatment) and MOM (groundwater treatment) remedies
05/31/89	-	Consent decree was signed by EPA Regional Administrator

TREATMENT SYSTEM DESCRIPTION (CONT.)

Table 4 (continued): Timeline [1]

Start Date	End Date	Activity
09/91	-	Source control pilot activities began
05/12/92	06/10/92	X*TRAX™/DECHLOR pilot test was conducted
06/11/93	-	EPA issued an ESD to eliminate the DECHLOR process from the remedy
06/18/93	-	EPA approved the Re-Solve group's submittals to begin full-scale remediation
06/21/93	06/19/94	Full-scale X*TRAX ™ treatment of PCB-contaminated soils and sediments was conducted
12/14/94	06/21/95	Source control closeout walkthrough began and ended (three walkthroughs were conducted)
-	12/21/94	Demobilization ended after approximately four to six weeks

TREATMENT SYSTEM PERFORMANCE

Cleanup Goals/Standards [1, 3]

The 1987 ROD identified a cleanup level for PCBs in soil and sediment of 25 mg/kg. That cleanup level was based on a $1x10^{-5}$ health-based risk level. In addition, the ROD required that sediment contaminated with PCBs at concentrations greater than 1.0 mg/kg be excavated. Although it was required that sediment containing PCBs at concentrations greater than 25 mg/kg be treated, it is not clear from the available references whether sediment containing PCBs at concentrations between 1.0 and 25 mg/kg was treated or simply backfilled with treated soil. The ROD did not specify cleanup goals for VOCs for soil and sediments.

Additional requirements were established for the following aspects of this application:

- Perimeter air monitoring
- Process vent emission rate
- Limits on concentrations of contaminants in the effluent from the WTS

Table 5 summarizes the perimeter air monitoring action levels for VOCs and dust, and required response activities should the action levels be exceeded.

The process vent emission rate was limited to 0.38 lb/hr of THC, calculated on the basis of 150 mg/kg of THC in untreated soil, a processing rate of 150 tons of soil per day, and 80 percent reduction of THC across the carbon vessel.

Table 5: Perimeter Air Monitoring Action Levels [1]

Parameter	Action Level	Response
VOCs	5 ppm above background for 15 minutes or 0.5 ppm average above background for 8 hours (0900-1700 hours)	Stop excavation, initiate vapor control measures, implement contingency plan, if needed
Dust	5 milligrams per cubic meter (mg/m^3) above background for 15 minutes or 0.15 mg/m^3 average above background for 24 hours	Stop excavation, initiate dust control measures, implement contingency plan, if needed

TREATMENT SYSTEM PERFORMANCE (CONT.)

Effluent from the WTS had daily and monthly limits for VOCs (acetone, methyl ethyl ketone, and methylene chloride), PCBs, and metals (arsenic, lead, and manganese); these limits are shown under treatment performance data.

Treatment Performance Data

Treatment performance data for the application of this technology include results of analysis from the pilot-scale SITE demonstration and from the full-scale remedial activity. SITE demonstration results are provided in Appendix A to this report.

Remedial Action Performance Data [1]

Post-treatment confirmatory analysis was performed by collecting a grab sample every six hours from the product conveyor while the bin was being filled. Once the 150 yd^3 bin was filled, (approximately 30 to 36 hours of operation), grab samples were composited into one sample for analysis for PCBs. More than 250 samples of treated soil were collected. Only one of these samples had a concentration of PCB higher than 25 mg/kg, and approximately 200 tons of soil were retreated.

Table 6 summarizes the results of analysis of treated soil for PCBs from full-scale operations.

The data show that the concentration of PCBs in treated soil ranged from 0.59 to 21 mg/kg, with an average concentration of PCBs of 2.8 mg/kg.

No additional data were provided on the concentrations of PCBs in specific samples of treated soil.

Table 7 summarizes the results of testing of process vent emissions from the full-scale operation. The process vent emissions were monitored continuously for THC with an FID, both before and after they passed through a 1,000-lb carbon adsorption vessel. Table 7 shows the process vent emissions of VOCs which ranged from 0.002 to 0.296 lb/hr, with an average emission rate of 0.138 lb/hr.

Perimeter air monitoring was performed with real-time instruments such as a MicroTIP photoionization detector for VOCs and dust monitor and filter/media. The results of filter media samples were used for comparison with real-time monitoring, primarily to identify contaminants. The perimeter air monitoring system was connected to a computer that recorded continuous readings. The monitoring static alarms were triggered when a VOC level of 5 ppm above background or a dust level of 5 mg/m^3 above background was detected.

