Abstracts of Remediation Case Studies

Volume 10

Federal Remediation Technologies Roundtable

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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
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FOREWORD

This report is a collection of abstracts summarizing 9 new case studies of site remediation applications prepared primarily by federal agencies. The case studies, collected under the auspices of the Federal Remediation Technologies Roundtable (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 innovative 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 (EPA), 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 abstracts are organized by technology, and cover a variety of *in situ* treatment technologies and some containment remedies. The abstracts and corresponding case study reports are available through the Roundtable Web site, which contains a total of 383 remediation technology case studies (the 9 new case studies and 374 previously-published case studies). Appendix A to this report identifies the specific sites, technologies, contaminants, media, and year published for the 383 case studies. Appendix A is only available in the online version of this report and can be downloaded from the Roundtable Web site at: *http://www.frtr.gov.*

Abstracts, Volume 10, covers a wide variety of technologies, including full-scale remediations and large-scale field demonstrations of soil, groundwater, and sediment treatment technologies. Previously published versions of the Abstracts Volume are listed below. Additional abstract volumes will be compiled as agencies prepare additional case studies.

<u>Abstracts</u>

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

Volume 4: EPA-542-R-00-006; June 2000

Volume 5: EPA-542-R-01-008; May 2001

Volume 6: EPA-542-R-02-006; June 2002

Volume 7: EPA 542-R-03-011; July 2003

Volume 8: EPA 542-R-04-012; June 2004

Volume 9: EPA-542-R-05-021; July 2005

Volume 10: EPA-542-R-06-002; August 2006

Accessing Case Studies

All of the Roundtable case studies and case study abstracts are available on the Internet through the Roundtable Web site at: http://www.frtr.gov/costperf.htm. This report is also available for downloading at this address. The Roundtable Web site also 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, primary and supplemental technology types, site name, and site location. The search function provides users with basic information about the case studies, and allows users 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.

In addition to being accessible through the Roundtable Web site, a limited number of copies of this document are available free of charge by mail from the National Service Center for Environmental Publications (NSCEP) (allow 4-6 weeks for delivery), at the following address:

U.S. EPA/NSCEP
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 and demonstration-scale remediation projects. At this time, the Roundtable is publishing 9 new remediation technology case studies to the Roundtable Web site (http://www.frtr.gov/costperf.htm). A total of 383 case studies have now been completed, primarily focused on contaminated 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). They 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).

By including a recommended reporting format, the Roundtable is working to standardize the reporting of costs and performance to make data comparable across projects. In addition, the Roundtable is working to capture information in case study reports that identifies and describes the primary factors that affect cost and performance of a given technology. Factors that may affect project costs include economies of scale, contaminant concentration levels in impacted media, required cleanup levels, completion schedules, and matrix characteristics and operating conditions for the technology.

The case studies and abstracts 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, contaminants and media treated, technology, cost and performance, and points of contact for the technology application. The case studies and abstracts contain varying levels of detail based on the availability of data and information for each application.

The case study abstracts in this volume describe a wide variety of *in situ* treatment technologies for both soil and groundwater. Contaminants treated included polychlorinated biphenyls; explosives/propellants; petroleum hydrocarbons and benzene, toluene, ethylbenzene, and xylenes; polycyclic aromatic hydrocarbons; pesticides and herbicides; metals; halogenated volatiles and semivolatiles; and nonhalogenated volatiles and semivolatiles.

Table 1 provides summary information about the technology used, contaminants and media treated, and project duration for the 9 technology applications in this volume. This table also provides highlights about each application. Table 2 summarizes cost data, including information about quantity of media treated and quantity of contaminant removed. In addition, Table 2 shows a calculated unit cost for some projects, and identifies key factors potentially affecting technology cost. The column showing the calculated unit costs for treatment provides a dollar value per quantity of media treated and contaminant removed, as appropriate. The cost data presented in the table were taken directly from the case studies and have not been adjusted for inflation to a common year basis. The costs should be assumed to represent dollar values for the time period that the project was in progress (shown on Table 1 as project duration).

Appendix A to this report provides a summary of key information about all 383 remediation case studies published to date by the Roundtable, including information about site name and location, technology, media, contaminants, and year the project began. The appendix also identifies the year that the case study was first published by the Roundtable. All projects shown in Appendix A are full-scale unless otherwise noted. Appendix A is only available in the online version of this report and can be downloaded from the Roundtable Web site.

Table 1. Summary of Remediation Case Studies

Site Name, State (Technology)	Principal Contaminant Groups*											Media (Quantity Treated)	Project Duration	Summary
	PCBs	Pesticides/Herbicides	Explosives/Propellants	Volatiles - Halogenated	Semivolatiles - Nonhalogenated	BTEX	Petroleum Hydrocarbons	PAHs	Volatiles - Nonhalogenated	Semivolatile - Halogenated	Metals			
***In Situ* Soil Treatment**														
Argonne National Laboratory-East, 317/319 Area, Illinois (Phytoremediation)												Soil, Groundwater (up to 30 ft bgs)	SITE Evaluation period from July 1999 to September 2001. Treatment period up to 20 years after project started.	Use of phytoremediation to treat soil and groundwater contaminated with BTEX, halogenated and nonhalogenated volatiles, and halogenated semivolatiles.
Jones Island Confined Disposal Facility, Wisconsin (Phytoremediation)												Soil (1,613 cy)	June 2001 to September 2002	Use of phytoremediation to treat dredged soil/sediment contaminated with PCBs, PAHs, and petroleum hydrocarbons.
Cleaners #1 Site, Washington (In Situ Bioremediation, Thermal Desorption)												Soil (24,000 cy), Groundwater (6 to 18 ft bgs over a 2,000 ft^2 area)	December 15, 1998 to July 2000	Use of in situ bioremediation and thermal desorption to treat soil and groundwater contaminated with halogenated volatiles.
Rocky Mountain Arsenal, Colorado (In Situ Thermal Desorption)												Soil (3,200 cy)	October 2001 to March 2002	Use of in situ thermal treatment to treat soil contaminated with pesticides/herbicides, and halogenated semivolatiles.
Onalaska Municipal Landfill Superfund Site, Wisconsin (Pump & Treat, Monitored Natural Attenuation, In Situ Bioventing)												Soil (NP), Groundwater (2.17 billion gallons)	May 1994 to April 2003	Use of in situ bioventing, pump and treat, and monitored natural attenuation to treat soil and groundwater contaminated with halogenated volatiles, nonhalogenated semivolatiles, BTEX, petroleum hydrocarbons, and metals.

Table 1. Summary of Remediation Case Studies (continued)

Site Name, State (Technology)	Principal Contaminant Groups*											Media (Quantity Treated)	Project Duration	Summary
	PCBs	Pesticides/Herbicides	Explosives/Propellants	Volatiles - Halogenated	Semivolatiles - Nonhalogenated	BTEX	Petroleum Hydrocarbons	PAHs	Volatiles - Nonhalogenated	Semivolatile - Halogenated	Metals			
Sulfur Bank Mercury Mine Superfund Site, California (In Situ Stabilization)												Soil (NP)	November 15, 2000 to April 29, 2001	Use of in situ stabilization to treat soil contaminated with metals.
***In Situ* Groundwater Treatment**														
Confidential Site, Maryland (Permeable Reactive Barrier)												Groundwater (approximately 405,000 gallons)	October 2003 to April 2005.	Use of a permeable reactive barrier to treat groundwater contaminated with halogenated volatiles.
Multiple (3) Naval Facilities (In Situ Chemical Reduction-Nanoscale Zero-Valent Iron)												Groundwater (Hunters Point: 1,818 ft^2 [1^{st} treatment]; 8,700 ft^2 [2^{nd} treatment] Jacksonville: NP Lakehurst: 8,470 ft^2 (North plume); 4,350 ft^2 [South plume])	Not Provided	Use of in situ chemical reduction to treat groundwater contaminated with halogenated volatiles at three Naval facilities.
Loring Air Force Base, Maine (In Situ Thermal Treatment)												Groundwater (NP)	September 1, 2002 to Spring of 2004	Use of in situ thermal treatment to treat groundwater contaminated with halogenated volatiles.

* Contaminant group focused on for the technology covered in the case study.

Key:

NP	= Not Provided	PCBs	= Polychlorinated Biphenyls
bgs	= below ground surface	PAHs	= Polycyclic Aromatic Hydrocarbons
cy	= cubic yards	BTEX	= Benzene, Toluene, Ethylbenzene, and Xylene
SITE	= U.S. EPA Superfund Innovative Technology Evaluation Program		

Table 2. Remediation Case Studies: Summary of Cost Data

Site Name, State (Technology)	Technology Cost ($)[1,2]	Quantity of Media Treated	Quantity of Contaminant Removed	Calculated Unit Cost for Treatment[1,2]	Key Factors Potentially Affecting Technology Costs
***In Situ* Soil Treatment**					
Argonne National Laboratory-East, 317/319 Area, Illinois (Phytoremediation)	T - $2,382,632 P - $4,592,632 (for 20 years)	Not Provided	Not Provided	Not Provided	The total cost would be affected by the climate, which has a direct impact on the growth of trees, thereby impacting the number of years required to achieve cleanup goals.
Jones Island Confined Disposal Facility, Wisconsin (Phytoremediation)	Corn: D - $47,227 Willow: D - $44,280	1,613 cy	Not Provided	Not Provided	Cost differences may result from changing the methods of grading, tilling and irrigating the plots.
Cleaners #1 Site, Washington (In Situ Bioremediation, Thermal Desorption)	D - $13,680 (for first two applications of HRC®)	Soil: 24,000 cy Groundwater: 6 to 18 ft bgs over a 2,000 ft^2 area	Not Provided	Not Provided	Not Provided
Rocky Mountain Arsenal, Colorado (In Situ Thermal Desorption)	T - $1,900,000	Soil: 3,200 cy	Not Provided	Not Provided	The nature of the waste at the site affected the cost because the wastes contained contaminants with very high boiling points, requiring high operating temperatures and treatment times.
Onalaska Municipal Landfill Superfund Site, Wisconsin (Pump & Treat, Monitored Natural Attenuation, In Situ Bioventing)	With P&T: AO - $200,000 Without P&T: AO - $60,000	Soil: NP Groundwater: 2.17 billion gallons	Area A: 7,780 kg of hydrocarbons Area B: 11,000 kg of hydrocarbons Area C: 1,247 kg of hydrocarbons	Not Provided	Not Provided
Sulfur Bank Mercury Mine Superfund Site, California (In Situ Stabilization)	ENTHRALL: T - $59,807,000 SME: T - $35,690,000 Generic: NP	Not Provided	Not Provided	ENTHRALL: $27.82 per ton SME: $16.60 per ton Generic: NP	The SBMM site has a larger volume of material than most waste sites, resulting in high cost estimates. Cost estimates were also developed independently by the technology vendors with differences in assumptions and cost factors.

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

Site Name, State (Technology)	Technology Cost ($)[1,2]	Quantity of Media Treated	Quantity of Contaminant Removed	Calculated Unit Cost for Treatment[1,2]	Key Factors Potentially Affecting Technology Costs
***In Situ* Groundwater Treatment**					
Confidential Site, Maryland (Permeable Reactive Barrier)	P - $161,400	Approximately 405,000 gallons	Not Provided	$0.02 per gallon treated	Costs associated with the injection process, includes the number and spacing of injection wells, volume of substrate and chase water injected, the time required for injection completion, and the number of injection events.
Multiple (3) Naval Facilities -(In Situ Chemical Reduction-Nanoscale Zero-Valent Iron)	Hunters Point: T - $289,300 (1st treatment); $1,390,000 (2nd treatment) Jacksonville: T - $259,000 Lakehurst: T - $255,500	Hunters Point: 1,818 ft^2 (1st treatment); 8,700 ft^2 (2nd treatment) Jacksonville: NP Lakehurst: 8,470 ft^2 (North plume); 4,350 ft^2 (South plume)	Not Provided	Not Provided	Cost comparisons of the three sites showed that the particle size of the injected iron reagent along with the method of injection affected the demonstration costs.
Loring Air Force Base, Maine (In Situ Thermal Treatment)	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided

1 Actual full-scale costs are reported unless otherwise noted.
2 Cost abbreviation: T = Total costs, AO = Annual operation and maintenance (O&M) costs, C = Capital costs, DI = Design and implementation costs, D = Demonstration-scale costs, P = Projected full-scale costs.

Key:
- HRC® = Hydrogen Release Compound
- cy = cubic yards
- kg = kilograms
- NP = Not Provided
- bgs = below ground surface
- SBMM = Sulfur Bank Mercury Mine

IN SITU SOIL TREATMENT ABSTRACTS

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Deployment of Phytotechnology in the 317/319 Area at Argonne National Laboratory-East, Argonne, Illinois

Site Name:
Argonne National Laboratory-East, 317/319 Area

Location:
Argonne, Illinois

Period of Operation:
Project started in June 1999. SITE Evaluation period from July 1999 to September 2001. Treatment period up to 20 years after project started.

Cleanup Authority:
RCRA Corrective Action

Purpose/Significance of Application:
The objectives of the project are to:
- Hydraulically contain the VOCs and tritium plumes south of the 317 Area French Drain and 319 Area Landfill.
- Continue the remediation of residual VOCs within the 317 Area French Drain.
- Minimize water infiltration into the 317 Area French Drain soils and stabilize the surface to prevent erosion, runoff, and downstream sedimentation.
- Protect downgradient surface and groundwater by hydraulically containing the contaminated plume.

Cleanup Type:
Full Scale

Contaminants:
317 Area:
- Soil:
  - Volatile-halogenated compounds: carbon tetrachloride (maximum of 54,000 : g/kg); chloroform (maximum of 21,000 : g/kg); PCE (maximum of 190,000 : g/kg); TCE (maximum of 47,000 : g/kg).
  - Volatile-nonhalogenated compounds: benzene (maximum of 3,200 : g/kg); 4-methyl-2-pentanone (maximum of 78,000 : g/kg).
- French Drain Groundwater:
  - Volatile-halogenated compounds: chloroform (maximum of 380 : g/L); PCE (maximum of 50,000 : g/L); TCE (maximum of 8,600 : g/L).
- Fence-line Groundwater:
  - Volatile-halogenated compounds: carbon tetrachloride (maximum of 8 : g/L); chloroform (maximum of 4 : g/L); methylene chloride (maximum of 14 : g/L); TCE (maximum of 6 : g/L); 1,2-DCE (maximum of 6 : g/L).

319 Area:
- Landfill Groundwater:
  - Tritium (maximum of 233,000 pCi/L)
  - Volatile-halogenated compounds: cis-1,2-DCE (maximum of 240 : g/L); TCE (maximum of 24 : g/L); vinyl chloride (maximum of 5 : g/L).
- Fence-Line Groundwater:
  - Volatile-halogenated compounds: TCE (maximum of 5 : g/L).

Waste Source:
Solid and liquid waste disposed at the site from various laboratory activities.

Contacts:

SITE Demonstration Contact:
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Technology:
Phytoremediation:
- The patented TreeMediation® TreeWell® Treatment System from Applied Natural Sciences was deployed at the site. System is designed to reach groundwater 30 feet below ground surface (bgs).
- In the 317/319 Area, approximately 800 trees were planted (approximately 600 hybrid poplars and 200 hybrid willows).
- In addition, the 317 Area French Drain area was seeded with a mix of legumes and grasses to minimize water infiltration and to stabilize the soil.
- Operational period for the phytoremediation treatment will last for 20 years. Afterwards the trees will be harvested, chipped, and used as landscaping material.

Deployment of Phytotechnology in the 317/319 Area at Argonne National Laboratory-East, Argonne, Illinois (continued)

Contacts (continued):

ANL-E Phytotechnology System Contact:
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SITE Program Contact:
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Type/Quantity of Media Treated:
Soil and groundwater up to 30 ft bgs.

Regulatory Requirements/Cleanup Goals:
Specific contaminant remediation goals are:
317 Area VOC concentrations:
- French Drain Soil (: g/kg): benzene (80); carbon tetrachloride (1,024); chloroform (1,670); PCE (152); TCE (80); 4-methyl-2-pentanone (28,200).
- French Drain Groundwater (: g/L): chloroform (211); PCE (316); TCE (127).
- Fence-line Groundwater (: g/L): carbon tetrachloride (5); chloroform (0.02); methylene chloride (5); TCE (5); 1,2-DCE (5).

319 Area Tritium/VOC concentrations:
- Landfill Groundwater (: g/L or pCi/L): cis-1,2-DCE (70); TCE (5); vinyl chloride (2); tritium (20,000).
- Fence-Line Groundwater (: g/L): TCE (5).

Results:
The phytoremediation technology deployed at the site is ongoing and was evaluated after three growing seasons. The effectiveness of the various plantings was monitored directly through groundwater and soil measurement and samples, as well as indirectly via plant tissue analysis, microbial surveys, geochemical analysis, soil moisture probes, and sap flow monitoring. Groundwater chemical data indicated decreasing concentrations of target VOCs and increasing concentrations of degradation byproducts. Tissue analysis of willows growing at the source area indicated that TCE and PCE were being taken up by the trees and that a portion of the transported contaminants were being degraded in the leaves. TCE and PCE and their degradation byproducts were seen at nearly all groundwater wells throughout the study area, implying that microbial attenuation of some form was occurring.

Costs:
The following conclusions have been drawn based upon the information provided by the Argonne National Laboratory-East:
- The total project cost, which included designing, installing and maintaining the system for the first four years (1999-2002), was $2,382,632.
- The total estimated treatment cost over 20 years of the project is $4,592,632.

Deployment of Phytotechnology in the 317/319 Area at Argonne National Laboratory-East, Argonne, Illinois (continued)

Description:
The 317/319 Area at the Argonne National Laboratory – East (ANL-E) is located on the far southern end of the ANL-E site, immediately adjacent to the DuPage County Waterfall Glen Forest Preserve, an area used for public recreation and as a nature reserve. It covers a surface area of approximately five acres and encompasses several sites used in the past to dispose of solid and liquid waste from various laboratory activities. Releases from the disposal of waste have contaminated the soil and groundwater with VOCs and low levels of tritium. Several interim actions have been implemented at the site in the past to reduce the VOC and tritium releases from this area; however, additional remedial actions are ongoing to further restore the site.

Starting in June 1999, ANL-E planted over 800 hybrid poplars and hybrid willows and a supplemental ground cover of herbaceous plants in the 317/319 Area. Earlier in 1999, EPA expressed an interest in participating with DOE in this study and subsequently included it as a demonstration project under the National Risk Management Research Laboratory (NRMRL) Superfund Innovative Technology Evaluation (SITE) program. ANL-E anticipates operating the phytoremediation system for 20 years. The phytoremediation technologies implemented at ANL-E are intended to eventually replace the existing pump-and-treat system. The project has so far has demonstrated success in decreasing target VOC concentrations and increasing concentrations of degradation byproducts and absorbing TCE and PCE into the plant tissue.

