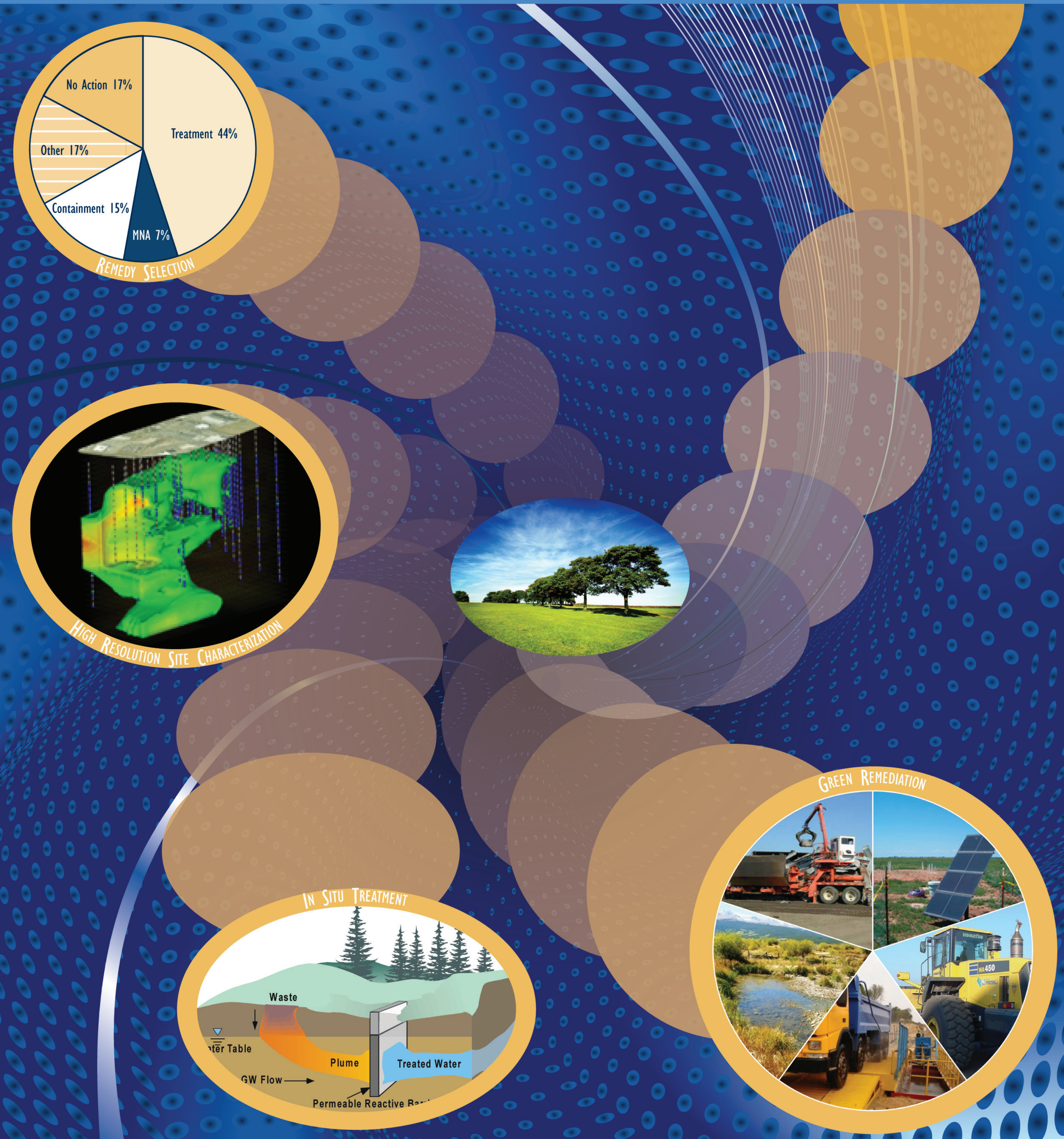
Superfund Remedy Report

Thirteenth Edition, September 2010

United States Environmental Protection Agency



Office of Solid Waste
and Emergency Response
(5203P)

EPA-542-R-10-004
September 2010
www.clu-in.org/asr

Superfund Remedy Report

Thirteenth Edition, September 2010

This page intentionally left blank.

Table of Contents

List of Appendices

List of Figures

List of Tables

Notice

Preparation of this report has been funded wholly or in part by the U.S. Environmental Protection Agency (EPA) under contract number EP-W-07-078. Mention of trade names or commercial products does not constitute endorsement or recommendation for use. A limited number of printed copies of Superfund Remedy Report (SRR) Thirteenth Edition (EPA-542-R-10-004) is available free of charge from:

U.S. EPA/National Service Center for Environmental Protection (NSCEP)
P.O. Box 42419
Cincinnati, OH 45242-0419
Toll-free: (800) 490-9198
Fax: (301) 604-3408
nscep@bps-lmit.com
www.epa.gov/nscep

A portable document format (PDF) version of SRR is available for viewing or downloading from the Hazardous Waste Cleanup Information (CLU-IN) website at www.clu-in.org/asr. Printed copies of SRR can also be ordered through that web address, subject to availability.

Acronyms

ASR	Annual Status Report
C3	Cryogenic compression and condensation
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CERCLIS	Comprehensive Environmental Response, Compensation, and Liability Information System
CLU-IN	Hazardous Waste Cleanup Information
DCA	1,2-dichloroethane
DHC	*Dehalococcoides sp.*
DNAPL	Dense non-aqueous phase liquids
EPA	U.S. Environmental Protection Agency
ESD	Explanation of Significant Differences
FRTR	Federal Remediation Technologies Roundtable
FY	Fiscal year
GW	Groundwater
H_2O_2	Hydrogen peroxide
HDPE	High density polyethylene
IC	Institutional controls
ISCO	In situ chemical oxidation
MCL	Maximum contaminant level
MNA	Monitored natural attenuation
NAPL	Non-aqueous phase liquids
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NPL	National Priorities List
nZVI	Nanoscale zero valent iron
OSRTI	Office of Superfund Remediation and Technology Innovation
OSWER	Office of Solid Waste and Emergency Response
P&T	Pump and Treat
PCE	Perchloroethene
POTW	Publicly owned treatment works
ppm	Parts per million
PRB	Permeable reactive barrier
ROD	Record of Decision
ROD-A	ROD Amendment
SDMS	Superfund Document Management System
SRR	Superfund Remedy Report
SVE	Soil vapor extraction
USEPA	U.S. Environmental Protection Agency
UV	Ultraviolet
VEB	Vertical engineered barrier
VOC	Volatile organic compound

Superfund Remedy Report

Executive Summary

The U.S. Environmental Protection Agency (EPA) has prepared the Superfund Remedy Report (SRR), which was formerly called the *Treatment Technologies for Site Cleanup: Annual Status Report (ASR)*. The SRR presents the analysis of Superfund remedial actions based on: (1) remedies selected in Records of Decision (ROD) and ROD amendments and (2) actions modified in Explanations of Significant Differences (ESD) from fiscal years (FY) 2005–2008 (FY 2005–08). The SRR also follows trends in remedy selection using ASR data through FY 2004 combined with SRR data. The SRR evaluates general remedy selection information and specific information on source control and groundwater remedy selection.

This analysis is a snapshot of recent remedy selection trends. Many of the sites in this report may have had other response actions, either removal actions or remedial actions, selected and conducted prior to FY 2005. Many sites address multiple sources and multiple inter-related media with one or more decision documents.

In general, the Superfund remedial program continues to select treatment as a primary component of decision documents that involve source control, groundwater, or both, which is consistent with the preference for treatment in the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and the National Oil and Hazardous Substances Pollution Contingency Plan (NCP). The Superfund remedial program continues to address complex sites involving multiple contaminated media by selecting remedial actions with a number of different components, including innovative and established *in situ* treatment technologies. In addition, the Superfund remedial program is more widely using institutional controls (IC) as a component of source control and groundwater remedial actions to enhance their effectiveness and protectiveness in the FY 2005–08 versus FY 1982–2004 time period. Increased knowledge and improved state programs facilitate using ICs as components of remedial actions.

The analysis of source control remedial actions indicates that the Superfund remedial program continues to select a treatment component for nearly half of all source control remedies. Of the source control remedial actions with a treatment component, approximately half include an *in situ* treatment component. Soil vapor extraction (SVE), solidification/stabilization, multi-phase extraction, and *in situ* thermal treatment were the most frequently selected *in situ* treatment technologies for sources. Solidification/stabilization continued to be the most frequently selected *ex situ* treatment technology while the selection of incineration decreased compared to its rate of selection in ASR 12th edition.

The analysis of groundwater remedial actions indicates that the Superfund remedial program continued its upward trend for the selection of *in situ* groundwater treatment remedies, but that the trend may be leveling off at around 30 percent of all groundwater treatment remedies. Bioremediation and chemical treatment are the most frequently selected *in situ* groundwater treatment technologies, and their selection has increased compared to their rate of selection in ASR 12th edition. The selection of groundwater pump and treat (P&T) has leveled off, while the selection of *in situ* treatment, monitored natural attenuation (MNA), and ICs has increased. The increase in the percentage of remedies using ICs is attributable in part to EPA's diligence in documenting the effectiveness and use of ICs as a component of remedies.

The SRR includes a project highlight about use of each of the following: green remediation concepts, *in situ* bioremediation, and high-resolution site

characterization. The SRR also identifies opportunities for conducting further analysis of remedy selection trends.

I. Purpose and Introduction

This report was prepared by the EPA Office of Superfund Remediation and Technology Innovation (OSRTI). It presents a snapshot of Superfund remedial actions selected in RODs and ROD amendments (collectively referred to as RODs) and actions modified in ESDs issued during FY 2005–08 for sites currently final on and deleted from the National Priorities List (NPL). The SRR does not include non-NPL sites, sites that are proposed for but not final on the NPL, or Superfund Alternative Sites. The data compiled and analyzed for this SRR build on the data used to generate 12 editions of *Treatment Technologies for Site Cleanup: Annual Status Report (ASR)* (which covered the time frame from FY 1982 through a portion of 2005). Where appropriate, trends in remedy selection for FY 2005–08 are compared with trends in remedy selection as reported in ASR 12th edition (September 2007). ASR 12th edition also analyzed remedies at sites final on and deleted from the NPL. This report and ASR 12th edition overlap in FY 2005. ASR 12th edition covered approximately 75 percent of the RODs issued in FY 2005, while this report covers all decision documents issued in FY 2005.

This report also highlights how recent trends in remedy selection relate to new and ongoing initiatives and advances in contaminated site management, such as green remediation, high-resolution site characterization, and *in situ* bioremediation.

The SRR includes eight sections.

- Section I discusses the purpose and introduces the report.
- Section II describes the approach used to collect and analyze data.
- Section III discusses overall trends in remedy selection.
- Section IV discusses source control remedies.
- Section V discusses groundwater remedies.
- Section VI presents conclusions.
- Section VII discusses observations, highlights, and further analysis.
- Section VIII lists the sources of the data used for this report and provides information on how to access the electronic version of this report and previous editions of ASR.