Table 8 summarizes the results for daily and monthly average concentrations for selected constituents in the WTS effluent. This table only shows those constituents detected in at least one of the effluent samples analyzed. As shown in Table 8, the following constituents were measured at concentrations that exceeded their respective toxicity limits: acetone (chronic), PCBs (acute and chronic), arsenic (chronic), and manganese (acute and chronic).

Table 6: Concentrations of PCBs in Treated Soil During Full-scale Operations [1]

Samples	Cleanup Level for PCBs (mg/kg)	Range of Concentrations (mg/kg)	Average Concentration (mg/kg)
Treated soil	25	0.59 to 21	2.8

Table 7: VOC Rates in Process Vent Emissions [1]

Location	Performance Standard (lb/hr)	Range of Emission Rates (lb/hr)	Average Emission Rate (lb/hr)
Process Vent	0.38	0.002 to 0.296	0.138

TREATMENT SYSTEM PERFORMANCE (CONT.)

To evaluate the effect of those episodic exceedances on the quality of water in the river to which the effluent was discharged, the treatment system vendor estimated the concentration of those contaminants in the riverusing data on the discharge concentrations, and the actual water discharge and river flow rates (as compared with the high discharge and low river flow assumptions used for establishing the discharge limits for the remedial action).

According to the vendor, the results from this estimation indicated that the concentration of acetone, PCBs, arsenic, and manganese would not be higher than the concentrations of those contaminants used in developing an effluent discharge permit.

Performance Data Quality [1]

The quality assurance and quality control (QA/QC) program used throughout the remedial action met the requirements of the EPA and the Commonwealth of Massachusetts. QC was established and assured during the remedy. Except for the ENSYS test kits, no problems or exceptions were noted.

All monitoring was performed according to the requirements set forth in the following documents:

- Field Operations Support Plan (FOSP), including a quality assurance project plan
- Implementation plan
- Remedial action work plan
- Source control remedy final (100 percent) design report

ENSYS immunoassay test kits were used to estimate concentrations of PCBs in soils. A comparison of results from the test kits with results from the off-site laboratory indicated that the data from the test kits correlated with the laboratory data in 90 percent of cases; in the other 10 percent, the results from the test kits showed higher concentrations than the laboratory data. Therefore, the test kits were shown to have a false positive bias.

Table 8: Summary of Daily and Monthly Average Concentrations for Selected Constituents in WTS Effluent [1]

	Acute Exposure		Chronic Exposure	
	Daily Limit (mg/L)	Range of Daily Averages (mg/L)	Monthly Limit (mg/L)	Range of Monthly Averages (mg/L)
Acetone	15.0	ND-15	3.0	ND-4.3
Methyl Ethyl Ketone	1.75	ND-0.052	0.35	ND-0.027
Methylene Chloride	0.35	ND-0.2	0.072	ND-0.036
PCBs	0.0005	ND-0.12	0.0001	ND-0.0123
Arsenic	0.05	ND-0.05	0.01	ND-0.05
Lead	0.075	ND-0.007	0.015	ND-0.006
Manganese	5.7	ND-14	5.7	0.12-10

Cost of the Treatment System

Procurement Process [1]

For this application, the Re-Solve Site Group procured ENSR Consulting and Engineering Inc. as its project coordinator, and RUST as the prime soil/sediment (source control) contractor.

In addition, EPA procured Halliburton NUS Corporation and Raytheon Engineers and Constructors Inc. to serve as EPA oversight contractor.

Region 1 determined that preparation of a nonbinding preliminary allocation of responsibility (NBAR) would promote expedited settlement with the RPs. Region 1 therefore prepared an NBAR that allocated 15 percent total liability to generators of PCBs and apportioned the remainder of the liability to non-generators of PCBs, proportionate to their volumetric contributions.

Costs [1, 2]

RUST was paid $19,190,000 to implement the source control remedy at this site. That cost included the cost of treatment of 44,400 tons, or 36,200 yd^3, of soils and sediments with the patented X*TRAX™ thermal desorption process.

The actual cost of the source control remedy included the costs of the following ancillary activities: design and implementation of a full-scale pilot study, preparation of remedial design documents, mobilization, on-site dewatering, installation and operation of an on-site WTS, excavation of soils and sediments, post-excavation sampling, sampling of treated soil, backfilling with treated soils, grading of the site, monitoring of the X*TRAX™ process, perimeter air monitoring, restoration of wetlands, and final grading, installation of an 18-inch gravel cap, demobilization, and installation of site fencing.

According to RUST, the actual cost to treat the contaminated soil and sediment at this site was approximately $6,800,000. This cost represents a unit cost of $155 per ton of soil treated (44,000 tons treated), and includes the following cost directly associated with the X*TRAX™ technology: site preparation and mobilization of the unit, capital equipment, startup, labor, consumable materials, utilities, handling of residues and waste associated with the unit, transportation and disposal, maintenance and modification, and demobilization of the unit.

