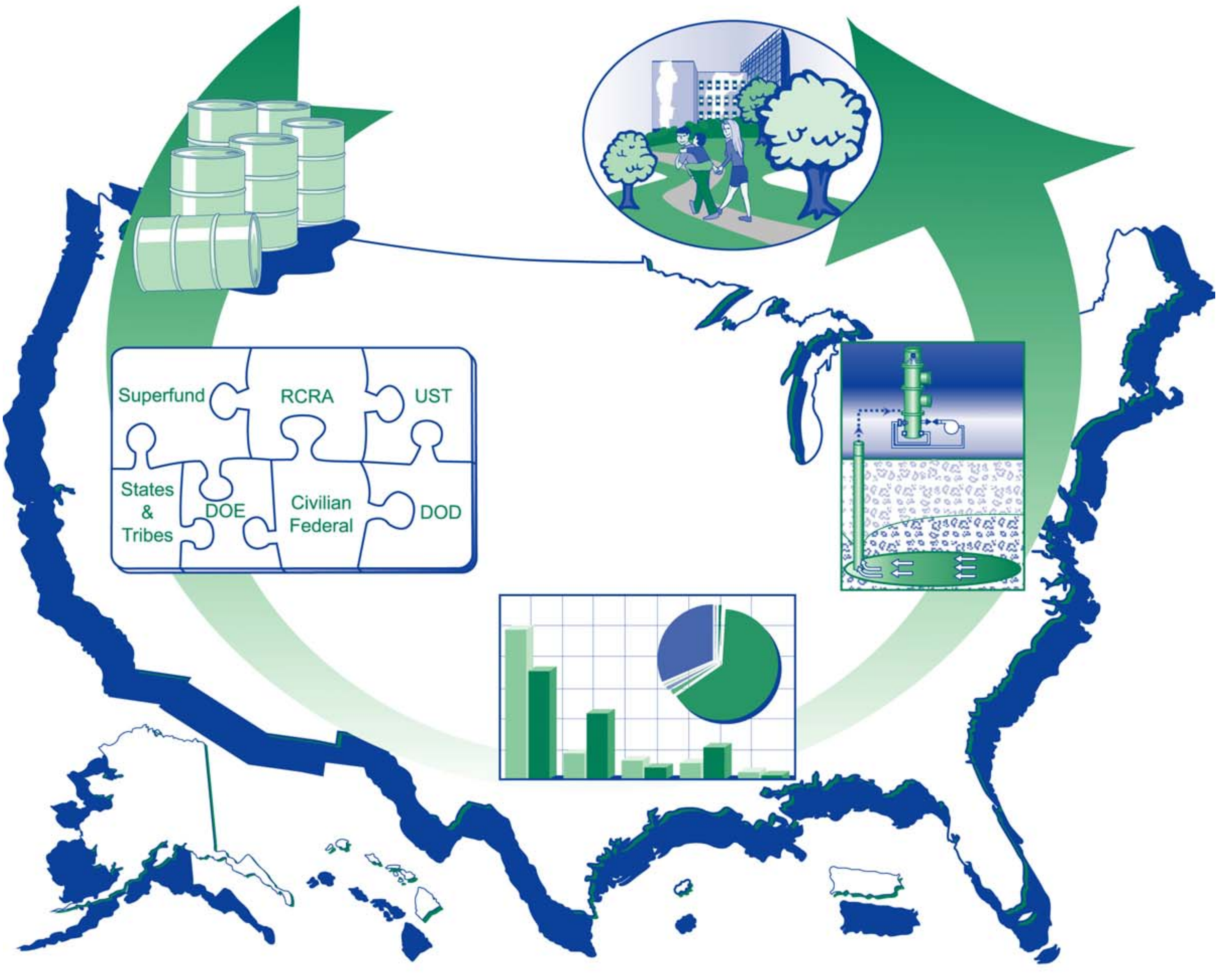
Cleaning Up the Nation's Waste Sites: Markets and Technology Trends



2004 Edition

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2004 Edition

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For More Information

For more information about remediation markets, including tools to help advance technologies through all stages of product development from bench scale to full commercialization, visit the EPA web site http://www.epa.gov/tio/vendor.

Acknowledgments

This document was prepared for the U.S. Environmental Protection Agency's Technology Innovation and Field Services Division (TIFSD). The report would not have been possible without the assistance of staff throughout EPA, the Department of Defense (DOD), and the Department of Energy (DOE). Special thanks go to staff in EPA's Office of Superfund Remediation and Technology Innovation; Office of Solid Waste; Office of Underground Storage Tanks; Federal Facilities Restoration and Reuse Office; and Office of Federal Facilities Enforcement; and Office of Brownfields Cleanup and Redevelopment. DOD's Office of the Assistant Under Secretary of Defense for Environmental Security, and DOE's Office of Environmental Restoration were exceptionally generous with their time and expertise. Important contributions were also received from a number of other parties identified in various sections of the report.

Executive Summary

Over the next several decades, federal, state, and local governments and private industry will commit billions of dollars annually to clean up sites contaminated with hazardous waste and petroleum products from a variety of industrial sources. This commitment will result in a continuing demand for hazardous waste site remediation services and technologies.

Hundreds of small, medium, and large companies across the nation will respond to this demand, supplying skilled professionals and advanced technologies to address contaminated sites. Researchers and technology developers will continue working to provide smarter and cheaper solutions to the complex environmental contamination problems still to be addressed. Investors will seek to identify technologies that provide the most promising technical and financial future. Universities continually seek to adjust their environmental sciences and engineering curricula to ensure that their future graduates are prepared for the challenges they will face in this field.

To make cost-effective and sound investment decisions, all these groups will need information on the nature and extent of the future cleanup market. With this need in mind, EPA has produced this overview of the site characterization and remediation market. EPA believes that information on the Nation's cleanup needs will help industry and government officials develop better and more targeted research, development, and business strategies.

Background

EPA's mission includes the important goal of restoring contaminated land to productive use, and the Agency has established ambitious targets.[1] The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA, or Superfund) and the Resource Conservation and Recovery Act (RCRA) provide the legal authority for most of EPA's work toward this goal. Cleanups are also generally required to comply with a number of other state and federal statutes. To achieve this goal, EPA works with many partners at all levels of government to ensure that appropriate cleanup tools are used; that resources, activities, and outcomes are coordinated with partners and stakeholders and effectively communicated to the public; and that cleanups are protective and contribute to community revitalization.

EPA is a leader in influencing how hazardous waste site cleanups are conducted in all cleanup programs. The agency directly conducts many cleanups and removals under the Superfund program. In addition, it conducts oversight of state, tribal, and federal facility cleanup programs; develops regulations, policies, guidances, and technical publications; and promotes technology innovation. In its efforts to coordinate across the various programs, EPA seeks to recognize the need for cleanup tools that will have wide applicability.

In developing this report, EPA has identified seven major cleanup programs or market segments that make up the national cleanup market:

- National Priorities List (NPL, or Superfund)
- Resource Conservation and Recovery Act (RCRA) Corrective Action
- Underground Storage Tanks (UST)
- Department of Defense (DOD)
- Department of Energy (DOE)
- Other (Civilian) Federal Agencies
- States and Private Parties (including brownfields)

While segmentation is necessary to better understand each market, the parties involved in site characterization and remediation require a unified picture of the market in order to make better informed investment, marketing, and other strategic decisions. This study provides both perspectives—it sums up the entire market based on a thorough analysis of each segment. Smarter investments by all involved parties will result in more cost-

[1] 2003-2008 EPA Strategic Plan, Objective 3, Land Preservation and Restoration. http://www.epa.gov/ocfo/plan/2003sp.pdf

effective remediation technologies, thereby reducing the cost burden for the nation as a whole as it works to recover contaminated land and groundwater and protect the public's health.

Study Approach

This report updates and expands a 1996 analysis that brought together valuable information on site characteristics, market size, and other factors that affect the demand for remediation services.[2] As with the previous report, the focus of this study is on the potential future applications of remediation technologies.

To provide a useful estimate of future needs, the demand estimates focus on remaining cleanup work at sites where the remedies have not yet been chosen, and do not include projects that are underway or completed. While the report considers a broad range of remediation services required in the future, its purpose is to provide insight into the potential for the application of new treatment and site characterization technologies.

This report is not a budgeting analysis. Most of the cleanups are typically funded by the public and private owners of the properties and those who are potentially responsible for the contamination. A small percentage of cleanups are likely to be conducted by EPA. The report's time horizon, approximately 30 years, is beyond the budgeting period of most private and public institutions. Moreover, the uncertainties in many of the market estimates, including who will conduct, oversee, and pay for the needed cleanups, make it impossible to convert these estimates to resource needs for specific government or private organizations.

In addition to providing a unified perspective of the nature and scope of the Nation's contaminated property cleanup needs, this report includes a more in-depth analysis of the seven major programs or market segments identified earlier, covering areas such as their structure, operation, and regulatory requirements. Information and analyses of the following are provided for each segment:

- Factors Affecting Demand—the economic, political, and technical factors and trends that may influence the size, timing, or characteristics of the market segment (market drivers);

- Numbers and Characteristics of Sites—measures of the market in terms of the number of sites to be remediated, occurrence of contaminants, and extent of remediation work needed;

- Estimated Cleanup Costs—remediation cost estimates, or the value of the market;

- Market Entry Conditions—considerations that may benefit vendors and researchers, such as contracting practices, competition, and information sources;

- Technology Issues and R&D—technologies used in a specific market segment and relevant research and development.

The study also includes analyses of remediation needs in three market "niches," each of which presents a specific set of remediation challenges—the cleanup of former manufactured gas plant (MGP) and other coal tar sites, mining sites, and drycleaner sites. It also addresses two specific issues that affect hazardous waste sites in most remediation programs—site characterization technology, and the remediation of dense non-aqueous phase liquids (DNAPLs). These niches cut across all seven market segments.

The data used for this report are from federal databases, such as the Comprehensive Environmental Response, Compensation, and Liability Information System (CERCLIS), RCRA Info, and DOD's Restoration Management Information System (RMIS), published studies, guidance documents, and web sites; commercial information; and other sources. Some are current through fiscal years (FY) 2001 and 2002, while others are current through 2003 and the first part of 2004. Because many hazardous waste sites are still undergoing evaluation, data availability differs from one market segment to another. Each chapter of the

[2] U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, Technology Innovation Office, *Cleaning Up the Nation's Waste Sites: Markets and Technology Trends*, EPA 542-R-96-005, April 1997.

report includes an explanation of the analytical methodology, information sources, and assumptions, and a detailed list of references. Supporting information is included in the appendices, as well as in explanations in the narrative, footnotes, and figures.

Study Limitations

The reliability and detail of the estimates in this report are a function of the availability and quality of data, and, obviously, the innate uncertainties in forecasting future events. In addition, each of the seven programs have somewhat different operational practices and use varying definitions of terms such as "sites," "facilities," "installations," and "operable units." Although most of the activities underlying this cost estimate are for remedial action and site evaluation, they also include some administrative work where costs are not reported separately.

It cannot be overemphasized that the estimates in this report are just estimates. It is likely that assumptions about the future, which are based on historical experience, will be more reliable for the earlier years than the later years. Likewise, estimates for sites already in a state or federal cleanup program would be more reliable than those for sites that have yet to be discovered. Nevertheless, the resulting estimates provide a plausible range of the likely extent of the nation's site cleanup needs.

The estimate of the total cost of each cleanup market segment is based on estimates of historical averages for each market segment and these may change in the future. Future cleanups may turn out to be more or less complex, or applications of advanced site characterization and cleanup technologies may improve the cleanup cost-effectiveness.

Predictions of potential future site discoveries and additions to the NPL are also based on recent history. The cleanup market includes sites that are not yet enrolled in a cleanup program, or have not yet been discovered. The ultimate number of additions to the NPL or discoveries of non-NPL sites depend upon several factors which are difficult to predict. Nevertheless, these sites are expected to be an important component of the market.

The limitations and uncertainties of the market estimates vary from one market segment to another. For example, the forecast of future releases from USTs is hampered by a paucity of data with which to estimate leakage rates; the estimate of the number and potential cost of mining site cleanups is presented as a wide range of values and reflects an attempt to develop a consensus of a number of industry and government sources; and the estimate of the number of potential manufactured gas plant sites needing cleanup is based on studies that have estimated the number of original facilities that cause the contamination and assumptions regarding their disposition since their operations ceased many years ago. Although DOD and DOE have clearly identified most of the contamination problems at their installations and facilities, there are technological uncertainties at some DOE sites which may cause the estimates to be overstated or understated.

Although this report estimates the potential scope of the market, it does not explicitly estimate the timing of the cleanup work. As in most economic activities, one cannot simply assume that the cleanup work will be conducted at a constant pace from year to year. The schedule of any project can be expedited or retarded by the availability of funds in any given year; technical uncertainties; difficulties in achieving agreements among stakeholders on a number of issues, such as cleanup approach and target end states, who will pay, who is responsible for damages, and how the site will be reused. In addition, long-term stewardship will be needed at many sites.

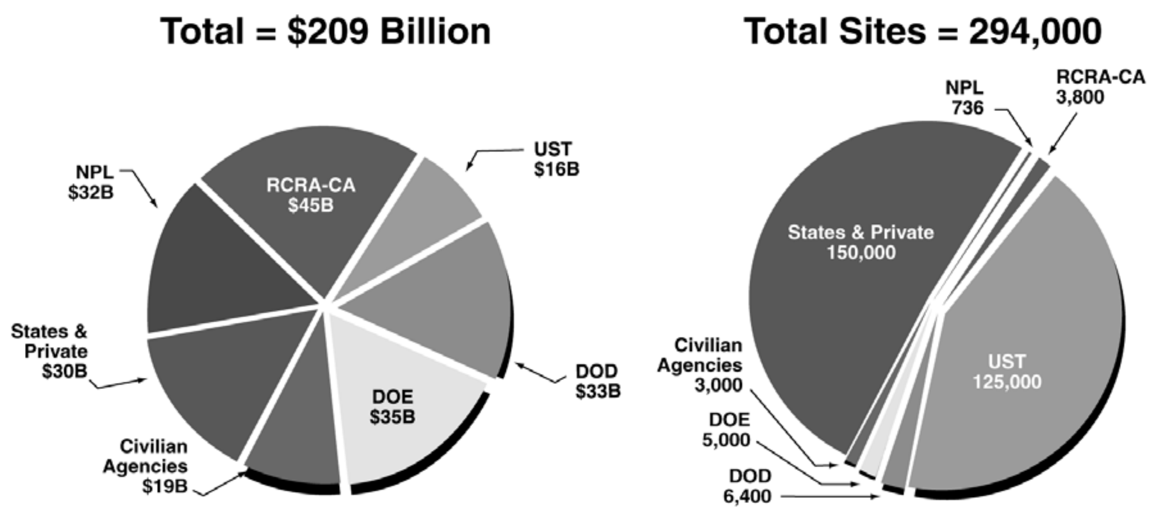
Major Findings

Although substantial progress has been made over the past quarter century, a considerable amount of cleanup work remains. At current levels of site cleanup activity in the U.S. (About $6-8 billion annually), it would take 30 to 35 years to complete most of the work needed.

Quantifying the amount and nature of future work is subject to the limitations and uncertainties described above and requires making a number of assumptions. Users of the report will reap the greatest benefit if they carefully review the discussions of how the estimates were developed, which are included throughout the report. Given these limitations, the following are some of the major findings:

- Under current regulations and practices a total of 235,000-355,000 sites (average 294,000) will need to be cleaned up in all seven programs (Exhibit). More than 90 percent of these sites are in programs that tend to have smaller, less-complex cleanup projects, such as UST sites and sites managed under state cleanup programs. The sites in the remaining programs, such as Superfund, DOD, and DOE, tend to be larger and more complex, on average.
- These cleanups are estimated to cost $170-250 billion (average $209 billion). Most of this cost will be borne by the owners of the properties (private and public entities) and those potentially responsible for the contamination.

Estimated Number of Hazardous Waste Sites and Cleanup Costs: 2004-2033



These estimates are derived from judgements regarding the most likely scenarios within a range of estimates. The estimates described in the report, include a number of assumptions such as the average cleanup cost per site, number of new site discoveries, and future additons to the NPL.

NPL: National Priorities List, or Superfund; RCRA-CA: Resource Conservation and Recovery Act Corrective Action program; UST: Underground Storage Tanks; DOD: Department of Defense; DOE: Department of Energy; Civilian Agencies: non-DOD and non-DOE federal agencies; and State & Private: state mandatory, voluntary, and brownfields sites, and private sites.

Totals may not add due to rounding.

- The estimated number of sites (294,000) includes sites that have already been discovered (77,000) plus an estimate of the number of sites to be discovered in the future (217,000). The estimated number of future sites (mostly NPL, UST and sites managed under state programs) is based on the rate of new sites discovered in the late 1990s and early 2000s:

- ÷ Between 1993 and 2003 an average of 28 sites per year were listed on the NPL. This report assumes that this rate will continue for 10 years. Although listings may continue beyond 10 years, they are not included because of uncertainties in predicting NPL listings.
- ÷ The estimated number of future UST site discoveries is based on the annual rate of new releases in recent years (6,000-12,000) and the assumption that this rate will continue for 10 years. Although tank releases may continue beyond 10 years and leakage rates may decline, these scenarios are not included because of uncertainties in predicting these trends.
- ÷ The estimated number of sites to be discovered under state mandatory and voluntary cleanup programs is based on an average of 5,000 cleanups completed annually in recent years. Because studies indicate that there are many sites yet to be discovered, it is assumed that this activity level will continue for at least 30 years.

- Most cleanup programs have similar contaminants: solvents and other organics, metals, and petroleum products.
- Over the next 30 years, there will be a need to address many smaller sites, primarily 125,000 UST and 150,000 state and private party sites (including brownfields). There is also a need to screen many more sites to determine whether or not they have contamination problems.
- The demand for cleanup of many sites will be influenced by real estate development activity as well as regulatory requirements. Some sites do not come to the attention of state or federal cleanup programs until they are investigated in the course of development activity or real estate transactions. For some properties, developers or prospective site users may assume all or part of the cleanup costs.
- Non-DOD and non-DOE federal agencies that have contaminated sites, including the Departments of Interior, Agriculture, and Transportation, combined, have been spending less than $200 million annually for site cleanups. They have an estimated $15-21 billion of cleanup work yet to be completed.
- Improved approaches to site characterization have been demonstrated to lead to faster, cheaper, and better cleanups. For example, newer site characterization approaches have made the removal and treatment of DNAPLs at some sites more cost effective than containing the material in the subsurface.
- The trend toward risk-based cleanups, which is found throughout the remediation market, may influence the remedy selection process, foster more flexibility in site reuse, and provide incentives for property owners to bring more sites into remediation programs. It is difficult to predict the impact of these developments on the use of specific remedy types.
- The need for monitoring and long-term operation and maintenance of remedy components is expected to increase in most market segments.

At current public and private spending levels for site cleanups, it will take several decades to complete all the cleanup work estimated in this report. As with most cleanups requiring technically complex solutions and coordination of multiple stakeholders, the work load will probably fluctuate from year to year. Most of these costs will be borne by private companies, and owners of state and federal facilities, such as DOD and DOE. This market represents a significant opportunity for continued development and implementation of cleanup approaches and technologies that will result in better, cheaper, and faster site cleanups, as well as technologies that enable us to better address challenging contamination problems such characterizing NAPLs in the subsurface.

Technical solutions to a particular contaminated site problem are generally similar, regardless of the regulatory program under which they are implemented. While individual markets may not support certain investment decisions, the aggregate demand across all markets might justify the up-front investment in a technology that ultimately drives down the cost of moving contaminated sites into productive use. By recognizing this potential for economies of scale in cleanup technology markets, the information in this report contributes to better investment decisions across all markets.

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Chapter 1
Introduction and Summary

1.1 Introduction

Over the next several decades, federal, state, and local governments and private industry will commit billions of dollars annually to clean up sites contaminated with hazardous waste and petroleum products. This commitment will result in a continuing demand for site remediation services and technologies. This report provides an overview of the site characterization and remediation market to help industry and government officials develop research, development, and business strategies. It was prepared to aid those who are developing, commercializing, and marketing new technologies to meet the future cleanup demand.

This report updates and expands a 1996 analysis that brought together valuable information on site characteristics, market size, and other factors that affect the demand for remediation services.[1] As with the previous report, the focus of this study is on the potential future applications of remediation technologies. To provide a realistic estimate of future needs, the estimates of demand focus on remaining cleanup work at sites where cleanup technologies have not yet been chosen, and exclude projects that are underway or completed. While the report considers a broad range of remediation services required in the future, its purpose is to provide insight into the potential application of new treatment and site characterization technologies.

In addition to providing a unified perspective of the characteristics and scope of the nation's contaminated property cleanup needs, this report provides a more in-depth analysis of the seven major cleanup programs or market segments:

- National Priorities List (NPL, or Superfund)
- Resource Conservation and Recovery Act (RCRA) Corrective Action
- Underground Storage Tanks (UST)
- Department of Defense (DOD)
- Department of Energy (DOE)
- Other (Civilian) Federal Agencies
- States and Private Parties (including brownfields)

In addition to providing updates and new information relating to these seven market segments, this report also includes analyses of remediation needs in three market "niches," each of which presents a specific set of remediation challenges—the cleanup of former manufactured gas plant (MGP) and other coal tar sites, mining sites, and drycleaner sites; and two specific issues that affect hazardous waste sites in most remediation programs—site characterization technology and the remediation of dense non-aqueous phase liquids (DNAPLs).

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1 U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, Technology Innovation Office, *Cleaning Up the Nation's Waste Sites: Markets and Technology Trends*, EPA 542-R-96-005, April 1997

1.2 Using This Document

This chapter contains a summary of the findings of this report. Chapter 2 describes the recent trends in the use of remedial technologies at Superfund sites. Because many contamination problems are similar across the seven market segments, the Superfund technology information is useful to help understand potential technology trends in the other markets. Chapters 3 through 9 address each of the seven market segments listed above. These seven segments can be added to arrive at the total remediation market.

Chapters 10 through 14 address five specialized portions of the remediation market. The analyses in these chapters are from a different perspective than the first seven market segments, and the estimates of market size and value are not additive to those in chapters 3 through 9. The five topics include manufactured gas plant sites (MGPs), mining sites, drycleaner sites, site characterization, and dense non-aqueous phase liquids (DNAPLs).

For most market segments, seven areas are addressed within each chapter:

- Program or Market Segment Description—the structure, operation, and regulatory requirements of the program;
- Factors Affecting Demand—the economic, political, and technical factors and trends that influence the size, timing, or characteristics of the market segment (market drivers);
- Numbers and Characteristics of Sites—measures of the market in terms of the number of sites to be remediated, occurrence of contaminants, and extent of remediation work needed;
- Estimated Cleanup Costs—remediation cost estimates, or the value of the market;
- Market Entry Conditions—considerations that may benefit vendors and researchers, such as contracting practices, competition, and information sources;
- Technology Issues and Research and Development (R&D)—technologies used in a specific market segment and relevant research and development; and
- References—citations are referenced at the end of each chapter.

Appendices A through F contain supporting data, sources for additional information on the remediation market and technologies, and definitions of terms used in this report. The acronyms are on the last four pages of the document (Appendix F).

1.3 Study Approach and Limitations

The data used for this report are from federal databases, such as the Comprehensive Environmental Response, Compensation, and Liability Information System (CERCLIS), RCRA Info, and DOD's Restoration Management Information System (RMIS), published studies, guidance documents, and web sites; commercial information; and other sources. Some are current through fiscal years (FY) 2001 and 2002, while others are current through 2003 and the first part of 2004. Because many sites are still undergoing evaluation, data availability differs from one market segment to another. Each chapter includes an explanation of the analytical methodology, information sources, and assumptions, and a list of references. Supporting information is included in the appendices.

This report is not a budgeting analysis. Most of the cleanups are typically funded by the public and private owners of the properties and those who are potentially responsible for the contamination. A small percentage of cleanups are likely to be conducted by EPA. The report's time horizon, approximately 30 years, is beyond the budgeting period of most private and public institutions. Moreover, the uncertainties in many of the market estimates, including who will conduct, oversee, and pay for the needed cleanups, make it impossible to convert these estimates to resource needs for specific government or private organizations.

It cannot be overemphasized that the estimates in this report are just estimates. It is likely that assumptions about the future, which are influenced by historical experience, will be more reliable for the earlier years than the later years. Likewise, estimates for sites already in a state or federal cleanup program would be more reliable than those for sites that have yet to be discovered. Nevertheless, the resulting estimates provide a plausible picture of the likely extent of the nation's hazardous waste site cleanup needs.

The limitations and uncertainties of the market estimates vary from one market segment to another. For example, the forecast of future releases from USTs is hampered by a paucity of data with which to estimate leakage rates; the estimate of the number and potential cost of mining site cleanups is presented as a wide range of values and reflects an attempt to develop a consensus of a number of industry sources; and the estimate of the number of potential manufactured gas plant sites needing cleanup is based on studies that have estimated the number of original facilities that caused the contamination and assumptions regarding their disposition since their operations ceased many years ago. Although DOD and DOE have clearly identified much of the contamination problems at their installations and facilities, there are a significant number of DOE sites that have not yet been fully characterized. The analysis is further complicated by the fact that the definitions of sites and facilities differ somewhat from one market segment to another. In this report, the term "site" is used to indicate an individual area of contamination, which can be small or large. The terms "facility" and "installation" identify an entire tract, including contiguous land within the borders of a property, and may contain more than one site.

Although this report estimates the potential scope of the market, it does not explicitly estimate the timing of the cleanup work. As in most economic activities, one cannot simply assume that the cleanup work will be conducted at a constant pace from year to year. The schedule of any project can be expedited or retarded by the availability of funds in any given year; technical uncertainties; difficulties in achieving agreements among stakeholders on a number of issues, such as cleanup approach and target end states, who will pay, who is responsible for damages, and how the site will be reused. In addition, long-term stewardship will be needed at many sites.

1.4 Market Size

Under current regulatory requirements and practices, an estimated 294,000 sites (range 235,000 - 355,000) in the seven market segments will need to be cleaned up (Exhibit 1-1). This estimate does not include sites where cleanup is completed or ongoing.

More than 90 percent of these sites are in programs that tend to have relatively smaller, less-complex cleanup projects, such as the UST program (125,000 sites) and state voluntary and mandatory cleanup programs (150,000). The sites in the remaining programs, such as Superfund, DOD, and DOE, tend to be larger and more complex, on average.

The 294,000 sites estimate includes 77,000 sites that have already been discovered plus an estimated 217,000 sites estimated to be discovered in the future. The estimate of the number of future sites is based on the rate of new site discoveries in recent years and is expected to be highly variable from year to year. Future discoveries could very well turn out to be higher or lower than in the past. Most of these "future" sites would be managed under the UST and state mandatory and voluntary cleanup programs, including brownfields.

This analysis assumes that EPA will add new sites to the NPL for another 10 years, UST site discoveries will continue for 10 years, and new state and private party site discoveries will continue for 30 years. Although new site discoveries may very well continue much longer, these longer-term scenarios are not included in the above estimates because of uncertainties regarding such long-term predictions. In addition to the initial site cleanup work, many sites will require long-term stewardship and groundwater treatment or monitoring for many years.

DOD and DOE, have identified most of the contaminated sites on their properties. Nevertheless, new ones continue to be reported each year, but at a declining rate. In addition, there is evidence that there may be thousands of sites from previous industrial activities, such as mining, gas manufacturing, and drycleaning, that may need to be cleaned up. Estimates for these sectors are not included in the above figures.

For four of the seven cleanup programs, regulatory authorities have identified most hazardous waste sites. There may be several hundred thousand contaminated state, private party, and UST sites yet to be identified, and additions to the NPL are continuing.

The estimated cost to clean up the 294,000 sites is about $209 billion (Exhibit 1-2). Most of this cost will be borne by the owners of the properties (private and public entities) and those potentially responsible for the contamination. This estimate represents the midpoint of a range that results from uncertainty regarding the extent and type of contamination at many sites, the number of sites that will be identified in the future, and the average per-site cost of remediation in some markets.

Although most of the activities underlying this cost estimate are for remedial action and site evaluation, they also include some administrative work where costs are not reported separately. Because this estimate does not include inflation for future years, the amounts actually to be expended probably will be higher in future-year dollars.

Exhibit 1-1. Estimated Number of Sites to be Remediated

Market Segment	Sites Remaining to be Remediated	Explanation
Superfund • Current Sites • Projected Sites • Subtotal, NPL	 456 280 736	The number of sites includes non-federal proposed and final National Priorities List (NPL) sites that still require at least one further remedial action (RA). The NPL also includes 177 federally-owned sites, which are addressed in the DOD, DOE, and civilian federal agencies market segments below. In addition to currently listed sites, it is assumed that EPA will add an average of 23-49 sites to the NPL each year for the next 10 years (Expected value 28).
RCRA Corrective Action	3,800	Although it is likely that construction of remedies at most of these cleanups can be completed in 30 years, many more decades may be needed for monitoring and groundwater treatment. RCRA Corrective Action sites related to large federal facilities are included in the DOD, DOE, and civilian federal agencies market segments below.
Underground Storage Tanks (USTs)	125,000	Includes 35,000 sites already identified as of March 2004, and 60,000-120,000 sites (average 90,000) that are projected to leak over the next 10 years The already identified sites may be underestimated because sites where "cleanups are initiated" are not included, even though some of these site do not yet have designated cleanup contractors. Although UST cleanups are expected to continue beyond 10 years as new leaks occur, and leakage rates may decrease in the future, these scenarios are not included in the estimate.
DOD	6,400	DOD originally identified over 30,000 sites on over 1,700 installations. Of these, responses have been completed or cleanups are planned or underway at about 24,000 sites.
DOE	5,000	DOE has completed active cleanup of contaminated soil, debris, and structures at half of its approximately 10,000 release sites. Groundwater remediation is expected to continue at many sites, and long-term stewardship will be needed at 129 DOE installations. The estimates also are based on the assumption that there will be a greater emphasis on containment than on treatment and other remediation strategies.
Civilian Federal Agencies	> 3,000	This figure does not include an estimated 8,000-31,000 abandoned mine sites.
States	150,000	Represents 23,000 sites already identified and 127,000 new sites projected to be identified over the next 30 years in state mandated programs, voluntary cleanup programs, and brownfield programs. Additional sites may be discovered beyond the 30 years.
Total	294,000	The total is the most likely value within a range of 235,000 to 355,000 sites. It represents sites requiring cleanup, and excludes sites where cleanup work is ongoing or complete.

Exhibit 1-2. Estimated Remaining Remediation Cost ($Billions)

Market Segment	Cost to Clean Up Remaining Sites: Middle Value	Range	Comments
Superfund • Current Sites • Projected Sites • Subtotal, NPL	 19.4 12.7 32.1	 16 - 23 8 - 27 24 - 50	The current sites estimate is for currently listed sites not owned by the federal government that still need remedial action. The projected sites figure is based on an assumed 28 new additions to the NPL annually (range 23-49) over the next 10 years.
RCRA, Corrective Action	44.5	31 - 58	Does not include long-term monitoring and groundwater treatment. RCRA Corrective Action costs related to large federal facilities are included in the DOD, DOE, and civilian federal agencies market segments.
RCRA, UST	15.6	12 - 19	Includes 35,000 sites already identified as of March 2004, and 60,000-120,000 sites (average 90,000) that are projected to leak over the next 10 years. Additional tank leaks will probably continue beyond 10 years.
DOD	33.2	NA	This figure includes some costs for sites where cleanup work has begun.
DOE	35.0	NA	Does not include the cost long-term stewardship, which is needed at 129 DOE installations; and the cost of cleaning up wastes for which no proven practical cleanup approach is currently available, such as contamination at nuclear test sites and certain groundwater and surface water.
Civilian Federal Agencies	18.5	15 - 22	Does not include the potential $18-51 billion cost for cleaning up 8,000-31,000 abandoned mine sites, most of which are on lands for which a federal agency is responsible for cleanup.
States	30.0	24 - 36	There is a potential of several hundred thousand additional sites beyond the 30 years.
Total	208.9	174 - 253	The total represents estimated cost for the cleanup of sites required under current regulations and practices, and excludes sites where cleanup work has begun or is complete.

Although this study estimates the long-term need for site cleanups, it does not estimate the pace of cleanup, which is likely to fluctuate from year to year, depending on private and public funding, who is paying for the cleanups, and other factors. However, Chapters 3 through 14 include discussions of the factors that affect the extent and timing of the cleanup work. Most of the cleanup program work considered in the above estimates will take 30-35 years to complete.

The estimates for each market segment are described below.

Superfund Sites

The 456 NPL sites not owned by the federal government (non-federal) that require one or more future remedial actions (RAs) make up a relatively well-defined market for remediation technologies. The NPL also includes 177 federally-owned sites with future RAs planned. These sites are included in the market estimates for federal agencies. The number of future listings, which are expected to be primarily non-federal sites, was assumed to average 28 sites annually, which is the average for 1993-2003. This average listing rate is within a range estimated in a 2001 study by Resources for the Future (RFF), a non-profit environmental research group. The RFF study predicted that listings would average between 23 and 49 sites per year over a 10-year period, with a most likely value of 35. In the three years since that study, the listing rate has averaged 23. Most new listings are not federal sites. Although listings may continue beyond 10 years, they are not included in this analysis because of uncertainties in predicting them.

The estimated cost for the 456 non-federal already listed Superfund sites that have not begun RA is $16-23 billion, with a middle value of $19 billion (2003 dollars). This estimate is based on an average cost per operable unit (OU) of $1.4 million for remedial investigations/feasibility studies (RI/FS), $1.4 million for remedial design (RD), $11.9 million for remedial action (RA), and $10.3 million for long-term remedial action (LTRA) for sites that require long-term treatment to restore groundwater or surface water. The range in values result from varying the RA costs by plus and minus 20 percent. The details of these calculations and data sources are provided in Section 3.5.

This estimate is more than twice that of a similar estimate in the 1997 edition of this report. The difference is explained by an 18 percent increase in the general price level, the fact that the remaining sites on the NPL that have not begun RA are expected to be more complex and have more OUs than the average for previous NPL sites, and the fact that LTRA costs were not included in the previous report. Although construction has been completed at many sites since the 1996 edition, about 200 sites have since been added to the NPL.

Using the same unit cost estimates per OU, and assuming 23-49 sites will be listed annually, the 230-490 sites assumed to be listed over the next 10 years will cost $8-27 billion. At the most likely listing rate of 28 sites annually, the cleanups would cost $13 billion. If more or fewer sites are listed, this total would be adjusted accordingly. This estimate is based upon the above assumptions plus the expectation that future sites will be more complex, larger, and have more OUs per site than the average NPL site in the past.

RCRA Corrective Action Sites

EPA estimates that 3,800 regulated hazardous waste treatment, storage, and disposal facilities (TSDFs) eventually will require remediation under the RCRA Corrective Action program. This number is more than half of the approximately 6,670 TSDFs that currently operate or have operated and are subject to the corrective action regulations. The emphasis in the short term is on stabilization remedies for risk reduction at about 1,700 of the 3,800 sites. Over the longer term, additional remedies may be required at most of the 3,800 RCRA Corrective Action sites.

Under current regulations, cleanup of the 3,800 sites that are likely to require corrective action will cost between $31 billion and $58 billion, with a middle value of $44.5 billion, or $11.4 million per facility. Approximately 41 percent of the total cost will be incurred by nine percent of the facilities with cleanup costs of greater than $50 million. The average cost-per-site estimate is based on cost data in an economic analysis in support of the development of the Corrective Action Management Unit (CAMU) Rule in 2000. Approximately 80-90 percent of this amount will be incurred by privately-owned facilities and the remainder by federal facilities. This estimate does not include costs for the large DOD and DOE facilities. However, since it includes costs for some smaller ones, there is some overlap with the estimates for DOD and DOE below.

This estimated average cost per site is about 20 percent lower than that estimated in the 1993 Regulatory Impact Analysis (RIA) for Subpart S. This difference reflects a variety of changes since that RIA, including more efficient site characterization and cleanup approaches, the use of risk-based cleanup approaches, and savings due to the CAMU policies described in Section 4.1. Over the past few years, implementation of the Corrective Action program has shifted toward more flexible, risk-based cleanups and away from the regulatory approach modeled in the 1993 RIA. In addition, the near-term costs of the program are likely to reflect the program's emphasis in the short term on stabilization remedies rather than permanent remedies.

Underground Storage Tank Sites

EPA estimates that 95,000 to 155,000 UST sites (middle value, 125,000) will require cleanup under the RCRA underground storage tank regulations over the next 30 years. This estimate includes 35,000 already identified sites that have not yet been cleaned up plus 60,000-120,000 projected releases over a 10-year period (6,000-12,000 per year). The 35,000-site figure may understate the actual market because it does not include all sites without designated cleanup contractors. Some sites reported as "cleanups initiated" actually have not yet selected remediation technologies or contractors. UST sites average an estimated 2.7 tanks per site, although the number varies widely from one site to another. Although USTs account for 43 percent of sites to be cleaned up, they account for only 7 percent of the above-estimated national cleanup costs. Tank sites are typically the smallest and least costly to remediate, There may be some overlap with the estimated number of state and private sites, which includes brownfield sites and UST sites.

> *Although USTs account for 43% of all cleanup sites, they account for only 7% of estimated national cleanup costs. These sites are typically among the smallest and least costly to remediate.*

The UST cleanup market could reach $12-19 billion, with a middle-value of $16 billion, or an average of $125,000 per UST site. This estimate does not include costs related to replacing, testing, or upgrading tanks, pipes, and related equipment. The availability of funds for UST cleanups is somewhat less dependent on public appropriations. Most of the UST costs are paid by property owners, state and local governments, and special trust funds, often based on dedicated taxes, such as fuel taxes.

Department of Defense Sites

The DOD estimated that, as of September 2003, remedies had not been selected for 6,400 sites on hundreds of installations and other locations that require remediation of contaminated materials. Cleanups are being planned or are underway at another almost 2,700 sites, bringing the total number of active DOD sites to about 9,000. These sites are distributed almost evenly among the Air Force, Army, Navy, and formerly used defense sites (FUDS). DOD estimates that all of these sites will be cleaned up by 2015. Of all DOD installations, including those where remedial action has begun, 146 are on the NPL.

Federal and state agencies have increased their emphasis on cleaning up sites needed for the closure or reassignment of government facilities or economic development.

DOD estimates that the cost of completing all the remaining remediation work at all DOD sites from FY 2003 onward will be about $33 billion. Although most of these funds will go to sites that have not yet selected remedies, they also include some expenditures at sites already in remedial design or remedial action. About $16.4 billion of these funds are for cleanups at sites being realigned or closed (BRAC) as well as non-BRAC installations. The remaining $16.8 billion is for the cost to complete over 1,700 sites that may contain unexploded ordnance or waste military munitions. About 20 percent of DOD's FY 2004 planned cleanup expenditures of about $1.7 billion is for evaluating and cleaning up properties that are to be transferred to other federal, state, or local government agencies or private parties (BRAC) sites. This percentage has ranged from 20 to 37 percent between 2000 and 2004 and averaged almost 30 percent.

Department of Energy Sites

The DOE has identified about 5,000 contaminated sites on 39 installations and other locations that require remediation. DOE is responsible for 19 currently listed NPL sites in 13 states. The Department expects to have almost all its sites cleaned up by 2035, although monitoring and groundwater treatment may continue beyond that period. In addition, no remedy is yet available for some of DOE's wastes. DOE estimates that long-term stewardship will be needed at up to 129 installations and has established the Office of Legacy Management to address this need.

The DOE market estimates utilize several critical assumptions, which make them sensitive to budget fluctuations, cleanup standards, and further site investigations.

The DOE estimates that environmental restoration of its properties will cost $35 billion and take until 2035 to complete active remediation at most of its sites.[2] The estimates do not include the cost of cleaning up wastes for which no proven cleanup technology currently exists, such as wastes at nuclear test sites and much of the groundwater contamination the agency is responsible for addressing. The estimates also are based on the assumption that there will be greater emphasis on containment than on treatment and other remediation strategies. Five installations account for 71 percent of the value of the remediation work: Rocky Flats Environmental Technology Site, Colorado; Idaho National Engineering Laboratory, Idaho; Savannah River Site, South Carolina; Oak Ridge Reservation, Tennessee; and Hanford Reservation, Washington. These costs include those for all environmental restoration required under the CERCLA, RCRA, other federal statutes, and state laws. About $2.2 billion of DOE's FY 2004 requested budget of $7.8 billion is likely to go for site cleanup.

[2] Environmental restoration accounts for about one-third of DOE's estimated environmental program. DOE anticipates spending $111 billion on environmental management by 2035. The other two-thirds of DOE's environmental management costs are for the following types of activities: waste management, nuclear material and facility stabilization, national program planning and management, landlord activities, and technology development. DOE's FY 2004 budget for environmental management is $7.2 billion, of which $2.4 billion is for restoration.

Civilian Federal Agency Sites

As of April 1995, over 3,000 contaminated sites on 700 facilities, distributed among 17 non-DOD and non-DOE federal agencies, were potentially in need of remediation. A facility may contain one or more contaminated areas or “sites.” Because investigations of many of these facilities are not complete, the exact number of facilities and sites to be remediated has yet to be determined. The Department of Interior (DOI), Department of Agriculture (USDA), and National Aeronautics and Space Administration (NASA) together account for about 70 percent of the civilian federal facilities reported to EPA as potentially needing remediation. Although 3,000 sites have been identified by these agencies, there are probably more that have not yet been reported, including an estimated 8,000-31,000 abandoned mine sites, most of which are on federal lands.

The $15-22 billion estimated cost for the cleanup of at least 3,000 civilian federal sites is based on estimates from various officials and reports from DOI, USDA, and NASA, which combined account for most civilian federal contaminated sites, and extrapolated to all federal agencies. The level and timing of these expenditures will depend upon the availability of resources and technologies. At current funding levels, about $100-200 million annually, it could take 100-200 years to clean up all these sites. The transfer of public properties to private use may require agencies to reallocate resources to clean up properties designated for transfer.

State, Private Party, and Brownfield Sites

It is estimated that total annual expenditures for state and private cleanups has averaged about $1 billion and that about 5,000 cleanups are typically completed annually under all mandatory and voluntary state programs. At this rate, 150,000 sites can be completed in 30 years, at a cost of $30 billion. Estimates beyond 30 years are not provided in this report, although there are probably several hundred thousand additional potentially contaminated sites that have not been identified. Sites tend to become identified and studied when a health or safety hazard becomes known, when a real estate transaction occurs, or when development proposals are being evaluated. These activities trigger development studies and due diligence investigations. Thus, increases in economic activity and redevelopment projects could lead to an increase in the number of cleanups needed at any given time.

About half of state site cleanups in recent years have been under mandated state programs and half have been under voluntary cleanup and brownfields programs. In addition, there may be several hundred thousand additional brownfield sites yet to be identified. EPA defines Brownfields as “real property, the expansion, redevelopment, or reuse of which may be complicated by the presence or potential presence of a hazardous substance, pollutant or contaminant.” Although the definition can vary from state to state, they are usually abandoned, idled, or under-used industrial and commercial facilities. EPA's investment in brownfields, more than $700 million since 1995, has leveraged more than $5.1 billion in cleanup and redevelopment funding and financed the assessment of more than 4,300 properties. The cleanup of most of these sites will be the responsibility of the property owners and will probably be conducted in conjunction with state voluntary cleanup programs. Over the past decade, interest in the redevelopment of potentially contaminated sites has grown. In this situation, the availability of funds will be on a site-specific basis. If states want to accelerate the pace of work, they will have to rely on non-budget sources of funds, such as private party actions, voluntary cleanups, and cost recovery/cost sharing.

Manufactured Gas Plant (MGP) Sites

There is no separate remediation program for the characterization and remediation of MGP and other coal tar sites, and no line item for this category of sites in the above exhibits. MGP sites may be addressed under any of the remediation programs, such as Superfund, RCRA, or a state environmental program, depending on the nature and extent of the contamination and other site-specific factors. Because these sites may be managed under different remediation programs, the estimates of the MGP market should not be added to those in the seven major market segments above. Adding these estimates would be double-counting sites and costs, thereby overestimating the scope of the market.

Before the United States had a network of natural gas pipelines and electricity, fuel for lighting, heating, and cooking was manufactured from coal and petroleum at thousands of manufacturing facilities across the country. As a result of these activities, hazardous materials are likely to be present in the subsurface and groundwater at thousands of locations. While some of these sites, especially those currently owned and operated by large gas and electric utility companies, are being addressed, most of the former manufactured gas sites have not been identified.

It is estimated that from 1800 to the mid-1900s between 36,000 and 55,000 manufactured gas plants and related coal tar sites were built in the United States. These sites varied in size from less than one acre to approximately 200 acres. Because of the nature of the gas manufacturing process and the practices at the time, almost all these plants released contaminated materials to the environment. It is estimated that 30,000-45,000 of these sites that probably had releases of hazardous substances have not been investigated and many may need to be cleaned up.

MGP cleanup costs have been documented to range from a few hundred thousand dollars to $86 million for a single site. Most tend to be in the $3-10 million dollar range. Should all 30,000-45,000 sites be need cleanup, the estimated cost would be $26-128 billion.

Mining Sites

There are about 14,500 active coal, metal, and nonmetal mineral mines in the United States, between 100,000 and 500,000 abandoned hard rock (metals and nonmetal minerals) mines on private, state, and federal lands in the west, and approximately 13,000 abandoned coal mines, mostly small and mid-sized, in the east. Many of these properties continue to threaten human health and the environment because of the materials left behind and because mined-out areas are exposed to the elements. Most of the mine sites are on land for which the federal government is responsible, primarily DOI and USDA. Most of the mining budgets of these agencies are directed to safety and water quality issues, and a smaller portion is available for site remediation.

Mining sites may be addressed under any of the remediation programs, such as Superfund, RCRA, or a state environmental program, depending on the nature and extent of the contamination and other site-specific factors. Therefore, the estimates of the mining-site market should not be added to those of the seven major market segments. Adding these estimates would be double-counting sites and, therefore, overestimating the scope of the market.

There is a wide range of estimates and opinions on how many mining properties pose a serious risk to the environment and are likely candidates for remediation. The most promising estimates indicate that about 8,000-31,000 abandoned mine sites pose a significant risk to the environment and human health. The estimated cost for hardrock mining sites alone is $20-54 billion.

Drycleaner Sites

Almost 16,000 active drycleaner sites will probably need site investigation and remediation at an estimated cost of $6 billion. Cleanup costs are estimated to average $403,000 per site and range from $19,000 to over $3 million. About 28 percent of the costs are for site characterization.

There may be 9,000 to 90,000 sites that were formerly occupied by drycleaners and that are likely to have released drycleaning chemicals to the environment.

These estimates do not include cleanup work that may be needed at a potential 9,000-90,000 "inactive" sites. Inactive sites are properties that do not currently have a drycleaning operation, but did have one in the past. Older drycleaners used more cleaning compounds per garment and tended to have more releases of chemicals to the environment than newer ones. Over the past several decades, the amount of perchloroethylene used by the industry has decreased more than 80 percent. Less than 10 percent of drycleaners still use petroleum solvents.

Site Characterization

Although the type and amount of site characterization work needed varies widely from site to site, all potential hazardous waste sites require some sort of site investigation. Despite the variability, it is useful to estimate an approximation of the number of sites that will need sampling and analysis work (see box). The phases of site assessment shown in the box are similar to, but not precisely those, used in American Society for Testing Materials (ASTM) standards. Approximations were made to align phases of RCRA, Superfund and other programs.

Estimated Sampling and Analysis Needs Over 30 Years (Number of Sites)

Phase I	0
Phase II	1.2 million
Phase III	285,000
Remedial Action	392,000
O&M and Long-Term Remedial Action	508,000

The cost of this work is estimated based on the ratio of RI/FS cost in the Superfund program to total cleanup cost. Remedial Investigation/ Feasibility Studies (RI/FS) have accounted for about 10 percent of total Superfund site expenditures and 16 percent for smaller sites. Applying these averages to the total site remediation market, and assuming historical site characterization practices continue, about $21 billion will be needed for site characterization work over the next 30 years. However, given the growing use of advanced site characterization approaches–including field analytical technologies, systematic planning, and dynamic work plans–site managers may allocate greater proportions of their budgets for site characterization in the future. Better site characterization can reduce the overall cost and improve the effectiveness of cleanups.

Sampling and analysis technologies are used during all phases of site work, except Phase I site assessments (estimated market of almost 12 million assessments over the next 30 years). The sampling and analysis required during remedial actions varies widely from one site to another. Remedial actions often require confirmation sampling and sometimes major additional site characterization. A significant amount of sampling and analysis is also needed during O&M and long-term remediation of groundwater and surface water. Thus the 508,000 site estimate is an upper-bound estimate for sites that will need continued sampling and analysis during O&M and, at a number of sites, long-term remediation.

DNAPLs

This report provides a general indication of the number of sites likely to have a DNAPL problem. It is estimated that 29-44 percent of NPL sites are likely to have free-phase liquid or residual DNAPLs present in the subsurface, or an average of 37 percent. The estimates are 28 percent for RCRA Corrective Action and state sites, and 30 percent for DOD and DOE sites. Applying these percentages, it is estimated that these four program areas have a combined 48,000 sites with a medium to high potential to have a DNAPL problem. For the other market segments, the data on the types of compounds used or constituents of releases were too sparse to develop an estimate.

Any estimate of the value of the DNAPL cleanup work needed is hampered by the extremely wide range of potential site conditions and the paucity of program-wide data on costs that pertain to specific DNAPL remediations. However, an indication of the level of costs is provided by studies of pump-and-treat (P&T) costs, a major expense in DNAPL cleanups. A 2001 EPA study found that the average annual O&M costs of pump-and-treat systems at 79 fund-financed sites is approximately $570,000, and the median is $350,000. This difference is due to a small number of systems with relatively high costs that raise the average. The periods of operation of these systems as well as the costs vary widely from site to site. The average pump-and-treat system in the EPA study operated for 18 years, for an average cost of $10 million. Pump-and-treat systems at some sites with DNAPLs may need to operate for considerably longer periods.

1.5 Hazardous Waste Site Characteristics

The selection of remedies at contaminated sites depends largely on the types of media and contaminants present. This section describes the types of contaminants and media that are to be remediated in the various market segments.

The data used to develop these estimates vary widely among the market segments. The Superfund (NPL) data are available from the Records of Decision (RODs) for over 1,100 sites. The characteristics of these sites are assumed to be representative of all NPL sites, including those needing further remediation. The DOD media and contaminant data are based on information from over 6,000 sites to be remediated as of September 2001. The RCRA estimates are based on data from fewer than 300 of the estimated 3,800 sites to be remediated. Although the DOE estimates are based on data from over 100 installations, the data do not include information from all 10,500 sites at these installations and other properties. The DOE and RCRA data are from data collected in the early and mid-1990s.

1.5.1 Contaminated Media

More than three-fourths of sites have contaminated soil or groundwater, or both. Contaminated sediment, sludge, and surface water also are present, but at fewer sites.

Groundwater and soil are the most prevalent contaminated media. In addition, large quantities of other contaminated material, such as sediments, landfill waste, and sludge, are present at many sites. Exhibit 1-3 shows the most common contaminated media for each of four market segments. More than three-quarters of NPL, RCRA, DOD, and DOE sites have contaminated soil or groundwater, or both. Contaminated sediment, sludge, and surface water also are present, but at fewer sites. Soil and groundwater also are a primary concern for UST sites, although comprehensive program-wide data are not available.

Exhibit 1-3. Media to be Remediated

	Percent of Sites		
Remediation Program	**Groundwater**	**Soil**	**Sediment**
NPL Sites	83%	78%	32%
RCRA Corrective Action Sites	82%	61%	6%
DOD Sites	63%	77%	18%
DOE Sites	72%	72%	72%

Notes:
- 11% of NPL sites contain contaminated sludge; 11% of the surveyed RCRA sites contain contaminated sludge and 10% contain contaminated surface water; 9% of DOE sites contain contaminated surface water, and about half of the DOE installations contain contaminated rubble and debris.
- The DOE soil percentages also contain sediment and sludge.

1.5.2 Contaminants of Concern

Many contamination problems and technology needs are similar across the major remediation programs. For example, solvents, petroleum products, and metals are common to most programs. Some markets also have more specialized needs arising from wastes that are unique to a particular industrial practice. For example, DOE has a need for technologies to characterize, treat, and dispose of mixed waste; remediate radioactive tank waste; stabilize landfills; and deactivate facilities. DOD is concerned with remediating soil contaminated with explosives, unexploded ordnance, and perchlorate.

VOCs, the most frequently occurring contaminant type, are present at more than two-thirds of Superfund, RCRA, and DOD sites, and almost half of the DOE installations. VOCs (BTEX) also are the primary contaminants at UST sites.

Almost all of the market sectors have substantial numbers of sites with metals and VOCs.

Exhibit 1-4 shows the frequency of occurrence of the most prevalent contaminant groups. VOCs, the most frequently occurring contaminant type, are present at more than two-thirds of Superfund, RCRA, and DOD sites, and almost half of the DOE sites.

VOCs, primarily in the form of BTEX (benzene, toluene, ethylbenzene, and xylenes) also are primary contaminants at UST sites. Many sites to be remediated by civilian federal agencies and states also are believed to contain VOCs, but only sparse data for these programs are available.

Metals are prevalent in almost all of the major market sectors. Metals, not including radioactive metals, are present at about three-quarters of the Superfund and DOD sites, and about half of the RCRA and DOE sites. They also are likely to be found in the other market segments. Of the 12 contaminants most frequently found at Superfund and DOD sites, more than half are metals, primarily arsenic, chromium, lead, zinc, nickel, and cadmium.

Exhibit 1-4. Contaminant Groups to be Remediated

Remediation Program	Percent of Sites		
	VOCs	Metals	SVOCs
NPL Sites	78%	77%	71%
RCRA Corrective Action Sites	67%	46%	32%
DOD Sites	64%	72%	57%
DOE Sites	38%	55%	38%

Notes:
- DOE figures for VOCs and SVOCs are combined. 90% of DOE sites contain radioactive elements.
- About 19% of DOD sites yet to be investigated and/or cleaned up may contain unexploded ordnance or waste military munitions.

The contamination characteristics of each market segment are discussed below.

For **NPL** sites, VOCs is the most common contaminant group remediated, followed by metals, and SVOCs. Most sites are complex, requiring remediation for more than one of these contaminant groups: 24 percent of the sites contain two contaminant groups and 52 percent contain all three. These contaminants are not necessarily in the same contaminated medium. Halogenated VOCs are by far the most common subgroup of organic contaminants, followed by BTEX, non-halogenated VOCs, polynuclear aromatic hydrocarbons (PAHs), non-halogenated SVOCs, phenols, pesticides, and polychlorinated biphenyls (PCBs). The most common metal cleaned up at NPL sites is arsenic, followed by chromium and lead. NPL data are based on contaminants for which remedies have been selected in the past.

The most common contaminant groups at **RCRA** sites are halogenated VOCs, found at 60 percent of sites; metals, found at 46 percent of sites; and non-halogenated VOCs, found at 32 percent of sites. These estimates are based on two studies in the early 1990s that used data from fewer than nine percent of all the likely corrective action projects.

Approximately 96 percent of **USTs** contain petroleum products including used oil and less than four percent contain hazardous substances. For USTs containing petroleum products, gasoline accounts for 66 percent and diesel fuel for 21 percent. The most likely constituents of concern in these products are BTEX and SVOCs, such as PAHs, creosols, and phenols.

Hundreds of DOD sites contain explosives and one percent contain radioactive contaminants. In addition, information from some installations indicates that the presence of unexploded ordnance may be significantly greater than these percentages indicate.

Based on information on over 6,000 **DOD** sites that needed remediation as of September 2001, metals are found at 72 percent of the sites, followed by VOCs at 64 percent, and SVOCs at 57 percent. Although many similar contaminants also are frequently found at non-defense related sites, some DOD sites contain contaminants that present unique problems for selecting remediation approaches. For example, hundreds of DOD sites with available data contain explosives, and about one percent contain radioactive contaminants.

Radioactive contaminants are found at 90 percent of **DOE** installations and include uranium, tritium, thorium, and plutonium. The most frequently present non-radioactive metals, which are found at 55 percent of the installations, include lead, beryllium, mercury, arsenic, and chromium. Organic chemicals are found at 38 percent of DOE installations and include PCBs, hydrocarbons from fuel and other petroleum products, and TCE. Mixed waste, containing radioactive and hazardous contaminants, also is a problem at many installations. The available data do not indicate if a specific contaminant has been identified at only one site or at more than one site on an installation.

Radioactive contaminants are found at 90 percent of the DOE installations and non-radioactive metals are found at 55 percent.

Waste at **civilian federal agency** and **state** sites is typical of industrial facilities and include organic chemicals, metals, and solvents. However, no national compilation of the specific contaminants at these sites is available.

Based on a limited data from samples of **state** sites, the most prevalent pollutant categories are organic chemicals, especially VOCs, SVOCs (PAHs and PCBs), solvents, and petroleum products.

1.6 Cleanup Program Status and Factors Affecting Demand

The demand for remediation services is driven largely by federal and state requirements, public and private expenditures, and activity in the real estate and property development industries.

Changes in these factors will affect each of the market segments in a different way, since each market has its own priorities and operating procedures. Thus, successful planning for technology development and marketing of remediation services should include consideration of the program structure, requirements, and site characteristics of the specific market sectors as well as the shifting requirements and budgets. The most prevalent factors that could alter the scope of the cleanup effort, as well as the technologies to be used in each market, are described below.

1.6.1 Superfund Sites

The Superfund program is the federal program to clean up releases of hazardous substances at abandoned or uncontrolled hazardous waste sites. As of September 30, 2003, EPA had listed 1,518 sites on the NPL, and proposed another 54. Of these, 274 sites were deleted from the list or referred for response to another authority, leaving a total of 1,244 final NPL sites. As additional sites are studied and ranked, they may be added to the NPL. The scope of the cleanup effort, as well as the technologies to be used in the future, will be influenced by the following factors:

- Between 1993 and 2003, EPA listed 305 sites, or an average of 28 sites per year. This report assumes that future listings will average 28 sites per year from 2004 to 2013. At this rate, 280 additional sites would be listed by 2013. If more "NPL-eligible" sites are found and evaluated, they may be addressed by other programs, such as RCRA Corrective Action or a state program, or may continue to await evaluation and/or cleanup. Because the decision on whether to list a site is complex, depending on many variables and input from many stakeholders, there is some uncertainty inherent in any such prediction.

- Based on information from two GAO reports (1998 and 1999) there appears to be a sufficient supply of Superfund-eligible sites and potentially-eligible sites in EPA's CERCLIS database to supply the aforementioned 280 sites. GAO identified 1,800 sites that have a Hazardous Ranking System (HRS) score of at least 28.5, which make them eligible for consideration for listing on the NPL and estimated that another 3,800 sites in CERCLIS are in earlier stages of the Superfund pipeline. Evaluations of the later sites have not progressed to the point where their NPL eligibility could be determined. Estimates of state and federal program managers have varied widely regarding the percentage of these sites that will ultimately be listed. Thus, we can only conclude that some portion of the 5,600 (1,800 + 3,800) sites awaiting a listing decision will eventually be listed on the NPL. In addition, from time to time, new site discoveries lead to new proposed listings. Thus the potential supply is not inconsistent with the 280-site assumption.

- Current resources appropriated to the program may be insufficient to fully implement the program, as defined above—to continue work on currently listed sites, address other CERCLA programs, such as removals, and begin the process of listing, evaluating, and cleaning up additional sites. The FY 2004 budget request to manage the Superfund program is about $1.4 billion. According to the 2001 RFF study, Superfund faces an average annual budget shortfall of approximately $100-200 million over a 10-year period. Depending on how the budget is allocated, this shortfall may or may not affect the sites where remedies have not yet been selected (the focus of this report). To address a number of long-term Superfund issues, EPA is working with the National Advisory Council for Environmental

Policy and Technology (NACEPT) to develop consensus on the issues and identify the future direction of the Superfund Program. In April 2004, The Superfund Subcommittee submitted its final report to the full NACEPT committee.

- State and PRP funding for Superfund site cleanups may fluctuate in the future. Many states are facing serious budget shortfalls in 2003 and 2004 and many PRPs face difficult business conditions. The PRPs have historically paid for 70 percent of Superfund site remediations. For Superfund remedial actions, the states contribute 50 percent of the construction and operation costs where they own the site and significant amounts of operation and maintenance (O&M) costs for certain Superfund actions in their state. In addition, as more Fund-lead NPL sites complete 10 years of long-term remedial actions, states will become responsible for continuing the LTRA work.

- In planning and implementing cleanups, EPA coordinates extensively with various EPA offices, PRPs, state and local governments, planning authorities, and local communities and developers. These requirements may influence the sequence of work, types of cleanup technologies selected for a site, and the number of sites to be listed on the NPL in the future.

1.6.2 RCRA Corrective Action Sites

The cleanup of RCRA Corrective Action sites is influenced by the regulatory and site-management refinements that EPA and the states have been building into the cleanup process, federal funding of state oversight, and improved field technologies which can lead to better site characterization, improved remedy design, lower cleanup costs, and better and faster cleanups.

- The RCRA Cleanup Baseline sites that are striving to meet 2005 interim Government Performance and Results Act (GPRA) goals represent the most immediate actions to be taken at RCRA sites. While these sites represent the readily identified, near-term cleanup market, many other RCRA sites with less immediate human health concerns will also need cleanup.

- Revisions to the Subtitle C requirement for cleaning up some hazardous waste implemented over the past decade are likely to encourage treatment and removal as compared to leaving waste in place.

- Refinements in site characterization technologies during the last decade have begun to decrease site-assessment costs, improve data quality and remedy design, and expand the applicability of less traditional remedies.

- The pace of the cleanups is affected by the availability of funds to pay for state and federal oversight. Many states are facing budget deficits in FY 2003 and 2004, and staffing levels and budgets for hazardous waste remediation in most states have not increased in about a decade.

- Land development trends are also likely to affect the pace and nature of RCRA cleanups. Redevelopment or transfer of commercial and industrial properties usually require site assessments and, if necessary, remediation. The 2002 brownfields law, (The Small Business Liability Relief and Brownfields Revitalization Act—P.L. 107-118), the Superfund Redevelopment Program, and the RCRA Brownfields Initiative are encouraging the reuse of former industrial and other properties. These programs have implemented policy changes and demonstrated many approaches that foster the cleanup and redevelopment of contaminated properties, including a number where waste has been left on site.

1.6.3 Underground Storage Tank Sites

The demand for remediation services at contaminated UST sites primarily will be influenced by federal and state requirements, and the number of releases occurring at old and new tanks. The timing of these cleanups will be influenced by the availability of state and federal funds for site assessment and cleanup and the pace of economic development.

- Since 1998, there has been a more than 50 percent drop in the number of new releases reported. As more tanks come into compliance with the new requirements, the number of new releases is expected to continue to drop.

- Even if the current backlog of all known sites is eliminated, there will always be additional releases at some sites in the future. Many older tanks still exist, many tanks are not in full compliance, some new or upgraded tanks leak due to failure of components or spills, many tanks are not operated and maintained properly, and over half of the states are not inspecting all of their tanks at the minimum recommended rate. The GAO has estimated that 76,000 active regulated tanks may not be upgraded, which implies that there is a backlog of potentially contaminated sites that may be discovered over a period of time as they are replaced or removed.

Although the number of releases has declined significantly, tanks continue to leak, because older tanks still exist, many tanks are not in full compliance with upgrade requirements, and many are not operated properly.

- The pace of the cleanups is affected by the availability of funds. Appropriations from one source of funds, the federal Leaking Underground Storage Tank Fund (LUST Trust Fund) have been about $70-80 million annually. At the end of 2003, the fund had a balance of $2.1 billion. The gasoline tax that supports the fund is scheduled to expire in 2005. The other two major funding sources–state tank trust funds and direct appropriations, and property owners or responsible parties–are stable.

- The 2002 brownfields law and EPA's USTfields initiative may lead to an increase in the number of UST sites identified as needing cleanup as well as the pace of cleanups.

- Concerns about methyl tertiary-butyl ether (MTBE) contamination may influence the amount and timing of UST cleanups in some states. Some states have passed legislation addressing MTBE. These activities will lead to more site evaluations and/or cleanups.

1.6.4 Department of Defense Sites

DOD installations typically have multiple contaminated sites regulated by either CERCLA, RCRA, state laws, federal statutes that mandate base realignments and closings, or a combination of these. The following factors strongly influence the nature of the cleanup needed.

- The pace of remediation is subject to change in response to budgetary and political developments. The FY 2004 planned DOD budget for restoration is almost $1.7 billion. Of these funds, approximately $328 million, or 20 percent, is allocated to closing (BRAC) sites. An additional BRAC round is scheduled for 2005.

> *The DOD cleanup budget has remained steady, and is expected to continue at its current level. The proportion of the cleanup budget going to the cleanup of facilities scheduled to close has fluctuated from 20 to 37% between 2000 and 2005.*

- The proportion of the environmental restoration budget allocated to cleanup at active installations and FUDS continues to increase (69% in FY 2003) relative to study and investigation funding.

- Although DOD believes that most sites have been located, new sites continue to be identified. The recently established munitions program has led to an increased the number of new sites. Between FY 2001 and FY 2003, DOD identified approximately 1,700 additional sites. Of these, about 1,000 are munitions program sites.

- In determining the priorities for funding at all sites, DOD generally addresses the worst sites first. As of the end of FY 2002, DOD has reduced the number of high relative risk sites at active installations and FUDS properties by 58 percent. DOD anticipates achieving remedy in place or remedy completes at all high relative-risk sites by 2007. In implementing its priorities, DOD may assign varying levels of priority to different sites on a given installation. This policy may lead to acceleration of some projects at a given installation while other projects at the same installation are postponed.

- The rate of base closures and realignments will affect the sequencing of cleanup for all sites. New schedules will need to be generated for the FY 2005 round of closures.

1.6.5 Department of Energy Sites

DOE is responsible for cleaning up installations and other locations that have been used for nuclear weapons research, development, and production for over five decades. The following policy, regulatory, economic, and technical factors will significantly affect the scope, schedule, and cost of DOE's remediation effort.

- Based upon a 2002 critical assessment of its program—the Top-to-Bottom Review–DOE began a major initiative to accelerate cleanup of its installations and other locations by at least 30 years, prioritize risks, improve its contracting practices, and reduce program costs. DOE expects this initiative to profoundly affect the scope and scheduling of its cleanups.

In 2002, DOE began a major initiative to accelerate cleanup of its sites by at least 30 years, prioritize risks, improve contracting practices, and reduce program costs.

- Under the initiative, DOE is promoting a new "risk-based" cleanup strategy that would assist in prioritizing risk—and thereby prioritize cleanups—among the various sites on a DOE-wide basis. The initiative also has the potential to increase the use of remediation approaches that leave more waste on site, compared to treatment and other active remediation approaches than previously planned, thereby reducing remediation costs for some projects.

- Cleanup schedules are heavily dependent upon the availability of funds. DOE's estimate that it can complete legacy waste cleanup at all DOE properties by 2035 could be lengthened or shortened, depending on the funds appropriated by Congress.

- At many sites it is difficult to forecast the extent of cleanup work needed, because remedy decisions usually require balancing potential land uses with the alternative cleanup options and long-term stewardship approaches, and collaboration with many stakeholders.

DOE estimates that long-term stewardship will be needed at up to 129 installations and has established the Office of Legacy Management to address this need.

- Groundwater remediation is expected to continue at many sites, and long-term stewardship will be needed at 129 DOE installations. The Department has established the Office of Legacy Management to address this need.

- There is a potential market for cleanup at sites for which there is no current feasible remediation approach. The costs for these activities are excluded from the above cost estimates, though applicable stewardship and monitoring costs for these sites are included. For example, costs are excluded for the nuclear explosion test grounds at the Nevada Test Site; large surface water bodies, including the Clinch and Columbia rivers; and most contaminated groundwater for which, even with treatment, future use will remain restricted.

These factors indicate that, despite significant progress in establishing the scope of work for DOE's cleanup program, there are uncertainties inherent in the remediation of DOE properties. The DOE cleanup market estimates rely on several critical assumptions, which makes them particularly sensitive to budget fluctuations, cleanup standards, and further site investigations

1.6.6 Civilian Federal Agency Sites

The responsibility to clean up non-DOD and non-DOE contaminated sites falls to 17 federal agencies. Because these programs are more fragmented throughout the government, detailed site characteristics data are limited and more site investigation is needed to fully identify cleanup needs. Three primary factors influence the market for remediation of civilian federal agency sites.