II. Approach

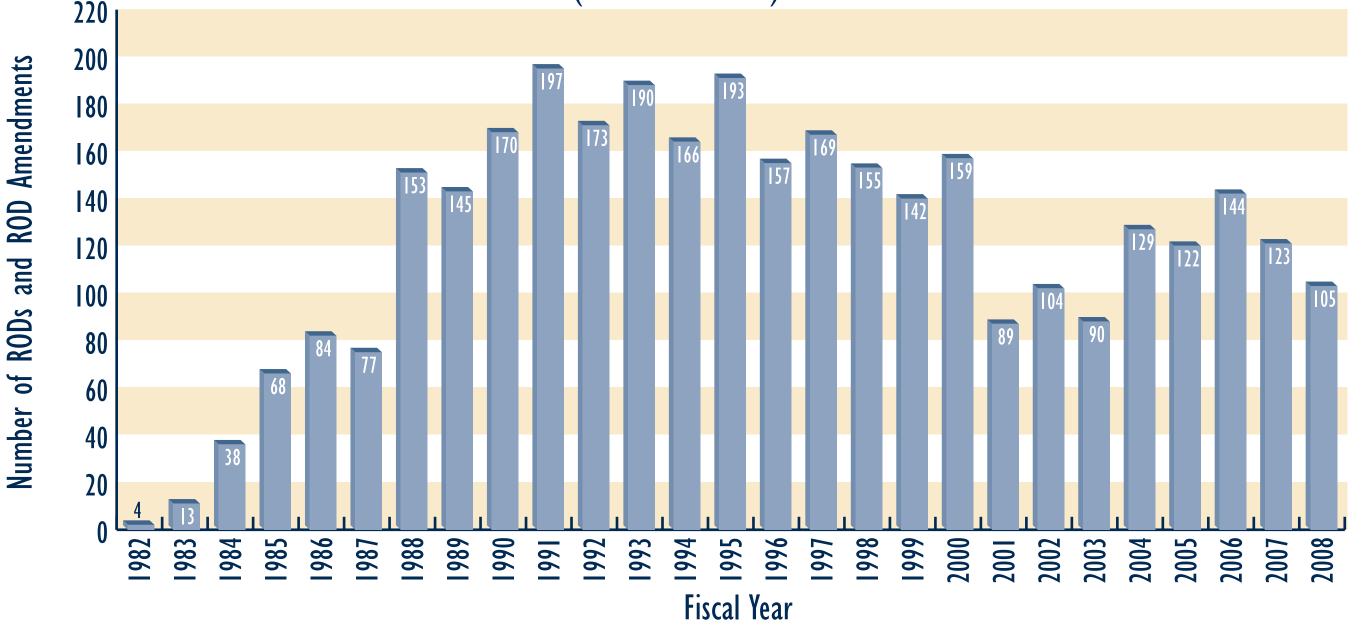
The EPA used data available in the Comprehensive Environmental Response, Compensation, and Liability Information System (CERCLIS) as of July 2009 and reviews of decision documents to compile information about remedy selection. CERCLIS data are continually updated; therefore, current queries may not match the query on which this report is based. The data used in this analysis consist of remedies selected in decision documents, which include RODs, ROD amendments, and select ESDs. Only ESDs with a remedy component were included in the data set. The report does not use project information generated after the decision document was signed. Since 1982, 1,620 sites have been finalized on the NPL and 343 sites have been deleted from the NPL. There are 1,277 sites on the NPL currently. Figure 1 depicts the number of RODs and ROD amendments issued each year from FY 1982–2008. In total, 594 decision documents were evaluated for FY 2005–08, which includes 494 RODs and 100 ESDs.

Rather than focusing on treatment technologies, as in past ASRs, this report analyzes all remedies, including containment and remedial components such as ICs. Appendix H of this report describes the way remedies are classified, and is only available electronically.

III. Overall Remedy Trends

EPA evaluated the general types of remedies selected at sites. Figure 2 presents a breakout of the types of remedies selected from FY 2005–08. The data in this figure include both source control and groundwater remedies and follow a hierarchy so that each decision document is included in only one category. The hierarchy used is outlined in Table 1 below. Figure 2 is consistent with the

Figure 1: Total Number of RODs and ROD Amendments Per Year
(FY 1982–2008)

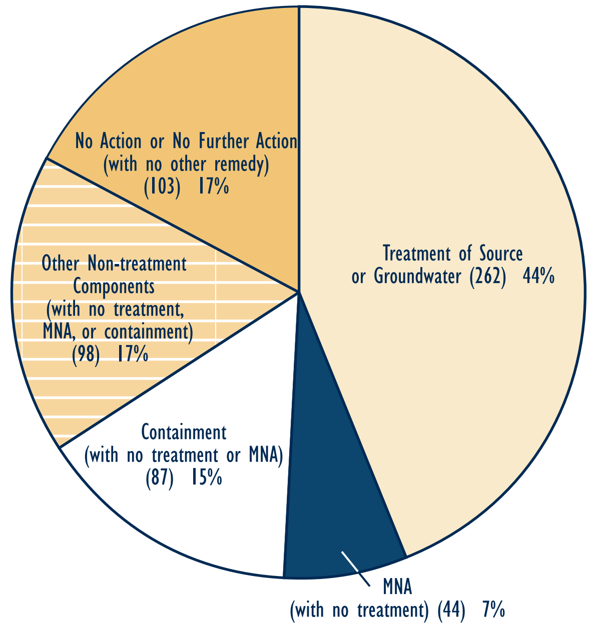


USEPA 2007a and USEPA 2009c.

Table 1: Hierarchy for Decision Documents in Figure 2

Category	Description
1. Treatment	Decision documents that select *in situ* or *ex situ* treatment of sources, groundwater, or both. These decision documents may also include monitored natural attenuation (MNA), containment, and other non-treatment components.
2. MNA	Decision documents that select groundwater MNA, but do not include source or groundwater treatment. These decision documents may also include containment and other non-treatment components.
3. Containment	Decision documents that select source containment or groundwater containment with a vertical engineered barrier (VEB) but that do not include source or groundwater treatment or groundwater MNA. These decision documents may also include other non-treatment components.
4. Other Non-Treatment Components	Decision documents that select other non-treatment components, such as ICs and monitoring, and that do not include source or groundwater treatment, source or groundwater containment, or groundwater MNA.
5. No Action/No Further Action	Decision documents that select no action/no further action and that do not include source or groundwater treatment, source or groundwater containment, groundwater MNA, or any other non-treatment components.

Figure 2: Remedies Selected in Decision Documents (FY 2005–08)
Total Number of Decision Documents = 594



- Decision documents are counted once in this figure using the following hierarchy: treatment, MNA, containment, other non-treatment components, and no action/no further action.
- Decision documents include RODs, ROD amendments, and select ESDs.

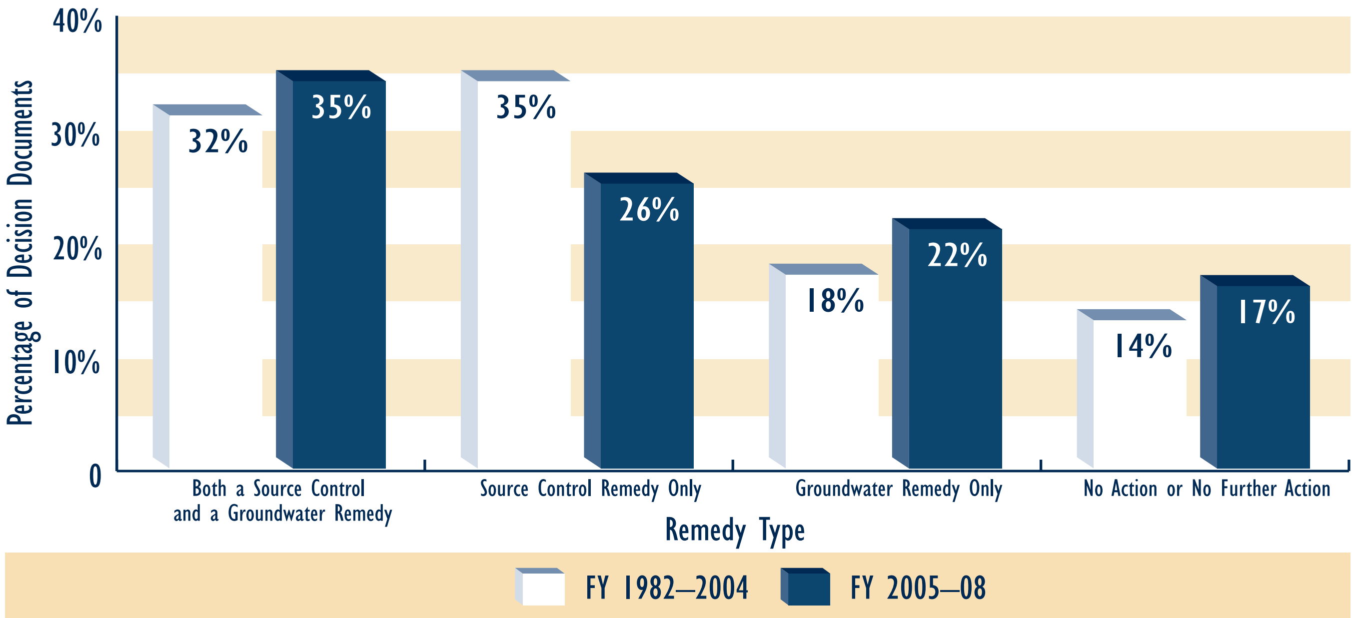
USEPA 2009c.

analysis in previous ASR reports in that nearly half of decision documents continue to select a treatment component for sources, groundwater, or both. Treatment remains a primary component of selected remedial actions. Appendix A of this report lists the type and number of *ex situ* and *in situ* source and groundwater treatment technologies by fiscal year from FY 1982–2008. Appendix B of this report contains definitions of specific source and groundwater treatment technologies selected in Superfund cleanups.

EPA evaluated the media addressed in decision documents for FY 2005–08 and classified the decision documents into four categories given in Figure 3. Only one category applies to any given decision document. Figure 3 shows the breakout of media in selected remedies for FY 2005–08 compared to the same breakout for FY 1982–2004. Over one-third of the decision documents address both source control and groundwater, which is consistent with data from previous years. This indicates that the Superfund remedial program continues to address complex sites involving multiple media. The percentage of the decision documents in each of the four categories is similar for the FY 1982–2004 and FY 2005–08 periods except for the source control only category. The percentage of decision documents addressing the source media only from FY 2005–08 is 9 percent less (26%) than the percentage of decision documents addressing the source media only from FY 1982–2004 (35%). It should be noted that future decision documents may address additional media at these sites and that not all sites have both source and groundwater media. Appendix G of this report, Remedy Selection Summary Matrix FY 2005–08, shows the media and remedy components associated with each decision document evaluated in the SRR. Appendix G is only available electronically.

Many sites address multiple sources and multiple interrelated media with one or more RODs. Often cleaning up contaminated soil or dense non-aqueous phase liquids (DNAPL) is a necessary part of restoring groundwater. Treatment of contaminated

Figure 3: Media Addressed in Decision Documents (FY 1982–2008)
Total Number of FY 1982–2004 Decision Documents = 2,862
Total Number of FY 2005–08 Decision Documents = 594



• Decision documents are only counted once in this figure as appropriate.
• Decision documents include RODs and ROD amendments for FY 1982–2004 and RODs, ROD amendments, and select ESDs for FY 2005–08.

USEPA 2009c.