Under the terms of a 1989 consent decree, EPA was required to reimburse the RPs approximately 30 percent of the reasonable remedial action costs, not to exceed a cap of $6,900,000. This condition would have required EPA to reimburse the RPs approximately $5,800,000 of the $19,190,000 expended on the action. (It is not known under what timetable such a reimbursement took or would take place.)

Observations and Lessons Learned

Cost Observations and Lessons Learned [1, 2]

The total cost for the remedial action at Re-Solve OU 2 was $19,190,000, which included approximately $6,800,000 to treat the contaminated soil and sediment at the site. This cost for treatment represented a unit cost of $155 per ton of soil treated (44,000 tons treated).

The remedy identified in the 1987 ROD required use of thermal desorption followed by dechlorination of the residual oil contaminated with PCBs. However, based on the results from the pilot-scale demonstration of the dechlorination technology, it was determined that dechlorination would not be cost-effective or economically feasible on a full-scale basis, and it was replaced in this application with off-site incineration of residual oils contaminated with PCBs. The final remedial action report

OBSERVATIONS AND LESSONS LEARNED (CONT.)

indicated that this modification saved money in the implementation of the remedy; however the amount of savings was not quantified.

Performance Observations and Lessons Learned [1, 2]

The soil and sediment treated in the remedial action met the cleanup goal of 25 mg/kg for PCBs, with only approximately 0.5 percent of the soil quantity required to be re-treated because it did not meet the cleanup goal on the first pass through the desorber. During the full-scale application, the concentration of PCBs in the treated soil, as analyzed using Method 8080, ranged from 0.59 to 21 mg/kg, with an average of 2.8 mg/kg.

As illustrated by the SITE demonstration results, the analytical results for total PCBs achieved by Method 8080 are relatively similar to the results achieved by Method 680, with both methods showing PCB removal efficiencies of greater than 99.7 percent for the pilot-scale testing.

The process vent emission rate during the full-scale application ranged from 0.002 to 0.296 lb/hr, with an average emission rate of 0.138 lb/hr, thus meeting the performance standard for an emission rate of 0.38 lb/hr.

The condensate water generated by the X*TRAX™ unit was treated on site using a multi-stage WTS. All treated water met acute and chronic limits identified for effluent water, except for the following constituents in some episodic samples: acetone (chronic), PCBs (acute and chronic), arsenic (chronic), and manganese (acute and chronic). To evaluate the impact of those exceedances on the quality of water in the river to which the effluent is discharged, the treatment system vendor estimated the concentration of these contaminants in the river using data on the measured discharge concentrations, and the actual water discharge and river flow rates. Information was not provided on whether those exceedances resulted in any action by the state. According to the vendor, the results from this estimation indicated that the concentration of acetone, PCBs, arsenic, and manganese would not be higher than the concentrations of those contaminants used in developing an effluent discharge permit.

Other Observations and Lessons Learned [1]

According to the vendor, the optimum moisture content for the X*TRAX™ system is 20 percent. At significantly higher moisture content, the system requires more heat and produces excess water that requires treatment or disposal, thereby increasing costs. At a moisture content below 20 percent, supplemental water is needed; during both the pilot-scale demonstration and the remedial action, supplemental water was provided from an on-site groundwater treatment system.

Table 9 shows observations and lessons learned as provided by EPA in its Remedial Action Closeout Report.

Table 9: Other Observations and Lessons Learned [1]

Treatment Process
• The original design for the transportation of treated soils to the product cooler by vibrating V-trough conveyors was modified to increase its effectiveness. Modifications included removal of the vibrating conveyer, repositioning of the product cooler immediately after the rotary dryer, and transportation of the wetted soils from the product cooler to a radial stacker by a standard conveyor belt system.
• The original design of the product cooler, consisting of a spray tower, a demister, and a blower, was inefficient in removing dust particles from the steam. The efficiency of the process was increased by the addition of a series of sprays, chevron packings, mesh pads, and a power cyclone (called a powerclone) to the vent stack. Installation of a high-pressure pump at the powerclone also enhanced the removal efficiency of the system.

TREATMENT SYSTEM DESCRIPTION (CONT.)

