Abstracts of Remediation Case Studies

Volume 11

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

Department of Energy
Department of Interior
National Aeronautics and Space Administration

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NOTICE

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FOREWORD

This report is a collection of abstracts summarizing 10 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* and *ex 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 393 remediation technology case studies (the 10 new case studies and 383 previously-published case studies). Appendix A to this report identifies the specific sites, technologies, contaminants, media, and year published for the 393 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 11, covers a wide variety of technologies, including full-scale remediations and large-scale field demonstrations of soil, groundwater, and acid rock drainage 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
Volume 11:	EPA-542-R-07-004; August 2007

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.

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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 10 new remediation technology case studies to the Roundtable Web site (http://www.frtr.gov/costperf.htm). A total of 393 case studies have now been completed, primarily focused on contaminated soil and groundwater cleanup.

The 10 new remediation technology 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* and *ex situ* treatment technologies for soil, groundwater, and acid rock drainage. Contaminants treated included halogenated volatiles and heavy metals.

Table 1 provides summary information about the technology used, contaminants and media treated, and project duration for the 10 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 for all 393 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. This report 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
	Volatiles - Halogenated	Metals			
In Situ Soil Treatment					
Camp Stanley Storage Activity, Texas (Solidification/Stabilization)			Soil (3,000 cy)	April 2002 to April 2003.	In situ stabilization using Apatite II ™ to treat soil contaminated with heavy metals (lead).
Palermton Zinc Superfund Site, Pennsylvania (Phytoremediation)			Soil (1,240 acres), Sediment (220 acres), Groundwater (NP)	1991 to Present - Ongoing	Use of phytoremediation to treat soil, sediment, and groundwater contaminated with heavy metals (cadmium, lead, and zinc).
Swift Cleaners, Florida (In Situ Chemical Oxidation and Soil Vapor Extraction)			Soil (NP), Groundwater (NP)	March 2001 to May 2006	Use of in situ chemical oxidation and soil vapor extraction to treat soil and groundwater contaminated with halogenated volatiles.
In Situ Groundwater Treatment					
Kelly Air Force Base, Texas (Bioaugementation)			Groundwater (NP)	November 1999 to May 2002	Use of in situ bioremediation to treat groundwater contaminated with halogenated volatiles.
F.E. Warren Air Force Base, Wyoming (Permeable Reactive Barrier)			Groundwater (NP)	August 2002 to August 2004	Use of a permeable reactive barrier to treat groundwater contaminated with halogenated volatiles.
Naval Air Joint Reserve Base, Texas (Phytoremediaiton)			Groundwater (NP)	August 1996 to September 2998	Use of phytoremediation to treat groundwater contaminated with halogenated volatiles.
East Helena, Montana (Permeable Reactive Barrier)			Groundwater (450 feet by 2,100 feet)	Spring 2005 to Present - Ongoing	Use of a permeable reactive barrier to treat groundwater contaminated with heavy metals (arsenic).

Site Name, State (Technology)	Principal Contaminant Groups*		Media (Quantity Treated)	Project Duration	Summary
	Volatiles - Halogenated	Metals			
Ex Situ Acid Rock/Mine Drainage Treatment					
Leviathan Mine, California (Active lime treatment, semi-passive alkaline lagoon treatment)			ARD (12.3 million L), ARD/AMD (17.4 million L), AMD (28.3 million L)	Active lime treatment: 1999 to Present - Ongoing, Semi-active lagoon treatment: 2001 to Present - Ongoing. SITE demonstration: June 2002 to October 2003.	Use of chemical precipitation to treat acid rock/mine drainage contaminated with heavy metals.
Leviathan Mine, California (Ex Situ Bioremediation)			ARD (31.34 million L)	Spring 2003 to Present - Ongoing. SITE demonstration: November 2003 to July 2005.	Use of ex situ bioremediation to treat acid rock drainage contaminated with heavy metals.
Copper Basin Mining District, Tennessee (constructed wetland)			Surface water/ARD (241 gpm)	1998 to present - Ongoing	Use of a constructed wetland to treat surface water and acid rock drainage contaminated with heavy metals.

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

Key:
NP = Not Provided
L = Liters
cy = cubic yards
SITE = U.S. EPA Superfund Innovative Technology Evaluation Program
ARD = Acid Rock Drainage
AMD = Acid Mine Drainage
gpm = gallons per minute

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					
Camp Stanley Storage Activity, Texas (Solidification/Stabilization)	D - $63,775	Soil: 3,000 cy	NP	$22 per cy of Soil	The key factor that affects this technology is the material and shipping costs for Apatite II.
Palermton Zinc Superfund Site, Pennsylvania (Phytoremediation)	T - $9 million (Initial 850 acres)	Soil: 1240 acres Sediment: 220 acres Groundwater: NP	NP	10,600 per acre (Based on initial 850 acres)	Costs may be affected by the type of materials used in the biosolids. After the initial 850 acres of Blue Mountain were treated sewage sludge in the biosolids was replaced with mushroom/leaf-litter compost.
Swift Cleaners, Florida (In Situ Chemical Oxidation and Soil Vapor Extraction)	DI - $428,000 AO - $30,000 (Soil) $30,000 (Groundwater)	NP	NP	NP	NP
In Situ Groundwater Treatment					
Kelly Air Force Base, Texas (Bioaugmentation)	T - $255,936 C - $67,727 AO - $188,209	40,000 gallons	NP	$6.4 per gallon	The single biggest factor that would affect the cost of the technology is the depth to contamination. Costs associated with drilling, disposal, and labor would be affected by the depth to contamination.
F.E. Warren Air Force Base, Wyoming (Permeable Reactive Barrier)	C - $74,863 T- $77,565	Groundwater: 63,000 gallons	NP	$419.63 per ft^2	The number of electrodes used to form the electrically induced redox barrier will potentially affect the costs
Naval Air Joint Reserve Base, Texas (Phytoremediaiton)	D - $641,467	NP	NP	NP	The major cost drivers for this technology are the amount of monitoring required to adequately evaluate the process over the life of the project and the labor required to prepare and maintain the tree plantations and to conduct sampling operations.
East Helena, Montana (Permeable Reactive Barrier)	D - $325,000	Groundwater plume: 450 ft wide by 2,100 ft long	NP	NP	The nature of the site's hydrogeology could determine whether or not the PRB could be implemented at the site.

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
Ex Situ Acid Rock Drainage Treatment					
Leviathan Mine, California (Active lime treatment, semi-passive alkaline lagoon treatment)	C -$1,021,415 (Active lime treatment - monophasic mode) C - $1,261,076 (Active lime treatment - biphasic mode) C - $297,482 (Semi-passive alkaline lagoon treatment)	ARD: 12.3 million L ARD/AMD: 17.4 million L AMD: 28.3 million L	NP	$20.97 per 1,000 L of water (Active lime treatment - monophasic mode) $16.97 per 1,00 L of water (Active lime treatment - biphasic mode $16.44 per 1,000 L of water (Semi-passive alkaline lagoon treatment)	Factors that would affect both treatment types include flow rate, concentration of contaminants, geographic site location, and type and quantity of residuals generated.
Leviathan Mine, California (Ex Situ Bioremediation)	C - $548,431 (Gravity flow mode) C - $554,551 (Reticulation mode)	ARD: 31.34 million L	NP	$15.28 per 1,000 gallons (Gravity flow mode) $16.54 per 1,000 gallons (Reticulation mode)	Factors that would affect both modes of treatment include flow rate, concentration of contaminants, geographic site location, and type and quantity of residuals generated.
Copper Basin Mining District, Tennessee (constructed wetland)	C - $1,300,000	Effluent Treated: 241 gmp	NP	NP	NP

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:

ft	= feet	NP	= Not Provided
cy	= cubic yards	L	= Liter
PRB	= permeable reactive barrier	ARD	= acid rock drainage
AMD	= acid mine drainage	gpm	= gallons per minute

IN SITU SOIL TREATMENT ABSTRACTS

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Phytoremediation at Palmerton Zinc Pile Superfund Site, Palmerton, Pennsylvania

Site Name:
Palmerton Zinc Pile Superfund Site

Location:
Palmerton, Pennsylvania

Period of Operation:
1991 - Ongoing

Cleanup Authority: CERCLA

Purpose/Significance of Application:
The site is being revegetated to:
-Stop or significantly reduce wind erosion, which will prevent the spread of heavy metal contamination through air-borne particulates
-Stop or significantly reduce surface water erosion, thus preventing the spread of heavy metal contamination into surface waters at the site
-Increase evapotranspiration by establishing a permanent vegetative cover over the site, which will prevent water from leaching through the contaminated soil and limit the migration of heavy metal contamination to groundwater

Cleanup Type: Full Scale

Contaminants:
Blue Mountain
Surface soil - Heavy Metals: Cadmium (Cd) (364 to 1,300 parts per million [ppm]), Lead (Pb) (1,200 to 6,475 ppm), Zinc (Zn) (13,000 to 35,000 ppm)

Cinder Bank
Sediment - Heavy Metals: Cd (250 ppm), Pb (3,600 ppm), Zn (27,000 ppm)

Stone Ridge
Groundwater - Heavy Metals: Cd (1 to 1,670 ppm), Pb (1 to 1,630 ppm), Zn (40 to 2,122,000 ppm)

Waste Source:
Zinc smelting operations

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Remedial Project Manager
Charlie Root
U.S. Environmental Protection Agency
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Phone: 215-814-3193
E-mail: root.charlie@epa.gov

Technology:
Phytoremediation
-850 acres of Blue Mountain and 220 acres of cinder bank were revegated using seed mixtures and Ecoloam (a mixture of municipal sewage sludge, power plant fly and/or bottom ash, and agricultural limestone).
-At Blue Mountain, Ecoloam application rates were adjusted as necessary to provide up to 2,000 pounds/acre of organic nitrogen.
-At the cinder bank, Ecoloam was applied at a rate of 60 dry tons per acre.
-An additional 350 acres of Blue Mountain and 40 acres of Stoney Ridge were revegetated using seed mixtures, mushroom/leaf-litter compost, lime, and fertilizer.