- Lack of funds constrains federal agency site remediation programs. Based on current and recent budgets, it would take 100 to 200 years to clean up all of the identified sites, under current environmental regulations. The limited resources available for site cleanups provide these agencies with incentives to prioritize efforts; encourage and eliminate barriers to the use of less costly innovative technologies; use more cost-effective contracting procedures; streamline management structures and processes; and seek cost recovery from other parties.

- Changes in federal and state environmental regulations and standards often impact the scope and pace of cleanup required at civilian federal facilities.

- The transfer of public properties to private use may require agencies to reallocate resources for cleaning up properties designated for transfer.

- Civilian federal agencies may be responsible for cleaning up between 8,000 and 31,000 abandoned mine sites, most of which have not been evaluated. The potential cost for this effort is not included in the discussion of the civilian agency budgets above.

1.6.7 State and Private Party Sites

Sites not owned by federal agencies that require cleanup, but cannot be addressed under the federal cleanup programs, are addressed by state cleanup programs. The cleanup of these sites are generally financed by the states or private parties. To manage the cleanup of contaminated sites, most states have created two types of programs—mandated cleanup programs and voluntary cleanup and brownfield programs. The mandated programs, which are roughly patterned after the federal Superfund program, generally include enforcement authority and state funds to finance the remediation of abandoned waste sites. The extent and pace of these programs are determined by states' financial and legal commitment to environmental restoration.

The financial and legal commitments to site restoration vary from state to state. Almost all states have programs to encourage voluntary cleanups and develop brownfield properties.

Voluntary cleanup programs (VCPs) and brownfield programs encourage private parties to voluntarily clean up sites rather than expend state resources on enforcement actions or remediations. Fifty states and territories have VCPs and 31 have established brownfield programs that are separate from their VCPs. It is often difficult to distinguish between a brownfield program and a VCP. Many brownfield sites are addressed by volunteers.

- The state market for remediation services is largely dependent upon the commitment and ability of states and private companies to establish and manage hazardous waste programs, to finance cleanups, and to encourage or compel responsible parties to clean up sites. Funding and staff levels of state cleanup programs have remained steady for about a decade.

- The Brownfields Revitalization Act is expected to expand the number of sites to be assessed and/or cleaned up. The law greatly mitigates the potential liability of innocent (not responsible for pollution) property owners, reduces financial uncertainties for investors and property owners, and directly funds various projects and programs, which serve as examples, case histories, and lessons learned for other sites.

- Over approximately the past decade, the U.S. capacity to address brownfields has grown enormously. Today, there is a growing cadre of developers, planners, consultants, engineering and construction firms, attorneys, and public officials with the expertise to evaluate, clean up, and revitalize brownfield properties. The growing acceptance of the practicability of cleaning up and revitalizing brownfield sites has the potential for enlarging the market for site characterization and cleanup services.

- The pace of development in a region will influence the number of brownfield and voluntary sites that need to be evaluated. It is estimated that only 10-15 percent, of the estimated one-half to one million brownfield sites, have been identified. Most of the remaining sites have not been identified, primarily because they are vacant or underused and the owners do not wish to become involved in the complicated and costly world of remediation.

- The growing popularity of smart growth policies are likely to advance the demand for the state and brownfield cleanups, since infill development and the preservation of greenfields are primary components of smart growth programs.

- Forty-one states have long-term stewardship programs for one or more of their cleanup programs. These programs are important because of the widespread use of remedies that allow hazardous substances to remain on site.

1.6.8 Manufactured Gas Plant Sites

Most of the cleanups at MGP sites have involved those owned or operated by utilities. Because the original commercial MGPs were in good locations, close to population or commercial centers, the utilities that owned them simply reused the property for modern facilities, such as natural gas or electricity distribution. Thus, there is a known history and chain of ownership. Many utilities are aware of the potential environmental problems associated with their properties and are conducting monitoring or cleanups under RCRA or a state program. However, the location and disposition of many of the other types of MGP sites is less defined.

Former manufactured gas plants, or their waste products, may be discovered over many years, in conjunction with other cleanup programs, such as RCRA, Superfund, or Brownfields. There is no dedicated effort to search for them.

Site investigators and remediation planners could benefit from knowledge of the history and operations of this defunct industry. When combined with the growing body of literature on site characterization and remediation techniques, they would be able to develop the most effective and practicable cleanups.

1.6.9 Mining Sites

The following primary factors influence the market for remediation of mine lands.

- The reclamation budgets of the federal and state agencies that manage mine lands are small in comparison to the magnitude of the abandoned mine waste problem.

- Growing markets for first or second homes and recreational activities in previously sparsely-populated mining areas may foster increased demand for cleanup of some sites or restrictions on park use.

- The transfer of properties in mining areas where complete control of the source of the pollution has not been achieved may require institutional controls. Thus, there is a growing need for methods to ensure compliance with institutional controls.

- A number of the over 14,000 active and inactive mine sites that are not abandoned also may require remediation. Releases of contaminants into the environment can result from inadequately designed facilities such as tailings dams, accidents, leaks and spills, or failure to properly operate a facility. Thus some portion of these sites are likely to require remediation of soil, groundwater, and/or surface water, among other things.

- The passage of Good Samaritan legislation would probably encourage more state and local governments to undertake some remediation.

1.6.10 Drycleaner Sites

The use of drycleaning solvents has been decreasing, primarily because the industry has been switching to new more efficient machines and, to a lesser extent, the use of alternative solvents. Nevertheless, there remain thousands of sites from previous operations.

- The declining use of perchloroethylene by drycleaners will mean fewer discharges to the environment in the future.

- For the 12 states with dedicated drycleaner remediation funds, the money available to the funds appears to be stable.

- For other states, general availability of state cleanup funds, will be a critical factor for many cleanups. Drycleaners have average revenues of about $250,000; remediation costs can run hundreds of thousands of dollars, and several have cost over a million. Even a moderate-cost cleanup can amount to several years of profit for the average drycleaner.

- In addition to active drycleaner facilities, many inactive facilities (properties that currently do not have a drycleaner, but did in the past) have not yet been discovered. Many of these facilities may have released hazardous substances to the environment that resulted in contaminated soil and groundwater. Although data on these facilities are sparse, it is estimated that there are between 9,000 and 90,000 sites.

- The level of assessment and cleanup is directly related to the cleanup standards adopted by the states. Many states have adopted risk-based cleanup standards for soil and groundwater.

1.6.11 Site Characterization

Although it averages only about 10 percent of cleanup costs, site characterization is a major determinant of the ultimate effectiveness, schedule, and cost of remedial actions. The following factors are driving the demand for sampling and analysis technologies:

- The use of field analytical technologies is expected to increase relative to traditional approaches. There is a growing body of evidence that indicates that substantial cost and time savings and better site characterizations are usually achieved with the use of field technologies, especially when combined with dynamic work plans and systematic planning. Field technologies can also foster significant savings in dollars and time during remedial action, because they provide accurate site characterization data and allow site crews to adapt to new information on a daily basis.

- The demand for revitalization of brownfields and UST sites implies a requirement to conduct many Phase I and Phase II type site assessments. A smaller percentage will require further site investigation and cleanup.

- The demand for due diligence by property purchasers, developers, and lenders also implies a significant demand for Phase I and, possibly, Phase II assessments.

- The demand to redevelop sites provides a powerful economic incentive for faster site assessments and cleanups. Developers and investors usually operate under serious time constraints to implement projects. The combination of field analytics, dynamic work plans, and systematic planning may allow development to proceed more expeditiously.

Based on these factors, it is expected that the use of newer characterization approaches will grow relative to older ones. To the extent that improved site characterizations reduce overall remediation costs, they would allow more sites to be cleaned up. Improved cost-effectiveness of cleanups is especially important, given the finite resources available for most cleanup programs.

1.6.12 DNAPLs

The CERCLA remedy selection process and NCP include a preference for remedies that provide "permanence and treatment." to the extent practicable. However, the ability to economically delineate the DNAPL source zones varies from site to site. Similarly, the ability to show that source reduction will dramatically reduce long-term costs of containment also varies from one site to another. Thus, the proportion of DNAPL sites that will be subject to containment and the number that will undergo source zone treatment is uncertain. A number of factors may affect decisions that attempt to strike a balance between remediating a source zone and long-term pump and treat at DNAPL sites, and hence the potential demand for remediation services. These factors, which are not mutually exclusive, include:

- Potential contamination at uncharacterized or undiscovered sites, such as MGP sites, former drycleaners sites, or other types of sites, may lead to continued additions to the number of sites that need to be assessed and/or cleaned up.

- A number of states have recognized the need to consider newer site characterization and remediation technologies prior to granting ARAR waivers for technical impracticability.

- Reuse considerations at a site may drive the need for faster cleanups. Developers may need the properties that might otherwise be encumbered by pump-and-treat equipment or institutional controls related to the contamination and remedy..

- Continued advances in site characterization techniques that allow a better definition of the source zone, which is especially needed for deep sources, offer the potential to reduce remediation costs. Such advances may be enhanced when coupled with more effective use of innovative in-situ technologies for the removal or destruction of DNAPL sources, and may contribute to increased use of treatment versus long-term containment remedies.

1.7 Implications for Site Characterization and Cleanup

Although substantial progress has been made over the past quarter century, a considerable amount of cleanup work, which will take 30 to 35 years to complete, remains. As with most cleanups requiring technically complex solutions and coordination of multiple stakeholders, the work load will fluctuate from year to year. Most of the costs will be borne by private and public owners of contaminated properties and responsible parties. This work includes the cleanup of a number of very large, complex sites as well as the assessment and, when necessary, cleanup of many small sites. The needed work represents a significant opportunity for the continued development and implementation of site characterization and cleanup approaches and technologies that can result in better, cheaper, and faster cleanups, as well as technologies that enable us to better address challenging contamination problems such characterizing NAPLs in the subsurface.

Technical solutions to a particular contaminated site problem are generally similar, regardless of the regulatory program under which they are implemented. While individual markets may not support certain important investment decisions, the aggregate demand across all markets might justify the up-front investment in a technology that ultimately drives down the cost of moving contaminated sites into productive use. By recognizing this potential for economies of scale in cleanup technology markets, the information in this report contributes to better investment decisions across all market segments.

Chapter 2
Remediation Technologies Used At National Priorities List Sites

The U.S. faces significant technological challenges as it seeks the most efficient and effective approaches to clean up its contaminated waste sites. This chapter examines trends in the use of remediation technologies at hazardous waste cleanup sites covered under the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), commonly known as Superfund.

Although Superfund sites are a small percentage of all contaminated sites, the program has been in the forefront in selecting and applying new site characterization and remediation technologies that are less costly and more effective. Developments in the Superfund sector tend to influence technology selection in other market segments. Many of the remediation projects in recent years involve technologies that were not even available when the law was reauthorized. The development of new technologies has been driven, in part, by a preference for "permanence and treatment" in the 1986 reauthorized law and the resulting quest for more cost-effective processes.

2.1 Definitions of Remediation Technologies

The text box summarizes the major types of remedies used at hazardous waste sites. Most Superfund records of decision (RODs) for remedial action address the source of contamination, such a soil, sediment, sludge, and solid-matrix wastes. Such "source control" RODs select "source control technologies." Groundwater remedial actions, also known as "non-source control actions," may be a component of a "source control" ROD and the treatment technologies chosen for groundwater remediation are referred to as "groundwater technologies."

Superfund Remedy Types

Source Control Remedy Types

- **Source Control Treatment:** Treatment of any source in situ or ex situ, including technologies such as chemical treatment and thermal desorption.
- **Source Control Containment:** Containment of a contaminant source using caps, liners, covers, on-site and off-site landfilling, or other means.
- **Other Source Control:** Other forms of remediation of a contaminant source, such as institutional controls, monitoring, and population relocation.

Groundwater Remedy Types

- **Pump and treat:** Extraction of groundwater from an aquifer and treatment above ground. Treatment can include technologies such as air stripping and ion exchange.
- **In-Situ Treatment:** Treatment of groundwater in place without extracting it from an aquifer, using technologies such as air sparging and permeable reactive barriers.
- **Monitored Natural Attenuation:** 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 to other alternatives.
- **Groundwater Containment:** Containment of groundwater through the use of a vertical engineered impermeable subsurface barrier, or a hydraulic barrier created by pumping.
- **Other Groundwater Remedies:** Groundwater remedies that do not fall into the above categories, such as water-use restrictions and the provision of alternative water supplies.

The term "treatment technology" means any unit operation or series of unit operations that alters the composition of a hazardous substance, pollutant or contaminant through chemical, biological, or physical means to reduce the toxicity, mobility, or volume of the contaminated materials being treated. Treatment technologies are an alternative to land disposal of hazardous wastes without treatment (see "definitions" at 40 CFR 300.5, 55 Federal Register 8819, March 8, 1990).

Established technologies are those for which cost and performance information is readily available. The most frequently used established technologies are on- and off-site incineration, solidification/stabilization (S/S), soil vapor extraction (SVE), thermal desorption, and pump-and-treat (P&T) technologies for groundwater. Technologies used to treat groundwater after it has been pumped to the surface usually involve traditional water treatment approaches, which are considered established technologies.

Innovative treatment technologies are alternative treatment technologies with a limited number of field applications and limited data on cost and performance. Often, these technologies are established in other fields, such as chemical manufacturing or hazardous waste treatment. In such cases, it is the application of a technology or process at a waste site (to soil, sediments, sludge, and solid-matrix waste, or groundwater) that is innovative, not the technology itself.

Both innovative and established technologies are grouped as source control treatment or in-situ groundwater treatment technologies on the basis of the type of application most commonly associated with the technology. Some technologies can be used for both source control and in-situ groundwater treatment.

Exhibit 2-1 lists 17 types of source control (primarily soil) technologies, 10 types of in-situ groundwater treatment technologies, eight types of groundwater P&T technologies, as well as other approaches, such as monitored natural attenuation (MNA) for groundwater, and groundwater containment. The definitions of these technologies may be found in the EPA report *Treatment Technologies For Site Cleanup: Annual Status Report (Eleventh Edition)* (EPA, 2004a). They are based on the *Remediation Technologies Screening Matrix Reference Guide, Version 3* (FRTR 2003a). Technologies that are applicable to both source control and groundwater treatment are also indicated. For P&T technologies, this report focuses on the treatment portion of the technology.

2.2 Historical Use of Remediation Technologies at Superfund Sites

This section reviews the types of hazardous waste remediation technologies that tend to be used at NPL sites. Most of the discussion on the selection and use of innovative and established technologies is derived from a more detailed analysis in the *Annual Status Report* which contains information on each planned, ongoing, and completed treatment technology project selected for use in the Superfund program through fiscal year (FY) 2002 (U.S. EPA 2004a). The analysis is based on data from RODs signed between FYs 1982 and 2002, which ended on September 30, 2002. During this period, EPA made cleanup decisions in 2,610 RODs for over 1,200 NPL sites. It also contains data on a limited number of non-Superfund federal facility sites.

Exhibit 2-1. Treatment Technologies

Source Control Treatment Technologies

- Bioremediation
- Chemical Treatment
- Electrokinetics
- Flushing
- Incineration (on-site and off-site)

- Mechanical Soil Aeration
- Multi-Phase Extraction
- Neutralization
- Open Burn (OB) and Open Detonation (OD)
- Physical Separation

- Phytoremediation
- Soil Vapor Extraction
- Soil Washing
- Solidification/Stabilization
- Solvent Extraction

- Thermal Desorption
- Thermally Enhanced Recovery
- Vitrification

In-situ Groundwater Treatment Technologies

- Air Sparging
- Bioremediation (also a source control technology)
- Chemical Treatment (also a source control Technology)
- Electrokinetics (also a source control technology)
- Flushing (also a source control Technology)

- In-well Air Stripping
- Multi-phase Extraction
- Permeable Reactive Barriers
- Phytoremediation (also a source control technology)
- Thermally Enhanced Recovery (also a source control technology)

Pump-and-treat Technologies (Ex-Situ Treatment)

- Adsorption
- Air Stripping (also a source control technology)
- Bioremediation
- Chemical Treatment (also a source control technology)
- Filtration

- Ion Exchange
- Metals Precipitation
- Membrane Filtration

Monitored Natural Attenuation for Groundwater

- Includes a variety of physical, chemical, or biological processes, such as biodegradation; dispersion; dilution; sorption; volatilization; radioactive decay; and chemical or biological stabilization, transformation, or destruction of contaminants.

In-situ Groundwater Containment

- Vertical engineered subsurface impermeable barrier
- Hydraulic Barrier created by pumping

Other Groundwater

- Groundwater Use Restrictions
- Alternative Water Supply
- Groundwater remedies that do not fall into above categories

Source: U.S. EPA, Office of Solid Waste and Emergency Response, *Treatment Technologies For Site Cleanup: Annual Status Report (Eleventh Edition),* EPA-542-R-03-009, February 2004. http://www.clu-in.org/asr; and *The Remedial Technologies Development Matrix and Reference Guide* web site maintained by the Federal Remediation Technology Roundtable. http://clu-in.org/remed1.cfm#tech_sele

2.2.1 Containment and Disposal Technologies for Source Control

Exhibit 2-2 shows the remedy types for source control implemented or planned over the life of the Superfund program. These data are based on an analysis of the RODs signed between 1982 and 2002. A source control remedy has been implemented or planned at 70 percent of NPL sites. Fifty-two percent of all source control sites have selected treatment of a source, such as contaminated soil or sediment. Fifty-five percent of sites have implemented or plan to implement containment or off-site disposal of a source.

Exhibit 2-2. Source Control Remedy Types Selected or Used for at NPL Sites, FY 1982-2002

Remedy Type	Number of Sites	Percent of Sites with Source Control
Treatment of a Source	541	52%
Containment or Off-site Disposal of a Source	576	55%
Institutional Controls of a Source	525	49%
Other Source Control	457	44%
Total Source Control Sites	1,046	100%

Notes:
- ROD = Record of Decision.
- Data for FY 2002 includes an estimated 70 percent of FY 2002 RODs.
- 1,046 sites with source control. More than one remediation application may be used at a site.

Source: U.S. EPA, Office of Solid Waste and Emergency Response, *Treatment Technologies For Site Cleanup: Annual Status Report (Eleventh Edition),* EPA-542-R-03-009, February 2004. http://www.clu-in.org/asr.

Prior to 1987, the most common methods for remediating hazardous waste were to excavate the contaminated material and dispose of it in an off-site landfill, or to contain the waste on site by means of containment systems (*e.g.*, caps or slurry walls). In the late 1980s and early 1990s, the number of remedies that included treatment began to increase. Later, in the second half of the 1990s, the percentage decreased. According to the *Annual Status Report*, the percentage of source control treatment RODs was generally higher from FY 1988 through FY 1996 (59 to 75 percent of the RODs) than for the period FY 1997 through FY 2002 (39 to 51 percent of the RODs) (U.S. EPA 2004a).

Many factors contribute to the selection of remedies at hazardous waste sites. Although the Superfund Amendments and Reauthorization Act of 1986 (SARA) requires a preference for the use of permanent remedies, existing regulations provide site managers with flexibility in remedy selection, so long as they meet the principle requirements for the selection of remedies. Remedy decisions may also be influenced by EPA's policies for considering cost (U.S. EPA 1996b) and land use (U.S. EPA 1995, 2001c) in remedy selection, new developments in remediation technologies, and changing knowledge and experience with technologies used for site characterization, containment, and treatment. By considering land use and cost-effectiveness, decision-makers may have the flexibility to base remedy selection on restricted, rather than unrestricted land uses. Thus, nontreatment remedies, such as containment and institutional controls, may be protective of human health and the environment at some sites, while other sites will require other remedies.

2.2.2 Treatment Technologies for Source Control

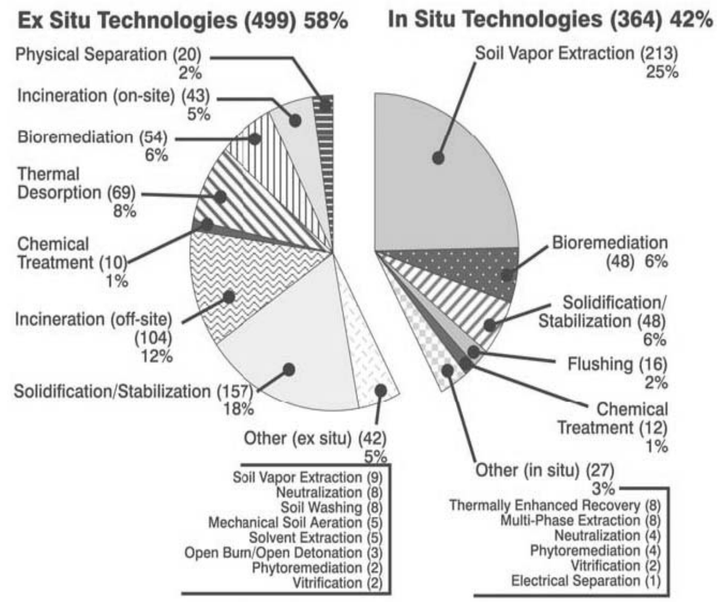
Between 1982 and 2002, 863 applications of treatment technologies were implemented or planned for source control at 638 Superfund sites. More than one type of technology may have been selected at a site. Exhibit 2-3 provides an overview of the in-situ and ex-situ technologies selected for source control. As the figure shows, 42 percent of all treatments selected for source control at Superfund remedial action sites were in-situ technologies. Soil vapor extraction (SVE) (213 projects, 25 percent), bioremediation (48 projects, 6 percent), and solidification/stabilization (48 projects, 6 percent) are the most common in-situ technologies, together accounting for 85 percent of all in-situ source control treatment projects.

The most common ex-situ technologies are solidification/stabilization (157 projects, 18 percent); incineration (147 projects, 17 percent); thermal desorption (69 projects, 8 percent); and bioremediation (54 projects, 6 percent). These technologies together account for 86 percent of ex-situ source control treatment projects.

The *Annual Status Report*, which is available on line, provides a detailed description of the trends in the use of these technologies from 1982 through 2002 (U.S. EPA 2004a). An appendix to the report lists treatment technology projects for source control at remedial sites by EPA region. While in-situ technologies as a percent of all treatment technologies tend to fluctuate from year-to-year, the general trend since 1985 has been an increase in their use. In-situ treatments as a percent of source control treatments increased from 31percent for the FY 1985 to FY 1989 period to 49 percent for the FY 1998 to FY 2002 period. Some of the key factors that have influenced this upward trend include:

- In-situ technologies are often more cost-effective than ex-situ approaches which require excavation and materials handling, especially for large sites.
- Because in-situ technologies require no excavation, the levels of exposure to contaminated substances is reduced, compared to that associated with ex-situ methods.
- As in-situ treatment technologies are used more frequently, site managers and other remediation professionals are more willing to accept them as a viable and reliable approach.

Exhibit 2-3. Superfund Remedial Actions at Source Control Treatment Projects FY 1982-2002 (Total Projects = 863)



Notes: Data for 2002 include an estimated 70% of FY 2002 RODs. More than one remediation application may be used at a site.

Source: U.S. EPA, Office of Solid Waste and Emergency Response, *Treatment Technologies for Site Cleanup (Eleventh Edition)*, EPA-542-R-03-009, February, 2004.

2.2.3 Groundwater Remedies

Groundwater treatment technologies are designed to remove or immobilize contamination in an aquifer. Groundwater remedies can be grouped into five general types: remedies specifying extraction of groundwater, usually by pumping, followed by aboveground treatment (pump and treat); remedies specifying in-situ treatment; remedies specifying MNA; remedies specifying containment using subsurface vertical engineered impermeable barriers or hydraulic barriers created by pumping; and other actions, such as groundwater use restrictions, drilling prohibitions, and other land use (institutional) controls (Exhibit 2-1).

Exhibits 2-4 and 2-5 display the application of groundwater remedies on a site basis. These data are based on an analysis of the 2,610 RODs and supplementary documents signed between 1982 and 2002. More than one type of remedy may have been selected at a site or in a specific ROD. At some sites, several applications of the same type of groundwater remedy may have been specified. At sites for which several types of groundwater remedies were selected, the remediation may not have occurred in the same aquifer or groundwater plume.

A groundwater remedy has been implemented or is planned at 71 percent of the NPL sites. Pump and treat has been implemented or planned at 67 percent, in-situ treatment at 13 percent, and

MNA at 19 percent of NPL groundwater sites. At many sites, more than one type of groundwater remedy is planned or implemented.

Exhibit 2-4. Groundwater Remedy Types Selected or Used at NPL Sites, FY 1982-2002

Remedy Type	Number of Sites	Percent of Sites
Groundwater Pump and treat	713	67%
In-situ Treatment of Groundwater	135	13%
MNA of Groundwater	201	19%
Institutional Controls for Groundwater	515	48%
Other Groundwater (includes other and VEB)	735	69%
Total Groundwater Sites	1,062	100%

Notes:
- ROD = Record of Decision; VEB = vertical engineered barrier
- Data for FY 2002 includes an estimated 70 percent of FY 2002 RODs.
- 1,062 groundwater sites. Pump and treat, in-situ treatment, or MNA has been used or selected as part of the remedy for 851 sites. More than one remediation application may be used at a site.

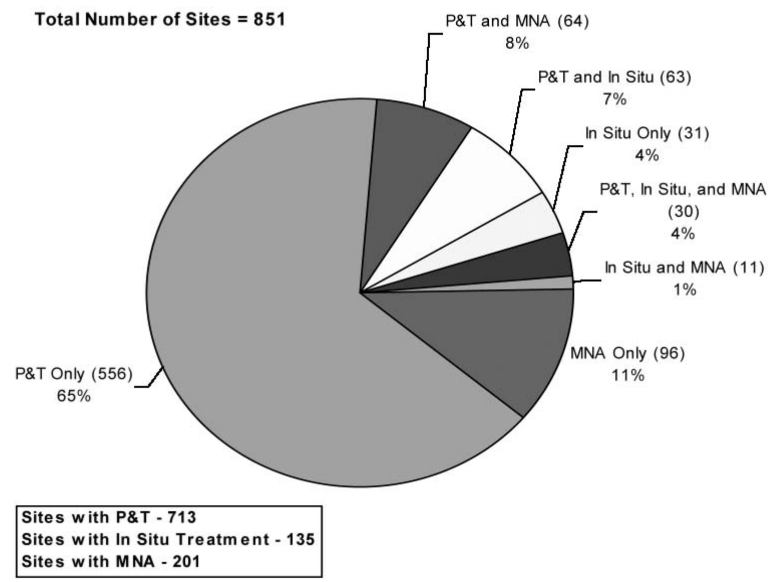
Source: U.S. EPA, Office of Solid Waste and Emergency Response, *Treatment Technologies For Site Cleanup: Annual Status Report (Eleventh Edition),* EPA-542-R-03-009, February 2004. http://www.clu-in.org/asr

Exhibit 2-5 shows the results of an analysis of the use of pump and treat, in-situ treatment, and MNA for groundwater, both alone and in combination with other remedies. This analysis focuses on these three remedies because they are intended to result in the reduction or immobilization of contaminants. Of the 851 sites, pump and treat alone was used in 556 (65 percent) of the sites, and in combination with other technologies at 713 (84 percent) sites; MNA alone at 96 sites (11 percent); and in-situ groundwater treatment alone at 31 sites (4 percent). In-situ treatment alone, or in combination with other technologies, was selected at 135 sites (16 percent) and MNA alone, or in combination with other technologies, was selected at 201 (24 percent) of the sites.

2.3 Advancing Remediation and Characterization Technologies

Opportunities exist for technology vendors who want to work cooperatively with EPA, and other federal agencies, such as the Departments of Defense (DOD) and Energy (DOE). In many cases the programs involve other industry partners as well. A number of programs are available to support the development and use of advanced technologies through research, development, testing, and evaluation, and through information sharing and networking about experiences with remediation technologies. Many of these programs also include resources to help vendors publicize the capabilities of their technologies to all interested parties. Some of the more important efforts are listed below:

Exhibit 2-5. Superfund Sites With P&T, In-situ Treatment, or MNA as Part of a Groundwater Remedy FY 1982-2002



Notes: Data for 2002 include an estimated 70% of FY 2002 RODs. More than one remediation application may be used at a site.

Source: U.S. EPA, Office of Solid Waste and Emergency Response, *Treatment Technologies for Site Cleanup (Eleventh Edition)*, EPA-542-R-03-009, February, 2004.

- **Clean-Up Information System (CLU-IN).** This web site, maintained by EPA's Technology Innovation and Field Services Division (TIFSD), provides information about innovative treatment and site characterization technologies and acts as a forum for all waste remediation stakeholders. It also provides tools to assist technology developers and vendors demonstrate and bring their technologies to market. Most of the resources referred to in this report and cited below are available for downloading from this web site. http://www.clu-in.org

- **Superfund Innovative Technology Evaluation (SITE) Program**. The EPA established the SITE Program to help promote the use of innovative remediation and monitoring and measurement technologies at hazardous waste sites. The program, which is administered by ORD's National Risk Management Research Laboratory, headquartered in Cincinnati, Ohio, offers a mechanism where the performance and costs of innovative technologies can be demonstrated and evaluated by an independent third party at a particular hazardous waste site. The demonstration projects allow participation by private entities, state environmental agencies and federal agencies. Under this program, EPA enables the field testing of technologies and provides reports on completed technology evaluations. The web site describes the current technologies of interest, how to participate in the program, and provides the publication *SITE Technology Profiles* for downloading. This publication describes each project and lists available reports. http://www.epa.gov/ORD/SITE

- **EPA REACH IT**. This EPA web site allows vendors to search, view, download and print information about innovative remediation and characterization technologies. It provides users access to comprehensive information about treatment and characterization technologies and their applications. It combines information submitted by technology service providers about remediation and characterization technologies with information from EPA, the U.S. Department of Defense (DOD), the U.S. Department of Energy (DOE), and state project managers about sites at which innovative technologies are being deployed. Those sources together provide up-to-date information, not only about technologies one can use to characterize or remediate a site, but also about sites at which those technologies are being used and the service providers that offer them. As of October 2002, REACH IT contained information on 607 remediation technology vendors; 1,380 technologies; and 1,564 sites at which remediation technologies have been applied. It also contained information on 128 characterization technology vendors; 209 technologies; and 232 sites at which characterization technologies have been applied. http://www.epareachit.org.

- **Groundwater Remediation Technologies Analysis Center (GWRTAC).** In 1995, EPA established GWRTAC at the National Environmental Technologies Applications Center (NETAC) in association with the University of Pittsburgh. This center develops and disseminates information on current research, development, and demonstration efforts related to in-situ groundwater technologies. The Center also analyzes trends in technology development. http://www.gwrtac.org.

- **Remediation Technologies Development Forum (RTDF).** The RTDF was established in 1992 after industry approached the EPA to identify what they could do together to develop and improve the environmental technologies needed to address their mutual cleanup problems in the safest, most cost-effective manner. The RTDF is a public-private partnership created to undertake research, development, demonstration, and evaluation efforts focused on finding innovative solutions to high priority problems. The RTDF includes partners from industry, several federal and state government agencies, and academia who voluntarily share knowledge, experience, equipment, facilities, and even proprietary technology to achieve common cleanup goals. http://www.rtdf.org.

- **Federal Remediation Technologies Roundtable (FRTR).** The FRTR works to build a collaborative atmosphere among federal agencies involved in hazardous waste site cleanup. FRTR was established in 1990 to bring together top federal cleanup program managers and other remediation community representatives to share information and learn about technology-related efforts of mutual interest; discuss future directions of the national site remediation programs and their impact on the technology market; interact with similar state and private industry technology development programs; and form partnerships to pursue subjects of mutual interest. http://www.frtr.gov.

Since these sources are often used in the preparation of lists of cleanup alternatives or bid documents, it is important that technology vendors and developers ensure that information on their products and services are represented. In addition, joining and participating in activities of various professional societies and trade groups may help a vendor promote specific capabilities.

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Chapter 3
Demand for Remediation of National Priorities List Sites

This chapter presents estimates of the number, location, size, characteristics, and cleanup costs of hazardous waste sites that have been or will be placed on the Superfund National Priorities List (NPL), but for which a remedy has yet to be selected. It also describes the implications of a number of technical, regulatory, and economic factors for the demand for cleanup technologies. Because many Superfund sites have undergone detailed site assessments, much information is available on their characteristics. In addition, the remediation technologies used for the Superfund program are likely to reflect needs in other programs with similar cleanup challenges.

3.1 The Superfund Program

Superfund is the federal program, administered by EPA, to clean up releases of hazardous substances at abandoned or uncontrolled hazardous waste sites. In addition to establishing enforcement authorities, the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) created a trust fund to be used for site identification and cleanup. CERCLA was substantially altered by the Superfund Amendments and Reauthorization Act of 1986 (SARA), which made three changes to the Superfund program that are of particular significance to technology vendors: (1) it stressed the importance of permanent remedies; (2) it supported the use of new treatment technologies to achieve permanent remedies; and (3) it expanded research and demonstrations to promote the development of innovative treatment technologies.

Highlights

- As of September 2003, remedial construction was complete at 886 of the 1,518 NPL sites. EPA had conducted more than 7,000 removal actions at over 5,000 sites.
- As of May 2003, 456 proposed and final NPL sites not owned by the federal government still require remedial action. Estimated cleanup cost for these sites are $16–23 billion (most likely $19 billion).
- Between 1993 and 2003, EPA added an average of 28 sites annually to the NPL.
- If 28 sites per year are added to the NPL for the next 10 years, the additional cost would be $13 billion. (The range of estimates is 23-49 sites annually for 10 years at an estimated cost of $8–27 billion).
- EPA is working with an advisory council to address the future direction of the program. These deliberations may impact how Superfund's budget is allocated among the various projects.
- The need to balance the interests of diverse stakeholders and consider redevelopment issues may influence the sequence of work, technologies selected, and NPL listings.
- About 83% percent of NPL sites require remediation of groundwater, 78% of soil, 32% of sediments, and 11% of sludge.
- VOCs are to be remediated at 78% of NPL sites, followed by metals (77%) and SVOCs (71%). More than half the sites have all three.

3.1.1 The National Contingency Plan

The procedures for implementing CERCLA are spelled out in the National Oil and Hazardous Substances Pollution Contingency Plan, commonly referred to as the National Contingency Plan (NCP). The NCP outlines the steps that EPA and other federal agencies must follow in responding to releases of hazardous substances or oil into the environment. Among other things, the NCP addresses selecting remedies that protect human health and the environment, maintaining protection over time, and minimizing untreated waste. With regard to treatment technologies, the NCP specifies several treatment expectations, including the following:

- Principal threats are to be treated wherever practical;
- Combination of treatment with containment, as necessary; and
- Consideration of innovative treatment technologies to the maximum extent practicable.

3.1.2 The Superfund Process

The site characterization and cleanup process established by the NCP begins with the discovery of a potential hazardous waste site, and includes the following general steps:

1) A "preliminary assessment" (PA) is conducted to determine the existence of potential threats to human health or the environment that require a "removal action" or further study. If the PA indicates an emergency requiring immediate or short-term action to reduce the risk to the public, a removal action is conducted to stabilize or clean up the site.

2) If a hazard is identified or remains after a removal action is performed, a "site inspection" (SI) is conducted to determine whether a site warrants scoring under the Hazard Ranking System (HRS). EPA uses the HRS to score sites on the basis of their potential effects on human health and the environment and to determine a site's eligibility for the National Priorities List (NPL), EPA's list of sites with the worst contamination problems. Sites that score above a threshold may be considered for proposal for the NPL. Inclusion on the NPL authorizes EPA to respond to the site by either pursuing enforcement against responsible parties or paying for a response using the Superfund funds.

3) When a site is added to the NPL, an in-depth planning and investigation phase begins, during which the nature and extent of contamination and site risks are determined, and treatment alternatives are evaluated. This phase is known as the "remedial investigation/feasibility study" (RI/FS). EPA requires the results of the RI/FS, including the rationale for selecting a remedy, to be presented to the public, and documented in a "Record of Decision" (ROD). Some sites require a series of RI/FSs and RODs to address different "operable units (OUs)," which are portions of a site reflecting pathways of exposure (*e.g.*, soil, water) that require separate cleanup actions.

   RODs provide useful information for technology vendors interested in gaining access to the hazardous waste cleanup market. First, RODs specify the technology type determined to be the appropriate remedy for a site. Second, technology vendors can use RODs to determine why EPA selected or rejected a specific remedy. EPA must consider nine criteria for remedy selection: overall protectiveness; compliance with other environmental laws and regulations; long-term effectiveness and permanence; short-term effectiveness; implementability; cost; reduction of toxicity, mobility, or volume of wastes; state acceptance; and community acceptance.

4) Following the ROD, detailed engineering specifications for the selected cleanup approach are developed. This phase is called "remedial design" (RD). The designs are used to solicit competitive bids to perform the "remedial action" (RA). In the RA phase, waste is actually treated, disposed, or contained. If necessary, "operation and maintenance" (O&M) begins at the conclusion of the RA. This phase can include such actions as groundwater monitoring and periodic site inspections to ensure continued effectiveness of remedies. The final step in the process is to delete the site from the NPL. This step is initiated when all necessary cleanup responses under CERCLA are completed.

At any point in this process, an emergency requiring a removal action can occur at a site. In addition, community involvement activities take place throughout the process to ensure that all interested parties participate in the decision-making process. Enforcement actions that compel those responsible for the contamination to clean up the site also occur throughout the cleanup process to ensure optimal use of Superfund resources.

As part of its responsibility for implementing the Superfund program, EPA is responsible for determining the best way to clean up each site. Other federal agencies such as the Department of Defense (DOD) and Department of Energy (DOE) are responsible for cleaning up NPL sites at their facilities in accordance with the requirements of the NCP and with EPA concurrence. Under the Superfund program, states also may take the lead to determine remedial alternatives and contract for the design and remediation of a site.

3.1.3 Program Status

Since its beginning in 1980, efforts under Superfund have included the identification and ranking of sites, detailed site investigation, mitigation of immediate threats, and selection and implementation of remedies to clean up the worst sites (those listed on the NPL). Over the life of the program, the number of sites that have progressed from study and evaluation to actual cleanup has grown. As of September 2003, EPA had listed 1,518 sites on the NPL and proposed another 54. Of these, 274 sites were deleted from the NPL, or referred for response to another authority, leaving a total of 1,244 final NPL sites. In addition, EPA had conducted over 7,000 removal actions at over 5,000 sites, over 80 percent of which are not NPL sites.

By September 30, 2003, remedial construction activity was complete at 886 sites and 375 remedial construction projects were underway at NPL sites (U.S. EPA 2004c). Another 230 sites were in the RD phase and the remainder were in various stages of site investigation or remedy selection. As additional sites are studied and ranked, they may be added to the NPL.

3.2 Factors Affecting Demand for Cleanup

Many technical, economic, public policy, and legal factors have combined to determine the number of sites currently included in the Superfund program, the cleanup standards and technologies to be used, and cleanup work schedule. Some factors that could influence the scope of the cleanup effort, as well as the technologies to be used in the future, are described below.

- The number of sites added to the NPL, which is difficult to forecast. Listing a site is ultimately a decision made by the Assistant Administrator of OSWER, typically, after consulting with state and EPA regional officials, potentially responsible parties (PRPs), local government, and the governor. Earlier in the program, new additions to the NPL fluctuated substantially from zero to over 400 in a single year. However between 1993 and 2003, the range has been much narrower (13 to 43) and averaged 28 per year. A 2001 study by an environmental research group predicted that it would range between 23 and 49 per year over the next decade, with a middle value of 35 (Probst & Konisky 2001). The average for the three years since that study has been 23. Listing rates of this magnitude are not inconsistent with the potential supply of "NPL-caliber" sites. Section 3.3 (Number of Sites) describes listing rate scenarios. If more "NPL-eligible" sites are found, they may be addressed through other programs, such as RCRA Corrective Action or a state program, or may continue to await evaluation and/or cleanup. Because the decision on whether to list a site is complex, depending on many variables and input from many stakeholders, there is some uncertainty inherent in any such prediction.

- Although the Superfund Trust Fund now accounts for a small portion of revenues, the Superfund operating budget has been relatively stable. Budget authority is $1.31 billion, $1.27 billion, and $1.39 billion (requested) for FY 2002, 2003, and 2004 (requested), respectively.

- State and PRP funding for Superfund site cleanups may fluctuate in the future. Many states are facing serious budget shortfalls in 2003 and 2004. For Superfund remedial actions, the states contribute 50 percent of the construction costs where they own the site and all operations and maintenance (O&M) costs for fund-financed sites in their state. For fund-financed remedies that involve long-term treatment or other measures to restore groundwater or surface water quality, CERCLA requires that states assume the costs after 10-years. The management of many of these sites are now being transferred to states. To improve O&M performance and ease the potential cost burden of these projects, EPA has been conducting studies on pump-and-treat systems to develop recommended optimization practices prior to takeover (U.S. EPA 2001).

  PRP contributions to site remediation may be affected by business conditions and EPA's enforcement program activities. State staffing and budgets for both Superfund and non-Superfund hazardous waste sites programs have been at about the same level in nominal dollars for at least seven years (See Chapter 9, State and Private Party Sites).

- Current resources appropriated to the program may be insufficient to fully implement the program. According to a 2001 Resources for the Future study, Superfund faces an average annual budget shortfall of approximately $100-200 million over a 10-year period (Probst & Konisky 2001). To address this and other long-term Superfund issues, EPA is working with the National Advisory Council for Environmental Policy and Technology (NACEPT) to help guide the future direction of the Superfund Program. While the work of this group cannot yet be quantified in terms of a market projection, it would be helpful for remediation service providers to keep abreast of developments in this area (U.S. EPA 2004c).

- In planning and implementing its cleanups, EPA coordinates extensively with its regions, potentially responsible parties (PRPs), state and local governments, planning authorities, local communities, and developers to ensure that the remedies protect public health and the environment and are consistent with the anticipated future use of the site. Balancing the considerations of these stakeholders may influence the sequence of work, types of technologies selected for a site, and the number of sites to be listed on the NPL in the future.

3.3 Number of Sites

The market for cleanup at NPL sites includes sites where remedial action (RA) is planned but has not yet begun. Remedial action is the phase of cleanup that typically involves construction, and in some cases operation, of the remediation technology. As of May 30, 2003, 456 proposed and final NPL sites not owned by the federal government and 177 NPL sites located at federal facilities still required at least one further remedial action (U.S. EPA 2003a). Federal facilities on the NPL are addressed in Chapters 6, 7, and 8. Exhibit 3-1 presents the geographical distribution of the 456 NPL sites for which future RAs are planned among states and EPA regions. The data reflect the industrialized nature of these regions which have many abandoned industrial facilities. New Jersey, Pennsylvania, New York, California, Texas and Florida alone account for approximately 45 percent of these NPL sites.

For some of the 456 sites EPA has identified more than one operable unit (OU) or part of the site for which an RA is planned. The total number of OUs with planned RAs is 1,073. There may be more than one remediation or site investigation technology employed at a given OU. Forty-eight percent of these OUs are undergoing remedial investigations and feasibility studies (RI/FSs), and

Exhibit 3-1. Location of NPL Sites With Planned Remedial Actions by State and EPA Region

Notes: Includes 456 proposed and final National Priority List (NPL) sites not owned by the federal government.
Source: U.S. EPA, Office of Emergency and Remedial Response, CERCLIS, June 2003

still awaiting the selection of remedial technologies (Exhibit 3-2). For 52 percent, remedies have been selected, but not implemented (*i.e.,* RA has not begun). Although the specific technologies selected are not included in this report, Chapter 2 enumerates the treatment technologies previously selected at NPL sites and provides references for additional site-specific information.

Exhibit 3-2. Phase of Remediation of Operable Units at Non-Federal NPL Sites with Planned Remedial Actions

Remedial Assessment Not Begun	Study Under Way	Remedy Selected	Design Under Way	Total Operable Units
174 (16%)	346 (32%)	70 (7%)	483 (45%)	1,073 (100%)

Note: Total sites equals 456; each site may contain more than one operable unit. There may be more than one remediation or site investigation technology employed at a given OU.

Source: Office of Emergency and Remedial Response, CERCLA Information System, June 2003.

Cleanup contractors for EPA-lead sites typically are selected after the remedial design (RD) has been completed. For PRP-lead sites, some PRPs may select a vendor to conduct both the RD and RA. Historically, PRPs have conducted RDs and RAs at about 70 percent of Superfund sites.

This report does not estimate the smaller market for remediation technologies in the Superfund removal program. As of the end of FY 2003, EPA had conducted over 7,000 removal actions at over 5,000 sites, over 80 percent of which are not currently NPL sites. It is difficult, to predict the number, type, and timing of the cleanup of these sites. Removals are usually limited to one year and $2 million, and historically have relied little on innovative technologies.

Future NPL Sites

The above estimate of the number of NPL sites to be remediated does not include future listings on the NPL, which also represents a market for remediation technologies. The number of sites that eventually will be listed is uncertain and may depend upon several factors which are difficult to predict. Most regions and states do not have a proactive site discovery process aimed at developing a complete inventory, which would provide information for such predictions. From time to time, there are "pop-up" sites that are a surprise. The estimate of future listings is based on recent listing trends. In addition, an examination of the potential supply of hazardous waste sites was conducted to ensure that the projected listing rate is feasible.

Between 1993 and 2003, EPA listed 305 sites, or an average of 28 per year. This report assumes that listings will average 28 sites per year from 2004 to 2013, totaling 280 additional sites by 2013. If more "NPL-eligible" sites are found and evaluated, they may be addressed by other programs, such as RCRA Corrective Action or a state program, or may continue to await evaluation and/or cleanup. Because the decision on whether to list a site is complex, depending on many variables and input from many stakeholders, there is some uncertainty inherent in any such prediction. Although EPA may continue to add sites to the NPL beyond 2013, longer-term scenarios are not included in this analysis because of uncertainties in making these predictions.

The 28-site per year estimate is within a range of estimates developed by a private environmental research group in 2001 (Probst & Konisky 2001). Based on interviews with EPA regions and nine states and an analysis of listing trends, this study predicted that new listings would range from 23 to 49 annually over a decade, with a most probable value of 35. In the three years since that study listings have averaged 23.

Based on information from two GAO reports (U.S. GAO 1998 and 1999) there appears to be a sufficient supply of Superfund-eligible and potentially-eligible sites in EPA's CERCLIS database to supply the assumed number of sites for listing. GAO identified 1,800 sites that have a Hazardous Ranking System (HRS) score of at least 28.5, which makes them eligible for consideration for listing. GAO also estimated that another 3,800 sites in CERCLIS are in earlier stages of the Superfund pipeline. Evaluations of the later sites have not progressed to the point where their NPL eligibility could be determined. Estimates of state and federal program managers have varied widely regarding the percentage of these sites that will ultimately be listed. Thus, we can only conclude that some portion of the 5,600 (1,800 + 3,800) sites awaiting a listing decision will eventually be listed on the NPL. In addition, from time to time, new site discoveries lead to new proposed listings. Thus the potential supply is not inconsistent with the 280-site assumption.

The characteristics of NPL sites vary with the basis for listing and when the listing occurs. The three basic mechanisms for adding sites to the NPL are the following:

- Each state may nominate a total of one site without regard to its Hazard Ranking System (HRS) score;
- The Agency may propose listing sites recommended by the Agency for Toxic Substances and Disease Registry; and
- A site may be evaluated with the HRS, and if the score is above 28.5, that score could be used to support adding that site to the NPL.

This third mechanism is the primary one used to add sites. In the earlier years of the program, sites listed on the NPL were ranked under the original HRS, which emphasized exposure to contaminated groundwater. The revised HRS also considers soil and sediment exposure and additional pathways (U.S. EPA 1990).

3.4 Site Characteristics

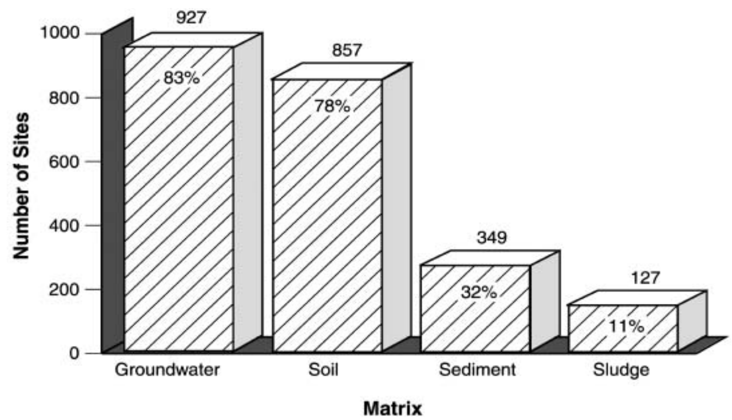
This section describes how frequently certain waste matrices and contaminants are being remediated at NPL sites. This information can be used to provide insight on the potential for the applications of certain remedial technologies at NPL sites where RAs are planned. Technologies that tend to be used at NPL sites are discussed in Chapter 2.

The analysis is based on a study of sites with signed RODs. As of May 2003, data on contaminants and contaminated matrices were available for 1,105 sites (U.S. EPA 2003a). Data are not available for another approximately 50 sites with RODs, many of which had "No Action" RODs which do not call for remediation. Because these 1,105 sites represent 79 percent of the 1,395 non-federally owned sites ever listed or proposed for listing on the NPL as of May 2003, EPA believes that their characteristics are likely to be representative of those of other NPL sites.

3.4.1 Types of Contaminated Matrices

Exhibit 3-3 shows the percentage of NPL sites remediated for various contaminated matrices: 83 percent of sites require remediation of groundwater, 78 percent of soil, 32 percent of sediments, and 11 percent of sludge. Because too few RODs contain data on other types of wastes, such as waste piles and mine tailings, a meaningful analysis for those types of wastes could not be done.

Exhibit 3-3. Frequencies of Contaminated Matrices at NPL Sites With RODs



Notes: Based on data available for 1,105 National Priorities List sites with fiscal year 1982-2003 Records of Decision (RODs). A site may contain more than one contaminated matrix.

Source: U.S. EPA, Office of Emergency and Remedial Response, CERCLIS, June 2003.

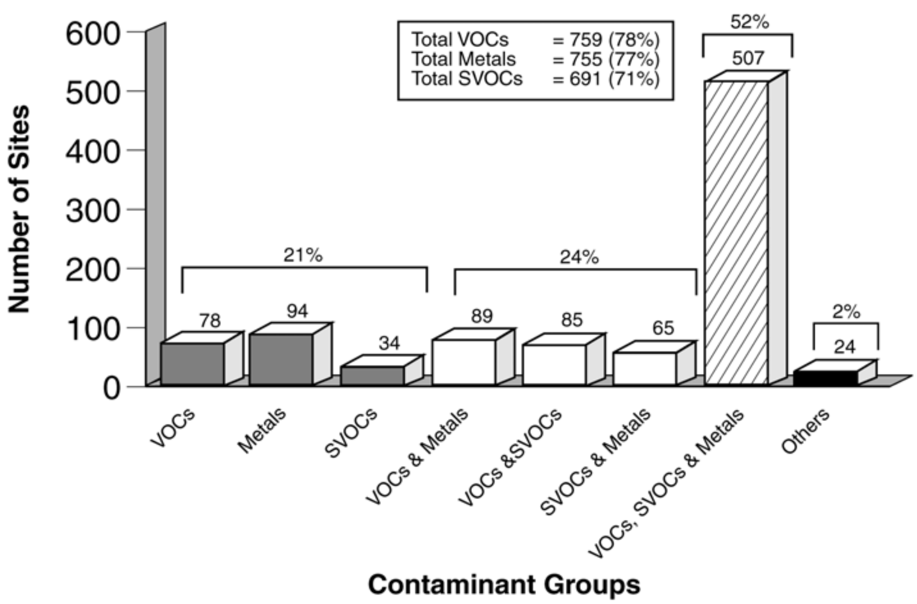
3.4.2 Types of Contaminants

Sites with RODs were analyzed for the presence of three major contaminant groups: volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), and metals. These broad groups of contaminants were further divided into more specific treatability subgroups that better coincide with the application of certain technologies, such as bioremediation. The 12 most frequently occurring contaminants also are identified. Appendix A, Exhibit A-1 lists common chemicals in each group. Chemicals and elements are grouped in accordance with EPA test methods for evaluating solid waste and standard chemical references, which are also identified in the exhibit.

Major Contaminant Groups

Exhibit 3-4 presents the frequency of cleanup of the major contaminant groups. VOCs, alone or in combination with other contaminant groups, are to be remediated at 78 percent of sites, followed by metals (77 percent) and SVOCs (71 percent). For this analysis the occurrence of a contaminant group at a site is counted only once, whether or not it was found in more than one matrix. These data also indicate that the NPL sites tend to be complex: all three groups (VOCs, SVOCs, and metals) are to be remediated at 52 percent of the sites and two groups are to be remediated at 24 percent of the sites, but not necessarily in the same matrix. The sites listed as "others" only contain contaminants described as radioactive elements, non-metallic inorganics such as nitric oxides, explosives and asbestos, or unspecified organics or inorganics.

Exhibit 3-4. Frequencies of Major Contaminant Groups at NPL Sites With RODs



Notes: Based on data available for 976 National Priorities List sites with fiscal year 1982-2003 Records of Decision (RODs). Percentages do not total to 100 due to rounding

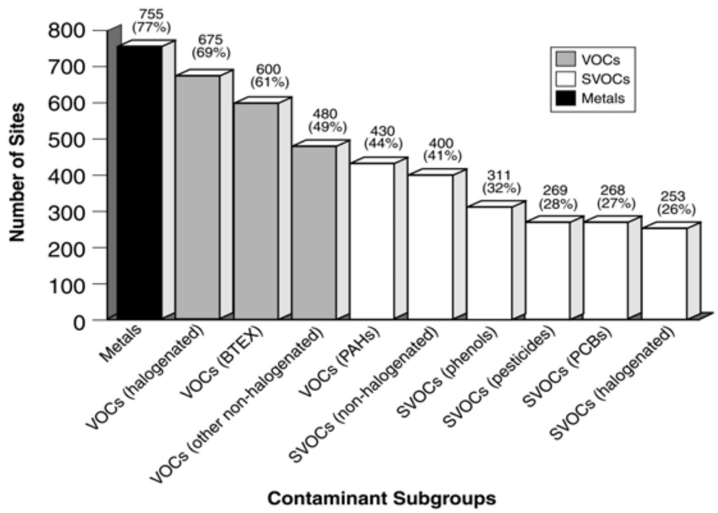
The 24 sites listed as "others" contain only radioactive elements, non-metallic inorganics, or unspecified organics or inorganics.

Source: U.S. EPA, Office of Emergency and Remadial Response, CERCLIS, June 2003.

Subgroups of Volatile and Semivolatile Organics

Two of the major contaminant groups, VOCs and SVOCs, were subdivided into more specific treatability subgroups that better coincide with the application of certain technologies, such as bioremediation. Exhibit 3-5 shows the frequency of cleanup of these subgroups as well as the metals group. The subgroups are described below, grouped according to the three major contaminant groups:

Exhibit 3-5. Frequencies of Major Contaminant Subgroups at NPL Sites With RODs



Notes: Based on data available for 976 National Priorities List Sites with fiscal year 1982-2003 Records of Decision (RODs). Contaminant information for 24 of the sites with data does not fall into these subgroups. A site may contain one or more of the 10 contaminant groups.

Source: U.S. EPA, Office of Emergency and Remedial Response, CERCLIS, June 2003.

- VOCs include: halogenated, BTEX (benzene, toluene, ethylbenzene, xylene), and other non-halogenated VOCs (ketones and alcohols). The most prevalent class of organics, halogenated VOCs, which are widely used as solvents, are being remediated at 675 (69 percent) of the sites. With regard to BTEX, although many of these compounds result from petroleum products, CERCLA prohibits listing sites on the NPL that are contaminated with petroleum products alone.

- SVOCs include: polychlorinated biphenyls (PCBs), polynuclear aromatic hydrocarbons (PAHs), pesticides, phenols (including pentachlorophenol), and other SVOCs, which include chlorobenzene and phthalates. The most common SVOCs are PAHs and phenols, to be addressed at 49 percent and 32 percent of sites, respectively.

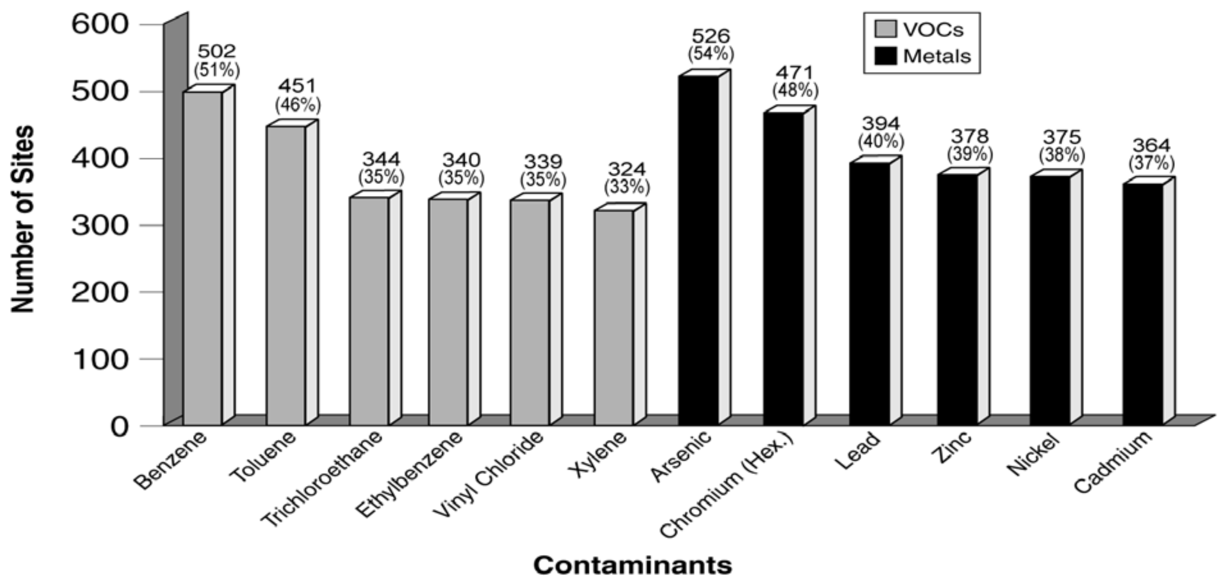
- Metals include: lead, arsenic, chromium, cadmium, zinc, nickel, and other less frequently found metals.

For this analysis, each subgroup was counted only once per site, regardless of whether it occurred alone, with other types of contaminants, or in more than one matrix. Because more than one contaminant subgroup can be present at a site, the total number of occurrences is greater than the total number of sites.

Most Common Individual Contaminants

Exhibit 3-6 shows the 12 contaminants most commonly found to need remediation at NPL sites. The list contains six VOCs and six metals. Again, a contaminant is only counted once for each site, even if it occurs in more than one matrix; and more than one contaminant can occur per site.

Exhibit 3-6. Frequencies of the Most Common Contaminants at NPL Sites With RODs



Notes: Based on data available for 976 National Priorities List Sites with fiscal year 1982-2003 Records of Decision (RODs). A site may contain one or more of these contaminants.

Source: U.S. EPA, Office of Emergency and Remedial Response, CERCLIS, June 2003.

3.4.3 Estimated Quantities of Contaminated Material

The market also can be described in terms of the quantity of contaminated material to be remediated. Fewer RODs contain quantity data than the number that contain contaminant and matrix information. The RODs for 42 percent of the 1,105 sites with RODs contain information on the quantities of soil, sludge, or sediment to be remediated using any method (*i.e.*, treatment, containment, or off-site disposal). The data from these sites are used to characterize the quantities of material requiring some type of remediation.

Distribution of Quantities

Exhibit 3-7 presents the distribution of the total quantities per site of contaminated soil, sediment, and sludge requiring remediation. Based on these estimates, almost 44 percent of the sites are expected to contain 10,000 or fewer cubic yards, and less than 17 percent of the sites are expected to contain 100,000 or more cubic yards of contaminated material. These data indicate an appreciable market for technologies that can effectively treat small quantities of contaminated media, as well as a number of sites with larger quantities. These data include all available data on material to be treated, contained, or disposed. However, because reviews of

RODs indicate that quantities of waste to be capped often are not documented in the ROD, the proportion of sites that contain large quantities of wastes may be greater than the data indicate. The quantity distributions for soil, sediment, and sludge shown in Exhibit 3-7 involve primarily contaminated soil to be remediated.

Exhibit 3-7. Distribution of Quantities of Contaminated Soil, Sediment, and Sludge at NPL Sites With RODs

Estimated Quantities (Cubic Yards)	Number of NPL Sites With Data By Matrix							
	Soil		Sediment		Sludge		Total	
	Federal Facilities	Non-fed. Facilities	Federal Facilities	Non-fed. Facilities	Federal Facilities	Non-fed. Facilities	Federal Fac.	Non-fed. Fac.
< 1,000	10	44	2	29	1	9	13	82
1,000 - 5,000	10	82	2	28	0	11	12	121
5,001 - 10,000	7	57	0	16	0	5	7	78
10,001 - 30, 000	9	95	3	14	1	14	13	123
30,001 - 50,000	10	52	2	10	1	11	13	73
50,001 - 100,000	6	39	2	9	0	12	8	60
> 100,000	14	75	2	16	2	10	18	101
Total	66	444	13	122	5	72	84	638

Note: Data are from 714 NPL sites.

Source: U.S. EPA, Office of Emergency and Remedial Response, CERCLA Information System, June, 2003.

Quantities by Major Contaminant Group

The quantities of contaminated material (soil, sediment, and sludge) at the 456 non-federal NPL sites with planned RAs were estimated for the three major contaminant groups (*i.e.*, VOCs, SVOCs, and metals) from estimates contained in the RODs for sites with similar contaminants. The average quantity for each contaminant group at the sites with ROD data was multiplied by the estimated number of sites that contain the same contaminant groups based on the percentages in Exhibit 3-4.

Exhibit 3-8 indicates the estimated quantities of contaminated materials at NPL sites by contaminant group. An estimated 74 million cubic yards of soil, sludge, and sediment are to be remediated at the sites. Much of this material, 66 million cubic yards, is accounted for by materials contaminated by metals alone, and in combination with other contaminants. VOCs, alone and combined with other contaminants, total 38 million cubic yards; and SVOCs total 60 million cubic yards.

In developing these estimates, it was assumed that all of the contaminated material at a site contained the contaminant groups present. The average site quantities by contaminant group varied from a low of 45,000 cubic yards for a single group (other) to a high of 682,000 cubic yards for SVOCs and metals.

Exhibit 3-8. Estimated Quantity of Contaminated Soil, Sediment, and Sludge for Major Contaminant Groups at NPL Sites With Planned Remedial Actions

Contaminant Group	No. of Sites With Data	Average Based on Available Data (Cu. Yds.)	Number of Sites With Planned Remedial Action [a]	Projected Total Quantity (Cu. Yds.) [b]
Single Contaminant Group				
Metals	46	230,920	46	10,622,320
VOCs	9	53,267	36	1,917,612
SVOCs	24	247,116	14	3,459,624
Others	5	45,556	9	410,004
Multiple Contaminant Groups				
VOCs & Metals	27	46,450	41	1,904,450
SVOCs & Metals	40	681,618	32	21,811,776
VOCs & SVOCs	46	53,527	41	2,194,607
VOCs, SVOCs & Metals	255	135,683	237	32,156,871
Totals	452	1,494,137	456	74,477,264

Notes:
a Based on the distribution of contaminant groups among the 976 sites with contaminant data shown in Exhibit 3-4. Each site is placed in one subgroup only.
b The total for each subgroup is calculated by multiplying columns (3) and (4).

Source: U.S. RODs, fiscal years 1982-2003. Site-specific data are not available for all quantities of material to be remediated at all sites with planned remedial actions.

3.5 Estimated Cleanup Costs

EPA has estimated the value of the market for the 456 non-federal facility NPL sites with planned RAs. The estimated cost for non-federal already listed Superfund sites that have not begun RA is $15.5-23.3 billion in 2003 dollars. This estimate is based on an average cost per OU of $14.7 million ($1.4 million for RI/FS + $1.4 million for RD + $11.9 million for RA), and $10.3 million for long-term remedial action (LTRA) for sites that require long-term treatment to restore groundwater and surface water (2003 dollars).[1] The range in values result from varying the RA costs by plus and minus 20 percent. The calculations are shown in Exhibit 3-9.

The unit cost estimates are applied to the 1,073 OUs that have not yet begun RA, as well as to the assumed 230-490 future NPL sites. It was assumed that 50 percent of sites with RD underway have already incurred the RD costs, 50 percent of sites with study underway already have incurred RI/FS costs, and 45 percent of all sites will require LTRA.

Exhibit 3-9. Estimated Cleanup Costs for NPL Sites [a]

	Low	Medium	High
Existing Pre-RA Sites (In the Relevant Market) [b]			
No. of Sites	456	456	456
No. of OUs	1,073	1,073	1,073
Total Cost	$15,516 mil	$19,395 mil	$23,274 mil
Assumed New NPL Listings 2004 - 2013 [a]			
No. of Sites Per Year	23 [c]	28 [d]	49 [e]
Total over 10 years	230	280	490
Number of OUs	541	658	1,152
Total Cost	$8,363 mil	$12,726 mil	$26,725 mil
Total NPL [a, b]			
Current & Future NPL Sites	$23,879 mil	$32,121 mil	$50,000 mil

Notes:
Low Cost of RI/FS+RD+RA = $11.6 million per OU (from text above) and 230 additional sites to the NPL.
Medium Cost of RI/FS+RD+RA= $14.7 million per OU (from text above) and 280 additional sites to the NPL.
High Cost of RI/FS+RD+RA= $17.6 million per OU (from text above) and 490 additional sites to the NPL.
NA Not applicable
LCC Life Cycle Cost, or cost to complete

a For purposes of this analysis, it is assumed that listings cease after 10 years, although cleanup work is likely to continue many years beyond. Although new sites may be added to the NPL beyond 10 years, they are not included because of uncertainties in predicting NPL listings.
b Does not include costs for sites that have begun RA.
c Low case in the Resources for the Future study, derived from the average for 1996-1999 (Probst & Konisky, 2001)
d Average of 1993-2003 actual additions to the NPL
e High case in the Resources for the Future study (Probst & Konisky 2001)

1 These 2003 figures are adjusted from 1999 dollars reported in the 2001 Resources for the Future study ($1.3 million each for RI/FS and RD, 11.0 million for RD) ± 20% (Probst & Konisky, 2001). The average LTRA cost per OU was reported in a 2001 EPA study using data from 79 LTRA projects as $10.0 million and adjusted to 2003 dollars (U.S. EPA 2001). Price adjustments are based on the gross domestic product (GDP) price deflator.

This estimate does not include (a) costs for federal facility NPL sites, which are described in Chapters 6 through 8, (b) the cost of continuing work at NPL sites that have already begun remedial action, and (c) costs for site assessments, removals, administrative costs such as payrolls, other federal agency support, oversight of potentially responsible party (PRP)-lead cleanups, and enforcement activities. This estimate is more than twice that of a similar estimate in the 1997 edition of this report. The difference is explained by an 18 percent increase in the general price level, the fact that the remaining sites on the NPL that have not begun RA are expected to be more complex and have more OUs than the average for previous NPL sites, and the fact that LTRA costs were not included in the previous report.

Using the same unit cost estimates per OU, and assuming 23-49 sites will be listed annually, the 230-490 sites assumed to be listed over the next 10 years will cost $8.7-26.7 billion (at the assumed most-likely value of 28 sites annually for 10 years, the cost would be $12.7 billion). If more or fewer sites are listed, this total would be adjusted accordingly. This estimate is based upon the above assumptions plus the expectation that future sites will be more complex, larger, and have more OUs per site than the average NPL site in the past.

Another indication of the amount of cleanup effort likely to be undertaken is the size of the EPA Superfund budget. During the mid-1990s, Congress allocated $1.4 billion annually. By 2002, budget authority had dropped to $1.27 billion (excluding a post-911 appropriation), and by 2003, it was $1.24 billion. For 2004, EPA has requested $1.39 billion. The EPA budget does not include costs incurred by PRPs, states, or other federal agencies. Although the Superfund budget has been relatively stable in nominal dollars, it has declined about 15 percent between 2000 and 2003 in real (adjusted for inflation) dollars.