Table 9 (continued): Other Observations and Lessons Learned [1]

Treatment Process (continued)
• The effectiveness of the phase separator used to separate the organic contaminants and water from the organic condensate wastewater stream was increased by the installation of a biological treatment process following the Calgon Klensorb 100™ (Klensorb) System (which involved a combination of granular activated carbon and clay filters). It turned out to be more cost-effective to incur increased costs for maintenance of the Klensorb System than to purchase new membranes for the ultrafiltration membrane system (if used as a separator) every time a membrane became clogged.
• The biological treatment system used to treat the separated aqueous stream required an extended startup period. The contractor recommended a self-adjusting pH monitoring and control system for the biological treatment system for future use of the X*TRAX™ application.
• Real-time air monitoring instruments were sensitive to changes in temperature and climate; that sensitivity caused false positive readings at perimeter monitoring stations. The perimeter air monitoring system, therefore was modified. The calibration frequency of the continuous monitoring instruments was increased to two times per day, and the instruments were checked an additional four times per day to ensure that instrument drift was not occurring.
• Much of the gas and liquid processing equipment was erected and operated under open air roofs. It was recommended that the structure used to house that equipment be oversized by 25 percent to accommodate unanticipated additions to the treatment facility.
Construction Process
• ENSYS immunoassay test kits were used to estimate concentrations of PCBs in soil. The testing provided an estimate of the concentration of PCBs within 30 minutes, allowing the contractor to determine whether to continue excavating or to move heavy equipment to another area.
• Covering large piles of soil with geotextiles to control fugitive dust proved to be ineffective. Wind consistently disturbed the geotextile fabric or blew it off the pile; resecuring the geotextile fabric was a labor-intensive task.
• As the excavation location changes, the surface-water runoff controls must be changed to prevent the migration of contaminants to previously excavated areas. Surface-water runoff controls should be implemented, monitored, and maintained continuously throughout the application.
• It would be more cost-effective to excavate to depths at which the concentration of PCBs is known to be below the clean-up level as compared with collecting large numbers of post-excavation samples. At Re-Solve, a kreiging model was used to predict the depth of the boundary layer. Samples were collected from the predicted boundary layer to confirm the results of the model. It would have been more cost-effective to excavate well beyond that layer. Results of analysis indicated that 75 percent of samples from the predicted boundary layer showed concentrations that required treatment. Excavating beyond the boundary layer would eliminate the use of intermediate bins, saving time and money by eliminating the need to collect samples for analysis and the need to construct and move the bins.
• The lowest production rates occurred in winter because snow and ice increased the moisture content of contaminated soils. If the pile of contaminated soil had been under roof to protect it from winter weather, the time schedule could have been reduced by 11 to 17 percent, saving as much as 16 to 21 percent of the total cost of remediation (less the cost of the structure).

TREATMENT SYSTEM DESCRIPTION (CONT.)

Table 9 (continued): Other Observations and Lessons Learned [1]

Remedial Action Management Structures
• The steering committee of Re-Solve Site Group hired an executive coordinator and an independent environmental consultant to report on the process of remedial design and remedial action (RD/RA) and to coordinate technical aspects of the RD/RA process. That organizational structure proved to be extremely successful at the Re-Solve Superfund site and was highly recommended by the contractor [that coordinated the organization].

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3. EPA Region 1. Re-Solve Site. 1987. Record of Decision. September 24.

4. MA Superfund. 1997. Letter in Response to Questions: To Tom Sinski, Tetra Tech EM Inc. (Tetra Tech). From Joseph F. LeMay, PE. June 19.

Preparation of Analysis

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

APPENDIX A

Results From EPA SITE Demonstration [2]

During the SITE demonstration, samples of untreated (feed) and treated soil were analyzed for PCBs by EPA Method 8080 and by EPA Method 680-SIM (specific ion monitoring). The results obtained by Method 8080 were used to determine compliance with the cleanup standard specified in the ROD. Results obtained by Method 680 were used to determine whether there were differences between the feed and treated soils in the specific patterns of Aroclors. It was believed that heating soil in the X*TRAX™ rotary dryer had the potential to affect Aroclor patterns.

Table A-1 summarizes the results of the SITE demonstration by both analytical methods for samples of feed and treated soil. As Table A-1 shows, the average total concentration of Aroclors as obtained by Method 680 was reduced from 247 mg/kg to 0.13 mg/kg, a removal efficiency of 99.95 percent. (For the 12 samples of feed soil analyzed by Method 680, total concentrations of PCBs ranged from 181 to 425 mg/kg. Concentrations of PCBs in treated soil were relatively consistent, ranging from not detected to 0.22 mg/kg in the 12 samples.)The average concentration of PCBs as obtained by Method 8080 was reduced from 318 mg/kg to 0.863 mg/kg, a removal efficiency of 99.73 percent. (Total concentrations of Arochlors ranged from 211 to 518 mg/kg in the three samples of feed soil and from 0.68 to 1.01 mg/kg in the samples of treated soil analyzed by Method 8080.)