Type/Quantity of Media Treated:
As of mid-2006, almost 1,200 acres of the Blue Mountain area, 220 acres of the cinder bank, and 40 acres of Stoney Ridge have been revegetated.

Regulatory Requirements/Cleanup Goals: Not Provided

Results:
After 10 years, the initial 850 acres of revegetated land on Blue Mountain has retained more than 70 percent of its vegetative cover.

Costs:
The estimated cost for revegetating the initial 850 acres of Blue Mountain was $9 million. This cost included the cost of revegetation and the construction of more than 60 miles of switchback roads for use by the application trucks.

Description:
The Palmerton Zinc Pile Superfund Site is located in Palmerton, Pennsylvania. The Site operated as a zinc smelter from 1898 till 1980. Smelting operations resulted in heavy metal contamination of the Site and caused defoliation of more than 2,000 acres of land in the vicinity of Blue Mountain. Additionally, process residue and other wastes were deposited along a cinder bank at the base of the Blue Mountain.

After several years of pilot testing, a full scale phytoremediation project was implemented to revegetate the Blue Mountain area. Initially, 850 acres of land on Blue Mountain were revegetated using seed mixtures and a biosolid consisting of lime, potash, sewer sludge, and fly ash. This operation lasted from 1991 to 1995 and cost $9 million. Additionally, 220 acres of the cinder bank were revegetated using this same procedure.

After the initial application on Blue Mountain and the cinder bank, sewage sludge in the biosolid material was replaced with mushroom and leaf-litter due to the public's negative perception of sewage sludge. In 2005, this new mixture was applied to 40 acres of Stoney Ridge and to an additional 350 acres of Blue Mountain.

Studies conducted 10 years after the start of the project, have shown that the initial 850 acres of treated land on Blue Mountain have retained more than 70 percent of their vegetative cover.

Phosphate-induced metal stabilization (PIMS) at Camp Stanley Storage Activity, Texas

Site Name: Camp Stanley Storage Activity (CSSA)	**Location:** Texas
Period of Operation: April 2002 to April 2003	**Cleanup Authority:** Demonstration conducted under the Department of Defense (DoD) Environmental Security Technology Certification Program (ESTCP).
Purpose/Significance of Application: The purpose of the full scale application was to determine suitable emplacement methodologies for the treatment of Pb-contaminated soils using PIMS™ and to determine actual field implementation costs.	**Cleanup Type:** Full Scale
Contaminants: Lead	**Waste Source:** Pb-containing bullets used at the firing range
Contacts: Dr. Judith Wright UFA Ventures, Inc. 403 West Riverside Dr. Carlsbad, NM 88220 Telephone: 505-628-0916 Fax: 505-628-0915 E-mail: judith@ufaventures.com Dr. James Conca Carlsbad Environmental Monitoring & Research Center Carlsbad, NM 88220 Telephone: 505-234-5555 Fax: 505-887-3051 E-mail: jconca@cemrc.org Brian Murphy CSSA 1408 Moore Place, SW Leesburg, VA 20175 Telephone: 571-331-5374 E-mail: murphyb@adelphia.net Ken Rice Parsons Inc. 8000 Centre Park, Suite 200 Austin, TX 78754 Telephone: 512-719-6050 Fax: 512-719-6099 E-mail: Ken.R.Rice@parsons.com	**Technology:** <u>Phosphate-induced metal stabilization (PIMS™) using Apatite II™</u> -Apatite II™ uses a natural, benign material derived from processing fishbone waste products to treat soil contaminated with heavy metals. -In August 2002, a full scale application was conducted by treating 3,000 cubic yards of lead (Pb)-contaminated firing range soil at Solid Waste Management Unit (SWMU) B-20 at the CSSA. Apatite II™ binds Pb into Pb-pyromorphite, an insoluble phase that is stable. Pb-pyromorphite has an extremely low solubility and will remain insoluble under most environmental conditions. -Approximately 3% by weight of Apatite IITM material was mixed with Pb-contaminated soil at a rate of about 500 yd3 per day. -Soil, groundwater and leachate samples were collected for chemical analysis.
Type/Quantity of Media Treated: Soil (3,000 cubic yards)	
Regulatory Requirements/Cleanup Goals: Three cleanup goals were established for the site -Cleanup goal for leachate from amended soils - Maximum contaminant level (MCL) for Pb in drinking water (0.015 milligrams per liter [mg/L]) -The State of Texas class 2 nonhazardous waste classification criterion for Pb (1.5 mg/L for soil) in leachate using the Toxicity Characteristic Leaching Procedure (TCLP) -Reduce the bioavailability or bioaccessibility of the Pb in the soil	

Phosphate-induced metal stabilization (PIMS) at Camp Stanley Storage Activity, Texas (continued)

Results: The untreated soil contained an average total Pb concentration of 1,942 mg/kg and did not meet State of Texas class 2 nonhazardous waste classification criterion of 1.5 mg/L Pb in leachate. After treatment with PIMS™, the treated soils met the TCLP criterion with an average TCLP Pb concentration of 0.46 mg/L. Analytical results of the field leachate from the site after treatment indicted an average of 0.0065 mg/L Pb concentration, well below the 0.0150 mg/L EPA standard for Pb in drinking water. Bioaccessibility data showed that treatment reduced the bioavailability of lead. A U.S. patent (#6,217,775) was awarded for PIMS™ using Apatite II™ during the course of this application.
Costs: The total costs for this demonstration was $63,775 which includes $8,100 in start-up costs and $55,675 in operational costs.
Description: Lead-contaminated soils at Department of Defense (DoD) range sites are widespread. These soils pose one of the costliest environmental issues facing the DoD. CSSA was chosen as the test site because it is representative of many other DoD sites, both in contaminant type and field characteristics. The PIMS™ technology is an in situ stabilization or sequestration technology that uses a natural, benign material, Apatite II™. During treatment, Apatite II™ is mixed into the contaminated soil using nonspecialized equipment such as a front-end loader and a maintainer. The Apatite II™ causes the Pb to form Pb-pyromorphite, which immobilizes the Pb without changing the basic nature of the soil. This technology allows the soil to be reused or disposed as a nonhazardous material.

Soil Vapor Extraction and In Situ Chemical Oxidation at Swift Cleaners, Jacksonville, Florida

<table>
<tr><td>Site Name: Swift Cleaners</td><td colspan="2">Location: Jacksonville, Florida</td></tr>
<tr><td colspan="2">Period of Operation:
<u>Soil Vapor Extraction</u>
March 6 to May 9, 2001 – SVE system installed and beginning of system operation
April 2002 to Present – SVE system operations and maintenance (O&M)

<u>In Situ Chemical Oxidation (ISCO)</u>
May 21 to June 21, 2001 – Two injection events conducted.
April 2002 – Third injection event conducted.

August 2001 to November February 2003 – Conducted quarterly groundwater sampling
September 2004, and May 2006 – Conducted annual groundwater monitoring</td><td>Cleanup Authority:
Bureau of Waste Cleanup (as part of FDEP's Dry Cleaning Solvent Cleanup Program)</td></tr>
<tr><td colspan="2">Purpose/Significance of Application: Full-scale remediation of PCE in soil and groundwater.</td><td>Cleanup Type: Full-scale</td></tr>
<tr><td colspan="2">Contaminants:
Volatiles-halogenated: 1,1-dichloroethene (DCE); cis-1,2-DCE; tetrachloroethene (PCE) DNAPL; trans-1,2-DCE; trichloroethene (TCE); vinyl chloride (VC).</td><td>Waste Source:
Inappropriately discarded spent filters containing PCE at the drycleaning facility</td></tr>
<tr><td colspan="3">Technology:

<u>SVE</u>
- The SVE system consists of five 12-ft vapor extraction wells (VEW).
- The design radius of influence is 15 ft with a design flow rate of 27 cubic feet per minute (cfm).
- Additional VEWs are being considered for the SVE system.