Illustration 1: Applied Superfund Terminology

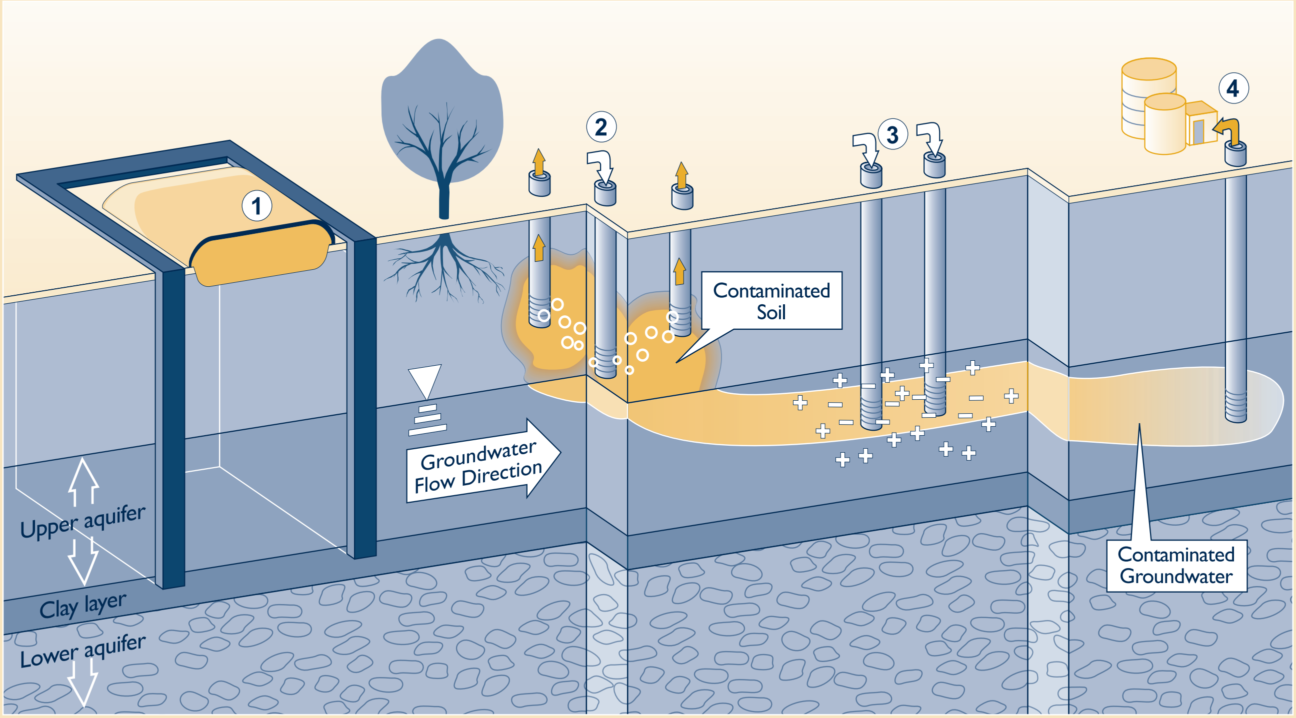


Illustration 1 depicts a hypothetical site with several sources and contaminated media that are addressed with source and groundwater remedies analyzed in this report. A single decision document may include multiple remedies.

Area 1 - Source Containment and Source Other (ICs): Area 1 is an existing landfill source. The landfill contains hazardous substances that present a threat to groundwater. The landfill source is being addressed with a Source Containment remedy that consists of a cap and slurry wall. The objectives of the cap and slurry wall are to (1) isolate the hazardous substances in the landfill from the soil and groundwater, and (2) prevent infiltration of precipitation into the landfill. ICs are also in place to restrict the future use of the landfill.

Area 2 - Source *In Situ* Treatment: Area 2 is a source of volatile organic compounds (VOC) in subsurface soil. The VOCs in the subsurface soil are a potential continuing source of groundwater contamination. The VOCs in soil are being addressed with the application of a soil vapor extraction (SVE) system that includes an air injection component. The objective of the SVE system is to reduce contaminant concentrations in subsurface soil to a level that will not pose a threat to the groundwater.

Area 3 - Groundwater *In Situ* Treatment and Groundwater Other (ICs): Area 3 is the contaminated groundwater in the upper aquifer. The contaminated groundwater in this area is more highly concentrated than that which has migrated farther downgradient. The contaminated groundwater in this area is being treated with the application of *in situ* chemical oxidation (ISCO), which involves the injection of chemical oxidants into the groundwater contaminant plume. The objective of the ISCO system is to reduce contaminants in the groundwater to levels that restore the groundwater to its beneficial use as drinking water. ICs are also in place to restrict use of contaminated groundwater at the site.

Area 4 - Groundwater Pump and Treat and Containment: Area 4 represents the leading edge of the groundwater contaminant plume. The concentrations of contaminants in this portion of the groundwater plume are less than those closer to the source but are still above cleanup standards. The contaminated groundwater in this area is being addressed by a groundwater pump and treat (P&T) system. The objectives of the P&T system are to (1) contain the plume and prevent it from migrating further downgradient, and (2) reduce contaminant concentrations to restore the groundwater to its beneficial use as drinking water.

Appendices B and H of this report contain definitions and descriptions of these source and groundwater remedy and technology types.

groundwater can directly impact sediment and surface water quality and protect against vapor intrusion into buildings. Illustration 1 depicts how multiple sources and multiple media might be addressed at a site. It shows how the application of several technologies can work together to address environmental problems.

IV. Source Control Remedies

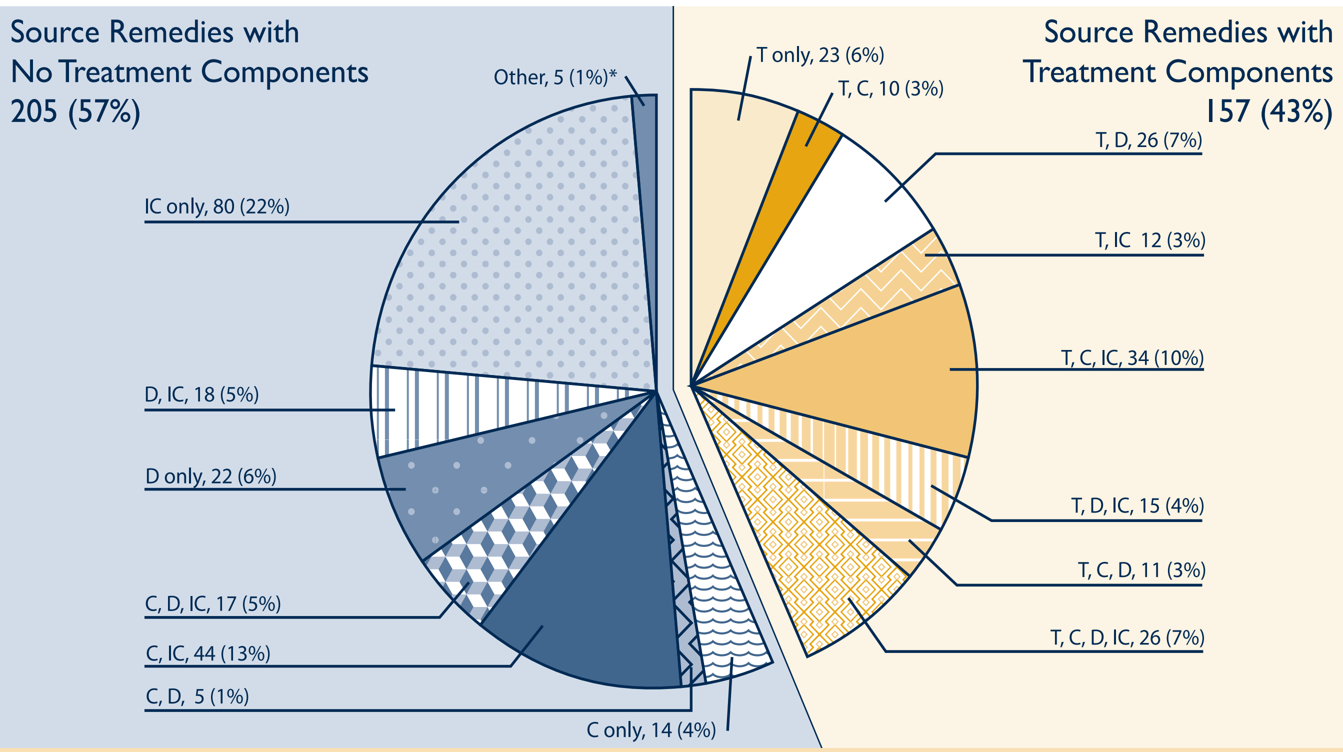
Source control remedies address soil, sediment, sludge, solid-matrix wastes, or NAPL (often the source of contamination) and do not address groundwater directly. Of the 594 decision documents issued from FY 2005–08, 61 percent (362) addressed the source of contamination.

Figure 4 shows the breakout for the types of remedy components addressed by the source control decision documents from FY 2005–08. Treatment was selected in 43 percent of source control decision documents, either by itself or in some combination with on-site containment, off-site disposal, and ICs, which is consistent with previous analysis reported in ASR 12th edition. Most source control remedies use combinations of remedy components to address the sources.

Figure 5 tracks the trend in the types of source control remedies selected in RODs from FY 1998–2004 and in decision documents from FY 2005–08 and does not use a hierarchy. The figure shows the percentage of source control RODs and decision documents that include treatment, containment, or other remedy components. RODs and decision documents may be counted in more than one category. Figure 5 shows:

- The percentage of source control RODs and decision documents with a treatment component has remained steady since FY 1998,
- The percentage of source control RODs and decision documents with a containment

Figure 4: Categories of Source Decision Documents (FY 2005–08)
Total Number of Decision Documents = 362



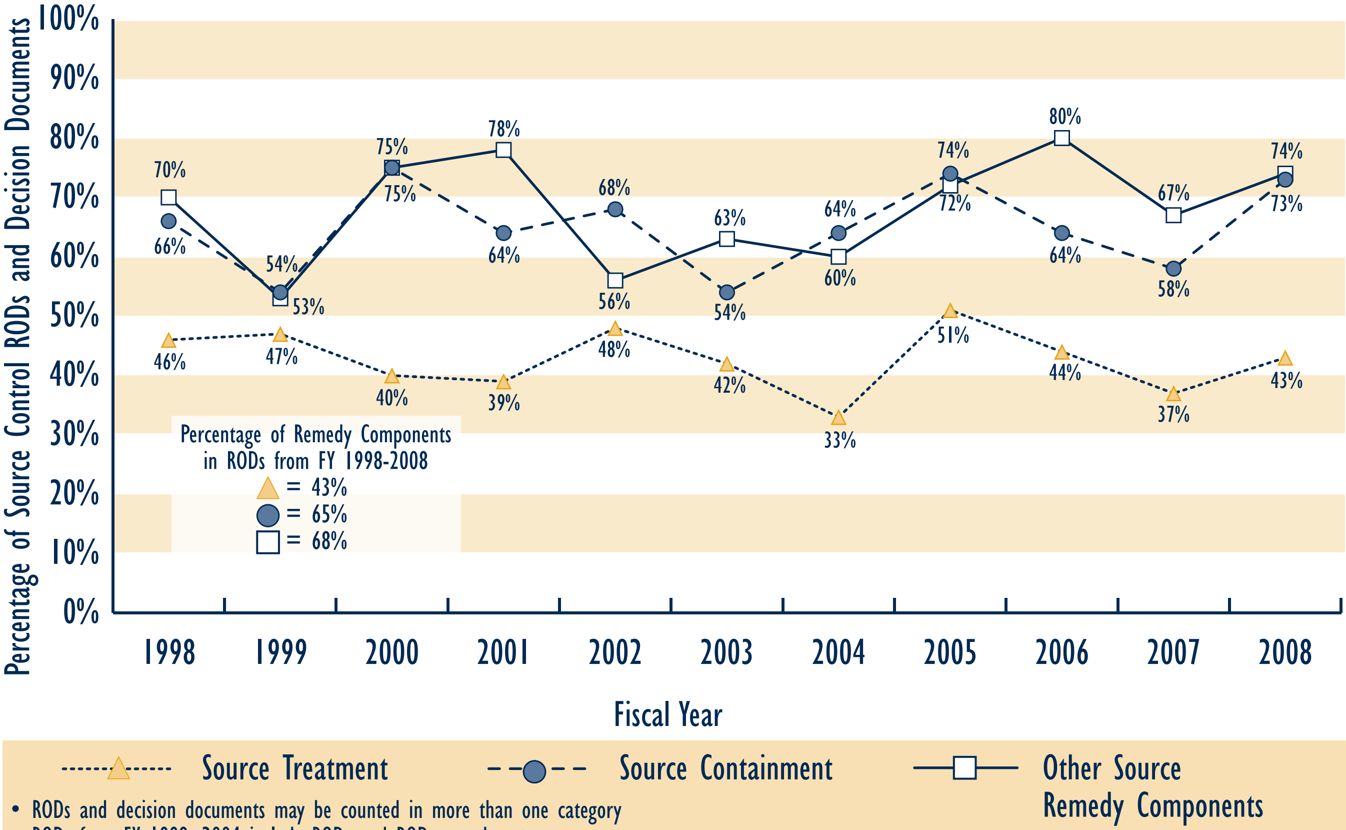
* Other includes 4 surface water monitoring remedies and 1 population relocation.
• Decision documents are counted once in this figure as appropriate.
• Decision documents include RODs, ROD amendments, and select ESDs.