Dredged Material Reclamation at the Jones Island Confined Disposal Facility, Milwaukee, Wisconsin

Site Name:
Jones Island Confined Disposal Facility

Location:
Milwaukee, Wisconsin

Period of Operation:
SITE testing period: June 2001 to September 2002.

Cleanup Authority:
USACE and the Milwaukee Port Authority.

Purpose/Significance of Application:
This demonstration was conducted to evaluate the feasibility of using phytoremediation to remediate dredged material at the Jones Island Confined Disposal Facility. The demonstration consisted of comparing and analyzing the results of three different plant species.

Cleanup Type:
Field Demonstration

Contaminants:
Analyte concentrations in individual cells ranged from:
- Polycyclic Aromatic Hydrocarbons (PAHs): 77 to161 mg/kg
- Polychlorinated Biphenyls (PCBs): 2.0 to 3.6 mg/kg
- Reduce diesel range organic (DRO): 24 to 440 mg/kg

Waste Source:
The dredged material was contaminated from airborne and regulated industrial discharges, spills, and urban run-off.

Contacts:

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Technology:
Phytoremediation
- Prior to the field demonstration, treatability studies were conducted by the technology developer at the USACE's Engineer Research and Development Center (ERDC) to determine the crops and grasses that would survive in the dredge material.
- Four field plots, each containing four treatment cells, were established on the Confined Disposal Facility (CDF) by excavating, screening, and depositing soil in the cells.
- Each test plot was 60 ft by 23 ft. The four treatment cells were each 12 ft by 20 ft. The intercell berms separating the treatment cells were 2 ft wide. The outer berms were 3 ft wide.
- Each plot had four randomized treatments: corn hybrid, sandbar willow, local grasses, and an unplanted control (plant suppression).
- Corn was planted twice during the growing season, from June through September.
- The project duration was for two growing seasons.

Dredged Material Reclamation at the Jones Island Confined Disposal Facility, Milwaukee, Wisconsin (continued)

Type/Quantity of Media Treated:
Dredged material containing PAHs, PCBs, and DRO above relevant Wisconsin Department of Natural Resources (WDNR) and USEPA standards.

Regulatory Requirements/Cleanup Goals:
- Reduce PAHs to Category 1 and 2 standards specified in WDNR NR 538.
- Reduce PCBs to less than or equal to 1 mg/kg.
- DRO to less than 100 mg/kg.

Results:
- After two growing seasons, the three treatments plots had PAH concentrations at or below numerical standards for 7 of the 16 PAH compounds listed in Category 1 of the WDNR NR 538. The control plot had 8 compounds at or below Category 1 standards.
- After two growing seasons, the three treatments plots had 8 PAH compounds at or below the Category 2 standards of the WDNR NR 538. The control plot had 11 compounds.
- None of the treatments produced concentrations of PCBs of less than 1 mg/kg.
- None of the treatments produced concentrations of DRO of less than 100 mg/kg.

Costs:
The estimated costs for remediating 1,613 cubic yards (1 acre surface area by 1 foot deep) of dredged material was $47,227 using corn, and $44,280 using willow plants. The costs included equipment costs, direct installation costs, indirect costs, and direct and indirect annual operating costs.

Description:
The Jones Island Confined Disposal Facility (JICDF) is located in Milwaukee Harbor, Milwaukee, Wisconsin. The facility receives dredged materials from maintenance operations of Milwaukee's waterways. USACE, in partnership with the Milwaukee Port Authority, is exploring a range of beneficial reuse options for the dredged material, from building and road fill to landscape material.

A field demonstration was conducted to evaluate the feasibility of using phytoremediation to remediate the dredged material. Treatability studies were conducted to determine suitable crops and grasses. Once the plants were selected, field plots were established on the CDF by excavating, mixing, and depositing soil in test cells. The test plots closely followed established protocols for plot size, sampling, and statistical design. The field demonstration involved four different treatment plots: hybrid corn, an indigenous willow, local grasses, and an unplanted control. The EPA Superfund Innovative Technology Evaluation Program (SITE) and USACE evaluated the demonstration from 2001 to 2002. The effectiveness of the various plantings was monitored directly through soil sampling and indirectly through a variety of assessments.

After two growing seasons, the three plant treatments plots had PAH concentrations at or below numerical standards for 7 of the 16 PAH compounds listed in Category 1 of the WDNR NR 538. The control plot had 8 compounds at or below Category 1 standards. Also, the three plant treatments plots had 8 PAH compounds at or below the Category 2 standards of the WDNR NR 538, with the control plot having 11 compounds at or below the standards. None of the treatments produced concentrations of PCBs of less than 1 mg/kg, and none produced concentrations of DRO of less than 100 mg/kg.

The estimated costs for remediating 1,613 cubic yards (1 acre surface area by 1 foot deep) of dredged material was $47,227 using corn, and $44,280 using willow plants. The costs included equipment costs, direct installation costs, indirect costs, and direct and indirect annual operating costs.

In Situ Bioremediation at the Cleaners #1 Site, Kent, Washington

Site Name: Cleaners #1	**Location:** Kent, Washington
Period of Operation: • In situ bioremediation – First application (injection application): December 15 to18, 1998 – Second application (excavation application): April 21 to 22, 1999 – Third application (injection application): July 21, 2000 • Mechanical soil aeration – April 1999 • Thermal desorption – April 1999	**Cleanup Authority:** State Corrective Action
Purpose/Significance of Application: Full-scale remediation of VOCs in groundwater and soil using in situ bioremediation.	**Cleanup Type:** Full scale
Contaminants: VOCs – PCE, TCE, DCE, and vinyl chloride	**Waste Source:** Dry cleaning facility operations.

Technology:

In Situ Bioremediation

- Hydrogen Release Compound (HRC®) is a proprietary mixture produced by ReGenesis that consists of ammonium chloride, potassium tripolyphosphate, lactic acid, yeast extract, and sodium hydroxide.
- In the first application, HRC® was injected using 55 Geoprobe boreholes over a 2,000 square foot area, and to a depth of 6 to 18 feet below ground surface (bgs). A total of 1,140 pounds (114 gallons) was injected.
- Following soil excavation to repair a leaky sewer pipe, HRC® was applied to the bottom of two excavations to address any remaining soil contamination. A third application (the second injection application of HRC®) was conducted in July 2000.

Mechanical Soil Aeration and Thermal Desorption

- Soils exceeding the state cleanup level of 0.5 milligrams per kilogram (mg/kg) for PCE were mechanically aerated in an on-site treatment cell, which consisted of a plastic liner with straw bale berms.
- Following mechanical soil aeration, these soils were transported off-site for treatment using thermal desorption.

In addition, approximately 80 cubic yards of soil excavated from the area close to the facility contained low levels of PCE (less than 0.5 mg/kg). These soils were also transported off-site for thermal desorption treatment prior to disposal.

Contacts:

State Contact	**Project Manager**	**Technology Vendor**
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Type/Quantity of Media Treated:

Groundwater

- 6 to 18 feet bgs over a 2,000 square foot area

Soil

- 24,000 cubic yards using in situ bioremediation (based on dimensions of injection area)
- 86 cubic yards using ex situ thermal desorption (6 cubic yards also treated by mechanical soil aeration prior to thermal desorption)

Regulatory Requirements/Cleanup Goals:
Groundwater cleanup goals are based on Washington State Model Toxic Control Act standards. Cleanup levels for three contaminants are based on residential use as follows: PCE at 5 micrograms per Liter (ug/L), TCE at 5 ug/L, and vinyl chloride at 0.2 ug/L. Cleanup levels for two other contaminants are based on universal use at all sites: cis-1,2-DCE at 80 ug/L and trans-1,2-DCE at 160 ug/L.

The soil cleanup levels for PCE and TCE are both 0.5 mg/kg.

Results:
In Situ Bioremediation:

Following HRC® injection into the groundwater in December 1998, PCE concentrations increased significantly at MW-1 (from 551 up to 67,000 micrograms per liter [ug/L]) in January, February, and March 1999. This increase was attributed to a leaking sewer pipe that allowed PCE-contaminated sewer effluent to seep into the subsurface. Following excavation activities, samples of remaining soils were collected and the results indicated concentrations below cleanup levels (0.5 mg/kg for PCE and 0.5 mg/kg for TCE). After excavation of soil, repair of sewer pipes, and treatment of soil with HRC® at the bottom of the excavations (second HRC® application), PCE and TCE concentrations in groundwater at MW-1 decreased by approximately 99% and 86%, respectively, but cleanup goals were not achieved. Concentrations of vinyl chloride in MW-1 increased due to increased degradation of cis-1,2-DCE. Samples of soil remaining in the excavations were below cleanup levels.

Following the third HRC® application, PCE, TCE, and DCE achieved cleanup goals. These concentrations decreased by 99.9% to less than 2 ug/L for PCE and TCE, and to 0.24 ug/L for DCE. Vinyl chloride also decreased by 99.9% but exceeded the cleanup level of 0.2 ug/L with a concentration of 0.29 ug/L in June 2004. Based on discussions with the project manager in June 2006, subsequent sampling indicated that concentrations of vinyl chloride were eventually reduced to non-detect levels. However, sampling data from the vendor were not available to verify the statement.

Groundwater samples collected from MW-4, MW-5, and MW-6, which are located further downgradient of MW-3, have not shown detectable concentrations of PCE or PCE-degradation by-products.

Mechanical Soil Aeration:

Laboratory analysis of treated soils indicated PCE concentrations ranging from 0.12 to 0.28 mg/kg prior to soil treatment using thermal desorption.

Costs:
The cost of HRC® was $13,860 for the two injection applications (December 1998 and July 2000).

Description:
Cleaners #1 is an operational dry cleaning facility located in a retail strip mall in Kent, Washington. The facility is approximately 1,600 square feet in area and is surrounded by mixed retail, commercial, and residential properties.

Contamination was first discovered at the facility in August 1998, during a Phase II Environmental Site Assessment (ESA). Interior and exterior soil samples were collected from below the facility floor near the dry cleaning machine, and outside the facility near the rear door. Groundwater samples were collected outside the facility. PCE and TCE were found at concentrations above state cleanup levels in groundwater, and PCE slightly exceeded cleanup levels in exterior soil samples. Interior soil samples showed only trace levels of PCE.

Additional soil sampling conducted in September 1998 from six exterior borings and three interior borings indicated that PCE and TCE concentrations were not detected above state cleanup levels. However, groundwater samples collected from three of the six exterior locations showed PCE above the state cleanup levels, with the highest concentration being closest to the rear door of the facility.

Description (continued):
Enhanced bioremediation using HRC® was used to primarily address groundwater contamination at the site, while also treating some residual soil contamination. Excavated soil was treated using thermal desorption and mechanical soil aeration. After the first round of HRC® injection at the site, PCE concentrations increased. To determine potential sources of the contamination, sampling of sewer effluent being discharged from the facility to the sanitary sewer system was conducted. Results showed that PCE was being discharged from the facility at levels above state cleanup standards through two potential leaks in the sewer pipe. Following this determination, approximately 86 cubic yards of soil were excavated and the pipes were repaired. HRC® was applied to the bottom of each excavation to address any residual soil contamination. Excavated soil was treated on site using mechanical soil aeration followed by off-site thermal desorption prior to off-site disposal. A third application included HRC® injection in July 2000. Subsequent sampling has shown PCE, TCE, DCE, and vinyl chloride at concentrations below state cleanup levels. The State of Washington is anticipating receipt of a No Further Action letter for this site.

In Situ Thermal Desorption at Rocky Mountain Arsenal Hex Pit, Denver, Adams County, Colorado

Site Name: Rocky Mountain Arsenal	**Location:** Denver, Adams County, Colorado
Period of Operation: October 2001 to March 2002	**Cleanup Authority:** • CERCLA - Remedial Action • Record of Decision issued in June 1996 • Technology evaluated under the U.S. Environmental Protection Agency (EPA) Superfund Innovative Technology Evaluation (SITE) program
Purpose/Significance of Application: To evaluate the performance of full-scale application of ISTD to treat soil contaminated with hex and other organochlorine pesticides	**Cleanup Type:** Full scale
Contaminants: Organic pesticides and herbicides (hex, aldrin, chlordane, dieldrin, endrin, and isodrin) Composite soil sample contained the following mean pretreatment contaminant concentrations (expressed in milligrams/kilogram [mg/kg]): hex, 7,600; dieldrin, 3,100; total chlordane, 670; endrin, < 280; isodrin, < 200; and aldrin, < 170.	**Waste Source:** Disposal of distillation products and other residues that were primarily generated during the production of hex, a chemical formerly used in pesticide manufacturing. The waste was disposed in an unlined earthen pit.

Technology:
In Situ Thermal Desorption (ISTD)

- The system design involved a total of 266 thermal wells (210 H-O wells and 56 H-V wells), installed to depths of 12.5 ft below ground surface in a hexagonal arrangement covering an area of 7,194 ft^2
- Dewatering wells were installed several feet below the ISTD thermal well field
- Each thermal well was equipped with an electrical heating element designed to reach maximum temperatures between 1,400 and 1,600 degrees Fahrenheit
- A vacuum pressure of approximately 20 inches of water column was maintained along the boundaries of the treatment area to capture steam and contaminant vapors

The captured off-gas was conveyed to an off-gas treatment system that consisted of a cyclone separator, a flameless thermal oxidizer, a heat exchanger, a knock-out pot, two acid gas dry scrubbers, two activated carbon adsorption beds, and two main process blowers.

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Type/Quantity of Media Treated:
Soil
- The volume of waste in the pit was approximately 3,200 cy, and the waste included solid and semisolid layers of tar-like material

The contaminated portion of the pit extended over an area of approximately 7,000 ft^2 and its depth varied from 8 to 10 ft.

Regulatory Requirements/Cleanup Goals:
- Remediation Goal I: meet or exceed the ROD requirement of 90 percent destruction removal efficiency (DRE) for the six contaminant of concerns (COCs) that include hex, aldrin, dieldrin, endrin, isodrin, and chlordane
- Remediation Goal II: reduce the mean concentration of the six COCs below the ROD human health exceedance criteria

The performance of the technology was also evaluated according to a number of secondary objectives.

Results:
- The ISTD system at the Hex Pit operated for 12 days. The system was shutdown because portions of the aboveground piping had been corroded by hydrochloric acid that was generated during heating of the organochlorine contaminants. Shutdown of the system prevented the evaluation of the effectiveness of the technology at this site.

During operation and post-treatment monitoring, sampling and analysis of air emissions indicated that none of the hourly average air quality standards for off-gas emissions had been exceeded during system operation or during the extended well field cool-down period.

Costs:
The total cost of design and construction of the ISTD system was approximately $1.9 million. Because of the short period of system operation, no operation and maintenance (O&M) costs are available.

Description:
Rocky Mountain Arsenal (RMA) near Denver, Colorado, was established in 1942 as a chemical agent and munitions facility, and was later used in the manufacture of pesticides. The disposal of pesticides in drums that later corroded or ruptured resulted in contamination of soil, surface water, and groundwater at the facility. In 1987, RMA was placed on the National Priorities List. One of the contaminated areas of RMA, the Hex Pit, was an unlined, earthen disposal pit used for the disposal of distillation products that were generated during the production of hex, a chemical formerly used in pesticide manufacturing. In addition, other organochlorine pesticides were disposed of in the pit. The 1996 ROD selected innovative thermal technology for remediation of the Hex Pit. The ROD required the application of specific criteria to evaluate the innovative thermal technology. The criteria included greater than 90 percent DRE for hex, dieldrin, and chlordane, and a cost lower than off-site incineration. Several thermal technologies were evaluated and ISTD was selected as the remedial technology because it could meet the criteria specified in the ROD.

The ISTD system was implemented to treat approximately 3,200 cy of contaminated soil. Installation of the system began in October 2001 and was completed in February 2002. The system design involved a number of H-O wells, H-V extraction wells and dewatering wells. The system was started up on March 3, 2002, and was expected to run for 85 days until the end of May 2002. However, because portions of the aboveground piping became corroded by hydrochloric acid that was generated during heating of the organochlorine contaminants, the system was shut down on March 15, 2002, 12 days after system startup. Following shutdown, the Hex Pit site was buried under approximately 3 ft of imported fill material, and the application was evaluated, and lessons learned noted.

The total cost of design and construction of the ISTD system was approximately $1.9 million. Because of the short period of system operation, no operation and maintenance costs are available.

Pump and Treat and In Situ Bioventing at Onalaska Municipal Landfill Superfund Site, Onalaska, Wisconsin

Site Name:
Onalaska Municipal Landfill Superfund Site

Location:
Onalaska, Wisconsin

Period of Operation:
Groundwater
- Pump and Treat (P&T) – June 1994 through November 2001 [data are available from May 2001 to October/November 2001]
- Monitored Natural Attenuation (MNA) – November 2001 to present [data are available from October 2001 to April 2003]

Soil
- In Situ Bioventing – May 1994 to February 1997

Cleanup Authority:
CERCLA – Remedial Action
ROD Date – August 14, 1990
ESD Dates – September 29, 2000; November 13, 2001
Five-Year Reviews – 1998, 2003

Purpose/Significance of Application:
Full-scale remediation of VOCs, SVOCs, and metals in groundwater and soil using P&T, in situ bioventing, and MNA.

Cleanup Type:
Full scale

Contaminants:
VOCs, SVOCs, and metals
- VOCs (groundwater) – TCE; 1,1-DCA (800 :g/L maximum); 1,1,1-TCA (8 :g/L maximum); 1,1-DCE; 1,2-DCE (27 :g/L maximum); and BTEX.
- SVOCs (soil) – petroleum hydrocarbon solvents, primarily naphtha, at levels as high as 550 mg/kg

Metals (groundwater) – barium, arsenic, iron, manganese, and lead

Waste Source:
Disposal of municipal and chemical wastes in a landfill

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Technology:
Pump and Treat
- Five extraction wells located along the downgradient edge of the landfill with a total design flow rate of 600 to 800 gallons per minute (gpm).
- Treatment system included aeration, clarification, and the addition of sodium hydroxide and polymer for iron removal.
- Air stripping used to remove volatile organic compounds (VOCs).
- Treated water was discharged to the river, and the clarifier sludge was dewatered and disposed in a landfill.
- During its 7.5 years of operation, more than 2 billion gallons of groundwater were extracted and treated.

Monitored Natural Attenuation
- After the P&T system was shut down, MNA was evaluated to address low levels of contamination.
- The monitoring network comprises of 26 monitoring points, including 6 air injection wells, 5 piezometers, 13 monitoring wells, and 2 residential wells.
- Analytes include VOCs; metals; benzene, toluene, ethylbenzene, xylenes (BTEX); naphthalene; and natural attenuation parameters such as oxidation-reduction potential, dissolved oxygen, pH, temperature, and specific conductance.
- Baseline monitoring of natural attenuation was performed in October 2001. The second and third monitoring events occurred in December 2002 and April 2003.