<u>ISCO</u>
- In June 1999, a pilot test was conducted in the source area located at the upgradient edge of the groundwater plume at the site. The test area covered approximately 2,500 square feet (ft^2) and consisted of three injections of Fenton's chemistry-based Oxy-Cat™.
- The full-scale operation for groundwater and dense non-aqueous phase liquid (DNAPL) remediation using Fenton's chemistry-based Oxy-Cat™ began in April 2001. According to the Remedial Action Plan (RAP) for this site, the full-scale remediation will include five phases (I to V).
- Baseline groundwater samples were collected from selected monitoring and injection wells prior to the first injection event.
- Phase I, which began in April 2001, focused on two areas – Area IA and Area IB. Area IA was the same as the 2,500 ft^2 pilot test area which contained a large portion of the contaminant mass. Seven new injection wells were installed in this area at depths ranging from 35 to 45 ft. Area IB was downgradient of area IA and covered 2,000 ft^2. Thirteen new injection wells were installed in this area.
- Based on the results of groundwater samples taken after the first two full-scale injection events in areas IA and IB, a third injection was conducted in April 2002 in 11 select injection wells from areas IA and IB.
- At the end of Phase I, it was determined that implementation of Phases II to V would be less cost effective. As of March 2007, FDEP planned to assess soil and evaluate various options to treat the downgradient PCE plume. Treatment options include enhanced biodegradation with reductive dechlorination, thermal treatment, and excavation of the contaminated soil in the source area.</td></tr>
</table>

Soil Vapor Extraction and In Situ Chemical Oxidation at Swift Cleaners, Jacksonville, Florida (continued)

Contacts:

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

Regulatory Requirements/Cleanup Goals:
Soil cleanup target levels for the site were based on leachability tests while the groundwater cleanup levels were based on the primary standards (maximum contaminant levels (MCLs)). The goal was to use active remediation activities such as chemical oxidation to reduce the contaminant levels to the Natural Attenuation Default Source Concentrations (NADSC) and use monitored natural attenuation (MNA) to lower concentrations below NADSCs to the primary standards.

Results:

SVE
- Quarterly monitoring of the SVE system indicated that the system continued to remove PCE from the soil target area.
- As of August 2006, the SVE system was operational and removing approximately one to four lbs per month and has removed a total of 140.7 lbs.
- Additional VEWs were being considered for the SVE system.

ISCO
- Results of the pilot test indicated that Fenton's chemistry was capable of remediating both the dissolved phase and adsorbed phase PCE at the site. However, the intermediate and deep areas with higher concentrations of PCE would require greater volume of the Fenton's reagent to reduce PCE levels to the groundwater cleanup goals.
- Samples collected from the source area in September 2001 after the first and second injections for Areas IA and IB showed that PCE concentrations were reduced to below 200 :g/L in most monitoring wells. However, monitoring results from November 2001 revealed that concentrations of PCE in several wells in the source area had increased to levels at, or above, baseline concentrations.
- A third injection was conducted in March 2002 at 11 selected wells in Areas IA and IB to address the areas where contaminant rebound was identified.
- Groundwater monitoring results from 2004 indicated that elevated concentrations of PCE are still present at certain locations on the site in the shallow, intermediate and deep zones of the aquifer.
- Groundwater sampling results from May 2006 indicated that PCE and TCE concentrations had decreased in all three surficial aquifers. The concentrations of cis-1,2-DCE, trans-1,2,DCE, and VC continued to be detected at low concentrations, indicating that the contaminants are not effectively degrading beyond TCE.

Costs:

Cost for site characterization totaled $164,000. Cost for design and implementation totaled $428,000, which included $110,000 for the ISCO pilot test, $118,000 for SVE construction, and $200,000 for 3 ISCO injection events. The operation and maintenance (O&M) costs for soil and groundwater were $30,000 per year.

Description:

Swift Cleaners in Jacksonville, Florida, is an active dry cleaning facility that has been in operation since 1971 and primarily uses PCE as a dry cleaning solvent. Three source areas of contamination were identified at the site, including 1) the area outside the service door of the facility where the spent filters were stored, 2) the soils beneath the building floor slab near the dry cleaning machine, and 3) a former sanitary sewer line leak. The main waste source at the site was found to be inappropriately discarded spent filters containing PCE and an assessment was conducted in 1997 to determine the extent of contamination. Maximum PCE concentration in the source area was approximately 40 milligrams per kilogram (mg/kg), with the highest concentration being near the surface at approximately 1 foot below ground surface (bgs). The groundwater PCE plume appeared to have migrated vertically and laterally westward to a maximum depth of approximately 60 ft in the area downgradient from the source. The highest PCE concentration in groundwater was found to be 10,000 : g/L, at a depth of 40 to 45 ft bgs. This indicated the presence of PCE as DNAPL, with the source zone located behind the Swift Cleaners building. The down gradient edge of the plume could not be determined due to offsite access issues.

The remedial action plan developed for the site included ISCO using Fenton's chemistry-based Oxy-Cat™ to treat groundwater and DNAPL contamination and SVE to treat the contaminated soil. A pilot test was conducted in 1999 to determine the viability of chemical oxidation at the site and based on the results, a multiphase approach was developed for the full-scale application. At the time of writing this report, full scale application of the remedial action was still being conducted at the site and approximately 22,500 cubic feet (ft^3) of soil and 37,500 ft^3 of groundwater had been treated.

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IN SITU GROUNDWATER TREATMENT ABSTRACTS

Permeable Reactive Barrier at East Helena site, East Helena, Montana

<table>
<tr><td>Site Name:
East Helena</td><td>Location:
East Helena, Montana</td></tr>
<tr><td>Period of Operation:
Spring 2005 to Ongoing</td><td>Cleanup Authority: CERCLA</td></tr>
<tr><td>Purpose/Significance of Application:
To remediate arsenic contaminated groundwater.</td><td>Cleanup Type: Field Demonstration</td></tr>
<tr><td>Contaminants:
Groundwater:-Heavy Metals; Arsenic (As) (20 milligrams per Liter [mg/L])</td><td>Waste Source:
Process ponds contaminated due to lead smelting operations.</td></tr>
<tr><td>Contacts:

Remedial Project Manager:
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U.S. Environmental Protection Agency Region VIII
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Email: Jacobson.linda@epa.gov

Project Manager:
Rick Wilkin
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National Risk Management Research Laboratory
Office of Research and Development
Phone: (580) 436-8874
Email: wilkin.rick@epa.gov</td><td>Technology:
<u>Zero-Valent Iron Permeable Reactive Barrier</u>
-The permeable reactive barrier (PRB) consists of a trench 30 feet long, 46 feet deep and 6 feet wide, with 175 tons of zero-valent iron (ZVI) placed in the trench.
-The ZVI PRB system was installed 600 feet downgradient of the source area, perpendicular to the flow of contaminated groundwater.</td></tr>
<tr><td colspan="2">Type/Quantity of Media Treated:
The ZVI PRB system is treating an arsenic contaminated groundwater plume that is 450 feet wide and extends 2,100 feet downgradient from the process ponds.</td></tr>
<tr><td colspan="2">Regulatory Requirements/Cleanup Goals:
The maximum contaminant level (MCL) for arsenic is 0.010 mg/L.</td></tr>
<tr><td colspan="2">Results:
Initial, post-installation monitoring evaluations indicated that arsenic concentrations in the groundwater had been reduced from 20 mg/L (highest concentration) to below 0.010 mg/L. Due to the limited evaluation of the system it has not been determined if the treatment has been successful. A two year evaluation to determine if the system should be implemented at a full scale will be completed in 2007.</td></tr>
<tr><td colspan="2">Costs:
The ZVI PRB system cost approximately $325,000 to construct. There are no additional operation and maintenance costs associated with this system.</td></tr>
</table>

Permeable Reactive Barrier at East Helena site, East Helena, Montana (continued)

Description:
The East Helena site is located in East Helena, Montana. The site was added to the National Priorities List (NPL) in 1984. The site was a lead smelting facility that operated from the late 1880s to 2001. Smelting operations over a period of a hundred years have lead to heavy metal contamination of soil, surface water, and groundwater at the site.

Groundwater at the site had become contaminated with arsenic due to leaching from the contaminated process ponds located over the shallow groundwater. The arsenic plume is approximately 450 feet wide and extended 2,100 feet downgradient from the process ponds. The ZVI PRB was installed as a pilot project in spring of 2005.

The ZVI PRB includes a 30 foot long trench that is 46 feet deep and 6 feet wide. The trench is filled with 175 tons of ZVI and coarse sand. The system was constructed approximately 600 feet downgradient from the process ponds, perpendicular to the flow of the arsenic contaminated groundwater plume.

The construction of the system cost approximately $325,000. There are no operation and maintenance costs associated with this system.