Although it is useful to examine the trends in the Superfund budget, these figures do not coincide with total national expenditures for site work. Since the EPA budget does not include costs incurred by PRPs, states, or other parties, the budget data do not compare with the above market value estimates. The market estimates include both cleanup costs incurred by PRPs and other parties and direct costs paid by EPA for sites for which there is no available responsible party. The amount paid by responsible parties compared to EPA varies from project to project and is difficult to forecast.

In addition to site work at Fund-paid sites, EPA's Superfund budget also pays for activities that are not for direct site work, such as administration and management, cost recoveries, enforcement, removals and other short-term actions, oversight of PRP activities, and research and development. About 25-35 percent of the EPA Superfund budget typically goes to long-term site remediation activities. Thus, the above market value estimates were not developed to be used for budget analysis or planning.

3.6 Market Entry Considerations

Technology decisions for Superfund sites are based on the specific information available for each site and the state-of-the-art of the available technologies. Information on new technologies is particularly critical at two points in the decision-making process: during remedy selection, and during remedy design and procurement. This section describes how technology vendors can benefit from understanding how site managers consider their options during these two cleanup phases.[2]

3.6.1 Market Considerations During Remedy Selection

The Superfund RI/FS process is an integrated, phased approach to characterizing the site risks and evaluating remedial alternatives. Early in the RI/FS stage, technologies are identified and screened with respect to technical implementability, effectiveness, and relative cost. To ensure that Superfund site managers and consulting engineers consider a given technology, it is important to make them aware of the technology at this early stage. During the final technology evaluation, later in the RI/FS, technologies are compared and evaluated using the nine evaluation criteria specified in the National Contingency Plan (NCP). Information on technology performance and cost is particularly important during this final evaluation. EPA and engineering consulting firms (who usually conduct the RI/FSs for EPA, states, and PRPs) use a variety of information sources, many of which are described in Section 2.3, to identify potential technologies and to make their capabilities more widely known. Since information for innovative technologies may be limited, treatability studies or on-site demonstrations may be used to assess cost and performance.

While Superfund policies encourage the selection and implementation of new technologies, the Superfund remedy selection process can present some hurdles for innovative technology vendors because:

- Information on innovative technologies is often limited. Superfund site managers and consulting engineers may not have as much information on the performance and cost of an innovative technology as for an established technology. Reports and databases about established remedial technologies have already been developed. Superfund site managers may have difficulty comparing the merits of an innovative to a conventional technology if they do not have information on a technology's cost, implementability, short- and long-term effectiveness, and ability to reduce the toxicity, volume, or mobility of the contaminants.

- Treatability studies and on-site demonstrations may be impractical. The NCP and EPA policy encourage the use of bench- or pilot-scale treatability studies, when appropriate and practical (EPA, 1990). EPA policy stipulates that: *promising new technologies should not be eliminated from consideration solely because of uncertainties in their performance and cost, particularly when timely treatability study could resolve those uncertainties* (U.S. EPA 1996a). In reality, the funding and schedule for site cleanup, as well as contracting and regulatory impediments, may preclude the use of studies and demonstrations.

- The RI/FS contractor may be prohibited from bidding on the RA. For example, at EPA-lead and state-lead sites, the remedial design contractor at a site usually does not conduct the remedial action. A technology vendor that has the capability to provide both RI/FS and

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[2] A useful source for tools to help technology vendors advance and implement their technologies is the Vendor Support web site maintained by OSRTI, http://clu-in.org/vendor/.

RD/RA services should determine the relative value of the two opportunities before deciding which service to provide.

To make their capabilities more widely known, technology vendors may consider participating in the programs cited in Section 2.3, and contacting remedial project managers (RPMs) and consulting engineers. A vendor who is interested in a particular NPL site, may contact the assigned EPA RPM for more information. The appropriate EPA regional office or web site, listed in Appendix A, can provide the identity of the RPM for a specific site. Also, information on specific technologies may be provided to consulting engineers for their consideration in the analysis of cleanup options. Appendix A also includes a list of current regional service contracts (RACs).

3.6.2 Market Considerations During Design and Procurement

Once a remedy has been selected and documented in a ROD, the project enters the design process, where the details of the cleanup, such as waste quantities and performance standards, are more clearly defined. At this stage, federal and state agencies can make use of technology information for preparing requests for proposals and evaluating bids.

All Superfund sites requiring cleanup for which EPA has the lead currently are funded by one of the following mechanisms:

- Remedial Action Contracts (RACs): The RACs provide professional architect/engineering services to EPA to support response planning and oversight of CERCLA. These services include: program support (management); remedial investigation and feasibility studies; engineering services to design remedial actions; engineering evaluations and cost analyses for non-time-critical removal actions, including issuing and managing subcontracts for construction of the selected remedy, and engineering services for construction oversight. RAC services also include enforcement support, such as negotiation support, and oversight of RI/FS studies, remedial designs, and remedial actions; and other technical assistance, including community relations, sampling and analysis, and pre-design investigations. Services may also include technical and management services supporting EPA's coordination and/or oversight of remedial activities performed by a State, the U.S. Army Corps of Engineers, or responsible parties.

- Emergency and Rapid Response Services (ERRS) Contracts: The ERRS contracts provide emergency, time-critical removal, and quick remedial response cleanup services for the CERCLA, Oil Pollution Act (OPA), and Underground Storage Tank (UST) programs. They provide cleanup personnel, equipment, and materials to contain, recover, or dispose of hazardous substances, analyze samples, and restore sites. Because of the broad range of cleanup services needed and the rapid time frame within which the contractors must respond, it is likely that the contractors will do substantial subcontracting.

- Interagency Agreements (IAGs): EPA enters into agreements with the U.S. Army Corps of Engineers, Bureau of Reclamation, or other federal agencies.

- Cooperative Agreements (CAs): EPA enters into agreements with states, political subdivisions, or Native American Tribes. The state performs work with its own resources, or by contracting for needed goods and services with private firms.

As previously stated, a list of regional service contracts is included in Appendix A, Exhibit A-2.

The most definitive sources of information on selected remedies for sites entering RD and RA are the RODs, *Treatment Technologies For Site Cleanup: Annual Status Report (Eleventh Edition)* (U.S. EPA 2004a), and the *Annual Status Report Remediation Database* (U.S. EPA 2004b). The RODs provide detailed information on the site contaminants and risks posed, the selected remedy, estimated costs, and associated cleanup levels. ROD information is also available on the EPA web site (http://www.epa.gov/superfund/sites/rods/index.htm). A copy of the ROD and other site background documents can also be obtained by contacting the Regional Community Involvement Coordinator (CIC) for the site and by visiting the site information repository. The location of the site information repository may be obtained from the EPA web site or the CIC. The Superfund Public Information System (SPIS), available on CD ROM, also contains ROD documents and abstracts as well as CERCLIS and Archive data. The SPIS is available on CD-ROM from the National Technical Information Services (NTIS), (telephone 1-800-553-6847) or from their web site at order@NTIS.gov. Their product number is SUB-5462.

For information on innovative treatment and selected established technologies, the *Annual Status Report Remediation Database* (U.S. EPA 2004b) provides the most current summary information on the contaminants and media to be remediated, anticipated or actual cleanup schedules, and expected site lead (EPA, state, PRP).

A vendor may use these publications to identify opportunities or assess remediation service or technology needs. Vendors also may provide cost, performance, and availability information to the EPA RPM or state site manager and the site remedial design firm or agency. Vendors can enhance their responsiveness to requests for proposals (RFPs) for site remedial actions by keeping abreast of site activities. Once an RFP has been issued, the award of a contract may take weeks or months.

3.6.3 Research, Development, and Demonstration

Technology vendors, property owners, A/E firms, site managers, and other stakeholders may benefit from new applications that are currently in various stages of research, development, testing an evaluation. Likewise, some vendors or technology developers may need help to disseminate information about their technologies and services. Section 2.3 describes the major programs that conduct or support RD&D, as well as sources to help vendors publicize to all stakeholders the capabilities of their technologies.

3.7 References

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Chapter 4
Demand for Remediation of RCRA Corrective Action Sites

Prior to the passage of the Resource Conservation and Recovery Act (RCRA) (42 U.S.C. §§6901-6922k), facilities that treated, stored, or disposed of hazardous waste, and occasionally waste generators and transporters (collectively known as waste handlers) often experienced releases of waste into the environment. Much of that waste, which is similar to the hazardous waste found at Superfund sites, was disposed of intentionally or unintentionally on the land. A number of RCRA sites have remediation needs that equal or exceed those of many Superfund sites. Although not all RCRA sites will require cleanup, this program represents a substantial market for environmental site characterization and cleanup services.

RCRA assigns the responsibility of corrective action to facility owners and operators and authorizes EPA to oversee corrective action. Unlike Superfund, oversight responsibility is delegated to authorized states. EPA estimates that the universe of RCRA hazardous waste handlers subject to corrective action exceeds 6,600 sites. EPA has discretionary or statutory authority to impose corrective action on these sites, when necessary. Of the 6,600 sites, about 3,800 are likely to require corrective action. These sites have had a preliminary evaluation by a regulatory authority and, based on these evaluations, are required to undergo further investigation and/or cleanup. EPA and the states are examining the extent of that contamination and the scope of corrective action needed at these sites.

> ***Highlights***
> - EPA and the states have identified 3,829 sites that are likely to require corrective action.
> - EPA and the states have identified 1,714 sites, known collectively as the RCRA Cleanup Baseline, that warrant early action to control current human exposures and migration of contaminated groundwater.
> - During the past five to ten years, refinements in site characterization methods have been resulting in reduced site-assessment costs, improved data quality, expanded applicability of less traditional remedies, and improved remedy design.
> - The pace of the cleanups is likely to be affected by fluctuations in state budgets. State staffing levels and budgets (in nominal dollars) for hazardous waste remediation and oversight has not increased in about a decade.
> - Land development trends are also likely to affect the pace and nature of RCRA cleanups, since property transfers or redevelopment generally require site assessments and, if necessary, remediation.
> - Based on limited samples of sites, over 80% of RCRA sites require remediation of groundwater, 60% of soil, 10% each of sludge and surface water, and 6% of sediments.
> - Based on limited samples of sites, VOCs are to be remediated at 60% of sites, followed by

Although RCRA requires that all sites in need of corrective action be cleaned up, EPA has set ambitious interim cleanup targets for 1,714 sites identified by EPA and the states as warranting early action. EPA and the authorized states selected these sites, known collectively as the RCRA Cleanup Baseline, because they pose potential unacceptable exposures of contaminants to humans and/or are likely to spread groundwater contamination. By 2005, 95 percent of these baseline sites will have controlled the potential for human exposure, and 70 percent of them will have controlled the migration of contaminated groundwater thereby decreasing the immediate health risks from these sites. Achieving these goals will enable the Agency to meet its interim goals for corrective action set under the Government Performance and Results Act (GPRA) of 1993. Nevertheless, in most cases, the interim goals are not the final remedy. While achieving final cleanups is not likely to occur as quickly as meeting the interim goals, the steps taken to attain interim goals are directing attention to cleanup at most baseline sites.

4.1 Program Description

RCRA has a long and complex regulatory history that has led to a performance-based approach to evaluating and cleaning up contaminated sites. To develop a practical understanding of this market, it is useful to understand this history, the general process that has evolved for managing RCRA sites, and how these steps are implemented by EPA and authorized states.

4.1.1 Regulatory History

RCRA mandates several regulatory programs, but the largest is the waste management program, known as Subtitle C. Subtitle C sets forth comprehensive national requirements for managing the treatment, storage, disposal, and recycling of solid and hazardous waste. Among other provisions, Subtitle C establishes a management system to control new hazardous waste from the time it is generated to its ultimate disposal ("cradle-to-grave"). In addition to its primary purpose of preventing releases of process waste into the environment by minimizing waste generation and by creating reuse and recycling incentives, Subtitle C contains important requirements that address releases of contaminants into the environment from RCRA sites. It is these requirements that influence the nature and amount of nationwide cleanup activities.

Releases of contamination at RCRA sites are addressed under the RCRA Corrective Action program, which is administered by EPA's Office of Solid Waste (OSW), EPA regional offices, and states that EPA has authorized to implement the program. Congress initially authorized EPA to promulgate requirements for monitoring and remediating only on-site releases to groundwater from hazardous waste management units, such as landfills. Later, with enactment of the 1984 Hazardous and Solid Waste Amendments (HSWA) of RCRA, Congress greatly expanded EPA's corrective action authority to include releases to all environmental media from regulated solid waste management units (SWMUs) at treatment, storage, and disposal facilities (TSDFs) seeking permits under Subtitle C. A solid waste management unit is a discernible unit in which solid waste has been placed at any time, irrespective of whether the unit was intended for the management of solid or hazardous waste. This definition includes any area of a facility at which solid waste has been routinely and systematically released. A release may include intentional or accidental spillage, leakage, pumping, pouring, emitting, emptying, discarding, injecting, escaping, leaching, dumping, or disposal of hazardous waste into the environment. It also may include the abandonment or discarding of barrels, containers, and other closed receptacles containing hazardous waste or hazardous constituents. RCRA Corrective Action can be conducted at any RCRA facility that handles hazardous waste.

In 1990, EPA proposed detailed regulations intended to govern the technical and procedural aspects of corrective action (40 CFR Part 264 Subpart S) (EPA 1990a) and in 1996, published an Advance Notice of Proposed Rulemaking (ANPR) that established guidance on areas of the program not addressed by the 1990 proposed regulations (U.S. EPA 1996a). Many provisions in these proposed rules were withdrawn, and only the ANPR continues to serve as EPA's primary corrective action implementation guidance.

In implementing the program, EPA and the authorized states have revised the basic approach to corrective action by (a) establishing interim goals that rely on near-term actions to reduce imminent threats and prevent further spread of contamination that had been released into the environment; (b) establishing long-term remediation goals; (c) streamlining the procedures for addressing newly generated waste that previously posed unintended barriers to cleaning up RCRA sites (remediation waste); (d) increasing emphasis on using risk-based approaches and parity with Superfund program requirements in determining appropriate cleanup levels; and (e) implementing a number of reforms to streamline program administration. EPA's intent has been to limit the regulatory barriers impeding timely and cost-effective cleanups, control present risks posed by RCRA sites, and allow EPA and authorized states to exercise considerable flexibility throughout the site management process.

Interim Goals

In conjunction with the proposed Subpart S regulations of 1990, EPA issued the *RCRA Implementation Study*. This report addressed the long-term goal of cleaning up RCRA sites but emphasized the importance of interim environmental actions to reduce imminent threats and prevent further spread of contamination that had been released into the environment (U.S. EPA 1990b). Soon after, EPA established procedures in the 1992 *RCRA Stabilization Strategy* for implementing near-term actions to prevent the migration of contamination within and outside facility boundaries (U.S. EPA 1991).

In 1993, EPA merged the Agency's near-term strategic interests in preventing human exposures and the spread of contamination with the GPRA goals. EPA also considered stakeholder concerns that the Corrective Action program was focused more on the process of cleanup than on outcomes. Therefore, in 1994, EPA established environmental indicators to measure near-term results at RCRA sites, effectively moving the focus of the Corrective Action program from process to outcomes. The two environmental indicators against which progress towards the 2005 GPRA goals are being measured are (1) the control of current human exposures, and (2) the control of migration of contaminated groundwater. These indicators provide a means of evaluating and reporting on current site conditions rather than on the conditions of sites following final cleanup. Considerable progress has been made toward this end. EPA and the states have identified 1,714 sites that warrant early action. See EPA's Corrective Action web site for the latest information on specific sites and progress at http://www.epa.gov/epaoswer/hazwaste/ca/facility.htm.

Long-Term Goals

Meeting the interim environmental indicator goals generally represents only a small component of a typical site's final corrective action. The ultimate goal of RCRA Corrective Action is to achieve final remedies that are appropriate for reasonably anticipated future land uses. EPA, the states, and other stakeholders are developing specific long-term goals for corrective action and are continuing to streamline the administrative process in anticipation of cleaning up all high, medium, and low-priority RCRA sites in the decade ahead. EPA and the states have identified 3,829 sites that are likely to require corrective action.

Remediation Waste

Early in the 1990s, EPA recognized that several Subtitle C regulations, which control newly generated waste, also pose unintended barriers to managing "remediation waste," which is waste generated during RCRA Corrective Action. To minimize or eliminate these and other barriers, the Agency and authorized states, with advice from stakeholders, took several actions.

In 1993, EPA proposed the Corrective Action Management Unit (CAMU) rule allowing sites to place waste generated during a cleanup into a CAMU or a temporary unit without first having to treat it. CAMUs are physical, geographic areas within a facility designated during cleanups for the treatment, storage, or disposal of remediation waste. Temporary units are tanks or container storage areas designated during cleanups for use solely to treat or store remediation waste. The CAMU rule eased the land disposal restrictions for remediation waste generated during a cleanup, thus exempting these units from the Subtitle C land disposal unit minimum technology requirements (§264.552 (a)(2)) (U.S. EPA 1993a). The CAMU rule established general performance-based standards to accommodate the variety of site situations that exist in the RCRA program and granted EPA and authorized states considerable regulatory relief and flexibility in the use of CAMUs and temporary units.

The rule was intended to result in more expeditious on-site treatment of greater volumes of remediation waste at less cost. However, in spite of broad support, the rule was challenged in court due in large part to concern that it lacked explicit waste treatment and unit design requirements for CAMUs. Following this challenge, EPA agreed to re-examine the CAMU rule in the context of developing the 1996 proposed Hazardous Remediation Waste Management Requirements (HWIR-Media) rule, and the litigation was stayed pending the outcome of this rulemaking process.

When EPA published the final HWIR-Media rule (63 FR 65874) in 1998, the specific provisions of the rule did not address the basic concerns of the litigants (U.S. EPA 1998a). To remove the litigation cloud that had been deterring the use of CAMUs in the field since 1993, EPA agreed in 2000 to amend the 1993 rule by imposing several minimal waste treatment and design standards and limits on the types of waste that may be managed in a CAMU. The CAMU definition was also modified to specify that CAMUs be located within contiguous property under the control of the owner/operator where the waste originated. The final amendments to the CAMU Rule became effective in January 2002 (U.S. EPA 2002a).

In 1998, EPA finalized selected portions of the 1996 proposed Hazardous Remediation Waste Management Requirements (HWIR-Media) rule (U.S. EPA 1998a). Although the final rule does not provide the broad reforms proposed in the 1996 HWIR-media rule (U.S. EPA 1996b), it does offer relief from some of the Subtitle C requirements on TSDFs during cleanup operations. It also makes available a special form of RCRA permit, called a remedial action plan (RAP), for the treatment, storage, or disposal of waste generated during cleanup activities. RAPs provide an alternative to traditional permits and help expedite cleanup.

Until that time, the treatment, storage, or re-disposal of hazardous remediation waste required the same type of traditional, facility-wide RCRA permit (Part B permit) as a TSDF engaged in managing process waste. Obtaining such a permit can take several years. The final HWIR-Media rule removed the facility-wide corrective action requirements and made available flexible performance-based standards that may be imposed via a traditional Part B permit or a RAP for remediation waste management sites. The new performance-based standards may be applied in lieu of 40 CFR 264 Subparts B, C, D, and 264.101.

The final HWIR-Media rule also contained a number of important provisions, including the creation of a new kind of waste management unit called a staging pile for storing (not treating) waste, which then is not subject to land disposal restrictions (LDRs) or minimum technology requirements (MTRs). The rule excludes dredged materials from RCRA Subtitle C regulations if the materials are managed by an appropriate permit under the Clean Water Act or the Marine Protection Research and Protection Act. The rule also simplifies the procedures states must follow when seeking authorization to manage their RCRA programs.

In 1998, EPA established alternative treatment standards under Phase IV of the LDR for contaminated soil produced during cleanup operations. If remediation waste is not amenable to waste-specific standards specified in the LDR (§268.40), a facility may apply the alternative treatment standards (§268.49; 63 FR 28556; May 26, 1998) promulgated pursuant to the 1984 HSWA (U.S. EPA 1998b). These standards are less stringent than those in §268.40.

Also in 1998, EPA amended the rule that specified the requirements for closing land disposal units containing hazardous waste. The amendment allowed EPA and authorized states to use a variety of authorities to impose requirements on non-permitted land disposal units requiring post-closure care and allowed for the closure of certain land-based units with released hazardous constituents to be addressed through the Corrective Action program (U.S. EPA 1998c). These changes give regulators increased flexibility to use alternate mechanisms under a variety of authorities to address closure requirements based on the particular needs of the facility.

As part of ongoing efforts to improve program coordination, the Agency issued a final memorandum entitled Risk-Based Clean Closure in 1998. The Risk-Based Clean Closure memorandum provides additional guidance on EPA's interpretation of clean closure, specifically with respect to the amount of residual contamination that may remain in an environmental medium while still meeting the clean closure standards (U.S. EPA 1998d). Further guidance on "restricted-use clean closure" is available in Final Guidance on *Completion of Corrective Action Activities at RCRA Facilities*, which guides EPA and authorized states through the process of determining when a cleanup is complete (U.S. EPA 2003a).

Risk-Based Corrective Action

EPA issued a parity policy in 1996 between the CERCLA (Superfund) and RCRA Corrective Action programs, entitled *Coordination Between RCRA Corrective Action and Closure and CERCLA Site Activities* (U.S. EPA 1996c). This guidance describes the conditions under which acceptance of decisions made by other remedial programs may be used. It recommends risk-based approaches when developing cleanup levels for RCRA regulated units and establishes the general principle that RCRA and CERCLA cleanups will achieve similar environmental results, thereby establishing a policy that cleanups under one program will be acceptable to the other program. It also identifies situations when deferral of activities to other programs is appropriate, and encourages coordination among the various cleanup programs at the federal and state levels. Risk-based corrective action provides an alternative to the use of strict numeric standards for specific contaminants as endpoints for cleanup activity, which is generally less cost effective.

RCRA Cleanup Reforms

Through a series of administrative reforms, known as the RCRA Cleanup Reforms, EPA continues to work with the states and stakeholders to develop new results-oriented cleanup guidelines, foster outreach and training to encourage flexible approaches to corrective action, and enhance community involvement. The RCRA Cleanup Reforms are expected to nurture creative, practical approaches which, in the field, means eliminating unnecessary administrative or technical steps, evaluating sites for overall risk, and applying appropriate risk-based facility-wide corrective action measures.

Several guidance documents have been issued since 1999 to promote effective cleanup results and enhance public involvement. For instance, EPA's final *Handbook of Groundwater Protection and Cleanup Policies for RCRA Corrective Action*, issued in 2002, is intended to help regulators, owners and operators of RCRA sites, and the public locate and understand EPA policies on groundwater use, protection, and cleanup within the framework of applicable state requirements (U.S. EPA 2002b). The *Results-Based Approaches and Tailored Oversight Guidance for Facilities Subject to Corrective Action Under Subtitile C of the Resources Conservation and Recovery Act* encourages technical and administrative innovation to achieve environmentally protective cleanups on a facility-specific basis (U.S. EPA 2003c). The approaches discussed in the document offer regulators flexibility in setting cleanup goals, planning data collection efforts, and letting owners/operators undertake cleanup actions with reduced Agency oversight when appropriate. A January 2001 memorandum discusses a variety of new enforcement approaches, such as reduced agency oversight and flexible compliance schedules, that are available to EPA and authorized states to help accomplish timely, protective, and efficient corrective action (U.S. EPA 2001).

EPA has also expanded outreach and developed comprehensive training as part of the 1999 reforms. Some of the training gives EPA and state regulators the opportunity to learn from their peers about successful cleanup approaches. EPA has also begun piloting the most innovative of these approaches at the site level. Twenty-five pilots were launched in the first year. Creating partnerships, training, connecting communities with cleanups, and capitalizing on the redevelopment potential of RCRA sites are likely to increase the number of cleanups started during this decade.

4.1.2 Corrective Action Process

A rigid process-oriented framework, such as that proposed in Subpart S (U.S. EPA 1990a) and the 1994 Corrective Action Plan (U.S. EPA 1994a), is not always applicable to the wide range of contamination problems at the diverse types of RCRA sites. The 1996 Advanced Notice of Proposed Rulemaking (ANPR), EPA's primary corrective action implementation guidance, emphasizes a performance-based approach and asserts that the elements of the process should not become ends in themselves (U.S. EPA 1996a). EPA recommends that cleanups be guided by several operating principles:

- Corrective action decisions should be based on risk;
- Corrective action should focus on results rather than process;
- Interim actions and stabilization should be used to reduce risks and prevent exposure;
- Corrective action activities should be phased to focus resources on the areas or exposure pathways of highest concern;
- Corrective action requirements should be addressed using the most appropriate authority, including state authorities, for any given facility (In certain cases, the states may rely on non-RCRA state authorities to satisfy correction action requirements); and
- Corrective action implementation should provide for meaningful inclusion of all stakeholders through full, fair, and equitable public participation.

Although the implementation of corrective action varies from site to site, it generally begins with an evaluation of existing site conditions, including information from the initial site assessment, called a RCRA facility assessment (RFA). EPA or an authorized state conducts the RFA, which involves examining a facility's SWMUs to determine if a release has occurred or if the potential for a release exists.

While site characterization is underway for the final cleanup, the owner or operator of a facility may be required to conduct an interim action, such as stabilizing contaminated waste to prevent the spread of contamination or providing an alternative source of drinking water if actual or potential contamination of drinking water supplies exists. Although an interim action typically occurs early during the investigation of the site, it may take place at any time prior to completion of the final remedy.

When additional site information is necessary to support an interim action, cleanup decision, or achievement of environmental indicators, the facility owner or operator may conduct a RCRA facility investigation (RFI). The RFI involves sampling, modeling, and other testing to determine the nature and extent of contamination and to characterize the site's geological and hydrological conditions.

If a corrective action is needed, a site owner will conduct a corrective measures study (CMS) to evaluate alternative remediation approaches and select a preferred alternative as the remedy. Sometimes, the CMS, which is the responsibility of the facility owner or operator with oversight from EPA or the state, can be conducted concurrently with the RFI. In cases where EPA or a state is using performance standards or a similar approach, or where the preferred remedy is apparent early in the process, the CMS may be highly focused. Upon approval of a remedy by the regulatory agency, the owner or operator may begin corrective measures implementation (CMI), which involves designing, constructing, maintaining, and monitoring the remedial measure. EPA recommends that current and reasonably expected future land uses be considered when selecting corrective action remedies.

4.1.3 Corrective Action Implementation

State Authorization

States are the primary implementors of the RCRA program, including RCRA Corrective Action. EPA provides several million dollars annually in grants to states for state oversight of cleanup at RCRA sites. As of April 17, 2003, EPA has authorized 48 states, some territories, and the District of Columbia to manage their own base programs for waste management and prevention. Thirty-nine states and one territory are authorized to oversee RCRA Corrective Action. EPA regional offices have the lead responsibility for implementing the program in Indian Territories and in states that have yet to be authorized for corrective action. Many other states have for some time been operating similar corrective action programs under their own authorities. The states have no RCRA universe of their own that is not reported to EPA. EPA's State Authorization Tracking System (StATS) tracks the status of each state and territory in establishing and maintaining RCRA authorized hazardous waste programs, including corrective action (see http://www.epa.gov/epaoswer/hazwaste/state/stats/stats.htm).

Prior to granting a state or territory full authorization for corrective action, EPA regional offices may develop grants and cooperative agreements under RCRA §3011 giving the state the lead for corrective action oversight at specific sites. Although authorized state programs must meet the minimum federal requirements, a state may adopt regulations that are more stringent than the federal requirement.

Permitting and Enforcement

Corrective action may be implemented through the RCRA permit process, state or federal enforcement orders, or voluntarily. All sites that are required to have RCRA permits, such as TSDFs, and those sites where EPA or a state has discretionary authority under RCRA to impose corrective action, are subject to corrective action requirements. About 86 percent of RCRA sites subject to corrective action are TSDFs. Corrective action may be imposed to clean up on-site contamination, offsite contamination, and one-time spills.

EPA or an authorized state permits all TSDFs to treat, store, or dispose of hazardous waste. Section 3004(u) of HSWA, which is directed specifically toward controlling releases from SWMUs, is the primary authority requiring corrective action at permitted TSDFs. It compels a facility owner or operator to address SWMU releases due to past disposal or recent contamination whenever seeking a RCRA permit. Additional authority is available under §3004(v) of HSWA to require a permitted TSDF to clean up contamination beyond the facility boundary. Thus, HSWA requires all hazardous waste facilities that obtain a RCRA permit after November 8, 1984, to take corrective action for any releases from past disposal or recent contamination from the facility, including all SWMU and off-site releases. For a TSDF operating under interim status rather than a RCRA permit, EPA can invoke HSWA §3008(h), which provides for enforcement orders, or state orders in an authorized state, to address any release of hazardous waste. The corrective action process for both permitting and enforcement orders is similar.

For actual or potential releases not originating from a SWMU, such as a one-time spill from a vehicle traveling across a facility, or for releases at RCRA sites with permits that pre-date HSWA, EPA may impose its omnibus permitting authority pursuant to HSWA §3005(c)(3). This provision allows EPA to modify the facility's permit as necessary, requiring corrective action for any potential threat to human health or the environment. Also, HSWA §7003 gives EPA broad authority to seek injunctive relief in the appropriate U.S. District Court or to issue administrative corrective action orders for any waste from any source, including SWMUs, where the handling, storage, treatment, transportation, or disposal of solid or hazardous waste may pose an imminent and substantial danger to public health or the environment.

To minimize the regulatory burden of RCRA Corrective Action without endangering public health or the environment, EPA created exemptions and special permits. For example, EPA conditionally exempts from the Subtitle C hazardous waste regulations any waste samples collected solely for the purpose of monitoring or testing the characteristics or composition of RCRA facility contamination. Referred to as the Treatability Studies Sample Exemption Rule (CFR 261.4(e) and (f)), the exemption places limits on the quantity of contaminated media than can be shipped, stored at a laboratory or testing facility, and treated there (U.S. EPA 1994b). The exemption rule also limits the amount of time the contaminated media may be retained for analysis or treatment. Although EPA encourages authorized states to adopt exemptions and special permits, the states are not required to adopt them because they are less stringent than existing federal requirements.

Special permits and modifications are available to facilitate the development and application of innovative technologies. For example, facility owners or operators may obtain RCRA research, development, and demonstration (RD&D) permits for pilot-scale evaluations of treatment technologies. EPA, in collaboration with the state, has the authority to modify a permit or enforcement order to allow on-site technology demonstrations at corrective action sites. In this case, EPA may grant a site-specific treatability variance for contaminated soils and debris when the facility cannot achieve the stringent technology-based treatment standards in the land disposal restrictions. Other permitting options are available through the Subpart X rule of RCRA, titled "Miscellaneous Units," which addresses hazardous waste management units that do not fit the current RCRA definition of container, tank, surface impoundment, pile, land treatment unit, landfill, incinerator, boiler, industrial furnace, or underground injection well (U.S. EPA 1987). For instance, EPA and the Department of Defense have worked together to dispose of munitions using the permitting options available for pilot-scale RD&D and the Subpart X rule.

The remedial action plan (RAP), a special type of RCRA permit, made available in the final HWIR-media rule (1998) as an alternative to traditional permits, can be used for the treatment, storage, or disposal of waste generated during remediation activities. RAPs can be used for cleaning up contaminated areas or areas in close proximity to the contamination, and they may be used for cleaning up offsite locations when treating, storing, or disposing of the waste off site is more protective than on site.

4.2 Factors Affecting Demand for Cleanup

The extent and timing of the cleanup of RCRA Corrective Action sites is significantly influenced by the regulatory and site-management refinements that EPA and the states have been building into the cleanup process; federal funding of state oversight; and improvements in field technologies that better characterize contamination, improve remedy design, lower overall cleanup costs, and improve the quality and pace of site cleanups. These factors create incentives for owners and operators in the broader market to consider actual cleanup over containment.

- The RCRA Cleanup Baseline sites that are striving to meet their 2005 interim GPRA goals represent the most immediate actions to be taken at RCRA sites. While these sites represent the readily identified, near-term market for cleanup, many other RCRA sites with less immediate human health concerns will also need to be cleaned up.

- Revisions to the Subtitle C requirement for cleaning up some hazardous waste implemented over the past decade are likely to encourage treatment and removal as compared to leaving waste in place. As described in section 4.1.1, the revisions most likely to impact the market include introducing alternative standards for CAMUs, temporary units, and staging piles specifically to handle remediation waste that is no longer considered newly-generated hazardous waste; defining LDR alternative treatment standards for cleanups; harmonizing the sometimes duplicative closure and corrective action requirements; streamlining permit requirements for cleanup activities; and removing the obligation for facility-wide corrective action.

  Before these changes occurred, the stringent Subtitle C requirement was frequently counterproductive when applied to the cleanup of individual sites because it imposed unnecessary costs and delays and limited cleanup options. Even if treating or permanently removing the waste was the preferred option, parties sometimes decided not to clean up certain sites or sought to leave the waste in place at others. Such actions may lead to increased long-term risk of human exposure to contamination and the potential that the contamination will spread offsite or to groundwater.

- The 1999 and 2001 cleanup reforms are intended to increase the number and efficiency of cleanups and establish aggressive national cleanup goals. The reforms established more flexible, facility-specific approaches to account for the variety of conditions at RCRA sites.

- Refinements in field technologies and methods used to characterize site contamination and its likely movement in the environment and to improve remedy design are changing the cleanup market. Refinements in these technologies during the last five to ten years have begun to decrease site-assessment costs, improve data quality, and expand the applicability of less traditional remedies. For instance, in the past, a semi-permanent well had to be installed to sample groundwater quality and a drill rig was needed to obtain soil borings at depth. While these technologies still have their place, newer technologies, such as the hydropunch and cone penetrometer, are available at a dramatically lower cost. Also available are geophysical technologies, such as remote sensing, to determine subsurface conditions. Almost 30 percent of all sites EPA sampled in a study of RCRA Corrective Action implementation used some type of innovative characterization approach (U.S. EPA 2002c). Low-priority sites were more likely than medium and high priority sites to employ these approaches. Site characterization, conducted at less cost, often results in better designed remedies for particular site conditions, rather than in over-designed remedies intended to account for the many unknowns associated with a site.

- The pace of the cleanups is affected by the availability of funds to pay for state and federal oversight. Many states have been facing budget deficits in 2003 and 2004 and, on average, state staffing levels and budgets for hazardous waste remediation has not increased in about a decade. Section 9.4 (State and Private Party Sites) includes a description of trends in state capabilities.

- Land development trends are also likely to affect the pace and nature of RCRA cleanups. If there is demand for the redevelopment or transfer of commercial and industrial properties, they will require site assessments and, if necessary, remediation. The 2002 brownfields law, titled "The Small Business Liability Relief and Brownfields Revitalization Act (P.L. 107-118)," the Superfund Redevelopment Program, and the RCRA Brownfields Initiative are encouraging the reuse of former industrial and other properties. These programs have implemented policy changes and demonstrated many approaches and ideas that foster the cleanup and redevelopment of contaminated properties, including a number where waste has been left on site. By publicizing the potential for reusing tainted properties, these activities may have the impact of increasing the pace of cleanup of corrective action sites. (See Section 9.1.2, Voluntary Cleanup and Brownfield Programs).

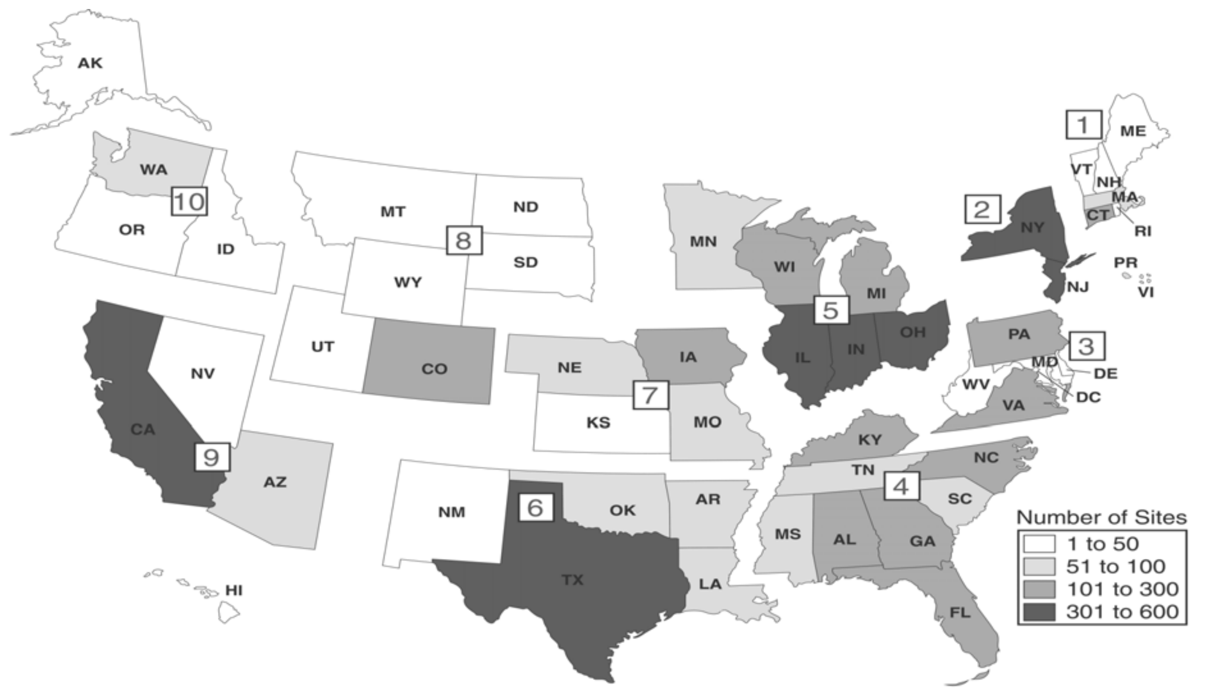
4.3 Number and Characteristics of RCRA Sites

All RCRA sites requiring permits and those where EPA or a state has discretionary authority to impose corrective action are subject to corrective action requirements. However, not all of these sites will actually require corrective action, and until further study is conducted, the number of RCRA sites that will require cleanup can only be estimated. Nevertheless, EPA's RCRAInfo electronic database and two previous EPA studies, can be used to estimate the potential extent of future cleanups.

4.3.1 Number of RCRA Sites

As of March 31, 2003, EPA's RCRAInfo database, a national program management and inventory system on hazardous waste handlers, contained information on 6,677 RCRA sites where EPA has discretionary or statutory authority to impose corrective action when necessary (U.S. EPA 2003b). Exhibit 4-1 shows the distribution among the states of the RCRA sites subject to corrective action. Exhibit 4-2 contains the current numbers of sites in this universe in EPA's ten regions. EPA and the states have identified approximately 29 percent high-priority sites, 24 percent medium-ranked sites, 29 percent low-ranked sites, and have not ranked 19 percent of the sites. A RCRA facility investigation (RFI) has been imposed at 38 percent of the sites subject to corrective action. The RFI involves sampling, modeling, and other testing to determine the nature and extent of environmental contamination and to characterize the site's geological and hydrological conditions. A RFI has been imposed at 79 percent of the high-priority sites, 38 percent of the medium-priority sites, and 20 percent of the low-priority sites. While about 20 percent of the sites in this universe are implementing stabilization measures, only 10 percent of them have selected a remedy.

Exhibit 4-1. Location of RCRA Sites Subject to Corrective Action by State and EPA Region



Notes: Includes 6,674 sites inthe Subject to Corrective Action Universe (sites reported to EPA or authorized states as having a release of a hazardous substance)

Source: U.S. EPA, Office of Solid Waste, RCRA Info database, March 31, 2003.

Exhibit 4-2. Priority Ranking of RCRA Sites Subject to Corrective Action

EPA Region	Ranking				Total Facilities
	High	Medium	Low	Unranked	
1	176	85	43	83	387
2	188	208	267	23	686
3	308	46	62	87	503
4	272	196	151	268	887
5	355	445	691	486	1,977
6	236	204	228	114	782
7	99	146	126	19	390
8	58	68	126	108	360
9	140	123	236	45	544
10	78	46	29	8	161
Total	1,910	1,567	1,959	1,241	6,677

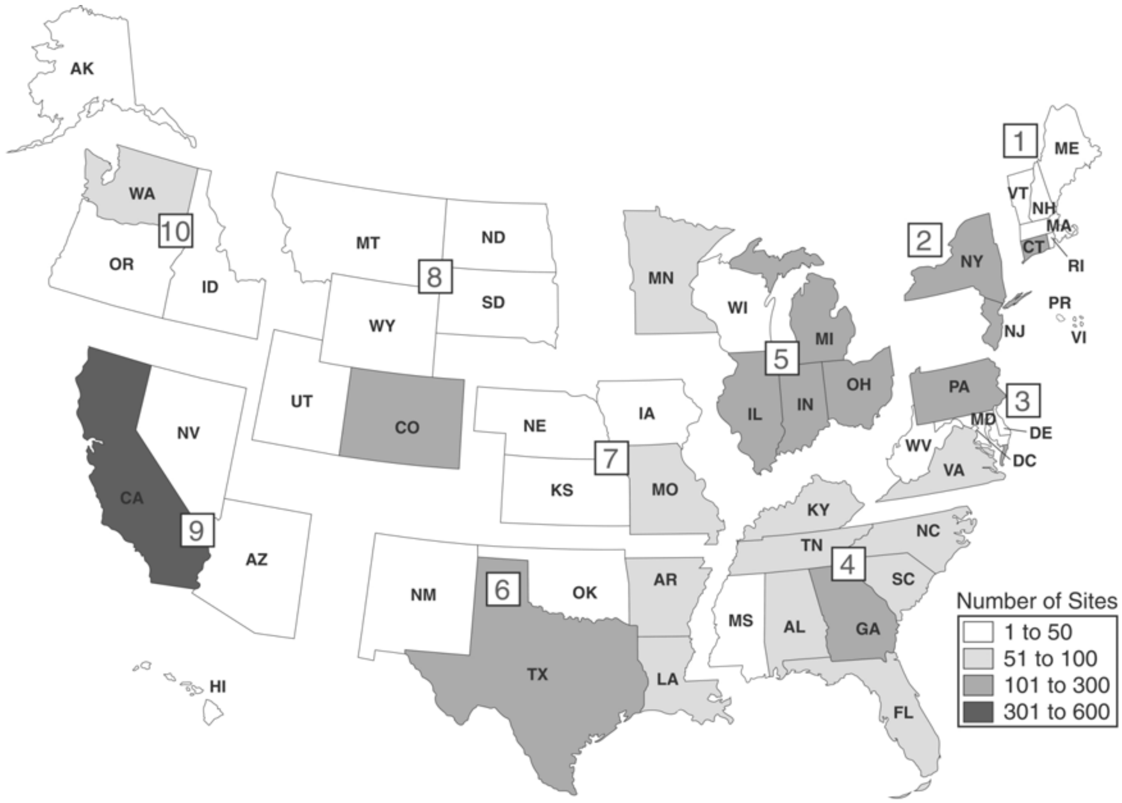
Source: U.S. EPA, Office of Solid Waste, RCRAInfo database, March 28, 2003

A subset of this universe represents 3,829 sites that are required to undergo further site investigation and or cleanup. These sites are most likely to require some sort of remedial action in the near term and already may be involved in some phase of corrective action. Approximately eight percent of these sites are federal facilities. Exhibit 4-3 shows the distribution among the states of the RCRA sites in this universe, which is called the "corrective action workload universe." Most states have fewer than 100 of these sites.

4.3.2 Types of RCRA Sites

The type of activities that have occurred at a site may lend insight into the nature of the cleanup needed. A TSDF may operate one or more types of hazardous waste management processes. Typical management processes include land disposal, such as landfills, land treatment units, surface impoundments, waste piles, and underground injection wells; incineration; treatment, storage in tanks; and boilers and industrial furnaces. A waste pile is any non-containerized accumulation of solid, nonflowing hazardous waste that is used for treatment or storage. The definitions of the other processes may be found in 40 CFR §260.10 (U.S. EPA 1980).

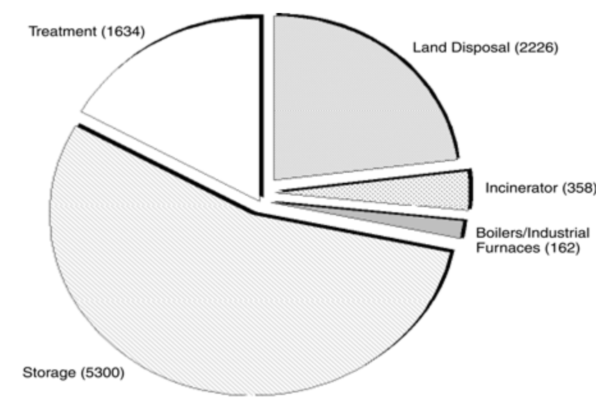
Exhibit 4-3. Location of RCRA Sites Likely to Require Corrective Action by State and EPA Region



Notes: Includes 3,829 facilities in the Corrective Action Workload Universe (facilities with statutory requirements for corrective action due to permitting requirements and facilities where corrective action has been imposed).

Source: U.S. EPA, Office of Solid Waste, RCRA Info database, March 31, 2003.

Exhibit 4-4. Major Waste Management Processes at RCRA Facilities



Source: U.S. EPA, Office of Solid Waste, RCRA Info database, March 31, 2003.

Exhibit 4-4 presents the major processes operated now or in the past by RCRA facilities in EPA's RCRAInfo database. Because each facility may be performing more than one process, the total number of processes exceeds the number of facilities. Storage and treatment account for 72 percent of the processes reported, followed by land disposal at 23 percent, and incineration at four percent.

In one study, EPA's Technology Innovation Office obtained information on a total of 275 TSDFs in 1992 and 1993 for the purpose of identifying relationships between site characteristics and the use of innovative technologies at RCRA Corrective Action sites (U.S. EPA 1994c). At the 214 TSDFs where contamination data were available, halogenated volatile organic compounds (VOCs), the most prevalent of all contaminant groups reported, were present at a majority of the TSDFs, followed by heavy metals, and nonhalogenated VOCs. Groundwater contamination was reported at 82 percent and soil contamination at 61 percent of the 256 TSDFs for which media data were available.

A second study is EPA's 1993 regulatory impact analysis (RIA), developed to support the corrective action rule, Subpart S (U.S. EPA 1993b). EPA analyzed information on a sample of 79 TSDFs to estimate contamination likely to be present in soil or groundwater at concentration levels that would require action. Of the 2,600 facilities, estimated at the time of the 1993 RIA to require corrective action, about 80 percent appeared to have significant releases to on-site groundwater and 30 percent were likely to have significant off-site groundwater contamination. This estimate is close to the 82 percent observed in EPA's study of 275 TSDFs (U.S. EPA 1994c).

Contaminants in groundwater and soil at RCRA facilities were estimated in the RIA. The top ten contaminants expected in groundwater at concentrations that were high enough in 1990 to trigger concern are, in order of frequency, chromium, benzene, methylene chloride, arsenic, lead, tetrachloroethylene, trichloroethylene, naphthalene, 1,1,2-trichloroethane, 1,1-dichloroethylene. Based on this data on-site soil contaminant concentrations above EPA action levels are expected to occur at about 68 percent of the 2,600 facilities estimated at the time of the study to require corrective action. In soil, tetrachloroethylene, trichloroethylene, chromium, and arsenic were expected to be at concentration levels above EPA's 1990 action levels.

In 1997, EPA developed a snapshot on corrective action implementation nationwide based on a statistically representative sample of 84 facilities among 889 corrective action sites that had final remedies selected or stabilization measures in place. The site data reflected the universe of RCRA facilities subject to corrective action in 1990. EPA surveyed Agency regional and state regulators responsible for the selected facilities and received 62 responses. The survey results were compiled into the RCRA Corrective Action Implementation Database (RCAID) (U.S. EPA 2002c).

The majority of facilities in the extrapolated RCAID universe were manufacturing industries. Although spills were estimated to be a major concern at over half of the facilities, landfills, surface impoundments, and underground storage tanks also contributed significantly to facility contamination. Nearly all of the facilities had both soil and groundwater contamination, and the contamination had migrated beyond the facility boundary at about half of the sites. Using the extrapolated data, OSW estimated that 84 percent of the facilities with a final remedy and/or stabilization measure in place had VOCs, 41 percent had SVOCs, 23 percent had metals, 10 percent had polychlorinated biphenyls, 5 percent had pesticides, and 20 percent had other types of contaminants, such as radionuclides and phenol.

Another study of treatment experiences at RCRA corrective actions involved 30 sites identified from readily available information sources in 2000 (U.S. EPA 2000a). EPA's Technology Innovation Office, which conducted the study, selected sites that were illustrative of the types of cleanups conducted at RCRA corrective actions. They were not necessarily representative of the entire universe of RCRA cleanups. The sites, which varied in size and complexity, had chlorinated solvents, polycyclic aromatic hydrocarbons (PAHs), benzene, toluene, ethylbenzene, and xylenes (BTEX), other VOCs and SVOCs, and petroleum hydrocarbons.

Information on contaminants and contaminated media at 99 RCRA sites was found in the statements of basis completed before 2000 (most were signed before 1995). A statement of basis is similar to a Superfund ROD. The number of sites reporting groundwater contamination exceeded 70 percent and was similar to the number reporting soil contamination. Nearly 70 percent of the sites in the database reported VOCs, about 40 percent reported SVOCs (including halogenated, nonhalogenated, PAHs, PCBs, phenols, and pesticides), and nearly 50 percent reported metals. Dense non-aqueous phase liquids (DNAPLs) were found at 53 sites; the most common were 1,1,1-trichloroethane (1,1,1-TCA), 1,1-dichloroethene, tetrachloroethylene and (PCE), and 1,1-dichloroethane.

4.4 Estimated Cleanup Costs

All known estimates of the ultimate cost of the RCRA Corrective Action program are subject to uncertainties inherent in predicting the course of a large multi-year program. The types and sizes of sites are quite diverse, and detailed data are available on only a sample of sites. The most appropriate estimate was prepared in the background work for the proposed amendments to the CAMU Rule in 2000 (U.S. EPA 2000b). This estimate is based on the RCAID survey data described in Section 4.3.3. EPA surveyed EPA regional and state regulators responsible for the selected facilities and received 62 responses. The cleanup cost varied widely from site to site, from under $1 million to over $50 million. Over half the facilities had cleanup costs under $5 million, and 9 percent had costs over $50 million. The data were reported in terms of ranges and precise average cost per site was not provided. However, by taking the upper and lower cost value of each range, a reasonable approximation of an upper and lower limit of the estimated costs were developed. These calculations appear in Exhibit 4-5.

Based on these estimates, cleanup of the 3,829 sites that are likely to require corrective action will cost between $31 billion and $58 billion, with a middle-value of $44 billion, or $11.4 million per facility. Approximately 41 percent of the total cost will be incurred by nine percent of the facilities. These estimated corrective action costs do not include those of the very large DOD and DOE facilities, although it may include some smaller ones.

This estimated average cost per site is about 20 percent lower (in 2003 dollars) than that estimated in the 1993 Regulatory Impact Analysis for Subpart S. This difference reflects a variety of changes since that RIA, including more efficient site characterization and cleanup approaches, the use of risk-based cleanup approaches, and savings due to the CAMU policies described in Section 4.1. Over the past few years, implementation of the Corrective Action program has shifted toward more flexible, risk-based cleanups and away from the regulatory approach modeled in the 1993 RIA. In addition, the near-term costs of the program are likely to be reduced due to the program's emphasis in the short-term on stabilization remedies rather than permanent remedies.

Exhibit 4-5. Estimated RCRA Corrective Action Costs ($Millions)

		Cost Per Site [a]			Total Cost [c]		
Cost	% of Sites	Low	High	No. of Sites [b]	Low	High	Average
< 1.0	32	0	1.0	1,225	245	1,225	735
1 - 5	24	1	5.0	919	919	4,595	2,757
5 - 10	13	5	10.0	498	2,489	4,978	3,734
10 - 25	20	10	25.0	766	7,658	19,145	13,402
25- 50	2	25	50 .0	77	1,915	3,829	2,872
> 50	9	51	70 .0	345	17,575	24,123	20,849
Total	100			3,829	30,800	57,895	44,347

a The lowest ($200,000) and highest ($70 million) values are conservative assumptions
b Sites likely to require corrective action, from Section 3.4.3.
c Number of sites multiplied by cost per site

Source: U.S. EPA, 2000c, *Economic Analysis of the Proposed Amendments to the Corrective Action Management Unit Rule (Background Document)*, Office of Solid Waste, August 7, 2000.

4.5 Market Entry Considerations

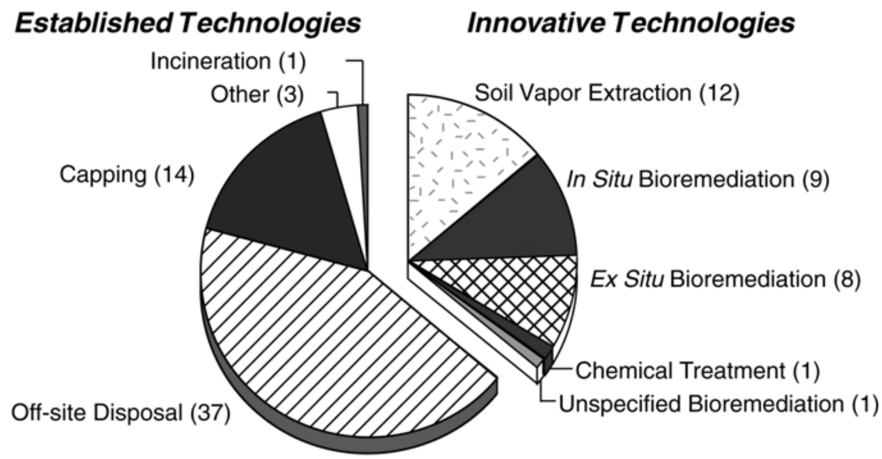
The responsibility for RCRA corrective action at individual sites lies with the owners and operators who contract directly with commercial vendors for services. RCRA requires that owners and operators be aware of technologies that may be used and those that are subject to restrictions or are banned. Although vendors interested in the corrective action market can obtain some information about specific sites by querying RCRAInfo on line, they will have to contact specific owners or operators to obtain information on an individual facility's corrective action requirements, waste characteristics, and cleanup needs. The RCRAInfo query form is at http://www.epa.gov/enviro/html/rcris/rcris_query_java.html. Many state hazardous waste agencies, and to a lesser degree EPA regional offices, have additional information about the corrective action needs of sites in their areas.

4.6 Remediation Technologies

Remedies selected for a given site may attain media cleanup standards through various combinations of removal, treatment, engineering, and institutional controls. While EPA maintains current information on the general characteristics of RCRA sites in the RCRAInfo database, it has not compiled information on remedial action decisions at sites undergoing cleanup.

Data on technology applications for 186 RCRA facilities are available from an EPA study completed in 1994 (U.S. EPA 1994c). Of 133 facilities treating groundwater, pump and treat was selected for 116 sites (87 percent) and innovative technologies were selected for nine sites (seven percent). The innovative technologies were in-situ bioremediation at four sites, ex-situ bioremediation for two sites, and unspecified bioremediation, thermal desorption, and chemical treatment for one site each. Of 86 sites requiring soil treatment, established technologies were selected for 55 sites (64 percent), including capping and off-site disposal at 51 sites, incineration for one site, and other technologies for three sites. Innovative technologies, such as soil vapor extraction (SVE), bioremediation, and chemical treatment, were selected for 31 (39 percent) of the sites requiring soil treatment. Of the innovative technologies selected for contaminated soil, most were likely to be used to remediate halogenated and non-halogenated VOCs. Exhibit 4-6 summarizes specific innovative and established technologies applied or likely to be applied to soil contamination at the 86 sites requiring soil treatment.

Exhibit 4-6. Remedies Selected for Soil at 86 RCRA Corrective Action Facilities



* More than one technology may be used at a single site.

Source: *Analysis of Facility Corrective Action Data*, January 1994

Another EPA study is available on remedies selected for 30 RCRA Corrective Action sites, 18 of which had ongoing cleanups while 12 had completed cleanups (U.S. EPA 2000c). EPA selected these sites from information readily available in 2000 on cleanups that had occurred or were underway between 1986 and 2000. The selected sites include a wide range of industries, such as wood treaters, chemical plants, refineries, paper mills, manufacturing facilities, and waste treatment plants, that vary in size, complexity, and contaminants. Seven of these sites selected soil vapor extraction—the most frequently used soil cleanup technology. Far less frequently selected in-situ technologies were bioremediation of soil and groundwater, bioventing, chemical oxidation, permeable reactive barriers, and air sparging. The ex-situ technologies selected included pump and treat, bioremediation, and thermal desorption.

Projected remedies selected for facilities in the RCAID database were based on site characterization data collected in 1992 and 1993 (U.S. EPA 2002c). The final remedy information on 78 solid waste management units in RCAID showed that pump and treat (15 percent) and cap/cover (31 percent) were selected most often. Barrier walls were selected for 13 percent of the units, and soil vapor extraction was selected for nine percent. Pump and treat and cap/cover were also the most common stabilization measures taken at many facilities prior to selecting the final remedy.

Information on final remedies selected for RCRA sites was found in 99 statements of basis. Most of the remedy or stabilization decisions reported in these documents were made in the mid-1990s. The most frequently selected remedies or stabilization measures for soil were excavation with off-site disposal, capping or cover, and in-situ soil vapor extraction. The remedies selected most frequently for groundwater were pump and treat and containment wall.

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Chapter 5
Underground Storage Tank Sites

Underground storage tanks (USTs) are used by a wide variety of industries, such as petroleum and chemical manufacturing and distribution, transportation, agriculture, and government. About 680,000 active tanks are currently subject to federal regulations. Ninety-six percent of these contain petroleum products, including used oil. Less than four percent contain hazardous substances. In addition, more than 1.5 million federally regulated USTs have been closed.

Subtitle I of the Hazardous and Solid Waste Amendments to the Resource Conservation and Recovery Act (RCRA) was enacted in 1984 to control and prevent leaks and spills from USTs. Subtitle I governs USTs storing regulated substances, including gasoline, aviation fuel, diesel fuel, other petroleum products, and hazardous substances defined under the Superfund program. Pursuant to Subtitle I, EPA has promulgated regulations requiring, among other things, that leaks and spills be remediated and future releases be prevented. These regulations have compelled cleanup activities at many UST sites, providing opportunities for the application of a variety of remediation technologies.

Releases of petroleum or hazardous substances can result from a spill during tank filling operations, leaks in the tank or pipes attached to the tank due to corrosion, structural failure, or faulty installation. As of March 31, 2004, more than 443,000 releases from federally regulated USTs had been confirmed (U.S. EPA 2004). These releases can contaminate soil and groundwater and cause fire or explosions. While considerable progress has been made in cleaning up contamination from underground storage tanks during the last decade—more than 311,000 contaminated sites have been cleaned up—many more remain to be remediated.

Highlights

- Although considerable progress has been made in cleaning up UST sites over the past decade, it is estimated that 95,000 to 155,000 UST sites will require cleanup under the RCRA underground storage tank regulations.
- This estimate includes 35,000 already identified sites that have not yet been cleaned up plus an estimated 60,000-120,000 sites that may have future releases over a 10-year period.
- Although new reported releases of contaminants from tanks may continue beyond 10 years and tank leakage rates may decline, these scenarios are not included in this report because of uncertainties in predicting these trends.
- The cost of these cleanups could reach $12-19 billion. This estimate does not include costs related to replacing, testing, or upgrading tanks, pipes, and related equipment.
- The year-to-year fluctuations in the number of cleanups will depend on the availability of funds from public and private sources; the failure rate of tank systems; cleanup cost savings through the growing use of newer site management approaches; and additional site characterization and remediation costs that may result from sites that are difficult to remediate (e.g., MTBE).
- Since 1998, the number of confirmed releases reported to EPA has been declining. Nevertheless, it is expected that there will always be some additional releases in the future.
- UST tank sites account for over 43% of all waste sites estimated in this report to be cleaned up.
- The average UST site is typically smaller and less costly to remediate than those of most

5.1 Federal Program Description

The federal regulatory program is implemented by EPA's Office of Underground Storage Tanks (OUST). The federal UST technical requirements and state program approval regulations were promulgated in September 1988 and became effective on December 22, 1988 (U. S. EPA 1988). These regulations, to a large extent, determine the size of the market for cleanup services.

The regulations apply to any UST, except those specifically exempted, excluded, or deferred, used to store petroleum products or substances defined as hazardous under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). The regulations do not apply to tanks storing hazardous wastes regulated under Subtitle C of RCRA. An UST is defined as any tank that has at least 10 percent of its volume buried below ground, including piping connected to the tank. Generally, the requirements for tanks containing chemicals are somewhat more stringent than those containing petroleum products.

The basic federal requirements include:

- A tank owner must register his or her tank(s) with the state authority by completing a notification form about the characteristics and contents of the UST.

- A tank owner must institute a periodic leak detection program to actively seek out releases. For tanks installed after December 1988, leak detection requirements become effective at the time of installation. For older tanks, the requirements were phased in over time with a final completion date of December 1993.

- A tank owner must maintain records of leak detection activities, corrosion protection system inspections, repair and maintenance activities, and closure site assessments.

- A tank owner must notify the appropriate regulatory authority of all suspected or confirmed releases as well as follow-up actions taken or planned. Suspected leaks must be investigated immediately to determine if they are real. If evidence of environmental damage is the cause for suspicion, it must be reported immediately to the regulatory authority.

- If a leak or spill is confirmed, tank owners must: (a) take immediate action to stop and contain the leak or spill; (b) notify the regulatory authority within 24 hours or other reasonable time period specified by the implementing agency; and (c) take action to mitigate further damage to people and the environment.

- All USTs must be protected from corrosion and have devices that prevent spills and overfills, in accordance with EPA's upgrade and new tank standards.

- A tank owner closing an UST must notify the regulatory authority 30 days before permanent closure.

The following kinds of tanks are currently *exempt* or *excluded* from the regulations:

- Farm and residential tanks holding 1,100 gallons or less of motor fuel used for non-commercial purposes.
- Tanks storing heating oil for use on the premises.
- Storage tanks on or above the floor of areas such as basements or tunnels.
- Septic tanks.
- Storm-water and waste-water collection systems.
- Flow-through process tanks.
- Tanks holding 110 gallons or less.
- Emergency spill and overflow containment UST system.
- Certain pipeline facilities, including gathering lines regulated under other federal or state statutes.
- Surface impoundments, pits, ponds, or lagoons.
- Liquid traps or associated gathering lines directly related to oil or gas production and gathering operations.
- UST systems holding hazardous substances listed or identified under Subtitle C of RCRA.
- Any wastewater treatment tank system that is part of a wastewater treatment facility regulated under Section 401 or 307(b) of the Clean Water Act (CWA).
- Equipment or machinery that contains regulated substances for operational purposes, such as hydraulic lift tanks and electrical equipment tanks.
- Any UST system that contains a *de minimis* concentration of regulated substances.

In addition, certain categories of tanks, known as deferred USTs, are not yet subject to the full federal UST regulations. Until EPA decides how to regulate these USTs fully, the only regulations that apply are Subpart A (Interim Prohibition) and Subpart F (release, response, and corrective action). Examples of deferred tanks include underground, field-constructed, bulk storage tanks, and UST systems that contain radioactive wastes.

Changes in the types of tanks covered by the regulations could significantly impact the potential size of the market. However, EPA is not contemplating any such changes at this time. Although these categories of tanks are currently excluded from federal regulations, some of them may be subject to state regulations.

EPA designed the UST program to be implemented by the states. Authority to implement the program is delegated to states through either the formal process of obtaining state program approval (SPA) or a cooperative agreement. Thirty-three states, the District of Columbia, and Puerto Rico have all been approved to act in lieu of the federal program. Most of the other states operate their own program under their own laws with limited federal oversight. The Act also allows for states to have more stringent requirements than that of the federal regulations. For example, some states may include home heating oil tanks in their program. EPA supports state programs by providing resources from the federal Leaking Underground Storage Tank Fund (LUST Trust Fund), grants to states and tribal programs, technical assistance, training, and information exchange.

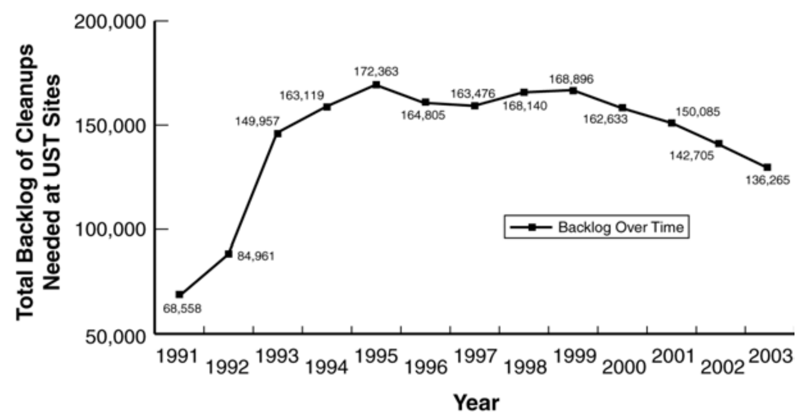
5.2 Factors Affecting Demand for Cleanup

The demand for remediation services at contaminated UST sites primarily will be influenced by federal regulations, state requirements, and the number of releases occurring at old and new tanks. The timing of these cleanups will be influenced by the availability of state and federal funds for site assessment and cleanup of UST sites and the pace of economic development.

5.2.1 General Trends

In October 2002, EPA established a national goal of completing between 18,000 and 23,000 cleanups each year for the fiscal years 2003-2007. If EPA is able to meet this goal, the backlog of sites needing remediation, which has remained steady over the past decade, will be halved by 2007. Exhibit 5-1 shows the number of sites in the backlog since 1991 (U.S. EPA 2003c).

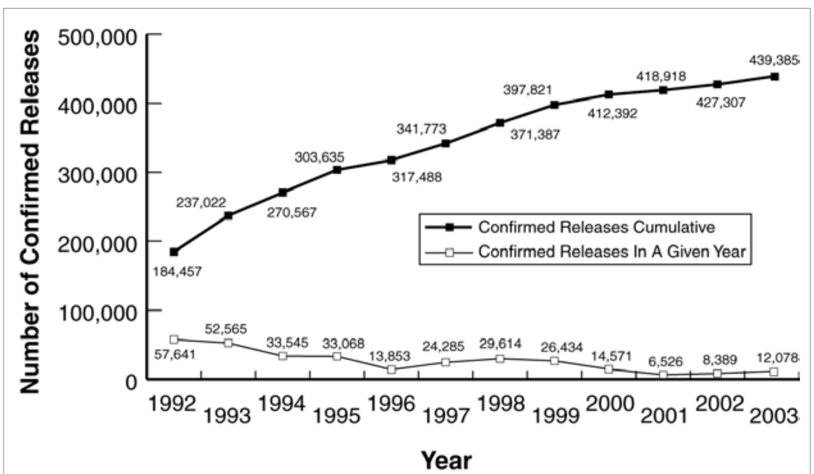
Exhibit 5-1. Backlog of UST Site Cleanups to be Completed



Source: U.S. EPA, Office of Solid Waste and Emergency Response, FY 2003 Semi-Annual End-of-Year Activity Report, November 25, 2003.

A number of factors led to an increase in the number of confirmed releases in 1997 and 1998, including the implementation of leak detection requirements (which became effective in 1993); tank upgrading requirements to prevent spills, overfills, and corrosion (which became effective in 1998); and reporting requirements. Since 1998, the number of confirmed releases has almost steadily declined from 29,600 to 12,000 (Exhibit 5-2). During the last three years, they have ranged from 6,000 to 12,000 and averaged 9,000. As more tanks come into compliance, the number of new releases is expected to continue to drop. However, it is expected that there will always be releases in the future. Many older tanks still exist and many older, as well as upgraded tanks, are not in full compliance.