USEPA 2009c.

KEY
T = Treatment of source in situ, ex situ, or off-site
C = On-site containment
D = Off-site disposal
IC = Institutional controls

Figure 5: Trends in Types of Source Control RODs and Decision Documents (FY 1998–2008)

Total Number of Source Control RODs and Decision Documents = 1,010



- RODs and decision documents may be counted in more than one category
- RODs from FY 1998–2004 include RODs and ROD amendments.
- Decision documents from FY 2005–08 include RODs, ROD amendments, and select ESDs.

USEPA 2009c and USEPA 2007a.

component has ranged between 54 percent and 75 percent over the past 11 years, and

- The percentage of source control RODs and decision documents that also include an "other" remedy component (such as ICs, monitoring, or relocation) has risen to as high as 80 percent in the last four years.
- From FY 1998–2008, 43 percent of source control RODs have included a treatment component, 65 percent of source control RODs have included a containment component, and 68 percent of source control RODs have included other non-treatment or non-containment components, such as ICs.

Table 2 summarizes the specific types of technologies selected in the source control treatment decision documents for FY 2005–08 and compares that data to the project-level data for FY 1982–2004 from ASR 12th edition. The table is divided into two sections: the top section lists *in situ* technologies, and the bottom section lists *ex situ* technologies. Data from Figure 8 in ASR 12th edition were used to populate the second and third columns of Table 2. (Note that data from ASR 12th edition are based on project information, while data presented in this analysis are based solely on decision documents). SVE, solidification/stabilization, *in situ* thermal treatment, and multi-phase extraction were selected most frequently for *in situ* source treatment remedies in FY 2005–08. The selection of chemical treatment (such as *in situ* chemical oxidation [ISCO]) and *in situ* thermal treatment has increased slightly in the last four years, from 2 to 4 percent and from 1 to 5 percent, respectively.

Table 2: Source Treatment Projects from FY 1982-2004 and Source Treatment Technologies Selected in Decision Documents from FY 2005–08

Technology	Total Source Treatment Projects for FY 1982–2004	% of Source Treatment Projects FY 1982–2004	Total Source Treatment Technologies for FY 2005–08	% of Source Treatment Technologies FY 2005–08
In Situ				
Soil Vapor Extraction	244	26%	32	14%
Solidification/Stabilization	41	4%	15	7%
In Situ Thermal Treatment	10	1%	12	5%
Multi-Phase Extraction	42	4%	12	5%
Bioremediation	53	6%	9	4%
Chemical Treatment	15	2%	9	4%
Bioventing	*	--	4	2%
Flushing	17	2%	2	1%
Phytoremediation	6	1%	2	1%
Other	5‡		3§	
ASR 12th Technologies	8¶		--	
Ex Situ				
Solidification/Stabilization	170	18%	33	14%
Physical Separation	19	2%	29	13%
Recycling	*	--	15	7%
Surface Water Treatment	†	--	11	5%
Unspecified Off Site Treatment	†	--	10	4%
Incineration (Off Site)	105	11%	6	3%
Free Product Recovery	*	--	5	2%
Composting	*	--	3	1%
Leachate Treatment	†	--	3	1%
Air Sparging	*	--	2	1%
Chemical Treatment	9	1%	2	1%
Neutralization	7	1%	2	1%
Soil Vapor Extraction	7	1%	2	1%
Unspecified On Site Treatment	†	--	2	1%
Other	14**		5††	
ASR 12th Technologies	178§§		--	
Total	**950**		**230**	

* These technologies were combined with other categories in ASR 12th edition.

† These technologies were not included in any category in ASR 12th edition

‡ Electrical Separation, Mechanical Soil Aeration, and Vitrification accounted for less than 1% each of identified in situ technologies from FY 1982–2004 project data.

§ Bioslurping, Fracturing, and Volatilization accounted for less than 1% each of identifed in situ technologies in FY 2005–08 decision documents.

¶ Neutralization was identified for 8 projects (1%) from FY 1982–2004, but was not selected in any FY 2005–08 decision documents.

** Mechanical Soil Aeration, Open Burn/Open Detonation, Solvent Extraction, Phytoremediation, and Vitrification accounted for less than 1% each of identified ex situ technologies in FY 1982-2004 project data.

†† Biopile, Evaporation, Open Burn/Open Detonation, Thermal Desorption, and Unspecified Thermal Treatment accounted for less than 1% each of identified ex situ technologies in FY 2005-08 decision documents.

§§ Bioremediation was identified for 60 projects (6%), On-site Incineration for 42 projects (4%), Soil Washing for 6 projects (1%), and Thermal Desorption for 70 projects (7%) from FY 1982-2004. On-site Incineration and Soil Washing were not selected in any decision documents from FY 2005-08, and Thermal Desorption was selected in less than 1% of FY 2005-08 decision documents. Bioremediation was divided into several subcategories for FY 2005-08 decision documents.

- Decision documents may be counted in more than one category. Decision documents include RODs, ROD amendments, and select ESDs.

USEPA 2009c and USEPA 2007a.

Solidification/stabilization continues to be the most frequently selected *ex situ* source treatment technology. There are, however, significant changes in the selection of several other *ex situ* treatment technologies. Both on- and off-site incineration were selected much less frequently in FY 2005–08 than in the past. Off-site and on-site incineration accounted for 15 percent of the source control treatment projects between FY 1982–2004. However, in FY 2005–08, off-site incineration was selected in only 3 percent of the decision documents, and on-site incineration was not selected. Thermal desorption was also selected less frequently than in the past. From FY 1982–2004, thermal desorption accounted for 7 percent of source treatment projects. In FY 2005–08, thermal desorption was selected in less than 1 percent of source treatment decision documents. Conversely, physical separation and recycling were selected more frequently since FY 2005. Physical separation was selected in 13 percent and recycling in 7 percent of treatment source control decision documents from FY 2005–08; physical separation accounted for 2 percent and recycling accounted for less than 1 percent of source treatment projects from FY 1982–2004. Appendix C of this report lists the source treatment technologies selected in decision documents from FY 2005–08 organized by technology. Appendix D of this report lists the source treatment technologies selected in decision documents from FY 2005–08 organized by location. Both Appendix C and D are only available electronically.

Table 3 shows the percentage of source control treatment decision documents that have selected an *in situ* treatment component from FY 2005–08 compared to source control projects that involve *in situ* treatment from FY 1982–2004. The percentage of source control treatment decision documents with *in situ* treatment ranges from 37 to 59 percent, with an average of 50 percent from FY 2005–08. The overall rate of selection for FY 2005–08 is higher than that of 46 percent from FY 1982–2004.

V. Groundwater Remedies

Of the 594 decision documents from FY 2005–08, 336 addressed groundwater contamination. Figure 6 shows the general types of groundwater remedies selected from FY 1986–2008. This figure does not use a hierarchy, thus RODs from FY 1986–2004 and decision documents from FY 2005–08 may be counted more than once. The selection of pump and treat (P&T) remedies leveled off after dropping significantly in the mid-1990s. The selection of *in situ* treatment remedies as a percent of remedy components selected has steadily increased since FY 1986 and has been fairly constant—at around 30 percent—in FY 2005–08. The selection of MNA saw a general increase from FY 1986–98, followed by a leveling off from FY 1998–2004 and a slight

Table 3: In Situ Treatment for Source Media FY 1982-2008

FY	Source Projects/ Decision Documents With In Situ Treatment	Total Source Treatment Projects/Decision Documents	% of Source Treatment Composed of In Situ Treatment
1982-2004*	**441**	**950**	**46%**
2005-2008			
2005	16	43	37%
2006	21	42	50%
2007	20	34	59%
2008	21	38	55%
Total 2005-08	**78**	**157**	**50%**
Total 1982-2008	**519**	**1,107**	**47%**

* FY 1982–2004 data are project-level data; FY 2005–08 are decision document-level data.

- Decision documents are counted only once in this table as appropriate.
- Decision documents include RODs, ROD amendments, and select ESDs.

USEPA 2009c and USEPA 2007a.

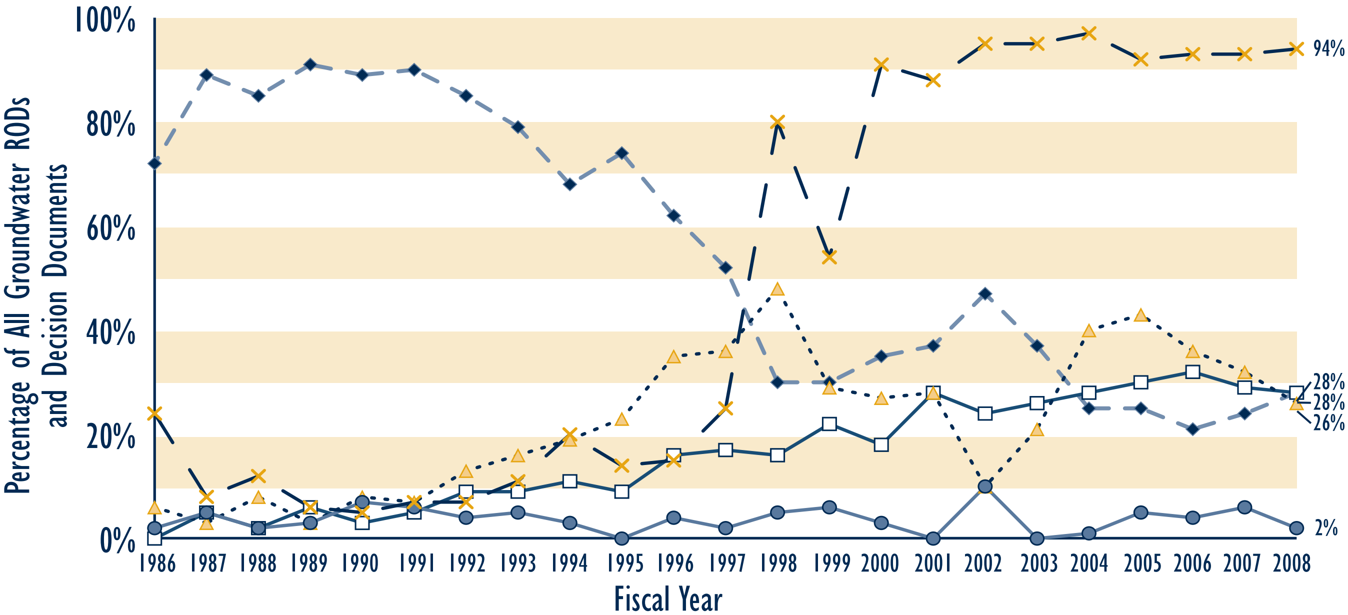
decline each year from FY 2005–08. The selection of other remedy components (ICs and other remedies not classified as MNA, *in situ* treatment, P&T, or containment) increased significantly in FY 1997 and has remained above 90 percent since FY 2002; 94 percent of the groundwater decision documents issued in FY 2008 selected "other" as a groundwater remedy component. Groundwater containment includes vertical engineered barriers, and continues to be selected in less than 5 percent of decision documents. Groundwater containment remedies in this report do not include P&T remedies used to control plume migration.