The first round of post-implementation groundwater data was collected in June 2005. Based on this data, arsenic concentrations in treated groundwater had been reduced from 20 mg/L to below 0.010 mg/L. The system is currently in the process of a two year evaluation to determine if the system should be implemented in full scale.

In Situ Remediation of a TCE-Contaminated Aquifer Using a Short Rotation Woody Crop Groundwater Treatment System, Naval Air Station Joint Reserve Base, Fort Worth, Texas

Site Name: Naval Air Station Joint Reserve Base (NAS-JRB)	**Location:** Fort Worth, Texas
Period of Operation: August 1996 to September 1998	**Cleanup Authority:** Department of Defense's (DoD's) Environmental Security Technology Certification Program (ESTCP)
Purpose/Significance of Application: To evaluate the capability of Eastern cottonwood trees (Populus deltoides) to intercept and treat groundwater contaminated with TCE and c-DCE.	**Cleanup Type:** Field Demonstration
Contaminants: Halogenated – volatiles; Tetrachloroethene (PCE); Trichloroethylene (TCE); Cis-1,2-dichloroethene (cDCE); trans-1,2-DCE; methylene chloride; vinyl chloride; toluene	**Waste Source:** Historically, manufacturing processes at Plant 4 of the NAS-JRB generated an estimated 5,500 to 6,000 tons of waste per year, including: waste solvents, oils, fuels, paint residues, and miscellaneous spent chemicals. TCE is believed to have leaked from degreasing tanks in the assembly building at Plant 4 and entered the underlying alluvial aquifer.
Contacts: Mr. Gregory Harvey ASC/ENVR Building 8, Suite 2 1801 10th Street, Area B Wright Patterson AFB, OH 45433 Telephone: 937-255-3276 Fax: 937-255-4155 E-mail: gregory.harvey@wpafb.af.mil Dr. Jeff Marqusee ESTCP Program Office 901 North Stuart Street, Suite 303 Arlington, VA 22203 Telephone: 703-696-2117 Fax: 703-696-2114 E-mail: jeffrey.marqusee@osd.mil Ms. Sandra M. Eberts United States Geological Survey 6480 Doubletree Avenue Columbus, OH 43229 Telephone: 614-430-7740 Fax: 614-430-7777 E-mail: smeberts@usgs.gov Mr. Steven Rock EPA NRMRL 26 West Martin Luther King Drive Cincinnati, OH 45268 Telephone: 513-569-7149 Fax: 513-569-7879 E-mail: rock.steven@epa.gov	**Technology:** Phytoremediation -The primary objective of the demonstration was to study the mechanism of phytocontainment. Phytocontainment is achieved via transpiration (the evaporative loss of water from a plant). Eastern cottonwood trees were chosen as the preferred vegetation for this demonstration. They are classified as a short rotation woody crop (SRWC) because they are fast-growing and are easy to regenerate. -The SRWC groundwater treatment (SRWCGT) system consisted of two 15 x 75 square meter (m2) plantations, one planted with seven rows of whips or 1-year old stem cuttings (438 total) and the other planted with seven rows of caliper trees or 1-year old seedlings (224 total). A total of 662 trees were planted at the site. The two sizes of trees were selected for planting so that differences in rate of growth, contaminant reductions, and cost based on planting strategy could be compared. -Both plantations were oriented generally perpendicular to groundwater flow direction and spanned the most concentrated portion of the underlying TCE-groundwater plume. -Contrary to many conventional treatment processes, a SRWCGT system does not require the addition of any chemical or biological enhancements.

In Situ Remediation of a TCE-Contaminated Aquifer Using a Short Rotation Woody Crop Groundwater Treatment System (continued)

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

Regulatory Requirements/Cleanup Goals:
The cleanup goals for the contaminants of concern were the maximum contaminant levels (MCL), in ug/L: TCE – 5; c-DCE – 70; t-DCE – 100; methylene chloride – 5; vinyl chloride – 5; toluene – 1,000.

The primary objective of the SRWCGT system focused on localized hydraulic containment and the goals were to:
-Achieve a 30% reduction in the mass of TCE in the aquifer that is transported across the downgradient end of the site during the second growing season, relative to baseline TCE mass flux calculations.
-Achieve a 50% reduction in mass of TCE in the aquifer that is transported across the downgradient end of the site during the third growing season, relative to baseline TCE mass flux calculations.

Results:
The SRWCGT system did not achieve the mass flux reductions goal of 30% and 50% for the second and third growing seasons, respectively. For the second growing season, the TCE mass flux was up 8% during peak season, as compared to baseline conditions. The planted trees reduced the outward flux of groundwater by 5% during the peak of the second season, but TCE concentrations in a row of wells immediately downgradient of the trees were higher, resulting in the increase in TCE mass flux. For the third growing season, the TCE mass flux was down 11% at peak season and down 8% near season's end, as compared to baseline conditions. Concentrations of TCE during the third season in the row of downgradient wells were similar to concentrations at baseline, and the reduction in TCE mass flux is primarily attributed to a reduction in the volumetric flux of groundwater out of the site. The primary objective was not met because the trees did not reach their full transpiration potential during the time period of the demonstration study, but greater hydraulic control at the site is anticipated in the future.

The data show a general decrease in TCE concentrations throughout the demonstration site over the course of the study. However, since a decrease in TCE concentration was observed in the upgradient monitoring wells as well as in the wells within the plantations, this trend does not appear to be predominantly related to the establishment of the whip and caliper tree plantations. Secondly, downgradient monitoring wells did not exhibit a significant decrease in TCE concentrations. The change in TCE concentrations within the study area over time may be attributed to dilution from recharge to the aquifer and volatilization of TCE from the water table.

Costs:
Total estimated demonstration costs were $641,467, which included $426,427 in actual labor costs, $172,740 in other direct costs and $42,300 in laboratory costs.

Description:
The site chosen for the demonstration was a DoD site with a large unattenuated contaminant plume due to the lack of adequate amounts of native and/or anthropogenic carbon and dissolved oxygen (DO) levels. The site was selected to demonstrate the SRWCGT system because of its geographical location, type of contamination, and depth of contamination. The site specifically exhibited the following characteristics:
-Type-3 conditions (i.e., DO levels >1 mg/L and a lack of carbon sources that prevented reductive dechlorination of chlorinated compounds).
-The groundwater at the site is shallow and thus accessible to trees soon after planting.
-An ample area, clear of obstructions, was available for plantations (i.e., the technology is well suited for use at very large field sites where other methods of remediation are not cost effective or practical).
-The site allowed for long-term, field-scale monitoring and evaluation.
-Previously installed wells were available to monitor the treatment system (water levels in wells provide a direct means for assessing groundwater uptake by the trees).

The site selected for the demonstration was an approximate 70-m-wide portion of a TCE plume on the north side of the site. Specifically, the study was undertaken to determine the potential for a SRWC to decrease TCE flux. Although TCE was the focus of the demonstration, other chlorinated organic compounds detected in the groundwater or plant tissue included, but were not limited to, cDCE, tDCE, PCE, methylene chloride, toluene, and VC.

Electronically Induced Redox Barriers for Treatment of Groundwater at F.E. Warren Air Force Base, Wyoming

<table>
<tr><td colspan="2">Site Name:
F.E. Warren Air Force Base</td><td colspan="2">Location:
Wyoming</td></tr>
<tr><td colspan="3">Period of Operation:
August 2002 to August 2004</td><td>Cleanup Authority:
Demonstration conducted under the Department of Defense (DoD) Environmental Security Technology Certification Program (ESTCP).</td></tr>
<tr><td colspan="3">Purpose/Significance of Application:
The purpose of the demonstration was to demonstrate/validate a potential new efficient and cost-effective technology for managing contaminated groundwater at the Department of Defense (DoD) facilities.</td><td>Cleanup Type: Field Demonstration</td></tr>
<tr><td colspan="3">Contaminants:
Trichloroethene (TCE), approximately 300 mg/L</td><td>Waste Source:
Historical missile maintenance and disposal activities.</td></tr>
<tr><td>Contacts:
Andrea Leeson
ESTCP Program Manager
901 North Stuart Street, Suite 303
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E-mail: jcramer@state.wy.us</td><td colspan="3">Technology:
<u>Electrically Induced Redox Barrier (e-Barrier)</u>
-An e-barrier consists of a panel of closely spaced permeable electrodes installed in a trench that intercepts a plume of contaminated groundwater.
-Application of an electrical potential to the electrodes creates oxidizing conditions at the positive electrodes and reducing conditions at the negative electrodes. This drives sequential oxidation and/or reduction of contaminants with the net benefit of reducing contaminant flux.
-The e-barrier constructed for this field demonstration consisted of 17 individual electrode panels each 0.3 x 2 square meters (m2) in area. Concentric interlocks linked the individual panels. The overall as-built dimension of the e-barrier is 9.2 x 1.9 m2. The effective cross-sectional area was 17 m2.
-Each panel contained three Ti-mmo electrodes, four layers of GeotextileTM, and six layers of Triplanar GeonetTM.
-Panels were framed in slotted 3-in inner diameter (ID) PVC pipe.
-Each e-barrier module includes a discrete electrical connection, gas vents, and washout tubing that are conveyed to the surface via 3-in PVC riser pipes.
-The assembled e-barrier was installed in two sections.
-Washed granular backfill from the Crow Creek alluvium was placed around the e-barrier to an elevation of approximately 1 foot (ft) above the barrier.
-Following installation at the site, the e-barrier was allowed to equilibrate with the contaminant in the plume for 5 months. Power was applied to the e-barrier in January 2003. Power was supplied by a 30V DC 200 amp single-phase rectifier. The rectifier was connected to a 110V AC 60 amp electrical service.
-As of August 2004, the e-barrier had been operating continuously for approximately 19 months.</td></tr>
<tr><td colspan="4">Type/Quantity of Media Treated:
Groundwater: .63,000 gallons</td></tr>
<tr><td colspan="4">Regulatory Requirements/Cleanup Goals:
Trichloroethene - 5 ug/L; cis-1,2-DCE - 70 ug/L.</td></tr>
</table>