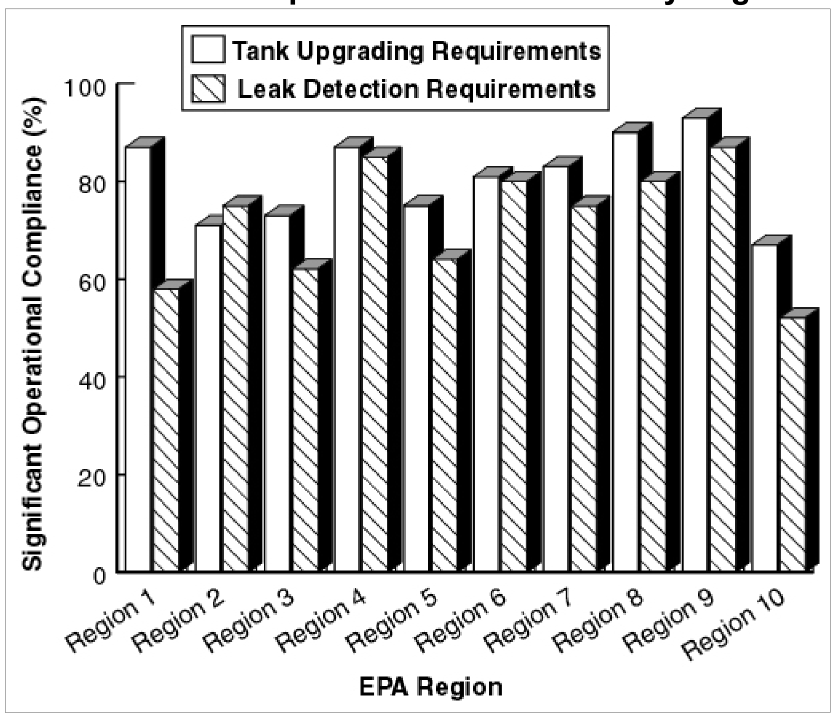
Exhibit 5-2. Confirmed Releases at UST Sites



Source: U.S. EPA, Office of Solid Waste and Emergency Response, FY 2003 Semi-Annual End-of-Year Activity Report, November 25, 2003.

The failure rate of tank systems is determined by such factors as tank age, material of construction, corrosion protection systems in place, and other design and site-specific factors such as soil type, weather, and operations and maintenance practices. Because information on these factors is limited, estimates of market size are subject to some uncertainty. The following observations have been made about some of the factors that influence tank failure rates.

Exhibit 5-3. Compliance Status of USTs by Region



- While none of the states are in full compliance with EPA's leak detection and upgrading requirements, most of the tanks that states monitor had the required leak prevention and detection equipment installed as of September 2003. The compliance rates were 79 percent for release prevention and 72 percent for leak detection. Region 9 had the highest percentage of operational compliance with release prevention requirements (93%), while Region 3 had the lowest (69%). For leak detection requirements, the range was from 89 percent (Region 9) to 55 percent (Regions 1 and 10). However, there is variation in the reporting by the states, since some states' reports are based on more stringent requirements. (Exhibit 5-3)

- According to a 2003 GAO report (based on data collected in 2001 and 2002), 29 percent of tanks are not operated and maintained properly, thus increasing the chance of leaks and posing health risks. In addition, over half of the states are not inspecting all of their tanks at the minimum rate of at least once every three years recommended by EPA (U.S. GAO 2001, and 2003). This implies that even if the backlog of all known sites is eliminated, there are likely to be additional releases at some sites in the future.

- GAO also estimates that 11 percent (76,000) of the active regulated tanks that states monitor and 30 percent of tanks on tribal lands, may not be upgraded (U.S. GAO 2003). Most of these tanks are believed to be empty or inactive. States reported to GAO that they generally do not discover tank leaks or contamination around tanks until the empty tanks are removed from the ground during replacement or closure. Thus, there is a backlog of potentially contaminated sites that may be discovered over a period of time as they are replaced or removed.

- Despite the upgraded equipment, a number of states reported to GAO that upgraded tanks leaked. GAO cites that researchers have concluded that tanks with upgraded equipment and monitoring systems do not provide complete protection against leaks. However, the extent of this problem is unknown.

5.2.2 State Regulations and Funding Sources

Some states have promulgated requirements that are more stringent than the federal standards, such as a requirement for double-lined tanks, more stringent monitoring procedures, or earlier upgrading compliance dates.

The pace of the cleanups is affected by the availability of funds to pay for cleanups and oversight. UST cleanups are primarily financed from three sources:

- The federal Leaking Underground Storage Tank Fund (LUST Trust Fund). Revenues from the fund are derived from a gasoline tax of 0.1 cent per gallon. Appropriations from the fund have been about $70-80 million annually.[1]

- State tank trust funds or direct appropriations are generally used to assist owners and PRPs in paying for cleanups. A number of these are also financed by gasoline taxes. Between 1999 and 2003, the annual revenues of these funds averaged $1.3 billion and they paid out an average of about $1.1 billion annually.

- PRPs and site owners.

State Tank Funds 1999-2003 (Billions of Dollars)

	1999	2000	2001	2002	2003	Average
Revenues	1.38	1.19	1.21	1.34	1.37	1.30
Approximate amount paid	0.70	1.49	0.68	1.49	1.16	1.10

Source: Association of State and Territorial Solid and Hazardous Waste Management Officials, *State Fund Survey Results 2003.*

EPA regulations that limit the liability of lenders for corrective action in many situations help to encourage the extension of credit to credit-worthy UST owners. The availability of credit to UST owners, especially the many small businesses that operate USTs, is necessary to assist them in meeting their obligations to upgrade, maintain, and otherwise comply with RCRA Subtitle I and

[1] The gasoline tax is scheduled to expire in 2005. The federal LUST Trust Fund helps states oversee corrective action and pay for cleanups at UST sites where the owner or operator is unknown, unwilling, or unable to respond, or which require emergency action. Most of the money appropriated from the fund goes to states, which use the funds to oversee corrective action by responsible parties, to clean up sites where no responsible party can be found, and for enforcement and administration. As of the end of 2003, the balance was $2.1 billion.

related environmental requirements. Under these regulations, which were promulgated in 1995, any person or lending institution that guarantees loans secured by real estate containing an UST or UST system may not be liable for the required corrective action, so long as the lender is not otherwise engaged in petroleum production, refining, or marketing (U.S. EPA 1995b).

5.2.3 2002 Brownfields Legislation and EPA's USTfields Initiative

The 2002 brownfields law, titled "The Small Business Liability Relief and Brownfields Revitalization Act (P.L. 107-118)," and EPA's USTfields initiative may lead to an increase in the total number of UST sites identified as needing cleanup as well as the pace of cleanups. This potential increase would result from the increased number of site assessments completed. The increased pace of cleanups could result from additional funds made available under the new law.

As many as 200,000 of the estimated 500,000 brownfield sites across the country are impacted by petroleum leaking from USTs, and many of these sites are gas stations that have shut down because they could not comply with the 1998 federal UST upgrade requirements (NEMW 2001). These properties pose threats to public health and the environment, and pose challenges for the redevelopment plans of the communities in which they are located.

Many UST cleanups are funded using state assurance funds, which usually do not have sufficient money to clean up all of the eligible sites in a given year. This scarcity of money has contributed to the backlog of over 136,000 sites nationwide that have not completed cleanup. The new brownfields law may help address this backlog. This law expands the current EPA Brownfields program and for the first time, allows "low-risk" petroleum sites to be eligible for assessment and cleanup grant funding under the Brownfields program. Prior to the new law, petroleum contamination was not eligible for Brownfields funding. The law authorizes up to 25 percent in grant awards annually through 2006 for the assessment and cleanup of brownfields contaminated with petroleum. In FY 2003, EPA awarded 103 new Brownfield Petroleum grants totaling $22.3 million. This new authority builds upon and complements EPA's USTfields Initiative, which addressed "high-priority" petroleum-contaminated properties and awards funds to states, tribes, and intertribal consortia. Under the USTfields Initiative, $4.8 million in grants were awarded to 36 states and three tribes to cleanup properties contaminated from leaking USTs. Although no further USTfields grants are planned, the petroleum grants under the Brownfields program continues to encourage further site assessments, cleanup, and redevelopment.

5.2.4 MTBE Contamination and the Remediation Market

Concerns about methyl tertiary-butyl ether (MTBE) contamination may influence the amount and timing of UST cleanups in some states. According to a 2003 survey of 50 states conducted by The New England Interstate Water Pollution Control Commission (NEIWPCC 2003), MTBE is detected in gasoline releases to groundwater 60 percent of the time, averaged among the states. Most states do not intend to open closed sites to look for MTBE or tertiary-butyl alcohol (TBA), unless they have reason to suspect a problem. Most states say there are very few cases where MTBE is the only concern. Thirty-three states say that MTBE drives cleanup and investigative efforts less than 20 percent of the time, or never. BTEX and free-product is the primary remediation driver in these states. In most states, less than 10 percent of the sites have situations where BTEX has been successfully remediated but MTBE remains.

Nevertheless, some states, such as California and New York, indicated that MTBE contamination drives remediation at LUST sites more than 80 percent of the time. Connecticut, Maryland, Nevada, and New Jersey indicated that MTBE drives remediation more than 60 percent of the time; Maine and New Hampshire indicated that MTBE drives remediation more than 40 percent of the time; and Delaware and Vermont indicated that MTBE drives remediation more than 20 percent of the time.

In this survey, Delaware indicated that the threat of lawsuits is a potential driver for remediation at sites where MTBE contamination is present. Illinois indicated that once it adopts new legislation to address MTBE contamination, it expects to see an increase in the number of LUST remediation cases at sites where MTBE is the only concern. New York indicated that its high percentage of sites where MTBE is the only concern is a reflection of the fact that more than 193 spills have impacted more than 860 private water supply wells, requiring alternate water supplies.

5.2.5 State Performance-Based Environmental Cleanup Programs

Traditionally, environmental cleanups have been completed using time and materials (T&M) reimbursable contracts. Under these T&M cleanups, contractors bill their clients for hours worked and the cost of materials. Historically, these types of contracts provide very few incentives for contractors to meet any performance standards and conduct the cleanup in a timely and cost effective manner. In addition, there is little incentive for contractors to use the best technologies or to develop innovative practices.

Many states are moving toward performance-based cleanup programs to reduce cleanup costs and improve accountability for cleanup performance at UST sites. These “Pay For Performance” (PFP) contracts include the following basic elements: 1) a firm fixed price; 2) a fixed time limit for achieving the environmental goals of the cleanup; 3) cleanup goals specified in terms of specific contamination levels detected at specific locations; 4) criteria for system start-up and contamination reduction milestone payments, including closure; 5) provisions for the state to take additional contamination measurements at its own expense and discretion; and, 6) escape clauses specifying conditions under which the contractor can be released from the contract. Useful information on the background of pay-for-performance and implementation tools are available on the U.S. EPA web site. http://www.epa.gov/swerust1/pfp/

States with experience using both T&M and PFP contracting report that LUST site cleanups are being done faster and cheaper at PFP sites. In addition, state officials report a greater use of innovative cleanup technologies and more aggressive approaches to cleaning up “hot spots” at PFP sites. States also have reported that their paperwork burden is reduced substantially under PFP because they no longer monitor the details of a contractor's expenditures. Oklahoma estimates that $6,629,000 of unnecessary expenses were incurred prior to obtaining cleanup guarantees using its Pay-For-Performance program (Oklahoma, 2001).

Contractors who conduct PFP cleanups have the opportunity to realize greater profit under a PFP contract than under a T&M contract because the contractor assumes some of the risk of the cleanup. PFP frees them to manage their sites more efficiently, lowers paperwork costs, allows the contractor to purchase equipment that can be reused on other jobs, and allows the government to pay the contractor in a more timely manner. In fact, PFP contractors in pioneering states, such as California, Florida, South Carolina, and Oklahoma, are generally doing quite well and most are looking for more PFP business.

The cost savings associated with PFP programs can be leveraged to conduct more cleanups in states with PFP programs. In addition, PFP programs encourage the use of innovative technologies, which may help drive the market for some newer remediation technologies applicable to LUST sites.

5.3 Number and Location of USTs

The data on the number and status of currently registered USTs are derived from data that EPA compiles semi-annually from reports it receives from 56 states and territories. The states compile their data from information received from tank owners. Reporting quality varies from state-to-state and has resulted in some under-reporting of the number of tanks subject to the regulations. EPA estimates that there is an average of 2.65 tanks per UST site, although this number actually varies widely from one site to another.

5.3.1 Population of UST Sites in the U.S.

The number of potential corrective actions are related to the population of active and closed tanks subject to the federal regulations. EPA reports that as of March 31, 2004, 679,249 active tanks and 1,582,638 closed tanks have been registered in the U.S. (U.S. EPA 2003d). Nearly all contain petroleum. These sites include marketers who sell gasoline to the public (such as service stations and convenience stores) and non-marketers who use tanks solely for their own needs (such as fleet service operators and local governments). EPA estimates about 25,000 tanks hold hazardous substances covered by the UST regulations. Using EPA's estimated average of the 2.65 tanks per site, over 256,000 active sites with USTs are subject to the UST corrective action regulations.

In 1988, EPA estimated that there were between 5 and 7 million USTs (U.S. EPA 1988). Taking the midpoint of this range implies a total UST population of 6 million, of which 2.2 million active and closed USTs are currently subject to the regulations. The remaining 3.8 million tanks are exempt from the federal regulations and are not included as part of the market for remediation services in this report. Section 5.1 identifies the seven exempt categories of tanks. Although the exempt tanks are not quantified in this report, they nevertheless represent a potential for cleanup work in selected states where state regulations include some federally exempt tanks.

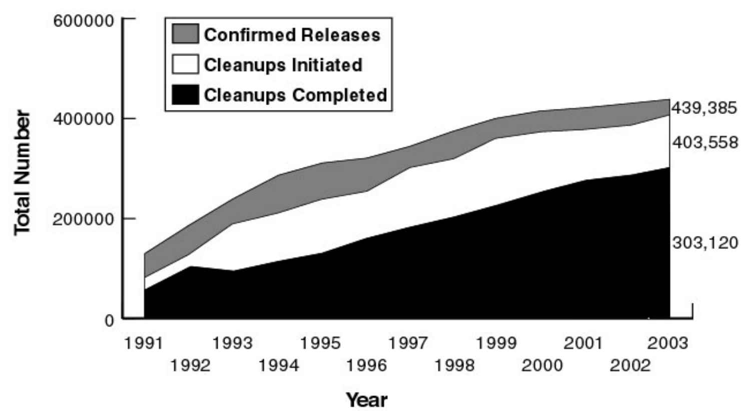
5.3.2 Location of Regulated Tanks

Appendix B lists the number of regulated tank sites by state, as reported to EPA in September 2003. Texas, California, Florida, New York, North Carolina, Michigan, Illinois, and Pennsylvania contain almost 40 percent of all active and closed tanks. The location data should be used with caution because a state's tank population may not be correlated with the number of releases, and cleanup program requirements, reporting practices, and data quality vary by state.

5.3.3 Potential Number of Sites to be Cleaned Up

By September 2003, 439,385 confirmed releases were reported to EPA. Remedial design or remedial action had been initiated at 403,558 sites and completed at 303,120 (Exhibit 5-4). Thus, cleanup has not been completed at 136,265 sites. Of these, cleanup has been initiated at 100,438 sites and no cleanup action has been taken at the remaining 35,827 sites. A cleanup is considered "initiated" if a state or responsible party has evaluated the site and initiated one or more of the following five types of activities: management of contaminated soil, removal of free-product, management or treatment of dissolved petroleum contamination, monitoring of the groundwater or soil being remediated by natural attenuation, or the state has determined that no further actions are necessary to protect human health or the environment. At this stage, some physical activity (such as pumping, soil removal, recovery well installation) has usually begun at a site. Thus, the term "cleanup initiated" covers a range of situations. EPA's data does not indicate the extent of work done. Although many of these sites have substantial amounts of work yet to be done, including these sites in the market for future cleanup work may overstate somewhat the true market potential. Remediation contractors for some of these sites may already have been selected.

Exhibit 5-4. UST Site Cleanup Progress 1991-2002



Source: U.S. EPA, Office of Solid Waste and Emergency Response, FY 2003 Semi-Annual End-of-Year Activity Report, November 25, 2003.

The total number of UST sites to be cleaned up in the future includes the already identified sites plus sites that will be reported in the future due to new releases or existing releases that have not yet been reported. Exhibit 5-5 displays the estimate of the number of UST sites likely to be cleaned up in the future. This exhibit, which uses data as of March 31, 2004, shows that there are 34,734 already confirmed releases for which cleanup has not begun (EPA 2004). In addition, as stated previously, there are likely to be new releases reported due to leaks in the future. The number of projected future releases can come from the active tank universe, the inactive universe, and unregulated tanks. There are numerous abandoned and empty tanks, many of which are not identified, that may need to be cleaned up. The estimated number of future UST site discoveries is based on the annual rate of new releases in recent years and the assumption that this rate will continue for 10 years. Although tank releases may continue beyond 10 years, and leakage rates may decline, these scenarios are not included because of uncertainties in predicting these trends.

Exhibit 5-5. Estimated Number of UST Sites Needing Remediation

	Reported to EPA Through 3/31/04	Estimated Future Releases (2004-2033) [a]	Total [b] (2004-2013)
Confirmed Releases	443,568	60,000 - 120,000	503,568-563,568
Cleanups Completed Through March 31, 2004	311,125	NA	311,125
Cleanups Initiated but Not Completed as of 3/31/04 [c]	97,709	NA	97,709
Releases Reported as of 3/31/04, but cleanups not initiated	34,734 [d]	NA	34,734
Future Cleanups Required, but not initiated (2004 -2033)	34,734 [d]	60,000 - 120,000	94,734-154,734 [c] (Average 124,734)

Notes:
NA Not applicable
a Assumes 6,000-12,000 confirmed releases annually for 10 years, which is the range for 2001, 2002, and 2003.
b Although tank releases may continue beyond 10 years, and leakage rates may decline, these scenarios are not included because of uncertainties in predicting these trends.
c Some of these sites may have designated cleanup contractors and some do not, but the number that already have contractors is unknown. To allow for a conservative market estimate, it is assumed that they all have selected contractors.
d This figure is derived by subtracting "cleanups initiated" and "cleanups completed" from "confirmed releases."

Between 2001 and 2003, the number of confirmed releases ranged from over 6,000 to over 12,000, with no specific increasing or decreasing trend (although these figures are about half what they were in 1998). Based on these figures, it is estimated that an average of 6,000-12,000 new releases will be reported per year over the next 10 years. Thus, an estimated 94,734-154,734 sites will need to be remediated over at least 10 years, with a middle value of 124,734.[2]

Although the size of the entire market has been estimated, the year-to-year fluctuations in cleanup efforts are difficult to predict. The difference between confirmed releases and cleanups initiated has averaged over 47,000 for the past four years. Exhibit 5-4 shows the comparison between the number of confirmed releases and cleanups initiated each year. During the first half of FY 2004, about 8,000 cleanups were completed. However, the year-to-year fluctuations in activity would depend upon the factors discussed in Section 5.2, such as the availability of private and public funds and real estate development activity.

2 6,000-12,000 X 10 years + 34,734 backlog as of March 31, 2004.

5.4 Estimated Cleanup Costs

Site characterization and cleanup costs vary widely from one site to another and EPA does not have a precise average cost per site.[3] Nevertheless, EPA estimates that the average remediation cost per site is $125,000. This cost estimate typically includes activities such as site investigations, feasibility studies, and treatment or disposal of soil and groundwater. Multiplying this average by the number of sites that will need remediation (94,734–154,734), the projected total remediation cost is $11.8–19.2 billion (average $15.6 billion). The presence of MTBE or other factors that may make remediation more difficult at these sites can boost the remediation cost (See section 5.2.3).

5.5 Market Entry Considerations

The following factors will be important to the success of vendors operating in the UST remediation market.

- Site work is primarily the responsibility of owners and operators of establishments such as retail gasoline stations, petroleum and chemical marketing operations, fleet maintenance and auto repair shops, and manufacturing or transportation facilities.

- Most work is contracted locally. However, some large firms and government agencies will use national contractors. Many of the national contractors tend to subcontract to local firms.

- States also issue contracts to cover large areas over a period of time for work done directly by the states.

- EPA is responsible for administering the program on tribal lands.

- The level of enforcement activity varies from one state to another. In addition, some states regulate tanks that are not regulated under RCRA. Information on these activities generally are available through state authorities. An indication of a state's commitment to its tank program can be obtained from its compliance rate with federal tank standards. EPA publishes a semi-annual report on its web site which provides the percent of tanks in each state that are in significant operational compliance with federal release prevention requirements and with leak detection requirements (U.S. EPA 2003c, 2004b).

- As tank testing and other requirements are implemented, the extent of cleanup activities and costs per site probably will decrease. Thus, economical ways to remediate smaller releases may be needed.

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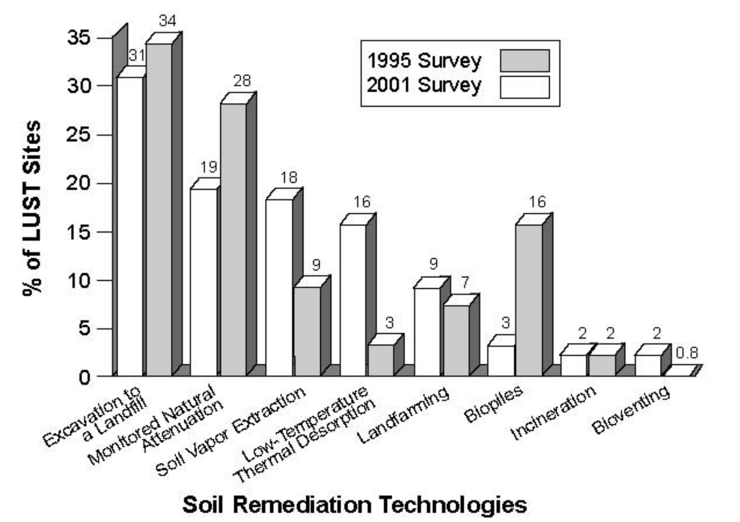
[3] Based on a review of literature and data, the University of Tennessee reported that the cost of remediating UST sites had varied widely, generally between $2,000 to over $400,000. Costs at individual sites can exceed a million dollars (Bueckman & Russell, 1991). If only a small amount of soil needs to be removed or treated, cleanup costs can run as low as $10,000. Corrective action for leaks that affect groundwater can cost from $100,000 to over $1 million, depending on the extent of contamination.

5.6 Remediation Technologies

Data on the kinds of innovative technologies used to remediate contaminated UST sites have not been centralized. However, a survey conducted in 2001 by the University of Massachusetts provided information on the use of remediation technologies for contaminated groundwater and soils at LUST sites (Kostecki and Nascarella 2001). Thirty five states responded to this 12-question survey. The questions dealt with the types of technologies used, use of technologies by site, changes in technology use over time, barriers to implementation, and the impact of monitored natural attenuation. The survey results were compared with similar data collected from 45 states in a 1995 University of Massachusetts survey. Comparisons were made based on a percentage of total sites for each survey (Exhibit 5-6).

Exhibit 5-6. Types and Frequencies of Soil Remediation Technologies at LUST Sites



Source: Kostecki, Paul and Marc Nascarella, "Lust Cleanup Landscape Changing: Landfilling Still In, Pump and Treat on the Way Out," ***Contaminated Soil Sediment and Water***, January/February 2003.

As the exhibit shows, landfilling continued to be the most frequently selected option for soil remediation at LUST sites (about one-third of the sites), although most environmentalists agree that it is not an ideal option because it transfers waste from one site to another. The percentage of UST sites using landfilling is considerably higher than occurs at NPL sites. Over the 2000 through 2002 period, only 23 percent of NPL sites used containment or off-site disposal (the data do not provide a separate figure for landfilling).

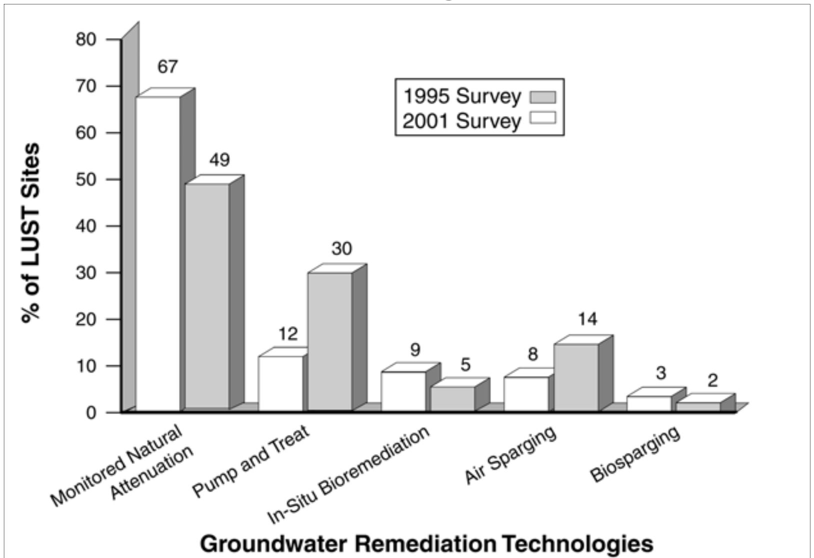
The next two most commonly used treatment technologies, soil vapor extraction (SVE) and low-temperature thermal desorption (LTTD), have grown in popularity between the 1995 and 2001 surveys. SVE use grew from 9 percent of LUST sites in 1995 to 18 percent in 2001. This is considerably greater than the SVE usage at NPL sites, where SVE was selected for only 8 percent of the sites between 2000 and 2002 (U.S. EPA 2004a).

The use of low-temperature thermal desorption (LTTD) at LUST sites has been growing steadily since the early 1990s. In a 1995 study, industry representatives reported that thermal desorption was only used on a limited basis in the early 1990s. By 1995 it was used at numerous sites in almost every state (Tremblay 1995). The 2001 data indicate that use of LTTD at LUST sites has continued to grow from 3 percent of sites in 1995 to 16 percent in 2001. This is considerably higher than the usage rates at NPL sites (11 percent of NPL sites between 2000 and 2002 used either low- or high-temperature thermal desorption).

Although monitored natural attenuation (MNA) and biopiles showed great promise for remediating soil at LUST sites in the early 1990s, their use declined from 28 to 19 percent and from 16 to 3 percent, respectively between 1995 and 2001. The decline in biopile use could be attributed to a lack of confidence in the technology while the decline in MNA is attributed to the fact that this method of cleanup takes too long and partly to an EPA Office of Solid Waste and Emergency Response (OSWER) directive, *The Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tanks Sites*. During the same period, the use of landfarming increased by 2 percent. It remains as popular in 2001 as it was in 1985 (Kostecki & Nascarella 2003).

The 2001 survey results indicate that MNA continues to be the most common option for remediating groundwater at LUST sites (Exhibit 5-7). Between 1995 and 2001, MNA use grew from 49 to 67 percent of sites while the use of pump and treat declined from 30 to 12 percent. The MNA usage rate is substantially higher than that of NPL sites. MNA-only RODs have hovered around 20 percent of groundwater RODs between 1999 and 2001, and dropped to only 7 percent in 2002. Pump and treat, which has been selected at 67 percent of NPL sites between 1982 and 2002 (U.S. EPA 2004a), has been declining at LUST sites (from 30 percent in 1995 to 12 percent in 2001). The decline of pump and treat may be attributed to the fact that it takes a long time to achieve cleanup goals, it has been demonstrated to spread contamination in some cases, and it is expensive to operate and maintain.

Exhibit 5-7. Type and Frequency of Groundwater Remediation Technologies at LUST Sites



Source: Kostecki, Paul and Marc Nascarella, "Lust Cleanup Landscape Changing: Landfilling Still In, Pump and Treat on the Way Out," *Contaminated Soil Sediment and Water*, January/February 2003.

In-situ bioremediation and air sparging are the other two most common technologies used at LUST sites (Kostecki & Nascarella 2003). Bioremediation use at LUST sites is significantly lower than at NPL sites (9 percent in 2001 compared to a range of 8 to 36 percent of NPL sites between 1997 and 2002).

The results of the 2001 survey indicate that, except for low-temperature thermal desorption, the older soil remediation technologies such as SVE and landfarming, are growing in popularity for soil remediation, while MNA continues to grow as the technology of choice for groundwater remediation. An interesting result of this study is that no new soil- or groundwater-remediation technologies has been developed in the past decade, according to respondents in 35 states.

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Chapter 6
Demand for Remediation of Department of Defense Sites

The Department of Defense (DOD) has undertaken the task of cleaning up wastes that have resulted from numerous industrial, commercial, training, and weapons activities, as well as cleaning up closing military bases so that the properties can be transferred to local communities for economic revitalization. DOD has estimated that of the approximately 9,000 sites it has remaining in the cleanup process or with future preliminary assessment starts planned, almost 6,400 of these sites have yet to start and/or complete evaluation and more than 2,600 sites have remedial design or other remedial action underway or planned for future completion. These sites contain hazardous waste contamination involving soil, groundwater, and other media. Typical contaminants include petroleum products, solvents, heavy metals, explosives and munitions residue, polychlorinated biphenyls (PCBs), and pesticides.

Over more than two decades, DOD has made considerable progress in locating, investigating, and cleaning up thousands of contaminated sites. DOD has identified more than 30,000 sites on over 1,700 installations. Of these, over 21,000 sites were cleaned up or found to require no further remedial action. To address sites in its cleanup program, DOD uses a prioritization scheme for sequencing work based on the relative risk of individual sites. Under this management approach, decisions regarding such issues as cleanup standards, remedy selection, and no further action determinations are made site-by-site rather than for an entire installation. Decisions on these issues are made on a risk management approach that considers the relative threat to human health and the environment, reasonable anticipated land use, cost-effectiveness, and speed of cleanup, and depend on early and meaningful public participation. DOD works with the regulatory agencies and other interested parties to streamline and find economies in the environmental restoration process.

Highlights
- Approximately 9,000 DOD sites remain in the remediation process.
- DOD estimates that it will cost $16.4 billion to complete cleanup of its active installations, BRAC and FUDS sites.
- An additional $16.8 billion is projected for Military Munitions Response sites. The full scope of MMRP cleanup is still uncertain.
- DOD estimates that it will complete remediation of all of its sites up by 2015.
- Achieving the above goals is contingent upon receiving adequate funding.
- An additional round of base closures and realignments scheduled to begin in FY 2005 could alter the sequence of the cleanup effort.
- The nature and magnitude of contamination at some sites have yet to be determined.

To accomplish site characterization and cleanups, DOD needs the services of firms that can clean up wastes similar to those found at private sector industrial facilities as well as firms that can remediate wastes that are unique to DOD, such as unexploded ordnance (UXO). These environmental service firms will have to understand DOD operating procedures and keep abreast of the overall direction of its environmental programs.

6.1 Program Description

The DOD created the Installation Restoration program (IRP) in 1975 to investigate and remediate contaminated sites resulting from past DOD activities. The Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), and the Resources Conservation and Recovery Act (RCRA) are the primary federal laws that govern the identification, investigation, and cleanup of DOD contaminated sites. Congress formally established the Defense Environmental Restoration Program (DERP) and its funding mechanism, the Defense Environmental Restoration Account (DERA) in 1986. DERP uses the CERCLA framework for DOD cleanup. Also during the 1980s, Congress recognized the need to close or reduce the size of many installations, and authorized four rounds of base realignment and closures (BRAC) in 1988, 1991, 1993, and 1995 (U.S. Congress, 1998). The FY 2002 Defense Authorization Act authorized another round of closures for FY 2005.

DOD installations typically have multiple contaminated sites regulated by CERCLA, RCRA corrective action provisions, RCRA underground storage tank (UST) provisions, or all three. Through Executive Order 12580, signed in January 1987, the President delegated to the Secretary of Defense Presidential CERCLA authorities for investigation and cleanup measures for releases of hazardous substances from facilities under the jurisdiction of the Secretary. The interface between CERCLA and RCRA authorities is determined by the circumstances at specific sites, including factors such as the source and cause of the contamination, the status of the installation as either a National Priorities List (NPL) or non-NPL site, and whether the installation has or is seeking a RCRA permit to manage hazardous wastes. DOD cleanups must also consider the requirements of state laws and the BRAC acts. Partnering efforts allow DOD, EPA, and the states to reconcile overlaps and inconsistencies in regulatory requirements to ensure the most effective and timely cleanups. A detailed description of their remediation programs is included in the *Defense Environmental Restoration Program Annual Report to Congress* (U.S. DOD, 2002a).

The implementation process for the DOD cleanup program generally follows those of the environmental statutes. Although the regulatory framework of CERCLA and RCRA differ in many ways, their implementation processes generally parallel one another. Each requires assessments and investigations to determine the need for cleanup, and the selection and design of appropriate remedies to ensure protection of human health and the environment. However, each program has its own nomenclature for the various phases of study, design, and cleanup.

6.1.1 Installation Restoration Program

DERP is the DOD program for the evaluation and cleanup of past contamination at DOD sites. The Deputy Undersecretary of Defense for Installations and Environment or ODUSD (I&E) oversees environmental restoration activities, including work conducted at BRAC installations.

DOD refers to the program for meeting its responsibilities under CERCLA as the IRP. Under IRP, DOD cleans up all contaminated sites for which cleanup is required by environmental statutes, whether or not the sites are on the NPL. Although policy direction and oversight of IRP are the responsibility of the ODUSD (I&E), each individual DOD Component (Army, Navy, Air

Force, and Defense Logistics Agency) is responsible for program implementation. The Army Corps of Engineers (Corps) is the execution agent for all Formerly Used Defense Sites (FUDS) as well as for the Defense and State Memorandum of Agreement (DSMOA) program which funds states and territories for technical services they provide to support the cleanup of DOD facilities. In 2001 DOD established the Military Munitions Response Program (MMRP) to manage cleanup of unexploded ordnance (UXO) and waste military munitions (WMM) at areas other than operational ranges. The DERP Management Guidance (U.S. DOD, 2001a) defined and established the MMRP, laying out specific requirements for the DOD components.

Each installation works toward completing its environmental restoration requirements by developing and maintaining a management action plan (MAP) or a base realignment and closure (BRAC) cleanup plan (BCP). A MAP contains information about an active installation's past activities and current status, presents a vision for future site-level requirements, establishes schedules, and identifies future funding requirements through completion. A BCP is the equivalent document for an installation undergoing base closure and transfer of property to the community. Each installation updates its MAP or BCP at least once a year.

DERP has specified procedures for evaluating sites and procuring cleanup services under the IRP that conform to the regulatory requirements of the National Oil and Hazardous Substances Contingency Plan (NCP). These procedures cover all the phases of site operations, including preliminary assessment (PA), site inspection (SI), remedial investigation/feasibility study (RI/FS), remedial design (RD), and remedial action (RA). In most cases, activities related to preliminary assessment through remedial design are conducted by different contractors than are those related to remedial action. Activities conducted under IRP are classified as follows:

- Investigation: Analysis to characterize the nature, extent, and risk of releases of hazardous substances to the environment and to develop and select cleanup remedy.

- Interim Action: Early measure to reduce the risk of releases of hazardous substances before the initiation of more complicated, comprehensive, and long-term cleanup remedies. For example, placing fences around contaminated areas or removing and treating or disposing of contaminated soil.

- Design: Performance specifications or detailed engineering plans and specifications to construct and implement a final cleanup remedy.

- Cleanup: Action to construct and implement a final cleanup remedy.

In selecting and designing remedies at NPL sites, DOD officials coordinate with EPA regional officials to ensure that cleanup goals meet regulatory requirements. Most contracting is done by installations, either through centralized contracting service centers or directly with the installation. Although the DOD Components follow the general procedures specified by DERP, each DOD Component procures its own cleanup services. Section 6.5 describes typical procurement practices.

6.1.2 Base Realignment and Closure (BRAC)

Additional procedures and expedited timetables have been established for the cleanup of bases being closed or realigned. These procedures, known as DOD's Fast Track Cleanup Program, have influenced the sequence of work to be conducted. This BRAC cleanup approach balances reuse needs and priorities with environmental requirements in prioritizing and sequencing cleanup of sites. In the past, most restoration projects included the same overall cleanup time line for an entire installation, regardless of the relative threat to human health and the environment that individual sites caused. In implementing the relative risk approach, DOD is working with EPA, the states, and the public to review the prioritization process.

A major influence on the selection of projects for remediation is DOD's effort to speed the economic recovery of communities with closed installations. In prioritizing sites and developing cleanup plans DOD considers the potential for local job creation and economic development, and the accelerated pace of site investigation, evaluation, and cleanup efforts. The key features of the program are:

- A BRAC Cleanup Team (BCT) is established at each installation slated for closure, to enhance environmental decision-making at the installation. Each BCT includes representatives from the installation, state environmental regulatory agency, and EPA Regional Office. These teams have the authority, responsibility, and accountability for environmental restoration programs at those installations.

- A BRAC Cleanup Plan (BCP) is prepared for each installation slated for closure and updated annually to reflect new information and changing conditions. The BCP serves as a comprehensive and consolidated statement of the status of the installation and strategy to expedite its cleanup. The BCT is responsible for the preparation of this plan.

- A Restoration Advisory Board (RAB) is established in communities where interest is sufficient to warrant it. RABs are intended to bring together people who reflect diverse interests within the community, in order to foster the early and continual flow of information between the affected community, the installation, and the state and federal regulatory agencies (U.S. DOD, 1994).

- An Environmental Baseline Survey (EBS) is conducted for each closing installation, as mandated the Community Environmental Response Facilitation Act (CERFA), which is an amendment to CERCLA. The CERFA requires DOD to identify and document all uncontaminated parcels of land and installations undergoing closure. These properties quickly can be turned over to communities for economic reuse.

The BRAC environmental program encompasses more than environmental restoration efforts. BRAC environmental funding also addresses closure-related environmental compliance, which includes such actions as the removal of USTs, closure of hazardous waste treatment, storage, and disposal facilities (TSDFs), radon surveys, and asbestos abatement.

6.1.3 The Military Munitions Response Program

Decades of military training, weapons system testing, and munitions production has resulted in the presence of UXO, discarded munitions, and munitions residue on ranges where training and testing occurred. In addition, excess, obsolete, and damaged munitions have been disposed of at numerous military installations. In 2001 DOD established the Military Munitions Response program (MMRP) to manage the cleanup of UXO, waste military munitions (WMM), and chemical residues of munitions at areas other than operational ranges. DOD has been addressing these issues since the inception of the IRP and will continue to conduct some incidental munitions response activities under the IRP. Sites within the MMRP are those where the firing or disposal of munitions has occurred during training exercises and were not addressed under the IRP. The 2001 Management Guidance for the Defense Environmental Restoration Program defines the requirements for the MMRP. The guidance specifies the eligibility, identification, characterization, tracking and reporting on munitions response sites that is similar to the IRP, including adding the MMRP data in the Restoration Management Information System (RMIS) database.

6.2 Factors Affecting the Demand for Cleanup

The following factors could alter the scope of the cleanup as well as the technologies used:

- The pace of remediation is subject to change in response to budgetary and political developments. The entire FY 2003 DOD budget for environmental restoration is approximately $2.07 billion. Of these funds, $760.6 million, or approximately 37 percent, represent BRAC funds (U.S. DOD, 2004).

- The proportion of the environmental restoration budget allocated for cleanup at active installations and FUDS continues to increase while study and investigation funding decreases. The FY 2003 budget obligated approximately 59 percent of the funds to cleanup and 26 percent to studies and investigations. The FY 2005 planned budget estimates that approximately 70 percent of the funds will go toward cleanup.

- Although DOD believes that most sites have been located, new sites continue to be identified. The recently established MMRP may impact on the number of new sites.

- DOD classifies all IRP sites in terms of a relative-risk framework, evaluating each site based on three factors: the nature and extent of the contaminant, the potential for it to migrate, and receptors that could be impacted by the contamination. The resulting evaluation is not an estimate of absolute risk or a substitute for a baseline risk or health assessment. It serves as a basis for discussing the relative risk of sites with involved stakeholders.

- In determining the priorities for funding at all sites, DOD generally addresses the worst sites first. The projected time line for the remediation of high relative-risk sites is significantly shorter than the time lines for medium or low risk sites. As of the end of FY 2002, DOD has achieved its goal of reaching remedy in place (RIP) or response complete (RC) status at 50 percent of its high-relative risk sites. In implementing its priorities, DOD may assign varying levels of priority to different sites on a given installation. This policy may lead to acceleration of some projects at a given installation while other projects at the same installation are postponed.

- At closing installations, DOD has been working to complete remediation at all of the current BRAC sites by the end of FY 2005. However, the department does not anticipate reaching this goal. It does expect to achieve RIP or RC at 83 percent of BRAC IRP sites. In addition, for the FY 2005 round of closures the schedule and sequencing of sites may change at the affected installations.

- DOD policy calls for extensive consultation with EPA, state environmental authorities, local communities, local planning authorities, and other interested parties in planning and implementing its cleanup programs. These requirements may influence the sequence of work and types of technologies selected for a site.

- Changes in regulatory requirements also may affect cleanup goals, technologies used, and cost.

- Cleanup requirements at many identified sites are uncertain because the nature and magnitude of contamination is only partially known. As DOD continues to characterize the contamination problem and accumulate data from site investigations, cleanup needs will become more clearly defined.

6.3 Number and Characteristics of Sites

Site characteristics data presented in this chapter are based on information in the *Defense Environmental Restoration Program: Annual Report to Congress for Fiscal Year 2003* (U.S. DOD, 2004) and an analysis of DOD's Restoration Management Information System (RMIS), which is an important tool DOD uses for program management and oversight. RMIS contains data provided by the Components on the status of DOD sites for which they are responsible (U.S. DOD, 2001b). This report uses data from two separate tabulations of RMIS data – one based on the program status as of September 30, 2003 and one based on the program status as of September 30, 2001 (U.S. DOD 2004 and 2002a). The 2003 data are presented only at the total program and component levels. The 2001 data provide more detail regarding the types of sites, media, and contaminants being addressed by DOD.

6.3.1 Number and Types of Sites

As of September 30, 2003, DOD has identified 30,273 sites (including 3,091 sites on FUDS properties) located on over 1,700 installations and facilities, that have or had potential hazardous waste contamination involving soil, groundwater or other media. This total includes 2,817 MMRP sites, mostly on FUDS properties (U.S. DOD, 2004). Response actions were completed at 21,213 sites (18,584 sites on DOD installations and facilities and 2,629 FUDS). Of the remaining 9,060 sites (6,827 DOD sites and 2,233 FUDS sites, including MMRP) 6,396 were planning for or in various phases of investigation, and 2,664 are planning for or are in various stages of cleanup. The remaining sites also include 1,729 MMRP sites. Exhibit 6-1 shows the status of these sites by component. Exhibit 6-2 shows the breakdown of the 9,060 sites needing cleanup by component. The most significant change in number of sites between 2001 and 2003 is an almost 85 percent increase in the number of identified MMRP sites.

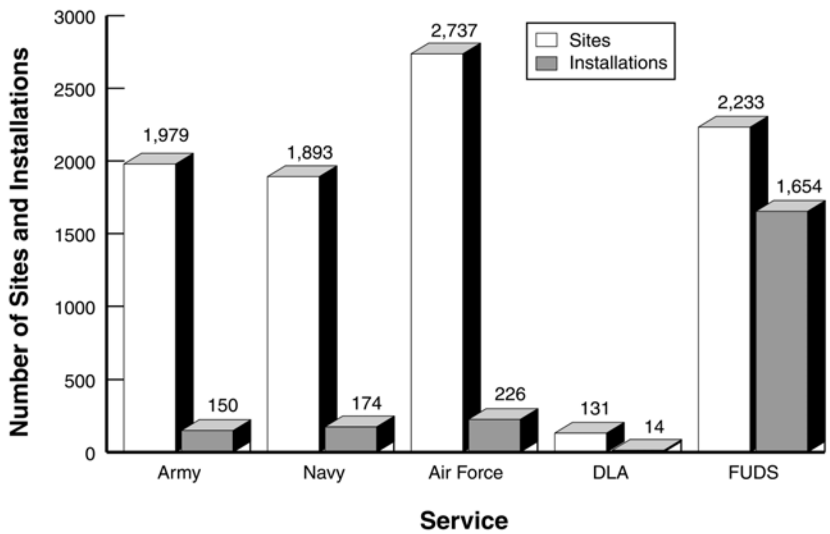
Exhibit 6-1. Number of DOD Sites by Status

DOD Component	Sites Identified			Responses Completed [a]	Sites Needing Cleanup [a]		
	IRP Sites	MMRP Sites	Total Sites		Cleanup Planned or Under way	Investi-gation Planned or Under way	Total
Army	12,266	560	12,826	10,927	398	1,501	1,899
Navy	4,715	225	4,940	3,220	536	1,184	1,720
Air Force	6,830	261	7,091	3,984	1,089	2,018	3,107
DLA	553	0	553	453	64	36	100
DTRA	1	0	1	0	1	0	1
FUDS	3,091	1,771	4,862	2,629	576	1,657	2,233
TOTAL	27,456	2,817	30,273	21,213	2,664	6,396	9,060

Notes:
[a] Includes MMRP sites
IRP = Installation Restoration Program; MMRP = Military Munitions Response Program
DTRA = Defense Threat Reduction Agency
Source: U.S. DOD, 2004, Defense Environmental Restoration Program, Annual Report to Congress, Fiscal Year 2003, Spring 2004

DOD derived the estimates on the types and characteristics of sites in the remainder of this chapter from a combination of data in RMIS, and information provided by the DOD Components as of September 30, 2001. Although the total number of sites in these tabulations is slightly lower than the FY 2003 sites indicated above, they depict typical DOD site characteristics. However, because SIs and RI/FSs have not been completed at a number of these sites, these estimates, as well as program cost estimates, may be revised either up or down over the next several years as more information becomes available. Exhibit 6-3 shows the geographic distribution of these sites, and Appendix Exhibit C-1 shows the breakdown by DOD component and state. California, with 2,011 sites has the most DOD sites needing cleanup.

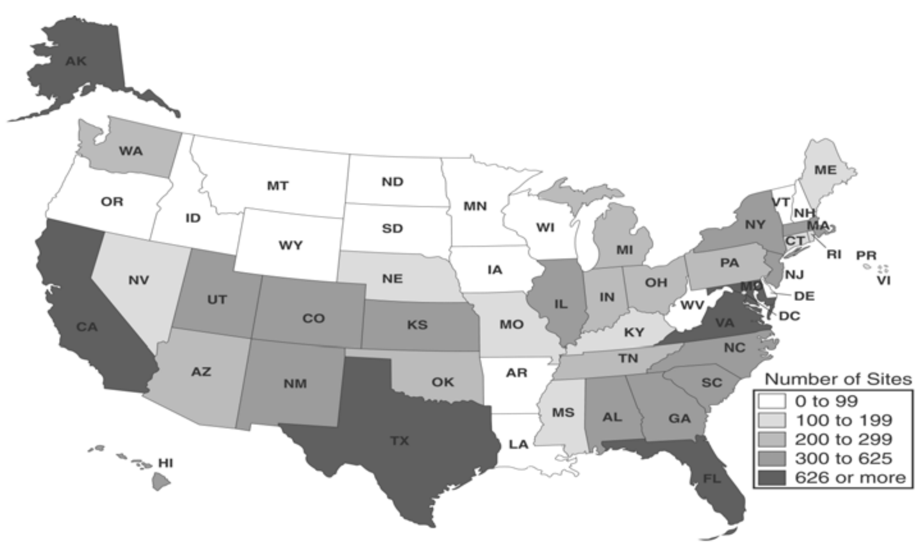
Exhibit 6-2. Number of DOD Sites and Installations Needing Cleanup



Note: Totals equal 8,974 sites and 2,218 installations to be remediated as of September 30, 2001. The number of installations is less than those appearing in Exhibit C-1 because some installations were included by more than one component.

Source: DOD, Office of the Deputy Under Secretary of Defense (Installations and Environment), Restoration Management Information System, November 2001.

Exhibit 6-3. Location of DOD Sites Needing Cleanup

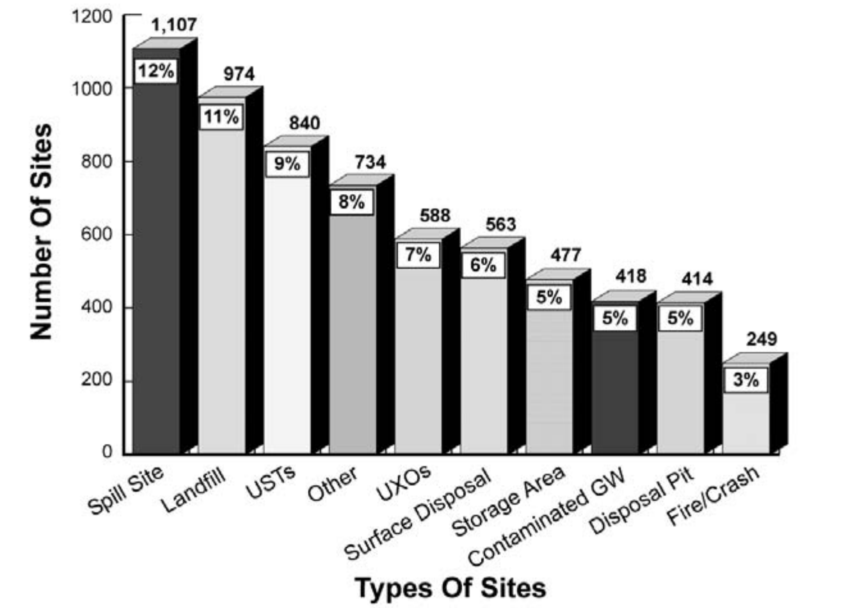


Notes: Total equals 8,974 sites to be remediated as of September 30, 2001. Appendix Exhibit C-1 provides the data by state and DOD component.

Source: DOD, Office of the Deputy Under Secretary of Defense (Installations and Environment), Restoration Management Information System, November 2001.

DOD categorizes its sites into 44 types, which are different than the site types used to categorize the NPL sites in Chapter 3 of this report. The DOD system of site nomenclature uses categories that include both activities and physical descriptions. Exhibit 6-4 shows the number of sites for each of the 10 most common site types that need cleanup. These sites account for 71 percent of all DOD sites needing remediation. Although some sites may have resulted from more than one type of activity, each site is counted in only one category. The definitions of all the site types are provided in Appendix Exhibit C-2. Appendix Exhibit C-3 details, by DOD Component, the number of each site type requiring remediation.

Exhibit 6-4. Most Common Types of DOD Sites Needing Cleanup



Notes: These 10 site types account for 6,364 (71%) of the 8,974 DOD sites to be remediated as of September 30, 2001. Appendix Exhibit C-2 gives definitions of the 44 site types. Appendix Exhibit C-3 lists the frequencies of all 44 site types.

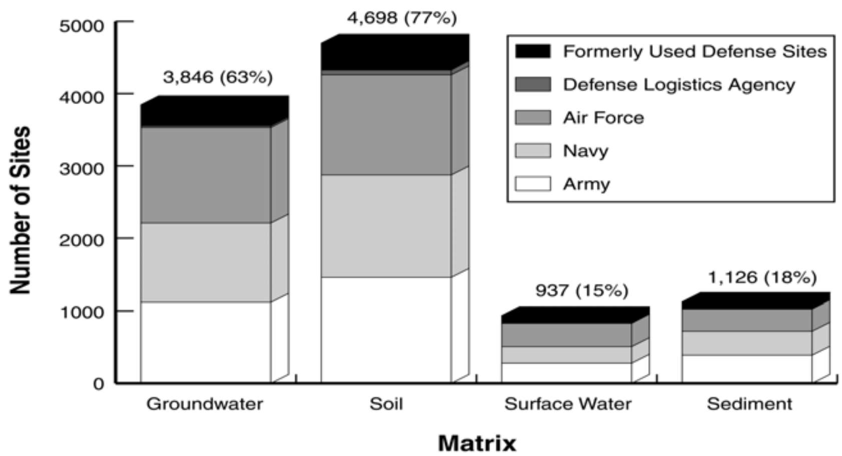
Source: DOD, Office of the Deputy Under Secretary of Defence (Installations and Environment), Restoration Management Information System, 2001.

6.3.2 Contaminated Matrices

Of the 8,974 sites estimated to need cleanup in FY 2001, data that identified the type of matrix (contaminated soil, groundwater, surface water, and sediment) were available for 6,119 sites, or 77 percent. Exhibit 6-5 shows, by DOD Component, the number of sites that contain each type of matrix. Sixty three percent of the sites have contaminated groundwater and 77 percent have contaminated soil. Contaminated surface water and sediment are associated with only 15 percent and 18 percent of the sites, respectively. The totals add to up to more than the number of sites, since a site may contain more than one type of contaminated media.

The relevant media vary from one site type to another (Exhibit 6-6). For example, contaminated groundwater was found at 85 percent of fire/crash area sites, but only 42 percent of the storage area sites. Likewise, 61 percent of underground storage tank sites had soil contamination, compared to 100 percent of pesticide shop sites and 91 percent of storage area sites. However, the amount of available data varies from one site type to another. Of the top 10 site types, data were available for a low of 9 percent of unexploded ordnance sites to a high of 91 percent of surface disposal areas. Appendix Exhibit C-4 provides the matrices associated with all 44 site types.

Exhibit 6-5. Frequency of Contaminated Matrices at DOD Sites Needing Cleanup



Notes: Based on 6,118 sites for which data were available as of September 30, 2001. Appendix Exhibit C-4 shows the breakdown of these data by site type. Appendix Exhibit C-5 shows the breakdown by DOD component.

Source: DOD, Office of the Deputy Under Secretary of Defense (Installations and Environment), Restoration Management Information System, November 2001.

Exhibit 6-6. Frequency of Contaminated Matrices by Site Type at DOD Sites Needing Cleanup

Site Type	No. of Sites	No. of Sites w/Data	Ground-water	Soil	Surface Water	Sediment
Spill Area	1,107	874 (79%)	58%	78%	12%	13%
Landfill	974	850 (87%)	74%	74%	27%	26%
Und. Storage Tanks	840	459 (55%)	80%	61%	5%	7%
Other	734	121 (16%)	8%	14%	2%	3%
Unexploded Munitions/Ord.	588	54 (9%)	5%	7%	2%	2%
Surface Disposal Area	563	512 (91%)	53%	82%	16%	22%
Storage Area	477	417 (87%)	42%	91%	10%	14%
Contaminated Groundwater	418	321 (77%)	90%	54%	17%	14%
Disposal Pit/ Dry Well	414	352 (85%)	54%	64%	13%	18%
Fire/Crash Training Area	249	208 (84%)	85%	85%	19%	19%

Notes: The 10 most common site types account for 6,364 or 71% of the 8,974 DOD sites to be remediated as of September 30, 2001. Appendix Exhibit C-4 lists the frequency of contaminated matrices for all 44 site types to be remediated.

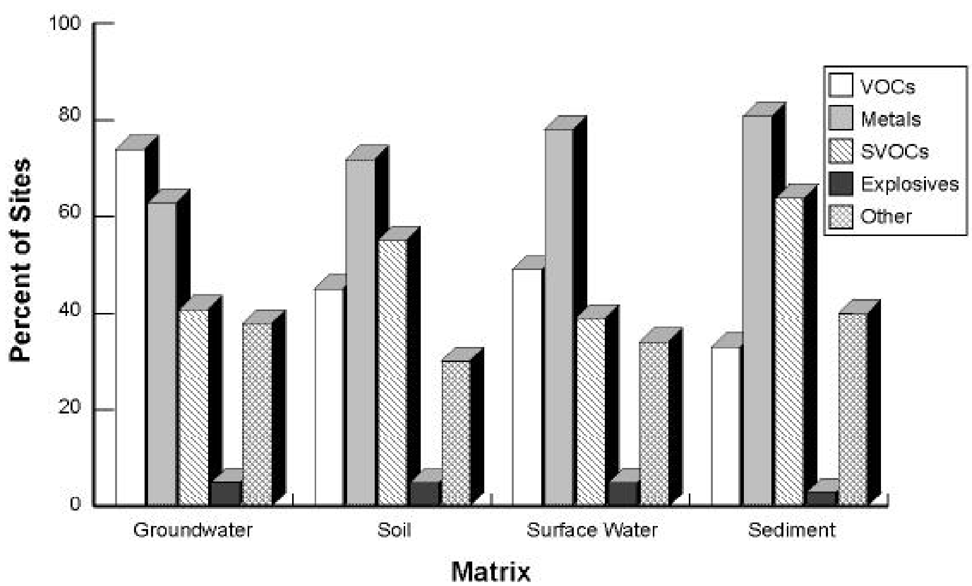
Source: DOD Office of the Deputy Under Secretary of Defense (Installations & Environment), Restoration Management Information System (RMIS), data as of September 2001.

6.3.3 Types of Contaminants

For this study, using available data, the contaminants were grouped into five categories: volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), metals, explosives and propellants, and "other." "Other" primarily includes inorganic elements and compounds such as asbestos, arsenic, inorganic cyanides, corrosives, pesticides, and herbicides. Exhibits 6-7 and 6-8 show the major contaminant groups by matrix and DOD Component. The data used to create these exhibits are in Appendix Exhibit C-5.

The most prevalent contaminant groups in groundwater are VOCs and metals, which appear in 74 percent and 63 percent of DOD groundwater sites, respectively (Appendix Exhibit C-5). However, while metals appear in the majority of sites in all matrices, VOCs are present in only 45 percent and 49 percent of the soil and surface water sites, respectively. SVOCs and metals were more consistent across different media than VOCs. SVOCs were found at between 49 and 64 percent of the sites, and metals were found at between 63 and 79 percent of the sites.

Exhibit 6-7. Major Contaminant Groups by Matrix at DOD Sites Needing Cleanup

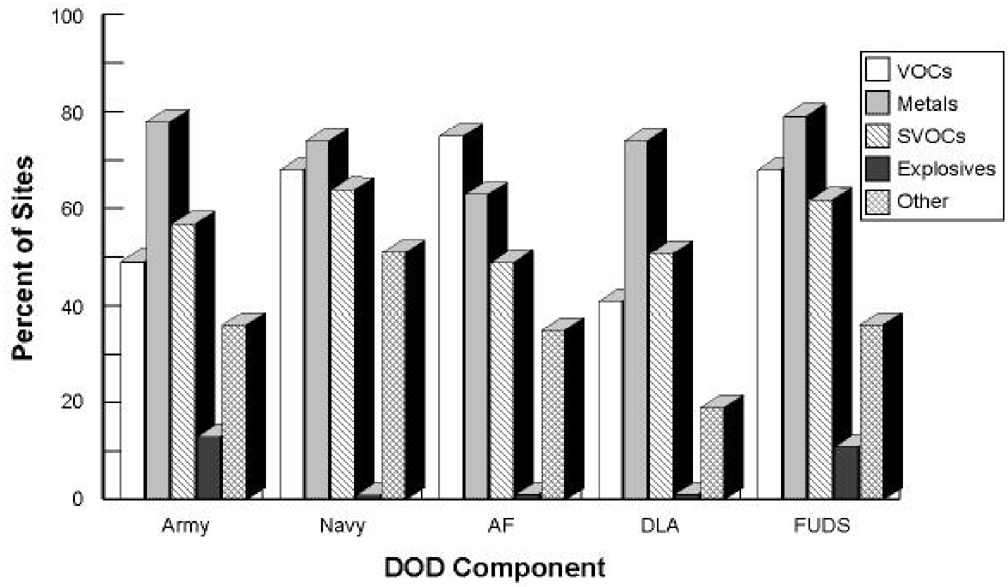


Notes: Based on 6,118 sites needing cleanup for which data were available as of September 30, 2001. A contaminant group may appear in more than one matrix at a site. Appendix Exhibit C-5 provides the supporting data.

Source: DOD, Office of the Deputy Under Secretary of Defense (Installations and Environment), Restoration Management Information System, November 2001.

The most frequently occurring group–metals– is found at 72 percent of all sites with available contaminant data, followed by VOCs at 64 percent, and SVOCs at 57 percent. VOCs are found at most sites in all the components, except at DLA sites, where VOCs account for only 41 percent of the sites. These waste groups also are frequently found at sites related to non-defense industrial facilities. In addition, some sites contain contaminants that are found less frequently in industry and that present unique problems for selecting remediation approaches. For example, over 6 percent of DOD sites contain explosives and some contain low-level radiation. Explosives are found at 13 percent of Army sites, but at 1 percent of Navy and Air Force sites. Appendix Exhibit C-5 shows a breakdown of these data into the frequencies of the most common contaminant groups for each medium and DOD Component.

Exhibit 6-8. Major Contaminant Groups By DOD Component at Sites Needing Cleanup

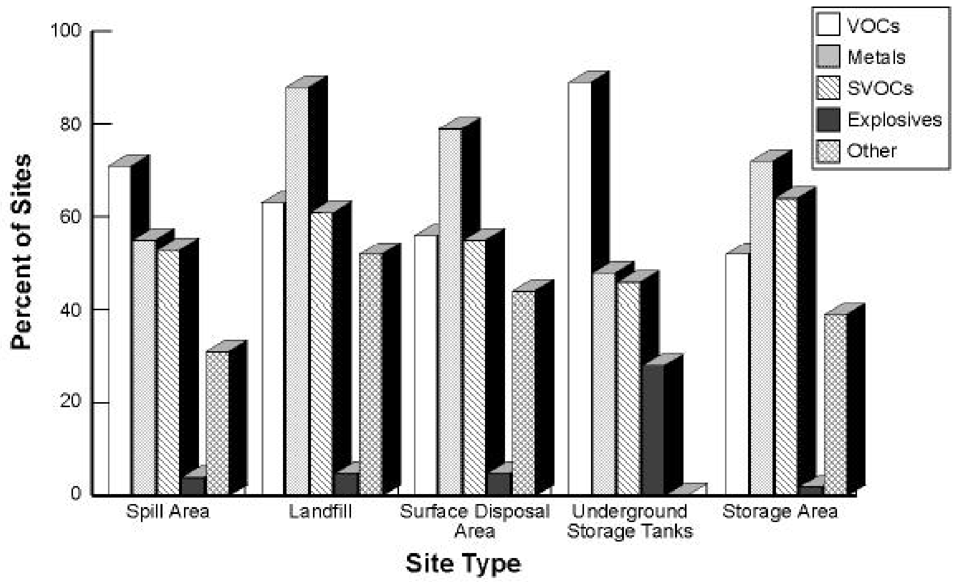


Notes: Based on 6,118 sites needing cleanup for which data were available as of September 30, 2001. More than one contaminant group can appear at a site. Appendix Exhibit C-5 provides the supporting data.

Source: DOD, Office of the Deputy Under Secretary of Defense (Installations and Environment), Restoration Management Information System, November 2001.

The frequency of occurrence of contaminants also varies by site type. Exhibit 6-9 shows the relative frequency of occurrence of the major contaminant groups for five of the seven most common site types. The "other" site type is not shown nor is the fifth most common site type unexploded munitions/ordnance since data for this site type is sparse. Metals and VOCs are common to all five site types, although the frequencies vary. For example the occurrence of metals ranges from 48 percent of underground storage tanks to 88 percent of landfills. Appendix Exhibit C-6 shows contaminant group occurrences for all 44 site types.

Exhibit 6-9. Frequency of Major Contaminant Groups for the Most Common DOD Site Types Needing Cleanup



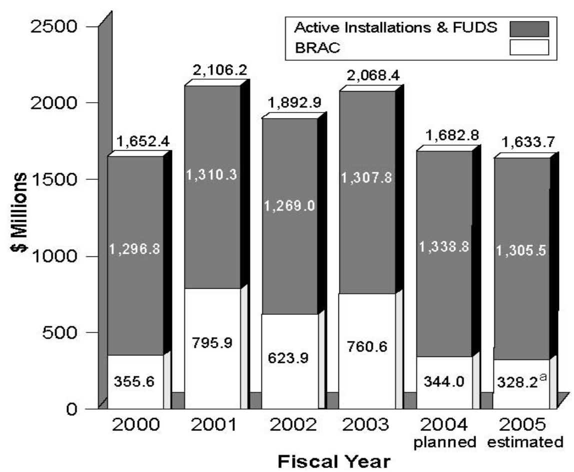
Notes: Based on 6,118 sites needing cleanup for which data were available as of September 30, 2001. More than one contaminant group can appear at a site. Appendix Exhibit C-6 shows the breakdown of the data for all site types.

Source: DOD, Office of the Deputy Under Secretary of Defense (Installations and Environment), Restoration Management Information System, November 2001.

6.4 Estimated Cleanup Costs

DOD annual funding for DERP and BRAC combined peaked at $2.5 billion in FY 1994. The FY 2003 funding was $2.1 billion and planned expenditures for FY 2004 are $1.7 billion. BRAC accounts for $344 million, or 20 percent of the planned budget (Exhibit 6-10). Between 2000 and 2005 (estimated), the BRAC percentage has ranged from 20 to 37 percent. However, BRAC expenditures may need to increase again with the addition of installations from the next round of BRAC scheduled for FY 2005. Also, because the environmental issues at a BRAC installation require more

Exhibit 6-10. DOD Cleanup Expenditures: FY 2001-2005



[a] includes DLA prior year unobligated balance available for execution FY 05.

Source: U.S. Department of Defense, Environmental Restoration Program, Annual Report to Congress, Fiscal Year 2003, 2004.

extensive consideration than active installations, BRAC cost-to-complete estimates are not declining at the same rate as the estimates for active installations.

It should be noted that not all BRAC environmental funds are used for site investigation and remediation. They may also be used for other closure-related environmental expenses such as environmental compliance and planning. Compliance efforts may include actions such as the removal of underground storage tanks, closure of hazardous waste TSDFs, and radon surveys. Planning may involve environmental analyses required under NEPA, or decision-making with regard to property reuse and redevelopment. On the other hand, BRAC funding is not limited to the designated amounts.

In the past 19 years, DOD has spent approximately $25 billion on environmental restoration (U.S. DOD 2004). DOD estimates that, as of September 2003, cost to complete of the 9,060 active installation, FUDS, and BRAC IRP sites still in progress or with anticipated future assessments planned will be approximately $16.4 billion. The cost to complete for the 987 MMRP sites with investigation or cleanup in progress or where future activity is anticipated is estimated to be approximately $16.8 billion. Most of these funds are for sites that have not yet begun remedial action, although some are for sites that have already selected remedies. These cost-to-completion estimates do not include program management, DTRA, or other miscellaneous overhead and support costs. Approximately $1.26 billion of the $16.4 billion IRP estimate is designated for investigation and approximately $2.55 billion of the $16.8 billion MMRP estimate is designated for investigation. As the MMRP develops, DOD's MMRP cost-to-complete estimates may change.

DOD's goal is to have remedial action complete at active installations by the end of FY 2014 and at the end of FY 2005 for most of the BRAC sites from pre-2005 BRAC rounds. Because completion dates have not been determined for some FUDS properties, it is more difficult to approximate a final cleanup date. With the MMRP still in development, it would be premature to deal with cleanup time tables.

6.5 Market Entry Considerations

Although policy is determined centrally by the Deputy Under Secretary of Defense (Installations and Environment), each service is responsible for investigating and restoring its own sites and manages its own efforts to perform this work. Almost all DOD site assessments and remedial actions are done by contractors. Generally, there are two groups of contractors: those that work on site investigations and assessments and those that do remedial actions. Contractors in the first group seldom do the construction work. Vendors seeking markets for innovative technologies should take action to ensure that their technologies are considered at the earlier stages of site investigation and assessment. For example, even if a vendor is precluded from working on the RI/FS of a particular site, he or she may provide information on their technology to the DOD officials and contractors working on the RI/FS. References and links to the various DOD offices involved in technology development and contracting appear at the end of this report. The following is a summary of the practices of each DOD Component.

Army

The Army's environmental restoration program is managed under the Assistant Secretary of the Army (Installations and Environment) (ASA(I&E)) and the Assistant Chief of Staff for Installation Management (ACSIM). In addition to managing active installations and BRAC environmental restoration programs, the ASA(I&E) and ACSIM oversee the management of the FUDS program. Execution of the cleanup is decentralized, with centralized oversight. In both the active installations and the BRAC programs, the Army installations are the focal point for restoration activity. The installation environmental coordinator manages the day-to-day activities, which are executed primarily through the U.S. Army Corps of Engineers (USACE). The Corps also implements remediation programs for DLA and the Air Force, and supports EPA, other federal agencies, and states in environmental restoration activities. The Army Environmental Center (USAEC), a field-operating agency under ACSIM, provides program management support and oversight for ACSIM, while the Center for Health Promotion and Preventive Medicine plays a key role in providing risk assessment expertise and review of decision documents. For additional information on these Army programs as well as details on the contracting process, opportunities, and contacts see the links in section 6.7.