Figure 7 depicts the groundwater decision document data from FY 2005–08. Figure 7 shows the number of decision documents that selected one or more of the four groundwater remedy components: (1) groundwater P&T, (2) groundwater *in situ* treatment, (3) groundwater MNA, and (4) groundwater ICs. The number of decision documents is depicted above each bar on the chart using the y-axis, while the percentage of groundwater decision documents that contained each of the four remedy components is shown on each bar. The total number of groundwater decision documents for each year is listed in parentheses next to the year on the x-axis. For example, in FY 2005, 22 groundwater decision documents identified P&T as a remedy component, which equates to 28 percent of the 79 groundwater decision documents issued in FY 2005. No hierarchy was used in this analysis; decision documents may be counted in more than one category.

Based on the data reflected in Figure 7, ICs were selected in 81 percent of the groundwater decision documents from FY 2005–08. Figures 6 and 7 show that P&T is being selected as a remedy component less frequently and *in situ* treatment technologies are being selected more frequently. The

Figure 6: Trends in RODs and Decision Documents Selecting Groundwater Remedies (FY 1986–2008)

Total Groundwater RODs and Decision Documents = 1,727



- Groundwater ICs and Other includes institutional controls and other components not classified as treatment, MNA, or containment, such as monitoring and alternative water supplies.
- Groundwater ICs and Other remedy components selected prior to FY 1998 may be under-represented in figure.
- RODs and decision documents may be counted in more than one category.
- RODs from FY 1986–2004 include RODs and ROD amendments.
- Decision documents from FY 2005–08 include RODs, ROD amendments, and select ESDs.

USEPA 2009c and USEPA 2007a.

number and use of ICs selected has increased over time. It should be noted that ICs are often used in conjunction with other remedy components.

Table 4 depicts the types of other groundwater remedy components selected in decision documents from FY 2005–08. Compared with FY 1982–2004 (Table 7 in ASR 12th edition, which is based on sites rather than RODs), the selection of (1) engineering controls is down from 6 percent to 1 percent, (2) ICs is up from 56 percent to 87 percent, and (3) water supply remedies are down from 13 percent to 8 percent. Historically and currently, groundwater monitoring has been identified as a remedy component in more than 75 percent of RODs and decision documents. Even when monitoring is not identified as a remedy component, nearly every groundwater remedial action includes some type of groundwater monitoring. Monitoring is typically required over a relatively long period, from several years to potentially decades.

Table 5 lists the remedy types selected in groundwater decision documents, as well as the technologies selected for the various remedy types for FY 2005–08. Appendix E of this report lists the remedy types in decision documents selecting groundwater remedies from FY 2005–08 organized by technology. Appendix F of this report lists the remedy types in decision documents selecting groundwater remedies from FY 2005–08 organized by location. Both Appendix E and F are only available electronically. Table 6 lists the specific techniques identified

Table 4: Decision Documents with Groundwater Other Remedies (FY 2005–08)

Total Number of Decision Documents with Groundwater Other Remedies = 311

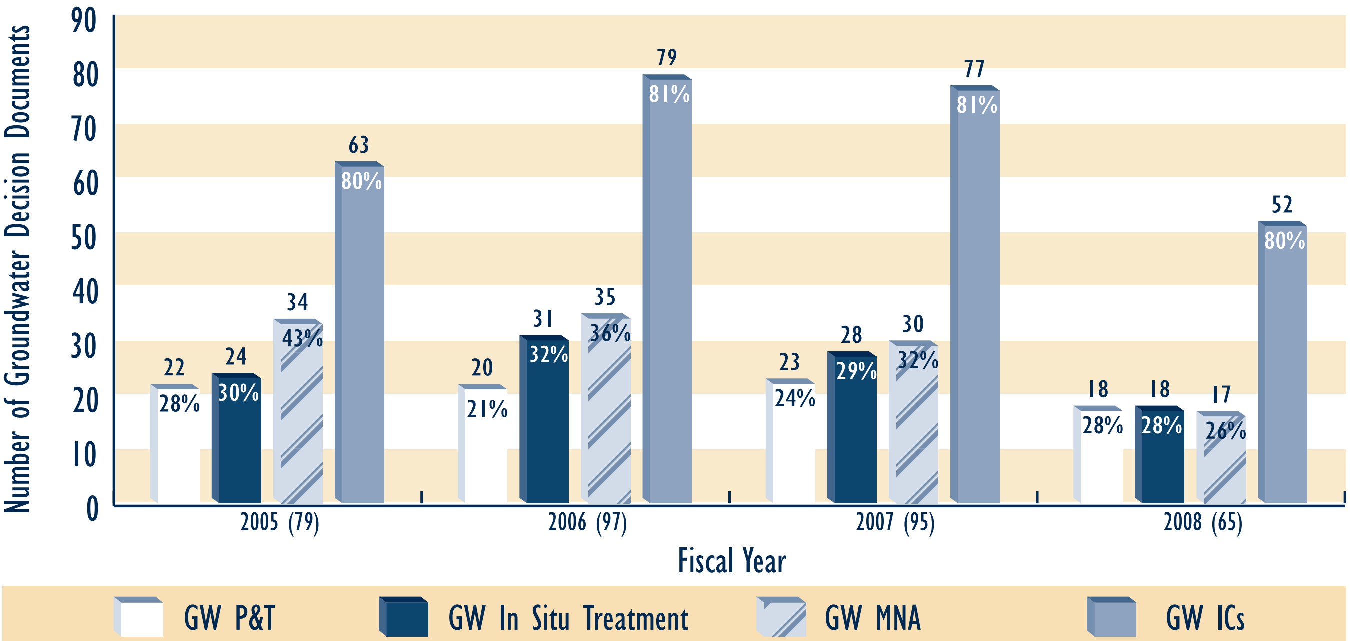
Remedy Type	Number of Decision Documents
Engineering Controls	4 (1%)
Groundwater Monitoring	239 (77%)
Institutional Controls	271 (87%)
Water Supply Remedies	26 (8%)

- Decision documents may be counted in more than one category.
- Decision documents include RODs, ROD amendments, and select ESDs.

USEPA 2009c.

Figure 7: Decision Documents Selecting Groundwater Remedies (FY 2005–08)

Total Number of Groundwater Decision Documents = 336



- Decision documents may be counted in more than one category.
- Decision documents include RODs, ROD amendments, and select ESDs.

USEPA 2009c.

Table 5: Remedy Types in Decision Documents Selecting Groundwater Remedies

(FY 2005–08)

Remedy Types and Technologies	2005	2006	2007	2008	Total
Groundwater Pump and Treat	**22**	**20**	**23**	**18**	**83**
In Situ Treatment of Groundwater	**24**	**31**	**28**	**18**	**101**
Bioremediation	13	20	17	12	62
Chemical Treatment	9	11	14	4	38
Air Sparging	5	2	1	2	10
Permeable Reactive Barrier	3	3	1	1	8
Phytoremediation	0	2	1	0	3
Fracturing	1	0	0	0	1
Multi-Phase Extraction	1	0	0	0	1
Unspecified Physical/Chemical Treatment	0	0	1	0	1
MNA of Groundwater	**34**	**35**	**30**	**17**	**116**
Groundwater Containment (Vertical Engineered Barrier)	**4**	**4**	**6**	**1**	**15**
Other Groundwater	**73**	**90**	**88**	**61**	**312**
Institutional Controls	63	79	77	52	271
Monitoring	62	80	58	39	239
Alternative Water Supply*	6	6	5	9	26
Engineering Control†	0	1	3	0	4
Total of Remedy Types	**157**	**180**	**175**	**115**	**627**

- Decision documents may be counted in more than one category.
- Decision documents include RODs, ROD amendments, and select ESDs.

* Alternative water supply includes alternative drinking water, well-head treatment, installation of new water supply wells, increasing capacity of existing water treatment plant, and treat at use location.

† Engineering control includes sewer/sump abandonment and the use of trees for hydraulic gradient control.

USEPA 2009c.

Table 6: In Situ Bioremediation and Chemical Treatment Techniques Selected in Groundwater Decisions Documents

(FY 2005–08)

Technologies and Techniques	2005	2006	2007	2008	Total
Bioremediation					
Bioremediation (In Situ)	13	20	17	12	62
Bioaugmentation	0	0	0	2	2
Co-Metabolic Treatment	0	0	0	1	1
Aeration	0	0	0	1	1
Chemical Treatment					
In Situ Chemical Oxidation (ISCO)	9	11	13	3	36
Nanoscale Zero Valent Iron (nZVI), (In Situ)	0	0	1	0	1
Ozone Sparging	0	0	0	1	1

- Decision documents may be counted in more than one category.
- Decision documents include RODs, ROD amendments, and select ESDs.

USEPA 2009c.

for selected technologies. Compared with the period before FY 2005, there has been an increase in selection of bioremediation and chemical treatment (such as ISCO) for groundwater treatment. Bioremediation and chemical treatment made up the majority of the *in situ* technologies selected from FY 2005–08. Of the 101 groundwater decision documents that selected *in situ* treatment, 62 identified bioremediation and 38 identified chemical treatment as technologies to be used. Note that decision documents may include more than one remedy component.

Figure 8 shows the breakout of sites selecting P&T, *in situ* treatment, and MNA as part of the groundwater remedy from FY 2005–08. Comparing data from FY 1982–2004 (Figure 14 in ASR 12th edition) with the data from FY 2005–08, trends in remedy selection are as follows:

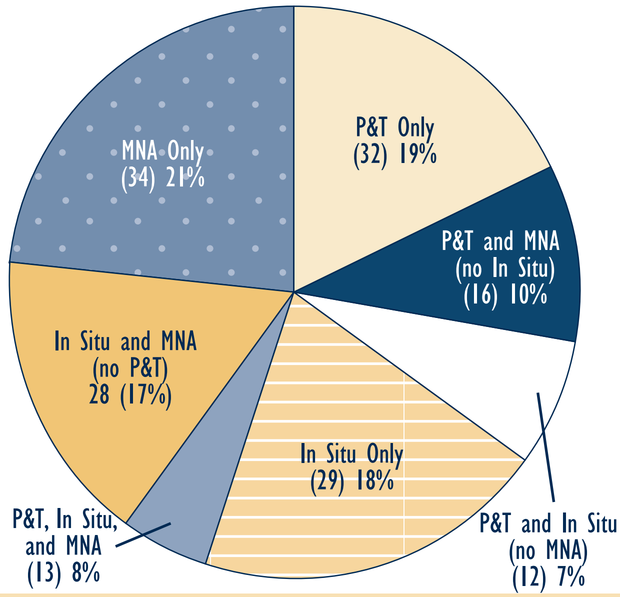
- Sites with P&T only have decreased significantly from 56 percent to 19 percent.
- Sites with *in situ* treatment only have increased from 4 percent to 18 percent.
- Sites with *in situ* treatment and MNA have increased from 2 percent to 17 percent.
- Sites with MNA only have increased from 11 percent to 21 percent.
- Of the 34 sites with MNA only, 82 percent had a prior decision document with a source control remedy, groundwater remedy, or both.

Figure 9 shows the trend in selection of *in situ* treatment as a component of groundwater RODs from FY 1986–2004 and groundwater decision documents from FY 2005–08. As the graph shows, selection of *in situ* treatment as a percentage of groundwater decision documents has followed an upward trend since FY 1986 but appears to be leveling off at about 30%.

VI. Conclusions

EPA's analysis of decision document data from FY 2005–08 indicates the following with regard to Superfund remedies in general:

Figure 8: Sites with P&T, In Situ Treatment, or MNA Selected as Part of a Groundwater Remedy (FY 2005–08)
Total Number of Sites with Groundwater Treatment or MNA = 164



- Sites are counted only once in this figure as appropriate.
- Sites are defined as those having a unique EPA ID number.
- Remedy components are those documented in RODs, ROD amendments, and select ESDs.

USEPA 2009c.