Table A-1: Average PCB Concentrations in Feed and Treated Soil Samples as Measured During SITE Demonstration [2]

Compound	Feed Soil (mg/kg)	Treated Soil (mg/kg)	PCB Removal Efficiency (%)
Method 680[a]			
Monochlorobyphenyls	ND (0.55)[b]	ND (0.11)	-
Dichlorobyphenyls	16	ND (0.11)	-
Trichlorobyphenyls	74	0.13[c]	-
Tetrachlorobyphenyls	91	ND (0.21)	-
Pentachlorobyphenyls	49	ND (0.21)	-
Heptachlorobyphenyls	1.0[c,d]	ND (0.32)	-
Total[e]	247	0.13	99.95
Method 8080[f]			
Aroclor 1242	213	0.756	-
Aroclor 1254	105	0.107	-
Total	318	0.863	99.73

a No octachlorobiphenyls, nonachlorobiphenyls, or decachlorobiphenyls were detected in any of the 12 samples analyzed by Method 680.
b ND indicates not detected, with the average laboratory target reporting limit (TRL) shown in parentheses.
c Compound was detected in some but not all soil samples; a value of one-half the TRL was used to represent ND samples in calculating an average concentration.
d Numerical result listed is less than the average TRL and should be considered approximate.
e ND values are assigned a value of zero in calculating total concentrations of PCBs.
f Three samples (one from each test) were analyzed by Method 8080.

APPENDIX A (CONT.)

Throughout the SITE demonstration program, the vendor measured concentrations of THCs in the process vent continuously at intervals of one hour. Measurements were made ahead of the first 150-lb guard bed and after the 1,000-lb main adsorber. The average upstream concentration of THCs was 7,123 ppm, with a maximum value of 8,762 ppm. The average downstream concentration was 795 ppm, with a maximum value of 1,349 ppm. The average removal efficiency was 89 percent. After the downstream monitoring location, the process vent gas passed through a second 150-lb carbon bed, where additional THC was removed before discharge to the atmosphere.

To measure VOCs, three samples of gas were collected during the SITE demonstration test. The average total concentration of VOCs in the process vent gas was 397 micrograms per cubic meter ($\mu g/m^3$). Two compounds, chloromethane and methylene chloride, accounted for almost 98 percent of VOC emissions. Monitoring and sampling results indicated that, during the SITE demonstration, air emissions from the X*TRAX™ process vent met the performance standard for process vent emissions.

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Thermal Desorption at the Waldick Aerospace Devices Site Wall Township, New Jersey

Thermal Desorption at the Waldick Aerospace Devices Site Wall Township, New Jersey

Site Name: Waldick Aerospace Devices Superfund Site	**Contaminants:** - BTEX - Total petroleum hydrocarbons (PHC) - Volatile organic compounds (VOC) - toluene, tetrachloroethane, tetrachloroethene - Metals (cadmium, chromium, nickel, zinc)	**Period of Operation:** June - October 1993
Location: Wall Township (Monmouth County), New Jersey		**Cleanup Type:** Full-scale cleanup
Vendor: RUST Remediation Services	**Technology:** Low Temperature Volatilization System (LTVS) - Primary treatment unit - rotary drum; external Hauck dual propane/fuel oil burner used to force heated air into the primary treatment unit - Secondary treatment unit - refractory-lined horizontal cylinder with a burner - Design capacity of 35 tons/hr; actual average system throughput was 20 tons/hr at a soil temperature of 450 to 500°F	**Cleanup Authority:** CERCLA - Original ROD date: 9/29/87 - Second ROD date: 3/29/91 (replaced in situ air stripping with low temperature thermal desorption followed by stabilization and solidification)
USACE Project Lead: Ron Ackerman U.S. Army Corps of Engineers New Jersey Area Office 1 Main St. (Suite 416) Eatontown, NJ 07724 (908) 389-3040		**EPA Remedial Project Manager:** Daniel Weissman U.S. EPA Region 2, EERD 290 Broadway, 19th Floor New York, NY 10007 (212) 637-4384
Waste Source: Contaminated wastewater discharged directly to the ground; leaking drums of spent machine oil	**Type/Quantity of Media Treated:** Soil - 3,450 yd^3	
Purpose/Significance of Application: Thermal desorption of soil contaminated with a wide range of organics		
Regulatory Requirements/Cleanup Goals: - Total VOCs - 1.0 mg/kg; total PHCs - 100 mg/kg; cadmium - 3.0 mg/kg; chromium - 100 mg/kg; nickel - 100 mg/kg; zinc - 350 mg/kg - Air emissions standards were specified in the NJDEPE air permit for the unit for particulates, sulfur oxides, nitrogen oxides, carbon monoxide, total hydrocarbons, hydrogen chloride, VOCs and metals.		