Navy

The Navy's environmental restoration program, begins with the Assistant Secretary of the Navy (Installations and Environment). Under the Assistant Secretary, the Chief of Naval Operations and the Commandant of the Marine Corps rely on a host of internal and external organizations to accomplish their DERP goals. The Naval Facilities Engineering Command (NAVFAC) and its eight Engineering Field Divisions and Activities (EFD/As) nationwide execute the Navy's restoration program. Remedial project managers (RPMs) are assigned for each installation in each of the geographic regions. The RPMs reside at the EFD/As but work closely with the installations and the regulators in planning, setting priorities, establishing budgets, and coordinating project execution. RPMs and the support staff at the EFD/As manage contracting, technical coordination, direction, and execution of the work on a regional basis. Installations maintain ultimate responsibility for their respective restoration programs. Detailed information and opportunities are available on the NAVFAC web site by command (link in section 6.7).

The Naval Facilities Engineering Service Center (NFESC) provides the Navy with specialized engineering, scientific, and technical products and services. It is the hub for the Navy's innovative environmental remedial technology demonstrations, evaluations, and technology information transfer efforts. NFESC encourages vendors and innovators to submit abstracts on their environmental technologies for potential application throughout the Navy and DOD. FY 2001 awards for field application projects totaled approximately $3.7 million. The Navy disseminates this information through regular technical seminars and collaborative efforts with other agencies and organizations involved in remediation technologies. For additional information on NFESC, see the link in section 6.7.

Air Force

The Air Force's environmental restoration program begins with the Assistant Secretary for Installations, Environment and Logistics, with a Deputy Assistant for Installations and another Deputy Assistant for Environment, Safety, and Occupational Health. The IRP is decentralized and executed by the nine Force Major Commands. The Air Force Center for Environmental

Excellence (AFCEE), headquartered at Brooks Air Force Base, Texas, is a field operating agency of the Civil Engineers of the Air Force. It has seven business lines, each with its own technical and support staff. AFCEE provides environmental, planning and construction management services and products. Small businesses can list themselves with the Air Force Small Business Environmental Database (AFSBED) managed by AFCEE. Information from AFSBED is available to small and minority businesses, government buyers, and large prime contractors who use the database regularly. The AFCEE also lists requests for proposal (RFPs) on its web site as well as on the federal government's general business opportunities site. Air Force HQ also has a web site dedicated to contracting procedures and opportunities. For more detailed information, see the links in section 6.7.

6.6 Remediation Technologies

DOD uses a variety of remediation technologies at its hazardous waste sites and actively conducts and supports research and demonstrations to meet its environmental restoration needs more efficiently and effectively.

6.6.1 Technologies Used at DOD Sites

EPA's treatment technologies database details the types of treatment technologies used at DOD NPL sites (EPA 2004). Comprehensive data on technology use at other DOD sites are not available. The available data from NPL sites may also be indicative of the types of approaches that might be needed for non-NPL DOD sites. Exhibit 6-11 lists the types of treatment technologies used in 153 source control applications at DOD sites and 164 groundwater projects. The most prevalent source control treatment technologies are SVE (31% of applications), in-situ bioremediation (15%), ex-situ bioremediation (10%), and ex-situ solidification/stabilization (10%).

DOD groundwater applications fall into three general approaches: monitored natural attenuation (40% of applications), pump and treat (33%), and in-situ treatment technologies (27%). The most frequently used groundwater treatments were air sparging (44% of in-situ treatment applications), in-situ bioremediation (20%), dual-phase extraction (13%), and chemical treatment (7%).

6.6.2 Research, Development and Demonstration

The Department's efforts predominantly focus on three major areas:

- Technology transfer,
- Demonstration and certification of emerging technologies, and
- Development of new technologies.

Technology Transfer

DOD uses the latest communications technologies to disseminate information, including the World Wide Web. In addition to DOD's own web sites, each of the services has at least one site dedicated to providing information on cleanup programs and technologies. The Army sites include the U.S. Army Corps of Engineers (USACE) and the U.S. Army Environmental Center (USAEC). The Navy sites include the Navy Environmental Leadership Program (NELP) and the Naval Facilities Engineering Service Center (NFESC). The Air Force Center for Environmental Excellence (AFCEE) is the key site for information on Air Force programs and technologies. These sites also provide information and links for innovators and vendors to contact the services and potentially become part of the military's cleanup process.

Exhibit 6-11. Treatment Technologies Used at DOD Sites

Remediation Approach	Type	Number of Projects	Remediation Approach	Type	Number of Projects
Source Control Treatment Technologies			**In-Situ Groundwater Treatment Technologies**		
Bioremediation	Ex Situ	16	Air Sparging	In Situ	20
Bioremediation	In Situ	23	Bioremediation	In Situ	9
Chemical Treatment	Ex Situ	1	Chemical Treatment	In Situ	3
Chemical Treatment	In Situ	1	Dual-Phase Extraction	In Situ	6
Dual-Phase Extraction	In Situ	1	In-Well Air Stripping	In Situ	1
Flushing	In Situ	1	Permeable Reactive Barrier	In Situ	3
Incineration	Ex Situ	19	Phytoremediation	In Situ	2
Open Burn/Open Detonation	Ex Situ	2	Thermally Enhanced Recovery	In Situ	1
Physical Separation	Ex Situ	5	**Total In-Situ Treatment Groundwater Technologies**		**45**
Phytoremediation	Ex Situ	1			
Phytoremediation	In Situ	1			
Soil Vapor Extraction	In Situ	48	**Groundwater Approaches Summary**		
Soil Washing	Ex Situ	2	Pump and Treat		54
Solidification/Stabilization	Ex Situ	15	In-Situ Groundwater		45
Solidification/Stabilization	In Situ	3	Monitored Natural Attenuation		65
Thermal Desorption	Ex Situ	11	**Total Groundwater**		**164**
Thermally Enhanced Recovery	In Situ	3			
Total Source Control Treatment Technologies		**153**			

Source: U.S. EPA, 2003. *Annual Status Report Remediation Database,* Office of Solid Waste and Emergency Response, Technology Innovation Office, http://epa.gov/tio/technologies

DOD has been active in facilitating technology transfer among development and demonstration programs and technology users. For example, DOD is working with the Federal Remediation Technologies Roundtable (FRTR), an interagency organization created to facilitate collaboration among federal agencies, such as the Department of Energy (DOE) and EPA, which also have a stake in technology development. The FRTR publishes a variety of documents on remediation technologies, including tool guides, case studies, and reports which are available on their web site.

Demonstrations and Certification of Emerging Technologies

The Department has two programs that research and assess technologies, the Strategic Environmental Research and Development Program (SERDP) and the Environmental Security Technology Certification Program (ESTCP). SERDP is a program in partnership with EPA and DOE which focuses on identifying, developing, and implementing environmental restoration technologies that minimize or eliminate the environmental impacts of DOD's activities. ESTCP is a program that demonstrates, tests, and validates new technologies. Each program introduces several cutting-edge restoration technologies. For example, in FY 2001 DOD supported a system that combines soil washing with phytoremediation to clean lead-contaminated soil from small arms ranges, and extended a successful pilot biowall treatment trench to clean up trichloroethene-contaminated hot spots.

With the increased attention to munitions cleanup, the Department plans to continue its significant investment in advancing the state of munitions response technology. To date, the focus has been on technologies related to site characterization. The Department is now planning to expand its technology development to address the hardware, methods, and scientific understanding to address other aspects of munitions response. In addition to the OSD programs, SERDP and ESTCP, that determine areas for technology investment, the Army, as the lead service for UXO technology development, is investing in research on improvements to detection hardware systems.

Each of the services also maintains technology development and demonstration programs. The Army Environmental Center, the Naval Facilities Engineering Service Center, and the Air Force Center for Environmental Excellence are leaders in cleanup technology demonstrations.

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Related Links:

DOD documents on environmental cleanup:

Office of the Secretary of Defense - Cleanup: http://www.dtic.mil/envirodod/
Defense Environmental Network & Information System: http://www.denix.osd.mil

DOD business opportunities:

Federal registry of business opportunities: http://www.fedbizopps.gov
DOD central contractor registration: http://www.dodbusopps.com/egov/dod.ccr.html
National Environmental Technology Test Sites (NETTS) Program: http://www.serdp.org/NETTS/
Environmental Security Technology Certification Program: http://www.estcp.org

Army

US Army Environmental Center: http://www.aec.army.mil
US Army Corps of Engineers: - http://www.usa00.army.mil
USACE Environmental Programs Contracting Opportunities: http://www.hq.environmental.usace.army.mil/tools

Navy

Naval Facilities Engineering Service Center: http://www.nfesc.navy.mil
Naval Facilities Engineering Command: http://www.navfac.navy.mil
Naval Environmental Leadership Program (NELP): http://nelp.navy.mil/

Air Force

Air Force Center for Environmental Excellence: http://www.afcee.brooks.af.mil/
Air Force Small Business Environmental Database: http://www.brooks-smallbusiness.com/afsbed.htm
Air Force HQ Contracting: http://www.safaq.hq.af.mil/contracting
Air Force HQ Environmental Restoration Branch: http://www.il.hq.af.mil/ilevr.html

Chapter 7
Demand for Remediation of Department of Energy Sites

One of the most serious and costly environmental remediation tasks facing the federal government is the cleanup and restoration of more than 100 installations and other locations that are the responsibility of the U.S. Department of Energy (DOE). DOE's "legacy" of environmental contamination at these sites has resulted from activities related to the development and production of nuclear weapons and other technologies that began in the 1940s with the Manhattan Project and continued through the Cold War. Nuclear weapons production halted in the United States in 1989, initially to correct widespread environmental and safety problems; later it was stopped indefinitely because of the end of the Cold War (U.S. DOE 1996a).

DOE properties contain unique radiation hazards, huge volumes of contaminated soil and water, and a large number of contaminated structures ranging from evaporation ponds to nuclear reactors to chemical plants used for the extraction of nuclear materials (U.S. DOE 1996b). DOE estimates that as of the end of fiscal year (FY) 2004, the remaining cost for restoration of its legacy sites would be $111 billion (U.S. DOE 2004). Hazardous waste remediation, including the cleanup of buried waste, soil, groundwater, surface water, and facility decontamination and decommissioning (D&D) account for about one-third of the total, or about $35 billion. DOE's most recent estimate for cleaning up its contaminated sites, under its accelerated cleanup initiative, aims for the completion of cleanup at all release sites by 2035. These costs are significantly lower than estimates in the FY 2002 and 2003 budgets because of a cost reduction made possible by management and organizational reforms within DOE. The remainder of DOE's environmental management costs are for activities such as waste management; facility stabilization; nuclear material stabilization, packaging, and transportation; program planning and management; landlord activities; and technology development.

Highlights

- DOE has estimated that the cost to complete active remediation of wastes at most of its legacy sites will be $35 billion, although this figure is probably an underestimate because it does not include the cost of addressing contamination problems that currently lack viable cleanup technologies.
- DOE aims to complete active cleanup at most of its sites by 2035.
- Five installations account for 73% of expected costs.
- An estimated 40 million cubic meters of soil and 1.7 trillion gallons of groundwater will require remediation.
- Approximately 3,000 surplus DOE facilities await D&D.
- Long-term stewardship will be needed at up to 129 installations and DOE has established the Office of Legacy Management to address this need.
- In 2002, DOE began a major initiative to accelerate cleanup of its sites, prioritize risks, improve contracting practices, and reduce program costs. This initiative will profoundly affect the scope and scheduling of cleanup work, and the types of remediation technologies used.
- Achievement of DOE's cleanup goals is largely contingent upon receipt of additional funding yet to be approved by Congress in future years.
- The full extent of the cleanup needed is still uncertain because the nature and extent of contamination at some sites have not been characterized and final remedial action or regulatory decisions have not been made for many sites still awaiting cleanup.

These figures are likely an underestimate of the total DOE cleanup cost because they do not include all cleanup activities needed, such as the cost of cleaning up new releases of contaminants, remediating facilities that are still in operation, or contamination problems that currently lack viable cleanup technologies, such as certain groundwater contamination and nuclear test sites. Nor does the current estimate include the costs of monitoring and maintaining site remedies over the thousands of years that radioactive hazards will remain. DOE's environmental cleanup program offers an enormous opportunity for firms that provide remediation services.

7.1 Program Description

Between the inception of its environmental management program in 1989 and FY 2003, DOE has spent over $70 billion on establishing the cleanup program, developing the management and remediation approaches to be employed, and cleaning up the less complex sites (U.S. DOE 2002d, 2003a, and 2004). The program constitutes nearly a third of the Department's budget, and remediation and restoration account for about a third of the cleanup program budget.

Programs to clean up environmental damage resulting from Cold War nuclear weapons development are managed by DOE's Office of Environmental Management (EM), established in 1989. In 2003, DOE established an Office of Legacy Management to focus on the long-term care of legacy liabilities of former nuclear weapons production areas following cleanup completion of the surface areas at each site. In the 2005 Budget Request to Congress, the Department proposes to create the Office of Future Liabilities, which will focus on the cleanup of facilities and contaminated media at active sites that fall outside the EM scope.

Information on the program's activities are available in the justifications in DOE's budget requests to Congress for the fiscal years from 2000 to 2005. Additional background is available from DOE's *Baseline Environmental Management Report* (BEMR), a multi-volume study published in 1995 and 1996.[1]

EM must ensure that environmental legacies of the Cold War are addressed and resolved in a manner that does not impede future national security missions, and that the nation's radioactive wastes are disposed of permanently and safely (U.S. DOE Web 2003b). The EM program historically has been managed as a loose association of individual field sites (U.S. DOE 2002d). EM provides budget and program support to nine Operations/Field Offices, each of which has the responsibility for directing cleanup work at one or more sites (U.S. DOE 1998). The offices are located in Albuquerque (NM), Chicago (IL), Idaho Falls (ID), Las Vegas (NV), Oakland (CA), Oak Ridge (TN), Miamisburg (OH), Rocky Flats (CO), Richland (WA), and Aiken (SC). The Field and Operations Offices oversee all activities to assess and clean up inactive hazardous and radioactive facilities—such as reactors, laboratories, equipment, buildings, pipelines, waste

1 The BEMR report was a key source of information for the 1996 edition of this study. The BEMR combined an analysis of current environmental management data with estimates of the future costs of the EM program. This analysis was replaced by the *Accelerating Cleanup: Paths to Closure* report, which established a baseline schedule and cost for each project. The information in *Paths to Closure* was updated in 1999 and 2000, but no comparably detailed information has been published since the introduction of DOE's Central Internet Database in 2000.

treatment systems, and storage tanks—and sites at all DOE installations, as well as at some non-DOE locations that have been specified by Congress.
The Albuquerque, Chicago, Nevada, Oakland, Ohio, Oak Ridge, Rocky Flats, and Small Sites Closure Offices are responsible for cleanup, facility decommissioning, and/or waste packaging at 110 (Fiori & Jones 2000) of DOE's 114 geographic sites. Many of these sites will have no continuing DOE presence after closure, except for stewardship activities. DOE presence will continue long term at the Idaho and Savannah River Sites and Hanford's Office of River Protection and Richland Operations Office, where the mission encompasses remediation of contaminated land, disposition of facilities for alternate uses, final decontamination and decommissioning, and operational oversight (as landlord) for the facilities and programs.

Environmental restoration of the DOE complex involves the following activities:

- Deactivation and decommissioning—decontamination and safe disposition of deactivated and surplus equipment, buildings, and other facilities;
- Remedial actions—site characterization to identify the contaminants and physical properties at a site, and remediation activities to stabilize, reduce, or remove site contaminants;
- Long-term surveillance and maintenance (S&M)—monitoring the site to ensure that contamination has been successfully addressed and providing maintenance services to ensure the long-term integrity of containment remedies or continued effective operation of pump-and-treat remedies; and
- Stabilization of high-risk materials—treatment and/or packaging of highly radioactive materials.

These restoration activities are described in greater detail in the following subsections.

7.1.1 Deactivation and Decommissioning of Surplus Facilities

DOE constructed over 20,000 facilities to support nuclear weapons production and other activities. More than 3,800 of them have been declared surplus to date, and approximately 3,000 await D&D. These facilities have exceeded their design life and no longer serve a mission for DOE. Many of them are contaminated with radioactive materials, hazardous chemicals, asbestos, and lead, including lead-based paint. Because of the potential for release of radioactive and hazardous materials to the environment, these surplus facilities must be monitored, maintained, and guarded. Four major types of structures require deactivation and decommissioning–reactor facilities, radionuclide separation facilities, fuel and weapons component fabrication facilities, and laboratories.

Deactivation involves actions that render a facility safe and stable until it can be decommissioned. It includes processes used to place nuclear materials and chemicals, equipment, and operating systems into a low-risk, low-cost and mostly passive condition. Decommissioning, which takes place after deactivation, includes surveillance and maintenance, decontamination, and/or dismantlement. It involves stabilizing, reducing, or removing radioactive and/or other types of contamination, and can consist of dismantling a facility, entombing or covering part or all of the facility, or converting a facility for other uses.

Based on the FY 2005 DOE Congressional Budget Request (U.S. DOE 2004) the remaining cost (remaining life cycle cost) for decontamination and decommissioning at legacy waste sites is about $20 billion, as of the end of FY 2004.

EM typically performs decommissioning under CERCLA as a "non-time-critical removal action." In fact, there are few regulatory compliance agreements for D&D at DOE sites. Most sites' Federal Facility Agreements deal with waste from weapons production, such as high-level waste, transuranics, mixed low-level waste, and contaminated soil and groundwater problems, not with contaminated buildings or other structures (U.S. DOE Web 2002).

7.1.2 Remedial Actions

Remedial actions involve the containment, treatment, or removal of radioactive and/or hazardous materials and pollutants in free product form or in soil, sediment, fractured bedrock, and groundwater. An estimated 3 million cubic meters of solid radioactive and hazardous wastes have been buried or otherwise released to the subsurface throughout the DOE complex. As a result of the release of these materials, an estimated 40 million cubic meters of soil and 1.7 trillion gallons of groundwater contain contaminants above an action level and will require remediation (U.S. DOE 2000). The largest contamination challenges are found at the Idaho, Oak Ridge, Hanford, Rocky Flats, and Savannah River sites (U.S. DOE 2002e).

The typical wastes found at DOE sites are shown in the text box. Contaminants include hazardous metals such as chromium, mercury, and lead; radioactive laboratory and processing waste; explosive and pyrophoric materials; solvents; and numerous radionuclides.

Sources of contaminants include plumes emanating from seepage basins, cribs, leaking tanks, and landfills; airborne releases deposited on the soil surface by wind or precipitation; wells used for underground injection of wastes; and waste-disposal areas with contaminants mobilized by precipitation, groundwater, or surface water flowing through the site. Burial of low-level radioactive waste, mercury, lead, spent solvents, explosives, and contaminated equipment has resulted in large inventories of poorly characterized land-stored waste.

DOE Waste Types:

hazardous—containing hazardous constituents but no radionuclides;

mixed—containing both hazardous and radioactive materials

low-level—radioactive waste not classified as high-level waste, TRU, or spent nuclear fuel. "Low" does not refer to its level of radioactivity

11e(2) byproducts—mill tailings containing very low concentrations of naturally occurring alpha-emitting radionuclides in large volumes of generally soil-like materials

"orphan waste"—those waste streams for which disposal pathways have not been identified;

transuranic (TRU)—containing plutonium, americium, and other elements with atomic numbers higher than uranium; and

high-level—defined based on its source rather than its constituents and their concentrations. Includes fission products, traces of uranium and

DOE considers cleanup at a site "complete" when it meets the following conditions:

- Deactivation or decommissioning of all facilities listed in the EM program has been completed, excluding any long-term surveillance and monitoring;
- All releases to the environment have been cleaned up in accordance with agreed-upon cleanup standards;
- Groundwater contamination has been contained, and long-term treatment or monitoring is in place;
- Nuclear material and spent fuel have been stabilized and/or placed in safe long-term storage; and
- Legacy waste (i.e., waste produced by past nuclear weapons production activities, with the exception of high-level waste) has been disposed of in an approved manner.

After closure, many DOE sites will require long-term surveillance and maintenance.

7.1.3 Long-Term Surveillance and Maintenance

Even after site closure, DOE will maintain a presence at most sites to ensure that the remedy remains effective, an important responsibility at sites where contaminants have been reduced or contained, but not eliminated. DOE has estimated that up to 129 geographic locations (e.g., installations) will require long-term stewardship (U.S. DOE 2001c). Such long-term stewardship will be active at the majority of sites with groundwater monitoring and/or treatment, containment systems such as covers and subsurface barriers, and passive or active institutional controls. At sites released for unrestricted use, stewardship will be passive, involving only maintenance of records. The extent of long-term stewardship to be conducted is determined by DOE and other stakeholders based on the end state reached at each site. In some cases, the cleanup plan addresses an entire geographic site; in other cases, long-term stewardship may occur at a portion of a large site long before cleanup of the entire area is completed.[2]

The Office of Legacy Management (LM) has responsibility for sites that have been closed and no longer support DOE's ongoing national security, energy, and science missions, such as the EM closure sites (Pinellas Plant, Weldon Spring), Uranium Mill Tailings Remedial Action (UMTRA) sites, and Formerly Utilized Sites Remedial Action Program (FUSRAP) locations where remediation is complete. As more sites are successfully remediated and closed, LM will manage the land and associated resources as a federal trustee, preserve records and information, perform surveillance and maintenance associated with environmental remedies, such as long-term pump and treat, and manage post-closure liabilities.

[2] DOE also conducts surveillance and maintenance activities during the environmental restoration process. For example, S&M activities may be conducted to prevent worker, public, and environmental exposure to potential hazards at a site awaiting D&D. For some facilities – particularly reactors and large processing canyons – an initial "interim" phase of long-term stewardship is needed after a facility has been stabilized, but where further remedial action or D&D is not expected to occur for a significant period of time (U.S. DOE 2001b).

7.1.4 Stabilization of High-Risk Materials

One of the most costly and dangerous components of DOE's cleanup effort—the stabilization of high-risk materials—presents a challenge unique in environmental restoration. High-risk materials include all highly radioactive wastes stored in tanks, spent nuclear fuel, all special nuclear materials, and some transuranic waste. A major cost driver in the EM complex is the plan to retrieve, treat, and vitrify waste in the tank farms, which alone is projected to cost $20 billion (U.S. DOE 2004). Special nuclear materials, primarily plutonium metals and oxides and highly enriched uranium, must be stabilized and then packaged for long-term storage. All spent nuclear fuel must be treated and/or packaged and placed in dry storage. Some transuranic waste must be treated to remove organics before it is packaged for shipment and stored in the Waste Isolation Pilot Plant. Additionally, all the structures from which high-risk materials have been removed must undergo decontamination and decommissioning (U.S. DOE 2002d).

7.1.5 Regulatory Requirements and Compliance Agreements

DOE installations typically have multiple areas of contamination regulated by either CERCLA, RCRA Corrective Action provisions, RCRA underground storage tank provisions, or all three. DOE also is required to consult with EPA and consider state environmental requirements and the needs of all stakeholders in designing and conducting remediations at facilities for which it is responsible. The interface between the regulatory authorities is determined by circumstances at specific sites, such as the sources and causes of the contamination, whether the installation is an NPL site (DOE has 19 currently on the NPL and 2 deleted), whether it is operating under a RCRA permit to manage hazardous waste, the anticipated future land use, the interest of nearby communities, and state actions and laws. DOE works with all stakeholders at its facilities to integrate and reconcile all the requirements and agree on an approach to address the environmental problems. The agreements are typically summarized in a compliance agreement, which is used for the majority of DOE cleanup work.

Compliance agreements provide for establishing legally enforceable schedule milestones that govern the work to be done and include, but are not limited to, Federal Facility Agreements, Interagency Agreements, settlement agreements, consent orders, and compliance orders. The 70 compliance agreements at DOE sites vary greatly but can be divided into three main types: (1) agreements specifically required by CERCLA to address cleanup of federal NPL sites or by RCRA to address the management of mixed radioactive and hazardous waste at DOE facilities, (2) court-ordered agreements resulting from lawsuits initiated primarily by states, and (3) other agreements, including state administrative orders enforcing state hazardous waste management laws (U.S. GAO 2002a).

Compliance agreements are site-specific and are not intended to provide a mechanism for DOE to use in prioritizing risks among the various sites. The agreements reflect local DOE and community priorities for addressing environmental contamination at individual sites and are not designed or developed to consider environmental risk from a DOE-wide perspective.

The first class of compliance agreements, those specifically required by CERCLA or by RCRA, are in effect at all of DOE's major sites. They tend to cover a relatively large number of cleanup activities and include most of the schedule milestones that DOE must meet. By contrast, agreements that implement court-ordered settlements exist at only a few DOE sites, tend to focus on a specific issue or concern, and have fewer schedule milestones. These agreements are typically between DOE and one or more states. The remaining agreements are based on state or federal environmental laws and address a variety of needs, such as cleaning up hazardous materials spills or remediating groundwater contamination. Some of these agreements may specify only a few milestones, while others incorporate detailed schedules and approaches.

7.1.6 Policy Initiatives: The Top-to-Bottom Review

Early in 2002, EM completed a critical assessment of its program—the "Top-to-Bottom Review." The Review's major observation was that EM had been oriented toward managing risks rather than actually reducing them. Based upon the Review's recommendations, DOE began a major initiative to accelerate cleanup of its legacy wastes by at least 30 years, prioritize risks, improve its contracting practices, and reduce program costs. Under this initiative, DOE would complete cleanup projects at some sites more quickly; revise other cleanup plans, such as reclassifying certain wastes to different risk categories to speed cleanup and reduce cost; and concentrate funding more on cleanup and less on maintenance and non-cleanup activities (U.S. GAO 2002b).

DOE expects this initiative to profoundly affect the scope and scheduling of its cleanups. As of mid-2004, DOE has signed letters of intent with state and federal regulators that outline an agreement in principle to accelerate cleanup at Amchitka Island (AK), Hanford (WA), Idaho National Engineering Laboratories (ID), Oak Ridge Reservation (TN), Nevada Test Site (NV), Paducah (KY), Pantex (TX), Pinellas (FL), and Savannah River (SC). Increased funding has been approved for this purpose. Of the remaining sites, some will not be able to accelerate the cleanup schedule, either for technical reasons or because closure is already near term.

Under the initiative, DOE is promoting a new "risk-based" cleanup strategy that would assist in prioritizing risk—and thereby prioritize cleanups—among the various sites on a DOE-wide basis. If implemented, this approach could alter the funding balance among DOE sites.

The initiative also has the potential to increase the use of remediation approaches that leave more wastes on site than previously planned, thereby reducing remediation costs at some projects. For example, one proposal is to change the current practice of classifying waste as high level, based on the treatment process that created it, to classifying the waste based on its actual composition. This change would result in the reclassification of much of DOE's high-level waste into low-level mixed or transuranic waste, which would significantly affect the cost of treatment and packaging and disposition.

7.2 Factors Affecting Demand for Cleanup

The nature, extent, and timing of the DOE cleanups is determined by the annual budget provided by Congress, DOE policy and resource allocation, the types of waste and contaminated media at DOE properties, compliance agreements with states and other stakeholders, and the provisions of CERCLA, RCRA, and other federal and state environmental statutes.

- DOE expects its accelerated site cleanup initiative (Section 7.1.6) to profoundly affect the scope and scheduling of its cleanups. DOE has signed letters of intent with a number of state and federal regulators, and is prioritizing risks, improving its contracting practices, and implementing other measures to reduce program costs and accelerate cleanups. These measures may lead to the reclassification of some waste to a different risk category and concentrate funding more on cleanup and less on maintenance and non-cleanup activities.

- Under the initiative, DOE is promoting a "risk-based" cleanup strategy that would assist in prioritizing risk among the various sites on a DOE-wide basis. In addition, it is likely to affect the types of remedies selected, such as increasing the use of remediation approaches that leave more wastes on site than previously planned.

- DOE may need to renegotiate and modify compliance agreements to implement many aspects of the new initiatives. Federal facility compliance agreements as well as environmental laws and regulations drive DOE's cleanup decisions. The effect of compliance agreements on certain aspects of DOE's initiative, especially its proposal to reclassify waste into different risk categories to increase disposal options, is unclear. Reclassifying the waste may involve the concurrence of the Nuclear Regulatory Commission, EPA, and other regulatory agencies. Securing the concurrence of all parties, plus potential legal challenges by stakeholders, can delay or alter cleanup decisions.

- Cleanup schedules are heavily dependent upon the availability of funds. DOE's estimate that it can complete remediation of legacy wastes at all DOE properties by 2035 could be lengthened or shortened, depending on the funds appropriated by Congress. A lack of funds could limit DOE's ability to meet milestones of some existing compliance agreements between DOE and other stakeholders, as well as limit DOE's ability to commit to new agreements. In 2002, Congress increased the EM appropriation by $800 million (in a special Cleanup Reform Account) to help DOE meet its 2035 cleanup completion goal. Achievement of the accelerated cleanup goals is largely contingent upon receipt of additional funding, yet to be approved by Congress, in future years (U.S. DOE 2003b). If milestones cannot be achieved because of budget shortfalls, stakeholders may renegotiate compliance plans.

- The type and extent of remediation to be undertaken will be affected by the cleanup standards/end states that are to be applied. At many sites, it is difficult to define the extent of cleanup work needed. The decision usually requires balancing potential land uses with the feasibility of alternative cleanup and long-term stewardship approaches. DOE determines end-state goals for a site only after consulting with the regulatory agencies, state and local authorities, and other affected parties. Communities must address how the land is to be used, and regulators must determine an acceptable level of residual contamination.

- Current site assumptions about planned end states do not rule out future decisions to change the target end state from that envisioned under those assumptions. The ultimate end state of a site may be revised due to the development of new technologies, more economical cleanup approaches, the availability of additional resources, and changes in the cleanup agreements.

- Uncertainty about the nature and extent of contamination at some sites contributes to the difficulty in defining the extent of cleanup work needed. Though nearly all of the release sites have been at least partially characterized, final remedial action and/or regulatory decisions have not been made for most sites still awaiting cleanup. In estimating the environmental liability related to each site, DOE used site-specific assumptions regarding the amount and type of contamination and remediation technologies that will be employed (U.S. DOE 2003b).

- DOE assumes only existing (baseline) technologies, such as groundwater pump and treat, to be available for estimating cleanup costs *where they are applicable*. Estimates are based on remedies considered technically and environmentally reasonable and achievable. Estimated cleanup costs at sites for which there is no current feasible remediation approach are excluded from the baseline estimates, though applicable stewardship and monitoring costs for these sites are included. The cost estimate would be higher if some remediation were assumed for these areas; however, absent effective remedial technologies for the sites, no basis for estimating costs is available. Significant areas for which cleanup costs are excluded include the nuclear explosion test grounds at the Nevada Test Site; large surface water bodies, including the Clinch and Columbia rivers; and contaminated groundwater for which, even with treatment, future use will remain restricted (U.S. DOE 2003b).

- The program scope may increase in the future due to the transfer of additional facilities and/or sites, further affecting the uncertainty of out-year work scope and schedules. For example, DOE sought and received funding and authority from Congress in 2001 to remediate a uranium mill tailings site at the former Atlas mill near Moab, Utah. The cleanup will be conducted under the Uranium Mill Tailings Radiation Control Act of 1978, which is the same authority used for the 22 sites that were remediated in the DOE UMTRA Project.

These factors indicate that there are many uncertainties inherent in the remediation of the facilities for which DOE is responsible, despite significant efforts in recent years to establish the scope of work for DOE's environmental management program. The work scope projections address long periods of time, which compounds the uncertainty.

7.3 Number and Characteristics of Sites

EM historically has been responsible for environmental restoration at 134 "geographic sites," which are distinct locations that generated waste or were contaminated by DOE or predecessor agency activities. Geographic sites range in size from as small as a football field to larger than the state of Rhode Island, and usually correspond to a DOE installation or campus, such as the Hanford Reservation in Washington or Oak Ridge Reservation in Tennessee. Altogether, they encompass an area of over two million acres—equal to the size of Rhode Island and Delaware combined. At the beginning of 1998, cleanup responsibility for 21 sites managed by EM under FUSRAP was transferred to the U.S. Army Corps of Engineers, leaving 113 geographic sites in the EM program (Applegate & Dycus 1998). The addition in 2001 of the former Atlas uranium mill site brought the number to 114 geographic sites located in 31 states and one territory (U.S. DOE 2000).

DOE uses the term "release site" to mean a specific area where contaminants may have been spilled, disposed of, or abandoned at an installation. A geographic site can contain many release sites, or it may contain none at all; for example, the contaminated areas at the General Electric site (CA) consist of a hot cell and a glove box enclosure. According to DOE's 2003 budget request to Congress, of the 10,527[3] release sites identified so far, 5,227 of them were cleaned up by the end of 2002. Completion of active cleanup signifies that mobilization to remove or treat contaminated soil, debris, and structures has ended. It does not necessarily signify that the site has been completely cleaned up. Groundwater cleanup, which could take decades, might yet remain to be accomplished.

Despite the complexity and size of the challenge, substantial progress has been made in cleaning up many sites over the past decade. For example, DOE's UMTRA project successfully concluded surface cleanup with the remediation of the 22nd and final uranium mill tailings site at Maybell, Colorado, in 1998; a second phase of the project aims to achieve groundwater compliance at the sites. At the beginning of FY 2003, DOE had completed active cleanup at 76 of the 114 geographic sites. Extensive work remains to be completed at some of the 38 remaining locations, particularly at the Hanford facility and the Savannah River Site.

DOE plans to complete cleanup at an additional 13 geographic sites by the end of FY 2006. At the sites remaining after 2006, which includes the largest ones, DOE will continue treatment of the remaining legacy waste streams and management of legacy nuclear materials, including nuclear material stabilization and disposition. To protect human health and the environment, the Department will implement long-term stewardship activities after active cleanup is completed at the sites. DOE expects to complete most high-risk work by 2012 and all currently defined work by 2035 (U.S. DOE 2003b).

Exhibit 7-1 shows the major DOE installations where cleanup of release sites and/or facilities has not been completed.[4] The locations that have only wastes to package, with no release sites or facilities to remediate, do not appear in the exhibit. About half of the release sites have been cleaned up, and roughly 905 of the remaining sites are expected to have cleanup completed by 2015, 250 more by 2025, and the remaining 3,135 by 2035. Estimates for several hundred release sites are not available. The Nevada Test Sites and the Hanford facility (including the Office of River Protection) account for 59 percent of the release sites remaining to be remediated. Other installations with large numbers of release sites include Los Alamos National Laboratory (795 sites), the Oak Ridge Reservation (374 sites), and the Savannah River Site (198 sites).

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3 DOE estimates of the number of release sites discovered to date vary: the number is reported as 9,995, 10,527, 10,082, and 10,374 in the 2002, 2003, 2004, and 2005 budget requests, respectively.

4 The numbers of release sites shown in Exhibit 7-1 are slightly lower than reported above because specific data for the "Other" category were not available.

Exhibit 7-1. Remaining Release Sites and D&D Facilities by Location

Installation	No. of Release Sites	No. of Facilities	Sites Completed by 2004	Facilities Completed by 2004	Release Sites Remaining	Facilities Remaining	Estimated Completion Date
Lab for Energy-Rel. Health Res.	17	1	17	1	0	0	2005
Ashtabula Env. Mgmt. Proj., OH	3	32	0	21	3	11	2006
Columbus Env. Mgmt. Proj., OH	2	15	1	14	1	1	2006
Fernald Env. Mgmt. Proj., OH	6	30	2	24	4	6	2006
Kansas City Plant	43	0	42	0	1	0	2006
Lawrence Berkeley Natl. Lab	181	0	166	0	15	0	2006
Lawrence Livermore Natl. Lab	120	0	112	0	8	0	2006
Mound/Miamisburg Mgmt. Proj., OH	178	135	121	96	57	39	2006
Rocky Flats Env. Tech. Center, CO	240	377	205	269	35	108	2006
Sandia National Labs	263	1	192	1	71	0	2006
Stanford Linear Accelerator Ctr.	20	0	19	0	1	0	2006
Energy Technology Eng. Center	10	26	7	23	3	3	2007
Brookhaven National Lab, NY	76	10	68	4	8	6	2008
Lawrence Livermore Site 300	73	0	65	0	8	0	2008
Pantex Plant	237	5	76	1	161	4	2008
Argonne National Lab, East	443	78	443	63	0	15	2009
Atlas Site (Moab)	1	0	0	0	1	0	2011
West Valley Demo. Proj., OH	1	0	0	0	1	0	2012
General Electric Vallecitos	0	1	0	0	0	1	2014
Separations Process Research Unit	6	4	0	0	6	4	2014
Los Alamos National Lab	2,124	1	1,329	0	795	1	2015
Oak Ridge Reservation, TN	654	248	280	114	374	134	2015
Portsmouth GDP, OH	163	0	149	0	14	0	2025
Savannah River Site	515	837	317	56	198	781	2025
Nevada Test Site & Off-Sites	2,082	0	762	0	1,320	0	2027
Paducah GDP, KY	237	2	87	0	150	2	2030
Hanford Site	1,618	1,382	302	173	1,316	1,209	2035
Idaho Nat. Eng. & Env. Lab	270	365	145	77	125	288	2035
Office of River Protection (Hanford)	322	148	5	0	317	148	2035
Total	**9,905**	**3,698**	**4,912**	**937**	**4,993**	**2,761**	

Notes:
- Completed sites are not listed, nor sites where closure is near term or the work involves only waste packaging and/or disposal: e.g., Argonne National Lab - West; General Atomics, CA; Salmon Site, MS; South Valley Superfund Site, NM; Princeton Plasma Physics Lab, NJ; Amchitka Island, AK; and the Inhalation Toxicology Lab, NM.
- The number of release sites in this table will be slightly different from that reported in other sources because specific data for the "Other" category were not available, and because of rounding.

Source: Department of Energy, *FY 2005 Budget Request to Congress*, Environmental Management.

Despite the size of the DOE complex, most of this land is uncontaminated. Less than 15 percent of the land at the five major sites (Hanford, Savannah River, the Idaho National Engineering and Environmental Laboratory, Rocky Flats, and the Oak Ridge Reservation) is contaminated. However, the contamination that does exist presents extraordinary technical challenges because of the presence of radionuclides (Probst 2000).

Contaminants of concern across the complex generally include radionuclides, metals, and dense non-aqueous phase liquids (DNAPLs). More specifically, key contaminants fall into the following groupings (U.S. DOE 2002c).

- **Radionuclides:** plutonium, strontium-90, cesium-137, isotopes of uranium, tritium, thorium, technetium-99, radium, and iodine-129.
- **Metals:** lead, chromium VI, mercury, zinc, beryllium, arsenic, cadmium, and copper.
- **DNAPLs:** carbon tetrachloride, trichloroethene, dichloroethene, tetrachloroethene, chloroform, dichloromethane, and polychlorinated biphenyls.

7.4 Estimated Cleanup Costs

DOE has estimated the cost to complete cleanup at all sites that are currently in its program. However, because of uncertainties that DOE has recognized, these estimates are based on a number of critical assumptions, and revisions to these assumptions could raise or lower the probable cost. This section presents the cost estimate and describes the critical assumptions.

7.4.1 Life Cycle Costs

DOE estimates that, as of the end of FY 2004, it will cost about $111 billion to complete the cleanup of the remaining legacy release sites currently in EM's program, and that it will complete active cleanup at most of its release sites by 2035 (U.S. DOE 2004).[5] About $35 billion of this total is anticipated to be for remediation. Environmental management funds not spent for site remediation are used for national program planning and management, landlord activities, waste management, facility stabilization, technology development, and nuclear material stabilization, packaging, and transportation.

The estimate relies on several critical assumptions. It does not include all cleanup activities needed, and hence is likely to underestimate the ultimate total cost of cleanup. DOE has yet to determine the cost of remediating facilities that are still in operation (for which cleanup and closure could become the responsibility of either the Office of Future Liabilities or the office operating the facility), or the cost of addressing one-of-a-kind or first-of-a-kind contamination problems that currently lack viable cleanup technologies, such as groundwater contaminated with metals, chlorinated organics, and/or radioactive isotopes. Nor does the current estimate include the costs of monitoring and maintaining site remedies over the thousands of years that radioactive hazards will remain. Thus the ultimate cost of cleaning up properties for which DOE is responsible may be greater than the estimates indicate.

The estimated life-cycle costs and remaining costs as of the end of FY 2004 for each of the major installations are shown in Exhibit 7-2. Two sites account for 55 percent of the program's life-cycle cost, and five sites account for 73 percent. DOE anticipates that by completing site cleanup more quickly, it will reduce the length of time it must bear the fixed costs associated

5 This estimate is considerably lower than the $220 billion estimate in the 2002 top-to-bottom review because DOE has undertaken a major effort to accelerate cleanup, improve business practices, and reduce restoration costs (U.S. DOE 2003a and 2004).

with maintaining the infrastructure of a site (a major component of DOE's overall costs). Hence, the Department intends to complete as much cleanup as possible in the near term.

Exhibit 7-2. Estimated Remaining Life Cycle Cost for DOE Site Restoration by Installation

Installation	Release Sites Remaining	Facilities Remaining	Est. Completion Date	Est. Total Life-Cycle Cost ($000)	Est. Remaining Life-Cycle Cost ($000)
Lab. for Energy-Related Health Res.	0	0	2005	40,577	967
Ashtabula Env. Mgmt. Project, OH	3	11	2006	156,923	33,605
Columbus Env. Mgmt. Proj., OH	1	1	2006	163,259	33,851
Fernald Env. Mgmt. Proj., OH	4	6	2006	3,553,013	1,324,958
Kansas City Plant	1	0	2006	28,660	7,373
Lawrence Berkeley Nat. Lab.	15	0	2006	33,758	7,028
Lawrence Livermore Nat. Lab/	8	0	2006	514,673	44,530
LLNL Site 300	8	0	2008	0	
Mound/Miamisburg Proj., OH	57	39	2006	1,503,413	771,800
Rocky Flats Env. Tech. Center	35	108	2006	9,297,868	4,555,884
Sandia National Laboratories	71	0	2006	230,721	30,018
Stanford Linear Accelerator Center	1	0	2006	20,599	3,316
Energy Technology Eng. Center	3	3	2007	204,976	67,746
Brookhaven National Lab	8	6	2008	373,359	154,055
Pantex Plant	161	4	2008	192,291	81,559
Argonne National Lab, East	0	15	2009	63,221	8,233
Atlas Site (Moab)	1	0	2011	186,034	172,388
West Valley Demo. Proj, OH	1	0	2012	1,366,841	933,942
General Electric Vallecitos b	0	1	2014	0	0
Separations Process Unit	6	4	2014	245,815	234,439
Los Alamos National Laboratory	795	1	2015	1,529,522	858,700
Oak Ridge Reservation	374	134	2015	7,351,982	3,290,155
Portsmouth GDP	14	0	2025	6,258,959	5,306,287
Savannah River Site	198	781	2025	28,643,636	17,859,407
Nevada Test Site & Off-Sites	1,320	0	2010-2027	2,317,170	1,655,160
Paducah GDP	150	2	2030	4,694,101	3,996,310
Hanford / River Protection	1,633	1,357	2035	56,184,732	43,765,834
Idaho Nat. Eng. & Env. Lab	125	288	2035	14,415,224	9,907,649
Waste Isolation Plant	NA	NA	NA	6,278,763	4,486,913
Completed				1,077,277	0
Subtotal, installations	4,993	2,761	NA	146,927,367	99,592,107
Other (unspecified)				11,520,380	11,520,380
Total	**4,993**	**2,761**		**158,447,747**	**111,112,487**

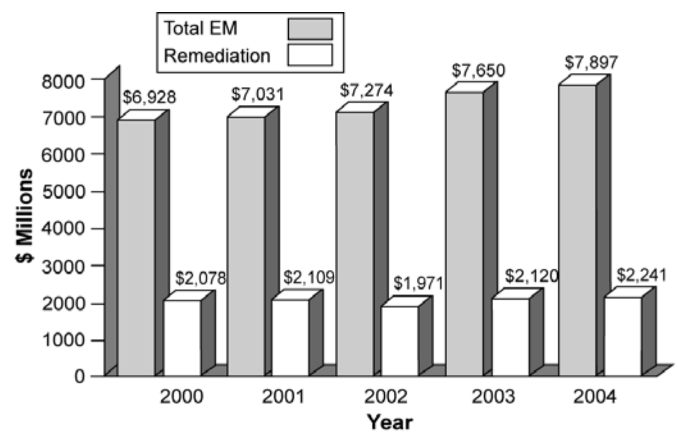
Notes:
- "Completed" includes life-cycle costs for sites completed prior to FY 2005, as well as life-cycle costs for various field activities that cannot be credibly allocated to their respective sites.
- "Other" includes life-cycle costs for technology development and deployment, decontamination and decommissioning contributions & offsets, program direction, and headquarters activities.
- This table includes non-remediation work, such as waste packaging and waste management. Remediation is about one-third of this figure.

Source: DOE FY 2005 Budget Request

7.4.2 Timing of Expenditures

The ultimate cost of DOE's cleanup will depend on annual funding levels and achievement of the work as scheduled. Higher annual funding tends to accelerate cleanup work and reduce total life-cycle costs in the long run; lower annual funding tends to delay work and increase total costs. Actual or anticipated EM expenditures for FY 2001 through FY 2005 are shown in Exhibit 7-3. Expenditures are expected to increase about 14 percent between FY 2001 and FY 2005. DOE anticipates that these current increases ultimately will lead to earlier completion of many sites and lower life-cycle costs. After 2005, EM's annual site restoration expenditures are expected to decline (U.S. DOE 2004).

Exhibit 7-3. Actual and Planned EM and Site Restoration Budget: FY 2000-2004



Source: U.S. DOE, Congressional Budget Requests for Environmental Management, FY 2003 and 2005 (DOE 2003a and DOE 2004)

Exhibit 7-4 shows actual or anticipated EM expenditures for FY 2002 through FY 2005 by major DOE activity type. Stabilization of high-risk materials alone consumed almost half of the EM budget in recent years. Remediation of soil and water took about one-tenth, and D&D of contaminated facilities took a little over one-sixth. The estimates do not include estimates of cleanup costs for facilities currently in use, since they are not part of the EM program.

The completion of cleanup work at release sites is the key measure of success for environmental management, but site cleanup is a very complex task, generally involving numerous activities over many years. The annual budget request, usually available on the DOE web site, contains information on EM program performance, such as the volume of waste treated and disposed of, number of release site cleanups completed and facilities decommissioned, quantity of nuclear material stabilized, quantity of spent nuclear fuel moved to dry storage and prepared and shipped for consolidation, and number and type of innovative technologies deployed.

7.5 Market Entry Considerations

DOE is the largest single U.S. purchaser of remediation services (over $2 billion annually), accounting for over one-third of the U.S. remediation market in recent years. DOE also is the largest civilian contracting agency in the federal government; about 90 percent of its annual

Exhibit 7-4. DOE Environmental Management Expenditures 2002-2004 ($000)

Activity	FY 2002 Comparable Appropriation	FY 2003 Comparable Appropriation	FY 2004 Comparable Appropriation	FY 2005 Budget Request
Nuclear Material Stabilization and Disposition	592,338	579,663	713,337	725,004
Spent Nuclear Fuel Stabilization and Disposition	403,617	402,307	358,176	244,681
Solid Waste Stabilization and Disposition	949,848	968,350	1,078,195	1,065,887
Radioactive Liquid Waste Stabilization and Disposition	863,087	1,002,371	1,049,629	1,261,084
Radioactive Liquid Waste Stabilization and Disposition: Major Construction	665,000	690,000	686,036	690,000
Safeguards and Security	244,361	254,747	291,124	265,059
Soil and Water Remediation	680,542	782,475	807,501	987,154
Nuclear Facility Decontamination & Decommissioning	1,095,039	1,167,695	1,257,843	1,206,800
Non-Nuclear Facility Decontamination & Decommissioning	31,264	21,085	55,025	47,183
Operate Waste Disposal Facility	154,916	176,663	153,577	174,637
Waste and Material Transportation	43,522	13,631	43,994	40,751
Technology Development	200,189	113,679	66,116	60,142
Community and Regulatory Support	43,763	38,589	41,217	39,854
Program Direction	301,422	279,723	276,510	271,059
Federal Contribution to the Uranium Enrichment D&D Fund	420,000	432,731	449,333	463,000
Pre-2004 Completions	105,392	11,786	0	0
Other	236,977	338,741	322,856	354,501
Total, EM	7,031,277	7,274,236	7,650,469	7,896,796

Note: The EM budget request also includes offsets, such as the Uranium Enrichment D&D fund, which are not shown above.

Source: DOE FY 2004 and 2005 Congressional Budget Requests (U.S. DOE 2003b and 2004).

budget is spent on contracts. DOE relies primarily on contractors (100,940 in 2002, according to the 2002 performance report) to operate its facilities and carry out its diverse missions (U.S. GAO 2003), including a small army of nearly 36,000 contractors to rectify the environmental hazards resulting from five decades of nuclear weapons production (Probst 2000).

Characteristics of DOE Contractors

Most of EM's work is accomplished through large prime contractor companies. In 2002, more than 60 percent of over $5 billion in EM contracting was managed by just three firms: Bechtel Group International, Washington Group International/Westinghouse, and Fluor Corporation. Of course, some of that money went to subcontractors. Another 30 percent of the total EM contract revenues flowed through four prime contractors: CH2M Hill, British Nuclear Fuel (BNFL), BWX Technologies, and Jacobs Engineering (Paterson 2002). Few new entrants have found a way to be competitive. A DOE study (*Analysis of the DOE Contractor Base*, 2001) reported that the number of potential bidders for major DOE contracts diminished from 20 to 30 companies a decade ago to about 10 companies in 2001. Recent procurements for multi-billion dollar site management contracts have received only one or two proposals (e.g., the Office of River Protection Tank Waste Remediation System, Fernald Environmental Management Project, and Savannah River Site)(YAHSGS 2002).

The consolidation of DOE remediation contractors reflects a general market trend in the remediation services industry, as noted by Farkas Berkowitz in a 2000 comparison of market shares. In 1994 the top ten companies claimed 38 percent of the remediation market; by 2000 the top five companies claimed 50 percent of the market (YAHSGS 2002). The reluctance of contractors to bid on major DOE procurements is based upon a combination of low profit margins and the difficulty of competing with incumbent contractors. The consolidation of firms and a diversification of firms into other, more profitable commercial markets means that EM now faces a smaller contractor base with less "risk-bearing capacity" as it seeks to accelerate cleanup (Tomlinson & Paterson 2002).

Increasing Emphasis on Performance-Based Contracting

DOE has committed to increasing its use of performance-based contracting as a means of achieving risk mitigation and to strengthen its business practices. In 1994, two-thirds of remediation contracts were based on time and materials (YAHSGS 2002). If DOE is successful in its effort to integrate performance-based approaches into all levels of its contracting system, companies providing risk-related services such as risk-based corrective action (RBCA) will continue to be a major factor in determining remediation technology applications as well as market share over the coming decade (U.S. DOE 2003a & 2002d).

EM's push to increase the use of pay-for-performance contracting is an important element in advancing its environmental restoration program. To implement this initiative, DOE must compete with commercial markets for the best contractors and contractor personnel. The Department also must alter internal business practices that are not yet consistent with a comprehensive pay-for-performance approach (YAHSGS 2002).

DOE's Accelerated Cleanup Schedules

In response to the top-to-bottom review, DOE EM has opted to move forward more rapidly with its cleanup activities. EM is reviewing remediation plans at many installations and negotiating with regulators and other parties. It is expected that end state goals, remediation approaches, and schedules will be revised, perhaps more than once, at many sites. This expected change in the business approach may offer opportunities to a cleanup contractor who is flexible, resourceful, and efficient in meeting these challenges.

Growing Need for Long-Term Stewardship

In the long run, DOE's program strategy anticipates that activities will shift from cleanup to long-term stewardship, including monitoring, maintenance, and repair of properties where waste has been left on site. For example, many nuclear sites (e.g., FUSRAP sites, low-level waste and mixed-waste burial grounds, closed mine and mine tailings sites) may require long-term attention. The required monitoring and maintenance work may be more suitable to smaller contractors than to those involved in the management and cleanup of DOE's large installations. Monitoring and stewardship programs also should open the door to new instruments and measurement technologies coupled with remote information management systems to maintain perpetual vigilance over past cleanups (YAHSGS 2002).

Encouraging the Use of Advanced Technologies

The contract reform mechanisms sought within EM may affect contractor incentives to use advanced remediation techniques. A cleanup contractor's willingness to deploy an innovative or emerging cleanup technology requires that the benefits achieved through deployment (e.g., reduced cost and schedule) substantially outweigh the down-side risk of failure and recovery due to the greater uncertainties associated with new technologies. In the interest of finding better cleanup approaches, demonstration projects can be structured so that the prime contractor's fees are not affected by success or failure of the demonstrations (YAHSGS 2002). DOE has shown its interest in emerging technologies by funding their development and deploying remedies such as phytoremediation and permeable reactive barriers at its sites, as has been documented in EPA's *Treatment Technologies for Site Cleanup, Annual Status Report, 11th Edition*.

7.6 Remediation Technologies and Research, Development, and Demonstration

Even for many experts in the environmental field, the terms and issues at DOE sites can differ significantly from what most environmental engineers encounter at privately owned sites that are subject to CERCLA or RCRA requirements. The presence of radioactive products resulting from nuclear fuel cycles and nuclear weapons production complicates the cleanup of the more familiar contaminants and hazardous wastes (Probst 2000) and present special hazards with regard to worker health and safety. Exhibit 7-5 describes technologies DOE has found useful to the cleanup effort.

Exhibit 7-5. Examples of Innovative Technologies Useful to DOE

Technology	Analysis
Soil Remediation	**Barometrically Enhanced Remediation Technology (BERT™)** — Passively capitalizes on wind effects and the vertical soil-gas movement resulting from natural barometric pressure oscillations and harnesses this mechanism to ensure a net-upward, vertical soil-gas flux in contaminated soil. Applicable to sites where contaminants are volatile under standard conditions, close to the soil surface, and at concentrations low enough to eliminate the need for off-gas treatment. BERT™ has been deployed at DOE's Idaho Engineering and Environmental National Laboratory. (DOE/EM-0516) **Well Injection Depth Extraction (WIDE)** — A hybrid soil flushing/soil gas extraction system developed by researchers from North Carolina State University. WIDE uses prefabricated vertical wells for the in-situ remediation of contaminated fine-grained soils. A WIDE demonstration of trichloroethene removal took place in Ohio at DOE's Ashtabula Environmental Management Project in 1999. (DOE/EM-0577) **in-situ Gaseous Reduction (ISGR)** — Reduction and immobilization of hexavalent chromium or other redox-sensitive metals in soils by injection of a low-concentration hydrogen sulfide gas mixture. The oxidized metals are reduced and immobilized as either an insoluble oxyhydroxide or sulfide. ISGR was demonstrated in1998 at White Sands Missile Range, New Mexico, in a cooperative DOE/DoD effort. (DOE/EM-0521)
Groundwater Remediation	**Hydrous Pyrolysis Oxidation/Dynamic Underground Stripping (HPO/DUS)** — A combination of steam and oxygen injection, electrical heating (if required), soil vapor extraction, in-situ bioremediation, electrical resistance tomography, and conventional pump-and-treat technologies that removes organics (e.g., DNAPLS) from soil and groundwater. DUS volatilizes contaminants, which are carried by the steam to a central extraction well. HPO is a chemical process for destroying contaminants in place in the subsurface. HPO/DUS was applied to full-scale cleanup at the Visalia Superfund Site in Visalia, CA, from 1997 to 1999. The technology is available for licensing. (DOE/EM-0504) **Enhanced in-situ Bioremediation** — Involves electron-donor injection to stimulate indigenous microbes, groundwater pumping, air stripping, and monitoring. The patented use of sodium lactate (or similar electron donors) at high concentrations to enhance bioavailability is marketed as Bioavailability Enhancement Technology™, or BET™. A 1999-2000 demonstration to treat the source area of a TCE plume in the groundwater at Idaho National Engineering and Environmental Laboratory worked so well that the Record of Decision was amended in 2001 to incorporate the technology. (DOE/EM-624) **In-Well Vapor Stripping Technology** — Represented in the United States by four types of commercial in-well vapor stripping systems: NoVOCs™, Density Driven Convection (DDC), Unterdruck-Verdampfer-Brunnen (UVB) Vacuum Vaporizer Well and Coaxial Groundwater Circulation (KGB), and C-Sparger®. Specially designed wells pump water or vapor through a screened interval and recirculate it back into the aquifer through a separate interval. Treatment occurs below ground within the well casing, which reduces costs. A UVB system successfully removed chlorinated solvents from groundwater at Brookhaven National Laboratory from 1999 through 2001. (DOE/EM-0626) **Permeable Reactive Barrier (PRB)** — A zone of reactive material placed in the path of a groundwater plume to reduce concentrations of dissolved organics or inorganics as the water flows through. The reactive medium selected varies with the contaminant(s) requiring treatment, though elemental iron filings are used most frequently. DOE has installed PRBs at many sites, including the Monticello Mill Tailings Site in Utah, the Kansas City Plant in Missouri, the Rocky Flats Mound Site in Colorado, and the Oak Ridge Reservation Y-12 Site in Tennessee. (DOE/EM-0557, DOE/EM-0623)

Exhibit 7-5: Examples of Innovative Technologies Useful to DOE (continued)

Technology	Analysis
Facilities Deactivation	**Modified Brokk Demolition Machine With Remote Operator Console** — A commercially available robotic machine purchased for deactivation and decommissioning (D&D) of nuclear facilities. At Idaho Engineering and Environmental Laboratory (INEEL), a Brokk 250 demolition system was demonstrated in 1999 in various D&D activities and was modified and demonstrated again in 2000. It is now part of the general INEEL D&D equipment pool. (DOE/EM-0597)
Tank Waste Stabilization	**Thermal Denitration** — Uses high temperatures and a carbon-based reductant (e.g., sugar) to decompose the nitrate and nitrite salts in aqueous sodium-bearing acidic waste to nitrogen gas and oxides of nitrogen. The three-step process calls for evaporation of the acidic liquid, decomposition of the highly volatile components, and chemical interaction of the waste components and the added mixture to form a solid. DOE has over 1,000,000 gallons of sodium-bearing acidic waste to denitrify, solidify, and dispose of. Demonstrated at Pacific Northwest National Laboratory. (DOE/EM-0616)
Mixed Waste Stabilization	**Solidification of Radioactive Waste Oils** — Products for free-liquid control in storage, transport, and disposal of radioactive and RCRA-defined waste oils. A polymer solidifying agent, Nochar Petrobond®, was demonstrated in 1999 at the Mound Large-Scale Demonstration and Deployment Project, in Miamisburg, Ohio, to absorb and solidify high-activity tritium-contaminated vacuum-pump oils. (DOE/EM-0598)
Nuclear Materials Processing	**Real-Time Monitor for Transuranics in Glass** — An optical sensor for remotely assaying transuranic elements in molten glass as it flows into containers during the vitrification process. The technology was demonstrated at the Savannah River Site three times between 1997 and 1999. (DOE/EM-0561)
Characterization	**Tomographic Site Characterization Using CPT, ERT, and GPR** — A geophysical system delivered via cone penetrometer technology (CPT) that incorporates results from electrical resistivity tomography (ERT) and ground penetrating radar (GPR). ERT can be used to monitor or detect subsurface processes such as water infiltration, underground tank leaks, and steam or electrical heating during soil cleanup operations. Data from GPR are used to produce a cross-sectional profile or record of subsurface features. Demonstrated at a test site in Vermont and at the Savannah River Site. (DOE/EM-0517)
Containment	**Alternative Landfill Cover** — A regulatory-acceptable alternative to the prescriptive RCRA Subtitle C and D cover design. To identify covers with cost and performance advantages over the prescriptive baseline covers at an arid or semi-arid site, DOE is monitoring an alternative landfill cover demonstration at Sandia National Laboratories in New Mexico to document the performance of four different alternative landfill covers. (DOE/EM-0558) **SEAtrace™ Monitoring System** — A low-cost, early detection system to verify the initial and long-term integrity of subsurface containment barriers by gaseous tracer injection, automated multipoint sampling, and real-time global optimization modeling. The system characterizes the integrity of impermeable barriers constructed above the water table and determines the size and location of leaks. Demonstrated at Dover Air Force Base, Naval Air Station Brunswick, and Brookhaven National Laboratories. (DOE/EM-0549)

Source: U.S. Department of Energy, the *Innovative Technology Summary Report* series. Available through DOE's Information Bridge at http://www.osti.gov/bridge/ or at apps.em.doe.gov/OST/itsrall.asp.

7.6.1 Private Sector Involvement: Mechanisms

DOE uses different mechanisms to invite the private sector to participate in its technology research and development programs. These include specific request for proposals (RFPs) issued in *Federal Business Opportunities* or the *Federal Register* and broad announcements designed to collect "best-in-class" technology providers (U.S. DOE Web 2003a).

Technology transfer can mean many things: technical assistance to solve a specific problem, use of unique facilities, access to patents and software, exchange of personnel, and cooperative research. The most appropriate mechanism will depend on the objective of each partner. A brief description of several technology transfer mechanisms appears below.

Cooperative agreements: instruments entered into by the government with industry, universities, and others to support or stimulate research. Agreements are generally cost-shared with the nonfederal participant.

Cooperative Research and Development Agreements (CRADAs): an incentive for collaborative research and development. CRADAs are agreements between a specific DOE laboratory and a non-federal source to conduct mutually beneficial research and development that is consistent with the laboratory's mission. CRADAs can be funded either entirely by the partner or by DOE/partner cost sharing. CRADA partnerships can be developed by identifying the specific area for research and development, the intellectual property owned, and the laboratories/facilities technology areas that best match the needs, and then contacting that laboratory/facility technology transfer office.

Cost-shared contracts/sub-contracts: collaboration through a procurement of mutual benefit to industry and to government. Often the government can agree not to disseminate, for a limited period of time, commercially valuable data that are generated under a cost-shared contract.

Licensing: the transfer of less than ownership rights in intellectual property, such as a patent or software copyright, to permit its use by the licensee. Licenses can be exclusive or for a specific field of use or for a specific geographical area. The potential licensee must present plans for commercialization. The DOE Invention Licensing Home Page and its associated databases provide information on Department-owned patents available for license for commercial use. (http://www.osti.gov/dublincore/gencncl/)

Personnel exchange programs: arrangements allowing government or laboratory staff to work in industry facilities and industry personnel to work in government laboratories and facilities to enhance technical capacities and support research in specific areas. Costs are borne by the organization sending the personnel. Intellectual property arrangements can be addressed in exchange agreements.

R&D consortia: arrangements involving multiple federal and non-federal parties working together for a common R&D objective. Funding for R&D consortia can be shared, but usually no funds are exchanged between participants.

Technical assistance to small business: undertaken by DOE/laboratory/facility personnel in response to an inquiry from an individual or organization seeking to further knowledge, solve a specific problem, or improve a process or product.

User facility agreements: arrangements permitting private parties to conduct research and development at a laboratory. For proprietary R&D, the laboratory is paid for the full cost of the activity. If the work will be published, cost can be adjusted. Intellectual property rights generally belong to the user.

Work for Others (WFO): arrangements permitting private parties to conduct research and development at a laboratory for either a federal agency or a non-federal entity. In this arrangement, the private entity pays the laboratory's full costs for performing a research project. A WFO arrangement permits a developer to gain access to highly specialized or unique DOE facilities, services, or technical expertise. A technology developer can acquire a WFO by identifying the unique expertise required, identifying the laboratories/facilities technology areas that best match the technology development need, and contacting the laboratory/facility technology transfer office. For proprietary R&D, the laboratory is paid for the full cost of the activity. If the work will be published, cost can be adjusted. Intellectual property rights generally belong to the user.

7.6.2 Private Sector Involvement: Programs

Among DOE's many technology development programs, the following are particularly useful to developers of environmental technologies.

The **Environmental Management Science Program (EMSP)**, sponsored by the Office of Science (SC), is designed to inspire breakthroughs in areas critical to the EM mission through basic research, and to fulfill DOE's continuing commitment to the cleanup of environmental liabilities. The program was initiated in FY 1996 to address long-term technical issues and provide EM with near-term fundamental data critical to the advancement of technologies that are under development, but not yet at full scale nor implemented. Proposed basic research should contribute to environmental management activities that would decrease risk for the public and workers, provide opportunities for major cost reductions, reduce time required to achieve EM's mission goals, and, in general, address problems that are considered intractable without new knowledge (NRC 2000). The EM Science Program's solicitations are published in the *Federal Register*. (http://emsp.em.doe.gov/)

Since 1996, the Program has held six competitions and has awarded over $290 million in funding for 361 research projects. A breakdown of the EMSP awards by year is as follows:

- 1996 and 1997: 202 awards totaling $160 million targeted at a broad spectrum of basic science cleanup and waste management issues.
- 1998: 33 awards totaling $30 million focused on high-level radioactive waste and decontamination and decommissioning issues.
- 1999: 39 awards totaling $30 million fostered basic research in the areas of vadose zone contamination and low dose radiation.

- 2000: 42 awards totaling $30 million in research renewals for 1996 and 1997 funded projects.
- 2001: 45 awards totaling $39 million focused on additional high-level radioactive waste and decontamination and decommissioning issues (DOE 2002c).
- 2002: 38 awards totaling $33 million for research on subsurface contamination in the vadose and saturated zones.

The **Natural and Accelerated Bioremediation Research Program (NABIR)** is sponsored by DOE's Office of Biological & Environmental Research within SC to increase understanding and utilization of contaminant bioremediation processes. (http://www.lbl.gov/NABIR/)

The **Small Business Innovation Research (SBIR)** and **Small Business Technology Transfer (STTR)** programs are designed to stimulate and foster scientific and technological innovation in the private sector, strengthen the role of small businesses in meeting federal research and development needs, and increase the commercial application of innovations derived from federally funded research. SBIR defines a small business as a for-profit enterprise operating in the United States with majority domestic ownership and with no more than 500 employees. Phase I SBIR awards up to $100,000 are awarded to explore the feasibility of innovative concepts for nine months. Phase II is the principal research or R&D effort, with awards up to $750,000 over a two-year period. DOE funds approximately 200 Phase I projects and about 90 Phase II projects per year. In Phase III, non-federal capital should be used by the small business concern to pursue commercial applications of the R&D. To aid awardees seeking follow-on funding for Phase III, DOE sponsors a Commercialization Assistance Project that provides individual assistance in developing business plans and preparing presentations to potential investment sponsors. The STTR pilot program is closely modeled on SBIR, with an additional requirement of co-participation by a research institution such as a university, non-profit institute, or contractor-operated, federally funded research and development center. Not less than 40 percent of the work conducted under an STTR award must be performed by the small business concern, and not less than 30 percent of the work must be performed by the non-profit research institution. The STTR awards are fixed-price grants of approximately $100K under Phase I, rising to about $500K in Phase II, given continued successful program performance. University or other non-profit involvement in a project does not limit the applicant to STTR only; application can be made under SBIR alternatively. (http://sbir.er.doe.gov/sbir/)

Within EM, the **Office of Science and Technology** program provides direct technical solutions to closure sites, which are DOE facilities whose primary mission has been completed or terminated and where current activities are focused solely on site remediation. At the start of each fiscal year, "alternative projects" will be identified that target immediate and specific cleanup needs at the sites. Department-wide competitive grant and contract regulations apply. (http://www.em.doe.gov/ost)

The **National Energy Technologies Laboratory (NETL)** supports cleanup by implementing several extramural technology development and deployment programs, with emphasis on technologies for deactivation and decommissioning, and minimization and/or abatement of environmental problems associated with the development and use of the nation's energy supply (e.g., fly ash from coal-burning facilities). NETL contracts with private-sector industrial and academic organizations for technology development. (http://www.netl.doe.gov/business/solicit/)

The **Strategic Environmental Research and Development Program (SERDP)** is the Department of Defense's corporate environmental R&D program, planned and executed in full partnership with DOE and EPA, with participation by numerous other federal and non-federal organizations. (http://www.serdp.org)

DOE encourages organizations and individuals to submit proposals that are relevant to the DOE research and development mission either in response to formal DOE solicitations or through self-generated unsolicited proposals. An **Unsolicited Proposal** is an application for support of an idea, method, or approach submitted by individuals, businesses, or organizations solely on the proposer's initiative, rather than in response to a formal government solicitation. Funding of Unsolicited Proposals is considered a noncompetitive action. A 50-page detailed booklet titled *Guide for the Submission of Unsolicited Proposals* outlines the Unsolicited Proposals process and is available at
http://professionals.pr.doe.gov/ma5/MA-5Web.nsf/WebPages/Proposal+System?OpenDocument

In 1994, EM's Office of Science and Technology implemented the **Technology Focus Area** approach as a strategy to leverage resources and facilitate sound technology development decisions in the following technology problem areas: deactivation and decommissioning, subsurface contaminants, transuranic and mixed waste, and tanks. The Focus Area approach sought to optimize resources by streamlining technology management activities into a single focus team for each major problem area. A National Research Council report, *Decision Making in the U.S. Department of Energy's Environmental Management Office of Science and Technology* (NRC 1999), provides an extensive overview of the aims and organization of the Technology Focus and Cross-Cutting Technology Areas. As a result of the reorganization brought about by the 2002 top-to-bottom review, EM is working to accelerate cleanup at specific sites and has refocused the science and technology program to address a limited number of critical site-specific cleanup needs, deliver expert services, and provide potentially high payback solutions. DOE terminated the Focus Area and most of the Cross-Cutting Technology Area programs at the end of FY 2002.