Pump and Treat and In Situ Bioventing at Onalaska Municipal Landfill Superfund Site, Onalaska, Wisconsin (continued)

Contacts (continued):

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State Support Contractor:
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ENSR Corporation
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Phone: (952) 924-0117

Technology (continued):

In Situ Bioventing
- Consisted of injecting air into the area of petroleum nonaqueous phase liquid (NAPL) contamination to stimulate naturally-occurring aerobic microbes and to promote biodegradation of the organic compounds.
- Area of NAPL contamination targeted was 2.5 acres downgradient of the landfill.
- 3- to 5-foot NAPL layer was estimated to be at a depth of 8 to 12 feet below ground surface (bgs).

System consisted of 29 vertical air injection wells (each 2 inches in diameter, installed on 40- to 50-foot centers, and screened within the NAPL layer). The wells were connected by a header piping network to a single aeration well blower and operated between 270 and 320 standard cubic feet per minute (scfm).

Type/Quantity of Media Treated:
Groundwater
- 10 to 70 feet below ground surface (bgs); 2.17 billion gallons of groundwater treated soil
- 11 to 15 feet bgs (quantity of soil treated was not reported)

Regulatory Requirements/Cleanup Goals:
- Estimated cleanup goal was 80 to 95 percent reduction of the organic contaminant mass in the soil (ROD did not establish chemical-specific soil cleanup goals).

In 2000, cleanup goals for groundwater were revised to the current state goals in an explanation of significant differences (ESD).

Results:
P&T
- The P&T system operated at an average extraction rate of 563 gpm.
- By May 2001, concentrations for organic contaminants (except benzene and trimethylbenzene) had decreased to below cleanup goals, based on results for samples collected from 14 wells located on- and off-site. Arsenic, barium, iron, and manganese continued to be detected in groundwater at concentrations above the cleanup goals.
- As of October and November 2001, elevated concentrations of organic contaminants were present, primarily in one well. Trimethylbenzenes were present in two wells, with concentrations as high as 670 µg/L.
- As of November 2001, arsenic, barium, and manganese were present in several monitoring wells at levels as high as 14.9, 997 µg/L, and 3,780 µg/L, respectively.

In Situ Bioventing
- The system operated with an air injection rate of 270 to 320 scfm and targeted 3 separate areas of the site (Areas A, B, and C).
- In situ bioventing resulted in aerobic soil conditions, as evidenced by a steady increase in oxygen concentrations at the site, to levels as high as 21 percent. Carbon dioxide concentrations decreased from an average of 10 percent to less than 1 percent, and average methane concentrations decreased from 1.4 to 0.1 percent.
- The average hydrocarbon degradation rate was estimated to be 1 milligram per kilogram per day (mg/kg/day) in Areas A and B and 0.5 mg/kg/day in Area C.
- The total mass of hydrocarbons removed was estimated to be 7,780 kilograms (kg) from Area A; 11,000 kg from Area B and 1,247 kg from Area C.

Results (continued):

MNA

- The results of the December 2002 and April 2003 sampling events showed that the oxidation-reduction potential (ORP) ranged from 87 to 190 millivolts (mV), indicating that reductive dechlorination may be occurring. Concentrations of dissolved oxygen ranged from 0.23 to 7.07 milligrams per liter (mg/L), indicating aerobic conditions in the groundwater.
- As of April 2003, two organic contaminants, trimethylbenzenes and methylene chloride, remained at concentrations above their respective cleanup goals. In addition, two inorganic compounds, iron and manganese remain at concentrations above their respective cleanup goals.

Monitoring for natural attenuation continues at the site.

Costs:

Operation and maintenance (O&M) costs for the P&T system before the system was shut down (for 1998 through 2001) were about $200,000 per year including groundwater extraction, wastewater treatment plant O&M, sampling and monitoring, monitoring well maintenance, and reporting. After system shutdown, O&M costs were about $60,000 per year for 2002 and 2003.

Description:

The Onalaska Municipal Landfill Superfund Site is located in Onalaska, Wisconsin and was originally used as a sand and gravel quarry from the early to mid-1960s. In the mid-1960s, the Town of Onalaska began using the site as a landfill for both municipal and chemical wastes. Landfill operations stopped in September 1980, and the landfill was capped in June 1982. Subsequent investigations found elevated levels of VOCs and metals in a groundwater plume that extended at least 800 feet from the southwestern edge of the landfill and discharged to nearby wetlands and the adjacent Black River. The aquifer beneath the landfill served as the primary source of drinking water for the residents in the area. In addition, soils above the groundwater table and adjacent to the southwestern edge of the landfill were contaminated with petroleum solvents.

The site was placed on the National Priorities List in September 1984 and remedial investigations were conducted in 1988 and 1989. A record of decision (ROD) was signed in August 1990, which specified a P&T system for groundwater and in situ bioventing for soils. The P&T system operated from June 1994 through November 2001 and was designed to remove VOCs and metals. In situ bioventing operated from May 1994 to February 1997. In 1998, as part of the first 5-year review, EPA concluded that bioventing was no longer affecting biodegradation, and the system was shut down. Based on confirmation of oxygen levels in soil gas, EPA determined that the bioremediation cleanup phase was completed. An ESD was issued in November 2001 that allowed for the temporary shutdown of the P&T system to evaluate the effectiveness of MNA, based on the long-term groundwater monitoring that was being conducted at the site. Monitoring of natural attenuation at the site is ongoing.

Operation and maintenance (O&M) costs for the P&T system before the system was shut down (for 1998 through 2001) were about $200,000 per year including groundwater extraction, wastewater treatment plant O&M, sampling and monitoring, monitoring well maintenance, and reporting. After system shutdown, O&M costs were about $60,000 per year for 2002 and 2003.

Stabilization of Mercury in Waste Material from the Sulfur Bank Mercury Mine, Lake County, California

<table>
<tr><td colspan="2">Site Name:
Sulfur Bank Mercury Mine Superfund Site</td><td>Location:
Lake County, California</td></tr>
<tr><td colspan="2">Period of Operation:
November 15, 2000 to April 29, 2001</td><td>Cleanup Authority:
• EPA’s Superfund Innovative Technology Evaluation (SITE) program
• Mine Waste Technology Program (MWTP)</td></tr>
<tr><td colspan="2">Purpose/Significance of Application:
To determine the effectiveness of three stabilization technologies for immobilizing mercury in waste rock material, thereby reducing leachable mobile mercury in the effluent.</td><td>Cleanup Type:
Bench Scale</td></tr>
<tr><td colspan="2">Contaminants:
Heavy Metals
• Mercury: Mercury concentrations ranged from 312 to 1360 milligrams per kilogram (mg/kg) in the mercury ore and 130 to 447 mg/kg in the waste rock</td><td>Waste Source:
Historic mining activities at the site.</td></tr>
<tr><td>Contacts:

U.S. Environmental Protection Agency Contacts:
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Klean Earth Environmental Company
Amy Anderson
Project Manager
19023 36th Ave. West, Ste. E
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Phone: (425) 778-7165</td><td colspan="2">Technology:
Three stabilization technologies were used for immobilizing mercury in sulfide mine waste materials from the Sulfur Bank Mercury Mine (SBMM) site. The three technologies are listed below:

• ENTHRALL Technology:
– Developed by E & C Williams, Inc.
– Uses inorganic sulfide reagent to target heavy metals. The treatment forms permanent bonds between the reagent surface and heavy metals.
– Used a proprietary sonic drilling rig to inject the reagent. Two rigs were used concurrently to inject the reagent directly into the waste pile at 15-foot intervals.

• KEECO’s Silica Micro Encapsulation (SME) process:
– Developed by Klean Earth Environmental Company (KEECO).
– Encapsulates metal in an impervious microscopic silica matrix, which eliminates the adverse effects of the metal on human health and the environment.
– A modified ex situ process in which material is removed from its location for treatment at an adjacent on-site facility. The material is mixed with the reagent at the on-site facility and then returned to the site where it is replaced and compressed in place.

• Generic Phosphate treatment:
– Forms insoluble phosphate salts containing the contaminant.
– Phosphates stabilize metals by chemically binding them into new stable phosphate phases, such as apatites, and other relatively insoluble phases in the soil.</td></tr>
<tr><td colspan="3">Type/Quantity of Media Treated:
Waste Material (quantity not provided)</td></tr>
</table>

Stabilization of Mercury in Waste Material from the Sulfur Bank Mercury Mine, Lake County, California (continued)

Regulatory Requirements/Cleanup Goals:
To achieve a 90% reduction in the total mass of mercury leached from each treatment (relative to the control) over a 12-week continuous column leaching study.

Results:
E&C William's ENTHRALL Technology:
- The ENTHRALL Technology was not effective in reducing levels of mobile mercury in the mercury ore columns.
- The total mass of mercury in both the particulate and dissolved fractions were similar to the control column.

KEECO's SME Technology:
- The SME process was applied both ex situ and in situ and was effective in reducing mobile mercury (< 25 µm).
- The in situ process reduced leachability by 88% and the ex situ process by 86%, when compared to the control.
- Both the in situ and ex situ treatments achieved a 99% reduction in particulate-associated mercury, relative to the control.
- There was however a significant increase in the mass of mercury in the dissolved fraction (< 0.45 µm). The in situ applications showed a 198% increase in comparison to the control, and the ex situ showed a 238% increase.

Generic Phosphate:
- The phosphate treatment increased the levels of both the particulate and dissolved fractions (< 0.45 µm) over the course of the 12-week study.
- The mass of mercury leached was high during the first two weeks or monitoring.
- The treatment accelerated the breakdown of the mercury ore material matrix and facilitated the release of particulates.
- The rise in leachable mercury invalidates this treatment as a possible remedial alternative for the materials at the SBMM site.

Costs:

E&C William's ENTHRALL Technology:
- Estimated total operating cost for remediating the SBMM piles was $59,807,000. No cost for residual handling was presented because the technology does not produce residuals.
- The largest cost component, the chemical reagents, was $57,008,000 (93.5% of the total cost).
- The second highest cost, equipment, was $1,633,500 (2.7% of the total cost).
- The remediation cost per ton of material is $27.82.

KEECO's SME Technology:
- Estimated total operating cost for remediating the SBMM piles is $35,690,000. No cost for residual handling was presented because the technology does not produce residuals.
- The largest cost component, the chemical reagents, was $26,700,000 (68% of the total cost).
- The KEECO technology requires residual handling, which costs $1,283,000 and constitutes the second highest cost item.
- The remediation cost per ton of material is $16.60.

Generic Phosphate:
- Full-scale treatment costs were not provided. Based on the study results, further experimentation and product modifications are required before the reagent can be considered for use at the SBMM site.

Description:
The Sulfur Bank Mercury Mine (SBMM) Superfund site is located on the south shore of Oaks Arm of Clear Lake, in Lake County, California. SBMM was mined periodically from 1865 to 1957, with open pit mining beginning in 1915. Starting in the late 1920s, heavy earthmoving equipment was used on a large-scale basis, which dramatically increased the environmental impacts of the mining. Various mining activities over the years have deposited large amounts of mercury in the Clear Lake ecosystem.

Two innovative in situ stabilization technologies and one generic phosphate stabilization treatment were evaluated in a treatability study, using material from the SBMM. The two innovative technologies were the ENTHRALL, developed by E & C Williams, Inc., and the Silica Micro Encapsulation (SME) process, developed by the Klean Earth Environmental Company.

The ENTHRALL technology uses an inorganic sulfide reagent, which forms a permanent bond between the reagent and the heavy metals. The reagent is injected using a proprietary sonic drill. The SME process encapsulates the heavy metals in an impervious microscopic silica matrix. The process can be conducted ex situ by first excavating the material and mixing it with the reagent at an adjacent on-site facility. The material is then returned to the site and compressed into place. The generic phosphate treatment stabilizes the heavy metals by chemically binding them into stable phosphate phases, such as apatites, and other relatively insoluble phases in soil.

The ENTHRALL technology was not effective in reducing levels of mobile mercury in the mercury ore columns. The SME process was applied both ex situ and in situ and was effective in reducing mobile mercury. Both the in situ and ex situ treatments achieved a 99% reduction in particulate-associated mercury, relative to the control, but there was a significant increase in the mass of mercury in the dissolved fraction. The phosphate treatment increased the levels of both the particulate and dissolved fractions. The rise in leachable mercury invalidates this treatment as a possible remedial alternative for the materials at the SBMM site.

The estimated total operating cost for the ENTHRALL and SME process technologies were $59,807,000 and $35,690,000, respectively. Residual handling costs were not included in these costs because the technologies do not produce residuals. Full-scale treatment costs were not provided for the generic phosphate treatment.

IN SITU GROUNDWATER TREATMENT ABSTRACTS

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Edible Oil Barriers for Treatment of Perchlorate Contaminated Groundwater

Site Name:
Confidential Site

Location:
Maryland

Period of Operation:
Demonstration was conducted in October 2003. Monitoring lasted for 18 months (from October 2003 to April 2005).

Cleanup Authority:
Field Demonstration

Purpose/Significance of Application:
The primary objective of the project was to evaluate the cost and performance of an EOS® PRB to control the migration of perchlorate plumes at the Site.

Cleanup Type:
Field Demonstration

Contaminants:
Explosives/Propellants, Volatiles-Halogenated:
- Explosives/propellants: perchlorate: 3,100 to 20,000 :g/L; Volatiles-halogenated: 1,1,1-TCA: 5,700 to 17,000 :g/L; 1,1-DCA: 7 to 62 :g/L; chloroethane: <5 to <20 :g/L; 1,1-DCE: 270 to 1,200 :g/L; PCE: 25 to 110 :g/L; TCE: 28 to 210 :g/L; cis-1,2-DCE: 5.5 to 10 :g/L; trans-1,2-DCE: <5 to <20 :g/L; vinyl chloride <5 to <20 :g/L; ethane: 0.16 to 4.28 :g/L; ethene: 0.04 to 1.94 :g/L.

Waste Source:
Former lagoon that received ammonium perchlorate and waste solvent.

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Technology:
Permeable Reactive Barrier:
- The field demonstration consisted of a one-time injection of emulsified oil substrate (EOS®) and chase water to create a 50-ft long permeable reactive barrier (PRB).
- Approximately 110 gallons of EOS® and 2,070 gallons of chase water were injected into the subsurface.
- The PRB was located approximately 50 ft upgradient of an existing interceptor trench.

Groundwater was extracted from the interceptor trench, treated using an air stripper, and re-injected using an upgradient infiltration gallery.

Type/Quantity of Media Treated:
Groundwater:
- The shallow aquifer (5 to 15 ft below ground surface). Approximately 405,000 gallons of groundwater was treated.

Edible Oil Barriers for Treatment of Perchlorate Contaminated Groundwater (continued)

Regulatory Requirements/Cleanup Goals:
National Primary Drinking Water Regulations and the Maryland Department of the Environment Generic Numeric Cleanup Standards for Groundwater. Also, a reduction of perchlorate concentration by 90% was targeted.

Results:
- Perchlorate concentrations were less than 4 :g/L in all of the injection wells within 5 days of injection.
- 18 months after the injection of EOS, the perchlorate removal rates remained greater than 90 percent of the pre-injection levels in the downgradient wells.
- 1,1,1-TCA was reduced 94 to 98% twenty feet downgradient of the barrier.

The average chlorine number was reduced from 3.0 to 1.5, indicating that biodegradation to less chlorinated daughter products was occurring.

Costs:
Costs for installing a full-scale PRB was compared to that of adding an ion exchange unit to an existing pump-and-treat system. The breakdown of costs is as follows:

- Estimated costs for the installation of a full-scale PRB at the site was $38,000, which is equivalent to $19 per square foot of barrier or $0.02 per gallon treated. The estimated capital cost for ion exchange was $50,000 and $17,000 annual O&M.
- The 30-year life cycle costs for installing an emulsified oil PRB are estimated to be $161,400 compared to $383,600 for adding an ion exchange unit to the existing pump-and treat system.

Description:
A permeable reactive barrier (PRB) field demonstration was conducted at a confidential site in Maryland to remediate mixed perchlorate and 1,1,1-trichloroethane (TCA) in a groundwater plume. The demonstration was conducted in 2003 and monitoring was conducted for 18 months.

The demonstration consisted of a one-time injection of EOS® and chase water to create a 50-ft long PRB. The PRB was located about 50 ft upgradient from an existing interceptor trench. Groundwater was extracted from the interceptor trench, treated using air stripping, and then re-injected using an upgradient infiltration gallery.

EOS® injection resulted in substantial reductions in perchlorate and 1,1,1-TCA concentration within and downgradient of the PRB. Costs for the demonstration were not provided but estimated costs for the installation of a full scale PRB at the site were provided. The estimated initial costs for installation were $38,000. The 30-year cycle costs for were estimated to be $161,400.

Nanoscale Zero-Valent Iron Technology for Source Remediation

Site Name:
Multiple (3) Naval Facilities: Hunters Point Shipyard, Naval Air Station Jacksonville, and Naval Air Engineering Station Lakehurst.

Location:
- Hunters Point Shipyard: San Francisco, California
- Naval Air Station Jacksonville: Jacksonville, Florida
- Naval Air Engineering Station Lakehurst: Lakehurst, New Jersey

Period of Operation:
Not Documented

Cleanup Authority:
- Hunters Point Shipyard: Navy
- Naval Air Station Jacksonville: CERCLA
- Naval Air Engineering Station Lakehurst: Navy

Purpose/Significance of Application:
A field demonstration of various NZVI technologies was conducted to determine their effectiveness in treating source areas contaminated primarily with TCE, PCE, DCE, and vinyl chloride.

Cleanup Type:
Field Demonstration

Contaminants:

Hunters Point Shipyard:
- First study (source area, groundwater):
  - Volatiles-Halogenated: TCE (88,000 : g/L, maximum); PCE; cis-1,2-DCE; vinyl chloride; total chlorinated ethenes; chloroform; and carbon tetrachloride.
- Second study (downgradient area, groundwater):
  - Volatiles-Halogenated: TCE; cis-1,2-DCE; vinyl chloride.

Naval Air Station Jacksonville:
- Soil:
  - Volatiles-Halogenated: 1,1,1-TCA (25,300 : g/kg, maximum); PCE (4,360 : g/kg, maximum); and TCE (60,100 : g/kg, maximum).
- Groundwater:
  - Volatiles-Halogenated: PCE (173 : g/L, maximum); TCE (5,520 : g/L, maximum); and cis-1,2-DCE (1,350 : g/L, maximum).

Naval Air Engineering Station Lakehurst:
- Groundwater:
  - Volatiles-Halogenated: PCE; TCE; 1,1,1-TCA; cis-DCE; and vinyl chloride.

Waste Source:
- Hunters Point Shipyard: Leakage from an underground storage tank (UST) and the associated floor drain and underground piping; a grease trap and associated cleanout and underground piping; and five steel dip tanks from a former paint shop.
- Naval Air Station Jacksonville: Leakage from two USTs.
- Naval Air Engineering Station Lakehurst: Not provided.

Contacts:
Not Documented

Technology:

Hunters Point Shipyard:
- Two zero-valent iron (ZVI) injection studies were conducted, one in the source area and the other in the groundwater plume.
- In the first study, 16,000 lbs of micron-sized ZVI powder was mixed with tap water to produce an iron slurry (265 grams per Liter [g/L]). The iron slurry was then injected into the dense non-aqueous phase liquid (DNAPL) source zone by pneumatic fracturing, using nitrogen as the carrier gas.
- In the second study, 72,650 lbs of microscale ZVI was made into a 300 g/L slurry with tap water and was injected into a region of less contamination next to the DNAPL source using pneumatic fracturing.