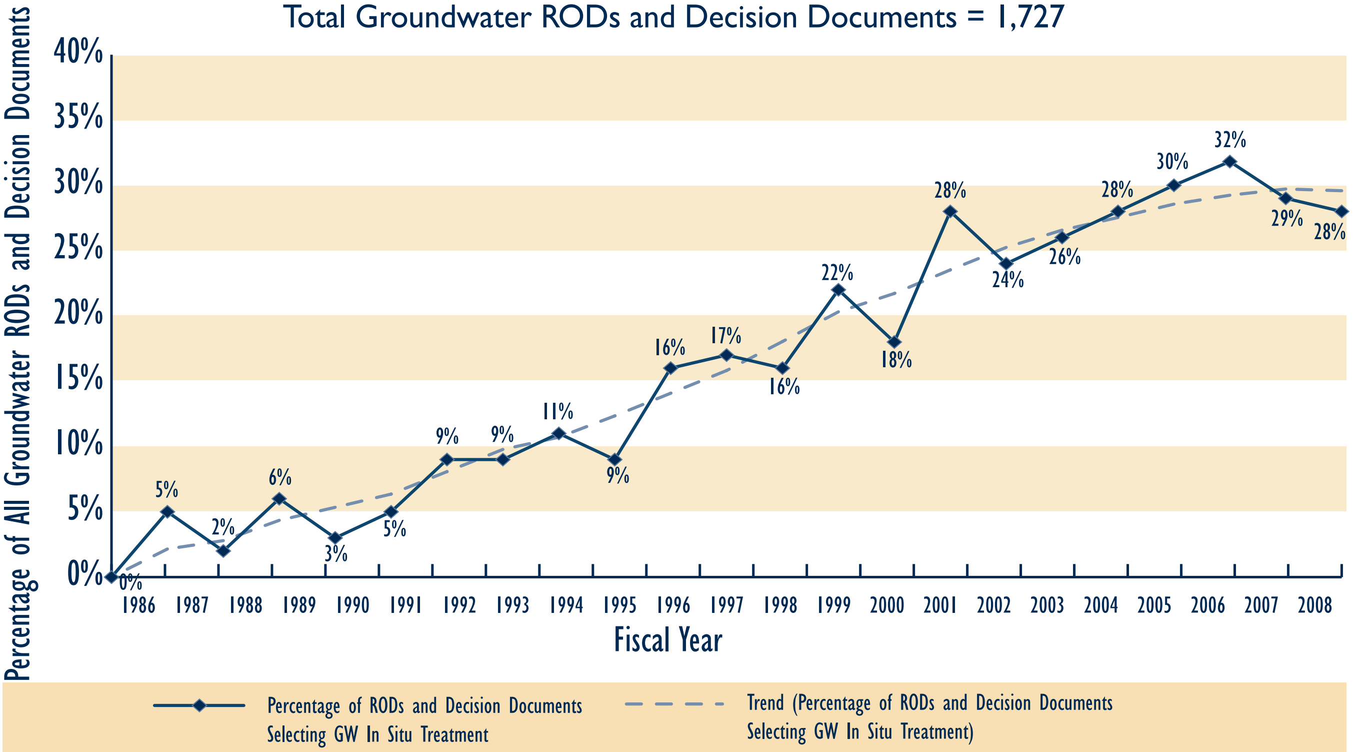
- The Superfund remedial program continues to select treatment as a primary component of decision documents that involve source control, groundwater, or both.
- The Superfund remedial program continues to address complex sites involving multiple media.

EPA's analysis of decision document data from FY 2005–08 indicates the following with regard to source control remedies:

- The Superfund remedial program continues to select treatment for a large number of source control remedies.
- Selected source control remedies include a combination of remedy components to address the complex problems that sites present.
- Solidification/stabilization continues to be the most frequently selected *ex situ* treatment technology, while the selection of incineration

Figure 9: Trends in Groundwater RODs and Decision Documents Selecting In Situ Treatment (FY 1986–2008)

Total Groundwater RODs and Decision Documents = 1,727



- RODs from FY 1986–2004 include RODs and ROD amendments.
- Decision documents from FY 2005–08 include RODs, ROD amendments, and select ESDs.

USEPA 2009c and USEPA 2007a.

has decreased significantly and the selection of physical separation and recycling has increased.

- SVE, solidification/stabilization, multi-phase extraction, and *in situ* thermal treatment were the most frequently selected *in situ* treatment technologies.
- On average, half of the source treatment decision documents included an *in situ* treatment component.
- The increase in the Source Other remedy components is mainly attributable to ICs. The Superfund remedial program is more widely using ICs as a component of source control remedial actions to enhance their effectiveness and protectiveness. Increased knowledge and improved state programs facilitate using ICs as components of remedial actions.

EPA's analysis of decision document data from FY 2005–08 indicates the following with regard to groundwater remedies:

- The selection of P&T has leveled off, while the selection of *in situ* treatment, MNA, and ICs has increased.
- The types of other non-treatment remedy components selected for groundwater changed with an increase in ICs, a decrease in engineering control and water supply remedies, and continued selection of monitoring. The Superfund remedial program is more widely using ICs as a component of groundwater remedial actions to enhance their effectiveness and protectiveness. Increased knowledge and improved state programs facilitate using ICs as components of remedial actions.
- There was an increase in selection of bioremediation and chemical treatment technologies for *in situ* groundwater treatment.

High-Resolution Site Characterization

Fort Lewis Logistics Center Superfund Site, Washington

High-resolution site characterization was employed during the design phase to better delineate treatment isolation areas in the subsurface at this site. The investigation used multiple innovative field sampling methods including push probe groundwater sampling with an on-site laboratory; rotosonic drilling with sheen, dye, and ultraviolet (UV) fluorescence test to determine NAPL presence; electromagnetic geophysical techniques to find buried drums; and installation of multi-port wells for vertical groundwater profiling. The sampling and analysis program was designed to increase data density and limit decision uncertainty using systematic planning, dynamic work plans and field-based measurement technologies for real-time decision-making. The result was the development of a detailed and more accurate conceptual site model to more effectively design and implement the site remedy. If the design of the primary remedial technology, electrical resistivity heating, had been based on the remedial investigation alone, the system would have been oversized.

USEPA 2005.

- The selection of *in situ* treatment for groundwater continued its overall upward trend but appears to be leveling off at about 30% of groundwater treatment remedies.

VII. Observations, Highlights, and Further Analysis

EPA has made observations that are suggested by the remedy selection data and provides project highlights related to the observations. In addition, where appropriate, opportunities for further analysis are identified.

In Situ *Treatment Technologies*

The increase in selection of *in situ* technologies may be attributable to better characterization techniques and improvements in the application of specific *in situ* technologies. The high selection rate of *in situ* technologies supports the need for ongoing research into the application of *in situ* processes to continue to improve their effectiveness. These *in situ* remedies can reduce potential risks and costs from materials handling and can be more cost effective than *ex situ* technologies. The high rate of selection of *in situ* technologies also supports the need for high-resolution site characterization, which can better define source areas where an *in situ* treatment technology should be applied and which can measure treatment effectiveness. High-resolution site characterization techniques can provide a vertical and horizontal contaminant profile of the subsurface that can then be integrated with existing maps and depicted in three dimensions, as well as over time. This information can then be used to support selection, design, and implementation of *in situ* treatment technologies that directly address source areas. The highlight above describes how high-resolution site characterization was used at a site.

***In Situ* Bioremediation Project**

Iceland Coin Laundry Superfund Site, New Jersey

In situ bioremediation technologies were used to remediate the groundwater plume that contained perchloroethene (PCE) at levels above 10 parts per million (ppm). Geology at the site consists of unconsolidated sands, silts and clays underlain by sands that are highly permeable and low in organic matter and calcium carbonates. The core of the groundwater plume migrated vertically downward and horizontally. Bioremediation was selected to remediate the plume to maximum contaminant levels (MCLs) and involved injection of emulsified vegetable oil substrate, injection of sodium bicarbonate solution to adjust the pH of the groundwater, and bioaugmentation, which involved injecting *Dehalococcoides* sp. (DHC) bacteria to seed the groundwater. Preliminary geochemical/chemical analyses indicate that reductive dechlorination occurred as expected.

USEPA 2007b.

In Situ *Bioremediation*

In situ bioremediation is a specific *in situ* treatment technology the selection of which may be related to improvements in the application of *in situ* methods and site characterization techniques. The project highlight below shows how *in situ* bioremediation was successfully applied.

Further analysis opportunities include (1) comparing the use of bioremediation in the past with the current use of bioremediation to identify lessons learned and areas that may need further research, and (2) examining how EPA's efforts to improve site characterization have enabled more effective evaluation of *in situ* treatment in general and bioremediation technologies specifically and to identify what other characterization improvements might further assist in improving the evaluation, selection, and design of bioremediation technologies.

Groundwater P&T

The decrease in the selection of P&T alone for groundwater may correspond to an increase in source treatment as a replacement for or enhancement to P&T. Despite the decrease in the selection of P&T, it continues to play a substantial role in groundwater remediation.

Further analysis is being conducted to determine if the frequency of P&T use is being inflated because of the way in which information is extracted from decision documents and entered into CERCLIS.

Further analysis may be warranted to assess whether lessons learned from EPA's remedial system evaluations and P&T optimization efforts are being applied when P&T remedies are selected at new sites. Specifically, it may be beneficial to evaluate whether EPA is incorporating optimization elements and value engineering into selected P&T remedies to ensure they are designed with the most current innovations.

Recycling and Green Remediation

Selection of recycling technologies for sources increased significantly (see page 9 of this report). This may be a result of more accurate data entry or it may be attributable to a move toward greener remedies. Recycling is a technology that is consistent with EPA's green remediation initiative. The highlight below provides information about a project that selected a technology to reduce the carbon footprint of the remedial action, consistent with green remediation principles.

Further analysis could be conducted to show the degree to which green remediation concepts are being considered during remedy selection and implementation. This information would help guide efforts to promote green remediation principles.

Other Remedy Components

The increase in the "other" remedy component may be a result of an emphasis on selecting ICs to enhance the effectiveness and protectiveness of

VOC Recovery from an Air Stripper and SVE System: Applying Green Remediation Concepts

State Road 114 Groundwater Plume Superfund Site, Hockley County, Texas

An innovative technology will be implemented at this site that will help reduce the project's carbon footprint. The Ogalalla Aquifer, which is the only source of high-quality drinking water in the area, is contaminated with 1,2-dichloroethane (DCA) and benzene. In order to treat the groundwater plume, an air stripper and soil vapor extraction (SVE) system will be used to remove the VOCs, and chemical precipitation will be used to remove the dissolved metals. A cryogenic compression and condensation (C3) system will be employed to collect and condense the vapor from the air stripper and SVE system which will then be recovered for potential recycling and resale. The C3 technology will reduce the carbon footprint for the site cleanup by eliminating air emissions from the treatment plant and allowing for an accelerated cleanup using the SVE system.

USEPA 2009a and USEPA 2009b.

source control and groundwater remedial actions. The high prevalence of monitoring at the majority of groundwater sites supports EPA's efforts to optimize long-term monitoring.

VIII. Sources and Electronic Versions

This section lists the sources of information used in this report and provides information on how to access the electronic version of this report and previous versions of ASR.

Sources

1. USEPA 2009a. Superfund Preliminary Close Out Report, State Road 114 Ground Water Plume Superfund Site, Levelland, Hockley County, Texas. September 1, 2009. Superfund Document Management System (SDMS) docid # 872955.

2. USEPA 2009b. State Road 114 Superfund Summary Fact Sheet. Updated August 3, 2009. www.epa.gov/earth1r6/6sf/pdffiles/0605177.pdf.

3. USEPA 2009c. Comprehensive Environmental Response, Compensation, and Liability Information System (CERCLIS). http://cfpub.epa.gov/supercpad/cursites/srchsites.cfm. This report uses CERCLIS data as of July 31, 2009. The CERCLIS data includes all RODs, ROD amendments, and ESDs with a remedy component issued by EPA in FY 2005–08 and information from review of individual decision documents from FY 2005–08 as necessary to clarify the CERCLIS information.