Thermal Desorption at the Waldick Aerospace Devices Site Wall Township, New Jersey (continued)

Results:
- The soil treated by the thermal desorber met the cleanup goals for total VOCs and total PHCs.
- The results of the July 1993 testing indicated that the emissions failed to meet air permit requirements, and the unit was shut down on August 26, 1993. On September 8, 1993, NJDEPE approved restarting operations after corrective measures had been implemented and the unit was reported to have met the emission standards.
- No results were provided with regard to concentrations of metals; treated soil was disposed offsite in a RCRA Subtitle C hazardous waste landfill.

Cost:
- Total cost of $4,995,159 including $3,610,086 for activities related to the remediation of contaminated soil and $1,385,073 for such other activities as demolition of two buildings and off-site disposal of debris, removal of three underground storage tanks and off-site disposal of equipment and debris, and abandonment of 17 wells at the site.
- The cost of $3,610,086 for activities related to the soil remediation includes $2,017,361 for the sum of costs for capital and O&M elements; this corresponds to a unit cost of $585 per yd^3 of soil treated (3,450 yd^3 treated)

Description:
The Waldick Aerospace Devices Superfund Site is a 1.7-acre hazardous waste site located in Wall Township (Monmouth County), New Jersey. The site was used primarily as a manufacturing facility that included degreasing and metal-plating operations. Wastewaters containing heavy metals and solvents were discharged directly to the ground surrounding the main building for a period of at least three years, and spent machine oil leaked onto the ground from perforated drums located near the main building. In 1982, the state ordered Waldick to conduct cleanup activities; however, sampling following these activities indicated that the soil and groundwater at the site were still contaminated with volatile organics and metals. Contaminants included VOCs; benzene, toluene, ethylbenzene, and xylene (BTEX); petroleum hydrocarbons (PHC); other nonhalogenated volatile organic compounds; and metals. While the initial Record of Decision (ROD) for this site specified in situ air stripping for contaminated soil, a second ROD, signed in March 1991, revised the remedy to replace in situ air stripping with low temperature thermal desorption followed by stabilization/solidification. At the Waldick site, contaminated soils were treated on site using low temperature thermal desorption and residuals were sent off-site for stabilization and solidification and disposal at a RCRA-permitted landfill.

A Low Temperature Volatilization System (LTVS) designed by Rust Remedial Services (Rust) was used to treat an estimated 3,450 yd^3 of soil at this site. The unit was trailer-mounted and included feed hoppers/conveyors, a primary treatment unit (rotary drum), a discharge conveyor with pugmill, cyclones, a secondary treatment unit (thermal oxidizer), a quench tower, a baghouse, packed-bed scrubbers with stacks, and a power generator operated with fuel oil. The unit had a design capacity of 35 tons/hr; the actual average system throughput was 20 tons/hr at a soil temperature of 450 to 500°F. The unit operated from June 1993 until the results of stack testing, performed in July 1993, indicated that the emissions failed to meet air permit requirements. The unit was shut down on August 26, 1993. On September 8, 1993, NJDEPE approved restarting operations after corrective measures had been implemented. Operations were restarted at the end of September to treat the remaining soil. The soil treated by the thermal desorber met the cleanup goals for total VOCs and total PHCs.

The costs for excavation of soil and disposal of residuals were relatively high compared with the capital and O&M costs for this application. Approximately $1,000,000 was spent on commercial disposal of treated soil, which may be attributed to the disposal of treated soil as a RCRA hazardous waste. In addition, the RPM indicated that the cost of the project was higher than originally estimated because the total amount of soil treated was greater than had been anticipated.

Cost and Performance Summary Report
Thermal Desorption at the Waldick Aerospace Devices Site
Wall Township, New Jersey

Summary Information [1, 2, 3, 5, 6]

The Waldick Aerospace Devices Superfund Site is a 1.7-acre hazardous waste site located in Wall Township (Monmouth County), New Jersey. The site was used primarily as a manufacturing facility that included degreasing and metal-plating operations. The property presently houses three vacant buildings: the Main Waldick Building, the Pac-n-Post Building, and the Auxiliary Building.

Wastewaters containing heavy metals and solvents were discharged directly to the ground surrounding the main building for a period of at least three years, and spent machine oil leaked onto the ground from perforated drums located near the main building. In 1982, the state ordered Waldick to conduct cleanup activities (specific activities not specified); however, sampling following these activities indicated that the soil and groundwater at the site were still contaminated with volatile organics and metals.

From May 1985 through September 1986, EPA conducted a remedial investigation (RI) and feasibility study (FS) at the Waldick site. Primary contaminants of concern in soil and groundwater included benzene, toluene, ethylbenzene, and xylene (BTEX); petroleum hydrocarbons (PHC); other nonhalogenated volatile organic compounds (VOC); and cadmium, chromium, and other metals. Concentration data provided by the EPA Remedial Project Manager (RPM) showed a number of constituents in the soil, including total petroleum hydrocarbons at 493 milligrams per kilogram (mg/kg); toluene and tetrachloroethane at 26 mg/kg; tetrachloroethene at 160 mg/kg; cadmium at 1,220 mg/kg; chromium at 548 mg/kg; nickel at 100 mg/kg; and lead at 625 mg/kg.