Technology (continued):

Naval Air Station Jacksonville:

- 300 lbs of bimetallic nanoscale particles (BNP) was mixed with water drawn from an extraction well to produce an iron slurry (4.5 to 10 g/L).
- The slurry was injected into the subsurface by a combination of direct push and closed-loop recirculation wells.
- Injection was conducted first at 10 "hot spot" locations and the recirculation wells were used to distribute the slurry to the rest of the suspected source zone.

Naval Air Engineering Station Lakehurst:

- 300 lbs of BNP was mixed with water drawn from an extraction well and from a fire hydrant to produce a dilute iron slurry (2 g/L).
- The slurry was injected in to the subsurface using direct push technology.
- Injections were done at 10 locations in the Northern Plume and at five locations in the Southern Plume.

Type/Quantity of Media Treated:

- Hunters Point Shipyard: First study, treatment zone covered an area of 1,818 ft^2. Second study, treatment zoned covered an area of approximately 8,700 ft^2.
- Naval Air Station Jacksonville: Groundwater (Quantity not provided).
- Naval Air Engineering Station Lakehurst: Northern groundwater plume – approximately 8,470 ft^2; Southern groundwater plume – approximately 4,350 ft^2.

Regulatory Requirements/Cleanup Goals:

- Hunters Point Shipyard: Not provided.
- Naval Air Station Jacksonville: Reduce the total site contaminated mass by 40 to 50%.
- Naval Air Engineering Station Lakehurst: Not provided.

Results:

Hunters Point Shipyard:

- *First study:*
  - TCE levels declined sharply in all monitoring wells in the treatment zone without any significant formation of cis-1,2-DCE and vinyl chloride.
  - Sharp declines in oxygen-release potential (ORP) and noticeable increases in pH supported the contention that strongly reducing condition suitable for abiotic reduction of CVOCs was created.
  - Pneumatic fracturing combined with liquid atomization injection of the ZVI slurry was successful in distributing ZVI through most of the target treatment zone.
  - Injecting at shallow depths may lead to nitrogen and slurry seeping up to the ground surface.
- *Second study:*
  - TCE and DCE were reduced rapidly in the treatment zone wells.

Naval Air Station Jacksonville:

- Within five weeks after injection, concentrations of parent VOCs were reduced by 65 to 99%.
- ORP reduction was experienced in most of the source zone monitoring wells, indicating that the direct push and recirculation methods of injection worked relatively well.
- The injection did not create the strongly reducing conditions necessary to generate substantial abiotic degradation of TCE.

Naval Air Engineering Station Lakehurst:

- TCE and PCE concentrations were reduced on average by 79% and 83%, respectively.
- The average decrease in total VOC concentrations was 74%.
- Monitoring data was unable to determine what caused reductions in the CVOC concentrations.

Costs:

- *Hunters Point Shipyard:*
  - Total cost for the first study was $289,300. This included costs for mobilization, equipment and supplies (ZVI cost $32,500), labor, drilling services, sampling and analysis including waste disposal, and other miscellaneous costs.
  - For the second study the total cost was $1,390,000. This included $770,000 for materials, equipment, field labor for the injection, and waste characterization and disposal; $452,000 for baseline and post-injection groundwater sampling and analysis; and $168,000 for project management, data management, and reporting.

- *Naval Air Station Jacksonville:*
  - The approximate total cost reported for the field demonstration was $259,000 with an additional $153,000 for administrative tasks such as project management, work plan development, and a bench scale study. The field demonstration total cost included cost from mobilization, monitoring well installation, injection/circulation events (NZVI cost $37,000), sampling and analysis as well as waste disposal, and other miscellaneous costs.

- *Naval Air Engineering Station Lakehurst:*
  - The approximate total cost reported for the field demonstration was $255,500 which included monitoring well installation, baseline sampling, nanoscale iron injection, six-month post injection sampling, and reporting results.

Description:

- *Hunters Point Shipyard:*
  - Hunters Point is situated on a long promontory located in the southeastern portion of San Francisco County and extends eastward into the San Francisco Bay. From 1869 through 1986, it operated as a ship repair, maintenance, and commercial facility. In 1991, the Navy designated Hunters Point for closure under the federal Base Closure and Realignment Act. Hunters Point was divided into six separate geographic parcels (Parcels A through F) to facilitate the closure process. The first and second ZVI demonstrations were performed at Site RU-C4 in Parcel C, which is located in the eastern portion of Hunters Point. The groundwater plume at Site RU-C4 had been contaminated with chlorinated solvents, primarily TCE.
  - The first ZVI injection was conducted in the source area of the contamination. The treatment zone covered an area of 1,818 ft^2. The total cost of the first study was $289,300. The second ZVI injection was conducted in the groundwater plume. The approximate treatment area was 8,700 ft^2. The total cost for the second injection project was $1,390,000.

- *Naval Air Station Jacksonville:*
  - Naval Air Station (NAS) Jacksonville is located in Duval County, Florida and has been used for Navy operations since 1940. The demonstration site, H1K, was located in the interior portion of the facility and contained two USTs. The USTs previously received waste solvents and other substances from a wash rack, manhole and other operations. The tanks and associated pipelines were removed and capped in 1994. Cleanup of H1K is managed under CERCLA, and the groundwater monitoring program is managed under RCRA.
  - In 2000 and 2001, an Interim Remedial Action consisting of chemical oxidation was conducted in the source area. In March 2002, a site characterization sampling effort was performed to redefine the extent of contamination. The horizontal extent of contamination is approximately 1,450 ft^2 with a thickness of 18 ft (saturated zone), resulting in a total volume of 967 cubic yards of soil.
  - Iron slurry was injected into the subsurface by a combination of direct push and closed-loop recirculation wells. Within five weeks after injection, concentrations of parent VOCs were reduced by 65 to 99%. The approximate total cost reported for the field demonstration was $259,000, with an additional $153,000 for administrative tasks.

Description (continued):

- *Naval Air Engineering Station Lakehurst:*
  - Naval Air Engineering Station Lakehurst is located in Jackson and Manchester Townships, Ocean County, New Jersey, 14 miles inland from the Atlantic Ocean. The facility covers 7,383 acres and is within the Pinelands National Reserve.
  - The demonstration project involved two areas with the highest groundwater contaminant concentrations within the northern plume and the southern plume, Areas I and J. The contamination vertically extends 70 ft below the groundwater table. The largest amount of contamination is located in the zone from 45 to 60 ft below the groundwater table.
  - A bench-scale treatability study in 2001 and a pilot test study in 2003 were performed at the facility to evaluate the feasibility of using BNP as an in situ remediation technology to reduce or eliminate the contaminants at Areas I and J. This preliminary testing showed that BNP had the potential to perform better than NZVI without any catalyst coating. 10 injections of BNP were conducted in the northern plume and five injections were conducted in the southern plume. The approximate total cost for the field demonstration was $255,500.

Steam Enhanced Remediation Research for DNAPL in Fractured Rock Loring Air Force Base, Limestone, Maine

Site Name:
Loring Air Force Base

Location:
Limestone, Maine

Period of Operation:
September 1 to November 19, 2002. Post-steam injection monitoring: Spring 2003 to Spring 2004.

Cleanup Authority:
- EPA's Office of Research and Development (ORD) National Risk Management Research Laboratory (NRMRL),
- U.S. EPA Region 1,
- Maine Department of Environmental Protection (MEDEP), the United States Air Force, and EPA's Superfund Innovative Technology Evaluation (SITE) program.

Purpose/Significance of Application:
The main objectives of the study were to:
- Develop an improved understanding of the mechanisms controlling DNAPL and dissolved phased contaminant behavior in fractured bedrock systems;
- Evaluate how a remediation technology could be successfully implemented and controlled in a fractured bedrock environment;
- Reduce the mass of contaminants in the subsurface to reduce the overall remediation timeframe; and
- Evaluate characterization needs for fractured bedrock systems.

Cleanup Type:
Pilot Study

Contaminants:
Volatiles-halogenated: 1,1-dichloroethylene; benzene; chlorobenzene; cis-1,2-dichloroethylene; ethylbenzene; tetrachloroethylene; trans-1,2-dichloroethylene; toluene; trichloroethylene; vinyl Chloride; xylenes (total)

Waste Source:
Past disposal practices of wastes from construction, industrial, and maintenance activities at the Base.

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Technology:
Thermal Treatment (in situ):
- The steam remediation system consisted of a network of vertical wells and borings. 13 boreholes were used as injection or extraction wells and 10 boreholes were used as geophysical and/or temperature monitoring locations.
- Steam was produced in an above ground steam generating unit, which transferred steam using a steam header at 690 kilopascal (kPa) gauge pressure (corresponding to a temperature of 170 ºC).
- Steam injection rates varied from 27 to 508 kilograms per hour (kg/hr).
- At the injection wellhead, steam was reduced to pressures between 200 and 620 kPa (corresponding to 135 to 155 ºC) depending on the depth of delivery.
- Air was injected in order to help develop fractures for improved steam injection rates, to create a buoyant vapor phase, and to assist in vadose zone flushing.
- During operations, a total of 824,000 cubic meters of non-condenseable vapor was extracted.
- Over the course of the test, a total of 739,000 liters of water was extracted as liquid phase.

Contacts (continued):

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Type/Quantity of Media Treated:
Groundwater (quantity not documented).

Regulatory Requirements/Cleanup Goals:
None documented.

Results:
- Based on the limited duration of the project it could not be determined conclusively that steam injection would be capable of heating the entire treatment area to the target temperature.
- The vapor and water treatment system employed by the vendor effectively treated these effluent streams to meet discharge limitations.
- For Steam Enhanced Remediation (SER) to be successful for the remediation of the site, extensive characterization would be needed and extremely long injection times would be required.
- Further research is warranted on steam injection remediation in fractured rock at a less complex site.

Costs:
Not documented.

Description:
The former Loring Air Force Base (AFB) is located in the northeastern portion of Maine, approximately 5 km west of the United States/Canadian border. A quarry at the site, located near the northwestern boundary, had historically been used for the disposal of wastes from construction, industrial, and maintenance activities at the Base. The site was added to the Superfund National Priorities List in 1990. During remedial activities in the 1990s, approximately 450 drums were removed from the quarry. The Record of Decision (ROD), signed in 1999, recognized that it was impractical at the time to restore groundwater in fractured rock to drinking water standards. However, an agreement was made between the Air Force, the MEDEP, and EPA Region 1 to use the quarry to conduct a research project to further develop remediation technologies for fractured bedrock. An evaluation of potential technologies to be tested at the site was issued in 2001, and SER was chosen from the proposals received.

Construction was initiated in August 2002 and extraction began on August 30, 2002. Steam injection was initiated on September 1, 2002, and continued until November 19, 2002, when funding for the project was no longer available. Extraction was terminated on November 26, 2002.

Based on the limited duration of the project, it could not be determined conclusively that steam injection would be capable of heating the entire treatment area to the target temperature. The vapor and water treatment system employed by the vendor effectively treated these effluent streams to meet discharge limitations. It was concluded that for SER to be successful for the remediation of the site, extensive characterization would be needed and extremely long injection times would be required. No cost information was provided.

APPENDIX A

SUMMARY OF 383 CASE STUDIES

Appendix A is only available in the online version of this report and can be downloaded from the Roundtable Web site at: *http://www.frtr.gov.*

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APPENDIX A. SUMMARY OF 383 CASE STUDIES

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
Soil Vapor Extraction (41 Projects)						
Basket Creek Surface Impoundment Site, GA	18	SVE	Soil	TCE; Volatiles-Halogenated; Ketones; Volatiles-Nonhalogenated; Heavy Metals	1992	1997
Camp Lejeune Military Reservation, Site 82, Area A, NC	32	SVE	Soil	BTEX; PCE; TCE; Volatiles-Halogenated; Volatiles-Nonhalogenated	1995	1998
Commencement Bay, South Tacoma Channel Well 12A Superfund Site, WA	45	SVE	Soil; DNAPLs	PCE; TCE; DCE; Volatiles-Halogenated	1992	1995
Davis-Monthan AFB, Site ST-35, AZ	51	SVE	Soil	Petroleum Hydrocarbons; BTEX; Volatiles-Nonhalogenated	1995	1998
Defense Supply Center Richmond, OU 5, VA	52	SVE (Field Demonstration)	Soil	PCE; TCE; Volatiles-Halogenated	1992	1998
East Multnomah County Groundwater Contamination Site, OR	370	SVE; Air Sparging; Pump and Treat	Soil; Groundwater; LNAPLs	PCE; TCE; DCE; Volatiles-Halogenated	1991	2004
Fairchild Semiconductor Corporation Superfund Site, CA	68	SVE	Soil	PCE; DCE; Volatiles-Halogenated; BTEX; Volatiles-Nonhalogenated	1989	1995
Fort Lewis, Landfill 4, WA	84	SVE; Air Sparging	Soil	TCE; DCE; Volatiles-Halogenated; Heavy Metals	1994	1998
Fort Richardson, Building 908 South, AK	88	SVE	Soil	BTEX; Petroleum Hydrocarbons; Volatiles-Nonhalogenated; Volatiles-Halogenated	1995	1998

APPENDIX A. SUMMARY OF 383 CASE STUDIES (continued)

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
Fort Greely, Texas Tower Site, AK	82	SVE; Air Sparging; Bioremediation (*in situ*) Enhanced Bioremediation	Soil; Groundwater	Petroleum Hydrocarbons; BTEX; Volatiles-Nonhalogenated	1994	1998
Hastings Groundwater Contamination Superfund Site, Well Number 3 Subsite, NE	104	SVE	Soil	TCE; Volatiles-Halogenated	1992	1995
Holloman AFB, Sites 2 and 5, NM	108	SVE	Soil	BTEX; Petroleum Hydrocarbons; Volatiles-Nonhalogenated	1994	1998
Intersil/Siemens Superfund Site, CA	117	SVE	Soil	TCE; Volatiles-Halogenated	1988	1998
Luke Air Force Base, North Fire Training Area, AZ	145	SVE	Soil	BTEX; Petroleum Hydrocarbons; Volatiles-Nonhalogenated; Ketones	1990	1995
McClellan Air Force Base, Operable Unit D, Site S, CA	154	SVE (Field Demonstration)	Soil	PCE; TCE; DCE; Volatiles-Halogenated	1993	1995
Multiple (2) Dry Cleaner Sites - *In situ* SVE, Various Locations	366	SVE	Soil; Groundwater	PCE; TCE; DCE; Volatiles-Halogenated; BTEX; Volatiles-Nonhalogenated	1994	2004
Multiple (3) Dry Cleaner Sites - *In Situ* Treatment, Various Locations	363	SVE; Chemical Oxidation/Reduction (*in situ*); Thermal Treatment (*in situ*)	Soil; Groundwater; DNAPLs	PCE; TCE; DCE; Volatiles-Halogenated	2001	2004
Multiple (3) Dry Cleaner Sites - SVE/Air Sparging, Various Locations	317	SVE; Air Sparging	Soil; Groundwater; DNAPLs	PCE; TCE; Volatiles-Halogenated	Various years - starting 1995	2003
Multiple (3) Dry Cleaner Sites - SVE/MNA, Various Locations	320	SVE; Monitored Natural Attenuation; Pump and Treat	Soil; Groundwater	PCE; TCE; DCE; Volatiles-Halogenated	Various years - starting 1996	2003

APPENDIX A. SUMMARY OF 383 CASE STUDIES (continued)

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
Multiple (4) Dry Cleaners - SVE and SVE Used with Other Technologies, Various Locations	365	SVE; Air Sparging; Chemical Oxidation/Reduction (*in situ*); Pump and Treat; Monitored Natural Attenuation; Multi Phase Extraction	Soil; Groundwater; DNAPLs	PCE; TCE; Volatiles-Halogenated; BTEX; Volatiles-Nonhalogenated; Semivolatiles-Nonhalogenated	1997	2004
Multiple (6) Dry Cleaner Sites, Various Locations	345	SVE	Soil; DNAPLs	PCE; TCE; DCE; Volatiles-Halogenated; BTEX; Volatiles-Nonhalogenated	Various years - starting 1992	Various years - 2002, 2003
Multiple (7) Dry Cleaner Sites	176	SVE; Pump and Treat	Soil; DNAPLs	PCE; TCE; DCE; Volatiles-Halogenated	Various years - starting 1998	Various years - 2001, 2002
Multiple (7) Dry Cleaner Sites - P&T/SVE/MPE, Various Locations	349	SVE; Multi Phase Extraction; Pump and Treat	Soil; Groundwater; DNAPLs; Off-gases	PCE; TCE; DCE; Volatiles-Halogenated; BTEX; Volatiles-Nonhalogenated	Various years - starting 1991	Various years - 2002, 2003
Multiple (3) Dry Cleaner Sites, Various Locations	379	SVE	Soil; Groundwater; DNAPLs	DCE; PCE; TCE; Volatiles-Halogenated; BTEX; Volatiles-Nonhalogenated	Various years - starting 1999	2005
NAS North Island, Site 9, CA	183	SVE (Photolytic Destruction) (Field Demonstration)	Soil	PCE; TCE; DCE; BTEX; Volatiles-Nonhalogenated; Volatiles-Halogenated	1997	1998
Patrick Air Force Base, Active Base Exchange Service Station, FL	214	SVE (Biocube™) (Field Demonstration)	Soil	BTEX; Petroleum Hydrocarbons; Volatiles-Nonhalogenated	1994	2000
Patrick Air Force Base, Active Base Exchange Service Station, FL	215	SVE (Internal Combustion Engine) (Field Demonstration)	Soil	BTEX; Petroleum Hydrocarbons; Volatiles-Nonhalogenated	1993	2000

APPENDIX A. SUMMARY OF 383 CASE STUDIES (continued)

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
Rocky Mountain Arsenal Superfund Site (Motor Pool Area - Operable Unit #18), CO	237	SVE	Soil	TCE; Volatiles-Halogenated	1991	1995
Sacramento Army Depot Superfund Site, Tank 2 (Operable Unit #3), CA	241	SVE	Soil	Ketones; BTEX; Volatiles-Nonhalogenated; Volatiles-Halogenated	1992	1995
Sacramento Army Depot Superfund Site, Burn Pits Operable Unit, CA	240	SVE	Soil	PCE; TCE; DCE; Volatiles-Halogenated	1994	1997
Sand Creek Industrial Superfund Site, Operable Unit 1, CO	242	SVE	Soil; LNAPLs	PCE; TCE; Volatiles-Halogenated; Petroleum Hydrocarbons; BTEX; Volatiles-Nonhalogenated	1993	1997
Seymour Recycling Corporation Superfund Site, IN	258	SVE; Containment - Caps; Bioremediation (*in situ*) Enhanced Bioremediation	Soil	PCE; TCE; Volatiles-Halogenated; BTEX; Volatiles-Nonhalogenated	1992	1998
Shaw AFB, OU 1, SC	261	SVE; Free Product Recovery	Soil; Groundwater; LNAPLs	BTEX; Petroleum Hydrocarbons; Volatiles-Nonhalogenated	1995	1998
SMS Instruments Superfund Site, NY	264	SVE	Soil	Volatiles-Halogenated; BTEX; Volatiles-Nonhalogenated; Semivolatiles-Halogenated; Semivolatiles-Nonhalogenated	1992	1995
Stamina Mills Superfund Site, RI	273	SVE; Multi Phase Extraction (Field Demonstration)	Soil; Off-gases	TCE; Volatiles-Halogenated	1999	2001
Tyson's Dump Superfund Site, PA	285	SVE	Soil	PCE; TCE; DCE; Volatiles-Halogenated	1988	1998