Numerous reports exploring DOE's environmental technology research and development needs have been produced by the National Research Council (see the extended bibliography in the appendix). Also, a collaborative effort to draft DOE's *Long-Term Stewardship Science and Technology Roadmap* will define the strategic path forward for the critical science and technology required to support the long-term stewardship program with regard to near-term (5-10 year), intermediate-term (10-20 year), and long-term (20-50 year) general environmental research and development needs (U.S. DOE 2002b).

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Chapter 8
Demand for Remediation of Sites Managed By Civilian Federal Agencies

This chapter describes the market for cleanup of sites owned or operated by "civilian" federal agencies, which includes all federal agencies except the Departments of Energy and Defense. Civilian agencies are collectively responsible for the management of millions of acres of land and may ultimately be responsible for site characterization and remedial actions at thousands of sites.[1]

Highlights
- About 70% of civilian federal agency contaminated sites are on lands managed by the DOI and USDA. These agencies combined manage over 700 million acres of land, about a third of U.S. land.
- DOI and USDA have identified at least 3,000 contaminated sites that will require cleanup. In addition, between 5,000 and 25,000 abandoned mine sites are on lands for which these agencies are responsible.
- The cost to complete cleanup at civilian federal agency sites is estimated to be $15-22 billion. This estimate does not include all of the mining sites. Mining sites are addressed in Chapter 11.
- The 17 federal agencies on EPA's docket typically spend an estimated $100-200 million annually for contaminated site cleanup at their properties. This figure may underestimate the total remediation expenditures, because it includes only some of the potential cost recovery and cost sharing.
- Based on the above annual funding level, it will take between 100 and 200 years to clean up the contaminated sites at civilian federal agencies.
- Given the types of environmental problems present, remediation approaches at civilian federal sites are likely to be similar to those used in other programs, such at RCRA and NPL sites.

The most comprehensive source of information on contaminated facilities for which civilian agencies are responsible is the "Federal Agency Hazardous Waste Compliance Docket" ("the docket") (U.S. EPA 2003a). Section 120(c) of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), as amended by the Superfund Amendments and Reauthorization Act (SARA), requires EPA to maintain the docket as a repository for information about federal facilities that manage hazardous waste or from which hazardous substances have been, or may be, released. As of January 2003, 1,099 facilities, distributed among 18 civilian federal agencies, were listed on the docket. It is estimated that approximately 70 percent of these facilities may require environmental cleanup.

Although an overall estimate of the potential cost of cleaning up these facilities is unavailable, estimates are available for agencies managing a significant portion of the facilities listed on the docket and for which selected information is available: the U.S. Department of Interior (DOI), U.S. Department of Agriculture (USDA), U.S. Department of Transportation (DOT), and National Aeronautics and Space Administration (NASA). These

[1] Throughout this chapter, the term "site" is used to indicate an individual area of contamination. The term "facility" identifies an entire tract, including contiguous land, that is the responsibility of the subject agency. A "facility" may contain one or more contaminated areas or "sites."

agencies together account for 75 percent of the civilian federal agency facilities listed on the docket. These agencies are also entrusted with managing vast amounts of public land. The largest federal land holder, DOI, is responsible for 507 million acres of surface land, or about one-fifth of the land in the United States; and the U.S. Forest Service (part of USDA) manages 192 million acres of national forest and grasslands.

8.1 Civilian Federal Agency Cleanup Programs

Cleanup at hazardous waste sites is regulated in large part by CERCLA/SARA and the Resource Conservation and Recovery Act (RCRA). Federal agencies must comply with CERCLA and RCRA provisions in the same manner as private parties, and are liable for cleaning up contaminated waste at currently- or formerly-owned facilities. Under SARA, the federal agencies also may be liable for cleaning up contaminated waste at facilities acquired through foreclosure or other means and at facilities purchased with federal loans. To meet these requirements, civilian federal agencies implement various programs for assessing potentially contaminated sites and conducting any needed cleanup actions. Some agencies have established central offices to manage these programs, while others have adopted a decentralized approach involving the organization of programs by function or geographic location.

For example, **DOI's** Office of Environmental Policy and Compliance coordinates and develops the agency's environmental policy and programs through three teams and eight regional offices to address: (1) requirements of the National Environmental Policy Act and Council on Environmental Quality; (2) remedial and corrective actions involving hazardous materials; and (3) requirements of the National Oil and Hazardous Substances Pollution Contingency Plan (NCP). In 1995, DOI established the Central Hazardous Materials Fund (CHF) to fund medium- to long-term CERCLA cleanup actions. Each year, bureaus and offices within DOI nominate projects for funding that impact sites on DOI land or that impact DOI resources. Between 1995 and 2002, the CHF, which is administered by the Bureau of Land Management (BLM), received $87.4 million in appropriated funds. An additional $84 million was added through cost sharing and cost recovery. Appropriations for FY 2003 are expected to be about $10 million. This fund may be used for site investigations, feasibility studies, and cleanups at sites for which DOI is responsible. Additional cleanup activities may be funded through the appropriations of the various DOI offices and bureaus. The major land-management components of DOI are shown in the box.

> ***DOI Agencies Manage 507 Million Acres, One Fifth of U.S. Land:***
>
> Bureau of Land Management: 262 million acres
>
> Fish and Wildlife Service: 96 million acres
>
> National Park Service: 84 million acres
>
> Bureau of Indian Affairs: 56 million acres
>
> Bureau of Reclamation: 9 million acres

USDA's Hazardous Materials Policy Council (HMPC) provides overall departmental leadership, in addressing issues relating to hazardous waste management and site cleanup. The council, which consists of senior policy representatives from the major affected offices and agencies within USDA, was established in 1999 to improve consistency across USDA service areas, and consists of senior policy representatives from those areas. The implementation of the hazardous waste-related activities is the responsibility of the Department’s Hazardous Materials Management Program (HMMP). In addition to direct funding, HMMP receives funds from the Hazardous Materials Management Appropriation, which was established in 1988 to provide targeted funding for priority hazardous material cleanup projects on facilities and lands under USDA’s jurisdiction, custody, or control and for USDA’s share of the costs for cleanup projects on non-USDA property where USDA activities may have contributed to the pollution. The appropriation has been about $15.7 million over the past two years. An additional $26.7 million annually is available for the department’s environmental mission from direct USDA funds.

NASA’s Environmental Compliance and Restoration Program (ECR) is managed from NASA Headquarters under the Office of Management Systems. ECR serves as a centralized lead for ensuring environmental stewardship and sustainability of the agency’s facilities. NASA’s environmental cleanup and compliance activities are implemented through 10 research or space flight centers located across the country.

DOT consists of 13 operating administrations responsible for different transportation sectors (as of 2002). Each administration holds responsibility for restoration activities at its operational facilities, including identification, investigation, and cleanup. In addition to its national mission to protect the navigable water of the U.S., the U.S. Coast Guard provides DOT’s short- and long-term emergency response to hazardous substance or oil spills covered under CERCLA/SARA and the NCP. Coast Guard operations were transferred from DOT to the U.S. Department of Homeland Security in 2002.

8.2 Factors Affecting Demand for Cleanup

Four primary factors influence the market for remediation of civilian federal agency contaminated waste sites.

- Budget considerations constrain all federal agencies planning site remediation. Although agencies may request funds for contaminated site management and remediation, Congress may not provide the necessary funding. Agencies have intensified their efforts to prioritize cleanup activities within and across facilities by more effectively evaluating alternative future land uses, estimating and prioritizing risks to human health and the environment, evaluating a broad range of remediation technologies, and analyzing the relative costs and benefits of various approaches to cleanup.

  In addition, the federal budget process has created incentives for agencies to implement management reforms that will reduce the costs of operations. Some of these include encouraging and eliminating barriers to the use of less costly, innovative remediation technologies; using more cost-effective contracting procedures; streamlining management structures and processes; and using the “lessons learned” from other agencies and the private sector (U.S. CEQ 1995).

- Federal agencies are subject to the CERCLA "Lender Liability Rule," which assigns responsibility for cleaning up contamination at acquired properties. Although federal agencies that involuntarily acquire contaminated property (through foreclosure or other mechanisms) generally are exempt from CERCLA liability, an agency may be liable for remediating a hazardous waste site if it loans money to, and actively participates in management of, an organization using or generating the hazardous waste. Federal liability is determined on a case-by-case basis for each site that is acquired involuntarily.

- Changes in federal and state environmental regulations and standards often impact the level and pace of cleanup required at civilian federal facilities. If cleanup standards become more rigorous in the future, the market may require more advanced technologies or longer-term and more intensive use of existing technologies than anticipated currently. Conversely, if standards become less stringent, the market for new remedial technologies could decrease.

  In January 2002, for example, EPA amended regulations covering corrective action management units (CAMUs) created under RCRA to facilitate treatment, storage, and disposal of hazardous wastes managed for implementing cleanup. The revised regulations established more detailed minimum design and operating standards for CAMUs and outlined treatment requirements for wastes that are placed in CAMUs without violation of RCRA land disposal restrictions. In addition, the amendment established specific information requirements for CAMU applications, including opportunity for public comment. The U.S. General Accounting Office reviewed the proposed regulations and determined that the process for requesting and obtaining CAMU approval would increase the time and cost of site cleanups (U.S. GAO 2000).

- The transfer of public properties to private use may require agencies to reallocate resources for cleaning up properties designated for transfer. Recent years have witnessed an increase in public-to-private transfers of large properties, many of which are managed for a period of time by the General Services Administration.

8.3 Number of Facilities and Sites

Estimates of the number of civilian federal facilities that will require some type of remedial action can be derived from the docket. CERCLA requires that the docket be updated every six months to reflect newly characterized sites. In January 2003, the docket reflected a total of 1,099 facilities (Exhibit 8-1). The docket contains information submitted by civilian agencies under CERCLA Section 103(a), which requires that the National Response Center be notified of a hazardous substance release or potential release. The docket also contains information submitted to EPA by the agencies under RCRA Sections 3005, 3010, and 3016, which addresses facility permitting, notification of hazardous waste activity, and each agency's biennial inventory of hazardous waste activities.

Exhibit 8-1. Number of Civilian Federal Facilities Potentially Requiring Cleanup

Agency	Facilities Listed on Docket
Department of Agriculture	201
Architect of the Capitol	1
Central Intelligence Agency	1
Department of Commerce	10
Army Corps of Engineers	50
Environmental Protection Agency	23
General Services Administration	38
Department of Health and Human Services	10
Department of Housing and Urban Development	3
Department of the Interior	468
Department of Justice	27
Department of Labor	3
National Aeronautics and Space Administration	17
U.S. Postal Service	26
Tennessee Valley Authority	45
Department of Transportation	134
Department of the Treasury	9
Veterans Administration	33
Total	1099

Notes:
[a] The number of "sites" (individual areas of contamination) at each facility is not included in the docket.
[b] The U.S. Army Corps of Engineers manages environmental cleanup projects for a variety of civilian federal agencies as well as the Department of Defense and Department of Energy.

Source:
U.S. Environmental Protection Agency. "Federal Agency Hazardous Waste Compliance Docket," 68 *Federal Register* 107, January 2, 2003.

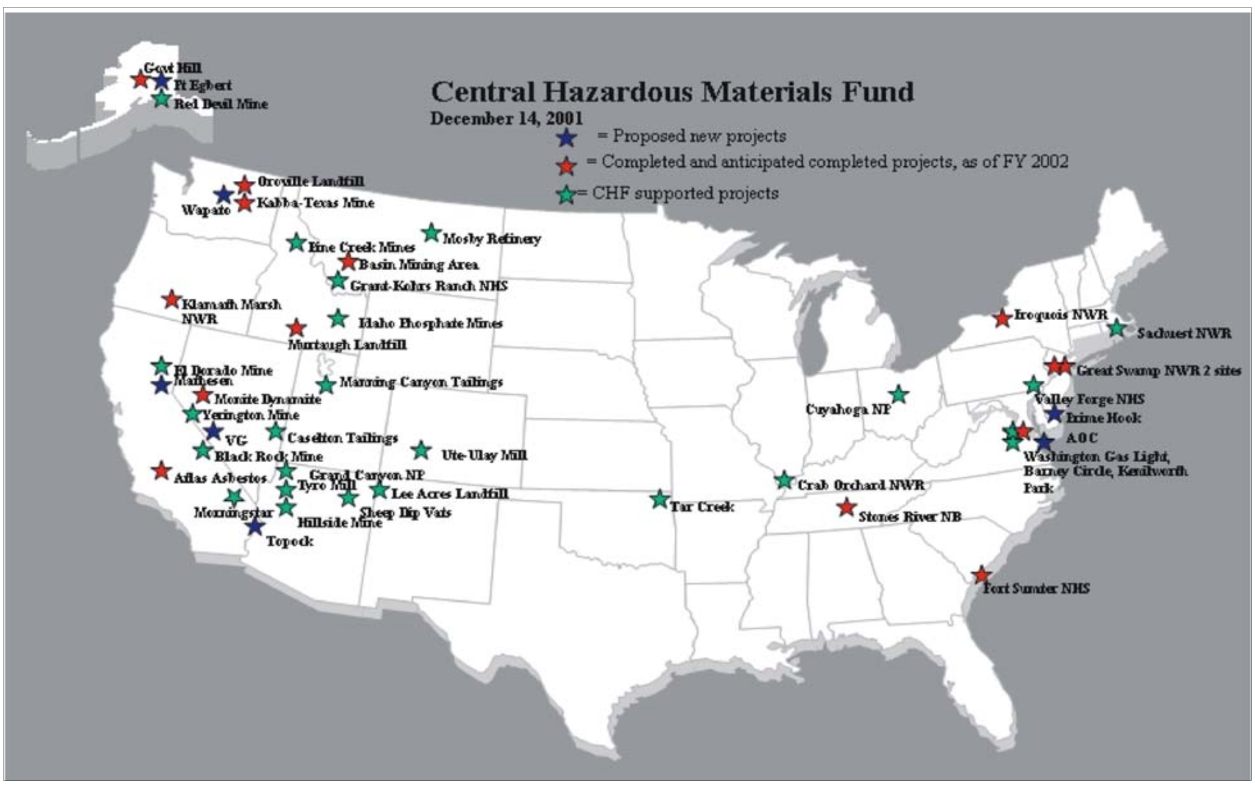
Although it is the most comprehensive source available, the docket provides only broad indications of the remediation market. Some of the factors that limit its utility for market analysis are: many sites listed on the docket do not require remediation; sites that have undergone remediation are not removed from the docket; the docket does not indicate the number of contaminated sites at each facility (a facility can have one or more sites or areas of contamination); and many sites at federal facilities remain to be inventoried and characterized. In addition, the docket excludes federal facilities that have been sold, private facilities where the federal government may have contributed to site contamination, and facilities that generate small quantities of hazardous waste. Thus, the docket may not account for all potentially contaminated sites on land for which civilian federal agencies are responsible.

In accordance with CERCLA Section 120(d), a preliminary assessment (PA) is conducted for each facility listed on the docket to evaluate the threat they pose to public health and the environment. If warranted, a site inspection is conducted to determine if CERCLA response actions are necessary. If further actions are warranted, an evaluation is conducted to determine whether the site should be placed on the National Priorities List (NPL) for long-term evaluation and remedial response. As of October 2001, 15 civilian federal agency sites had been added, proposed, or deleted from the NPL (U.S. EPA 2003b).

Approximately 30 percent of the docket facilities listed pursuant to CERCLA Section 103 require no further EPA actions, and accordingly are designated "no further remedial action planned" (NFRAP). Although the NFRAP designation means that the contamination at a site is not severe enough to warrant listing the site on the NPL and remediation under the Superfund program, the site still may require cleanup under other environmental programs, such as a state regulation.

DOI estimates that about 1,000 sites under DOI stewardship require restoration. (U.S .DOI 2003b). By 2005, DOI aims to increase its cumulative number of restoration projects to 135 and the cumulative amount of damage settlement funds within the DOI Restoration Fund to $200

Exhibit 8-2. DOI Allocation of the Central Hazardous Materials Fund



million. For example, DOI allocated approximately $10 million of Central Hazardous Materials Fund (CHF) money during 2001 to 35 projects spread among five bureaus: 14 projects in the Bureau of Land Management (BLM); 13 projects in the National Park Service; 4 projects in the Fish and Wildlife Service; 3 projects in the Bureau of Indian Affairs; and 1 project in the U.S. Geological Survey (U.S. DOI 2003a). The geographic distribution of these projects are shown in Exhibit 8-2. By 2005, DOI also plans to have completed cleanup of its 1,000th BLM hazardous material site (U.S. DOI 2003b).

In addition to hazardous waste sites it has already identified, other sites may be discovered on its properties in the future. An estimated 3.5 million acres under the Department's stewardship are in need of restoration. DOI plans to restore about 1.1 million of these acres by 2005. This land includes mined lands, wildlife refuges, park lands, and forests. In the course of implementing this task, additional remediation needs are likely to arise. For example, BLM estimates that between 5,000 and 25,000 abandoned mines on public lands the Bureau administers have caused or could cause environmental damage, mostly from water pollution. In a typical year, DOI works on between 50 and 150 remediation sites.

In 2001, USDA estimated that over 2,000 sites with releases or threatened releases of hazardous substances remained to be addressed over the next 50 years, at an estimated cost of $4 billion (USDA 2001). From 2003 to the end of 2007, USDA anticipates completing 150 CERCLA cleanups. During 2003 alone, USDA planned to complete 68 CERCLA site assessments, 59 CERCLA cleanup plans, and 6 RCRA cleanups. (In contrast, the agency targeted 17 CERCLA cleanups during fiscal year 2002.) More than half of the agency's CERCLA cleanups planned for 2003 involve mining sites (USDA 2003). USDA recognizes that preparation of cleanup plans is emerging as a potential "bottleneck." While 137 CERCLA cleanups were completed in fiscal years 1998-2001, only 84 cleanup plans were completed during that time.

DOT has made significant progress in remediating its contaminated sites. In fiscal year 2002, DOT reported that 91 of its facilities required no further remedial actions under SARA, and that all SARA cleanup efforts were completed (U.S. DOT 2002). This leaves 43 DOT facilities that require remediation. The Coast Guard received DOT funding to conduct response and cleanup activities required of the DOT under CERCLA/SARA. Continued restoration activity is anticipated at three Coast Guard facilities for several years. In addition, the Federal Aviation Administration plans continued cleanup activities at several facilities, and replacement of outdated underground storage tanks and cleaning or removal of unused tanks at decommissioned facilities. DOT uses a "worst first" prioritization system to address problems posed by DOT facilities where significant pollution problems are identified.

8.4 Site Characteristics

The types of contamination problems at civilian federal agency facilities vary from agency to agency. Exhibit 8-3 provides examples of the types of contaminated facilities managed by agencies listed most often on the docket. Contaminated facilities owned or operated by other civilian federal agencies encompass research laboratories, properties acquired through foreclosure, and operational facilities such as the Department of Justice federal penitentiaries, Tennessee Valley Authority power generating plants, and Department of Veterans Affairs medical centers.

Exhibit 8-3. Examples of Types of Contaminated Facilities at Civilian Federal Agencies

Department of Interior	
Bureau of Land Management	Landfills (approximately 3,400 closed sites)
	Abandoned mining operations
	Unauthorized hazardous waste sites
Bureau of Reclamation	Reservoirs and drinking water supplies contaminated with agricultural runoff
National Park Service	Landfills and dumps (inherited with acquired land)
	Abandoned mining operations
Fish and Wildlife Service	Contaminated sites resulting from agricultural runoff or upstream industrial operations
	Inherited land previously used for industrial or defense purposes
Department of Agriculture	
Forest Service	Abandoned mining sites
	Sanitary landfills and aboveground dumps
	Wood preservation sites and laboratories
Agricultural Research Service	Research laboratories
Commodity Credit Corporation	Grain storage facilities
Farmers Home Administration	Farms (acquired through foreclosure) where pesticides and other hazardous materials may have been disposed
Department of Transportation	
Federal Aviation Administration (FAA)	FAA Technical Center, with soil and groundwater contamination of 22 areas
	Airfields with hazardous solvent or oil spills
U.S. Coast Guard	Fuel storage and operation/maintenance facilities
National Aeronautics and Space Administration	Research laboratories, industrial plants

8.5 Estimated Cleanup Costs

Detailed site information for developing accurate cleanup cost estimates for civilian federal agency sites is not readily available from the agencies. EPA's FEDPLAN-PC information system has been discontinued and information sources on environmental activities of the agencies are scattered among their bureaus and offices. To provide insight into the probable cost of completing cleanup at federal civilian sites, it is useful to examine (a) the probable cost of all sites that have been or are likely to be discovered, given current regulatory requirements, and (b) the probable funding likely to be committed to remediation.

Estimated Cost To Complete Cleanup

Because information on contaminated sites at most agencies is fragmented, it is difficult to develop a clear picture of the cost to complete cleanups at civilian federal agencies. The U.S. General Accounting Office's (GAO) recent study of the issue of environmental liabilities of federal agencies indicates the nature of this difficulty. In an effort to improve the Congressional budgetary process for federal agencies' environmental liabilities, the GAO recently studied the problems posed by the waste-producing assets of these agencies. GAO recommended that the Office of Management and Budget require federal agencies to include in their budget requests supplemental information on estimated environmental cleanup/disposal costs for new acquisitions (U.S. GAO 2003). This requirement implies that agencies will be required to conduct Phase I and Phase II type site assessments when contemplating real estate transactions. It will also ensure that agencies explicitly recognize the financial cost of their potential environmental liabilities.

GAO also assessed the efforts that federal agencies with major cleanup responsibilities have made in setting priorities for spending limited cleanup funds at the sites posing the highest risks (U.S. GAO 1999). GAO found that EPA and USDA had made progress in setting priorities on the basis of site risks, but that additional efforts were required by DOI to complete a site inventory and establish a risk-based prioritization of its sites.

Despite these difficulties, DOI, USDA, and NASA planning and budgetary information indicate that cleanup of sites covered under CERCLA, RCRA, and other environmental regulations will continue to require extensive resources over many years. The following points summarize an estimate of the cost to complete remediation at contaminated federal civilian agency sites.

Exhibit 8-4. Estimate Cleanup Cost for Civilian Federal Agencies

Agency	Cost to Complete ($ Billions)	Explanation/Limitations
DOI	$4.7-9.8	Over 1,000 sites identified on 468 facilities. It could require over 100 years to address these sites. DOI reports it could have as many 25,000 sites. (U.S. DOI 2003a and U.S. CEQ 1995).
USDA	$4.2	Over 2,000 sites with releases or threatened releases of hazardous substances (USDA 2001). USDA expects this work to take about 50 years.
NASA	$1.3	Environmental remediation of NASA's research and space flight centers could require an additional 80 years to complete.
Subtotal	$10.2-15.3	These agencies account for 70% of the facilities on the docket.
Total, all agencies	$14.6-21.9	Divide previous figure by 0.7.

Sources: See explanation in text and references above .

Available Funding

Given the magnitude of the cost to complete cleanups at civilian federal sites, it is useful to examine the level of recent funding.

- Between 1995 and 2002, DOI received $87.4 million in direct funding and an additional $84 million in cost sharing or cost recovery to address sites with hazardous materials. The direct funding comes from the Central Hazardous Materials Fund described in Section 8.1. In recent years, annual CHF funding has been $10 million. These funds may be supplemented through cost sharing and cost recovery from responsible parties or business operators. Historically, about one dollar of PRP funds becomes available for each dollar of direct appropriations.

  DOI's BLM was appropriated $1 million in FY 1997, $3 million in FY 1998, and $10 million in fiscal years 1999, 2000, and 2001 for water quality-related cleanup actions at abandoned mine land sites. In addition, states obligated $10.2 million and the Office of Surface Mining obligated $5.9 million for emergency reclamation projects at abandoned mine lands during 2001. The Office of Surface Mining also distributed $6.9 million to 12 states for elimination of environmental problems caused by acid mine drainage from abandoned coal mines. Although most of these appropriations, which total $33 million, are for land reclamation, safety hazards and other non-remediation activities, a portion of these funds, perhaps 20 percent ($6 million) is likely to be used for site remediation. Thus, the funds available to DOI for remediation of contaminated sites are likely to amount to $26 million annually ($10 million from CHF + $10 million from cost recovery and cost sharing + $6 million directly funded by bureau programs).

- USDA funding for priority CERCLA and RCRA activities are supplemented by Hazardous Materials Management Appropriations (HMMA). For fiscal year 2003, the department requested $15.7 million in HMMA funding, 47 percent ($7.3 million) of which covered actual cleanup work. This request is about equal to HMMA appropriations for fiscal years 2000 and 2001, each of which totaled $15.7 million. Approximately $5.1 million of the HMMA request targeted cleanup of abandoned and inactive mine sites on national forest lands. Of the total HMMA budget request, approximately 88 percent covered CERCLA activities. The remaining 12 percent was allocated to RCRA regulatory compliance, including the removal of underground storage tanks.

  A total of $26.7 million in USDA funds also were committed to meet the agency's environmental mission. USDA anticipates that, between 2003 to the end of 2007, it will complete 150 CERCLA cleanups. Thus, the upper-bound of funds likely to be available to USDA for remediation of contaminated sites is estimated to be about $34 million annually ($7.3 + $26.7 million).

- NASA anticipates that 80 percent of its $41 million annual environmental restoration budget anticipated for fiscal years 2004-2008, or $32.8 million, will be used for remediation of contaminated sites (NASA 2003).

- The total anticipated annual budget for the three agencies is $92.8 million, and extrapolating this figure to all 17 agencies on the docket results in an estimated annual budget of $133 million for contaminated site remediation at federal agencies. This figure may underestimate the total remediation expenditures, because it includes only some of the potential cost recovery and cost sharing that will be available.

Based on the above analysis, and the assumption that funding remains at $133 million annually, it will take 130 to 160 years to remediate the contaminated sites at civilian federal agencies.

8.6 Remediation Technologies

Little information is available on the technologies used to clean up facilities owned or operated by civilian federal agencies. Given the types of environmental problems present, the remediation approaches are likely to be similar to those used in other programs, such at RCRA and NPL sites. A useful EPA publication *Innovative Treatment Technologies: Annual Status Report (Eleventh Edition)* describes trends in technologies used at NPL, Department of Defense, and Department of Energy sites (U.S. EPA 2004). Many of those technologies, in particular those implemented at NPL industrial and mining sites, may be implemented at civilian federal agency sites.

To stimulate the use of innovative technologies at federal, including civilian, contaminated sites, EPA is fostering the use of federal facilities as testing and demonstration centers. For example, several new cleanup technologies are under demonstration at the Kennedy Space Center in Florida as part of EPA's Superfund Innovative Technology Evaluation Program. These demonstrations will help to identify cost-effective and easily-implemented technologies for treating groundwater contaminated with dense non-aqueous phase liquids. Also, in an effort to reduce regulatory and institutional barriers to innovative technology development, EPA is working with DOI and the Western Governor's Association to develop innovative technologies for use at mining sites.

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Chapter 9
Demand for Remediation of States and Private Party Sites

The cleanup market includes thousands of sites managed by states and private parties. Non-federal agency sites that are not being cleaned up under the Comprehensive Environmental Response, Compensation, Liability Act (CERCLA), Resource Conservation and Recovery Act (RCRA) Corrective Action, and Underground Storage Tank (UST) Programs, but still need attention, become the responsibility of state cleanup programs, private parties, or local jurisdictions. Most private party sites are remediated under state voluntary cleanup programs (VCPs). State sites can vary from sites that are similar to NPL sites to small sites with low levels of contamination.

The majority of states have enforcement authority to compel cleanups and state cleanup funding mechanisms dedicated to financing the cleanup of abandoned sites. It has been estimated that as of December 2000, about 23,000 non-National Priority List (NPL) sites were known or suspected to be contaminated and need further attention requiring additional evaluation and/or some level of cleanup (ELI 2002). The extent of contamination at these sites is largely unknown. However, information in this chapter about state sites that have been remediated indicates the likely characteristics of these sites.

In addition to direct state cleanups, many state sites are cleaned up by private parties in accordance with state cleanup standards. To encourage private party cleanups, almost all states have created voluntary cleanup programs that often provide incentives for private parties to assess and cleanup their sites, with state oversight. Most states have also created brownfield programs that target the cleanup and redevelopment of properties that have been abandoned or are underused because of the potential for contamination.

Highlights

- There may be as many as ½ to1 million brownfield sites, 85–90% of which have not been evaluated or cleaned up.
- Based on data from EPA's brownfields grant projects, 350,000 to 700,000 of these may require cleanup. The exact percentage is unknown.
- About 5,000 cleanups are typically completed annually under state mandatory and voluntary control programs. At this rate, 150,000 sites can be completed in 30 years.
- Annual expenditures for these cleanups are estimated to average about $1 billion. If states with limited funds want to accelerate the pace of work, they will likely have to rely on private party actions, voluntary cleanups, and cost recovery.
- The Brownfields Revitalization Act will likely lead to an expansion in the number of sites assessed and cleaned up.
- The federal brownfields program has served as a catalyst for other development that use private, state, and local funds. EPA's investment in brownfields, more than $700 million since 1995, has leveraged more than $5 billion in cleanup and redevelopment funding.
- State site cleanup and redevelopment involves coordination of many disciplines and stakeholders, which has led remediation firms to form alliances with firms and consultants with other specialties.
- The use of advanced remediation techniques appears to have grown in recent years, although data are scant.
- There is a need to screen many sites to determine whether or not they have contamination problems.

In recent years, an average of about 5,000 cleanups have been completed annually under direct state cleanups, voluntary cleanup programs, and brownfield programs. During 2000, states spent more than $505.6 million (38 states reporting) for remediation of NPL and non-NPL sites. Most of these funds were for direct state cleanups at non-NPL sites. Despite this progress in completing cleanups, the backlog of sites to be cleaned up has been stable, primarily because new sites are still being identified.

9.1 Programs Addressing State Sites

The cleanup of state and private party sites is strongly influenced by a myriad of state and federal programs that seek to encourage site investigations, cleanup, and redevelopment. The structure and operations of these programs vary widely from state-to-state and many of them preexist the federal brownfield program. These programs typically can require cleanups of certain types of contamination and provide incentives for cleanup, redevelopment, and long-term stewardship. There are two types of state hazardous waste programs: programs that primarily address enforcement issues and oversee cleanups of abandoned sites, and state voluntary cleanup and brownfield programs. In addition, federal programs actively encourage and assist states in their efforts to evaluate and clean up contaminated sites.

9.1.1 State Hazardous Waste Cleanup Programs

Almost all states have established hazardous waste programs to ensure that potentially contaminated sites are assessed and, if necessary, cleaned up. Information on these state programs, numbers of contaminated sites, and the status of those sites has been derived from existing published information and state web sites. Contacting individual states to obtain data was outside the scope of this study.

Three key sources provide extensive information about the state programs, *An Analysis of State Superfund Programs: 50-State Study, 2001 Update*, and *An Analysis of State Superfund Programs: 50-State Study, 1998 Update*, and *An Analysis of State Superfund Programs: 50-State Study, 1995 Update*. These studies, prepared by EPA and the Environmental Law Institute are based on information collected from the 50 states, Puerto Rico, and the District of Columbia. For convenience, these are referred to as 52 "states." These studies describe each of the states' programs, including enabling legislation, enforcement provisions, staffing levels, funding, and other aspects of the programs. Exhibit 9-1, which is based on data in the *50-State Study* summarizes the prevalence of the major state programs.

Unlike some environmental statutes which mandate minimum national standards that could be administered by the states after their programs are approved by a federal agency, each state cleanup program is developed according to the state's criteria. Nevertheless, most state hazardous waste programs include authorities similar to the federal Superfund program. They typically include provisions for emergency response and long-term remedial actions; cleanup funds or other mechanisms to finance site investigation and remedial activities; enforcement authorities to compel responsible parties to conduct or pay for studies and site remediations; staff to administer state-lead cleanup activities and to oversee remediations conducted by other parties; and efforts to ensure public participation in decision-making regarding site cleanup and reuse. About half the states also authorize long-term stewardship under their statutes (ELI 2002). Many states have been cleaning up land contaminated by hazardous substances, or overseeing such cleanups, for about two decades.

Exhibit 9-1. State Cleanup Program Summary [a]

State Program	Number of States	Explanation
Cleanup Funds	49	Idaho, Nebraska, and the District of Columbia do not have cleanup funds.
Voluntary Cleanup Program (VCP)	50	North Dakota and Vermont do not have formal programs; however, they allow private parties to initiate voluntary cleanups.
Brownfields Program	31	In addition to the 31 states with formal brownfield programs, 14 target brownfields through their VCPs.
Long-term Stewardship Program	41	Most of these states have committed scant resources to date.

[a] Based on 50 states plus Puerto Rico and the District of Columbia, referred to as "52 states."

Sources: U.S. EPA, *2002, An Analysis of State Superfund Programs: 50-State Study,* 2001 Update, November 2002.

State Cleanup Funds

As of December 2000, 49 states, including Puerto Rico, have established cleanup funds or provide another mechanism to pay for the cleanup of non-NPL sites where no responsible party is available, able, or willing to do so. Only Idaho, Nebraska, and the District of Columbia do not have an authorized state cleanup fund. Thirty-six states have more than one fund for cleaning up contaminated waste sites, resulting in a total of 117 state cleanup funds. There are a variety of reasons that states have more than one fund. A state may have multiple funds to differentiate sources or uses of funds. For example, funds may receive money through appropriations, penalties, cost recoveries, or proceeds from a hazardous waste fee. Some funds may apply only to specific uses, such as for emergency response, brownfields, a voluntary cleanup program, or a specific type of site or waste. For example, a number of states have established funds dedicated to dry cleaning sites.

State Site Databases

State site lists are a potential source with which to evaluate the extent of the state remediation market. Many state statutes authorize the development of a priority list, inventory, or registry of state sites. Some states use these compilations to determine the order in which sites will be cleaned up. By the end of 2000, about 40 states had some kind of list, registry, or inventory, with a total of 15,000 sites. However, because the approaches and definitions used by the states vary widely, the aggregation of these data is neither useful for this market assessment nor to make comparison among states. Some states list all known and suspected sites, others include only those that have completed a long evaluation process, and others include only sites where cleanup is funded directly by the state. Some states' lists may be useful for contractors seeking opportunities for site investigation or remediation work in selected states.

Long-Term Stewardship

Forty-one state cleanup programs explicitly address long-term stewardship for sites where hazardous substances are to remain in place at levels that do not allow for unrestricted use. The statutes of these states are designed to protect the public health, safety, and the environment at such sites. Institutional controls are the most common mechanism used for long-term stewardship. These include property-law-based restrictions such as restrictive covenants and easements; information systems such as signs, educational materials, published notices, warnings about consumption of fish or wildlife, and site databases; and governmental controls such as zoning, local ordinances, building permits, and groundwater and well-drilling restrictions. Although forty-one states have long-term stewardship programs for one or more of their cleanup programs, most states have committed scant resources to monitoring institutional controls.

Liability

Most state statutes provide a means for charging parties, such as owners, operators, generators, and transporters, with liability for cleanups. These are the same parties usually charged under CERCLA. Liability may be charged under state hazardous waste laws or under another statute, such as a solid waste, water pollution control, or imminent danger statutes.

Many state statutes include provisions for retroactive, strict, and/or joint and several liability (CERCLA has all three). Forty-three states impose retroactive liability. That is, the state can impose liability for cleanup of hazardous substances disposed of prior to the enactment of the statute. Forty-one states have strict liability standards and 36 states use joint and several liability to allocate liability among multiple responsible parties. Under a strict liability standard, liability is based solely on the occurrence of a release and does not require proof of fault, such as through negligence. Under joint and several liability, the state may pursue one or more responsible party for the full amount of the cleanup. These provisions are potentially powerful incentives for companies to undertake site remediations.

Given the prevalence of strict, joint and several, and retroactive liability, the potential for cleanup cost liability is a significant obstacle to redevelopment and, in some cases, to cleanup. Many state voluntary cleanup and brownfield programs include mechanisms for mitigating the potential liability of responsible parties, prospective purchasers, owners, and developers. These programs are described in the next section.

9.1.2 Voluntary Cleanup and Brownfield Programs

Voluntary cleanup programs, a major component of state cleanup efforts, encourage private parties to voluntarily clean up sites rather than expend state resources or cleanup fund money on enforcement actions or remediations. VCPs are designed to reduce factors that tend to discourage voluntary cleanups, such as liability for cleanups, lack of control over the remediation, and cost. These programs began as innovative programs created by states to respond to requests by landowners and others for state assistance in facilitating private cleanups of their sites. By the end of 2000, 50 states (including the District of Columbia and Puerto Rico) had established formal VCPs through statute, regulation, or policy. Although the structure, formality, and operating practices of VCPs differ from state-to-state, there are a number of common elements. States will generally establish eligibility requirements for participation, clear cleanup standards, and closure procedures; provide timely oversight; and offer incentives to encourage participation.

The most common forms of incentives are liability release mechanisms, an expedited cleanup oversight process, and financial incentives, such as low-interest loans, grants, and tax credits. Liability protection is the most common of these incentives. Liability protection is provided by covenants not to sue, no further action letters, certificates of completion, and other mechanisms. States typically limit the protection only to contamination addressed by the cleanup activities, excluding unknown or pre-existing contamination, or new releases of hazardous substances. The Small Business Liability Relief and Brownfields Revitalization Act, signed into law in January 2002, clarifies state and federal roles for overseeing cleanups by providing federal CERCLA liability protection for parties who conduct a cleanup of certain properties under a state response program designed specifically for protection of human health and the environment. Prior to this provision, a state could provide state liability protection for brownfields cleaned up under its own laws, but a state could not provide federal liability protection.

Most states require a participant to reimburse the state for the cost of overseeing a voluntary cleanup. Most states also supplement the fees with state and federal funds. The 2002 brownfields law also provides states with new resources for VCPs. As much as $50 million may be appropriated annually over the next four years to states and tribes to help them establish and enhance VCPs and similar response programs.

Of the 50 states that have VCPs, 14 target brownfields through their VCPs, and 31 states have established brownfield programs that are separate from their VCPs. States define brownfields in a variety of ways, but the term typically refers to industrial or commercial facilities that are abandoned or underutilized due, in part, to environmental contamination or fear of contamination. This differs somewhat from the definition under the 2002 brownfields law (See Section 9.1.3 below). The scope of the various state programs also vary. States use a wide range of approaches and tools to facilitate the investigation and cleanup of brownfields. For example, some states emphasize site investigations or financial incentives, but do not authorize cleanups, while others may take a more active role in remediations.

It is often difficult to distinguish between a brownfield program and a VCP. Many brownfield sites are addressed by volunteers. Also, some states are reluctant to identify brownfields that are not already being remediated because property owners are concerned about the stigma associated with this designation, which may affect property values. This reluctance has led some states to carefully control lists or to not publish a list of sites. State brownfield programs are supplemented by a substantial federal brownfields initiative, which is described in the next section.

9.1.3 Federal Initiatives Affecting State Cleanups

The federal government has actively encouraged and assisted states in their efforts to clean up their contaminated properties. EPA’s program dedicated to help states address brownfields has already affected a large number of sites and will probably affect many more in the future. EPA defines “brownfield” as “real property, the expansion, redevelopment, or reuse of which may be complicated by the presence or potential presence of a hazardous substance, pollutant, or contaminant.” These sites are usually abandoned, idled, or under-used industrial and commercial facilities. Many brownfields are located in urban areas and are generally associated with - declining property values, increased unemployment, and movement of industries to the suburbs. EPA estimates that there are between 500,000 and one million brownfield sites.

Where past use of a site raises the possibility that the site may be contaminated, fear of being caught in the Superfund liability net often stymies further development at the site. Lenders, developers, and prospective purchasers are discouraged from getting involved with a site because of the risk of a delay in site development or having to pay cleanup costs. Current brownfield owners often are not willing to conduct an assessment of their sites for fear of finding contamination that may have been a result of their activities or those of past owners. Many brownfields end up as the property of local governments through foreclosure.

The central focus of the federal effort is the Brownfields Program and Small Business Liability Relief and Brownfield Revitalization Act, which was signed into law in January 2002.

Brownfields Program

The EPA Brownfields Program provides technical and financial support for brownfields revitalization. EPA's brownfields efforts are based on four themes: protecting the environment; promoting partnerships; strengthening the marketplace; and sustaining reuse. EPA's investment in brownfields, more than $700 million since 1993, has leveraged more than $5.1 billion in cleanup and redevelopment funding, generated more an 25,000 jobs and assessed more than 4,300 properties. The Small Business Liability Relief and Brownfields Revitalization Act (2002) provides the Brownfields Program with Congressional authorization, increased funding, strengthened liability protections for certain property owners, and expanded assistance for State and Tribal response programs.

First, the Brownfields Program protects the environment by providing grants for assessment and cleanup to states, tribes, local governments, redevelopment authorities, and in some cases, non-profit organizations. Assessment grants of up to $200,000 per entity can fund efforts to inventory, characterize, assess, and conduct planning and community involvement related to brownfields. Cleanup Revolving Loan Fund grants of up to $1million per eligible entity help capitalize local funds that can provide both loans and subgrants for property cleanup. Direct cleanup grants were added by the brownfields law and provide up to $200,000 per site to public and nonprofit entities, who must own the site to be eligible. The brownfields law added petroleum contamination to the list of sites eligible for brownfields funding and directed that 25 percent of brownfields funds be used for petroleum sites. The Brownfields Program also gives technical assistance and targeted assessments to help communities.

Partnership efforts are a second key aspect of the Brownfields Program. At the federal level, the Brownfields National Partnership brings together more than 20 federal agencies to help communities with issues related to brownfields revitalization. For example, the Department of Housing and Urban Development and the Economic Development Administration provides funds to help with the redevelopment activities beyond EPA's programs, such as acquiring property and helping rebuild infrastructure. The National Oceanic and Atmospheric Administration leads an interagency "Portfields" project that focuses on interagency collaboration to revitalize port and waterfront areas. The Brownfields Program provides $50 million a year to support state and tribal response programs and has signed Memoranda of Agreement with many states to clarify regulatory responsibilities. The Brownfields Program works with a wide range of organizations to conduct research, training, and technical assistance for communities, including grants of up to $200,000 to communities for Brownfields Job Training. The annual Brownfields Conference, co-sponsored by EPA, brings together the entire range of stakeholders—more than 4,200 people attended Brownfields 2003 in Portland, Oregon.

Third, the Brownfields Program works to strengthen the private sector marketplace for brownfields. The brownfields law provides liability protections for innocent landowners, prospective purchasers and contiguous property owners. Enforcement policies and tools have helped change perceptions that discouraged brownfields revitalization. As required under the brownfields law, EPA is developing regulatory standards for "all appropriate inquiries" that will specify actions property developers and owners must take prior to a property transfer to qualify for liability protections. The private sector is further supported by financial tools such as brownfields tax incentives and new insurance and risk management vehicles.

Lastly, the Brownfields Program is a strong force for sustainable development. A study conducted by George Washington University shows that every acre of brownfields redeveloped saves 4.5 acres of greenspace. The Brownfields Program has worked closely with Smart Growth advocates and Green Building experts to conduct pilot projects and encourage redevelopment that provides long-term economic and environmental benefits.

9.2 Factors Affecting Demand for Cleanups

The state market for remediation services is largely dependent upon the pace of development, the commitment and ability of states and private companies to establish and manage hazardous waste programs and to finance cleanups, and the extent of state and federal efforts to encourage or compel responsible parties to clean up sites.

- Increases and decreases in state cleanup funds will affect the number and complexity of remedial actions undertaken by the states. Total funding to state cleanup funds has remained steady in recent years, which indicates that many states will have to rely on their ability to either compel private parties or encourage voluntary cleanup actions. State assurance funds may be impacted by economic and political conditions that influence state revenues.[1]

[1] In a survey of 231 cities of all sizes published in 2000, 90 percent of the cities identified lack of funding for cleanup as the most important impediment to cleanup and redevelopment. (U.S. Conference of Mayors 2000).

- Although total funding to state cleanup funds has remained steady, there have been shifts in funding levels among different types of funds. For example, dry cleaner funds have grown in recent years.

- The Brownfields Revitalization Act is expected to expand the number of sites to be assessed and/or cleaned up. The law greatly mitigates the potential liability of innocent (not responsible for pollution) property owners; reduces financial uncertainties for investors and property owners; and directly funds various projects and programs, which serve as examples, case histories, and lessons learned for other sites.

- By removing obstacles that cause investment capital to flee from brownfields, the Brownfields Revitalization Act is expected to foster new opportunities for site characterization, cleanup, and redevelopment, especially in the following situations:

  ÷ Communities that use smart growth and infill strategies, and that are seeking to improve community-wide quality of life;
  ÷ Sites with "relatively low risk" petroleum contamination, which previously were generally not eligible for federal assistance;
  ÷ Sites where cleanup and development have been hampered by an inability to obtain financing or insurance because of uncertainties in remediation costs;
  ÷ States without effective voluntary and other cleanup programs or those whose programs have been hampered by a lack of funding; and
  ÷ Sites where cleanup and redevelopment had previously been hampered by a potential for Superfund liability.

- The new law strengthens liability protections for innocent purchasers, contiguous property owners, and prospective purchasers, thereby encouraging more brownfield site assessments, cleanups, and redevelopment. The 1986 amendments to CERCLA (SARA) attempted to provide protection to "innocent landowners" through the addition of Section 101(35). This provision applies if a party that acquired real property after the disposal of hazardous substances did not know about the hazardous substances on, in, or at the property when it was acquired. However, this authority was used only infrequently because it was difficult to establish a legal defense. The new brownfields amendments provide significant statutory changes affecting the potential liability of owners, developers, and prospective purchasers of real estate. It is expected that the law will reduce the potential liability and transaction costs of owners, developers, and prospective purchasers of brownfield sites.

- The pace of development in a community or region will influence the number of brownfield and voluntary sites that need to be evaluated and/or cleaned up. Because there are an estimated hundreds of thousands of potentially contaminated brownfield sites that have not been located, most development in populated areas are likely to encounter contaminated sites from time-to-time.

- As neighborhoods become revitalized and as communities grow, the demand for, and price of, land will increase. Higher property values can support more investments in site cleanups.

- Given the potentially large number of brownfields compared to the number of voluntary cleanup program and brownfield sites addressed in recent years (7,100 cleanups underway and 2,200 completed in FY 2000), brownfield cleanups are likely to continue for many years.

- The growing popularity of smart growth policies is likely to advance the demand for the state and brownfield cleanups, since infill development and the preservation of greenfields are primary components of smart growth programs.

- Forty-one states have long-term stewardship programs for one or more of their cleanup programs. These programs are important because of the widespread use of remedies that allow hazardous substances to remain on site, so long as land-use restrictions are implemented. States have been establishing and enhancing their long-term stewardship programs. One of the greatest needs are systems to keep track of sites requiring stewardship.

- Considering the growing use of risk-based corrective action and the practice of leaving waste on site, there is a perceived need for enhancement of long-term stewardship programs.

Over approximately the past decade, the U.S. capacity to address brownfields has grown enormously. A decade ago, few developers and investors were willing to consider potentially contaminated properties. Today, there is an expanding cadre of developers, planners, consultants, engineering and construction firms, attorneys, and public officials with the expertise to evaluate, cleanup, and revitalize brownfield properties. The increasing acceptance of the practicability of cleaning up and revitalizing brownfield sites has the potential for enlarging the market for site characterization and cleanup services.

9.3 Number and Characteristics of Sites

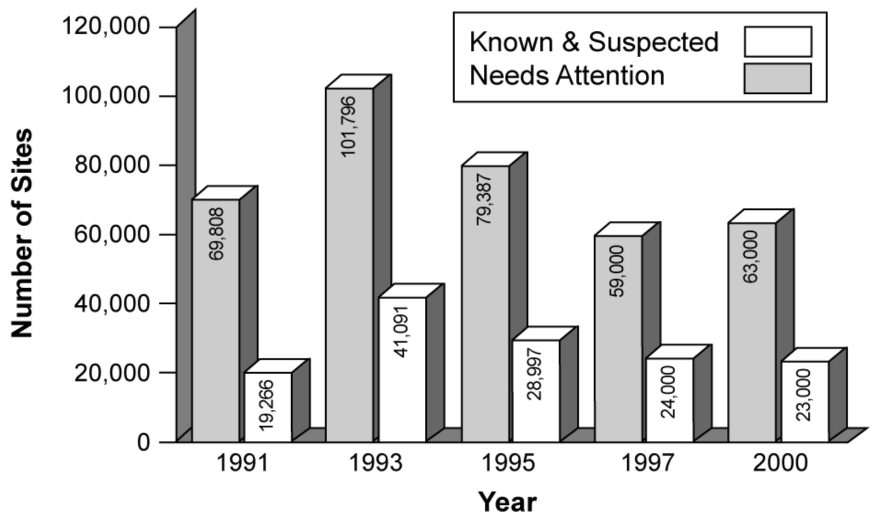
This subsection presents estimates of the number of state and private party sites expected to require remediation under state mandatory hazardous waste remediation programs and voluntary cleanup and brownfield programs.

9.3.1 State Mandatory Hazardous Waste Programs

The 50-State Studies present the results of surveys in which each state was asked to identify the total number of "known and suspected sites" and "sites needing attention." The number of known and suspected sites generally is the largest number of potentially contaminated sites known to the state and includes, in some states, sites that have not yet undergone any type of assessment. This category is useful in determining the outer limit of the universe of state sites. The sites needing attention are known and suspected sites that have been evaluated by the state and determined to require some level of further evaluation or cleanup. This category is the best indicator of the workload facing each state's cleanup program. The studies do not present estimates of the number of sites that definitely require remedial action. Exhibit 9-2 presents trends in these variables and Exhibit 9-3 shows each state's estimate for both categories of sites.

The total number of **known and suspected** sites reported in 2000 was 63,000 (up from 59,000[2] in 1997 and down from 79,000 in 1995). Because a number of states have reclassified their sites over the years, it is difficult to establish a firm trend. However, it appears that the universe of sites is stable and that the states are continuing to identify new sites. The number of known and suspected sites ranges from zero to 5,416 (Connecticut). Twenty-six states reported increases in known and suspected sites while eight reported decreases. The states with the largest increases between 1997 and 2000 were Connecticut, Florida, Louisiana, Missouri, New Mexico, Oregon, Rhode Island and South Carolina; and the states with the largest decreases were Alaska, Arizona, New Jersey, Washington, and Wisconsin.

Exhibit 9-2. Sites in State Hazardous Waste Programs



Source: Environmental Law Institute, *An Analysis of State Superfund Programs: 50-State Study, 2001 Update*, November 2002.

Although states are progressing to clean up their sites, they continue to identify new ones. The total number of sites needing further attention in 2000 was 23,000, an increase from 19,000 in 1997.[3] During this time, states completed cleanup of over 19,000 sites. While some of the data reflects progress in completing cleanups, it also reflects reclassification of sites by some states and a decline in the number of states reporting. The number of sites needing attention ranges from zero to 3,900 (New Jersey).Only five states report having more than 1,000 sites needing attention– Connecticut, Florida, Kentucky, Massachusetts, and New Jersey.

Of the sites reporting in both 1997 and 2000, 23 had increases and 12 states had decreases in sites needing attention. The states with the largest increases between 1997 and 2000 were Connecticut, Florida, Georgia, Kentucky, and South Carolina. The states with the largest decreases were Alaska, Arizona, New Jersey, Washington, and Wisconsin. After considering reporting discrepancies, such as those in the footnotes, it appears the total universe of sites needing attention is stable, or growing slightly. (50-State Study 2000).

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2 The 1998 50-State Study reported 69,000. However since then, the State of New Jersey subtracted 10,000 home-owner tanks sites from the list.

3 The 1998 50-State Study reported 23,000; however, the 2000 study revised the data, primarily because of reclassification of sites and because two states that reported in 1997 did not report in 2000. Counting only the states that provided data in both years, the total for 1997 is 20,100 and the total for 2000 is 22,700.

Exhibit 9-3. Number of Non-NPL State Hazardous Waste Sites

	Known & Suspected Sites[a]		Sites Needing Attention[b]	
State	1997	2000	1997	2000
Alabama	700	730	125	125
Alaska	1,625	968	1,206	783
Arizona	900	71	75	38
Arkansas	363	415	98	67
California	3,247	3,603	420	522
Colorado	624	495	178	200
Connecticut	3,029	5,416	668	2,107
Delaware	600	532	185	331
District of Columbia	NA	NA	NA	NA
Florida	1,900	2,646	1,094	2,460
Georgia	1,012	1,280	126	422
Hawaii	524	558	103	105
Idaho	NA	NA	NA	NA
Illinois	5,000	5,000	140	159
Indiana	NA	200	NA	61
Iowa	400	475	200	210
Kansas	720	NA	484	NA
Kentucky	1,900	2,200	850	1,500
Louisiana	410	730	120	130
Maine	465	475	128	83
Maryland	440	440	33	33
Massachusetts	2,679	2,305	2,679	2,305
Michigan	NA	NA	2,789	NA
Minnesota	3,000	3,000	219	100
Mississippi	960	1,100	500	500
Missouri	1,475	2,321	225	250
Montana	NA	NA	187	288
Nebraska	400	475	200	225
Nevada	129	112	129	12
New Hampshire	474	388	474	388
New Jersey [c]	5,177	5,000	4,915	3,900
New Mexico	344	1,210	133	153
New York	1,567	1,628	769	851
North Carolina	1,040	1,122	793	730
North Dakota	NA	NA	NA	NA
Ohio	1,460	1,884	403	403
Oklahoma	793	850	124	170
Oregon	1,933	2,469	306	499
Pennsylvania	50	50	20	20
Puerto Rico	NA	NA	NA	NA
Rhode Island	400	1,200	100	150
South Carolina	603	1,037	150	516
South Dakota	1,424	1,342	NA	229
Tennessee	1,360	1,501	234	210
Texas	388	611	52	48
Utah	325	390	40	50

Exhibit 9-3. Number of Non-NPL State Hazardous Waste Sites (Continued)

	Known & Suspected Sites[a]		Sites Needing Attention[b]	
State	1997	2000	1997	2000
Vermont	362	390	255	250
Virginia	2,015	2,015	411	411
Washington	1,493	946	1,006	623
West Virginia	600	NA	150	NA
Wisconsin	5,000	3,000	600	NA
Wyoming	140	NA	NA	NA
Total	**59,450**	**62,580**	**24,096**	**22,617**

Notes:
[a] Known and suspected sites are those that states have identified as being potentially contaminated. Many of these sites will not require action beyond a preliminary assessment. Site numbers are derived from Table IV-3 of the 2001 *50-State Study* and Table V-3 of the 1997 *50-State Study*, unless otherwise noted. The totals include an unknown, but small, percentage of UST and RCRA sites.
[b] Sites needing attention are those known and suspected sites that have been assessed and determined to require further assessment or cleanup. Many of these sites will require removal or remedial actions. Site numbers are derived from Table IV-3 of the 2001 *50-State Study* and Table IV-3 of the 1997 *50-State Study,* unless otherwise noted. The totals include an unknown, but small, percentage of UST and RCRA sites.
[c] The 1998 50-state Study reported 69,000 sites in New Jersey. However, since then, the state subtracted 10,000 homeowner tank sites from the list.
NA Indicates that data were not provided.
Sources:
Environmental Law Institute, *An Analysis of State Superfund Programs: 50-State Study, 2001 Update*, November 2002.
Environmental Law Institute, *An Analysis of State Superfund Programs: 50-State Study, 1998 Update*.

The total number of sites determined to need further attention includes an unknown but small percentage of RCRA and UST sites, which are addressed in Chapters 4 and 5 of this report. During collection of data from the states, authors of the *50-State Study* requested that the states exclude RCRA and UST sites from their reports, if they could. However, some states were unable to separate the RCRA and UST site data from other hazardous waste sites.

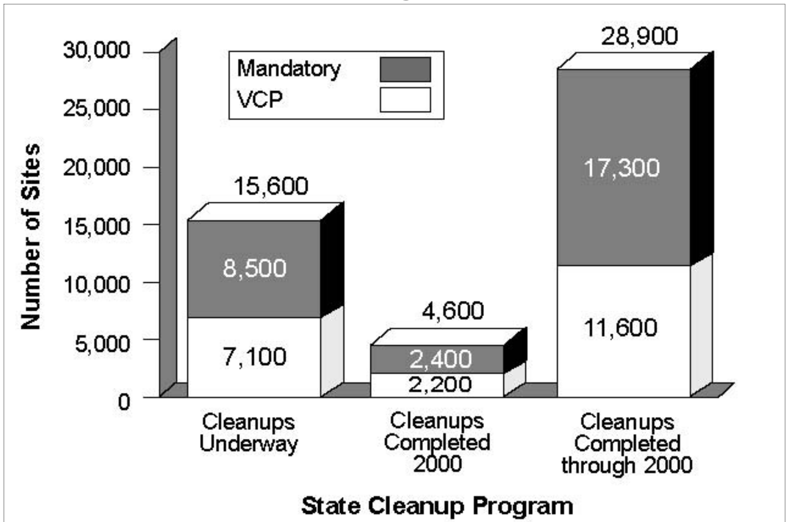
9.3.2 Voluntary Cleanup and Brownfield Programs

The 50-State Studies also asked states to report the number of voluntary cleanup and brownfield sites. Exhibit 9-4 presents the national totals from the survey data. Since the inception of their programs, states have completed cleanup at 11,600 sites under their voluntary programs and 17,300 sites under their mandatory programs. In FY 2000, states completed 2,200 voluntary cleanups and 2,400 mandatory-program cleanups, and had a total of 15,600 cleanups underway.

By the end of 2000, the reporting states had identified 18,700 brownfields, had cleanups underway at over 1,000 brownfield sites, and had redeveloped over 700 sites. To avoid double counting some sites, this study does not add the data on brownfield sites to the above figures, since many are cleaned up under voluntary and mandatory programs. Nevertheless, many sites identified by a brownfields program may not have been reported on a voluntary or mandatory program list. Thus, the estimates of total state and private party site market may be understated somewhat. Another factor that may contribute to the underestimation of brownfields sites is the fact that some states are reluctant to identify brownfields that are not already being remediated because property owners are concerned about the stigma associated with this designation, which may affect property values.

Based on these data, total state cleanups under all state programs has averaged approximately 5,000 per year in recent years. Despite the progress in completing many cleanups in recent years, the known number of sites listed as needing attention or entered into a voluntary program has remained approximately stable. As of the end of FY 2000, this inventory of sites was about 30,000 (22,600 from Exhibit 9-3 +7,100 from Exhibit 9-4). This apparent discrepancy is attributed to the fact that state regulatory agencies are continuing to identify new sites and new sites are continuing to enter voluntary and brownfields programs. In addition, some of the 18,700 brownfield sites identified by states are not included in this figure, in order to avoid potential double-counting of some sites. Thus, the currently identified inventory of sites likely to need remediation (30,000) is probably underestimated.

Exhibit 9-4. Voluntary and Mandatory Cleanup Program Status



Source: Environmental Law Institute, *An Analysis of State Superfund Programs: 50-State Study, 2001 Update*, November 2002.

Based on the above data, about 44,500 state sites have been identified, including those that have completed or are undergoing remediation. Although it is anticipated that many brownfields will not require remediation, the actual number is unknown. An indication of the percentage of sites needing cleanup is provided from data EPA has collected from recipients of EPA brownfields pilot grants. Of 5,000 sites targeted by previous grants, about two-thirds required further investigation and/or remediation beyond a Phase I and Phase II site assessment (EPA 2003). This figure implies that, even if the percentage of future sites needing cleanup is lower, it is still likely to represent a substantial number of sites; and at the current rate of 5,000 cleanup completion annually in all state programs, it will take many years to remediate all the brownfield sites.

9.3.3 Contaminants and Media

A central source of information on the types and quantities of contaminants and media found at state sites is not available. Three sources provide information on technologies used at state sites across the country. Although none of these sources is based on a comprehensive survey, they provide a picture of the types of contaminants and technologies likely to be found at state sites. In addition, some information on contaminants found are available from a number of states.

The first source, *The XL Environmental Land Reuse Report 2002*, and *The XL Environmental Land Reuse Report 2001*, are reports on a unique data collection conducted by XL Environmental, Inc. and the International Economic Development Council. These studies are based on a literature search of media coverage of brownfield-related stories. The researchers used online newspaper and journal archives, such as Lexis-Nexis, to search for articles that mention brownfields issues. The search identified 331 brownfield-related articles between July 2001 and June 2002 discussing 428 brownfield sites; and 317 articles between July 2000 and May 2001 discussing 346 sites. Chemicals, metals, and petroleum are the most frequently mentioned contaminants. Solvents and pesticides were also an issue at some sites. (Exhibit 9-5)

The second source is the Brownfields Management System, a database containing information about brownfield properties that are in EPA's grant programs. As of December 2002, contaminant data are available for only approximately 90 sites. Metals are the most frequently identified category of pollutant. VOCs, SVOCs (including PAHs and PCBs) and petroleum products were also frequently identified.

Exhibit 9-5. Contaminants Found at a Sample of Brownfield Sites

Contaminant	2001		2002		Total	
	Number	Percent	Number	Percent	Number	Percent
Chemicals	86	25%	56	13%	142	18%
Metals	61	18%	25	6%	86	11%
Other	55	16%	43	10%	98	13%
Petroleum	35	10%	50	12%	85	11%
Solvents	13	4%	10	2%	23	3%
Pesticides	4	1%	3	1%	7	1%
No. of Sites in sample [a]	346		428		774	

[a] Not all articles provided information on contaminants. Thus, this data is an indication of the types of contaminants and perhaps their relative frequency, rather than a precise accounting. There may be more than one contaminant reported per site.

Source: XL Insurance, Inc. and the International Economic Development Council, *The XL Environmental Land Reuse Report 2002*, and *The XL Environmental Land Reuse Report 2001*. XL Environmental, Inc.

The types of contaminants present at some state sites can also be inferred from sites listed in EPA's CERCLA Information System (CERCLIS), EPA's database of potentially contaminated sites. EPA has performed preliminary assessments at these sites to screen them for potential listing on the federal NPL. The majority of these sites (those not listed on the NPL) are deferred to the states for action. CERCLIS data show that the most prevalent wastes at these sites are organic chemicals, metals, solvents, and oily waste (U.S. EPA 1991).

In addition to national data sources, some states with established, well-funded programs are able to produce this type of information. For example, the California Department of Toxic Substances Control, within the state's Environmental Protection Agency, publishes extensive information about its site mitigation programs as well as access to its Site Mitigation and Brownfields Reuse Program Database on its web site. The database contains information on almost 10,000 potential and known sites (CALEPA 2003).

9.4 Estimated Cleanup Costs

The cost of cleaning up state mandatory and voluntary cleanup program sites is determined by the number of state sites and the amount of remediation work at each site. As described in Section 9.3, the number of potential state sites is so large relative to state and private resources that it is likely to take a number of decades to complete all the cleanups. Thus, a key determinant of cleanup activity in a given year will be resources available, primarily in state cleanup funds, which account for most state-funded cleanups. This section describes the trends in state expenditures, the status of state cleanup funds, and an estimate of the total cost to complete the cleanup of all known and likely to be discovered state sites over a period of 30 years.

9.4.1 Status and Capacity of State Cleanup Funds

A fund is an essential element of a state's program to clean up sites. It is a readily available source of money separated from other state operations that allows activities to continue without the need for annual appropriations or other legislation. It allows a state to avoid disruptions to cleanups and to investigate, plan, design, and conduct emergency response and remedial actions at sites where immediate action is required or where responsible parties are unavailable, unable, or unwilling to conduct or pay for remedial actions. Forty-nine states have established cleanup funds or provided a mechanism for the state agency to pay for one or more types of cleanup activities at non-NPL sites. Idaho, Nebraska and the District of Columbia are the only states without cleanup funds that are authorized to pay for cleanups. Although most state-financed cleanups are paid from a state cleanup fund, some are funded by direct appropriations. Thus, the estimate of state expenditures may understate the actual expenditures.

The combination of fund balances, additions to funds, and expenditures can indicate the capability and stability of a state cleanup program. Exhibit 9-6 compares the fund balances, additions to funds, and expenditures of the states in 1995, 1997, and 2000. Total fund balances for all states in 2000 was $1.2 billion. The trends in fund balances are confounded by the fact that in each survey there are some states that do not provide data and they differ from one survey to another. Comparing only the states that provided data in both 1997 and 2000, the decrease would be about 10 percent. Fund balances have been declining since 1990.

Most of the state fund balances (including bonding authority) are concentrated in a relatively few states. In 2000, eight states (Alaska, California, Massachusetts, Michigan, New Jersey, New York, Pennsylvania, and Texas) accounted for $909 million (73.5 percent) of the total fund balances for all states. This concentration has been observed since this survey was first conducted in 1991. The annual contributions to state funds fluctuated from year to year, but have averaged between $400 and $500 million. As with fund balances, the amounts added to funds are concentrated in a relatively few states.

Exhibit 9-6. State Fund Activity
1995, 1997, and 2000 ($ millions)

	1995	1997	2000
Total Fund Balances [a]	$1,464.9	$1,413.0	$1,240.0
Additions to Funds	$444.6	$538.3	$436.2
Expenditures	$386.1	$565.1	$505.6
Obligations	$363.4	$448.0	$564.4
Number of Known and Suspected Sites	79,387	59,000	63,000
Number of Sites Needing Attention	29,000	24,000	23,000

[a] Fund balances include both money in the fund and authority to sell bonds to raise additional monies. The expenditures and obligations totals are likely to be understated for two reasons: Between 35 and 38 states out of 49 provided 2000 data for most of these items. The response rate for 1997 was higher. In addition, some states did not report expenditures for all their funds.

Exhibit 9-7 presents the Superfund balances for each state as of December 2000 and 1997 and provides the total expenditures and obligations of funds by each state for hazardous waste activities in 2000 and 1997. The state fund balances totaled $1.2 billion in 2000, including bond authorizations (authority by state law to issue bonds and spend the proceeds on cleanups). While the average state site cleanup costs less than a quarter million dollars, many sites can cost more than $1 million. While almost all states have some cleanup funds, fund balances in some states are quite small. These funds could pay for little more than emergency responses and removal actions. At the end of 2000, 6 states had fund balances of less than $1 million (Alabama, Iowa, Mississippi, North Dakota, Oklahoma, and Utah). Another 8 states had balances between $1 million and $5 million; 3 between $5 million and $10 million; 15 between $10 million and $50 million; and 8 had balances over $50 million.

Although a state's fund balance indicates its ability to pay for a cleanup at any given time, this indication is only an approximation of cleanup activity in a state in a given year. The level of cleanup activity also depends on the rate that funds flow into and out of the fund, which differs from one state to another. Thus a state that rapidly replenishes its funds, for example by recovering cleanup costs from responsible parties, would have a high level of cleanup activity relative to the balance of the fund at any given time. Also, states may supplement funds with appropriations for specific projects.

Another indication of state's ability to manage mandatory cleanups and oversee voluntary cleanup programs is the level of state cleanup program staffing. In 2000, total state cleanup program staffing (3,344) was about the same level as in 1991 (3,394). Over those years, they have fluctuated only within a range of about 3 percent.