Electronically Induced Redox Barriers for Treatment of Groundwater at F.E. Warren Air Force Base, Wyoming (continued)

Results:
The primary effect of the e-barrier was to shift thermodynamic conditions in the vicinity of the electrodes, resulting in an overall effect of oxidation followed by reduction. This facilitated oxidation and/or reduction of the TCE. The groundwater became more acidic (approximately 1 pH unit) close to the e-barrier. On day 290, the highest potential was applied. Samples of groundwater collected at this time showed a 95% reduction in TCE concentration between 0.5 meters up- and downgradient face of the e-barrier. This achieved the cleanup goal of 5ug/L.

In general, no adverse reaction intermediates were observed. An exception was the apparent formation of chloroform at the center of the e-barrier. Plausible explanations for chloroform formation include highly toxic conditions developed at the e-barrier and/or unanticipated reactions with polyvinyl chloride (PVC) pipe cement. Operation of the e-barrier had no apparent impact on the mobility of inorganic constituents in groundwater.

Costs:
The total costs associated with the demonstration included capital expenditure (96.5% of total) and operation and maintenance (O&M) (3.5% of total). The capital costs consisted of e-barrier installation (29.7%), electrode materials (15.5%), and labor for panel fabrication (9%). Total observed capital and O&M costs, normalized to the cross-sectional area of the e-barrier, were $409/ft2/year and $10/ft2/year, respectively.

Description:
Research on e-barriers has been underway at Colorado State University (CSU) since September 1998. The e-barrier was designed and fabricated at CSU in May through July 2002 and was installed at F.E. Warren AFB in August 2002. Warren AFB was selected for this demonstration due to favorable geologic conditions at the site, the presence of the desired target compound, and proximity to CSU. Some primary site attributes include a background TCE concentration of approximately 300 ug/L; depth to groundwater of approximately 12 ft (below grade); and a groundwater seepage velocity of 0.37 ft/day.

F.E. Warren is a 7,000-acre facility underlain by alluvial deposits and the Ogallala Formation. Locally, the Ogallala Formation consists of interbedded gravel, sand, and silt with varying clay content and cementation. The site selected for the demonstration is a shallow alluvial plume containing approximately 300 ug/L of TCE.

Demonstration of Bioaugmentation at Kelly Air Force Base, Texas

Site Name: Kelly Air Force Base	***Location:*** Texas
Period of Operation: November 1999 to May 2002	***Cleanup Authority:*** Demonstration conducted under the Department of Defense (DoD) Environmental Security Technology Certification Program (ESTCP).
Purpose/Significance of Application: The primary objective of the demonstration was to determine if complete reductive dechlorination could be stimulated through the introduction of a microbial culture KB-1 known to contain halorespiring bacteria. Secondary objectives involved testing the robustness of the applied microbial culture by depriving it of electron donor and adding sulfate to the system.	***Cleanup Type:*** Field Demonstration
Contaminants: Volatiles – Halogenated; Tetrachloroethene (PCE); Trichloroethene (TCE)	***Waste Source:*** Not provided

Technology:
<u>Bioaugmentation</u>
-Bioaugmentation was tested to treat chlorinated solvents-contaminated groundwater. The KB-1 culture, consisting of halorespiring bacteria, was added to a bioaugmentation demonstration plot.
-The bioaugmentation system consisted of one injection well and three extraction wells. Groundwater was extracted and pumped into a tank; electron donors (methanol and acetate) were added to the groundwater stream to achieve a total concentration of 7.2 milliMoles (mM). The groundwater was then pumped into the injection well. A groundwater recirculation rate of 3 gallons per minute (gpm) was maintained throughout the test with a residence time in the demonstration plot of approximately 8 days.
-The demonstration plot included nine wells: one injection well, three extraction wells, and five monitoring wells. Three of the monitoring wells were aligned along the center of the plot parallel to the groundwater flow direction and located at a distance of 8, 12, and 22 ft downgradient of the injection well. The other two monitoring wells were aligned perpendicular to groundwater flow, and were initially installed to be outside the zone of influence of the system. Each of the wells in both plots were completed to a depth of 25 feet below ground surface (ft bgs) and were screened from 15 to 25 ft bgs to reduce the opportunity for aeration and increased oxygen concentrations of the groundwater as it moved through the treatment system.
-Groundwater samples were collected monthly during operation or when system operating parameters were modified. During each sampling event, groundwater was collected for pH, temperature, conductivity, dissolved oxygen (DO), oxidation-reduction potential, salinity, and turbidity volatile organic compound (VOC), volatile fatty acid (VFA), sulfate, nitrite, nitrate, bromide (tracer), and dissolved gas analyses. In addition, samples were collected for gene probe analysis for detection of the KB-1 culture.

Demonstration of Bioaugmentation at Kelly Air Force Base, Texas (continued)

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Type/Quantity of Media Treated: Groundwater: 40,000

Regulatory Requirements/Cleanup Goals: No regulatory requirements or cleanup goals were provided for the demonstration.

Results: Baseline monitoring, in November 1999, indicated that PCE was the dominant chloroethene species at the site. When the electron donors alone was added to the demonstration plot, limited reductive dechlorination of PCE occurred (PCE conversion to dichlorothene [DCE]). The demonstration plot was then bioaugmented with KB-1 on May 6, 2000. Within 72 days of the addition of the KB-1 culture, ethane was detected in the demonstration plot and the PCE, TCE, and c-DCE were observed at the lowest levels observed since 1999. This indicates that the addition of the KB-1 culture stimulated complete reductive dechlorination of PCE to ethene.

After demonstrating the effects of bioaugmentation for the potential to promote complete reductive dechlorination, the system was shut down (the addition of the electron donor stopped on September 25, 2000). Groundwater samples were collected from the test plot on August 23, 2001 to determine the effects of eliminating the electron donor for one year on the population of the KB-1 culture and the reductive dechlorination process. Gene probe analysis of the groundwater samples indicated presence of KB-1 from demonstration plot. Samples from a non-augmented control plot tested negative for KB-1. The microbial analyses and the distribution of chloroethenes indicated that the KB-1 culture was present and complete dechlorination was still occurring in the demonstration plot.

Sulfate was added to the system at 3.6 mM on March 9, 2002, to determine if the competitive use of the electron donor between the chloroethenes and sulfate would limit the reductive dechlorination occurring in the test plot. Monitoring data collected on May 9, 2002 indicated that the addition of sulfate did not significantly affect reductive dechlorination.

The study indicated that the KB-1 culture was robust and able to compete with, and survive among, the indigenous microbial population. It also indicated that bioaugmentation may not require continuous monitoring following inoculation at sites where the natural attenuation requirements are met.

Costs: The total cost for the field demonstration of the bioaugmentation technology at Kelly AFB was $333,936, including: $78,000 for microcosm testing; $67,727 for capital costs for full-scale study; and $188,209 for operation and maintenance (O&M).

Demonstration of Bioaugmentation at Kelly Air Force Base, Texas (continued)

Description: A field demonstration was conducted at Kelly AFB to test the capability of a microbial culture, KB-1, to dechlorinate PCE to ethane, and to test the survivability of the culture in the field under various conditions such as presence and absence of electron donors. Bioaugmentation had been successfully demonstrated earlier at Kelly AFB in microcosm studies. The demonstration plot was selected for the earlier microcosm bioaugmentation study based on the presence and concentrations of the contaminants, access to an existing test infrastructure, hydrogeology/ geology of site, and site logistics (site access, electrical power, water, etc.). The geology in the vicinity of the test site consisted of unconsolidated alluvial deposits that have been deposited on the top of the undulatory erosional surface of the Navarro Clay. The alluvial deposits consisted of gravel, sand, silt, and clay, ranging in thickness from 20 to 40 ft bgs. From the surface down, the geology typically consists of 1 to 4 ft of black organic clay, 6 to16 ft of tan silty, calcareous clay; and 4 to 20 ft of clayey limestone and chert gravel (denoted as clayey/gravel). The water table was approximately 15 to 20 ft bgs, and the saturated zone thickness was between 5 to12 ft bgs. Generally, groundwater flow is to the southwest with a flow velocity of approximately 0.3 ft/day. The volatile organic compounds (VOC) at the site groundwater consisted primarily of PCE, TCE, and their degradation products c-DCE and vinyl chloride. Total chlorinated ethene concentrations in the groundwater exceed 8,000 μg/L.