The initial Record of Decision (ROD) for this site, signed September 29, 1987, specified in situ air stripping for contaminated soil. However, this remedial activity was not performed. A second ROD, signed March 29, 1991, revised the remedy to replace in situ air stripping with low temperature thermal desorption followed by stabilization/solidification.

Remedial work at the site was performed from May 1993 until October 1993. Remedial activities included demolition of two buildings, removal of three underground fuel oil storage tanks, and removal of the septic tank at the Main Waldick Building. Contaminated soils were treated on site by low temperature thermal desorption, followed by off-site stabilization and solidification. The solid residues were disposed of as hazardous waste under the provisions of the Resource Conservation and Recovery Act (RCRA). Approximately 3,450 cubic yards (yd^3) of soil were treated in this application.

CERCLIS ID Number:	NJD054981337
Lead:	Federal Lead/Fund-Financed

Timeline [1, 2, 3, 5, 6]

May 1985 - September 1986	RI/FS conducted
September 29, 1997	Initial ROD signed
March 29, 1991	Second ROD signed
June - October 1993	Thermal desorber operated
August 26 - September 14, 1993	Thermal desorber temporarily shut down

Factors That Affected Cost or Performance of Treatment [6]

Listed below are the key matrix characteristics for this technology and the values measured for each during site characterization.

Matrix Characteristics

Parameter	Value
Soil Classification:	Sand with some silt and clay and gravel
Clay Content and/or Particle Size Distribution:	Range of 0.1 to 10 mm - sand (5 of 6 borings at 3 ft to 11 ft bgs); <0.1 mm - silt (1 boring)
Moisture Content:	Range 12-14%; mean 13.8%
pH:	Not available
Petroleum Hydrocarbons:	493 mg/kg
Bulk Density:	Not available

Treatment Technology Description [1, 3, 6, 7]

The thermal desorption unit used at the Waldick site was a Low Temperature Volatilization System (LTVS) designed by Rust Remedial Services (Rust). The unit is trailer-mounted and included feed hoppers/conveyors, a primary treatment unit (rotary drum), a discharge conveyor with pugmill, cyclones, a secondary treatment unit (thermal oxidizer), a quench tower, a baghouse, packed-bed scrubbers with stacks, and a power generator operated with fuel oil. Contaminated soil was stored in twin feed hoppers (7.5 yd^3 capacity) and fed to the primary treatment unit via conveyors. The primary treatment unit was a rotary drum with a burner. An external Hauck dual propane/fuel oil burner was used to force heated air into the primary treatment unit. The treated soil exiting the primary treatment unit was discharged to a pugmill where it was mixed with water to minimize fugitive dust emissions. From the pugmill, the treated soil was sent to a stockpile for analysis and storage prior to transport off-site for disposal.

Vapors and particles from the primary treatment unit were directed to four high efficiency cyclone separators, each 2.66 ft in diameter and rated at 27,500 cubic feet per minute (cfm) at 800°F. The particulate matter from the cyclones was discharged to the pugmill via a screw conveyor where it was mixed with the treated soil and water. The process air stream was directed to the secondary treatment unit, which consisted of a refractory-lined horizontal cylinder with a burner. The process air stream was heated to a minimum temperature of 1,800°F for 1.9 seconds to destroy organics. The process air stream was then sent through a spray cooler to a baghouse. Particulates removed from the process air stream were sent to the pugmill and the off-gas was routed to a packed-bed wet scrubber (counter current flow of 300 to 360 gpm) and discharged through a stack. The scrubber blowdown was sent to the pugmill.

The unit had a design capacity of 35 tons/hr. The actual average system throughput was 20 tons/hr at a soil temperature of 450 to 500°F. The unit was operated for a total of approximately 540 hours (45 days at 12 hr/day). The unit began operating in June 1993 and had been operating for six weeks when the first performance testing was conducted. According to the EPA RPM, the six weeks of operation included time to perform startup and shakedown of the system, and time to receive analytical results from the laboratory (due to normal laboratory turnaround time), and the conduct of internal data quality reviews.