Exhibit 9-7. State Hazardous Waste Funds Expenditures and Balances 2000 and 1997

	Expenditures [a]		Fund Balances [b]	
State	1997	2000	1997	2000
Alabama	199,290	332,700	615,590	450,000
Alaska	20,830,212	7,720,413	76,154,222	64,955,963
Arizona	4,488,566	15,275,703	813,192	17,895,429
Arkansas	201,174	c	8,798,191	c
California	228,000	c	2,411,121	84,548,000
Colorado	1,200,000	2,452,380	19,000,000	16,119,065
Connecticut	c	c	13,500,000	24,170,610
Delaware	2,670,000	3,500,000	8,400,000	13,000,000
District of Columbia	c	c	c	c
Florida	22,199,865	4,337,746	24,529,984	15,006,808
Georgia	17,589,411	10,484,945	1,073,451	12,762,010
Hawaii	711,096	1,200,288	225,000	1,981,063
Idaho	c	c	c	c
Illinois	8,800,000	17,452,500	21,900,000	24,033,600
Indiana	4,284,377	12,514,959	24,511,554	41,350,404
Iowa	650,391	328,080	1,060,868	89,484
Kansas	1,516,000	c	c	c
Kentucky	1,800,000	700,000	4,000,000	1,500,000
Louisiana	200,790	6,497,001	1,693,995	3,851,299
Maine	2,267,436	1,991,420	7,400,000	9,270,375
Maryland	c	7,000	500,000	1,816,898
Massachusetts	7,100,000	35,900,000	86,300,000	53,900,000
Michigan	40,088,000	46,330,000	7,644,000	133,172,000
Minnesota	5,144,005	7,897,000	5,300,398	12,800,000
Mississippi	2,280,000	2,681,383	750,000	112,800
Missouri	2,700,000	3,500,000	(1,300,000)	2,900,000
Montana	7,312,614	7,312,614	14,506,467	14,506,467
Nebraska	c	c	c	c
Nevada	300,000	c	1,000,000	c
New Hampshire	1,700,000	2,100,000	1,500,000	7,800,000
New Jersey	81,300,000	25,130,961	114,700,000	189,093,523
New Mexico	230,412	440,836	1,659,814	1,623,000
New York	158,794,899	122,081,213	612,041,042	215,009,586
North Carolina	938,311	582,972	4,823,533	10,430,858
North Dakota	c	c	160,000	163,000
Ohio	16,841,377	c	31,081,540	c
Oklahoma	877,718	1,339,036	17,168	313,451
Oregon	11,080,828	13,625,860	12,142,352	21,242,558
Pennsylvania	37,397,633	39,000,000	120,026,484	110,000,000
Puerto Rico	c	c	c	c
Rhode Island	300,000	c	50,000	c
South Carolina	630,613	3,100,000	25,077,100	5,000,000
South Dakota	c	1,183,092	1,750,000	2,835,732
Tennessee	7,209,656	11,316,640	9,559,569	12,082,752
Texas	41,242,559	24,002,551	69,898,478	55,721,609
Utah	500,000	0	1,500,000	400,000
Vermont	5,200,000	7,219,000	4,800,000	1,696,000
Virginia	123,422	6,500	3,569,781	0
Washington	42,682,982	28,731,105	44,867,955	14,374,009

Exhibit 9-7. State Hazardous Waste Funds Expenditures and Balances 2000 and 1997 (Continued)

	Expenditures [a]		Fund Balances [b]	
State	**1997**	**2000**	**1997**	**2000**
West Virginia	758,585	c	1,800,000	c
Wisconsin	2,567,000	9,076,600	21,381,000	26,542,200
Wyoming	c	c	c	c
Total	**565,137,222**	**477,352,498**	**1,413,193,849**	**1,224,520,553**

Notes:
[a] Includes funds spent by the states in 1997 and 2000 for NPL and non-NPL site cleanups. Totals differ slightly from those in the 2001 50-State Study because of rounding.
[b] Includes bonding authority. Totals differ slightly from those in the 2001 50-State Study because of rounding.
c Indicates that data were not provided

Sources: Environmental Law Institute, *An Analysis of State Superfund Programs: 50-State Study, 2001 Update*, November 2002.
Environmental Law Institute, *An Analysis of State Superfund Programs: 50-State Study, 1998 Update*.

9.4.2 Annual and Projected Cleanup Costs

The estimate of the cost of cleanup is based on trends in state and private party cleanups over the past six years.

- It has been estimated that there are between ½ and 1 million brownfield sites in the U.S. (Section 9.1.3). However, the percentage of sites that will need cleanup is unknown. About 70 percent of the 5,400 properties that have been part of a federal brownfield assistance program and that have completed site assessments require cleanup activities. However, this percentage is likely to be lower for sites not yet in a federal brownfields program. Thus, the 70 percent (or 350,000 to 700,000 sites) is the estimated upper limit of the potential market.

- Non-NPL cleanup expenditures by states have typically been about $500 million annually. This figure is the total of mostly non-NPL expenditures for 37 states that reported this item separately in the 2001 *50 State Study* (ELI 2002a). This figure does not include 13 states for which data are not available, nor does it include direct appropriations for specific cleanup projects. On the other hand the total includes some costs for administration and Superfund site cleanups.

- Responsible party expenditures are estimated to be equal to state expenditures, based on a 1994 EPA/ASTSWMO study (U.S. EPA 1994). Cost data submitted for 3,395 sites listed in CERCLIS during the period 1980-1992 indicated that responsible parties paid $555 million and the states paid $650 million to clean up these sites. Responsible parties' expenditures appear to be roughly equal to state expenditures at state sites. No centralized source of data are available that includes private party expenditures for cleanups through the states' voluntary cleanup or brownfield programs.

- Adding the above figures indicates that total cleanup expenditures at state sites has been averaging about $1 billion annually in recent years. During this same period, cleanup has been completed at about 5,000 state and private party sites annually. At this rate, about 150,000 sites can be completed over the next 30 years, at a cost of $30 billion (Exhibit 9-8).

- This level of effort may or may not be sufficient to address cleanup at all state sites within 30 years. If a small percentage of the ½ to 1 million brownfield sites require cleanup, this level of effort may be sufficient to clean up all state sites. However, if the percentage of sites that require remediation approaches those in the EPA brownfield assistance programs (70 percent), this level of funding will only pay for ¼ to ½ of the required cleanups.

Thus, total expenditures for both state and privately-funded remediation is estimated to be $30 billion (Exhibit 9-8). If more than 150,000 sites need cleanup it will likely take more than 30 years, unless additional funding becomes available. There may also be sites addressed by private parties which are not under the auspices of a state or federal program. Nationwide data on these sites are not available.

Exhibit 9-8. Estimated Total Cost of State Site Cleanups ($Millions)

	Annual Average	30-Year Total
State Expenditures	$500	$15,000
Private Expenditures	$500	$15,000
Total Expenditures	$1,000	$30,000

Source: See explanation in text.

9.5 Market Entry Conditions

The following factors will be important to the success of vendors seeking to operate in the state and brownfield site characterization and cleanup market:

- By the end of 2000, about 40 states had some kind of list, registry, or inventory of state sites, with a combined total of 15,000 sites (ELI 2002). Some states use these compilations to determine the order in which sites will be cleaned up. Some states list all known and suspected sites, others include only those that have completed a long evaluation process, and others include only sites where cleanup is funded directly by the state. Some states' lists may be useful for contractors seeking opportunities for site investigation or remediation work in selected states.

- The Brownfields Revitalization Act mandates that, as a prerequisite for certain CERCLA liability protections provided to certain sites cleaned up under state response programs, and to receive certain federal assistance funds, states must maintain a public record of sites addressed through their brownfield programs. These records, once established, may serve as a source for vendors to review for prospective remediation needs. Some existing state site lists do not include all sites that are likely to require investigation and cleanup. Nevertheless they provide a method to quickly identify potential projects and issues.

- The operating practices of state cleanup, brownfields, and voluntary programs vary from state-to-state. Remediation technology vendors could benefit by knowledge of the practices and trends in each state, and perhaps forming alliances and partnerships with developers in specific areas. Much development is done by local or regional firms with knowledge of local markets. Information on state programs is available in several publications by the Northeast-Midwest Institute, EPA, the General Accounting Office, and the state web sites (Bartch 2000, Bartch 2002, GAO 2000, EPA 2002a).

- Some states have cleanup funds, such as an emergency response fund or a drycleaning site fund. These funds are potential sources of information about potential cleanup projects and technology needs.

- Companies interested in R&D, site assessment, cleanup, or revitalization at a brownfield site may encourage their communities or state to apply for funds from one or more of the federal or state programs.

- Often, the site investigation and cleanup is only a small portion of the total cost of a development project. A site may not even enter into a cleanup program until development occurs in the area. For example, a public works project such as a pipeline or sewer line may call for environmental assessments which result in the discovery of contaminated materials. Remediation vendors would benefit from comprehensive knowledge of development projects in their areas.

- Development of brownfields often involves the integration of diverse disciplines (urban and transportation planners, developers, real estate professionals, environmental engineers, remediation experts, community involvement experts) and cooperation of many stakeholder groups (developers, residents, local businesses, state and federal environmental regulators, local zoning and planning officials). Thus, firms that specialize in remediation may form alliances with firms that specialize in other aspects of brownfield projects. A number of firms with both remediation and development capabilities have emerged over the past decade.

9.6 Remediation Technologies

Three sources provide information on technologies used at state sites. Although none of these sources is based on a comprehensive survey, they provide a picture of the types of contaminants and technologies likely to be found at state sites.

The first source, *The XL Environmental Land Reuse Report 2002* and *The XL Environmental Land Reuse Report 2001*, are reports on a unique data collection conducted by XL Environmental, Inc. and International Economic Development Council. These studies are based on a literature search of media coverage of brownfield-related stories. The researchers used online newspaper and journal archives, such as Lexis-Nexis, to search for articles that mention brownfield issues. The search identified 331 brownfield-related articles between July 2001 and June 2002 discussing 428 brownfield sites; and 317 articles between July 2000 and May 2001 discussing 346 sites. The most frequently used remediation approaches are shown in Exhibit 9-9.

Demolition, excavation, and capping were the most frequently used techniques. Lead paint and asbestos are the most common contaminants in buildings. Excavation is the removal and offsite disposal of contaminated soil from the property. Capping was used on many sites intended for public recreation or ecological use, such as ballparks, golf courses, and nature reserves. About one-third of the capping applications were on former landfills. More advanced methods, such as SVE, thermal desorption, and bioremediation were mentioned infrequently. These approaches are fairly new, and are more difficult for most developers and communities to understand. However, the incidence of the use of innovative technologies at brownfield sites may be understated in the source articles because reporters have chosen not to address the remediation aspects of the projects. Because most of the articles are written for the general public, remediation techniques and technical details are not the main focus of many articles.

Since there are numerous potential site characterization and cleanup situations that may arise at a given state site, and since many of the sites to eventually be cleaned up are still unidentified, it is impossible to detail the specific technologies that will be needed. Technologies that will accelerate the pace of development or reduce remediation costs or the total cost of a project will be needed. Real estate developers put a premium on saving time and completing projects quickly. Delays tend to be very expensive, since they can drive up the cost of projects. EPA's Technology Innovation Program has published a useful reference to help developers, communities, and remediation professionals engage the process of cleanup and redevelopment. This document, *Road Map to Understanding Innovative Technology Options for Brownfields Investigation and Cleanup,* is available from the EPA web site (U.S. EPA 2001). The document also provides links to state brownfield programs.

Exhibit 9-9. Remediation Techniques Used at a Sample of Brownfield Sites

Remediation Technique	2001 Number	2001 Percent	2002 Number	2002 Percent	Total Number	Total Percent
Demolition	46	38	31	46	77	41
Excavation/ Removal	44	36	16	23	60	32
Caps	17	14	14	21	31	17
SVE	5	4	1	2	6	3
Natural Attenuation	3	2	1	2	4	2
Soil Flushing	2	2	1	2	3	2
Thermal Desorption	2	2	1	2	3	2
Solvent Extraction	1	1	NA	NA	1	1
Slurry Walls	1	1	NA	NA	1	1
Bioremediation	NA	NA	1	2	NA	NA
No. of Sites Reporting [a]	121	100%	66	100%	187	100%

[a] Not all articles provided information on remediation technologies. Out of 772 sites, technology information was available for 187 sites. Thus, this data is an indication of the types of approaches rather than a precise accounting.

Source: XL Environmental, Inc. and the International Economic Development Council. *The XL Environmental Land Reuse Report 2002*, and *The XL Environmental Land Reuse Report 2001*.

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Chapter 10
Demand for Remediation of Manufactured Gas Plants and Related Coal Tar Sites

Before the United States had a network of natural gas pipelines and electricity, fuel for lighting, heating, and cooking was manufactured from coal and petroleum at thousands of manufacturing facilities across the country. As a result of these activities, hazardous materials are likely to be present in the subsurface and groundwater at thousands of locations. While some of these sites, especially those currently owned and operated by large gas and electric utility companies, are being addressed, most of the former manufactured gas sites have not been identified.

There is no separate remediation program for the characterization and remediation of MGP and other coal tar sites. MGP sites may be addressed under any of the remediation programs, such as Superfund, RCRA, or a state environmental program, depending on the nature and extent of the contamination and other site-specific factors. Because these sites may be managed under different remediation programs, the estimates of the MGP market should not be added to those in the previous chapters of this report. Adding these estimates would be double-counting sites and, therefore, overestimating the scope of the market.

This chapter provides information to help vendors, regulators, and other stakeholders understand the potential sources of risk to people and the environment that may have resulted from past MGP operations. It provides background for site investigators to understand potential sources of NAPLs, coal tars and other pollutants. The effectiveness and efficiency of site investigations and remdiations could benefit from a good understanding of this defunct industry.

10.1 History

From the early 1800s through the mid-1900s manufactured gas plants (MGP) were operated nationwide to provide gas from coal or petroleum for lighting, heating, and cooking. The first manufactured gas plant built in the United States was in Baltimore in 1816. By the turn of the 20th century almost every good-sized city had its own manufactured gas plant (Gonzalo, 1995). Larger cities had more than one plant.

A 2003 EPA report estimated that as many as 50,000 plants were built during the over 140 years of MGP operations (U.S. EPA 2003). The first plants were located in downtown areas adjacent to waterways and rail spurs for easy access to coal (EI Digest, 1995). As the technology developed, it became a common source of light, heat and fuel for a variety of industrial and commercial facilities and residences. After electricity and piped in natural gas became common, many of the larger MGP properties were converted for new uses by the utilities and other companies that owned them. In addition to the commercial MGPs, many railroad companies, military installations, large institutions (e.g. hotels, hospitals, prisons, schools), industrial facilities, and large private homes were equipped with gas plants (Heritage Research, 2002).

The manufacturing practices at the time left an environmental legacy of hazardous waste contamination in groundwater, soil, sediment, sludge, and surface water. Because almost all MGPs were decommissioned over 50 years ago, prior to most federal environmental regulations, it is difficult to assess the nature and scope of the environmental legacy left behind. MGP sites represent a potentially significant market for site characterization and remediation technologies.

10.2 Gas Manufacturing Processes

Manufactured gas was produced primarily by three processes; coal carbonization, carburetted water gas, and oil gas (NYDEC, 2003). Coal carbonization, was used exclusively until 1875. In this process, the coal was heated in a closed oven with limited air contact. The volatile products of this oxygen-deficient heating was driven off as a gas which was collected, cooled, and purified for use. The gas was then measured, stored, and delivered to customers via underground pipes. The solid remains would become coke, a fuel which burned hotter and more cleanly than coal.

The carburetted water gas process was introduced in the 1875. The process involved heating coal or coke in a closed vessel into which steam was injected. This resulted in a flammable gas mixture of methane and carbon monoxide. Then gas works napthalene or light oil petroleum products were sprayed into this gas mixture, resulting in petroleum constituents that were cracked to form methane, a gas that burned hotter and brighter.

The most common oil gas process was patented in 1889. It is similar to the carburetted water gas process with a vaporizer replacing the carburetor. Oil is added to the reactor thereby generating more heat. The oil vapors are thermally cracked and fixed into gases.

After 1928 the Northeast was subjected to shortages of both coke and light carbureting oils and a wide variety of newly developed oil-based gas manufacturing processes came into being. These processes were prominent until the 1950s when reliable supplies of natural gas were in place.

10.3 Number and Characteristics of Sites

As with other types of sites, former MGP sites are subject to current environmental regulations, and, when discovered, may be managed under either the federal Superfund, RCRA Corrective Action, Underground Storage Tank, or other federal or state programs. However, no single source provides definitive information on the number and characteristics of former MGP sites, nor on the number that may require remediation. Until further investigation is conducted, the number of MGP facilities that are likely to require remediation can only be estimated.

According to the U.S. Bureau of the Census' 1910 *Manufactures Report for Principal Industries*, there were 1,296 MGP plants, mostly owned by corporations and municipalities, selling manufactured gas in the country. Most of the sites were in the Northeast quadrant of the United States (Heritage Research, 2002). In 1985 EPA estimated that there were a total of 1,500 MGP plants in North America (*Brown's Directory of North American Gas Plants* - from 1887). This tally however did not include plants that were not members of gas associations, those that did not report information to the directory's publisher, or multiple plants owned by the same entity. A more recent estimate by the Electric Power Research Institute (1995) indicates that there may be as many as 2,500 MGP sites that are now associated with modern electric and gas utility properties. Con Edison estimates that in New York State alone there are approximately 250 former gas manufacturing sites related to utility operations. An extensive proprietary database with data on approximately 7,000 MGP and other coal tar sites provides additional information on the potential universe of sites that may still require some sort of site characterizations and/or remediation (Hatheway 1997).

Based on these sources, it is estimated that from 1800 to the mid-1900s between 36,000 and 55,000 manufactured gas plants and related coal tar sites operated in the United States. These sites varied in size from less than one acre to approximately 200 acres. Exhibit 10-1 identifies the types of sites, their typical sizes, and an estimate of the number of sites for each site type. These site types vary greatly in size, volume of releases, and location. For example, commercial MGPs tended to be medium-to-large plants located in urban areas where they piped gas to consumers, businesses, and municipalities. This gas was primarily used for lighting, heating, and cooking. In contrast, there were many more institutional and residential gas machines owned by hotels, hospitals, universities, private estates, and other entities, that manufactured gas for their own use. These sites ranged from several hundred square feet to a few acres.

Although most of the former MGP properties are now vacant or being used for other purposes, many of them have not been investigated for potential soil or groundwater contamination resulting from previous MGP activities. Nevertheless, based on the manufacturing practices at the time, it is believed that most of these facilities had releases of contaminants to the environment. The aforementioned sources were reviewed to estimate how many of the 36,000 to 55,000 sites were likely to have had releases and the number of those that had not been investigated or remediated.

Estimated Land Use Around MPG Sites

Industrial/commercial	50%
Residential	30%
Recreational & vacant	20%

By subtracting the estimated number of sites that have been found to require no further action planned (NFRAP), those that are enrolled in a state voluntary cleanup program (VCP), and those that have completed remediation under a federal or state program, the balance of the sites represent those that have not been investigated, and are likely to require characterization and remediation work.[1] These estimates are shown in Exhibit 10-2 and the calculations in Appendix Exhibit D-1. As the exhibit indicates, approximately 88 percent of the sites are suspected to have had releases of contaminated materials to the environment. It is estimated that only a small percentage of these sites have been identified and entered into a federal or state remediation program. Thus it is likely that the remaining 30,000 to 45,000 sites have not been investigated and represent a significant potential for site characterization and remediation work. Approximately 50 percent of these sites are in industrial/commercial areas, 30 percent are in residential areas, and the balance are in recreational and vacant areas (Appendix Exhibit D-1).

[1] A keyword search of EPA's CERCLIS database indicated that about 800 NFRAP sites were former MGP and coal tar sites. Although these sites did not become candidates for listing on the NPL, they may still require remediation under other environmental authorities such as RCRA or state laws.

Exhibit 10-1. Types and Numbers of Former Manufactured Gas Plants & Related Coal Tar Facilities in the U.S.

Site Type	Description/Use	Site Size Range & (Average)	Time frame	Number of Sites
Commercial MGPs	Produced and sold gas for lighting, heating & cooking Small: <5 million cu ft per yr. Med. : 5-100 mil. cu ft per yr. Large: >100 mil. cu ft per yr.	1-3 acres (2) 3-10 (5) 10-100 (40)	1816-1950s	3,500
District Gas Holders	Held & distributed gas beyond commercial MGPs original distribution radius	1-4 acres (1.5)	1860-1910	500 - 1,500
Rail Yard Pintsch Oil-Gas Plants	Produced illuminating gas for rail passenger cars	0.5- 1.5 acres (1)	1873-1960	100-150
Military Gas Plants	Produced illuminating and fuel gas for use at military posts, naval stations, arsenals, and munitions plants	0.5-1.5 acres (1)	1849-1993	150-250
Ice & Refrigeration Plants with Gas Producers	Commercial block ice and commodity refrigeration; used coal-gas ammonia as a refrigerant	1-2 acres (1.5)	1870-1940	200-400
Institutional Gas Machines	Hotels, resorts, hospitals, universities, asylums, monasteries, private schools	500-1500 sq ft (700 sq ft); Mostly indoors	1850-1950	5,000-10,000
Domestic/Residential Gas Machines	Mansions and country estates	400-1000 sq ft (600 sq ft); Basements & exterior bldg	1890-1950	10,000-15,000
Captive Gas Producers (both Pressure &Suction)	Fuel gas for wide variety of industrial plants with furnaces/kilns and smelters	600 to 30,000 sq ft; highly Variable; Most enclosed	1880-1950	11,000-15,000
Bottled Manufactured Gas Plants	Manufactured oil-enriched water gas or solvent vapor gas	1-3 acres (1.5); Variable; most enclosed	1912-1940	100
Kerosene Refiners	Distilled lamp oil from soft coal	1-2 acres (1.5)	1850-1870	100-150
Compressed Fuel Briquette Plants	Bound by-product with tars and compressed solid fuel	1-2 acres (1.5) Variable; enclosed	1910-1950	100

Exhibit 10-1. Types and Numbers of Former Manufactured Gas Plants & Related Coal Tar Facilities in the U.S. (Continued)

Site Type	Description/Use	Site Size Range & (Average)	Time frame	Number of Sites
Beehive Coke Works	Produced coke without recovery of by-products	40-100 acres; Highly variable	1800-1930	2,000-4,000
Merchant and Utility Coke Works	Produced coke with recovery of coal tar by-products	40-100 acres; variable	1890-1996	250-300
Charcoal Plants	Produced charcoal as fuel	10-100 acres (25); Highly variable	1820-1960	2,000-3,000
Tar Distilleries	Converted tar residues to industrial chemicals	10-100 acres (15); Variable	1900-1960	200-400
WWI Federal Wood-Tar Distillation Plants	Produced cellulose acetate aircraft fabric dope	40-200 acres (80); Variable	1918-1921	11
WWI Federal Toluene Plants	Produced munitions and fuel-grade toluene from gas-works benzol	80-200 acres (100); Variable	1918-1920	10
Wood Preservation Plants	Pressure and non-pressure impregnation of timber with coal tar products	10-200 acres (40); Highly variable	1880-1960	800-1,000
U.S. Bureau of Mines coal Gasification Plants	coal gasification plants to exploit WWII German technologies; operated mainly by universities and industrial grantees	10-40 acres (20); Variable	1947-1990	37-55
U.S. Department of Energy Coal Gasification Plants	Coal & oil shale gasification pilot projects	10-40 acres (20); Variable	1970-1985	63-75
Total				36,121 -55,001

Notes:

- Acetylene gas plants were common from 1890 to 1940, for use in rural small-town, business and residential markets. These plants are not included in these tabulations since they are not regarded as having produced or left environmentally-hazardous wastes.

Source: Hatheway, Allen W. "Estimated Number of Manufactured Gas and Other Coal-Tar Sites in the United States," *Environmental Engineering Geoscience*, Vol. III, No. 1, Spring 1997, pp. 141-142 and personal communication with the author, February-March 2003. The data are based on Dr. Hatheway's database on MGPs which includes information on approximately 7,000 sites, assembled from *Brown's Directory of North American Gas Plants*, historic gas industry literature, Sandborn Fire Insurance maps, state agencies, and direct on-site observations.

Exhibit 10-2. Estimated Magnitude & Disposition of Former Manufactured Gas Plants & Other Coal Tar Sites in the U.S.

Site Type [a]	Original Number of Sites	Number of Sites w/Releases	No. of Sites Not Yet Investigated
Commercial MGPs	3,500	3,500	2,275+
District Gas Holders	500-1,500	500-1,500	450-1,350+
Rail Yard Pintsch Oil-Gas Plants	100-150	100-150	>85-129
Military Gas Plants	150-250	150-250	150-250-
Ice & Refrigeration Plants w/Gas Producer	200-400	150-300	143-285
Institutional Gas Machines	5,000-10,000	2,500-5,000	2,375-4,750
Domestic/Residential Gas Machines	10,000-15,000	10,000-15,000	9,800-14,700+
Captive Gas Producers - Pressure & Suction	11,000-15,000	11,000-15,000	10,450-14,250
Bottled Manufactured Gas Plants	100	50	50
Kerosene Refiners	100-150	100-150	93-140+
Compressed Fuel Briquette Plants	100	50	50
Beehive Coke Works	2,000-4,000	2,000-4,000	1,800-3,600+
Merchant & Utility Coke Works	250-300	250-300	125-150
Charcoal Plants	2,000-3,000	2,000-3,000	1,800-2,700
Tar Distilleries	200-400	200-400	160-320
WWI Federal Wood Tar Distillation Plants	11	11	6
WWI Federal Toluene Plants	10	10	5
Wood Preservation Plants	800-1,000	800-1,000	440-550
U.S. Bureau of Mines - Coal Gasification Plants	37-55	37-55	33-49
U.S. Dept. of Energy - Coal Gasification Plants	63-75	63-75	57-67
Total	36,121-55,001	33,471- 49,801	29,975-44,926

a See Table 1 for descriptions of the site types.

Source: Hatheway, Allen W, "Estimated Number of Manufactured Gas and Other Coal-Tar Sites in the United States," *Environmental Engineering Geoscience*, Vol. III, No. 1, Spring 1997, pp. 141-142 and personal communication with the author, February-March 2003. The data are based on Dr. Hatheway's database on MGPs which includes information on approximately 7,000 sites, assembled from *Brown's Directory of North American Gas Plants*, historic gas industry literature, Sandborn Fire Insurance maps, state agencies, and direct on-site observations.

10.4 Waste Types and Quantities

The gas manufacturing processes resulted in a variety of residuals, some of which were converted to by-products, while others, many of which are hazardous, were managed as wastes. Some of the by-products were sold to other industries. For example, coke was sold to the steel industry. Others materials were transported offsite for disposal. It was common practice to dump coal tar and other wastes into on-site pits or ponds, bury it, or use it as fill to adjust the grade of the gas yard. The gas manufacturing process also involved the use of wood chips and iron filings to remove sulfur and cyanide from the gas. These chips and filings were also disposed of in pits or buried. As a result of these practices, wastes from manufactured gas processing can be found in soil, sediment, groundwater and surface water.

These wastes pose potential risks to humans and the environment. A critical concern with regard to coal tar is the fact that less than 40 percent of the mass of coal tar constituents can be quantified using common organic chemistry extraction and chromatographic techniques. The remaining 60 percent known as "pitch" are comprised of aromatic compounds with high molecular weight and relatively low aqueous solubility. The compounds that make up this pitch are of concern since many are suspected to cause mutagenic and/or carcinogenic effects. In addition, the presence of pitch can influence the rates of release of the more soluble coal tar constituents. Some researchers who are now looking at tar as a "supercompound" with a potent combination of carcinogens, much like cigarette smoke, instead of studying its individual constituents (WDNR, 1999).

The types of wastes produced depended upon the production processes and the period in which the plants operated. Coal tar, a by-product of all MGP sites, is a dense, non-aqueous phase liquid (DNAPL). When released into an aquifer, it migrates downward until it encounters a low-permeability layer. This dense substance does not dissolve in the aquifer and releases constituents into the water. The lighter oil by-products (LNAPLs) of the manufactured gas process migrate through the groundwater. They tend to float on top of the water, contaminating it from above.

Exhibit 10-3 shows the types and estimated quantities of residuals and wastes remaining in the soil and groundwater at MGP and coal tar sites. The most common releases are liquids, solids, sludges, and tar. The quantity estimates are based on information from public and private databases cited in the footnote to the exhibit.

From 1880 to 1950, MGPs produced approximately 15 trillion cubic feet of gas and approximately 11 billion gallons of tar as a by-product resulting in thousands of contaminated acres of land and millions of gallons of impacted water (Fischer et al, 1999).

Exhibit 10-3. Estimated Quantities of Residuals and Wastes Released at Former MGP & Other Coal Tar Sites in the U.S.

Site Type [a]	Original Number of Sites	Number of Sites With Releases	Type of Releases	Volume of Residuals/Waste Per Site (000)
Commercial MGPs	3,500	3,500	Liquids & Solids	2,000-50,000 m^3
District Gas Holders	500-1,500	500-1,500	Liquid Leaks, Solids inside	100 -500 m^3
Rail Yard Pintsch Oil-Gas Plants	100-150	100-150	Liquids & Solids	500-10,000 m^3
Military Gas Plants	150-250	150-250	Liquids & Solids	500-1,000 m^3
Ice & Refrigeration Plants w/Gas Producer	200-400	150-300	Liquids & Limited Solids	500-1,000 m^3
Institutional Gas Machines	5,000-10,000	2,500-5,000	Liquids	<100 m^3
Domestic/Residential Gas Machines	10,000-15,000	10,000-15,000	Limited Liquids[b] &Solids	<50 m^3
Captive Gas Producers - Pressure & Suction	11,000-15,000	11,000-15,000	Tars & Solids	100-10,000 m^3
Bottled Manufactured Gas Plants	100	50	Limited Sludges	100-500 m^3
Kerosene Refiners	100-150	100-150	Liquids & Sludges	100-1,000 m^3
Compressed Fuel Briquette Plants	100	50	Limited Liquids & Sludges	100-1,000 m^3
Beehive Coke Works	2,000-4,000	2,000-4,000	Tars	1,000-10,000 m^3
Merchant & Utility Coke Works	250-300	250-300	Tars & Solids	5,000-100,000 m^3
Charcoal Plants	2,000-3,000	2,000-3,000	Tars	1,000-5,000 m^3
Tar Distilleries	200-400	200-400	Liquids & Tar Sludges	1,000-100,000 m^3
WWI Federal Wood Tar Distillation Plants	11	11	Liquids & Tar Sludges	1,000-10,000 m^3
WWI Federal Toluene Plants	10	10	Liquids & Sludges	1,000-10,000 m^3
Wood Preservation Plants	800-1,000	800-1,000	Liquids & Sludges	1,000-10,000 m^3

Exhibit 10-3. Estimated Quantities of Residuals and Wastes Released at Former MGP & Other Coal Tar Sites in the U.S. (Continued)

Site Type [a]	Original Number of Sites	Number of Sites With Releases	Type of Releases	Volume of Residuals/Waste Per Site (000)
U.S. Bureau of Mines-Coal Gasification Plants	37-55	37-55	Liquids & Sludges	500-1,000 m^3
U.S. Department of Energy-Coal Gasification Plants	63-75	63-75	Limited Liquids & Sludges	500-1,000 m^3
Total	36,121-55,001	33,471-49,801		

Notes:
a See Exhibit 10-1 for definitions of site types.
b Limited connotes a few hundred to one thousand gallons over the period of weeks to a few months.

Source: Hatheway, Allen W, "Estimated Number of Manufactured Gas and Other Coal-Tar Sites in the United States," *Environmental Engineering Geoscience*, Vol. III, No. 1, Spring 1997, pp. 141-142 and personal communication with the author, February-March 2003. The data are based on Dr. Hatheway's database on MGPs which includes information on approximately 7,000 sites, assembled from *Brown's Directory of North American Gas Plants*, historic gas industry literature, Sandborn Fire Insurance maps, state agencies, and direct on-site observations.

Six major constituent classes are potentially present in MGP residuals (Middleton, 1995):

- polynuclear aromatic hydrocarbons (PAHs);
- volatile aromatics (BTEX);
- phenolics;
- inorganic nitrogen (including cyanide compounds);
- inorganic sulfur; and
- trace metals.

10.5 Remediation Technologies

Investigation and remediation at many MGP sites are complicated by the:

- Nature and variety of waste materials and media, including the fact that the constituents of concern tend to interact differently in different media;
- Location of the sites (i.e near waterways or in the heart of residential neighborhoods); and
- Condition of the sites (i.e. infrastructure at the sites, lack of surface features and mixed debris is subsurface).

A variety of site investigation techniques are available to address some of these complications. They include ground penetrating radar (GPR), Electromagnetic (EM) Induction, Infrared Monitoring (IM), and Seismic Reflection and Refraction to detect and measure buried debris or other subsurface anomalies. Direct Push Sampling and Seismic Reflection and Refraction may be used to produce a geophysical profile of the subsurface. Flame Ionization Detectors (FID) and Photoionization Detectors (PID) are used to screen soil for contamination. Once the location and profile of the waste is determined, many of the same sampling techniques are employed to test both soil and water. These include Direct Push sampling which can be used for any constituent, drilling both for the collection of samples and the installation of groundwater wells; Immunoassay test fits to detect and quantify contaminants by measuring compound reactions; Laser-Induced Fluorescence/Cone Penetrometry using a fiber optics-based chemical system to screen primarily for petroleum contamination in the field; and, X-ray Fluorescence (XRF) to detect and quantify individual metals in the field. In addition, soil gas surveys are used to identify and quantify individual organic compounds (VOCs and SVOCs) that occur between particles of the earth and soil with the help of a portable gas chromatograph (Fischer 1999).

Both established and innovative technologies are being used to remediate former MGPs. Most of the technologies involve thermal desorption, biological processes, and/or chemical oxidation processes (Brown et al, 1995). A number of the technologies can be applied either in situ or ex situ. In some cases, these technologies serve to recover fuels for recycling.

A variety of remediation alternatives are available for use at former MGP sites. Exhibit 10-4 enumerates many of these alternatives and their application by waste stream category and contaminant/media. According to the Institute for Gas Technology, wastes from former MGP sites fall into six major categories; pumpable liquid free product (free tars & oils); organic waste or tar/oil-contaminated waters; organic waste or tar-contaminated soil and sediments; non-pumpable tars and sludges; purifier box (or spent oxide) waste; and, demolition debris (Fischer 1999).

Exhibit 10-4. Remediation Alternatives by Category of Waste at Former Manufactured Gas Plants

Waste Category	Remediation Alternatives	Contaminants and Media
Organic waste or Tar-Contaminated Soils and Sediments	Soil vapor extraction - use of vacuum to separate contaminants from soil	VOCs and some SVOCs
	Bioremediation (in-situ or ex-situ)	PAHs
	Bioventing (combines SVE and Bioremediation)	Petroleum products
	Excavation & Aeration	VOCs, some SVOCs
	Low Temperature Thermal Desorption	VOC, SVOC, & petroleum contaminated soil
	High Temperature Thermal Desorption	SVOCs in impacted soil, some VOCs
	Incineration	VOCs & SVOCs in impacted soil
	Soil washing	Metals, gasoline, & fuel oils
	Solvent extraction	PCBs, VOCs, halogenated organics, & petroleum from soil, sediments, & sludges
	Soil flushing	Heavy metals, halogenated organics, aromatics, & PCBs
	Clean Soil Process (CSP)	Coal Tar
Non-pumpable tars and sludges	Excavation & soil mixing - to dilute the concentration of TPAHs - removal to RCRA class D landfill - daily cover	Petroleum hydrocarbons
Purifier box (or spent oxide) waste	Spent wood chips - burnt and ash dumped	Other spent purification media
	Spent oxides - some sold for Vitriol - most removed to RCRA class D landfill	Sulphur-related PH conditions that can release cyanide
Demolition Debris	Scanned and steam cleaned - removal to RCRA Class D landfill	NA

Exhibit 10-4. Remediation Alternatives by Category of Waste at Former Manufactured Gas Plants (Continued)

Waste Category	Remediation Alternatives	Contaminants and Media
Pumpable liquids (free tars & oils)source material	Solvent extraction (separates or removes hazardous organic contaminants)	Sediments, sludges, soil with primary organic contaminants (PCBs, VOCs, halogenated organic compounds)
	Surfactant flushing - increases solubility and mobility of contaminants in water	Groundwater with NAPLs
Organic waste or tar/oil-contaminated waters	Bioremediation (in-situ or ex-situ) (use of microorganisms to break down hazardous substances)	PAHs
	Air sparging - captures contaminants by vapor extraction	Volatile contaminants
	Treatment wall	Chlorinated solvents, metals or radioactive contaminants
	Groundwater extraction using a system of wells and pumps w/ UV oxidation, activated carbon treatment, or air stripping	VOCs and SVOCs
	Surfactant flushing	NAPLs

Sources:
- Fischer, Corey L.J., Schmitter, Robert D., and Lane, Eliesh O'Neil, 1999, *Manufactured Gas Plants: The Environmental Legacy*, South & Southwest Hazardous Substance Research Center, Georgia Institute of Technology, Atlanta, GA, November.
- Personal communication with Allen W. Hatheway.

10.6 Estimated Cleanup Costs

MGP cleanup costs have been documented to range from a few hundred thousand dollars to $86 million for a single site. No single source provides a total nation-wide estimate of MGP cleanup costs. To estimate the potential value of the market for cleaning up MGP and other coal tar sites, estimates of ranges of costs for each site type were developed and multiplied by the estimated number of sites of each type. The estimates of average costs were developed from published information on MGP remediation costs and from analysis of data in a proprietary database containing data on thousands of MGP and other coal tar sites (Hatheway, 1997).

The published sources provide cleanup costs for specific projects or averages for specific utility companies that have a number of MGP sites. In 1995 the Electric Power Research Institute estimated that cleanup and containment costs for approximately 2,500 former MGP properties to be between $25 and 75 billion and that it would take over 30 years to clean them up (Murarka, 1995). The MGP sites in this study are those that are now part of modern utilities. This report implies an average cost of $10-30 million per site. Other reports estimate that most per site cleanups fall in the $3-10 million range. For example, a 2001 article reports that per site cleanup for MGPs are in the $3-5 million range, although many sites have run much higher (Ginsburg, 2001). In 1995, the Niagara Mohawk Power Corporation of New York estimated its environmental liability from the legacy of 55 sites in 24 cities and towns to be more than $200 million, or an average of $3.6 million per site (Neuhauser, 1995). The estimated cost varied widely from site to site, with the cost of one site estimated as high as $86 million (Ginsburg, 2001). The Atlanta Gas Light Company is expected to spend $186 million to clean up 12 MGP sites in Florida and Georgia, or $15.5 million per site.

The Hatheway database provided ranges of costs for a number of sites for the various site types (Hatheway, 1997). Some engineering judgement was used to apply these to the various site types, and to eliminate outliers (i.e., the few cases that have extremely high costs and tend to bias the average). These estimates do not include the cost of contamination resulting from activities at the sites after the MGP operations were closed down, nor do they consider legal costs or awards for potential damages. The published data generally confirmed the data from this database.

> It is estimated that should the 30,000-45,000 MGP and other coal tar sites require cleanup, it could cost $26-$128 billion.

The results of this analysis is presented in Exhibit 10-5, which shows the range of estimated average remediation cost for each site type, along with the typical contaminants and contaminated media. The estimated number of sites that have yet to be investigated is taken from Exhibit 10-2. Based on these estimates, the cleanup of between 30,000 and 45,000 MGP and other coal tar sites would cost between $26 billion and $128 billion. Captive gas producer plants account for 44 percent of the total and commercial plants account for 23 percent. Although the average cleanup cost for captive producer plants is about a third of that of commercial plants, there are 5 to 7 times as many captive plants sites.

Exhibit 10-5. Estimated Average Remediation Cost by Site Type

Site Type	Range of Site Size	Number of Sites Not Investigated	Average Per Site Remediation Cost $ Millions
Commercial MGPs	small (1-100 acres)	2,275+	3.0 - 100.0
District Gas Holders	1-4 acres	450-1350+	0.25 - 1.5
Rail Yard Pintsch Oil-Gas Plants	0.5-1.5 acre	95-142	0.5 - 5.0
Military Gas Plants	0.5-1.5 acre	150-250	1.0 - 4.0
Ice & Refrigeration Plants with Gas Producers	1-2 acres	147-294	0.5 - 1.5
Institutional Gas Machines	500-1500 ft^2	2,450-4,900	0.2 - 0.75
Domestic Residential Gas Machines	400-1000 ft^2	9,800-14,700	0.05
Captive Gas Producers (Pressure & Suction)	20/30 ft to 50x600 ft	10,450-14,250	1.0 - 10.0
Bottled Manufactured Gas Plants	1-3 acres	50	0.2 - 0.5
Kerosene Refiners	1-2 acres	95-142	1.0 - 5.0
Compressed Fuel Briquette Plants	1-2 acres	50	0.5 - 1.0
Beehive Coke Works	40-100 acres	1,900-3,800	0.5 - 2.0
Merchant & Utility Coke Works	40-100 acres	100-120	10.0 - 100.0
Charcoal Plants	10-100 acres	1,900-2,850	0.5 - 2.0
Tar Distilleries	10-100 acres	150-300	10.0 - 100.0
WWI Federal Wood Tar Distillation Plants[c,d]	40-200 acres	11	1.0 - 2.0
WWI Federal Toluene Plants[c,d]	80-200 acres	10	1.0 - 5.0
Wood Preservation Plants	10-200 acres	480-600	5.0 - 20.0
U.S. Bureau of Mines - Coal Gasification Plants[c]	10-40 acres	33-49	1.0 - 2.0
U.S. Department of Energy - Coal Gasification Plants[c]	10-40 acres	57-67	1.0 - 2.0

Source: Appendix Table D-2.

These data provide a reasonable estimate of a range of probable cleanup costs for all MGPs, should they require cleanup. However, because these costs vary widely, and because the above values of the number of MGP sites remaining to be cleaned up are estimates, the cost estimates provided here are considered a general indication of the market size.

10.7 References

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Chapter 11
Demand for Remediation of Mining Sites

The thousands of abandoned, inactive, and operating mines in the United States present serious potential risks to human health and the environment. The extraction and processing of metals, nonmetal minerals, and coal result in the generation of large quantities of contaminated solid wastes, wastewater, and air emissions which cause significant environmental impacts, including groundwater and surface water contamination, soil erosion, and soil contamination. Mining wastes have been detected many miles downstream from their source. This Chapter presents estimates of the extent of mining waste environmental problems in the U.S. and its implications for the demand for remediation technologies.

There is no separate remediation program for the characterization and remediation of mining sites. Mining sites may be addressed under one or more of the major remediation programs, such as Superfund, RCRA, or a state environmental program, depending on the nature and extent of the contamination and other site-specific factors. Because these sites may be managed under different remediation programs, the estimates of the market should not be added to those in the previous chapters of this report. Adding these estimates would be double-counting sites and, therefore, overestimating the scope of the market. Addressing mining sites across all remediation programs provides vendors and regulators information from the unique perspective addressing the hazardous waste challenges facing a specific industrial sector.

The Mine Safety and Health Administration reports that, as of 2001, there were approximately 14,500 operating coal, metal, and nonmetal mineral mines in the U.S. The Bureau of Land Management (BLM), a component of the Department of Interior, estimates that there are between 100,000 and over 500,000 small and mid-sized abandoned hard rock (metals and nonmetal minerals) mines on private, state and federal lands in the west and approximately 13,000 abandoned coal mines, mostly small and mid-sized, in the east. Many of these properties continue to threaten human health and the environment because of the materials left behind and because mined-out areas and materials are exposed to the elements. There is a wide range of estimates and opinions on how many of these properties pose a serious environmental risk and are likely candidates for remediation. The most promising estimates indicate that approximately 5 to 10 percent of abandoned mines pose a significant risk to the environment and people.

11.1 Industry Description

Identifying, prioritizing, and implementing the necessary cleanup actions at thousands of sites across the country is expected to take many years. To understand the nature of and potential extent of the cleanup effort, it is necessary to understand the nature of mining operations in the U.S. This section summarizes the basic characteristics of mining operation in the U.S. and their environmental impacts, including the types of mines, common production processes and their likely waste streams, and the regulatory programs that address them.

11.1.1 Types of Mining

The Department of Commerce identifies three major segments of the mining industry: metal ore mining, nonmetallic mineral mining, and coal mining. The term "mining" is used in the broad sense to include ore extraction, quarrying, and beneficiation (e.g., crushing, screening, washing, sizing, concentrating, and floatation), customarily done at the mine site. The term "hardrock mining" refers primarily to the extraction and processing of metals (e.g., copper, gold, iron, lead, magnesium, silver, uranium, zinc) and nonmetallic, non-fuel minerals (e.g., asbestos, gypsum, phosphate rock, sulfur). Hardrock minerals are key raw materials used in many industrial products. Non-hardrock mineral mines, such as sand, gravel, and limestone are not addressed in this study.

Most of the minerals and coal extraction in this country is done with surface mining techniques, primarily open pit mining. Underground techniques may be used when the deposits are hundreds or thousands of feet below surface level. Non-metallic mineral deposits generally have far less waste rock and foreign materials associated with them than metallic deposits. Wastes associated with non-metallic minerals and waste rock are generally of lower toxicity and more manageable than those associated with hardrock or coal mining wastes.

11.1.2 Mining Processes

Mining generally involves three basic processes–extraction, beneficiation, and processing–each of which can seriously impact the environment and human health (U.S. EPA 2000).

Extraction is the removal of rock and other materials that contain the target ore/mineral. There are three basic types of extraction used today: surface, underground, and in-situ solution mining. A fourth type, placer mining, is no longer used in the U.S.

- Surface mining accounts for the greatest volume of mined materials in the U.S. It involves rock removal, blasting, mucking (removal and transport of ore), crushing, and hauling. The open pit method is the most common form of surface mining. This technique allows access to the ore bodies by removing the surface covering (overburden) of soil and rock. Ore-bearing rock is then removed for further processing to extract the target mineral. After the ore body is exhausted, open pits and huge mounds of finely-ground tailings and coarser waste rock are usually left behind. The extraction process generates large volumes of waste rock because of the high waste-to-product ratios associated with most ores.

  Strip mining is likely to be used to extract horizontal, close to the surface deposits. It has been used for phosphate mining and coal mining. The strip mining technique is usually more efficient but also more environmentally destructive than underground mining. In this process, the soil and rock above the seam of coal or other target mineral are removed. The seam is then blasted, the target material is scooped up by huge front end loaders or power shovels and transported to a processing plant where it is subjected to physical and/or chemical processes to separate the target material from waste rock and other materials. The coarser waste rock is piled up adjacent to the mined out area, and the finer tailings from the plant are discharged as a thick slurry into an impoundment. After the mining operations have ceased, the mine is reclaimed by regrading waste rock and other wastes to approximate the original contours of the land and replanting the area with native vegetation. Mountaintop mining, a relatively new variant of strip mining, is common in locations where valleys adjacent to the areas being mined can serve as repositories for the soil and waste rock.

- Underground mining involves digging tunnels and shafts to reach mineral-rich ore. The most common scenario is to sink vertical shafts or dig adits (horizontal entrances into hillsides) to reach into the mineral deposit and then bore a series of horizontal tunnels to access the entire deposit. Underground techniques may be used when the deposits are hundreds or thousands of feet below surface level. After the ore body is exhausted, underground tunnel complexes are left behind. In order to support the roof rock of coal tunnels, about 50 percent of the coal is often left behind in the form of pillars. A variant of this technique, in which hydraulic jacks are used to support the roof, allows for an 80 to 90 percent recovery rate; although this technique can result in subsidence once the equipment is removed. Tunneling generates considerable amounts of waste rock which are either disposed of underground or are placed in waste rock piles.

- Underground mining is more expensive than surface mining, requiring more skilled workers and specialized equipment. Coal, salt, and potash are often mined underground. As with hardrock mining, the minerals must be separated from the waste rock.

- in-situ solution mining involves drilling wells and circulating a solvent into an ore body left in place to extract minerals. Although this causes little surface physical disturbance, the solvents and pumping may adversely affect groundwater quality.

- Placer mining, a gold mining technique that was once common in the United States, is still being used to extract surface deposits of gold in Alaska. In this technique, miners dam small streams and dig up and process stream sediments to extract gold.

Beneficiation involves separating the target ore from waste rock. Beneficiation activities generally do not change the mineral values themselves other than by reducing (e.g. crushing or grinding) or enlarging (pelletizing or briquetting) particle size to facilitate processing. Some common types of beneficiation include:

- Gravity separation relies on large differences in density between the target metal and the surrounding materials. This techniques utilizes devices such as trommels, sluices, cyclones, jigs, and shaker tables.
- Magnetic separation is applied in the ore milling industry for iron, columbium and tantalum, and tungsten. Among other things, it is used for the separation of multiple valuable minerals recovered from complex ores.
- Electrostatic separation involves taking ore that is charged and dropping the charged particles onto a conductive rotating drum. The particles lose the charge quickly and are thrown off and collected.

- Flotation, the most common beneficiation method, involves adding a reagent chemical to ore slurry causing minerals to become less dense than the waste rock or other worthless material and rise to the top of the tank.
- Leaching involves extracting a soluble metallic compound by dissolving the ore with a solvent, such as sulfuric acid (copper) or sodium cyanide solution (gold).

Processing is the refining of ore after beneficiation to extract the target material. Mineral processing operations can be based on high temperatures (i.e. smelting, roasting), hydrometallurgical (the use of liquid reagents in the treatment or reduction of ores), or electrometallurgical techniques (the use of electric and electrolytic processes to purify metals or reduce metallic compounds to metals). The most common of these processes is smelting which involves applying heat to a batch of ore to separate and refine the metal.

11.1.3 Types of Wastes

The extraction, beneficiation, and processing steps can result in four types of wastes: mine water, waste rock, overburden, and tailings.

Mine water consists of all water that collects in mine works, both surface and underground, as a result of inflow from precipitation and surface water and groundwater seepage. In active mining operations this water can be pumped out and used for other mining activities or discharged to surface water under a water discharge permit. At inactive or abandoned mines the water accumulates in the mine pit and saturates the fill material. Depending on the source of the water and the regional and hydrological conditions, this mine water can have high concentrations of heavy metals and total dissolved solids as well as elevated temperatures and altered pH, which may contaminate down-gradient groundwater and surface water.

Waste rock consists of non-mineralized and low-grade mineralized rock removed from an ore body during extraction. It includes granular, broken rock that range in size from fine sand to large boulders and is typically piled or disposed in piles or dumps near the point of extraction. The geochemistry of waste rock varies widely from mine to mine and may even vary significantly at individual mines over time. Generally, waste rock contains some concentration of the target mineral, along with other metals and minerals. Waste rock can be a source of acid rock drainage and heavy metals such as arsenic. Acid rock drainage occurs when precipitation or runoff leaches sulfuric and other materials from waste rock. The resulting contaminated water can flow offsite, where it may contaminate soil, surface waters, and groundwater.

Overburden is the surface rock and soil removed to expose the ore at surface mines. As long as this material is salvaged and returned to the mine site during closure or decommissioning it is exempt from Resource Conservation and Recovery Act (RCRA) regulations.

Tailings are the coarsely and finely ground waste portions of mined material remaining after beneficiation. The physical and chemical characteristics of tailings vary according to the ore being mined and the beneficiation process used. Tailings have traditionally been disposed of in a variety of configurations including impoundments, piles, in backfill for underground mines, and under water. Subaqueous disposal is currently prohibited by the Clean Water Act (CWA).

Like mineral mining, coal mining generates large quantities of solid waste materials which are piled on the surface and subject to saturation and runoff resulting in an increase of total suspended solids in water bodies, acid drainage into surface and groundwater, and increased build-up of sediments in local waters. At the processing stage, the impurities removed during the screening and washing of the coal are also placed in waste piles, thereby adding to the hazardous waste problems of the coal mining process. Coal piles are flammable, susceptible to spontaneous combustion, and prone to erosion which leads to highly acidic runoff and seepage.

11.1.4 Regulatory Programs

Mining activities, including the investigation and cleanup of abandoned mine sites, are managed in accordance with a complex web of jurisdictions, laws, and regulations covering several environmental media. Generally, the Comprehensive Environmental Response Compensation and Liability Act (CERCLA) and CWA are the most prevalent statutes that are applicable to mine cleanup programs. For coal mining, the Surface Mining Control and Reclamation Act of 1977 is the primary authority on mining operations and reclamation. Depending on the circumstances of any specific mine site, its operations and/or cleanup may also be governed by the provisions of RCRA, National Environmental Policy Act (NEPA), the Clean Air Act, the Emergency Planning and Community Right to know Act, the Safe Drinking Water Act, the Atomic Energy Act, the Toxic Substances Control Act, and state or local statutes. Cleanup requirements may further be complicated by land ownership and tenancy issues, such as whether it is on federal, state, or tribal land.

This document concentrates on the environmental aspects of mining sites. Many mine sites also contain physical hazards, such as open shafts and unstable slopes and buildings. Although these safety hazards are not the focus of this report, they also deserve consideration in developing site management strategies since they are part of the overall responsibility of site owners.

CERCLA. CERCLA's main applicability to mining activities is that it provides EPA with the authority to conduct or require a private party to conduct a removal or remedial activity. Federal agencies that are responsible for land must comply in the same manner as private parties with the provisions of CERCLA (and RCRA). This responsibility is especially important for the Department of Interior (BLM, Fish and Wildlife Service, National Park Service, Bureau of Indian Affairs, and Bureau of Reclamation) and USDA (U.S. Forest Service), DOD, and DOE, each of which is responsible for management of mining sites. Their responsibilities also extend to many non-NPL mining sites. Where a site crosses property boundaries between private and federal ownership, all parties generally coordinate to develop agreements that specify the responsibilities of all parties. Inactive sites classified as having the most severe environmental problems are placed on the NPL. As of December 2002, close to 90 mining and processing sites were listed on the NPL.

Under CERCLA, EPA can require compliance with appropriate regulations adopted under other relevant and appropriate regulations (ARARs), which may include state standards as well as other federal regulations such as RCRA. EPA has published a manual outlining all potential federal ARARs that may be requirements at Superfund sites (CERCLA Compliance With Other Laws Manual, Part I, August, 1988, and Part II, August 1989).

Clean Water Act (CWA). The CWA provides a mandate for controlling discharges from point sources and non-point sources of pollution. The Act prohibits any pollution discharges from "point sources" into navigable waters of the United States (33 U.S.C. § 1251-1387). A point source includes any "discernible, confined, and discrete conveyance, including such structures as pipes, ditches, and channels." All point source discharges to surface waters must be permitted by EPA or authorized states, in accordance with the National Pollutant Discharge Elimination System (NPDES). This requirement is especially important to the mining industry, since waters coming into contact with mining materials often become acidic or contaminated with other materials. The CWA also regulates the construction of impoundments that serve as repositories for tailings and treatment of waste from mining and mineral processing operations. Although mining permits are issued by the states, EPA's Office of Water may review these permits to ensure compliance and proper application of guidelines. A landowner is liable for pollution stemming from activities that took place prior to his/her ownership of the land.

RCRA. Section 3001(b)(3)(A)(ii) of RCRA excluded certain solid wastes from mining and processing from regulation as a hazardous waste under Subtitle C, pending certain studies by EPA. Congress included this provision, also known as the "Bevill Amendment," to apply to "high-volume, low-hazard waste."[1] In 1989 EPA promulgated regulations defining the criteria for "high volume, low hazard" and published a list of waste types that are no longer excluded. EPA also stated that it may conduct evaluations of additional waste streams in the future to determine whether they should remain excluded (40 CFR Part 26, Mining Waste Exclusion, 54 FR 36592, September 1, 1989). The rule does not impose Subtitle C requirements on mineral processing wastes that were disposed prior to the effective date of the rule.

As a result of these regulatory proceedings, wastes from the extraction and beneficiation processes continue to be excluded from Subtitle C requirements. Only 20 wastes from mineral processing are exempt from RCRA (40 CFR 261.4(b)(7)). Today, relatively little mining waste is subject to RCRA regulation as hazardous waste. Overburden is exempt from RCRA regulations, so long as it is returned to the mine site.

Surface Mining Control and Reclamation Act (SMCRA). The SMCRA was passed in 1977 to ensure that coal mines are operated in a manner that protects citizens and the environment during mining, ensure that the land is restored to beneficial use following mining, and mitigate the effects of past mining by aggressively pursuing reclamation of abandoned mine lands. The Surface Mining Law gives primary responsibility for regulating surface coal mine reclamation to the states, a responsibility that 31 states have chosen to exercise.

The Office of Surface Mining (OSM) was established within the Department of the Interior to help carry out the SMCRA. The OSM handles enforcement on federal lands and Indian Reservations and in coal states that have not set up regulatory programs. Funds for reclamation of abandoned mines come from tonnage-based fees paid by active coal mines - 35¢/ton of surface mined coal, 15¢/ton of coal mined underground, and 10¢/ton of lignite. The fund consists of fees, contributions, late payment interest, penalties, administrative charges, and interest earned

[1] The Bevill Amendment was Section 7 of Public Law 96-482, which was enacted on October 21, 1980, to include several amendments to RCRA.

on investment of principal. From January 1978 when the first fees were paid through March 2003 over $6.7 billion has been collected. As of March 2003 the balance of unappropriated funds is in excess of $1.4 billion (DOI, 2003). States that have completed the reclamation of coal mines can apply unused funds for the remediation of safety and environmental hazards at hardrock and other non-coal sites.

11.1.5 Mines on Federal Lands

Hardrock and non-coal mining exist in all 50 states. A significant number of both active and abandoned mines are located on public lands. Three of the four major land managing agencies - the Bureau of Land Management, the National Park Service, and the Fish and Wildlife Service - are part of the Department of the Interior. The fourth agency, the Forest Service (USFS), is part of the Department of Agriculture (USDA). Most federal lands are managed by the BLM and the USFS.

Most of the BLM-managed 264 million acres are in 12 western states, and 90 percent of this land is open to mining. The Bureau administers 700 million acres of sub-surface mineral assets throughout the nation. The Bureau has a budget of $1.8 billion and a workforce of about 9,000 employees. The USFS manages 163 million acres in the west of which about 80 percent is open to mining. Together, the two land management agencies are responsible for 38 percent of the total area of the western states. These lands are important for their minerals, timber, and grazing resources; as a source of clean water; as a location for recreational activities; and as wildlife habitats and scenic areas, among other purposes. Regulations promulgated by the BLM (1980) and the Forest Service (1974), require that once mining activities are completed, mine operators must reclaim all areas disturbed by their operations (U.S. GAO, 1996). Prior to these regulations, state laws required reclamation of mined sites.

With regard to coal mines, OSM is responsible for enforcement of SMCRA on federal lands and Indian reservations and in coal states that have not set up regulatory programs. As noted above, the Surface Mining Law gives primary responsibility for regulating surface coal mine reclamation to the states, a responsibility that 31 states have chosen to exercise.

Funding Cleanups

Unlike coal mining, there is no single source of federal funding for the reclamation of abandoned hardrock mining lands. However, as noted above, states with both coal and non-coal mines may use funds left over from the coal mining reclamation funds for non-coal mining remediation.

There have been a number of efforts over the years to pass Good Samaritan and/or a hardrock mines reclamation fund legislation.[2] A bill proposed in 2002 (HR 4078) would have created a sliding scale fee on existing mining operations and a permit program detailing cleanup

[2] A "Good Samaritan" provision would protect a remediating agency or "Good Samaritan" who does not otherwise have liability for abandoned or inactive mine sites, and that attempts to improve the conditions at these sites even though all impacts from the site will not be eliminated, from becoming legally responsible, under section 301(a) and section 402 of the Clean Water Act, for any continuing discharges from the mined land after completion of a cleanup project. This potential liability is an overwhelming disincentive to voluntary remedial activities financed or conducted by public entities to address the serious problems associated with abandoned or inactive mined lands.

requirements and liability limits of parties undertaking voluntary cleanup of the sites. Proponents of this legislation estimate that the program outlined in this bill would generate approximately $45 million annually to clean up abandoned mines. At least one other proposal in committee excludes the funds and focuses solely on the Good Samaritan issue.

The Role of Watershed Management

In the 1990s, the DOI and USDA, in conjunction with the EPA, began to focus environmental remediation on the nation's watersheds and the problems caused by abandoned mines on federally administered lands. Investigations into watersheds involve surface and groundwater sampling, adit discharges, surface runoff, mine wastes, and surrounding rock to locate and characterize the contamination. Biological assessments are conducted on local species, engineering cost estimates for reclamation are developed, and searches are performed to identify potentially responsible parties. This interagency effort eventually led to a cooperative agreement between the National Mining Association, Western Governors Association and Department of Energy resulting in the establishment of the Abandoned Mine Land Initiative. The goal of this Initiative is to increase public and private investment in remediation and consolidate financial resources and technological expertise to promote cleanup. By 1999 DOE's Federal Energy Technology Center, now known as the National Energy Technology Laboratory, signed an agreement with the Office of Surface Mining to share technical services, expertise, and information on mining and environmental issues (Greeley, 1999).

11.2 Factors Affecting Demand

The following primary factors influence the market for remediation of mine lands.

- Federal and state agencies that manage mine lands are constrained by budget considerations. The reclamation budgets for the federal agencies are small in comparison to the magnitude of the abandoned mine waste problem. The OSM fund is designated primarily for coal mines, and there is very little left for non-coal mining. In addition, the law mandates that priority be given to addressing safety, health and general welfare rather than environmental problems.

- A growing market for first or second homes in previously sparsely-populated mining areas may foster increased demand for cleanup of some sites. Because mine wastes can travel long distances, contamination from abandoned mines can affect areas many miles downstream from the source.

- Increase of recreational activities on public lands, in the vicinity of many abandoned mine sites, may spark increased demand for cleanup or restrictions on park use.

- The transfer of properties in mining areas where complete control of the source of the pollution has not been achieved may require institutional controls to ensure that prospective purchasers or developers are aware of any potential risks resulting from a mining operation. Thus, there is a growing need for methods to ensure compliance with institutional controls.

- A number of the over 14,000 active and inactive mine sites that are not abandoned also may require remediation. Releases of contaminants into the environment can result from inadequately designed facilities such as tailings dams, accidents, leaks and spills, or failure to properly operate a facility. Thus some portion of these sites are likely to require remediation of soil, groundwater, and/or surface water, among other things.

- The passage of Good Samaritan legislation would probably encourage more state and local governments to undertake some remediation. This point is explained in Section 11.1.5.

11.3 Number of Sites

All mining operations have the potential for releasing hazardous materials to the environment. However because data collection practices vary widely among various sources, it is difficult to establish the number of mines in the U.S. Moreover, not all of these facilities will actually require remediation. Until further investigation, the number of mining sites and the number of these sites that are likely to require remediation can only be estimated.

Active Mines

Information on the numbers and production levels of active mines are available in Department of Interior, Department of Energy, Department of Labor and the National Mining Association data. Exhibit 11-1 summarizes these numbers by type of mining operation for the year 2001. The 1,714 active coal mines operating in 26 states produced a total of 1,121.3 million short tons, 66.2 percent at surface mines and 33.8 percent at underground mines. The fees that these mines pay into the Office of Surface Mining reclamation fund for abandoned mines is based on this tonnage. Almost 92 percent of active non-coal mines are stone and sand/gravel operations. Metal and non-metal mineral mines account for 1,039 sites, or almost 8 percent the mines and processing facilities. Nevertheless, these non-coal mining activities, which operate in all fifty states, are responsible for the production of between 1 and 2 billion tons of mine waste annually. In the nine western states, where most of the hardrock mines are concentrated, the industry is responsible for polluting 3,400 miles of streams and over 440,000 acres of land (U.S. EPA 2000b). Although remediation will probably be needed at active mines, no quantitative estimate is available.

Abandoned Mines

There are an estimated 13,000 abandoned coal mines, mostly small and mid-sized in the east (Stone, 2001). Reclamation work at these sites may be funded in part by the Abandoned Mine Land Fund. However, by law, the bulk of the funding (86 percent in FY 2002) is given to priority 1 and 2 sites, sites with problems that pose a threat to the health, safety and general welfare of people. Only 16 percent in FY 2002 went to funding priority 3, environmental hazards. If a state has completed its 1 and 2 priority sites, funding can be applied to priority 3 sites. According to the 2002 annual report, $13.9 million went to funding watershed projects and another $1.6 million in the form of watershed cooperative agreements for acid mine drainage treatment programs.

Exhibit 11-1. Number of Active Mining Sites - 2001

	Underground Mines	Surface Mines	Total Active Mines	Processing Facilities	Total
Coal	777	937	1,714	418	2,122
Metal	78	124	202	72	274
Non-metal mineral	44	542	586	179	765
Stone	113	3,914	4,027	228	4,255
Sand/Gravel	NA	7,069	7,069	NA	7,069
Total	1,012	12,586	13,416	897	14,485

Source: National Mining Association, (updated 2003), reprinted from the U.S. Department of Labor, Mine Safety & Health Administration, Number of Coal and Non-Fuel Mineral Operations in the United States

Since the definition of abandoned hardrock and non-metal mineral mines is slightly different from state to state and from agency to agency, it is difficult to accurately establish the number of these mines around the U.S. In some states, multiple shafts and openings in one location are considered a single mine. In other cases, each opening, shaft, or disturbance is considered a separate mine. Several organizations have attempted to estimate the number of mines, mostly based on data from individual states, federal agencies, and USGS maps. However, these numbers cannot be added for an estimate of the total number of sites. Because of the built-in uncertainties, most analyses of the scope of the abandoned mine problem are presented in terms of ranges (Exhibit 11-2).

The BLM estimates that 5 percent (5,000-25,000) of the 100,000 - 500,000 abandoned hard rock mines on the public lands which the Bureau administers, has caused or could cause environmental damage, mostly in the form of water pollution (Stone, 2001). The Forest Service estimated that 5 percent of the approximately 25,000 - 35,000 abandoned mine sites on its lands would require cleanup under CERCLA and about 12 percent would require remediation of non-CERCLA water quality problems (Greeley, 1999 and U.S.GAO, 1996). The Mineral Policy Center estimates that approximately 15,000 of the 557,000 sites have surface or groundwater contamination, and an undetermined number have other environmental hazards (Lyon et al, 1993 and 2003). Based on discussions with officials at land management agencies, states, and EPA regional staff, EPA estimates that approximately 5 to 10 percent of abandoned mine lands require site investigation and cleanup.

Given these data, between, 7,700 and 31,000 abandoned mining sites are likely to require cleanup. This wide range in the estimate is due primarily to the fact that most sites have not been evaluated and, therefore, there is a wide range of estimates regarding how many will require remediation.

Exhibit 11-2. Comparison of Estimates of Number of Abandoned Hard Rock Mining Sites

Source	Estimated Number of Sites	Explanations/Comments
Federal Agencies		
Bureau of Land Management (Department of Interior) 1996, 2003	100,000-500,000	On lands managed by BLM; based on targeted surveys conducted by BLM and states, and the Abandoned Mine Land Inventory which is not yet completed.
Forest Service (Department of Agriculture) 1996, 1999	25,000-34,500	On lands within FS boundaries; based on aerial photos, fieldwork, and Dept. of Agriculture data.
National Park Service (Department of Interior) 1996	2,500	Actual count in some states, not including Alaska and part of California
Fish and Wildlife (Department of Interior) 1996	240	Based on department files and field office confirmation
Bureau of Mines (defunct agency) 1996	15,300 on Dept. of Interior lands; 12,500 on Dept. of Agriculture lands	Based on database of past mineral deposit activities
US Geological Survey (Department of Interior) 1996	88,000 on Dept. of Interior lands	Based on data assembled from agencies and Western Governors' Association estimates
Other Organizations		
Mineral Policy Center 1993, 2003	557,700	Based on 32 western states; compiled from state databases and records
Western Governors' Association 1998, 2003	No total estimates given	Estimates for 13 of the 15 states involved, if added would total 263,000; some state numbers based on inventory; range from 150 in North Dakota to 100,000 in Arizona; wide variations in definition of mines.

Sources:

- U.S. GAO, 1996. *Federal Land Management, Information on Efforts to Inventory Abandoned Hard Rock Mines,* GAO-RCED-96-30, February 1996.
- Stone, George, 2001. Bureau of Land Management, *Overview of Mining in the USA* , Abandoned Mines. Problems, Issues and Policy Challenges for Decision Makers, Santiago, Chile (Updated in conversation in May 2003).
- Greeley, Michael N., 1999. US Department of Agriculture - Forest Service, *National Reclamation of Abandoned Lands*.
- Western Governors Association (1998), *Cleaning Up Abandoned Mines: A Western Partnership* (Updated in conversation in May 2003).
- Lyon, James S., Hilliard, Thomas J., and Bethell, Thomas N., 1993, *Burden of Gilt*. Mineral Policy Center, (Updated in 2003 draft report on Cleaning Up Western Watersheds).