APPENDIX A. SUMMARY OF 383 CASE STUDIES (continued)

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
U.S. Department of Energy, Portsmouth Gaseous Diffusion Plant, OH	292	SVE; Chemical Oxidation/Reduction (*in situ*); Solidification/Stabilization; Thermal Treatment (*in situ*) (Field Demonstration)	Soil	TCE; DCE; Volatiles-Halogenated	1992	1997
U.S. Department of Energy, Savannah River Site, SC	295	SVE (Flameless Thermal Oxidation) (Field Demonstration)	Soil; Off-gases	PCE; TCE; Volatiles-Halogenated	1995	1997
U.S. Department of Energy, Savannah River Site, SC, and Sandia, NM	251	SVE; In-Well Air Stripping; Bioremediation (*in situ*) ALL; Drilling (Field Demonstration)	Soil; Groundwater	Volatiles-Halogenated	1988	2000
Vandenberg Air Force Base, Base Exchange Service Station, CA	306	SVE (Resin Adsorption) (Field Demonstration)	Soil	BTEX; Petroleum Hydrocarbons; Volatiles-Nonhalogenated	1994	2000
Verona Well Field Superfund Site (Thomas Solvent Raymond Road - Operable Unit #1), MI	307	SVE	Soil Light Non-aqueous Phase Liquids	Ketones; BTEX; Volatiles-Nonhalogenated; PCE; Volatiles-Halogenated	1988	1995
Other *In Situ* Soil/Sediment Treatment (49 Projects)						
Alameda Point, CA	5	Electrokinetics(Field Demonstration)	Soil	Heavy Metals	1997	2001
Argonne National Laboratory-East, 317/319 Area, Argonne, IL	390	Phytoremediation	Soil; Groundwater	BTEX; Volatiles-Nonhalogenated; Volatiles-Halogenated; Semivolatile-Halogenated	1999	2006
Argonne National Laboratory - West, Waste Area Group 9, OU 9-04, ID	12	Phytoremediation(Field Demonstration)	Soil	Heavy Metals	1998	2000

APPENDIX A. SUMMARY OF 383 CASE STUDIES (continued)

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
Avery Dennison, IL	329	Thermal Treatment (*in situ*)	Soil; DNAPLs	Volatiles-Halogenated	1999	2003
Beach Haven Substation, Pensacola, FL	20	Electrokinetics (Field Demonstration)	Soil	Arsenic	1998	2000
Brodhead Creek Superfund Site, PA	24	Thermal Treatment (*in situ*)	Soil; DNAPLs	PAHs; Semivolatiles-Nonhalogenated; BTEX; Volatiles-Nonhalogenated; Arsenic	1995	1998
California Gulch Superfund Site, OU 11, CO	373	Solidification/Stabilization (Field Demonstration)	Soil	Heavy Metals	1998	2005
Castle Airport and Various Sites, CA	361	Bioremediation (*in situ*) Bioventing (Field Demonstration)	Soil	Petroleum Hydrocarbons; BTEX; Volatiles-Nonhalogenated;	1998	2004
Castle Airport, CA	35	Bioremediation (*in situ*) Bioventing (Field Demonstration)	Soil	BTEX; Volatiles-Nonhalogenated	1998	1999
Cleaners #1, Kent, WA	394	Bioremediation (*in situ*) Enhanced Bioremediation, Thermal Desorption (*ex situ*)	Soil, Groundwater	DCE; PCE; TCE; Volatiles-Halogenated	1998	2006
Confidential Chemical Manufacturing Facility, IN	330	Thermal Treatment (*in situ*)	Soil; DNAPLs; Off-gases	PCE; TCE; DCE; Volatiles-Halogenated	1997	2003
Crooksville/Roseville Pottery Area of Concern (CRPAC), OH	327	Solidification/Stabilization (Field Demonstration)	Soil	Heavy Metals	1998	2002
Dover Air Force Base, Building 719, DE	57	Bioremediation (*in situ*) Bioventing (Field Demonstration)	Soil	TCE; DCE; Volatiles-Halogenated	1998	2000
Eielson Air Force Base, AK	64	Bioremediation (*in situ*) Bioventing (Field Demonstration)	Soil	Petroleum Hydrocarbons; BTEX; Volatiles-Nonhalogenated	1991	1995

APPENDIX A. SUMMARY OF 383 CASE STUDIES (continued)

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
Ensign-Bickford Company - OB/OD Area, CT	66	Phytoremediation	Soil	Heavy Metals	1998	2000
Former Mare Island Naval Shipyard, CA	75	Thermal Treatment (*in situ*) (Field Demonstration)	Soil	PCBs; Semivolatiles-Halogenated	1997	2000
Fort Richardson Poleline Road Disposal Area, OU B, AK	89	Thermal Treatment (*in situ*); SVE (Field Demonstration)	Soil	PCE; TCE; Volatiles-Halogenated	1997	2000
Frontier Hard Chrome Superfund Site, WA	381	Chemical Oxidation/Reduction (*in situ*)	Soil; Groundwater	Heavy Metals	2003	2005
Hill Air Force Base, Site 280, UT	106	Bioremediation (*in situ*) Bioventing	Soil	BTEX; Petroleum Hydrocarbons; Volatiles-Nonhalogenated	1990	1995
Hill Air Force Base, Site 914, UT	107	Bioremediation (*in situ*) Bioventing; SVE	Soil	Petroleum Hydrocarbons; BTEX; Volatiles-Nonhalogenated	1988	1995
Hunter Army Airfield, Former Pumphouse #2, GA	382	Thermal Treatment (*in situ*)	Soil; Groundwater; LNAPLs	BTEX; Petroleum Hydrocarbons; Volatiles-Nonhalogenated PAHs; Semivolatiles-Nonhalogenated	2002	2005
Idaho National Engineering and Environmental Laboratory, ID	114	Bioremediation (*in situ*) Bioventing (Field Demonstration)	Soil	Volatiles-Halogenated	1996	2000
Jones Island Confined Disposal Facility, Milwaukee, WI	393	Phytoremediation (Field Demonstration)	Sediment	PCBs; PAHs; Petroleum Hydrocarbons	2001	2006
Koppers Co. (Charleston Plant) Ashley River Superfund Site, SC	350	Solidification/Stabilization	Sediment; DNAPLs	PAHs; Semivolatiles-Nonhalogenated	2001	2006
Lowry Air Force Base, CO	143	Bioremediation (*in situ*) Bioventing	Soil	BTEX; Petroleum Hydrocarbons; Volatiles-Nonhalogenated	1992	1995

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
Magic Marker, NJ and Small Arms Firing Range (SAFR) 24, NJ	146	Phytoremediation (Field Demonstration)	Soil	Heavy Metals	Magic Marker - 1997; Fort Dix - 2000	2002
Missouri Electric Works Superfund Site, MO	160	Thermal Treatment (*in situ*) (Field Demonstration)	Soil	PCBs; Semivolatiles-Halogenated	1997	1998
Morses Pond Culvert, MA	351	Chemical Oxidation/Reduction (*in situ*)	Soil	Heavy Metals	2001	2004
Multiple Air Force Test Sites, Multiple Locations	180	Bioremediation (*in situ*) Bioventing (Field Demonstration)	Soil	BTEX; Petroleum Hydrocarbons; Volatiles-Nonhalogenated	1992	2000
Multiple (4) Dry Cleaner Sites - In Situ Chemical Oxidation, Various Locations	380	Chemical Oxidation/Reduction (*in situ*)	Soil; Groundwater	DCE; PCE; TCE; Volatiles-Halogenated BTEX; Volatiles-Nonhalogenated Semivolatiles-Nonhalogenated	Various years-starting 1999	2005
Multiple (3) POL-Contaminated Sites, AK	376	Phytoremediation; Bioremediation (*in situ*) (Field Demonstration)	Soil	BTEX; Petroleum Hydrocarbons; Volatiles-Nonhalogenated PAHs; Semivolatiles-Nonhalogenated; PCE; Volatiles-Halogenated; Heavy Metals	Various years - starting 1998	2005
Naval Air Weapons Station Point Mugu Site 5, CA (USAEC)	188	Electrokinetics (Field Demonstration)	Soil; Sediment	Heavy Metals	1998	2000
Naval Air Weapons Station Point Mugu Site 5, CA (USEPA)	189	Electrokinetics (Field Demonstration)	Soil	Heavy Metals	1998	2000

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
Onalaska Municipal Landfill Superfund Site, Onalaska, WI	387	Bioremediation (*in situ*) Bioventing, Pump and Treat, Monitored Natural Attenuation	Soil; Groundwater	BTEX; DCE; Heavy Metals; Petroleum Hydrocarbons; Semivolatiles-Nonhalogenated; PCE; TCE; Volatiles-Halogenated	1994	2006
Paducah Gaseous Diffusion Plant (PGDP) Superfund Site, KY	328	Lasagna™	Soil	TCE; Volatiles-Halogenated	1999	2002
Parsons Chemical/ETM Enterprises Superfund Site, MI	212	Vitrification (*in situ*)	Soil; Sediment	Pesticides/Herbicides; Semivolatiles-Halogenated; Heavy Metals; Dioxins/Furans	1993	1997
Portsmouth Gaseous Diffusion Plant, X-231A Site, Piketon, OH	225	Fracturing (Field Demonstration)	Soil; Groundwater	TCE; Volatiles-Halogenated	1996	2001
Rocky Mountain Arsenal Superfund Site, Denver, CO	386	Thermal Treatment (*in situ*)	Soil	Pesticides/Herbicides; Semivolatiles-Halogenated	2001	2006
Sandia National Laboratories, Unlined Chromic Acid Pit, NM	246	Electrokinetics (Field Demonstration)	Soil	Heavy Metals	1996	2000
Savannah River Site 321-M Solvent Storage Tank Area, GA	337	Thermal Treatment (*in situ*) (Field Demonstration)	Soil; DNAPLs	PCE; TCE; Volatiles-Halogenated	2000	2003
Sulfur Bank Mercury Mine Superfund Site	391	Solidification/Stabilization (Bench Scale)	Soil	Heavy Metals	2000	2006
Twin Cities Army Ammunition Plant, MN	283	Phytoremediation (Field Demonstration)	Soil	Heavy Metals; Arsenic	1998	2000
U.S. Department of Energy, Savannah River Site, SC, and Hanford Site, WA	296	Thermal Treatment (*in situ*) (Field Demonstration)	Soil; Sediment	PCE; TCE; Volatiles-Halogenated	1993	1997
U.S. Department of Energy, Paducah Gaseous Diffusion Plant, KY	291	Lasagna™ (Field Demonstration)	Soil; Groundwater	TCE; Volatiles-Halogenated	1995	1997

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
U.S. Department of Energy, Portsmouth Gaseous Diffusion Plant, OH and Other Sites	293	Fracturing (Field Demonstration)	Soil; Groundwater; DNAPLs	TCE; Volatiles-Halogenated	1991	1997
U.S. Department of Energy, Multiple Sites	288	Drilling (Field Demonstration)	Soil; Sediment	-	1992	1997
U.S. Department of Energy, Hanford Site, WA, Oak Ridge (TN) and Others	289	Vitrification (*in situ*)	Soil; Sludge; Debris/Slag/ Solid	Pesticides/Herbicides; Heavy Metals; Arsenic; Dioxins/Furans; Semivolatiles-Halogenated PCBs; Radioactive Metals	Not Provided	1997
White Sands Missile Range, SWMU 143, NM	313	Chemical Oxidation/Reduction (*in situ*) (Field Demonstration)	Soil	Heavy Metals	1998	2000
Young-Rainy Star Center (formerly Pinellas) Northeast Area A, FL	355	Thermal Treatment (*in situ*)	Soil; Groundwater	BTEX; Petroleum Hydrocarbons; Volatiles-Nonhalogenated DCE; PCE; TCE; Volatiles-Halogenated	2002	2004
Incineration (on-site) (18 Projects)						
Baird and McGuire, MA	15	Incineration (on-site)	Soil; Sediment	Dioxins/Furans; Semivolatiles-Halogenated; PAHs; Semivolatiles-Nonhalogenated; Arsenic; Heavy Metals; Volatiles-Halogenated	1995	1998
Bayou Bonfouca, LA	19	Incineration (on-site)	Soil; Sediment	PAHs; Semivolatiles-Nonhalogenated	1993	1998

APPENDIX A. SUMMARY OF 383 CASE STUDIES (continued)

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
Bridgeport Refinery and Oil Services, NJ	23	Incineration (on-site)	Soil; Debris/Slag/ Solid; Sediment; Organic Liquids; Sludge	PCBs; Semivolatiles-Halogenated; BTEX; Volatiles-Nonhalogenated; Heavy Metals; Volatiles-Halogenated	1991	1998
Celanese Corporation Shelby Fiber Operations, NC	36	Incineration (on-site)	Soil; Sludge	PAHs; Semivolatiles-Nonhalogenated; TCE; Volatiles-Halogenated; Volatiles-Nonhalogenated; Heavy Metals; BTEX	1991	1998
Coal Creek, WA	43	Incineration (on-site)	Soil	PCBs; Semivolatiles-Halogenated; Heavy Metals	1994	1998
Drake Chemical Superfund Site, Operable Unit 3, Lock Haven, PA	59	Incineration (on-site)	Soil	Volatiles-Halogenated; BTEX; Volatiles-Nonhalogenated; Semivolatiles-Halogenated; Semivolatiles-Nonhalogenated	1998	2001
FMC Corporation - Yakima, WA	72	Incineration (on-site)	Soil; Debris/Slag/ Solid	Pesticides/Herbicides; Semivolatiles-Halogenated; Heavy Metals	1993	1998
Former Nebraska Ordnance Plant - OU 1, NE	76	Incineration (on-site)	Soil; Debris/Slag/ Solid	Explosives/Propellants	1997	1998

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
Former Weldon Springs Ordnance Works, OU 1, MO	79	Incineration (on-site)	Soil; Debris/Slag/ Solid	Explosives/Propellants; Heavy Metals; PCBs; Semivolatiles-Halogenated; PAHs; Semivolatiles-Nonhalogenated	1998	2000
MOTCO, TX	165	Incineration (on-site)	Soil; Sludge; Organic Liquids	PCBs; Semivolatiles-Nonhalogenated; Heavy Metals; Volatiles-Halogenated; BTEX; Volatiles-Nonhalogenated	1990	1998
Old Midland Products, AR	206	Incineration (on-site)	Soil; Sludge	Semivolatiles-Halogenated; PAHs; Semivolatiles-Nonhalogenated; Volatiles-Nonhalogenated; Volatiles-Halogenated	1992	1998
Petro Processors, LA	217	Incineration (on-site)	Soil; Organic Liquids; DNAPLs	PAHs; Semivolatiles-Nonhalogenated; Heavy Metals; Volatiles-Halogenated	1994	1998
Rocky Mountain Arsenal, CO	236	Incineration (on-site)	Soil; Organic Liquids	Pesticides/Herbicides; Heavy Metals; Arsenic	1993	1998
Rose Disposal Pit, MA	238	Incineration (on-site)	Soil	PCBs; Semivolatiles-Halogenated; TCE; Volatiles-Halogenated; Volatiles-Nonhalogenated	1994	1998

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
Rose Township Dump, MI	239	Incineration (on-site)	Soil	PCBs; Semivolatiles-Halogenated; Heavy Metals; BTEX; Volatiles-Nonhalogenated; Semivolatiles-Nonhalogenated; PAHs; Ketones	1992	1998
Sikes Disposal Pits, TX	262	Incineration (on-site)	Soil; Debris/Slag/Solid	PAHs; Semivolatiles-Nonhalogenated; Volatiles-Halogenated; BTEX; Volatiles-Nonhalogenated	1992	1998
Times Beach, MO	280	Incineration (on-site)	Soil; Debris/Slag/Solid	Dioxins/Furans; Semivolatiles-Halogenated	1996	1998
Vertac Chemical Corporation, AR	308	Incineration (on-site)	Soil; Debris/Slag/Solid; Organic Liquids	Dioxins/Furans; Semivolatiles-Halogenated; Volatiles-Halogenated; BTEX; Volatiles-Nonhalogenated	1992	1998
Thermal Desorption (30 Projects)						
Anderson Development Company Superfund Site, MI	8	Thermal Desorption (*ex situ*)	Soil; Sludge	PAHs; Semivolatiles-Nonhalogenated; Volatiles-Halogenated; BTEX; Volatiles-Nonhalogenated; Heavy Metals	1992	1995

APPENDIX A. SUMMARY OF 383 CASE STUDIES (continued)

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
Arlington Blending and Packaging Superfund Site, TN	13	Thermal Desorption (*ex situ*)	Soil	Pesticides/Herbicides; Semivolatiles-Halogenated; Arsenic	1996	2000
Brookhaven National Laboratory(BNL), NY	325	Thermal Desorption (*ex situ*) (Field Demonstration)	Soil	Heavy Metals	Not provided	2002
Cape Fear Superfund Site, NC	33	Thermal Desorption (*ex situ*)	Soil	PAHs; Semivolatiles-Nonhalogenated; Arsenic; Heavy Metals; Volatiles-Nonhalogenated; BTEX	1998	2002
FCX Washington Superfund Site, NC	69	Thermal Desorption (*ex situ*)	Soil	Pesticides/Herbicides; Semivolatiles-Halogenated	1995	1998
Fort Lewis, Solvent Refined Coal Pilot Plant (SRCPP), WA	86	Thermal Desorption (*ex situ*)	Soil	PAHs; Semivolatiles-Nonhalogenated	1996	1998
Fort Ord, CA	354	Thermal Desorption (*ex situ*) (Field Demonstration)	Debris/Slag/Solid; Off-gas	Heavy Metals	2002	2004
Industrial Latex Superfund Site, NJ	348	Thermal Desorption (*ex situ*)	Soil; Off-gases	Pesticides/Herbicides; Semivolatiles-Halogenated; PAHs; PCBs; Arsenic	1999	2002
Letterkenny Army Depot Superfund Site, K Areas, OU1, PA	135	Thermal Desorption (*ex situ*)	Soil	TCE; Volatiles-Halogenated; Heavy Metals	1993	2000
Lipari Landfill, Operable Unit 3, NJ	137	Thermal Desorption (*ex situ*)	Soil	TCE; Volatiles-Halogenated; BTEX; Volatiles-Nonhalogenated; Arsenic; Heavy Metals; Semivolatiles-Halogenated; Semivolatiles-Nonhalogenated	1994	2002