The results of the July 1993 testing indicated that the emissions failed to meet air permit requirements, and the unit was shut down on August 26, 1993. On September 3, 1993, Rust (formerly CWM) proposed an extensive list of modifications to the LTVS to correct the problems and requested approval from the New Jersey Department of Environmental Protection and Energy (NJDEPE) to re-start operations. At that time, the contractor estimated that only about 2 to 3 days of operating time was necessary to complete the cleanup at the site. On September 8, 1993, NJDEPE approved restarting operations after corrective measures had been implemented, including operating the system at no more than 25 tons/hr (versus the design capacity of 35 tons/hr), reducing system air flow, adding a pre-coat to the baghouse, improving the scrubber system, monitoring pH, and adjusting burners to control nitrogen oxide emissions. Operations were authorized to restart on September 14, 1993. Thermal processing of the remaining soils was completed from September 28 through October 7, 1993. Available emissions data indicated that the unit was in compliance with all air permit requirements.

Following treatment, the soil was stabilized to contain metals, which were not destroyed by thermal desorption. The stabilized soil was disposed of off-site in a Class C landfill.

Listed below are the key operating parameters for this technology and the values measured for each.

Operating Parameters

Operating Parameter	Value
Residence Time:	7-8 minutes
System Throughput:	20 tons/hr
Soil Temperature:	450 - 500°F

Performance Information [1, 4, 6, 7]

The ROD identified the following cleanup goals for soil:

- Total VOCs - 1.0 mg/kg
- Total PHCs - 100 mg/kg
- Cadmium - 3.0 mg/kg
- Chromium - 100 mg/kg
- Nickel - 100 mg/kg
- Zinc - 350 mg/kg

Air emissions standards were specified in the NJDEPE air permit for the unit. Emission standards were specified for particulates, sulfur oxides, nitrogen oxides, carbon monoxide, total hydrocarbons, hydrogen chloride, VOCs and metals.

The soil treated by the thermal desorber met the cleanup goals for total VOCs and total PHCs. As discussed above, the results of the performance testing indicated that the unit did not meet the air emission standards. After instituting corrective measures defined by NJDEPE, the unit met all air emission standards specified in the permit.

Performance Data Quality

No information was provided on quality assurance/quality control for this application.

Cost Information [2, 3]

Cost information provided by the U.S. Army Corps of Engineers (USACE) indicated that a total of $4,995,159 was expended for remedial activities at Waldick. The total consists of $3,610,086 for activities related to the remediation of contaminated soil and $1,385,073 for such other activities as demolition of two buildings and off-site disposal of debris, removal of three underground storage tanks and off-site disposal of equipment and debris, and abandonment of 17 wells at the site.

The cost of $3,610,086 for activities related to the soil remediation includes $2,017,361 for the sum of costs for capital and O&M elements; this corresponds to a unit cost of $585 per yd^3 of soil treated (3,450 yd^3 treated).

Actual Project Costs

Cost Element	Cost ($ in 1993)
Excavation (of soil)	**552,000**
Capital	
Mobilization/Demobilization	
- Mobilization	20,000
- Demobilization	15,000
Site Work/Preparation	
- Site security	60,822
- Site access	2,000
- Prepare and revise plans, conduct site survey	90,000
- Construct soil storage and decontamination areas	37,500
- Site utilities and temporary facilities	18,000
- Earthwork - gravel, backfill, paving	227,300
- Vegetative cover, installation and maintenance of black pine trees	75,050
Equipment and Appurtenances	
- Process equipment and appurtenances	801,811
- Miscellaneous (not specified)	556,845
Startup and Testing	
- Project startup	25,000
Capital Subtotal	**1,929,328**
Operation & Maintenance	
Direct Labor/Materials	Included with capital costs
Health and Safety	66,469
Analytical (related to technology performance, not compliance monitoring)	
- Stack sampling	21,564
O&M Subtotal	**88,033**
Disposal of Residuals	**955,650**
Analytical (related to compliance monitoring, not technology performance)	**85,075**
Total Project Cost	**$3,610,086**

Observations and Lessons Learned [6]

The costs for excavation of soil and disposal of residuals were relatively high compared with the capital and O&M costs for this application. Approximately $1,000,000 was spent on commercial disposal of treated soil, which may be attributed to the disposal of treated soil as a RCRA hazardous waste.

The unit had been operating for six weeks and the treatment was almost complete (within 2-3 days) before the initial performance test was performed. The system was shut down when the unit failed to meet applicable air emission standards. According to the EPA RPM, it would have been preferable to identify the non-compliance at an earlier time. Further, the RPM indicated that better emissions control design would have prevented the problem.

The RPM indicated that the cost of the project was higher than originally estimated because the total amount of soil treated was greater than anticipated. The additional cost was negotiated between the contractor and USACE.

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Acknowledgments

This report was prepared for the U.S. Environmental Protection Agency's Office of Solid Waste and Emergency Response, Technology Innovation Office. Assistance was provided by Tetra Tech EM Inc. under EPA Contract No. 68-W5-0055.

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