EX SITU ACID ROCK DRAINAGE TREATMENT ABSTRACTS

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Constructed Wetland at Copper Basin Mining District, Ducktown, Tennessee

<table>
<tr><td colspan="2">Site Name:
Copper Basin Mining District</td><td colspan="2">Location:
Ducktown, Tennessee</td></tr>
<tr><td colspan="3">Period of Operation:
1998 to Present</td><td>Cleanup Authority:
CERCLA</td></tr>
<tr><td colspan="3">Purpose/Significance of Application:
The wetland was constructed to aide in the overall remediation of manganese and aluminum contamination at the site.</td><td>Cleanup Type:
Field Demonstration</td></tr>
<tr><td colspan="3">Contaminants:
-Heavy Metals: Iron (Fe) (7.0 mg/L), Manganese (Mn) (1.2 mg/L), Copper (Cu) (0.6 mg/L), Zinc (Zn) (1.7 mg/L), Aluminum (Al) (4.2 mg/L).</td><td>Waste Source:
Copper and sulfur mining operations.</td></tr>
<tr><td>Contacts:
Remedial Project Manager:
Loften Carr
U.S. Environmental Protection Agency, Region IV
Phone: 404-562-8804
E-mail: Carr.Loften@epa.gov</td><td colspan="3">Technology:
<u>Constructed Wetland</u>
-The system consists of an anaerobic cell and a concrete diversion dam, both constructed in 1998. Two aerobic cells and a limestone-rock filter were later constructed in 2003.
-The concrete diversion dam was constructed to control the flow of the McPherson Branch into the constructed wetland and to provide a settlement basin to remove silt from the flow before it enters the wetland.
-A liner was installed in 1998 on the west bank of the McPherson Branch, 70 meters (m) upstream of the concrete dam to minimize infiltration into, and drainage from, mined waste rock under the roadway parallel to McPherson Branch.
-The wetland includes a Geosynthetic Clay Liner (GCL) covered by a 0.7 m thick agricultural lime-enriched soil layer; a 0.7 m thick layer of crushed 2.5 centimeter (cm) limestone (minimum 75% Calcium Carbonate [CaCO3]); hay bales; and a 0.15 m layer of spent mushroom compost.
-The limestone-rock filter and aerobic cells were added to oxygenate the constructed wetland effluent, volatilizate hydrogen sulfides in the effluent, and provide additional settlement for metal precipitates in the effluent.
-The constructed wetland is 2 acres in size.
-The average flow of water into the constructed wetland is 291 gallons per minute (gpm) and the average flow out of it is 241 gpm.</td></tr>
<tr><td colspan="4">Type/Quantity of Media Treated:
The average flow of water entering the anaerobic wetland is 241 gpm.</td></tr>
<tr><td colspan="4">Regulatory Requirements/Cleanup Goals:
EPA secondary maximum contaminant level (MCL) standards for public water systems:
-Heavy Metals: Fe (0.3 mg/L), Mn (0.05 mg/L), Cu (1.0 mg/L), Zn (5 mg/L), Al (0.05 – 0.2 mg/L).</td></tr>
<tr><td colspan="4">Results:
After the initial construction of the wetland in 1998, a study was conducted from September 15, 1999 to February 5, 2003 to evaluate the performance of the wetland. The study found that the wetland was reducing the acidity and concentration of most of the metals in the McPherson Branch flow. However, concentration of manganese was not being reduced. The study also found an increase in the hardness of water and a decrease in sulfate concentration. Later in 2003, two additional aerobic cells and a limestone-rock filter bed were installed to help decrease manganese concentrations.

As of 2006, the effluent concentrations of heavy metals are:
-Al at 0.055 mg/L
-Fe at 0.133 mg/L
-Mn at 0.294 mg/L
-Cu at 0.017 mg/L
-Zn at 0.197 mg/L

With the exception of manganese, all metal concentrations have been reduced to below the EPA MCL standards.</td></tr>
</table>

Constructed Wetland at Copper Basin Mining District, Ducktown, Tennessee (continued)

Costs:
-The construction cost of the anaerobic wetland in 1998 was approximately $1 million. This included the initial removal of waste material and the construction of the anaerobic cell.
-In 2003, the cost of adding the two additional aerobic cells to the wetland was approximately $300,000. This included the cost for the installation of the two cells, the cost for adding a rock filter, and the restoration of a segment of habitat on McPherson Branch downstream of the anaerobic wetland.

Description:
The Copper Basin Mining District is located in Polk County, Tennessee and Fannin County, Georgia. Copper and sulfur mining and processing occurred at the site from 1843 until 1987, with sulfuric acid production continuing until 2000. As a result of mining activities, an area of more than 35 square miles, including the Davis Mill Creek Watershed, the North Potato Creek Watershed, and sections of the Ocoee River, had become contaminated.

The site is currently being investigated and remediated through a collaborative three-party effort that was formalized by a Memorandum of Understanding (MOU), dated January 11, 2001. The three parties overseeing remediation of the site are: the EPA, the Tennessee Department of Environment and Conservation, and OXY USA (a subsidiary of Occidental Petroleum Corporation). Glenn Springs Holdings, Inc. (GSHI), also a subsidiary of Occidental Petroleum Corporation, is conducting the remedial work at the site.

The constructed wetland was installed by GSHI on the McPherson Branch near its convergence with Burra Burra Creek within the North Potato Creek Watershed. The two-acre wetland was constructed on a highly eroded watershed, near the location of a former ore roast yard. In 1998 the initial anaerobic cell of the wetland was installed on the McPherson Branch. The construction cost of the wetland and removal of waste from the area was approximately $1 million.

After construction of the wetland, a study was initiated in September 1999 to monitor the performance of the system. The study ended in February 2003 and found that the wetland had succeeded in reducing the acidity and concentration of most of the metal contamination in the McPherson Branch. The only metal that was not reduced to below the EPA MCL was manganese.

To help reduce the concentrations of manganese, two additional aerobic cells were added to the wetland system. In addition, a rock filter was constructed to provide oxygenation, volatilization of hydrogen sulfide, and settlement for metal precipitates. These additions to the wetland were conducted in 2003 at a cost of $300,000. This also includes the cost for the restoration of a segment of the stream downriver from the wetland.

The average volume of influent into the constructed wetland system is 291 gpm. Iron, copper, zinc, and aluminum concentrations have been reduced by an order of magnitude. In addition, acidity has been reduced with the pH of treated water increasing from 3.82 to 6.50.

Compost-free Bioreactor at Leviathan Mine Superfund Site, Markleeville, California

<table>
<tr><td>Site Name:
Leviathan Mine</td><td colspan="2">Location:
Markleeville, CA</td></tr>
<tr><td colspan="2">Period of Operation:
Spring 2003 – Ongoing

Superfund Innovative Technology Evaluation (SITE): November 2003 to July 2005</td><td>Cleanup Authority:
CERCLA

Technology evaluated under the U.S. Environmental Protection Agency (EPA) SITE program</td></tr>
<tr><td colspan="2">Purpose/Significance of Application:
The primary objectives of the SITE evaluation were to:
-Determine the removal efficiencies for the primary target metals (Al, Cu, Fe, and Ni) over the evaluation period
-Determine if the concentrations of the primary target metals in the treated effluent are below the interim (pre-risk assessment and record of decision) discharge standards mandated in 2002 Action Memorandum for Early Actions at Leviathan Mine</td><td>Cleanup Type: Full Scale</td></tr>
<tr><td colspan="2">Contaminants:
Average gravity flow mode influent ARD concentrations:
-Heavy metals: Aluminum (Al) (37,467 ug/L), Copper (Cu) (691 ug/L), Iron (Fe) (117,167 ug/L), Nickel (Ni) (487 ug/L)

Average recirculation mode influent ARD concentrations:
-Heavy metals: Al (40,029 ug/L), Cu (795 ug/L), Fe (115,785 ug/L), Ni (529 ug/L)</td><td>Waste Source:
Copper and sulfur mining activities.</td></tr>
</table>

Compost-free Bioreactor at Leviathan Mine Superfund Site, Markleeville, California (continued)