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
Longhorn Army Ammunition Plant, Burning Ground No. 3, TX	138	Thermal Desorption (*ex situ*)	Soil	TCE; Volatiles-Halogenated	1997	2000
McKin Superfund Site, ME	155	Thermal Desorption (*ex situ*)	Soil	BTEX; Volatiles-Nonhalogenated; PAHs; Semivolatiles-Nonhalogenated	1986	1995
Metaltec/Aerosystems Superfund Site, Franklin Borough, NJ	156	Thermal Desorption (*ex situ*)	Soil	TCE; DCE; Volatiles-Halogenated; Heavy Metals	1994	2001
Naval Air Station Cecil Field, Site 17, OU 2, FL	182	Thermal Desorption (*ex situ*)	Soil	BTEX; Volatiles-Nonhalogenated; Volatiles-Halogenated	1995	1998
New Bedford Harbor Superfund Site, New Bedford, MA	197	Thermal Desorption (*ex situ*) (Field Demonstration)	Sediment	PCBs; Semivolatiles-Halogenated	1996	2001
Outboard Marine Corporation Superfund Site, OH	209	Thermal Desorption (*ex situ*)	Soil; Sediment	PCBs; Semivolatiles-Halogenated	1992	1995
Port Moller Radio Relay Station, AK	223	Thermal Desorption (*ex situ*)	Soil	BTEX; Petroleum Hydrocarbons; Volatiles-Nonhalogenated	1995	1998
Pristine, Inc. Superfund Site, OH	227	Thermal Desorption (*ex situ*)	Soil	Pesticides/Herbicides; PAHs; Semivolatiles-Nonhalogenated; Heavy Metals	1993	1995
Re-Solve, Inc. Superfund Site, MA	230	Thermal Desorption (*ex situ*)	Soil	PCBs; Semivolatiles-Halogenated; Ketones; BTEX; Volatiles-Nonhalogenated; TCE; Volatiles-Halogenated	1993	1998

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
Reich Farm, Pleasant Plains, NJ	228	Thermal Desorption (*ex situ*)	Soil	Volatiles-Halogenated; Volatiles-Nonhalogenated; Semivolatiles-Halogenated; Semivolatiles-Nonhalogenated	1994	2001
Reilly Industries Superfund Site, Operable Unit 3, IN	229	Thermal Desorption (*ex situ*)	Soil	PAHs; Semivolatiles-Nonhalogenated; BTEX; Volatiles-Nonhalogenated	1996	2002
Rocky Flats Environmental Technology Site, Mound Site, Golden, CO	234	Thermal Desorption (*ex situ*)	Soil	PCE; TCE; Volatiles-Halogenated	1997	2001
Rocky Flats Environmental Technology Site, Trenches T-3 and T-4, CO	235	Thermal Desorption (*ex situ*)	Soil; Debris/Slag/ Solid	TCE; Volatiles-Halogenated; Ketones; BTEX; Volatiles-Nonhalogenated; Radioactive Metals	1996	2000
Sand Creek Superfund Site, OU 5, CO	243	Thermal Desorption (*ex situ*)	Soil	Pesticides/Herbicides; Arsenic	1994	2000
Sarney Farm, Amenia, NY	248	Thermal Desorption (*ex situ*)	Soil	TCE; DCE; Volatiles-Halogenated; Ketones; BTEX; Volatiles-Nonhalogenated	1997	2001
Site B (actual site name confidential), Western United States	333	Thermal Desorption (*ex situ*)	Soil; Off-gases	Pesticides/Herbicides; Semivolatiles- Halogenated; Semivolatiles-Nonhalogenated	1995	2003
TH Agriculture & Nutrition Company Superfund Site, GA	277	Thermal Desorption (*ex situ*)	Soil	Pesticides/Herbicides	1993	1995

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
Waldick Aerospaces Devices Superfund Site, NJ	310	Thermal Desorption (*ex situ*)	Soil	BTEX; Petroleum Hydrocarbons; Volatiles-Nonhalogenated; PCE; Volatiles-Halogenated; Heavy Metals	1993	1998
Wide Beach Development Superfund Site, NY	314	Thermal Desorption (*ex situ*); Chemical Oxidation/Reduction (*ex situ*)	Soil	Semivolatiles-Halogenated; PCBs	1990	1995
TH Agriculture and Nutrition Site, OU2, GA	374	Thermal Desorption (*ex situ*)	Soil	Pesticides/Herbicides; Semivolatiles- Halogenated; Semivolatiles-Nonhalogenated	1999	2005
Other *Ex Situ* Soil/Sediment Treatment (33 Projects)						
Bonneville Power Administration Ross Complex, Operable Unit A, WA	22	Bioremediation (*ex situ*) Land Treatment	Soil	PAHs; Semivolatiles-Nonhalogenated; Semivolatiles-Halogenated	1994	1998
Brookhaven National Laboratory, NY	25	Physical Separation	Soil	Radioactive Metals	2000	2001
Brown Wood Preserving Superfund Site, FL	27	Bioremediation (*ex situ*) Land Treatment	Soil	PAHs; Semivolatiles-Nonhalogenated	1989	1995
Burlington Northern Superfund Site, MN	29	Bioremediation (*ex situ*) Land Treatment	Soil; Sludge	PAHs; Semivolatiles-Nonhalogenated	1986	1997
Dubose Oil Products Co. Superfund Site, FL	60	Bioremediation (*ex situ*) Composting	Soil	PAHs; Semivolatiles-Nonhalogenated; BTEX; Volatiles-Nonhalogenated; Semivolatiles-Halogenated	1993	1997

APPENDIX A. SUMMARY OF 383 CASE STUDIES (continued)

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
Fort Polk Range 5, LA	87	Acid Leaching; Physical Separation(Field Demonstration)	Soil	Heavy Metals	1996	2000
Fort Greely, UST Soil Pile, AK	83	Bioremediation (*ex situ*) Land Treatment	Soil	BTEX; Volatiles-Nonhalogenated; Semivolatiles-Halogenated	1994	1998
French Ltd. Superfund Site, TX	91	Bioremediation (*ex situ*) Slurry Phase	Soil; Sludge	PAHs; Semivolatiles-Nonhalogenated; Volatiles-Halogenated; PCBs; Semivolatiles-Halogenated; Arsenic; Heavy Metals	1992	1995
Hazen Research Center and Minergy GlassPack Test Center, WI	358	Vitrification (*ex situ*) (Field Demonstration)	Sediment	PCBs; Dioxins/Furans; Semivolatiles-Halogenated; Heavy Metals	2001	2004
Idaho National Environmental and Engineering Laboratory (INEEL), ID	116	Physical Separation	Soil	Radioactive Metals	1999	2001
Joliet Army Ammunition Plant, IL	121	Bioremediation (*ex situ*) Slurry Phase (Field Demonstration)	Soil	Explosives/Propellants	1994	2000
King of Prussia Technical Corporation Superfund Site, NJ	125	Soil Washing	Soil; Sludge	Heavy Metals	1993	1995
Los Alamos National Laboratory, NM	141	Physical Separation	Soil; Debris/Slag/Solid	Radioactive Metals	1999	2000
Lowry Air Force Base, CO	144	Bioremediation (*ex situ*) Land Treatment	Soil	BTEX; Petroleum Hydrocarbons; Volatiles-Nonhalogenated	1992	1995

APPENDIX A. SUMMARY OF 383 CASE STUDIES (continued)

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
Massachusetts Military Reservation, Training Range and Impact Area, Cape Cod, MA	152	Solidification/Stabilization	Soil	Heavy Metals	1998	2001
Naval Construction Battalion Center Hydrocarbon National Test Site, CA	190	Bioremediation (*ex situ*) Composting (Field Demonstration)	Soil	Petroleum Hydrocarbons; BTEX; Volatiles-Nonhalogenated	1996	1998
New Bedford Harbor Superfund Site, New Bedford, MA	198	Vitrification (*ex situ*) (Field Demonstration)	Sediment	PCBs; Semivolatiles-Halogenated	1996	2001
New Bedford Harbor Superfund Site, New Bedford, MA	195	Solidification/Stabilization (Field Demonstration)	Sediment	PCBs; Semivolatiles-Halogenated	1995	2001
New Bedford Harbor Superfund Site, New Bedford, MA	196	Solvent Extraction (*ex situ*) (Field Demonstration)	Sediment	PCBs; Semivolatiles-Halogenated	1996	2001
Novartis Site, Ontario, Canada	199	Bioremediation (*ex situ*) Land Treatment (Field Demonstration)	Soil	Pesticides/Herbicides; Semivolatiles-Halogenated	1996	1998
Oak Ridge National Laboratory, TN	201	Vitrification (*ex situ*) (Field Demonstration)	Sludge	Heavy Metals; Radioactive Metals	1997	2000
Pantex Plant, Firing Site 5, TX	211	Physical Separation	Soil; Debris/Slag/ Solid	Radioactive Metals	1998	2000
Peerless Cleaners, WI; Stannard Launders and Dry Cleaners, WI	216	Bioremediation (*ex situ*) Composting	Soil	PCE; TCE; DCE; Volatiles-Halogenated; Semivolatiles-Nonhalogenated	Not Provided	2001
RMI Titanium Company Extrusion Plant, OH	231	Solvent Extraction (*ex situ*)(Field Demonstration)	Soil	Radioactive Metals	1997	2000
Sandia National Laboratories, ER Site 16, NM	245	Physical Separation	Soil	Radioactive Metals	1998	2000
Sandia National Laboratories, ER Site 228A, NM	244	Physical Separation	Soil	Radioactive Metals	1998	2000

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
Scott Lumber Company Superfund Site, MO	254	Bioremediation (*ex situ*) Land Treatment	Soil	PAHs; Semivolatiles-Nonhalogenated	1989	1995
Southeastern Wood Preserving Superfund Site, MS	270	Bioremediation (*ex situ*) Slurry Phase	Soil; Sludge	PAHs; Semivolatiles-Nonhalogenated	1991	1997
Sparrevohn Long Range Radar Station, AK	272	Solvent Extraction (*ex situ*)	Soil	PCBs; Semivolatiles-Halogenated	1996	1998
Stauffer Chemical Company, Tampa, FL	275	Bioremediation (*ex situ*) Composting (Field Demonstration)	Soil	Pesticides/Herbicides	1997	2001
Tonapah Test Range, Clean Slate 2, NV	282	Physical Separation	Soil; Debris/Slag/ Solid	Radioactive Metals	1998	2000
Umatilla Army Depot Activity, OR	300	Bioremediation (*ex situ*) Composting (Field Demonstration)	Soil	Explosives/Propellants	1992	1995
Umatilla Army Depot Activity, OR	301	Bioremediation (*ex situ*) Composting	Soil	Explosives/Propellants	1994	1997
Pump and Treat (50 Projects)						
Amoco Petroleum Pipeline, MI	7	Pump and Treat; Air Sparging	Groundwater; LNAPLs	BTEX; Volatiles-Nonhalogenated	1988	1995
Baird and McGuire Superfund Site, MA	16	Pump and Treat	Groundwater	BTEX; Volatiles-Nonhalogenated; PAHs; Semivolatiles-Nonhalogenated; Pesticides/Herbicides; Semivolatiles-Halogenated	1993	1998

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
Bofors Nobel Superfund Site, OU 1, MI	21	Pump and Treat	Groundwater	BTEX; Volatiles-Nonhalogenated; Semivolatiles-Halogenated; Volatiles-Halogenated; Semivolatiles-Nonhalogenated	1994	1998
Charnock Wellfield, Santa Monica, CA	37	Pump and Treat; Chemical Oxidation/Reduction (*ex situ*)(Field Demonstration)	Drinking Water	MTBE; Volatiles-Nonhalogenated	1998	2001
City Industries Superfund Site, FL	41	Pump and Treat	Groundwater	BTEX; Volatiles-Nonhalogenated; Volatiles-Halogenated; Ketones; Semivolatiles-Nonhalogenated	1994	1998
Coastal Systems Station, AOC 1, FL	44	Pump and Treat (Field Demonstration)	Groundwater	Petroleum Hydrocarbons; BTEX; Volatiles-Nonhalogenated; Heavy Metals	1997	1998
Commencement Bay, South Tacoma Channel Well 12A Superfund Site, WA	46	Pump and Treat	Groundwater	PCE; TCE; DCE; Volatiles-Halogenated	1988	1995
Commencement Bay, South Tacoma Channel Superfund Site, WA	47	Pump and Treat; SVE	Groundwater; Soil; DNAPLs; LNAPLs	PCE; TCE; DCE; Volatiles-Halogenated	1998	2001
Des Moines TCE Superfund Site, OU 1, IA	54	Pump and Treat	Groundwater	TCE; DCE; Volatiles-Halogenated	1987	1998
Former Firestone Facility Superfund Site, CA	73	Pump and Treat	Groundwater	PCE; TCE; DCE; Volatiles-Halogenated; BTEX; Volatiles-Nonhalogenated	1986	1998

APPENDIX A. SUMMARY OF 383 CASE STUDIES (continued)

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
Fort Lewis Logistics Center, WA	85	Pump and Treat	Groundwater	TCE; DCE; Volatiles-Halogenated	1995	2000
Ft. Drum, Fuel Dispensing Area 1595, NY	81	Pump and Treat; Free Product Recovery	Groundwater; LNAPLs	BTEX; Volatiles-Nonhalogenated	1992	1995
JMT Facility RCRA Site (formerly Black & Decker RCRA Site), NY	119	Pump and Treat	Groundwater	TCE; DCE; Volatiles-Halogenated	1988	1998
Keefe Environmental Services Superfund Site, NH	122	Pump and Treat	Groundwater	PCE; TCE; DCE; Volatiles-Halogenated; BTEX; Volatiles-Nonhalogenated	1993	1998
King of Prussia Technical Corporation Superfund Site, NJ	126	Pump and Treat	Groundwater	BTEX; Volatiles-Nonhalogenated; Volatiles-Halogenated Heavy Metals	1995	1998
Lacrosse, KS	127	Pump and Treat	Drinking Water	BTEX; Petroleum Hydrocarbons; MTBE; Volatiles-Nonhalogenated	1997	2001
Langley Air Force Base, IRP Site 4, VA	128	Pump and Treat	Groundwater; LNAPLs	BTEX; Petroleum Hydrocarbons; Volatiles-Nonhalogenated	1992	1995
LaSalle Electrical Superfund Site, IL	129	Pump and Treat	Groundwater	PCBs; Semivolatiles-Halogenated; TCE; DCE; Volatiles-Halogenated	1992	1998
Lawrence Livermore National Laboratory (LLNL) Site 300 - General Services Area (GSA) Operable Unit, CA	134	Pump and Treat	Groundwater; Soil; DNAPLs	TCE; Volatiles-Halogenated	1991	1998

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
Marine Corps Base, OU 1 and 2, Camp Lejeune, NC	149	Pump and Treat	Groundwater	PCBs; Semivolatiles-Nonhalogenated; Pesticides/Herbicides; Heavy Metals; BTEX; Volatiles-Nonhalogenated; Volatiles-Halogenated	1995	2001
Marine Corps Base, Campbell Street Fuel Farm, Camp Lejeune, NC	150	Pump and Treat	Groundwater; Soil	BTEX; Volatiles-Nonhalogenated	1996	2001
McClellan Air Force Base, Operable Unit B/C, CA	153	Pump and Treat	Groundwater	PCE; TCE; DCE; Volatiles-Halogenated	1988	1995
Mid-South Wood Products Superfund Site, AR	158	Pump and Treat	Groundwater	Semivolatiles-Halogenated; PAHs; Semivolatiles-Nonhalogenated; Heavy Metals; Arsenic	1989	1998
Mystery Bridge at Hwy 20 Superfund Site, Dow/DSI Facility - Volatile Halogenated Organic (VHO) Plume, WY	181	Pump and Treat; SVE	Groundwater	PCE; TCE; DCE; Volatiles-Halogenated	1994	1998
Naval Air Station, Brunswick, Eastern Groundwater Plume, ME	185	Pump and Treat	Groundwater	PCE; TCE; DCE; Volatiles-Halogenated	1995	2001
Odessa Chromium IIS Superfund Site, OU 2, TX	204	Pump and Treat	Groundwater	Heavy Metals	1993	1998
Odessa Chromium I Superfund Site, OU 2, TX	203	Pump and Treat	Groundwater	Heavy Metals	1993	1998
Offutt AFB, Site LF-12, NE	205	Pump and Treat	Groundwater	BTEX; Volatiles-Nonhalogenated; TCE; DCE; Volatiles-Halogenated	1997	1998

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
Old Mill Superfund Site, OH	207	Pump and Treat	Groundwater	TCE; DCE; Volatiles-Halogenated; BTEX; Volatiles-Nonhalogenated	1989	1998
Ott/Story/Cordova Superfund Site, North Muskegon, MI	208	Pump and Treat	Groundwater	PCE; DCE; Volatiles-Halogenated; BTEX; Volatiles-Nonhalogenated; PCBs; Semivolatiles-Halogenated; Pesticides/Herbicides	1996	2001
Paducah Gaseous Diffusion Plant, KY	344	Pump and Treat(Field Demonstration)	Groundwater	Radioactive Metals	1999	2002
Pinellas Northeast Site, FL	219	Pump and Treat (Membrane Filtration - PerVap^{TM}) (Field Demonstration)	Groundwater	TCE; DCE; Volatiles-Halogenated	1995	1998
Pope AFB, Site SS-07, Blue Ramp Spill Site, NC	222	Pump and Treat; Free Product Recovery	Groundwater; LNAPLs	Petroleum Hydrocarbons; BTEX; Volatiles-Nonhalogenated	1993	1998
Pope AFB, Site FT-01, NC	221	Pump and Treat; Free Product Recovery	Groundwater; LNAPLs	Petroleum Hydrocarbons; BTEX; Volatiles-Nonhalogenated	1993	1998
Rockaway, NJ	233	Pump and Treat	Drinking Water	MTBE; BTEX; Volatiles-Nonhalogenated; TCE; Volatiles-Halogenated	1980	2001
SCRDI Dixiana Superfund Site, SC	255	Pump and Treat	Groundwater	PCE; TCE; DCE; Volatiles-Halogenated	1992	1998
Shaw AFB, Sites SD-29 and ST-30, SC	260	Pump and Treat; Free Product Recovery	Groundwater; LNAPLs	Petroleum Hydrocarbons; BTEX; Volatiles-Nonhalogenated; Volatiles-Halogenated	1995	1998