4. USEPA 2007a. Treatment Technologies for Site Cleanup: Annual Status Report (ASR) Twelfth Edition (EPA-542-R-07-012). EPA. Office of Solid Waste and Emergency Response (OSWER). September 2007.

5. USEPA 2007b. Superfund Preliminary Close Out Report, Iceland Coin Laundry Superfund Site, Vineland, New Jersey. September 27, 2007. SDMS docid # 134691.

6. USEPA 2005. Expedited Site Characterization of Mixed Chlorinated Solvents and Petroleum Dense Non-Aqueous Phase Liquid (DNAPL) Using Multiple Investigative Techniques in Conjunction with Mobile and Fixed Labs at Fort Lewis Logistics Center, Fort Lewis, WA. www.triadcentral.org/user/includes/dsp_profile.cfm?Project_ID=13. May 2005.

Electronic Versions

SRR 13th edition is available electronically at www.clu-in.org/asr. The body of the report and its appendices can be downloaded from the Web site. The list below describes the appendices for this SRR.

Appendix A. Treatment Technologies by Fiscal Year. This appendix lists the *ex situ* and *in situ* source treatment technologies and the groundwater *in situ* treatment technologies and groundwater pump and treat remedies by fiscal year from 1982–2008.

Appendix B. Definitions of Specific Treatment Technologies. This appendix defines the specific treatment technologies selected as part of remedial actions.

Appendix C. Source Treatment Technologies Selected in Decision Documents from FY 2005–08, Organized by Technology (Only available electronically). This appendix lists the source treatment technologies selected from FY 2005–08 and sites/operable units with which these technologies are associated.

Appendix D. Source Treatment Technologies Selected in Decision Documents from FY 2005–08, Organized by Location (Only available electronically). This appendix lists the source treatment technologies selected from FY 2005–08 and sites/operable units with which these technologies are associated

Appendix E. Groundwater Remedies Selected in Decision Documents from FY 2005–08, Organized by Technology (Only available electronically). This appendix lists the groundwater technologies selected in decision documents from

FY 2005–08 and the sites/operable units with which these technologies are associated.

Appendix F. Groundwater Remedies Selected in Decision Documents from FY 2005–08, Organized by Location (Only available electronically). This appendix lists the groundwater technologies selected in decision documents from FY 2005–08 and the sites/operable units with which these technologies are associated.

Appendix G. Remedy Selection Summary Matrix FY 2005–08 (Only available electronically). This appendix lists the remedy components selected in each decision document analyzed for the SRR.

Appendix H. Identification of Remedy and Record of Decision Types for Superfund Remedial Actions (Only available electronically). This appendix provides the remedy definitions used to identify the types of remedy components selected in decision documents and subsequently entered into CERCLIS.

In addition, electronic versions of previous ASR reports can be downloaded from www.clu-in.org/asr.

Index

Appendix A

Treatment Technologies by Fiscal Year

Appendix A: Treatment Technologies by Fiscal Year*

Ex Situ Source Control Technologies	82-85	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	Total
Bioremediation	1	1	0	3	5	2	1	8	3	4	6	6	0	5	6	1	0	1	1	6	1	0	3	0	64
Chemical Treatment	1	0	1	0	0	0	1	1	0	0	1	1	0	0	1	0	1	0	0	1	2	0	0	0	11
Incineration (on-site)	4	3	4	6	6	4	3	3	1	1	2	1	4	0	0	0	0	0	0	0	0	0	0	0	42
Incineration (off-site)	3	2	3	9	9	15	13	6	8	5	9	5	4	3	2	5	1	2	0	1	1	3	1	1	111
Mechanical Soil Aeration	0	0	0	1	0	1	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	4
Neutralization	0	0	0	1	0	0	0	3	0	0	2	0	0	0	0	0	0	1	0	0	1	1	0	0	9
Open Burn/Open Detonation	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	1	0	0	0	5
Physical Separation (including recycling)	0	0	0	0	0	1	0	0	0	0	0	0	0	1	2	9	3	2	1	0	12	12	5	9	57
Phytoremediation	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
Soil Vapor Extraction	0	0	0	0	0	0	0	0	2	1	0	2	0	1	1	0	0	0	0	0	1	0	1	0	9
Soil Washing	0	0	0	0	1	2	0	1	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	6
Solidification/Stabilization	3	4	6	7	8	14	20	23	13	13	3	7	4	13	8	5	2	6	1	10	8	10	6	9	203
Solvent Extraction	0	0	0	0	1	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
Thermal Desorption	2	1	4	4	3	6	8	2	4	4	5	1	5	4	2	4	3	6	1	1	1	0	0	0	71
Vitrification	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Total	14	11	19	31	33	45	47	47	33	29	29	24	18	28	23	24	10	21	4	19	28	26	16	19	598
In Situ Source Control Technologies	82-85	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	Total
Bioremediation	0	0	1	2	1	3	1	4	4	5	4	6	0	6	4	4	3	2	1	2	3	6	2	1	65
Chemical Treatment	1	0	0	0	0	0	1	0	0	0	0	0	0	1	3	1	2	5	0	1	3	3	2	1	24
Electrical Separation	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
Flushing	1	1	0	0	3	1	1	1	1	4	0	0	0	0	1	1	1	0	0	1	0	0	0	2	19
Mechanical Soil Aeration	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	2
Multi-Phase Extraction	0	1	0	0	0	0	3	4	1	4	0	2	5	3	3	4	2	6	1	3	3	1	5	3	54
Neutralization	0	0	0	0	0	0	0	1	0	1	0	1	0	1	0	2	1	1	0	0	0	0	0	0	8
Phytoremediation	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	0	1	1	0	1	0	2	0	0	8
Soil Vapor Extraction	4	2	1	8	21	18	34	19	14	8	11	22	16	12	16	8	7	6	11	6	7	7	8	10	276
Solidification/Stabilization	0	1	3	2	4	2	1	3	5	0	2	4	2	3	3	1	0	3	2	0	2	6	2	5	56
Thermal Treatment	0	0	0	0	0	1	1	0	0	1	0	2	1	1	1	1	0	0	0	1	5	3	2	2	22
Vitrification	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	2
Total	7	5	5	12	29	25	43	32	25	23	17	37	24	29	33	23	17	25	15	15	23	28	21	24	537
In Situ Groundwater Technologies	82-85	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	Total
Air Sparging	0	1	0	0	1	1	8	3	2	0	4	8	6	10	7	8	4	4	1	2	5	2	1	2	80
Bioremediation	0	0	0	0	4	3	2	2	3	2	2	1	2	3	1	3	12	5	5	5	13	20	17	12	117
Chemical Treatment	0	0	0	0	0	0	0	1	1	0	0	1	1	0	3	5	6	6	1	7	9	11	14	4	70
Flushing	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
In-Well Air Stripping	0	0	0	0	0	0	0	0	0	0	1	0	1	0	1	2	1	0	1	1	0	0	0	0	8
Multi-Phase Extraction	0	1	0	0	0	0	1	2	0	2	1	1	5	2	1	2	0	3	0	3	1	0	0	0	25
Permeable Reactive Barrier	0	0	0	0	0	0	0	1	0	1	1	1	2	2	2	4	3	1	1	4	3	3	1	1	31
Phytoremediation	0	0	0	0	0	0	0	0	0	0	0	0	1	2	3	2	1	0	1	4	0	2	1	0	17
Total	0	2	0	0	5	4	11	9	6	5	9	12	18	19	18	26	28	19	10	26	31	38	34	19	349
Ex Situ Groundwater Technologies	82-85	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	Total
Pump and Treat	11	16	7	26	36	26	48	59	56	70	47	48	64	51	43	41	19	23	11	13	22	20	23	18	798

* Data for FY 1982–2004 are project-level data; data from FY 2005–08 are decision document-level data.

Appendix B: Definitions of Specific Treatment Technologies

This appendix provides definitions of 18 types of source control (primarily soil) treatment technologies, 10 types of in situ groundwater treatment technologies, 8 types of groundwater P&T technologies, and 3 containment technologies. Technologies that are applicable to both source control and groundwater treatment are described only once under the source control treatment section. For P&T technologies, the descriptions focus on the treatment portion of the technology. Groundwater pumping technologies are not addressed in this report. Definitions are based on the Remediation Technologies Screening Matrix and Reference Guide, Version 4.0, which can be viewed at the Federal Remediation Technologies Roundtable (FRTR) website at www.frtr.gov, except as noted.

Source Control Treatment Technologies

Bioremediation uses microorganisms to degrade organic contaminants in soil, sludge, solids, and groundwater either *in situ* or *ex situ*. It can also be used to make metals or metalloids less toxic or mobile. When treating organic contaminants, the microorganisms break down contaminants by using them as a food source or cometabolizing them with a food source. Aerobic processes require an oxygen source, and the end-products typically are carbon dioxide and water. Anaerobic processes are conducted in the absence of oxygen, and the end-products can include methane, hydrogen gas, sulfide, elemental sulfur, and dinitrogen gas. *Ex situ* bioremediation technologies for groundwater typically involve treating extracted groundwater in a bioreactor or constructed wetland. *In situ* techniques stimulate and create a favorable environment for microorganisms to grow and use contaminants as a food and energy source, or to cometabolize them. Generally, this process involves providing some combination of oxygen, nutrients, and moisture, and controlling the temperature and pH. Microorganisms that have been adapted for degradation of specific contaminants are sometimes applied to enhance the process. For the treatment of metals and metalloids, it involves biological activity that promotes the formation of less toxic or mobile species, by either creating ambient conditions that will cause such species to form, or changing the chemical form of the contaminant directly. The treatment may result in oxidation, reduction, precipitation, coprecipitation, or another transformation of the contaminant.

Chemical Treatment, also known as chemical reduction/oxidation, typically involves reduction/oxidation (redox) reactions that chemically convert hazardous contaminants to compounds that are nonhazardous, less toxic, more stable, less mobile, or inert. Redox reactions involve the transfer of electrons from one compound to another. Specifically, one reactant is oxidized (loses electrons) and one is reduced (gains electrons). The oxidizing agents used for treatment of hazardous contaminants in soil include ozone, hydrogen peroxide, hypochlorites, potassium permanganate, Fenton's reagent (hydrogen peroxide and iron), chlorine, and chlorine dioxide. This method may be applied *in situ* or *ex situ* to soils, sludges, sediments, and other solids, and may also be applied to groundwater *in situ* or *ex situ* (P&T). P&T chemical treatment may also include the use of ultraviolet (UV) light in a process known as UV oxidation.

Electrokinetics is based on the theory that a low-density current will mobilize contaminants in the form of charged species. A current passed between electrodes is intended to cause aqueous media, ions, and particulates to move through the soil, waste, and water. Contaminants arriving at the electrodes can be removed by means of electroplating or electrodeposition, precipitation or coprecipitation, adsorption, complexing with ion exchange resins, or by the pumping of water (or other fluid) near the electrode.

For **Flushing**, a solution of water, surfactants, or cosolvents is applied to the soil or injected into the subsurface to treat contaminated soil or groundwater. When treating soil, the injection is often designed to raise the water table into the contaminated soil zone. Injected water and treatment agents are recovered together with flushed contaminants.

Both on-site and off-site **Incineration** use high temperatures (870 to 1,200 °C or 1,600 to 2,200 °F) to volatilize and combust (in the presence of oxygen) organics in hazardous wastes. Auxiliary fuels are often employed to initiate and sustain combustion. The destruction and removal efficiency (DRE) for properly operated incinerators exceeds the 99.99% requirement for hazardous waste and can be operated to meet the 99.9999% requirement for polychlorinated biphenyls (PCB) and dioxins. Off-gases and combustion residuals generally require treatment. On-site incineration typically uses a transportable unit; for off-site incineration, waste is transported to a central facility.

Mechanical Soil Aeration agitates contaminated soil, using tilling or other means to volatilize contaminants.