<table>
<tr>
<td>

Contacts:
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Technology:
<u>Compost-free Bioreactor</u>
-A compost-free bioreactor system was installed in the spring of 2003.
-The system consists of a flow control weir, a pretreatment pond, two sulfate-reducing bioreactors, a settling pond, and an aeration channel.
-Influent acid rock drainage (ARD) enters the system through a flow control weir. Sodium hydroxide is added to the influent to adjust the pH to approximately 4. Precipitates formed during the pH adjustment are settled out in the pretreatment pond. Ethanol is added to the ARD as it flows into a series of two sulfate-reducing bioreactors where sulfate is reduced to sulfide. Effluent from the bioreactors enters a settling pond where metal sulfide precipitates are removed. Finally, effluent from the settling pond flows through a rock lined aeration channel to promote gas exchange before being discharged into Aspen Creek.
-Ethanol is contained in a 7,600 Liter (L) ethanol feed stock tank and sodium hydroxide is contained in three 3,800 L feed stock tank.
-The system is designed to handle influent flows up to a maximum of 115 liter per minute (L/min). During the evaluation inlet flows were evaluated up to 91 L/min.
-The two bioreactors are lined with 60 mil high density polyethylene (HDPE) and filled with 20 to 40 centimeters (cm) of river rock.
-The system operated in two modes: gravity flow mode and recirculation mode. The gravity flow mode operates by having the ARD pass through two successive sulfate-reducing bioreactors followed by precipitation of metal sulfides in the continuous flow settling pond. The recirculation mode operates by having ARD come into direct contact with the sulfide rich water from the bioreactors followed by precipitation of the metal sulfides in the settling pond. Also in the recirculation mode, a portion of the settling pond supernatant containing excess sulfate is then pumped back to the head of the bioreactors to generate additional sulfides.

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Type/Quantity of Media Treated:
From November 2003 to mid-May 2004 the system treated 9.24 million liters of ARD while in gravity flow mode. From mid-May 2004 to July 2005, 22.1 million liters of ARD were treated using the recirculation mode.

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Regulatory Requirements/Cleanup Goals:
Maximum EPA Interim Discharge Standards:
-Heavy Metals: Al (4,000 ug/L), Cu (26 ug/L), Fe (2,000 ug/L), Ni (840 ug/L)

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Compost-free Bioreactor at Leviathan Mine Superfund Site, Markleeville, California (continued)

Results:
The evaluation showed that the compost-free bioreactor system is effective in neutralizing acidity and reducing the concentrations of the heavy metal contamination to below the interim discharge standards. During the gravity flow mode, the system removed an average of 94 percent of the total heavy metal contamination from the ARD. The recirculation mode approach removed an average of 96 percent of the contamination. In addition, the metal sulfide precipitates created by the system were found to be non-hazardous, did not pose a threat to water quality, and could be used as a soil amendment for site reclamation.

Costs:
The estimated initial fixed cost to construct a treatment system for the gravity flow mode was $836,617 and $864,119 for the recirculation mode system. These costs included site preparation, permitting, and capital and equipment costs. The site preparation costs included costs for system design, project and construction management, and preconstruction site work. The capital and equipment costs ($548,431 for gravity flow mode and $554,551 for recirculation mode) included costs for all equipment and materials used during construction, delivery of equipment and materials, earthwork, and initial system construction. The equipment and materials costs included costs for reagent storage tanks, pumps, valves, pond liners, rock substrate, pH control equipment, automation equipment and satellite phones for reliable communication at the remote site.

The total variable cost to operate the treatment system was $82,155 for gravity flow mode (over a 6-month period) and $75,877 for the recirculation mode (over a 16-month period). These costs include the cost of system startup and acclimation, consumable and rentals, labor, utilities, waste handling and disposal, analytical services, and maintenance and system modifications.

Description:
The Leviathan Mine is a former copper and sulfur mine located in Alpine County on the eastern slopes of the Sierra Nevada Mountain range. Mining activities since the 1860s have resulted in significant acid mine drainage (AMD) and ARD contamination. In the 1950s, approximately 22 million tons of overburden and waste rock were removed from the site's open pit mine and were placed in the Aspen Creek drainage channel.

In the spring of 2003 installation of a compost-free bioreactor at the site was completed. From November 2003 to July 2005 the treatment system was evaluated by the EPA SITE program to determine its effectiveness in treating ARD collected from the Aspen Seep.

The system operated in gravity flow mode from November 2003 through mid-May and in recirculation mode from mid-May through July 2005. During both periods the influent flow of ARD into the system ranged from 25 to 91 L/min. During gravity flow mode the system treated 9.24 million liters of ARD and during recirculation mode the system treated 22.1 million liters of ARD. The initial fixed cost to construct the treatment system for gravity flow mode is $836,617 and $864,119 for a recirculation mode system.

Results from the evaluation showed that the system was able to remove on an average 94 to 96 percent of the total heavy metal contamination from the ARD. Based on the success of the system, remediation of the ARD from the Aspen Seep continued.

Lime Treatment at Leviathan Mine Superfund Site, Markleeville, California

<table>
<tr><td colspan="2">Site Name:
Leviathan Mine</td><td colspan="2">Location:
Markleeville, CA</td></tr>
<tr><td colspan="3">Period of Operation:
Active lime treatment system: 1999 – ongoing; semi-passive lagoon treatment system: 2001 – ongoing

Superfund Innovative Technology Evaluation (SITE): June 2002 to October 2003.</td><td>Cleanup Authority:
CERCLA

Technology evaluated under the U.S. Environmental Protection Agency (EPA) SITE program</td></tr>
<tr><td colspan="3">Purpose/Significance of Application:
The primary objectives of the SITE evaluation were to:
-Determine the removal efficiencies for the target metals over the evaluation period
-Determine if the concentrations of the target metals in the treated effluent are below the interim (pre-risk assessment and record of decision) discharge standards mandated in 2002 Action Memorandum for Early Actions at Leviathan Mine

The secondary objectives of the evaluation were to:
-Document operating parameters and assess critical operating conditions necessary to optimize system performance
-Monitor the general chemical characteristics of the AMD or ARD water as it passes through the treatment system
-Evaluate operational performance and efficiency of solids separation systems
-Document solids transfer, dewatering, and disposal operations
-Determine capital and operation and maintenance costs</td><td>Cleanup Type:
Full Scale</td></tr>
<tr><td colspan="3">Contaminants:
Average active lime treatment biphasic operation influent AMD concentrations:
-Heavy metals: Aluminum (Al) (381,000 ug/L), Copper (Cu) (2,383 ug/L), Iron (Fe) (461,615 ug/L), Nickel (Ni) (7,024 ug/L)

Average active lime treatment monophasic operation influent ARD/AMD concentrations
-Heavy metals: Al (107,800 ug/L), Cu (2,152 ug/L), Fe (456,429 ug/L), Ni (2,560 ug/L)

Average semi-passive alkaline lagoon treatment influent ARD concentrations
-Heavy metals: Al (31,988 ug/L), Cu (13.5 ug/L), Fe (391,250 ug/L), Ni (1,631 ug/L)</td><td>Waste Source:
Copper and sulfur mining activities.</td></tr>
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Lime Treatment at Leviathan Mine Superfund Site, Markleeville, California (continued)

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Technology:
<u>Active lime treatment system</u>
-Acid rock drainage (ARD) and acid mine drainage (AMD) are neutralized using lime to precipitate dissolved iron, other metals, and oxy-hydroxides.
-Influent flows into a reaction tank where it is mixed with lime slurry. The process solution then flows through a 4,000 Liter (L) flash/floc mixing tank where polymer flocculent is added. The solution then flows into a 40,000 L clarifier for floc settling and thickening. Solids are periodically pumped from the clarifier into a 550 L-capacity batch filter press for dewatering.
-The system operated in two modes: monophasic and biphasic. The monophasic mode is a single stage process that treats a combined flow of ARD and AMD. The biphasic mode consists of two stages where only AMD is treated. During biphasic mode, the AMD flow passes through two sets of reaction tanks, flash/floc mixing tanks, and clarifiers.
-The monophasic mode of the system treated ARD/AMD flows up to 250 liter per minute (L/min) while the biphasic mode treated AMD flow up to 720 L/min.
-Forty-five percent lime slurry was added to the AMD at a rate of up to 1.3 L/min for biphasic mode and to the ARD/AMD at 0.35 L/min for monophasic mode.

<u>Semi-passive alkaline lagoon treatment system</u>
-ARD with low arsenic concentration is neutralized using lime to form hydroxide precipitate.
-The semi-passive system operates as a continuous flow lime contact system.
-ARD influent passes through three 4,000 L air sparge/lime contact tanks where initial precipitation occurs. Forty-five percent lime slurry is added to each contact tank at a combined rate of 0.16 L/min. The tanks are sparged with compressed air to mix the ARD and lime. The ARD/lime solution then flows through a series of six, spun fabric bag filters where approximately 60 percent of the precipitate is captured. Effluent from the bag filters then flows into a 5.4 million L multi-cell settling lagoon. Treated ARD is periodically discharged from the settling lagoon into the Leviathan Creek.
-The system treats low ARD flows of approximately 120 L/min with relatively low arsenic content.