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
Shaw AFB, Site OT-16B, SC	259	Pump and Treat	Groundwater; DNAPLs	PCE; TCE; Volatiles-Halogenated	1995	1998
Sol Lynn/Industrial Transformers Superfund Site, TX	265	Pump and Treat	Groundwater	TCE; Volatiles-Halogenated	1993	1998
Solid State Circuits Superfund Site, MO	266	Pump and Treat	Groundwater; DNAPLs	TCE; DCE; Volatiles-Halogenated	1993	1998
Solvent Recovery Services of New England, Inc. Superfund Site, CT	267	Pump and Treat; Containment - Barrier Walls	Groundwater	Semivolatiles-Nonhalogenated; PCBs; Semivolatiles-Halogenated; Heavy Metals; TCE; DCE; Volatiles-Halogenated	1995	1998
Sylvester/Gilson Road Superfund Site, NH	276	Pump and Treat; Containment - Barrier Walls; Containment - Caps; SVE	Groundwater; LNAPLs	Volatiles-Halogenated; Ketones; BTEX; Volatiles-Nonhalogenated; Heavy Metals	1982	1998
Tacony Warehouse, PA	278	Pump and Treat	Groundwater	PCE; TCE; DCE; Volatiles-Halogenated	1998	2000
Twin Cities Army Ammunition Plant, MN	284	Pump and Treat	Groundwater	PCE; TCE; DCE; Volatiles-Halogenated	1987	1995
U.S. Department of Energy Kansas City Plant, MO	290	Pump and Treat	Groundwater	PCE; TCE; DCE; Volatiles-Halogenated; Semivolatiles-Halogenated PCBs; Petroleum Hydrocarbons; BTEX; Volatiles-Nonhalogenated; Heavy Metals	1983	1995
U.S. Aviex Superfund Site, MI	286	Pump and Treat	Groundwater; DNAPLs	Volatiles-Halogenated; BTEX; Volatiles-Nonhalogenated	1993	1998

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
U.S. Department of Energy Savannah River Site, A/M Area, SC	297	Pump and Treat	Groundwater; DNAPLs	PCE; TCE; Volatiles-Halogenated	1985	1995
Union Chemical Company Superfund Site, ME	302	Pump and Treat; Chemical Oxidation/Reduction (*in situ*); SVE	Groundwater; Soil	TCE; DCE; Volatiles-Halogenated	1996	2001
United Chrome Superfund Site, OR	303	Pump and Treat	Groundwater	Heavy Metals	1988	1998
Western Processing Superfund Site, WA	312	Pump and Treat; Containment - Barrier Walls	Groundwater; LNAPLs; DNAPLs	TCE; DCE; Volatiles-Halogenated; BTEX; Volatiles-Nonhalogenated; PAHs; Semivolatiles-Nonhalogenated; Heavy Metals	1988	1998
***In Situ* Groundwater Bioremediation (44 Projects)**						
Abandoned Manufacturing Facility - Emeryville, CA	2	Bioremediation (*in situ*) Enhanced Bioremediation	Groundwater	TCE; Volatiles-Halogenated; Heavy Metals	1997	2000
Altus Air Force Base, Landfill 3 (LF 3), OK	338	Bioremediation (*in situ*) Enhanced Bioremediation (Field Demonstration)	Groundwater	TCE; Volatiles-Halogenated	2000	2003
Avco Lycoming Superfund Site, PA	14	Bioremediation (*in situ*) Enhanced Bioremediation	Groundwater	TCE; DCE; Volatiles-Halogenated; Heavy Metals	1997	2000
Balfour Road Site, CA; Fourth Plain Service Station Site, WA; Steve’s Standard and Golden Belt 66 Site, KS	17	Bioremediation (*in situ*) Enhanced Bioremediation	Groundwater	BTEX; Petroleum Hydrocarbons; Volatiles-Nonhalogenated	1995	1998
Brownfield Site, Chattanooga, TN (specific site name not identified)	28	Bioremediation (*in situ*) Enhanced Bioremediation	Groundwater	MTBE; BTEX; Volatiles-Nonhalogenated	1999	2001

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
Contemporary Cleaners, Orlando. FL	49	Bioremediation (*in situ*) Enhanced Bioremediation (HRC)	Groundwater	PCE; TCE; DCE; Volatiles-Halogenated	Not Provided	2001
Cordray's Grocery, Ravenel, SC	50	Bioremediation (*in situ*) Enhanced Bioremediation (ORC)	Groundwater	BTEX; MTBE Volatiles-Nonhalogenated; Semivolatiles-Nonhalogenated	1998	2001
Dover Air Force Base, Area 6, DE	56	Bioremediation (*in situ*) Enhanced Bioremediation (Field Demonstration)	Groundwater	PCE; TCE; DCE; Volatiles-Halogenated	1996	2000
Dover Air Force Base, Area 6, DE	55	Bioremediation (*in situ*) Enhanced Bioremediation (Field Demonstration)	Groundwater	TCE; DCE; Volatiles-Halogenated	1996	2002
Edwards Air Force Base, CA	63	Bioremediation (*in situ*) Enhanced Bioremediation (Field Demonstration)	Groundwater	TCE; Volatiles-Halogenated	1996	2000
Former Industrial Property, CA	372	Bioremediation (*in situ*) Enhanced Bioremediation	Groundwater	TCE; Volatiles-Halogenated	2000	2004
French Ltd. Superfund Site, TX	92	Bioremediation (*in situ*) Enhanced Bioremediation	Groundwater	BTEX; Volatiles-Halogenated; Volatiles-Nonhalogenated	1992	1998
Gas Station, Cheshire, CT (specific site name not identified)	94	Bioremediation (*in situ*) Enhanced Bioremediation	Groundwater	BTEX; MTBE Volatiles-Nonhalogenated	1997	2001
Hanford Site, WA	96	Bioremediation (*in situ*) Enhanced Bioremediation (Field Demonstration)	Groundwater	Volatiles-Halogenated	1995	2000
Hayden Island Cleaners, Portland, OR	105	Bioremediation (*in situ*) Enhanced Bioremediation (HRC)	Groundwater	PCE; TCE; DCE; Volatiles-Halogenated	Not Provided	2001

APPENDIX A. SUMMARY OF 383 CASE STUDIES (continued)

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
Idaho National Engineering and Environmental Laboratory, Test Area North, ID	115	Bioremediation (*in situ*) Enhanced Bioremediation (Field Demonstration)	Groundwater; DNAPLs	PCE; TCE; DCE; Volatiles-Halogenated	1999	2002
ITT Roanoke Site, VA	118	Bioremediation (*in situ*) Enhanced Bioremediation (Field Demonstration)	Groundwater	DCE; Volatiles-Halogenated	1998	Not Provided
Lawrence Livermore National Laboratory, CA	133	Bioremediation (*in situ*) Enhanced Bioremediation	Groundwater; Soil	MTBE Volatiles-Nonhalogenated	Not Provided	2001
Libby Groundwater Superfund Site, MT	136	Bioremediation (*in situ*) Enhanced Bioremediation; Pump and Treat	Groundwater	Semivolatiles-Halogenated; PAHs; Semivolatiles-Nonhalogenated	1991	1998
Moffett Field Superfund Site, CA	162	Bioremediation (*in situ*) Enhanced Bioremediation (Field Demonstration)	Groundwater	Volatiles-Halogenated	1986	2000
Moss-American Site, WI	369	Bioremediation (*in situ*) Enhanced Bioremediation; Permeable Reactive Barrier	Groundwater	PAHs; Semivolatiles-Nonhalogenated; BTEX; Volatiles-Nonhalogenated,	2000	2004
Multiple Dry Cleaner Sites	174	Bioremediation (*in situ*) Enhanced Bioremediation (HRC)	Groundwater; DNAPLs	PCE; TCE; Volatiles-Halogenated	Not Provided	2001
Multiple (4) Dry Cleaner Sites - *In Situ* Bioremediation, Various Locations	346	Bioremediation (*in situ*) Enhanced Bioremediation	Groundwater	PCE; TCE; DCE; Volatiles-Halogenated; Volatiles-Nonhalogenated; BTEX; MTBE	Various years - starting 2002	2003
Multiple (4) Dry Cleaner sites - In Situ Bioremediation, Various Locations	384	Bioremediation (*in situ*) Enhanced Bioremediation	Soil; Groundwater	DCE; PCE; TCE; Volatiles-Halogenated; Volatiles-Semihalogenated; BTEX; Volatiles-Nonhalogenated	Various years - starting 2000	2005

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
Multiple (5) Dry Cleaner sites - In Situ Bioremediation, Various Locations	383	Bioremediation (*in situ*) Enhanced Bioremediation	Soil; Groundwater; DNAPLs	DCE; PCE; TCE; Volatiles-Halogenated; BTEX; Volatiles-Nonhalogenated; Semivolatiles-Nonhalogenated	Various years - starting 2001	2005
National Environmental Technology Test Site, CA	371	Bioremediation (*in situ*) Enhanced Bioremediation	Groundwater	MTBE	2001	2004
Naval Weapons Station Seal Beach, CA	194	Bioremediation (*in situ*) Enhanced Bioremediation Field Demonstration)	Groundwater; Soil; LNAPLs	BTEX; Petroleum Hydrocarbons; Volatiles-Nonhalogenated	1997	2000
Naval Air Station New Fuel Farm Site, NV	360	Bioremediation (*in situ*) Bioventing; Free Product Recovery	Groundwater	Petroleum Hydrocarbons; LNAPLs	Not Provided	2004
Naval Weapons Industrial Reserve Plant (NWIRP) , TX	315	Bioremediation (*in situ*) Enhanced Bioremediation (Field Demonstration)	Groundwater	TCE, Volatiles-Halogenated	1999	2002
Naval Base Ventura County, CA	352	Bioremediation (*in situ*) Enhanced Bioremediation	Groundwater	TCE; DCE; Volatiles-Halogenated	1999	2004
Offutt Air Force Base, NE	339	Bioremediation (*in situ*) Enhanced Bioremediation (Field Demonstration)	roundwater	TCE; Volatiles-Halogenated	Not provided	2003
Pinellas Northeast Site, FL	218	Bioremediation (*in situ*) Enhanced Bioremediation (Field Demonstration)	Groundwater; DNAPLs	TCE; DCE; Volatiles-Halogenated	1997	1998
Savannah River Site Sanitary Landfill (SLF), SC	362	Bioremediation (*in situ*) Enhanced Bioremediation	Groundwater	TCE; DCE; Volatiles-Halogenated	1999	2004
Savannah River Site, SC	250	Bioremediation (*in situ*) Enhanced Bioremediation (Field Demonstration)	Groundwater; Sediment	PCE; TCE; Volatiles-Halogenated	1992	2000

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
Service Station, CA (specific site name not identified)	256	Bioremediation (*in situ*) Enhanced Bioremediation (ORC)	Groundwater	BTEX; MTBE; Volatiles-Nonhalogenated	Not Provided	2001
Service Station, Lake Geneva, WI (specific site name not identified)	257	Bioremediation (*in situ*) Enhanced Bioremediation (ORC)	Groundwater	BTEX; MTBE; Volatiles-Nonhalogenated	Not Provided	2001
Site A (actual name confidential), NY	263	Bioremediation (*in situ*) Enhanced Bioremediation; Pump and Treat; Air Sparging; SVE	Groundwater	BTEX; Petroleum Hydrocarbons; Volatiles-Nonhalogenated	1995	1998
South Beach Marine, Hilton Head, SC	268	Bioremediation (*in situ*) Enhanced Bioremediation	Groundwater	PAHs; Semivolatiles-Nonhalogenated; BTEX; MTBE; Volatiles-Nonhalogenated	1999	2001
Specific site name not identified	304	Bioremediation (*in situ*) Enhanced Bioremediation (Bench Scale)	roundwater; Soil	MTBE; Volatiles-Nonhalogenated	Not Provided	2001
Texas Gulf Coast Site, TX	279	Bioremediation (*in situ*) Enhanced Bioremediation	Groundwater	TCE; Volatiles-Halogenated; Heavy Metals	1995	2000
U.S. Navy Construction Battalion Center, Port Hueneme, CA	299	Bioremediation (*in situ*) Enhanced Bioremediation (Field Demonstration)	Groundwater	MTBE; BTEX; Volatiles-Nonhalogenated	1998	2001
U.S. Department of Energy Savannah River Site, M Area, SC	298	Bioremediation (*in situ*) Enhanced Bioremediation (Field Demonstration)	Groundwater; Sediment	PCE; TCE; Volatiles-Halogenated	1992	1997
Vandenberg Air Force Base, Lompoc, CA	305	Bioremediation (*in situ*) Enhanced Bioremediation (Field Demonstration)	Groundwater	MTBE; BTEX; Volatiles-Nonhalogenated	1999	2001

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
Watertown Site, MA	311	Bioremediation (*in situ*) Enhanced Bioremediation (Field Demonstration)	Groundwater; Soil	PCE; TCE; Volatiles-Halogenated	1996	2000
Other *In Situ* Groundwater Treatment (83 Projects)						
328 Site, CA	1	Multi Phase Extraction; Fracturing	Groundwater; Soil	TCE; Volatiles-Halogenated	1996	2000
A.G. Communication Systems, IL	332	Thermal Treatment (*in situ*)	Groundwater; Soil	TCE; DCE; Volatiles-Halogenated; BTEX; Volatiles-Nonhalogenated	1995	2003
Aberdeen Proving Grounds, Edgewood Area J - Field Site, MD	3	Phytoremediation(Field Demonstration)	Groundwater	TCE; DCE; Volatiles-Halogenated	1996	2002
Amcor Precast, UT	6	In-Well Air Stripping; SVE	Groundwater; Soil	BTEX; Petroleum Hydrocarbons; Volatiles-Nonhalogenated; PAHs; Semivolatiles-Nonhalogenated	1992	1995
Brookhaven National Laboratory, NY	26	In-Well Air Stripping (Field Demonstration)	Groundwater	PCE; TCE; DCE; Volatiles-Halogenated	1999	2002
Butler Cleaners, Jacksonville, FL	30	Chemical Oxidation/Reduction (*in situ*) ($KMnO_4$)	Groundwater; DNAPLs	PCE; TCE; DCE; Volatiles-Halogenated; BTEX; Volatiles-Nonhalogenated	Not Provided	2001
Camp Lejeune Marine Corps Base, Bldg 25, Camp Lejeune, NC	31	Flushing (*in situ*) (SEAR and PITT)	Groundwater; DNAPLs	PCE; TCE; DCE; Volatiles-Halogenated	1999	2001
Cape Canaveral Air Force Station, Launch Complex 34, FL	340	Thermal Treatment (*in situ*) (Field Demonstration)	Groundwater; Soil DNAPLs	TCE; Volatiles-Halogenated	1999	2003
Carswell Air Force Base, TX	34	Phytoremediation (Field Demonstration)	Groundwater	TCE; Volatiles-Halogenated	1996	2002

APPENDIX A. SUMMARY OF 383 CASE STUDIES (continued)

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
Charleston Naval Complex, AOC 607, SC	378	Thermal Treatment (*in situ*)	Groundwater; DNAPLs	DCE; PCE; TCE; Volatiles-Halogenated	2001	2005
Clear Creek/Central City Superfund site, CO	326	Phytoremediation (Field Demonstration)	Groundwater	Heavy Metals	1994	2002
Confidential Manufacturing Facility, IL	48	Thermal Treatment (*in situ*)	Groundwater; Soil; DNAPLs	TCE; DCE; Volatiles-Halogenated	1998	2000
Confidential Maryland Site, MD	388	Permeable Reactive Barrier (Field Demonstration)	Groundwater	DCE; Explosives/Propellants; TCE; PCE; Volatiles-Halogenated	2003	2006
Defense Supply Center, Acid Neutralization Pit, VA	53	Multi Phase Extraction (Field Demonstration)	Groundwater; Soil	PCE; TCE; DCE; Volatiles-Halogenated	1997	2000
Del Norte County Pesticide Storage Area Superfund Site, CA (Air Sparging and Pump and Treat)	359	Air Sparging; SVE	Groundwater	Pesticides/Herbicides; Semivolatiles-Halogenated; Heavy Metals	1990	2004
Eaddy Brothers, Hemingway, SC	61	Air Sparging; SVE	Groundwater; Soil	BTEX; MTBE Volatiles-Nonhalogenated; Semivolatiles-Nonhalogenated	1999	2001
Edward Sears Site, NJ	62	Phytoremediation (Field Demonstration)	Groundwater	PCE; TCE; Volatiles-Halogenated; BTEX; Volatiles-Nonhalogenated	1996	2002
Eight Service Stations, MD (specific sites not identified)	65	Multi Phase Extraction	Groundwater; Soil LNAPLs	BTEX; MTBE Volatiles-Nonhalogenated	1990	2001
Fernald Environmental Management Project, OH	70	Flushing (*in situ*) (Field Demonstration)	Groundwater	Heavy Metals	1998	2001
Former Sages Dry Cleaners, Jacksonville, FL	78	Flushing (*in situ*) (Ethanol Co-solvent)	Groundwater; DNAPLs	PCE; TCE; DCE; Volatiles-Halogenated	Not Provided	2001

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
Former Nu Look One Hour Cleaners, Coral Springs, FL	77	In-Well Air Stripping (NoVOCs™)	Groundwater	PCE; TCE; DCE; Volatiles-Halogenated	Not Provided	2001
Former Intersil, Inc. Site, CA	74	Permeable Reactive Barrier; Pump and Treat	Groundwater	TCE; DCE; Volatiles-Halogenated	1995	1998
Fort Devens, AOCs 43G and 43J, MA	80	Monitored Natural Attenuation	Groundwater; Soil LNAPLs	BTEX; Volatiles-Nonhalogenated	1997	2000
Fort Richardson, AK	331	Thermal Treatment (*in situ*) (Field Demonstration)	Groundwater; Soil DNAPLs; Off-gases	PCE; TCE; DCE; Volatiles-Halogenated; BTEX; Volatiles-Nonhalogenated	1999	2003
Four Service Stations (specific site names not identified)	90	Air Sparging	Groundwater	BTEX; MTBE Volatiles-Nonhalogenated	1993	2001
Fry Canyon, UT	93	Permeable Reactive Barrier (Field Demonstration)	Groundwater	Radioactive Metals; Heavy Metals	1997	2000
Gold Coast Superfund Site, FL	95	Air Sparging; Pump and Treat	Groundwater; DNAPLs	PCE; TCE; DCE; Volatiles-Halogenated; BTEX; Volatiles-Nonhalogenated	1994	1998
Hanford Site, 100-H and 100-D Areas, WA	101	Chemical Oxidation/Reduction (*in situ*) (Field Demonstration)	Groundwater	Heavy Metals	1995	2000
Multiple (3) Naval Facilities - In Situ Chemical Reduction, Various Locations	389	Chemical Reduction (*in situ, nanoscale zero-valent iron*) (Field Demonstration)	Groundwater, DNAPLs	DCE; TCE; PCE; Volatiles-Halogenated	Not Provided	2006
Hunter's Point Ship Yard, Parcel C, Remedial Unit C4, CA	357	Chemical Oxidation/Reduction (*in situ*)	Groundwater; DNAPLs	TCE; Volatiles-Halogenated	2002	2004
ICN Pharmaceuticals, OR	334	Thermal Treatment (*in situ*); SVE	Groundwater; Soil DNAPLs	TCE; DCE; Volatiles-Halogenated	2000	2003