Multi-Phase Extraction uses a vacuum system to remove various combinations of contaminated groundwater, separate-phase petroleum product, and vapors from the subsurface. The system typically lowers the water table around the well, exposing more of the formation. Contaminants in the newly exposed vadose zone are then accessible to vapor extraction. Once above ground, the extracted vapors or liquid-phase organics and groundwater are separated and treated.

Nanoremediation is a relatively new technology for environmental remediation. "Nanotechnology is the understanding and control of matter at dimensions between approximately 1 and 100 nanometers, where unique phenomena enable novel applications" (National Nanotechnology Initiative [NNI] 2008). Nanoparticles can be highly reactive due to their large surface area to volume ratio and the presence of a greater number of reactive sites. This allows for increased contact with contaminants, thereby resulting in rapid reduction of contaminant concentrations (*Nanotechnology for Site Remediation*, EPA OSWER, EPA-542-F-08-009, 2008).

Neutralization is a chemical reaction between an acid and a base. The reaction involves acidic or caustic wastes that are neutralized (pH is adjusted toward 7.0) using caustic or acid additives.

Open Burn (OB) and **Open Detonation (OD)** operations are conducted to destroy excess, obsolete, or unserviceable (EOU) munitions and energetic materials. In OB operations, energetics or munitions are destroyed by self-sustained combustion, which is ignited by an external source, such as a flame, heat, or a detonation wave. In OD operations, explosives and munitions are destroyed by detonation, which generally is initiated by an energetic charge.

Physical Separation processes use physical properties to separate contaminated and uncontaminated media, or separate different types of media. For example, different-sized sieves and screens can be used to separate contaminated soil from relatively uncontaminated debris. Another application of physical separation is the dewatering of sediments or sludge.

Phytoremediation is a process that uses plants to remove, transfer, stabilize, or destroy contaminants in soil, sediment, or groundwater. The mechanisms of phytoremediation include enhanced rhizosphere biodegradation (takes place in soil or groundwater immediately surrounding plant roots), phytoextraction (also known as phytoaccumulation, the uptake of contaminants by plant roots and the translocation/accumulation of contaminants into plant shoots and leaves), phytodegradation (metabolism of contaminants within plant tissues), and phytostabilization (production of chemical compounds by plants to immobilize contaminants at the interface of roots and soil). Phytoremediation applies to all biological, chemical, and physical processes that are influenced by plants (including the rhizosphere) and that aid in the cleanup of contaminated substances. Phytoremediation may be applied *in situ* or *ex situ* to soils, sludges, sediments, other solids, or groundwater.

Soil Vapor Extraction (SVE) is used to remediate unsaturated (vadose) zone soil. A vacuum is applied to the soil to induce the controlled flow of air and remove volatile and some semivolatile organic contaminants from the soil. SVE usually is performed *in situ*; however, in some cases, it can be used as an *ex situ* technology.

For **Soil Washing**, contaminants sorbed onto fine soil particles are separated from bulk soil in a water-based system on the basis of particle size. The wash water may be augmented with a basic leaching agent, surfactant, or chelating agent, or by adjusting the pH to help remove contaminants. Soils and wash water are mixed *ex situ* in a tank or other treatment unit. The wash water and various soil fractions are usually separated using gravity settling.

Solidification/Stabilization (S/S) reduces the mobility of hazardous substances and contaminants in the environment through both physical and chemical means. The S/S process physically binds or encloses contaminants within a stabilized mass. S/S is performed both *ex situ* and *in situ*. *Ex situ* S/S requires excavation of the material to be treated, and the resultant material must be disposed. *In situ* S/S uses auger/caisson systems and injector head systems to add binders to the contaminated soil or waste without excavation, leaving the resultant material in place.

Solvent Extraction uses an organic solvent as an extractant to separate contaminants from soil. The organic solvent is mixed with contaminated soil in an extraction unit. The extracted solution then is passed through a separator, where the contaminants and extractant are separated from the soil.

For **Thermal Desorption**, wastes are heated so that organic contaminants and water volatilize. Typically, a carrier gas or vacuum system transports the volatilized water and organics to a gas treatment system, typically a thermal oxidation or recovery system. Based on the operating temperature of the desorber, thermal desorption processes can be categorized into two groups: high temperature thermal desorption (320 to 560 °C or 600 to 1000 °F) and low temperature thermal desorption (90 to 320 °C or 200 to 600 °F). Thermal desorption is an *ex situ* treatment process. *In situ* thermal desorption processes are discussed below as *in situ* thermal treatment.

***In Situ* Thermal Treatment** is a treatment process that uses heat to facilitate extraction through volatilization and other mechanisms or to destroy contaminants *in situ*. Volatilized contaminants are typically removed from the vadose zone using SVE. Specific types of *in situ* thermal treatment techniques include conductive heating, electrical resistive heating, radio frequency heating, hot air injection, hot water injection, and steam enhanced extraction.

Vitrification uses an electric current to melt contaminated soil at elevated temperatures (1,600 to 2,000° C or 2,900 to 3,650 °F). Upon cooling, the vitrification product is a chemically stable, leach-resistant, glass and crystalline material similar to obsidian or basalt rock. The high temperature component of the process destroys or removes organic materials. Radionuclides and heavy metals are retained within the vitrified product. Vitrification may be conducted *in situ* or *ex situ*.

In Situ *Groundwater Treatment Technologies*

Air Sparging involves the injection of air or oxygen into a contaminated aquifer. Injected air traverses horizontally and vertically in channels through the soil column, creating an underground stripper that removes volatile and semivolatile organic contaminants by volatilization. The injected air helps to flush the contaminants into the unsaturated zone. SVE usually is implemented in conjunction with air sparging to remove the generated vapor-phase contamination from the vadose zone. Oxygen added to the contaminated groundwater and vadose-zone soils also can enhance biodegradation of contaminants below and above the water table.

Bioremediation - See Source Control Treatment Technologies.

Chemical Treatment - See Source Control Treatment Technologies.

Electrokinetics - See Source Control Treatment Technologies.

Flushing - See Source Control Treatment Technologies.

For **In-Well Air Stripping**, air is injected into a double-screened well, causing the volatile organic compounds (VOC) in the contaminated groundwater to transfer from the dissolved phase to the vapor phase in air bubbles. As the air bubbles rise to the surface of the water, the vapors are drawn off and treated by a SVE system.

Multi-Phase Extraction - See Source Control Treatment Technologies.

Nanoremediation – See Source Control Treatment Technologies.

Permeable Reactive Barriers (PRB), also known as passive treatment walls, are installed across the flow path of a contaminated groundwater plume, allowing the water portion of the plume to flow through the wall. These barriers allow the passage of water while prohibiting the movement of contaminants by employing treatment agents within the wall such as zero-valent metals (usually zero-valent iron), chelators, sorbents, compost, and microbes. The contaminants are either degraded or retained in a concentrated form by the barrier material, which may need to be replaced periodically.

Phytoremediation - See Source Control Treatment Technologies.

Pump and Treat Technologies (Ex Situ *Treatment)*

In **Adsorption**, contaminants concentrate at the surface of a sorbent, thereby reducing their concentration in the bulk liquid phase. This technology is typically applied by passing extracted groundwater through a column containing granular adsorbent. The most common adsorbent is granulated activated carbon. Other natural and synthetic adsorbents include activated alumina, lignin adsorption, sorption clays, and synthetic resins.

Air Stripping partitions volatile organics from extracted groundwater by increasing the surface area of the contaminated water exposed to air. Aeration methods include packed towers, diffused aeration, tray aeration, and spray aeration.

Bioremediation - See Source Control Treatment Technologies.

Chemical Treatment - See Source Control Treatment Technologies.

Filtration is the physical process of mechanical separation based on particle size, whereby particles suspended in a fluid are separated by forcing the fluid through a porous medium. As fluid passes through the medium, the suspended particles are trapped on the surface of the medium and/or within the body of the medium.

Ion Exchange removes ions from the aqueous phase by the exchange of cations or anions between the contaminants and the exchange medium. Ion exchange materials may consist of resins made from synthetic organic materials that contain ionic functional groups to which exchangeable ions are attached.

Membrane Filtration separates contaminants from water by passing it through a semipermeable barrier or membrane. The membrane allows water and other low molecular weight chemicals to pass, while blocking contaminants with a higher molecular weight. Membrane filtration processes include microfiltration, ultrafiltration, nanofiltration, and reverse osmosis.

Metals Precipitation transforms dissolved contaminants into an insoluble solid, facilitating the contaminant's subsequent removal from the liquid phase by sedimentation or filtration. The process usually uses pH adjustment, addition of a chemical precipitant, and flocculation.

Monitored Natural Attenuation (MNA) for Groundwater

Groundwater MNA is the reliance on natural attenuation processes (within the context of a carefully controlled and monitored approach to site cleanup) to achieve site-specific remediation objectives within a time frame that is reasonable, compared with that offered by other, more active methods. The "natural attenuation processes" include a variety of physical, chemical, or biological processes that, under favorable conditions, act without human intervention to reduce the mass, toxicity, mobility, volume, or concentration of contaminants in soil or groundwater. These *in situ* processes include biodegradation; dispersion; dilution; sorption; volatilization; radioactive decay; and chemical or biological stabilization, transformation, or destruction of contaminants. Guidance on MNA is available from the document *Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites* (OSWER Directive 9200.4-17P, EPA, April 21, 1999).

Monitored Natural Recovery (MNR) for Sediments

Sediment MNR relies on a wide range of naturally occurring processes to reduce risk from contaminated sediments to human and/or ecological receptors. These processes may include physical, biological, and chemical mechanisms that act together to reduce the risk posed by the contaminants. The key difference between MNA for groundwater and MNR for sediment is in the type of processes most often being relied upon to reduce risk. Transformation of contaminants is usually the major attenuating process for contaminated groundwater; however, these processes are frequently too slow for the persistent contaminants of concern (COCs) in sediment to provide for remediation in a reasonable time frame. Therefore, isolation and mixing of contaminants through natural sedimentation is the process most frequently relied upon for contaminated sediment (*Contaminated Sediment Remediation Guidance for Hazardous Waste Sites*, EPA OSWER, EPA-540-R-05-012, 2005).

Containment Technologies

Cover Systems, also known as caps or covers, are surface barriers composed of one of more layers of impermeable material designed to contain contaminated source material. Cover systems can be used to prevent direct contact with the source material or minimize leachate creation by preventing surface water infiltration into the contained source material.

A **Bottom Liner** is a subsurface impermeable barrier designed to prevent the spread of leachate from contaminated source material. They are often used in conjunction with cover systems in the containment of source material.

Vertical Engineered Barriers (VEB) are subsurface barriers made of an impermeable material designed to contain or divert groundwater. VEBs can be used to contain contaminated groundwater, divert uncontaminated groundwater from a contaminated area, or divert contaminated groundwater from a drinking water intake or other protected resource. VEBs can also be used for the containment of source material.

Appendices C, D, E, F, G, and H Available Electronically

Appendix C. Source Treatment Technologies Selected in Decision Documents from FY 2005–08, Organized by Technology

Appendix D. Source Treatment Technologies Selected in Decision Documents from FY 2005–08, Organized by Location

Appendix E. Groundwater Remedies Selected in Decision Documents from FY 2005–08, Organized by Technology

Appendix F: Groundwater Remedies Selected in Decision Documents from FY 2005–08, Organized by Location

Appendix G. Remedy Selection Summary Matrix FY 2005–08

Appendix H. Identification of Remedy and Record of Decision Types for Superfund Remedial Actions

These appendices do not appear in the printed version of the *Superfund Remedy Report 13th Edition*. The appendices are available in the online version of this report at www.clu-in.org/asr

United States
Environmental Protection Agency
(5203P)
Washington, D.C. 20460

Official Business
Penalty for Private Use $300

Superfund Remedy Report,
Thirteenth Edition

Office of Solid Waste and
Emergency Response

EPA-542-R-10-004
September 2010
www.clu-in.org/asr