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Type/Quantity of Media Treated:
In monophasic mode, the active lime treatment system treated 17.4 million liter of combined AMD and ARD using 23.8 dry tons of lime over 6 months. During the biphasic mode the active treatment system treated 28.3 million liter of AMD using 125 dry tons of lime over 6 months.

The semi-passive alkaline lagoon treatment system treated 12.3 million liters of ARD using 19.4 dry tons of lime over 6 months.

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Regulatory Requirements/Cleanup Goals:
EPA Project Discharge Standards (Maximum):
-Heavy metals: Al (4,000 ug/L), Cu (26 ug/L), Fe (2,000 ug/L), Ni (840 ug/L)

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Results:
-Both the monophasic and biphasic modes for active lime treatment were able to remove on average 93.1 to 100 percent of each metal contaminant, with the exception of lead, which had a removal percentage of 74.6 to 78.3 percent.
-The semi-passive alkaline lagoon treatment system was able to remove on an average 88.5 to 100 percent of each metal contaminant, with the exception of lead (removal efficiency of 66.4 percent) and copper (removal efficiency of 58.3).
-Despite the low average percent removal efficiency for lead and copper, all contaminant metal concentrations in the effluent were below the interim discharge standards for both systems.

Costs:
The initial fixed costs to construct the lime treatment systems were:
-Active lime treatment operated in monophasic mode: $1,021,415
-Active lime treatment operated in biphasic mode: $1,261,076
-Semi-passive alkaline lagoon treatment: $297,482

The initial fixed costs consisted of site preparation costs, permitting costs, and capital and equipment costs. Site preparation costs included system design, project management, and construction management. Capital and equipment costs included all equipment and materials used, delivery, and initial system construction. Equipment and materials included reaction tanks, settling tanks, piping, pumps, valves, pH control equipment, automation equipment and satellite phones to support communication in the remote location.

Variable costs to operate each system over the 6-month evaluation period were as follows:
-Active lime treatment operated in monophasic mode: $200,022
-Active lime treatment operated in biphasic mode: $224,813
-Semi-passive alkaline lagoon treatment: $195,151

Variable costs included system startup and shakedown, consumables and rentals, labor, utilities, waste handling and disposal, analytical services, maintenance and system modification, and system winterization.

Description:
The Leviathan Mine is a former copper and sulfur mine located in Alpine County on the eastern slopes of the Sierra Nevada Mountain range. Mining activities since the 1860s has resulted in significant AMD and ARD contamination. In the 1950s, approximately 22 million tons of overburden and waste rock were removed from the open pit mine and distributed throughout the site.

The active lime treatment system was installed at the site in 1999 and the semi-passive alkaline lagoon treatment system was installed in 2001. The SITE evaluation was conducted from June 2002 to October 2003. Each system used lime to neutralize AMD and/or ARD. The initial fixed costs for active lime treatment were $1,021,415 and $1,261,076 for monophasic and biphasic treatment respectively, and $297,482 for the semi-passive alkaline lagoon treatment system.

Both treatment systems were able to remove an average of 88.5 to 100 percent of each metal contaminant from the influent, with the exception of lead for the active lime treatment system (both modes), and copper and lead for the semi-passive alkaline lagoon treatment system. Lead had an average removal efficiency percentage of 74 to 78 with the active lime treatment and 66 percent removal efficiency with the semi-passive alkaline lagoon treatment. Copper had an average 58 percent removal efficiency with the semi-passive alkaline lagoon treatment. Based on these results, both lime treatment systems were continued after the SITE evaluation, with the active lime treatment system operating in biphasic mode to treat AMD and the semi-passive alkaline lagoon treatment system treating ARD.

APPENDIX A

SUMMARY OF 393 CASE STUDIES

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APPENDIX A. SUMMARY OF 393 CASE STUDIES

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
Soil Vapor Extraction (43 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 393 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

APPENDIX A. SUMMARY OF 393 CASE STUDIES (continued)

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
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
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

APPENDIX A. SUMMARY OF 393 CASE STUDIES (continued)

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
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
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

APPENDIX A. SUMMARY OF 393 CASE STUDIES (continued)

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
Swift Cleaners, FL	404	SVE; Chemical Oxidation/Reduction (*in situ*)	Soil; Groundwater	TCE; PCE; Vinyl Chloride; DCE; Volatile-Halogenated	2001	2007
Tyson's Dump Superfund Site, PA	285	SVE	Soil	PCE; TCE; DCE; Volatiles-Halogenated	1988	1998
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 (51 Projects)						
Alameda Point, CA	5	Electrokinetics(Field Demonstration)	Soil	Heavy Metals	1997	2001

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
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
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
Camp Stanley Storage Activity, TX	401	Solidification/Stabilization	Soil	Heavy Metals	2002	2007
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

APPENDIX A. SUMMARY OF 393 CASE STUDIES (continued)

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
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
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

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
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
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

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
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
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
Palmerton Zinc Superfund Site, PA	396	Phytoremediation	Soil; Sediment; Groundwater	Heavy Metals	1991	2007
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

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
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
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

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
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
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

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
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
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

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
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
Rose Township Dump, MI	239	Incineration (on-site)	Soil	PCBs; Semivolatiles-Halogenated; Heavy Metals; BTEX; Volatiles-Nonhalogenated; Semivolatiles-Nonhalogenated; PAHs; Ketones	1992	1998

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
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
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

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
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
Longhorn Army Ammunition Plant, Burning Ground No. 3, TX	138	Thermal Desorption (*ex situ*)	Soil	TCE; Volatiles-Halogenated	1997	2000

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
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

APPENDIX A. SUMMARY OF 393 CASE STUDIES (continued)

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 393 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

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

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

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
Offutt AFB, Site LF-12, NE	205	Pump and Treat	Groundwater	BTEX; Volatiles-Nonhalogenated; TCE; DCE; Volatiles-Halogenated	1997	1998
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™) (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

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
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
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

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
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
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 (46 Projects)**						
Abandoned Manufacturing Facility - Emeryville, CA	2	Bioremediation (*in situ*) Enhanced Bioremediation	Groundwater	TCE; Volatiles-Halogenated; Heavy Metals	1997	2000

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
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
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

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
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
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
Kelly Air Force Base, TX	400	Bioremediaiton (*in situ*)	Groundwater	TCE; PCE; Volatiles-Halogenated	1999	2007
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

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
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
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

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
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
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

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
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
Watertown Site, MA	311	Bioremediation (*in situ*) Enhanced Bioremediation (Field Demonstration)	Groundwater; Soil	PCE; TCE; Volatiles-Halogenated	1996	2000
Other *In Situ* Groundwater Treatment (86 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

APPENDIX A. SUMMARY OF 393 CASE STUDIES (continued)

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
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
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

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
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
East Helena, MT	395	Permeable Reactive Barrier (Field Demonstration)	Groundwater	Arsenic; Heavy Metals	2005	2007
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
F. E. Warren Air Force Base, WY	403	Permeable Reactive Barrier (Field Demonstration)	Groundwater	TCE; Volatiles-Halogenated	2002	2007
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
Former Nu Look One Hour Cleaners, Coral Springs, FL	77	In-Well Air Stripping (NoVOCs™)	Groundwater	PCE; TCE; DCE; Volatiles-Halogenated	Not Provided	2001

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
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
Johannsen Cleaners, Lebanon, OR	120	Multi Phase Extraction	Groundwater	PCE; TCE; DCE; Volatiles-Halogenated	Not Provided	2001

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
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

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

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 Joint Reserve Base, TX	402	Phytoremediation (Field Demonstration)	Groundwater	DCE; PCE; TCE; Volatiles-Halogenated	1996	2007
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

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
Naval Air Engineering Station (NAES) Site (Area I), NJ	353	Chemical Oxidation/Reduction (*in situ*)	Groundwater	PCE; TCE; DCE; Volatiles-Halogenated	2002	2004
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

APPENDIX A. SUMMARY OF 393 CASE STUDIES (continued)

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
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
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

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
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
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

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
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
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

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
Idaho National Engineering and Environmental Laboratory, Pit 2, ID	111	Solidification/Stabilization (Polysiloxane) (Field Demonstration)	Debris/Slag/ Solid; Groundwater	Heavy Metals	1997	2000
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

Site Name, Location	Case Study ID	Technology *†	Media	Contaminants	Year Operation Began	Year Published
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
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
Ex Situ Acid Rock Drainage Treatment (3 Projects)						
Copper Basin Mining District, TN	397	Bioremediation (Field Demonstration)	AMD/ARD	Heavy Metals	1998	2007
Leviathan Mine, CA	398	Bioremediation	AMD/ARD	Heavy Metals	2003	2007
Leviathan Mine, CA	399	Chemical Precipitation	AMD/ARD	Heavy Metals	1999	2007

* 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	ARD	=	Acid Rock Drainage
SVE	=	Soil Vapor Extraction	PCE	=	Tetrachloroethene	AMD	=	Acid Mine Drainage
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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