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
Johannsen Cleaners, Lebanon, OR	120	Multi Phase Extraction	Groundwater	PCE; TCE; DCE; Volatiles-Halogenated	Not Provided	2001
Keesler Air Force Base Service Station, AOC-A (ST-06), MS	123	Monitored Natural Attenuation	Groundwater; Soil	BTEX; Volatiles-Nonhalogenated; Heavy Metals	1997	2000
Kelly Air Force Base, Former Building 2093 Gas Station, TX	124	Monitored Natural Attenuation	Groundwater; Soil	BTEX; Petroleum Hydrocarbons; Volatiles-Nonhalogenated	1997	2000
Lawrence Livermore National Laboratory Gasoline Spill Site, CA	130	Thermal Treatment (*in situ*) (Field Demonstration)	Groundwater; Soil	BTEX; Volatiles-Nonhalogenated	1992	1995
Loring Air Force Base, Limestone, ME	392	Thermal Treatment (*in situ*) (Field Demonstration)	Groundwater	DCE; PCE; TCE; Volatiles-Halogenated	2002	2006
Louisiana Army Ammunition Plant, LA	142	Monitored Natural Attenuation	Groundwater	Explosives/Propellants	Not Provided	2001
Marshall Space Flight Center, AL	336	Chemical Oxidation/Reduction (*in situ*); Fracturing; Permeable Reactive Barrier (Field Demonstration)	Groundwater	TCE; Volatiles-Halogenated	2000	2003
Massachusetts Military Reservation, CS-10 Plume, MA	159	In-Well Air Stripping (UVB and NoVOCs) (Field Demonstration)	Groundwater	PCE; TCE; DCE; Volatiles-Halogenated	1996	2002
McClellan Air Force Base (AFB), OU A, CA	151	Air Sparging; Bioremediation (*in situ*) Enhanced Bioremediation (Field Demonstration)	Groundwater; Soil	TCE; DCE; Volatiles-Halogenated	1999	2001
Miamisburg, OH	343	Air Sparging; SVE	Groundwater; Soil	PCE; TCE; DCE; Volatiles-Halogenated; BTEX; Volatiles-Nonhalogenated	1997	2001
Milan Army Ammunition Plant, TN	157	Phytoremediation (Field Demonstration)	Groundwater	Explosives/Propellants	1996	2000

APPENDIX A. SUMMARY OF 383 CASE STUDIES (continued)

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
Moffett Field Superfund Site, CA	163	Permeable Reactive Barrier (Field Demonstration)	Groundwater	PCE; TCE; DCE; Volatiles-Halogenated	1996	2000
Moffett Federal Airfield, CA	161	Permeable Reactive Barrier (Field Demonstration)	Groundwater; DNAPLs	PCE; TCE; Volatiles-Halogenated	1996	1998
Monticello Mill Tailings Site, Monticello, UT	164	Permeable Reactive Barrier (Field Demonstration)	Groundwater	Metals	1999	2001
Multiple Dry Cleaner Sites	171	Air Sparging; SVE	Groundwater; Soil DNAPLs	PCE; TCE; DCE; Volatiles-Halogenated	Not Provided	2001, 2002
Multiple (10) Sites - Air Sparging, Various Locations	342	Air Sparging	Groundwater; Soil	TCE; PCE; DCE; Volatiles-Halogenated; PAHs; Semivolatiles-Nonhalogenated; BTEX; Volatiles-Nonhalogenated; MTBE; Petroleum Hydrocarbons	Various years	2002
Multiple Air Force Sites	177	Multi Phase Extraction (Field Demonstration)	Groundwater; LNAPLs	Petroleum Hydrocarbons; BTEX; Volatiles-Nonhalogenated	Not Provided	2001
Multiple Air Force Sites	178	Monitored Natural Attenuation (Field Demonstration)	Groundwater	TCE; DCE; Volatiles-Halogenated	1993	1999
Multiple Air Force Sites	179	Monitored Natural Attenuation (Field Demonstration)	Groundwater	BTEX; Petroleum Hydrocarbons; Volatiles-Nonhalogenated	1993	1999
Multiple DoD Sites, Various Locations	347	Permeable Reactive Barrier (Field Demonstration)	Groundwater	Volatiles-Halogenated	Various years	2003

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
Multiple (2) Dry Cleaner Sites, Various Locations	324	Chemical Oxidation/Reduction (*in situ*)	Groundwater; Dense Non-aqueous Phase Liquids (DNAPLs)	PCE; TCE; Volatiles-Halogenated	Various years - starting 1998	2003
Multiple (2) Dry Cleaners - In Well Air Stripping	364	In-Well Air Stripping	Soil; Groundwater	PCE; TCE; Volatiles-Halogenated	1994	2004
Multiple Dry Cleaner Sites	175	Chemical Oxidation/Reduction (*in situ*) (Field Demonstration)	Groundwater; DNAPLs	PCE; TCE; Volatiles-Halogenated	1999	2001, 2002
Multiple Dry Cleaner Sites	173	Multi Phase Extraction; Pump and Treat	Groundwater; Soil; DNAPLs	PCE; TCE; Volatiles-Halogenated	Not Provided	2001, 2002
Multiple Sites	167	Permeable Reactive Barrier (Full scale and Field Demonstration)	Groundwater	PCE; TCE; DCE; Volatiles-Halogenated	1991	2002
Multiple Sites	166	Permeable Reactive Barrier (Full scale and Field Demonstration)	Groundwater	TCE; Volatiles-Halogenated; Heavy Metals; Radioactive Metals; Arsenic	1997	2002
Multiple Sites	169	Permeable Reactive Barrier (Full scale and Field Demonstration)	Groundwater	PCE; TCE; DCE; Volatiles-Halogenated; BTEX; Volatiles-Nonhalogenated; Heavy Metals; Radioactive Metals; Arsenic	1995	2002

APPENDIX A. SUMMARY OF 383 CASE STUDIES (continued)

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
Multiple Sites	170	Permeable Reactive Barrier (Full scale and Field Demonstration)	Groundwater	PCE; TCE; DCE; Volatiles-Halogenated; BTEX; Volatiles-Nonhalogenated; Heavy Metals; Radioactive Metals; Pesticides/Herbicides	1995	2002
Multiple Sites	168	Permeable Reactive Barrier (Full scale and Field Demonstration)	Groundwater	PCE; TCE; DCE; Volatiles-Halogenated; Heavy Metals; Radioactive Metals	1995	2002
Multiple Dry Cleaner Sites	172	Flushing (*in situ*); Thermal Treatment (*in situ*); In-Well Air Stripping (Field Demonstration)	Groundwater; DNAPLs	PCE; TCE; Volatiles-Halogenated	Not Provided	2001
Multiple (4) Dry Cleaner sites - In Situ Chemical Oxidation	385	Chemical Oxidation/Reduction (*in situ*)	Groundwater; Soil; DNAPLs	DCE; PCE; TCE; Volatiles-Halogenated; Heavy Metals	Various years - starting 2001	2005
Naval Air Station - Joint Reserve Base Fort Worth, TX	34	Phytoremediation (Field Demonstration)	Groundwater	TCE; Volatiles-Halogenated	1996	2005
Naval Air Station, Pensacola, FL	187	Chemical Oxidation/Reduction (*in situ*)	Groundwater	TCE; DCE; Volatiles-Halogenated	1998	2001
Naval Submarine Base, Kings Bay, GA	193	Chemical Oxidation/Reduction (*in situ*); Monitored Natural Attenuation	Groundwater	PCE; TCE; DCE; Volatiles-Halogenated	1999	2001
Naval Submarine Base, Kings Bay, GA	192	Chemical Oxidation/Reduction (*in situ*)	Groundwater	PCE; TCE; DCE; Volatiles-Halogenated	1998	2000
Naval Air Engineering Station (NAES) Site (Area I), NJ	353	Chemical Oxidation/Reduction (*in situ*)	Groundwater	PCE; TCE; DCE; Volatiles-Halogenated	2002	2004

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
Naval Amphibious Base Little Creek, Site 11, GA	375	Flushing (*in situ*) (Field Demonstration)	Groundwater; Soil	DCE; TCE; Volatiles-Halogenated	2002	2005
Naval Air Station, North Island, CA	186	In-Well Air Stripping (NoVOCs) (Field Demonstration)	Groundwater	TCE; DCE; Volatiles-Halogenated	1998	2000
Naval Air Station, Pensacola, OU 10, FL	184	Chemical Oxidation/Reduction (*in situ*) (Field Demonstration)	Groundwater	TCE; Volatiles-Halogenated	1998	2000
Oak Ridge National Laboratory, TN	202	Permeable Reactive Barrier - Funnel and Gate Configuration and Trench (Field Demonstration)	Groundwater	Radioactive Metals	1997	2002
Pinellas Northeast Site, FL	220	Thermal Treatment (*in situ*) - Dual Auger Rotary Steam Stripping (Field Demonstration)	Groundwater; Soil DNAPLs	PCE; TCE; DCE; Volatiles-Halogenated; BTEX; Volatiles-Nonhalogenated	1996	1998
Portsmouth Gaseous Diffusion Plant, X-701B Facility, OH	226	Chemical Oxidation/Reduction (*in situ*) (Field Demonstration)	Groundwater; DNAPLs	TCE; Volatiles-Halogenated	1988	2000
RMI Titanium Plant, Ashtabula Environmental Management Project, OH	232	Flushing (*in situ*) (WIDE) (Field Demonstration)	Groundwater; Soil	TCE; Volatiles-Halogenated; Radioactive Metals	1999	2001
Scotchman #94, Florence, SC	253	Multi Phase Extraction; Air Sparging; SVE	Groundwater; Soil	PAHs; Semivolatiles-Nonhalogenated; BTEX; MTBE; Volatiles-Nonhalogenated	1998	2001
Site 88, Building 25, Marine Corps Base Camp Lejeune, NC	147	Flushing (*in situ*) (SEAR) (Field Demonstration)	Groundwater; DNAPLs; LNAPLs	Petroleum Hydrocarbons; Volatiles-Nonhalogenated; PCE; Volatiles-Halogenated	1999	2001

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
South Prudence Bay Island Park, T-Dock Site, Portsmouth, RI	269	Air Sparging; Bioremediation (*in situ*) Enhanced Bioremediation	Groundwater	BTEX; Volatiles-Nonhalogenated	1998	2001
Sparks Solvents/Fuel Site, Sparks, NV	271	Multi Phase Extraction	Groundwater; LNAPLs	BTEX; MTBE; Volatiles-Nonhalogenated; PCE; TCE; Volatiles-Halogenated	1995	2001
Tinkham's Garage Superfund Site, NH	281	Multi Phase Extraction	Groundwater; Soil	PCE; TCE; Volatiles-Halogenated	1994	2000
U.S. Coast Guard Support Center, NC	287	Permeable Reactive Barrier	Groundwater; DNAPLs	TCE; Volatiles-Halogenated; Heavy Metals	1996	1998
U.S. Department of Energy Savannah River Site, A/M Area, SC	294	In-Well Air Stripping; Pump and Treat (Field Demonstration)	Groundwater; Soil DNAPLs	PCE; TCE; Volatiles-Halogenated	1990	1995
Visalia Superfund Site, CA	309	Thermal Treatment (*in situ*) (Field Demonstration)	Groundwater	Semivolatiles-Halogenated; Semivolatiles-Nonhalogenated	1997	2000
Westover Air Reserve Base, MA	377	Phytoremediation; Bioremediation (*in situ*) (Field Demonstration)	Stormwater	Semivolatiles-Nonhalogenated	2001	2005
Debris/Solid Media Treatment (28 Projects)						
Alabama Army Ammunition Plant, AL	4	Thermal Desorption (*ex situ*)(Field Demonstration)	Debris/Slag/ Solid	Explosives/Propellants	1995	1998
Argonne National Laboratory - East, IL	9	Physical Separation (Scabbling) (Field Demonstration)	Debris/Slag/ Solid	Radioactive Metals	Not Provided	2000
Argonne National Laboratory - East, IL	11	Physical Separation (Concrete Demolition) (Field Demonstration)	Debris/Slag/ Solid	Radioactive Metals	1997	2000

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
Argonne National Laboratory, IL	10	Solidification/Stabilization (Phosphate Bonded Ceramics)(Field Demonstration)	Debris/Slag/ Solid; Groundwater	Heavy Metals	Not Provided	2000
Chicago Pile 5 (CP-5) Research Reactor, Argonne National Laboratory, IL	38	Physical Separation (Centrifugal Shot Blast)(Field Demonstration)	Debris/Slag/ Solid	Radioactive Metals	1997	1998
Chicago Pile 5 (CP-5) Research Reactor, Argonne National Laboratory, IL	39	Physical Separation (Rotary Peening with Captive Shot)(Field Demonstration)	Debris/Slag/ Solid	Radioactive Metals	1997	1998
Chicago Pile 5 (CP-5) Research Reactor, Argonne National Laboratory, IL	40	Physical Separation (Roto Peen Scaler with VAC-PAC[R] System)(Field Demonstration)	Debris/Slag/ Solid	Radioactive Metals	1996	1998
Clemson University, SC	42	Solidification/Stabilization (Sintering) (Bench Scale)	Debris/Slag/ Solid	Heavy Metals	1995	2000
Envirocare of Utah, UT	67	Solidification/Stabilization(Field Demonstration)	Debris/Slag/ Solid	Radioactive Metals	1996	1998
Fernald Site, OH	71	Physical Separation (Soft Media Blasting)(Field Demonstration)	Debris/Slag/ Solid	Radioactive Metals	1996	2000
Hanford Site, C Reactor, WA	102	Solidification/Stabilization (Polymer Coating) (Field Demonstration)	Debris/Slag/ Solid	Radioactive Metals	1997	1998
Hanford Site, WA	97	Physical Separation(Concrete Grinder) (Field Demonstration)	Debris/Slag/ Solid	Radioactive Metals	1997	2000
Hanford Site, WA	98	Physical Separation (Concrete Shaver) (Field Demonstration)	Debris/Slag/ Solid	Radioactive Metals	1997	2000

APPENDIX A. SUMMARY OF 383 CASE STUDIES (continued)

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
Hanford Site, WA	99	Physical Separation (Concrete Spaller) (Field Demonstration)	Debris/Slag/ Solid	Radioactive Metals	1998	2000
Hanford Site, WA	100	Solidification/Stabilization (Polyester Resins) (Field Demonstration)	Debris/Slag/ Solid; Groundwater	Radioactive Metals; Heavy Metals; Arsenic	Not Provided	2000
Hanford Site, WA	103	Physical Separation; Solvent Extraction (Ultrasonic Baths) (Field Demonstration)	Debris/Slag/ Solid	Radioactive Metals	1998	1998
Idaho National Engineering and Environmental Laboratory, ID	110	Solidification/Stabilization (Innovative Grouting and Retrieval) (Full scale and Field Demonstration)	Debris/Slag/ Solid; Soil	Radioactive Metals	1994	2000
Idaho National Engineering and Environmental Laboratory, ID	109	Solidification/Stabilization (DeHg^{SM} Process) (Field Demonstration)	Debris/Slag/ Solid	Heavy Metals	1998	2000
Idaho National Engineering and Environmental Laboratory, ID	113	Physical Separation (Wall Scabbler) (Field Demonstration)	Debris/Slag/ Solid	Heavy Metals	2000	2001
Idaho National Engineering and Environmental Laboratory, ID	112	Vitrification (*ex situ*) (Graphite Furnace) (Field Demonstration)	Debris/Slag/ Solid; Organic Liquids; Soil	Heavy Metals; Radioactive Metals	1997	2000
Idaho National Engineering and Environmental Laboratory, Pit 2, ID	111	Solidification/Stabilization (Polysiloxane) (Field Demonstration)	Debris/Slag/ Solid; Groundwater	Heavy Metals	1997	2000

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
Lawrence Livermore National Laboratory, CA	132	Chemical Oxidation/Reduction (*ex situ*) (Field Demonstration)	Debris/Slag/ Solid; Groundwater	PCE; TCE; Volatiles-Halogenated PCBs; Semivolatiles-Halogenated; Explosives/Propellants	Not Provided	2000
Los Alamos National Laboratory, NM	139	Solidification/Stabilization (ADA Process) (Field Demonstration)	Debris/Slag/ Solid	Heavy Metals	1998	2000
Los Alamos National Laboratory, Technical Area 33, NM	140	Solidification/Stabilization (Field Demonstration)	Sludge	Heavy Metals; DCE; Volatiles-Halogenated; Radioactive Metals	1997	2000
Pacific Northwest National Laboratory, WA	210	Solidification/Stabilization (Sol Gel Process) (Bench Scale)	Debris/Slag/ Solid; Groundwater	Heavy Metals	Not Provided	2000
Portsmouth Gaseous Diffusion Plant, OH	224	Solidification/Stabilization (ATG Process)(Field Demonstration)	Organic Liquids	Heavy Metals; Radioactive Metals	1998	2000
Savannah River Site, SC	249	Acid Leaching(Field Demonstration)	Debris/Slag/ Solid	Radioactive Metals	1996	2000
STAR Center, ID	274	Vitrification (*ex situ*) (Plasma Process)(Field Demonstration)	Debris/Slag/ Solid; Soil; Sludge	Heavy Metals; Radioactive Metals	1993	2000
Containment (7 Projects)						
Dover Air Force Base, Groundwater Remediation Field Laboratory National Test Site, Dover DE	58	Containment - Barrier Walls (Field Demonstration)	Groundwater	-	1996	2001
Lawrence Livermore National Laboratory (LLNL) Site 300 - Pit 6 Landfill OU, CA	131	Containment - Caps	Debris/Slag/ Solid	TCE; Volatiles-Halogenated; Radioactive Metals	1997	1998

APPENDIX A. SUMMARY OF 383 CASE STUDIES (continued)

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
Marine Corps Base Hawaii, HI	148	Containment - Caps (Field Demonstration)	Soil	-	1994	1998
Naval Shipyard, CA	191	Containment - Caps (Field Demonstration)	Soil	BTEX; Volatiles-Nonhalogenated	1997	1998
Oak Ridge National Laboratory, TN	200	Containment - Barrier Walls (Field Demonstration)	Soil; Sediment; Groundwater	Radioactive Metals	1996	2000
Sandia National Laboratory, Albuquerque, NM	247	Containment - Caps (Field Demonstration)	Soil	-	1995	2001
U.S. Department of Energy, SEG Facilities, TN	252	Containment - Barrier Walls (Field Demonstration)	Soil	-	1994	1997

* Full scale unless otherwise noted
† Technology focused on in case study listed first, followed by other technologies identified in the case study

Key:

DNAPLs	= Dense Non-Aqueous Phase Liquids	TCE	= Trichloroethene
SVE	= Soil Vapor Extraction	PCE	= Tetrachloroethene
BTEX	= Benzene, Toluene, Ethylbenzene, and Xylene	DCE	= Dichloroethene
PAHs	= Polycyclic Aromatic Hydrocarbons	LNAPLs	Light Non-Aqueous Phase Liquids
PCBs	= Polychlorinated Biphenyls	MTBE	= Methyl tert-butyl ether

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