11.4 Market Entry Conditions

The great majority of the sites will be cleaned up under state and local programs, or by private parties. Federal agencies, since they are often the land managers, will also be involved. Although their remediation budgets are small, they may participate in negotiations with stakeholders, seek cost recovery, or may participate in cost sharing.

Superfund site contracting may differ depending on whether the cleanup is fund-lead or PRP-lead. For fund-lead sites, the EPA or state site manager will have information on the status of the site, the characterization already done on the site, any treatability studies that might be needed, and contracting plans and options. For PRP-lead sites, the RPM will be able to refer a vendor to the PRPs and their contractors. Large PRP-lead sites are usually handled by national architectural and engineering firms who tend to contract out elements of the cleanup to local operators. Technology vendors might contact these firms directly for targeted opportunities within larger cleanup efforts.

11.5 Estimated Cleanup Costs

No single source provides information on remediation costs for mining sites. Some sources deal with a specific category of sites, while others fold mining remediation costs into an overall estimate for total reclamation. Because most of the latter category of estimates include costs for activities beyond remediation, such as correcting safety hazards and landscaping, the amount of the costs attributable to remediation is unknown.[3]

The Mineral Policy Center does break down cleanup costs by category and provides estimates for surface and groundwater cleanup and for cleanup of Superfund sites. According to the MPC, cleanup of 14,400 surface water contaminated sites would run $1-3 million per site, cleanup of 500 groundwater contaminated sites would run $7.5-12.5 million per site, and Superfund sites would run $250-350 million per site. However, the MPC analysis does not consider other media, its estimates are based on only 32 states, and the per site range of cost estimated for Superfund sites is considerably higher than estimates from other sources both inside and outside of the EPA. A reasonable estimate can be developed by combining the MPC's non-Superfund estimates with per site Superfund cleanup estimates derived from Resources for the Future and EPA records. These estimates are derived from data from EPA's regional offices. Based on these data, the cost of remediating all hardrock mines is estimated to be between $20 and $54 billion. NPL sites account for about $3.5 billion of this amount. These estimates are shown in Exhibit 11-3.

These estimates represents costs necessary to clean up sites according to current regulatory standards and practices. However, if current levels of funding at the federal, state, and local levels continue, these sites are not likely to be cleaned up in 30 years. Total federal, state, and PRP outlays for mining site remediation has been averaging no more than $100-150 million

[3] Nevertheless, these data provide some useful insight. These estimates range from $165 million for the National Park Service, $4.7 billion for the Forest Service, and $4 to $35.3 billion for the Bureau of Mines (GAO, 1996). The Mine Waste Technology Program Annual Report for 2000 contains estimated remediation costs for all abandoned non-coal mine sites in the 15 western states (EPA 2000b). The report estimates that the cost of cleaning up these sites will be between $4 and $45 billion.

annually in recent years. At this rate of expenditures, no more than 8-20 percent of all the cleanup work could be complete in 30 years.

Exhibit 11-3. Estimated Remediation Costs for U.S. Hardrock Mines

Type of Site	Number of Sites	Average Cost Per site ($Millions)	Cost ($Billions)
Surface water contamination[a]	14,400	1 - 3	14.4 - 43.2
Groundwater contamination[a]	500	7.5 - 12.5	2.5 - 7.5
Superfund Mega sites[b]	20	100	2.0
Superfund Non-mega sites[b]	70	22[c]	1.5
Total			20.4 - 54.2

[a] Source: Lyon, James S., Hilliard, Thomas J., and Bethell, Thomas N.,, *Burden of Gilt*. Mineral Policy Center, Washington, D.C., 1993. This estimate may not include costs for soil and debris remediation.
[b] Source: Approximation based on EPA report, supplemented with updated data (EPA 2000a)
[c] Source: Probst, Katherine N., Konisky, David M., Hersh, Robert, Batz, Michael B., and Walker, Katherine D., (2001). *Superfund's Future What Will It Cost?*, Resources for the Future, Washington, D.C.

11.6 Remediation Technologies

There are a number of conventional technologies, both treatment and containment/diversion, that have become standard practice in the mining and mineral processing industries. Treatment technologies which involve changing the composition of the contaminant or limiting its mobility include chemical treatment (i.e. lime to neutralize acid drainage), stabilization (i.e pH adjustment), solidification (i.e. solidifying contaminant using cement), solvent extraction (i.e. leaching), soil washing, and soil flushing. When treatment technologies cannot control the contaminants to an acceptable level, collection, diversion, and containment technologies are used. These include landfill disposal, a variety of cutoff walls (i.e. slurry, cement, sheet piling), pumping groundwater for treatment, capping, diversion and erosion controls.

The prevalent technology today for the single most addressed issue in the remediation of mining waste is physical/chemical treatment of wastewater using settling agents in clarifying tanks to precipitate the heavy metals. This treatment costs between $0.5 to $1.00 per thousand gallons treated. A similar but somewhat less expensive and less successful method involves adding the chemicals to wastewater in a settling pond. A more innovative technology, mostly still in pilot or field scale operation, is the anaerobic bioreactor. This process involves adding biological nutrients to stimulate natural bioorganisms to stabilize heavy metals. Thus far, this technology has not caught on, probably because early models of the technology failed. The estimated costs for this treatment is $0.05 per 1,000 gallons.

11.7 Research and Development

There are two distinct EPA sponsored programs that focus on mining and mine waste. They work jointly on some projects and with other government, academic and private entities on a variety of research programs.

The Mine Waste Technology Program (MWTP) in Butte Montana is funded by EPA and jointly administered by EPA and DOE. MSE Technology Applications, Inc. is the principal contractor for the MWTP, with Montana Tech serving as a subcontractor for many of the projects. The Bureau of Land Management and Forest Service provide sites for demonstrations of technologies. The objective of the program is to develop and prove technologies that provide satisfactory short- and long-term solutions to the remedial problems facing abandoned mines and the ongoing compliance problems associated with active mines. Its activities include testing and evaluation at bench- and pilot-scale and education in training and technology transfer. Priority areas for research include source control technologies such as sulfate-reducing bacteria and transport control/pathway interruption techniques; short-term end-of-pipe treatment options for immediate alleviation of severe environmental problems; and, resource recovery options. http://www.mtech.edu; and http://www.epa.gov/ord/nrmrl/std/mtb/mwtpannual00.pdf

The Rocky Mountain Regional Hazardous Substance Research Center in Denver, with oversight from U.S. EPA Region 8, consists of a consortium made up of Colorado State University, Colorado School of Mines, Montana Tech, and a variety of participants from academe and the private sector from all over the U.S. and Canada. The center focuses on geochemical, biological, hydrological/mineralogical and engineering aspects of environmental problems associated with mining and mine waste. Research is divided into five areas including site characterization and contaminant transport/transformation; surface water and sediment transport; treatment processes; technologies; and, ecological and human health toxicity. http://www.engr.colostate.edu/hsrc/

In addition to the targeted mining programs, EPA sponsors the Superfund Innovative Technology Evaluation (SITE), administered by EPA's ORD National Risk Management Research Laboratory. SITE encourages the development and implementation of innovative treatment technologies for hazardous waste site remediation and monitoring and measuring. Technology is field tested on hazardous waste materials and engineering and cost data are gathered so that potential users can assess the technology's applicability to a particular site. EPA prepares reports evaluating all available information on the technology. SITE works closely with Montana Tech, helping to leverage funding for projects. http://www.epa.gov/ord/site/

U.S. DOE's, National Energy Technology Laboratory conducts in-house and contracted research and development including on technologies that identify and treat sources of water and air contamination at coal sites and watershed mapping. It works jointly with EPA on the Mine Waste Technology Program. http://www.netl.doe.gov

The National Mine Land Reclamation Center (NMLRC), headquartered at West Virginia University, addresses reclamation issues for both abandoned and active coal mine sites. Program participants perform research on acid mine drainage, prime farmland restoration, subsidence control, and groundwater purification. The NMLRC provides technical support to local watershed initiatives. www.nrcce.wvu.edu/nmlrc

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Western Governors' Association, 1998. *Cleaning Up Abandoned Mines: A Western Partnership*. http://www.westgov.org/wga/initiatives/aml/aml.htm

General Web Sites on Mining

Mineral Policy Center at http://www.mineralpolicy.org

National Mining Association at http://www.nma.org

U.S. Department of Energy, Energy Information Administration.http://www.eia.doe.gov

U.S. DOI, Office of Surface Mining Reclamation and Enforcement: information on coal mining and the Abandoned Mine Lands Program including the inventory system, AML grants, the AML fund, and annual reports. http://www.osmre.gov

U.S. DOI, Bureau of Land Management: information on the Abandoned Mine Lands Program in the western states, including project descriptions and the inventory system, http://www.blm.gov/aml

U.S. Department of Labor, Mine Safety and Health Administration at http://www.msha.gov

Chapter 12 Demand for Remediation of Drycleaner Sites

There are approximately 30,000 active commercial drycleaning facilities in the United States (IFI, 2003). It has been estimated that soil and groundwater contaminated with drycleaning solvent are associated with about 75 percent of these facilities (Schmidt, 1999). This does not imply that all of these facilities will require active remediation, but that further investigation is warranted. In addition, there is an undetermined number of inactive, or former drycleaning locations, many of which have not been identified. Because most drycleaning facilities are in urban and suburban areas, drycleaning solvent contamination has impacted many water supply wells and threatens many others. Addressing this problem will require the deployment of site characterization and remediation technologies at many diverse locations.

Drycleaning sites may be addressed under any of the remediation programs, such as Superfund, RCRA, or a state environmental program, depending on the nature and extent of the contamination and other site-specific factors. Because these sites may be managed under different remediation programs, the estimates of the drycleaning site remediation market should not be added to those in the previous chapters of this report. Adding these estimates would be double-counting sites and, therefore, overestimating the scope of the market.

Highlights
- An estimated 15,750 active drycleaners require cleanup at an estimated cost of $6.3 billion.
- In addition to active drycleaners, there may be between 9,000 and 90,000 inactive drycleaner sites (the facilities closed, moved, or otherwise disappeared) that have not been discovered.
- About 90% of active drycleaners use PCE as their primary solvent. Older facilities used petroleum solvents, which are LNAPLs.
- Cleanup costs at drycleaner sites range from $19,000 to $3 million per site and average $402,000, based on expenditure data from 50 sites with completed remediations.
- On average, about 28% of cleanup costs are for site assessment.
- Twelve states have dedicated programs and cleanup funds for drycleaners and several other states participate in industry activities through other environmental programs in their states.
- The cooperative efforts between EPA and states with dedicated drycleanling programs have fostered the sharing of substantial amounts of information about site characterization and cleanup technologies and costs, state cleanup program operating practices, and drycleaning industry trends.

12.1 Industry Description

Drycleaning is the washing of fabrics in non-aqueous solvents. The drycleaning industry provides garment cleaning, pressing, finishing, and related services, primarily to households. Although the sizes of drycleaning facilities vary, most are single-facility, family-owned businesses. This section summarizes the types of drycleaning processes, wastes produced, regulatory programs that affect demand, and industry efforts to address the contamination issues.

12.1.1 Drycleaning Processes

Drycleaning operations generally consist of three processes: precleaning, drycleaning, and finishing. In addition, many drycleaning establishments also do conventional laundering.

Precleaning

Prior to being dry cleaned, heavily stained garments are usually pre-cleaned, or "spotted." Spot cleaning may also be performed after fabrics are drycleaned and stains still remain on the fabric. A wide variety of chemicals may be used in spotting, depending on the type of stain and fabric.

Spotting is generally done on a "spotting board," where spotting agents, steam, and compressed air are used to clean stained fabrics. The board is supplied with steam and compressed air to allow steam or warm air to be applied to fabrics. Wastes are disposed of through a vacuum line and a drain receptacle mounted on the base of the spotting board. The spotting agents are contained in bowls or containers placed on or mounted on the board. The chemicals used depend on the type of stain and fabric being cleaned. There are three general types:

- Agents to clean water-soluble stains, including synthetic detergents; alkaline agents such as lye, ammonia, potassium hydroxide, and sodium hydroxide; and protein formula detergents containing digester enzymes and acid agents, such as acetic acid, hydrofluoric acid, glycolic acid, and sulfuric acid;
- Non-aqueous solvents and alcohols, such as tetrachloroethylene (PCE), trichloroethylene (TCE), trichloroethane (TCA), carbon tetrachloride, methylene chloride, amyl acetate, and petroleum solvents. These solvents tend to be of great concern from an environmental and regulatory standpoint.
- Bleaches, such as sodium perborate, hydrogen peroxide, sodium percarbonate, sodium hypochlorite, sodium bisulfite, sodium hydrosulfite, titanium sulfate, and oxalic acid.

Facts About PCE

- Manufacturers: Dow Chemical (trade name DowPer) Vulcan Chemicals (PerSec), PPG Industries, Ineos Chlor Americas (Perklone).
- Although not normally corrosive, PCE can cause corrosive problems when in the presence of heat and moisture, or other chlorinated compounds, such as trichloroethane (TCA), which has been used in spotting agents.
- To mitigate corrosion, small quantities (0.05-0.2% by volume) of stabilizers, such as nemethylmorpholine, diallylamine, tripropylene, cyclohexene oxide, benzotiriazeole, and betaethoxypropylnitrile are used.
- PCE used in dry cleaning may also be accompanied by other potential pollutants, since some dry cleaners may use reclaimed PCE, which can contain 1-5% impurities (SCRD 2001).Typical impurities include methyl ethyl ketone, mineral spirits, toluene, TCA, other chlorinated solvents, and butylated hydroxytoluene (BHT). Non-reclaimed PCE is generally 99.9% pure. The impurities are other chlorinated hydrocarbons.

Drycleaning Machine Processing

The drycleaning process is physically similar to the home laundry process, except that clothes are washed in a non-aqueous solvent instead of water. Drycleaning is usually done in a drycleaning machine that agitates the fabric in solvent, extracts the solvent by spinning it, and dries it through a combination of aeration, heat, and tumbling. Over the past century and a half, a number of different solvents and machines have been used (See text box on the history of dry cleaning). Today, about 80 percent of the drycleaning machines use PCE as the solvent. Solvent usage has become significantly more efficient over the years, declining from 82 pounds of PCE to 10 pounds to clean 1,000 pounds of clothing (National Clothesline, 2002). Coin operated drycleaning machines, introduced in the 1960s by Whirlpool Corporation, are no longer being manufactured. However, they are still being used, primarily in laundromats.

History of Drycleaning

Nineteenth Century: The drycleaning industry first emerged in Europe in the first half of the nineteenth century. Over the years, a number of different compounds have been used as drycleaning solvents, most of them petroleum-based. The most widely used solvents were petroleum naphtha, benzene, kerosene, and white gasoline. White gasoline was the predominant drycleaning solvent in the United States from the late 1800s until the early 1920s. Because of the high volatility of gasoline, many fires and explosions were associated with drycleaning operations. Drycleaning facilities were unable to obtain insurance and many cities banned drycleaning operations within their city limits.

1920s: During the 1920s, drycleaners began using Stoddard solvent, a less volatile petroleum solvent (flash point of 100 degrees Fahrenheit). From the late 1920s until the 1950s, Stoddard solvent was the predominant drycleaning solvent in the United States. This solvent is a mixture of petroleum distillate fractions (petroleum naphtha) which is composed of over 200 different compounds. These solvents are composed primarily of alkanes and cycloalkanes, with some aromatic compounds. Over the years, the trend has been toward the introduction of higher flash point solvents which have very low aromatics content.

To mitigate biodegradation of petroleum drycleaning solvents, bacteriacides or biocides are added to the system, usually in detergents. The biocides used today are similar to those used in shampoos, laundry products and cosmetics (SCRD, 2001). In the past, perchloroethylene (PCE) was added to drycleaning soaps as a bacterial inhibitor.

1920s-1960s: From the 1920s until the early 1960s, a number of chlorinated solvents were introduced into drycleaning operations.

- Carbon tetrachloride was used in the United States from the 1920s until early 1950s. Because of its high toxicity and tendency to corrode equipment, carbon tetrachloride is no longer used as a drycleaning solvent (SCRD, 2001).

- Trichloroethylene (TCE) was introduced as a drycleaning solvent in 1930. Because it causes bleeding of some acetate dyes, it is no longer used as a primary drycleaning solvent (SCRD, 2001).

- Perchloroetylene was introduced as a drycleaning solvent in 1934. In 1948, PCE surpassed carbon tetrachloride use in drycleaning operations. By the early 1960s, PCE had become the predominant drycleaning solvent in the U.S. (Linn, 2002b).

Today: It is estimated that over 90 percent of the commercial drycleaners in the United States use PCE (IFI, 2003).

Over the years, several other drycleaning solvents have been marketed, but never attained a large market share. For example, in the late 1960s, Dupont began marketing a chlorofluorocarbon as a drycleaning agent (trade name: valclene, also known as fluorocarbon 113). These are no longer being manufactured, largely because of the restrictions on chlorofluorocarbons in the Montreal Protocols. In the early 1980s, Dow Chemical introduced TCA as a solvent. It was used by only a small number of drycleaners, particularly for leather cleaning. This solvent proved to be unstable and to cause equipment corrosion. It is no longer being used as a drycleaning solvent.

Beginning in the 1990s, several new solvents were developed, including TYNEX (dipropylene glycol tertiary-butyl ether), liquid carbon dioxide, GreenEarth™ (a silicone-based solvent called decameethylcyclopentasiloxane), and PureDry (a mixture of petroleum hydrocarbons, hydrofluoroethanes, and perfluorocarbons).

An important influence on the design of drycleaning machines, drycleaning practices, and solvent usage are regulations promulgated under the Clean Air Act (CAA) Amendments of 1990. The primary CAA regulatory standards for controlling airborne emissions of PCE are the National Emission Standards for Hazardous Air Pollutants (NESHAP), which was promulgated in September 1993. These regulations require mandates for retrofitting or replacing certain types of drycleaning equipment that are based on PCE, record keeping, inspections, and reporting. They have encouraged the upgrading or replacement of much equipment in the industry. The newer drycleaning machines use considerably less solvent per pound of clothing than older machines. Detergents are also used in the drycleaning process to aid in the removal of water-soluble soil, to suspend the soil after it has been removed from the fabric, and as a spotting agent to penetrate the fabric, thereby allowing the solvent and water to remove stains. Detergents are added to comprise typically 1-2 percent of the drycleaning solvent. The earliest drycleaning detergents were soaps, usually composed of surfactant, Stoddard Solvent (see box), free fatty acids, and some water to create an emulsion. By the early 1950s, liquid soaps were rapidly being replaced by synthetic detergents.

Finishing

After drycleaning, fabrics are generally pressed with a steam press. The press is supplied with steam lines and serviced by vacuum lines which create a partial vacuum at the bottom of the press to hold fabrics in place. Steam from the pressing operation is vented to the atmosphere and steam condensate is collected in a tank.

In addition to pressing, a drycleaner's service may include the application of one or more garment-treating chemicals, including sizing, waterproofing, flame retardants, stain repellants, and fabric conditioners. Sizing is a finish used to impart body to a fabric. It is usually applied by textile and garment manufacturers, but becomes depleted after several cleanings. Sizing used in drycleaning operations consists of polymers or polymer blends and often uses a petroleum naphtha carrier. Often, anti-static agents and optical brighteners are added to sizing. The sizing can be applied in the drycleaning machine, by dipping fabrics in a tank of sizing, or by spraying in an aerosol form.

Waterproofing agents are usually wax-based products and the predominant carrying agents utilized have been PCE and petroleum solvent. Some of the chemicals used in flame retardants include decabromodiphenyl oxide (DBDPO), organo-phosphates, phosphate salts, and phosphated esters. Stain retardants are generally silicon based and the carrying agents are trichloroethane (TCA) or petroleum naphtha (IFI, 1994). These agents may be applied by several methods, such as immersion in a dip tank, spraying in the form of an aerosol spray, and in an auxiliary tank in the drycleaning machine. Drycleaning solvent may also be used as the carrying agent.

Conventional Laundry Operations

Many drycleaning establishments also have conventional laundries. If clothing is pre-cleaned with solvents prior to laundering, the washwater may contain solvents.

12.1.2 Types of Wastes and Waste Management Practices

The wide variety of chemicals and processes at drycleaning facilities results in a variety of wastes. Most of the wastes, especially those from chlorinated solvent drycleaning operations, are hazardous (Linn, 2002a). Releases of these wastes to the environment have caused soil and groundwater contamination at drycleaning sites. Prior to the enactment of the RCRA in 1980, almost none of the waste generated at drycleaning facilities was regulated. The primary wastes that contain hazardous materials include the following:

Contact Water. Contact water is any water that has come into contact with drycleaning solvents, solvent vapors or other hazardous materials. The primary sources of contact water are:

- Separator water. Separator water is generated during solvent recovery processes such as distillation. Distillation is used to capture solvent vapors and purify spent solvent. The distillation unit is usually incorporated into the modern drycleaning machines, although it is a separate piece of equipment in some older machines.
- Vacuum Water. Vacuum water results from the steam and condensate from steam pressing. This water generally contains drycleaning solvent. Vacuum water samples collected from PCE drycleaning operations generally contain PCE in concentrations in the tens of parts per billion range, although some samples have exceeded 100 parts per billion (Linn p. 2002b).
- Mop water. It is common to have spills and leaks within a drycleaning facility. When the floors are mopped, the solvent and other residues will saturate the mop water.
- Boiler Blowdown Water. This is water from water and steam used to clean the boilers daily. Because some drycleaners have disposed of separator water to the boiler, solvent residues can remain in the boiler.
- Conventional Laundry Water. As previously mentioned, the washwater may contain residues from pre-cleaning chemicals.

Historically, sanitary sewers and septic tanks have been the most common discharge points for contact water. Over 70.7 percent of 909 respondents to a 1988 survey conducted by the International Fabricare Institute indicated that separator water was being discharged either to a sanitary sewer or septic tank (Linn, 2002a). A study of drycleaning contamination in California in the early 1990s concluded that "the main discharge point for drycleaners is the sewer line" (Izzo, 1992). Studies in California have found evidence of free-phase PCE in sewer lines serving drycleaner facilities. Since sewers, especially older ones, have been known to leak, this could be a conduit for discharge of PCE and other chemicals to the environment.

Other disposal practices for contact water have included discharge to the ground, storm sewers, soakage pits, blind drains, cooling towers, and boilers at the drycleaning plant. Separator water has also been known to be used to mop floors (Linn 2002a). Contact water can also be filtered, followed by evaporation or misting to the atmosphere; or removed by a hazardous waste management firm. Filtering materials are usually granular activated carbon or polymers, which, after use, are considered hazardous waste.

Still Bottoms. Still bottoms and cooked powder residues are generated from the distillation process. They contain grease, oil, detergent, dyes, sizing, waxes, filter materials, and non-volatile residues. Distillation residues can contain up to 75 percent solvent by weight and are hazardous waste managed under RCRA. Prior to the mid-1980s, most of these wastes were either disposed of in landfills or discharged to the ground (Linn 2002b).

Muck. Muck is the filter waste generated by the purification and recovery of spent solvents by filtration using a powder filtering material. Muck, which can contain considerable solvent, is usually produced at petroleum-solvent drycleaning operations. Prior to the mid-1980s, most of these wastes were either disposed of in landfills or discharged to the ground.

Spent Filters. Spent cartridge filters can contain up to a gallon of solvent. Spent filters can be allowed to drain in a drycleaning machine overnight prior to being changed. Because this practice is not always followed, spent solvent is often spilled during filter changes. In the past, spent cartridge filters were stored in cardboard boxes or on the ground outside the facility prior to being discarded in the trash. Solvent tends to drain from these discarded filters if they have not been drained prior to disposal.

Spent Solvent. Spent solvents are those used as carriers for finishing agents (e.g., PCE) and petroleum solvents that have biodegraded. At drycleaning operations that use PCE as a carrier for waterproofing or other agents, oils, fats, and other non-volatile residues from the fabrics would accumulate in the dip tank and periodically the spent waterproofing agent, which contains solvent, would have to be discarded.

Spent Vapors. A considerable amount of solvent is lost to the atmosphere in the form of vapors from the drycleaning machine.

Spotting Residues. These wastes are generated from the leaks, splashes, and spills during spotting operations, and can contain a wide variety of solvents, bleaches, detergents, and other agents. These wastes have been discharged to floor drains, which usually go to a sanitary sewer, septic tanks, or into the ground.

Lint. Lint is generated at various points in drycleaning operations, such as from the button trap or pump strainer. Historically, the lint, which contains drycleaning solvent, has been disposed of with trash or discharged to the ground on the property.

12.1.3 State and Industry Drycleaner Site Cleanup Programs

Like other generally small sites, drycleaner sites may be remediated under one or more state or federal cleanup programs, such as RCRA Corrective Action, Superfund, and state mandatory or voluntary cleanup programs. A number of states have established programs dedicated to drycleaner sites and some of these programs include funds earmarked for the investigation and cleanup of these sites. Twelve states have legislation specific to the investigation and remediation of drycleaner sites (Alabama, Florida, Illinois, Kansas, Minnesota, Missouri, North Carolina, Oregon, South Carolina, Tennessee, Texas, and Wisconsin).

The 12 states with dedicated drycleaner programs comprise the State Coalition for Remediation of Drycleaners (SCRD), formed in 1998 to provide a forum, share information, and encourage the use of innovative technologies in drycleaner site remediation. Also active in the Coalition are California and New York, which do not have formal drycleaner programs, but are active in drycleaner remediation under other authorities. One-third of the nation's drycleaners are located in states that are participating in SCRD. SCRD, which operates with support from the U.S. EPA's Office of Superfund Remediation and Technology Innovation and the National Ground Water Association, provides a valuable forum for states to share programmatic, technical and environmental information to improve the characterization and remediation of drycleaner sites (http://www.drycleancoalition.org/). Much of the information in this chapter is derived from their research, analysis and forums.

Although the practices and procedures of each state program differ, they all share the same basic premise: drycleaners and, in some states, solvent suppliers pay fees in exchange for financial relief and/or liability protection, to clean up contaminated sites. The level of financial relief, type and amount of fees, and who conducts the site investigations and cleanups differ from one state to another. Some states, such as Florida and Kansas, hire and direct the activities of an environmental contractor that investigates and remediates drycleaner sites. Most states develop some sort of scoring system to prioritize sites. In other states, such as Wisconsin, the program is a reimbursement or insurance program in which the drycleaner is responsible for investigating and remediating the site. Usually, there is some cap on the amount of reimbursement per site and, sometimes, a deductible.

Some states require drycleaner facilities to register with the state, while others require licenses. Each state program also includes requirements for pollution prevention measures. Most states also charge drycleaner facilities annual fees, usually based on gross receipts from drycleaner services, and solvents fees per gallon of solvent used. The solvent fee has also provided an incentive for drycleaners to use solvents as efficiently as possible.

Drycleaner sites in other states or sites that are not eligible for these state drycleaner programs are investigated and remediated under other state authorities, such as state superfund, RCRA, brownfield, or voluntary cleanup programs. These programs are described in other chapters of this report.

12.2 Factors Affecting Demand for Remediation

- The declining use of PCE by drycleaners will mean fewer discharges to the environment in the future. The decline is the result of several developments: First, newer drycleaning machines require substantially less PCE per pound of fabric cleaned than older machines. Second, a number of new drycleaning solvents have become available in the last decade (Section 12.1.1). Third, there are movements in a number of communities around the country to ban the use of PCE in drycleaning. For example, California's South Coast Air Quality Management District has voted to phase out PCE by 2020. A bill has been introduced in the California Legislature to increase fees on PCE and provide grants for drycleaners to switch to non-PCE cleaning processes. In February, 2003, Environment Canada published new regulations for PCE drycleaners that, among other things, requires that new cleaning machines have a "manufacturer's design rating" of PCE consumption equal to less than 10 kilograms, or 6.2 liters, per 1,000 kilograms of clothing cleaned. This is equivalent to 1,350 pounds of clothing per gallon of solvent.

The use of solvents has been decreasing primarily by the industry's switching to new more efficient machines that use significantly less solvent. Perchloroethylene use by drycleaners dropped from 268 million pounds in 1985 to 47 million pounds in 2002 (National Clothesline, 2003). These data are based on a survey conducted by the Textile Care Allied Trades Association. Most of this decrease is due to conversion to newer drycleaning machines, although a smaller portion of the change may be due to the use of alternative solvents.

- For the 12 states with drycleaner remediation funds, the money available to the fund will influence the pace of site investigation and remediation work.

- For other states, general availability of state cleanup funds, as discussed in Chapter 9 (State Sites), will be the deciding factor for many cleanups. Drycleaners have average revenues of about $250,000; remediation costs can run hundreds of thousands of dollars; and several have cost over a million dollars. Even a moderate-cost cleanup can amount to several years of profit for the average drycleaner.

- In addition to active drycleaner facilities, many inactive facilities may have had releases of hazardous substances to the environment that have resulted in contaminated soil and groundwater that have not been discovered. Although data on these facilities are sparse, estimates range from 9,000 to 90,000 sites (See Section 12.3.2).

- The level of assessment and cleanup is directly related to the cleanup standards adopted by the individual states. Many states have adopted risk-based cleanup standards for soil and groundwater.

12.3 Number and Characteristics of Sites

12.3.1 Active Drycleaning Facilities

The drycleaning industry includes three types of operations: commercial, industrial, and coin-operated. The commercial facilities are by far the most prevalent and include full-service, retail operations located in shopping centers, urban neighborhoods, and other densely populated areas. Commercial facilities typically clean small quantities of garments from individuals and only a small minority clean furs or leathers. Exhibit 12-1 indicates the scale of the various types of operations. Commercial laundries tend to be located in urban areas because of the greater demand for drycleaning in these areas.

According to the International Fabricare Institute, there are about 30,000 active drycleaning facilities in the U.S. Almost all of these are commercial facilities, which are primarily small, neighborhood businesses whose primary customers are individuals. Based on data for a "model" drycleaning plant in a 1998 EPA study, it is assumed that the average commercial drycleaner facility cleans 26 tons of fabric, and produces 660 gallons of hazardous waste annually, mostly

PCE and PCE-containing materials from distillation residues and from filters (EPA 1998). Based on information from a hazardous waste treater, EPA estimated that this waste is, on average, 40 percent PCE.[1]

Exhibit 12-1. Number and Types of Active Drycleaners in the United States

	No. of Facilities	Average Tons Per Facility/year	Hazardous Waste Average Gal./Year	Hazardous Waste Total Gal./Year
Commercial	30,000 [a]	26 [b]	660 [b]	19,800,000 [c]
Industrial	325 [d]	578 [d]	14,672 [e]	4,768,000 [c]
Coin-Operated	100 [d]	1.6 [d]	40 [d]	4,000 [c]
Total				24,572,000

Notes:
[a] International Fabricare Institute, web site, 2003, http://www.IFI.org
[b] EPA, 1998
[c] Product of Column 2 and column 4
[d] EPA, 1995
[e] Based on gallons per output for commercial facilities

Industrial drycleaners, which tend to be larger than commercial facilities, clean uniforms, restaurant linens, wiping towels, floor mats, work gloves and other items for institutional, professional, and industrial customers. In many cases, industrial drycleaning firms also rent uniforms and other industrial clothing. Based on a 1995 EPA report, these facilities are assumed to average 578 tons of clothing annually (U.S. EPA1995). Assuming the same ratios of waste to output as for commercial cleaners, industrial cleaners average 14,672 gallons of hazardous waste annually. Industrial drycleaning is included within the Census category Industrial Laundry Services. About one-quarter of these establishments include drycleaning. The remainder are exclusively wet laundries.

Coin-operated drycleaners use machines that are self-service or are run by an attendant in self-service laundromats. Coin operated machines, which were introduced in the 1960s by Whirlpool Corporation, are no longer being manufactured. In 1993, EPA estimated that there were 3,000 coin-operated drycleaners (U.S. EPA 1993), although a 1995 EPA report speculated that there are fewer than 100 in operation (U.S. EPA 1995). For this report, it is assumed that there are 100. Based on the same ratios used for commercial cleaners above, the average coin-operated facility would average 40 gallons of hazardous waste annually.

[1] There are a number of uncertainties associated with these averages. Discharges vary widely from one drycleaning facility to another, because of differing processing technology, equipment, and operating practices. Thus, releases from a specific facility in the real world may not compare with these averages. Moreover, equipment and practices at many facilities have changed since the data upon which these estimates are based were collected (early 1990s). Nevertheless, these averages reflect the approximate discharges to be expected.

Another potential source of groundwater, surface water, and soil contamination is contact wastewater discharges. Most drycleaning contact water is discharged to sewer systems or directly to the ground. Because many sewer systems are known to leak, PCE can contaminate groundwater downstream from drycleaning facilities.

A 1999 study by SCRD estimates that about 75 percent of active commercial drycleaners have some level of contamination. Although not all of these sites will require remediation, they will probably require site investigation. Assuming that 70 percent of these will ultimately require remediation, there are about 15,750 active sites that will need remediation.[2] *This estimate does not include inactive sites.*

12.3.2 Inactive Drycleaning Facilities

In addition to releases of hazardous materials by active drycleaning facilities, there are a substantial number of sites that were formerly occupied by drycleaners that have moved or gone out of business. Some drycleaners have moved within the same shopping center or city block, thereby confounding site investigations. Another factor that may complicate site investigations and remediations is the fact that many drycleaners have changed the cleaning processes over the years, including changes in the solvents, other chemicals, and equipment, especially drycleaning machines.

> In addition to about 30,000 active drycleaners, there may be between 9,000 and 90,000 inactive drycleaner sites that have not been discovered.

One indication of the number of inactive sites can be discerned by observing trends in the number of drycleaner facilities. According to the Economic Census, the number of drycleaner facilities has fluctuated over time, from a peak of 30,525 in 1967 to a low of 21,257 in 1987, before growing to 27,939 in 1997.[3] This implies that at least 9,268 sites have closed over time (30,525 - 21,257). Since it is unlikely that newer establishments opened in the same location as the old ones, these figures imply that there are *at least* 9,000 inactive facilities. There are probably more than 9,000 facilities because the Census data do not indicate how many have moved or been replaced by another nearby dry cleaner. There are no data regarding how many of these may have been remediated over the years. Compounding these uncertainties is the fact that Census does not account for the fact that a drycleaning facility may move within the same shopping center or block, a fact that can easily elude site investigation efforts. Moreover, Census did not collect information on drycleaners prior to the 1960s and many drycleaners probably moved or closed before that time. Thus, there are at least, and probably many more than, 9,000 inactive sites that have not been explicitly identified. Some estimates, which are based on field experience with drycleaner sites, indicate that there could be 3 to 5 times as many inactive sites

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2 The 70% estimate is based on conversations with four states with active drycleaner programs (Florida, Kansas, Oregon, and Wisconsin).

3 This figure differs from the other estimate used in this report for currently active facilities (30,000) because of differences in survey methodology and industry definitions.

as active sites.[4] Older dry cleaners consumed, and released to the environment, substantially more solvent per pound of clothing processed than newer ones. The older dry cleaners tended to use more petroleum solvent and less PCE.

12.4 Market Entry Considerations

- The operating practices of drycleaner site cleanup programs vary from state to state. Some states have a fund dedicated to drycleaner site investigations and cleanups. These programs often have considerable information about potential drycleaner site projects and technology needs.

- Some states engage one or more contractors to address all sites under their drycleaner sites program. In other states, the property owner or operator is responsible for conducting the cleanup.

- Most states, including states that do not have formal drycleaner remediation programs, have drycleaner trade associations, which are a potential source of contacts and information on potential cleanups needed. Most of these are available through links available on the SCRD web site. http://www.drycleancoalition.org/links.cfm#industry

12.5 Estimated Cleanup Costs

To estimate the value of the drycleaner remediation market, EPA estimated the average remediation cost actually incurred from a sample of sites and multiplied this average by the estimated number of drycleaner sites likely to require remediation (15,750 sites estimated in Section 12.3). Only active sites were considered, since data on inactive sites are sparse.

EPA analyzed data on 50 drycleaner sites that reported total site cost data, as well as other site information to the SCRD. Total cost data includes site assessment, remediation, and O&M. While this sample was not scientifically designed, it is drawn from a number of different states and represents a wide variety of site conditions, and site assessment and remediation technologies. The costs vary from $19,000 to over $3 million, and average $402,400 per site (Exhibit 12-2).

Based on this average, the total value of the U.S. drycleaner remediation market would be $6.3 billion. This estimate does not include the potentially thousands of inactive drycleaner sites–properties that are either vacant or are being used for other purposes.

12.6 Remediation Technologies

Drycleaner sites have unique characteristics that need to be considered in site characterization and remediation work. A drycleaning facility may have used a chlorinated solvent, such as PCE, petroleum hydrocarbons, or a combination of chemicals. Sometimes the current owner may not

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4 Based on personal communications with four members of SCRD (Florida, Kansas, Oregon, and Wisconsin).

know what solvents were used in the past at the site, especially if it is an old facility. PCE, TCE, carbon tetrachloride, TCA, and Freon113 are DNAPLs and petroleum hydrocarbons are LNAPLs. A knowledge of the history of drycleaning processes may help identify what to look for. For example, earlier petroleum hydrocarbon solvents contained aromatic compounds. Over the years, the proportion of these compounds have been reduced, and the later petroleum drycleaning solvents contain little or no aromatic compounds (SCRD, 2001).

Exhibit 12-2. Estimated Drycleaner Site Remediation Costs

Average of 50 sites	$402,400	50 sites reporting
Range	$19,000 - 3.3 million	50 sites reporting
Percent Site Assessment Cost	28.2%	38 sites reporting
Percent O&M Cost	16.8%	38 sites reporting
Estimated National Total (active drycleaners requiring cleanup) [a]	$6.3 billion	15,750 sites estimated [a]
Range Detail		
Total Cleanup Cost	**Number of Sites**	**Percent**
$5,000 - 100,000	11 sites	22%
$100,000 - 250,000	17 sites	34%
$250,000 - 500,000	16 sites	32%
$500,000 - 1 million	3 sites	6%
Over $1 million	3 sites	6%

[a] Estimate from Section 12.3. No estimate is provided for inactive sites, as described in the text, though there may be thousands of them.
Source: Analysis of site profile data from State Coalition for Remediation of Drycleaners (SCRD, 2003)

Site investigators often use information on the location of the discharge point of contaminants to facilitate identification of the contaminant source areas. However, for inactive sites where the building has been razed or is being used for a different purpose, it may be impossible to locate these discharge points. Sampling and analysis for the above types of contaminants often must be conducted in and around active businesses, usually retail. To accommodate these businesses, the work may be scheduled after business hours or on weekends. Work space is often limited and samples must be collected from beneath building floor slabs.

In addition, a site investigation or remediation may need to address contaminated groundwater that has migrated off site. A study of site assessments conducted at 150 contaminated drycleaner sites in Florida found that contaminated groundwater had migrated off the property at about 57 percent of the sites (Linn 2002b). In an urban or suburban area, this could require obtaining site access to public areas, such as roads and parks, as well as other commercial or residential properties.

12.6.1 Site Assessment Technologies

In 1999, the SCRD conducted a survey of all states to determine what site investigation and remediation technologies were used at drycleaner sites (Jurgens, 1999). The 28 states that responded reported that they have employed 18 site assessment technologies (Exhibit 12-3). These include five media sampling techniques, such as gas surveys and direct push; five geophysical techniques, such as ground penetrating radar, soil conductivity analysis, and induced laser fluoroscopy, to assist in interpreting subsurface conditions; five sample analysis approaches, such as fixed laboratories, mobile laboratories, and portable gas chromatography, to determine the relative or actual concentrations of contaminants in the sampled media; and three techniques for the analysis of DNAPLs.

Exhibit 12-3. Site Assessment Technologies Used at Drycleaner Sites

Technology	Percent of States
Sampling Tools	
Monitoring Well/boring	91
Direct Push	87
Active Soil Gas	78
Passive Soil Gas	39
Microwells	26
Geophysical Techniques	
Soil Conductivity Surveys	39
Ground Penetrating Radar	30
Magnetometer	30
Induced Laser Fluoroscopy	17
Electrical Resistivity Survey	13
Analytical Techniques	
Fixed Laboratory	91
Mobile Laboratory	61
Portable Gas Chromatography	48
Immunoassay	30
Colorimetric Tube	17
DNAPL Detection	
Ultraviolet Fluorescence	17
Hydrophobic Dye	17
Partition Interwell Tracer Set	4

Source: Jurgens, Bob, et. al. *Study of Assessment and Remediation Technologies for Drycleaner Sites,* State Coalition for Remediation of Drycleaners, with support from the Technology Innovation Office, U.S. Environmental Protection Agency, 1999.

In addition, the respondents identified several other techniques that could be used. These techniques include fracture trace analysis, an inexpensive method of identifying fracture zones with aerial photographs and knowledge of area geology; sonic drilling, an expensive method of drilling that can penetrate consolidated and unconsolidated formations; and video cameras to inspect the inside of sewer lines to help identify joints, cracks, or holes in the lines that may allow the release of solvent-contaminated waste water. Cameras are also used in boreholes to identify fractures and dissolution zones (Jurgens, 1999).

12.6.2 Remediation Technologies

The SCRD survey also identified 18 remediation technologies that had been employed in the states (Exhibit 12-4). These include three soil remediation techniques, five general groundwater remediation techniques, six groundwater techniques that use bioremediation or chemical oxidation, and four groundwater techniques that use in-situ flushing or thermal treatment.

Exhibit 12-4. Site Remediation Technologies Used at Drycleaner Sites

Technology	Percent of States
Soil Remediation	
Excavation	86
Soil Vapor Extraction	86
Bioventing	29
Groundwater Remediation: General	
Natural Attenuation	71
Air Sparging	67
Multi-Phase Extraction	33
Permeable Wall	14
Recirculating Well	14
Groundwater Remediation: Bioremediation & Chemical Oxidation	
Hydrogen Release Compound (HRC)	29
Hydrogen Peroxide	24
Potassium Permanganate	19
Organic Release Compounds (ORC)	10
Recirculating Well	10
Potassium Permanganate	5
Groundwater Remediation: In-Situ Flushing & Treatment	
Surfactant Flush	14
Co-Solvent Flush	5
Steam Injection	5
Electrical Heating	5

Source: Jurgens, Bob, et. al. *Study of Assessment and Remediation Technologies for Drycleaner Sites,* State Coalition for Remediation of Drycleaners, with support from the Technology Innovation Office, U.S. Environmental Protection Agency, 1999.

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Chapter 13
Demand for Site Characterization Services

Site characterization is usually the first step in the remediation of soil and groundwater pollution and continues throughout all aspects of the cleanup process. Site characteristics data are crucial to locating the sources of contamination, predicting where chemicals may migrate, developing risk assessments and remediation strategies, influencing community reactions, evaluating reuse options, monitoring progress of remediation efforts, and conducting long-term monitoring. Although site characterization is usually a small part of total remediation costs, it lays the foundation for the entire project and can substantially affect the total project effectiveness, cost, and schedule.

This chapter examines the market for sampling and analysis technologies used to investigate the nature and extent of contamination at hazardous waste sites in the U.S. and its implications for the continued demand for newer, streamlined technologies. Sampling and analysis is an integral component of all site investigations and remediations, whether the work is conducted under Superfund, RCRA, or another cleanup program. Thus, the market estimates in this chapter should not be added to those in the previous chapters of this report. Adding these estimates would be double-counting sites and, therefore, overestimating the scope of the market.

In recent years, the use of more timely and more accurate site characterization approaches has been growing. Many analyses that previously were conducted in laboratories can now be done in the field. Better methods can reduce the time and cost needed to evaluate sites and result in more efficient remediation designs. These new technologies can be applied in conjunction with systematic planning and dynamic work plans that are used to manage the site from initial site assessment through remediation and closeout. The integration of these three strategies is referred to as the Triad approach to hazardous waste site cleanups. The use of the Triad approach has significantly reduced the overall cleanup costs and time at many sites.

13.1 Market Description

Site characterization is the process of identifying, quantifying and describing the nature, extent, and fate and transport of hazardous substances released into the environment to detect their impacts on human health and the environment. The information developed in site characterization studies have a profound influence on all future activities at a site. For example, underestimation of the nature and extent of the contamination, or inaccurate description of geological conditions, may lead to response actions that are inadequate to protect human health and the environment. If additional contamination is discovered during remedial action, costly construction delays and redesign of the remedy may be necessary. Conversely, if the nature and extent of contamination is overestimated, the remedy may be over-designed, causing greater remediation expenditures than necessary to protect human health and the environment. A more effective site characterization, even if greater sampling and analysis costs are incurred, can lead to lower total cleanup costs.

Site characterization information affects all stages of site management, from site discovery to close out. Specifically, site characterization is an important component in the following five steps of the site management process.

Phase One Site Assessment. The purpose of a Phase One site assessment is to determine the likelihood of environmental contamination at a property. This type of assessment is often done when a site is reported to a regulatory authority or in conjunction with the development, purchase, lease, sale, or other means of transfer of a property. Property purchasers and lenders hire environmental firms to conduct these assessments as part of their due diligence responsibility. A Phase One assessment is not expected to provide a detailed description of the contamination; its function is to indicate whether further study is warranted. Environmental samples are rarely collected at this point. This phase is approximately, but not precisely, equivalent to the 1994 American Society of Testing Materials (ASTM) industry standard E-1527 for Phase I environmental site assessments.

The structure and role of the ASTM standard may change as a result of new requirements under the Small Business Liability Relief and Revitalization Act (the "Brownfields Law") of 2002. Among other things, the law revises some of the provisions of CERCLA Section 101(35) clarifying requirements necessary to establish the innocent landowner defense under CERCLA and provides Superfund liability limitations for bona fide prospective purchasers and contiguous property owners. Among the requirements added to CERCLA is the requirement that such parties undertake "all appropriate inquiry" into prior ownership and use of a property at the time at which a party acquires the property. EPA plans to promulgate federal standards for "all appropriate inquiry." These standards may replace the ASTM standards in many, if not most, real estate industry practices.

The Phase One site assessment is similar to, but not precisely equivalent to, the Preliminary Assessment (PA) which is performed on every site listed in the CERCLA Information System (CERCLIS), and the RCRA Facility Assessment (RFA). The RFA is conducted for hazardous waste treatment, storage, and disposal facilities and other locations that may be subject to corrective action under the RCRA Corrective Action program. PAs are generally conducted by a state, or federal agency to distinguish, based on limited data, between sites that clearly pose little or no threat to human health or the environment and sites that may pose a threat and require further investigation. The PA also identifies sites requiring assessment for possible emergency response actions. If the PA results in a recommendation for further investigation, a Site Inspection is performed.

RFA's are conducted or directed by a state or federal regulatory agency to identify solid waste management units (SWMUs) that are, or are suspected to be, the source of a release to the environment. This information is used to determine whether a RCRA Facility Investigation (RFI), interim measures, or other corrective measures are needed.

Phase One assessments generally include the following components:

- Review of fundamental information about the site, such as that available from aerial photography, public information, and other sources;
- A review of historical documents and records search to determine whether there is any publicly available information on actual or potential contamination on or related to the property;
- A physical tour of the property to record visual, olfactory, and tactile observations. The tour may include interviews with on-site personnel who may have knowledge of past and present environmental practices; and
- A written report documenting the process and results of the Phase One assessment.

In addition to serving as a screening mechanism, the information collected during Phase One can be used to develop a preliminary conceptual site model (CSM), which is generally refined as work at the site continues. A CSM is a planning tool that organizes what is already known about the site and helps the site management team identify additional information needed to make the decisions that will achieve the project's goals.

Phase Two Site Assessment. The Phase Two site assessment includes further investigation of possible contamination discovered during phase one to confirm the presence of contamination. It may include on-site environmental testing and laboratory analysis. The investigation may require extensive sampling and analysis in several stages to obtain the required information. The ASTM standard appears in *E 1903, Standard Guide for Environmental Site Assessments: Phase II Environmental Site Assessment Process*. The Phase Two site assessment is similar to, but not precisely equivalent to, the Site Inspection (SI) which is often, but not always, performed on sites listed in CERCLIS; the sampling portion of the RFA, which is conducted for hazardous waste treatment, storage, and disposal facilities and other locations that may be subject to corrective action under the RCRA Corrective Action program; and tier evaluations of a risk-based corrective action (RBCA) at UST sites.

SIs are generally conducted by a state or federal agency to provide or augment the data needed for Hazard Ranking System (HRS) scoring and documentation. The HRS score is an important input to the decision of whether to list a site on the NPL. If a site receives an HRS score greater than 28.5, it is eligible for listing on the NPL. SI investigators may collect samples of soil, water, free product, and other media to determine if hazardous substances are present, and if there is human exposure or contamination of sensitive environments. The EPA publication *Guidance for Performing Site Inspections Under CERCLA; Interim Final*, September 1992, (NTIS PB92-963375, EPA 9345.1-05) provides more information on conducting SIs. This publication may be found at: http://www.epa.gov/superfund/whatissf/sfproces/pasi.htm

Phase Two assessments generally include one or more of the following components:

- Soil sampling to determine if a release has impacted site soil;
- Groundwater sampling to determine if a release has impacted groundwater;
- Drums and waste materials testing;
- Asbestos testing;

- Indoor air quality testing;
- Underground tank testing to determine whether tanks and associated piping have leaked or are likely to leak, and whether the tanks meet federal and state requirements; and
- A written report documenting the process, quality assurance procedures, and results of the Phase Two assessment.

Phase Three Site Assessment. A Phase Three site assessment is generally required if the results of Phase Two reveal the presence of contamination. The purpose of the Phase Three analysis is to quantify and characterize the full extent of the contamination, determine the risk, and select an appropriate remedy. The Phase Three site assessment is approximately, but not precisely, equivalent to the Remedial Investigation/Feasibility Study (RI/FS) which is performed on Superfund sites and the RFI/Corrective Measures Study (CMS) which is conducted for facilities that may be subject to corrective action under the RCRA Corrective Action program.

RI/FSs are generally conducted by potentially responsible parties, states, or EPA after a site is listed on the NPL. RFIs/CMS are generally conducted by the facility owners or operators, with oversight by a state or federal regulatory agency. For state voluntary cleanup program or underground storage tank sites the Phase Three assessment is generally conducted by the facility owners, with state oversight.

The RI and FS are generally done interactively. The RI serves as the mechanism for collecting data to characterize site conditions and further refine the conceptual site model; determine the nature of the waste; assess risk to human health and the environment; and provide data necessary for treatability studies. The FS is the mechanism for the development, screening, and detailed evaluation of alternative remedial actions. Data collected in the RI influence the development of remedial alternatives in the FS, which in turn affect the data needs and scope of treatability studies and additional field investigations. Treatability testing is conducted under the FS to evaluate the potential performance and cost of the treatment technologies being considered. This interactive approach encourages the continual scoping of the site characterization effort, which minimizes the collection of unnecessary data and maximizes data usability.

Generally, the more thorough and accurate the conceptual site model developed during the RI or RFI, the more cost effective the cleanup will be. The greater the uncertainty in the CSM, the greater the likelihood that problems will arise during the implementation of the remedy. For example, if the sampling plan during the RI caused investigators to overlook contaminated material, the contamination might be discovered during construction of the remedy. The contractor would then have to conduct additional sampling and analysis, revise cleanup plans and, perhaps, select different treatment technologies. These activities would cause delays and drive up cleanup costs.

It is generally impossible to completely collect and document information about all aspects of a site with 100 percent certainty because an RI or RFI can be expensive and time-consuming. Site investigators must address both sampling uncertainty and analytic uncertainty. Sampling uncertainty refers to the ability of the sample to represent the true site conditions, and generally is directly related to the density of sampling points and number of samples taken. Analytic uncertainty refers to the ability of the sample analysis techniques to accurately describe the constituents in the sample. Typically, site investigators and managers use their best judgement to determine how much effort to put into characterization on a case-by-case basis. There is a tradeoff between the level of effort invested in characterization and the probability of missing contaminants that may cause unforseen problems during remediation or uncorrected health risks.

Remedial Design and Construction. Although it may not be explicitly regarded as site characterization, sampling and analysis is necessary during remedy design and construction or other corrective measures at most sites. Sampling is used to confirm that various aspects of the remediation were successful and, sometimes, to revise the original site characterization plans based on site conditions that were not anticipated prior to construction. Site characterization during remedial design and construction would generally use sampling and analysis technologies that are similar to those used during the Phase Three site investigations.

Operations and Maintenance (O&M). The use of site characterization technologies also may occur during the O&M phase of the site. O&M measures related to waste containment and control are initiated after the remedy has been constructed in accordance with the ROD or other site agreements and is determined to be operational and functional based on state and federal agreement. For Superfund-lead sites, remedies are considered operational and functional either one year after construction is complete or when the remedy is functioning properly and performing as designed, whichever is earlier.

Typical remedy components requiring long-term O&M measures include landfill covers and liners; gas extraction, treatment, and monitoring systems; water collection, treatment, and monitoring systems; and permeable reactive barriers. The remedy and reuse plans must allow for access necessary for sampling, inspection, and repair of these components. O&M monitoring may include five types of activities: inspection, sampling and analysis, routine maintenance and small repairs, reporting, and five-year reviews. The five-year reviews are primarily a requirement for some Superfund sites. The most likely demands for site characterization technologies include periodic topographic surveys to measure the rate of movement or settlement, the collection and chemical analysis of gas, air, and water samples from wells, probes and other collection means.

13.2 Site Characterization Tools

Site characterization technologies can be grouped into those related to accessing, collecting, and analyzing samples and environmental data and geophysical tools that can sometimes be used to directly locate contamination such as a leachate plume or buried drums but are more often used to refine the CSM with regards to site stratigraphy. These technologies are supported by computer software and other decision support tools that facilitate efficient and effective data management, interpretation, and decision making as data are collected and analyzed. In addition, it is important to consider how the deployment of each technology is integrated into a characterization program, and ultimately into the general site management process. A number of newer characterization technologies have made possible more efficient and flexible site management processes. Conversely, site managers are using scientifically designed, systematic approaches to planning and conducting site investigations and cleanups which optimize the effectiveness of the technologies. A systematic approach to site characterization can ensure that data collected are appropriate, reduce the time and cost it takes to initiate cleanup, and reduce overall remediation costs.

The large number of characterization techniques makes it impossible to describe them all in this report. Exhibit 13-1 lists the major groups of tools. The publications *Field Sampling and Analysis Technologies Matrix* (FRTR 1998, http://www.frtr.gov/site) and Field Analytical Technologies Encyclopedia (EPA 2003) provide more detailed descriptions of the categories, the commonly used and proven techniques, conditions under which they tend to be used, and other useful information. The following four subsections provide an overview of these technologies.

Exhibit 13-1: Major Characterization Technology Subcategories

Sample Access Tool Groups

- Drilling methods - unconsolidated materials
- Drilling methods - consolidated materials
- Drive methods utilize a hydraulic device
- Sampling installations for portable samplers
- Portable in-situ groundwater samplers
- Fixed in-situ samplers cover
- Destructive sampling methods

Sample Collection Tool Groups

- Hand-held methods (soil)
- Portable positive displacement pumps
- Other portable groundwater sampling pumps
- Portable grab samplers (water)
- Extractive collection methods
- Gas/air collection methods

Sample Analysis Tool Groups

- Ex-situ methods for analyzing VOCs and SVOCs
- In-situ methods for analyzing VOCs and SVOCs
- Ex-situ methods for analyzing metals
- Ex-situ and in-situ methods for analyzing radionuclides
- Ex-situ methods for analyzing explosives

Geophysical Tools

- Electromagnetic
- Resistivity
- Conductance
- Ground Penetrating Radar
- Seismic

Decision Support Tool Groups

- Computer software to aid decision-tree analysis for CSMs
- Software that integrates geographic information systems, global positioning systems, imaging, analytical technologies, and databases to assist in modeling of site conditions and evolution of the CSM
- Statistical methods or sampling design and analysis

13.2.1 Sample Access and Collection Technologies

The access and collection techniques enable site investigators to access soil, groundwater and other media for the purpose of collecting samples; physically remove samples; and directly extract contaminants of concern from soil for subsequent analysis. Exhibit 13-1 above lists the major types of access and collection techniques.

13.2.2 Sample Analysis Technologies

Qualitative chemical analysis is used to determine whether chemicals of concern are present in a sample. Once it is known that chemicals of concern may be present, quantitative analysis is used to determine the identities and concentrations of the chemicals in the sample. To determine the extent and type of analyte to collect and the extent of quantitative analysis to conduct, site investigators first develop explicit data quality objectives (DQOs) early in the project. Exhibit 13-1 above lists the major types of sample analysis techniques.

13.2.3 Field Technologies

The technology groups listed in Exhibit 13-1 include both "traditional" technologies and newer technologies. In the traditional phased engineering approach samples are collected, shipped offsite for analysis, and the data are returned long after the sample collection staff have gone. The newer technologies allow sampling and analysis of groundwater and soil to be done on site to a greater extent, and more rapidly, than ever before. These newer approaches have been made possible by technological advances such as computerization, microfabrication, and biotechnology. Site investigators now have the capability to conduct analyses in the field that previously could only be done in a laboratory. By rapidly characterizing contaminated soil and groundwater on site, site staff are able to make immediate decisions which can guide characterization efforts, accelerate site assessment schedules, monitor progress of remediation efforts, and conduct confirmation sampling at closeout at reduced cost. Field analytical technologies also provide greater flexibility in responding to changes in conditions that are discovered during construction of the remedy.

Examples of the common field technologies are listed in Exhibit 13-2. Because of the advantages of field analytical technologies, especially when combined with adaptive site management strategies (described below), their use has been growing over the past decade. EPA has been promoting their use as a means of achieving faster, better, and more efficient cleanups, and expects them to replace the traditional phased engineering approach in many future cleanup projects.

13.2.4 Adaptive Site Management Approaches

Field analytical technologies provide site staff with the capability to use an adaptive sampling strategy, which feeds the previous day's results into the decision-making process to help direct the collection of the next round of samples. This strategy is typically implemented through a systematic planning process that relies on dynamic work strategies that are carefully aligned to provide data to support on-site decisions. A dynamic work strategy incorporates all known information about the site into a conceptual site model (CSM) and decision-making framework, such as a decision tree. This approach permits rapid location and definition of hot spots, guides the removal or treatment of contaminated media, and quickly identifies when enough information has been collected to address the site decision. It also helps avoid unnecessary treatment and the collection and analysis of uninformative samples, and to determine when enough information has been collected to meet site management goals. The use of field technologies, combined with a dynamic work strategy often allow some projects to be completed in only one field mobilization.

By rapidly characterizing contaminated soil and groundwater on site, site staff are able to make immediate decisions which can guide characterization efforts, accelerate site assessment schedules, monitor progress of remediation efforts, and conduct confirmation sampling at closeout at reduced cost.

Systematic planning is a process based on the scientific method for developing a framework for the effective use of dynamic work strategies and real-time field measurement and analytical technologies. It is a process for developing defensible site decisions by managing the uncertainties or unknowns that could cause decision errors. A typical systematic site plan would include collaboration of decision-makers with stakeholders, a clear statement of project goals, a multi-disciplinary technical team to develop realistic technical objectives that will achieve the goals, and the development of one or more conceptual site models that depict what is already known about the site and identifies what additional information and analysis will be needed to achieve the project's goals. The CSM can be used to direct field work, as a tool for planning and organizing work and interpreting data, and as a communication device.

The integration of systematic planning, dynamic work strategies, and real-time measurement technologies is often referred to as the *Triad approach* to planning and implementing data collection and technical decision-making at hazardous waste sites. More information on the theory and application of the Triad is available on an EPA web site (http://www.cluin.org/triad).

Exhibit 13-2. Examples of Common Field Analytical Technologies

Technology	Description
Sample Analysis Tools	
Test Kits	Measures select organic chemicals and classes of chemicals using immunoassay colorimetric techniques. Measures inorganic cations and anions and some organic chemicals in water using colorimetric techniques. Measures the presence or absence of DNAPL chemicals using dyes. Inorganic colorimetric techniques that use spectrophotometers are generally quantitative techniques. Immunoassay are generally semi-quantitative.
Ion Specific Electrodes	Measures selected cations and anions in water. Can be deployed in situ or ex situ.
Fiber Optic Chemical Sensors	In-situ measurements of the presence of chemicals or classes of chemicals using chemical specific cladding placed in water or exposed to vapors. Generally considered semi-quantitative.
Gas Chromatography	Measures the presence of volatile and semivolatile organics and some inorganics in soil gas (volatiles), soil, and water. Depending upon level of sample preparation and QA/QC imposed can be quantitative or semi-quantitative.
Infrared Spectroscopy	Is used in soil and water analysis for total extractable hydrocarbon analysis in the field.

Exhibit 13-2. Examples of Common Field Analytical Technologies (Continued)

Technology	Description
Open Path Air measurements	In open-path Fourier transform infrared spectroscopy can provide a quantitative average of various chemical concentrations in air over a predetermined distance. In open-path UV differential absorption can provide a quantitative average concentration of a limited number of chemicals in air over a predetermined distance. In open-path differential absorption lidar can provide a quantitative concentration of a limited number of chemicals (one at a time) in air at a predetermined distance which allows the construction of isopleth contour maps. In open-path Raman spectroscopy can, at close distance, detect a variety of chemicals in air (average concentration) or on a soil or building surface.
Laser-Induced Fluorescence	Generally employed as a tool for locating petroleum hydrocarbons (polycyclic aromatics) in situ, using direct push technologies to drive it into the subsurface.
Mass Spectrometry	Can be used in conjunction with a GC to provide quantitative speciation of organic chemicals in gases, soil, and water. As a stand alone instrument employing ion trap mass spectrometry, it is used to measure organic compounds brought to the surface by a membrane interface probe mounted on a CPT rig.
X-Ray Fluorescence	Depending on the rigor of the sample preparation technique used provides screening to semi-quantitative determinations of metals in soil and water. In the screening application the metal concentrations can be measured in situ at the ground surface with little sample preparation.
Ground Penetrating Radar	Has had very uneven success in locating LNAPL plumes and is not chemical specific.
Electromagnetics/ Resistivity for Environmental Applications	In specific settings can be used to delineate the extent of an electrically conductive plume.

Exhibit 13-2. Examples of Common Field Analytical Technologies (Continued)

Technology	Description
Sample Access and Collection Tools	
Direct-Push Analytical Systems (using rig)	Laser induced fluorescence probe uses fluorescence intensities to determine the relative presence of petroleum hydrocarbons (polycyclic aromatics) in soil. Membrane interface probe uses a heated permeable membrane to volatilize chemicals in soil and groundwater while applying a vacuum that brings them to the surface for analysis. Halogen specific probe uses a heated membrane to volatilize chemicals in soil and groundwater while applying a vacuum that draws them across a halogen specific detector located in the probe.
Direct-Push Geotechnical Sensors	Conductivity probe used to determine changes in lithology or conductivity changes that may be related to a change in the chemical makeup of soil and water.
Direct-Push Groundwater Samplers	Single point systems that are capable of providing access to groundwater at a predetermined depth. The groundwater is recovered by bailer or pump and brought to the surface for subsequent analysis. The system has to be withdrawn and cleaned before it can be driven to another depth. Multi-point systems that are capable of providing a vertical profile of groundwater at a single station. The groundwater is sampled using a pump and the system is driven further into the subsurface.
Direct Push Soil-Gas Samplers (without rig)	A sample probe in driven or vibrated into the ground using a hammer or hand held driver. A vacuum is applied to the probe and soil gas is drawn to the surface. The gas can be measured directly at the probe using a syringe and portable GC or can be collected in a container for subsequent analysis by GC or GC/MS instruments located on- or off- site.
Geophysical Tools	
Electromagnetic	An electromagnetic field is introduced into the ground which causes a current to flow that in turn produce a secondary electromagnetic field which is measured by a receiving unit. Most of the instruments in this class essentially measure a change in subsurface conductivity and are used to aid in conceptualizing the subsurface stratigraphy, identifying potential leachate groundwater plumes, and in some modes locating buried drums and piping. Methods include terrain conductivity, horizontal loop, very low frequency em, and time domain.
Resistivity/ Conductivity	Electrical currents are injected into the ground and the patterns of subsurface flow indicate the resistivity or conductivity of the material the current is flowing through. This technique is generally used to aid in conceptualizing the subsurface stratigraphy.
Magnetics	This method measures the change in the subsurface magnetic field as the instrument is moved across a site. Its primary use is in locating magnetic objects such as buried drums.

Exhibit 13-2. Examples of Common Field Analytical Technologies (Continued)

Technology	Description
Ground Penetrating Radar	In this method electromagnetic energy is pulsed into the ground where some of the energy is reflected by a change in strata while the rest passes through the layer. The instrument relates the time of reflection to the depth of the reflector and a cross section of subsurface reflectors is plotted. GPR can be used to locate the groundwater table, find buried objects, and contribute to the conceptualization of the subsurface stratigraphy.
Seismic	An acoustical wave is generated in one area. The wave propagates through the subsurface with some of it being reflected or refracted when there are changes in the subsurface and the rest continue on. Geophones are used to measure the time of arrival of the reflected or refracted sound and this is used to plot changes in the stratigraphy. These techniques are generally used to aid in conceptualizing the subsurface stratigraphy.

13.3 Factors Affecting Demand

To understand the direction of the market for site characterization technologies, it is important to examine the factors that are driving the demand for these technologies.

- Because site characterization is a critical component of all remediation efforts it is expected to account for a significant amount of work, although it is only a minor portion of the over $200 billion cleanup market. The overall demand for remediation services is expected to be stable over the next decade.

- The strong market for redevelopment of Superfund, brownfields, and other sites will likely foster demand for additional site assessments.

- The growing practice in the real estate industry (property purchasers, developers, and lenders) of conducting site assessments as part of standard due diligence activities at commercial properties may increase the demand for site assessment, primarily Phase One and Two type assessments.

- A number of case studies have demonstrated that the use of field analytical technologies can substantially reduce the cost and time to complete site investigations and improve the confidence of the results (Exhibit 13-3). Because these technologies have lower costs per sample, they permit higher sampling densities than is affordable using traditional laboratory analysis. Higher densities generally lead to a more complete and appropriate CSMs that facilitate effective remedy design and implementation.

- When combined with systematic planning and dynamic work strategies, real-time field measurement and analytical technologies can significantly reduce the overall cleanup costs at many sites and provide better site characterizations. For example, during remedial action, field technologies can provide accurate data that allow the site crew to rapidly adapt to new information, thereby realizing significant savings in dollars and time. Exhibit 13-3 provides examples of successes of newer approaches at specific sites.

Exhibit 13-3
Examples of Projects with Savings and Efficiency Improvements Associated With Advanced Site Characterization Technologies

- The site characterization and cleanup approach used at the Wenatchee Tree Fruit Test Plot, resulted in savings of 50% over traditional site characterization and remediation methods which rely on fixed-based laboratory analysis with multiple rounds of mobilization and demobilization. The approach used a combination of field analytical technologies, a dynamic work plan, and systematic site management. (U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, *Innovation in Site Characterization Case Study: Site Cleanup of Wenatchee Tree Fruit Test Plot Site Using a Dynamic Work Plan,* EPA 5420R-00-009, August 2000. http://clu-in.org/char1_edu.cfm#site_char).
- At the Hanscom Air Force Base in Middlesex County, Massachusetts, the original site investigation failed to find some contamination sources. As a result, a pump-and-treat system was operated for five years without achieving a sufficient reduction in pollutant concentrations. To better characterize the site, site investigators used field analytical instruments in the context of a dynamic work plan that relied on an adaptive sampling and analysis strategy. The project demonstrated that this approach could substantially reduce the cost and time and improve the confidence of the results of site investigations. (U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, *Innovation in Site Characterization Case Study: Hanscom Air Force Base Operable Unit 1 (Sites 1, 2, and 3)*, EPA-543-R-98-006, September 1998. http://clu-in.org/download/char/hafbcs2.pdf).
- A demonstration of several surface geophysical and direct push technologies at New York State Electric & Gas Company's Court Street Manufactured Gas Plant Site in Binghamton, New York, concluded, in part, that CPT/DP offered an excellent alternative to traditional investigation methods both in terms of cost per borehole and the information provided (EPA 2002).
- At Florida drycleaning sites, site characterization costs have been reduced by an estimated 30 to 50 percent when compared to conventional assessments. The state conducts rapid site characterizations using on-site mobile laboratories and direct push technologies to characterize soil and groundwater contamination, assess cleanup options, and install permanent monitoring wells, all in an average of 10 days per site (Applegate 1998).
- Argonne National Laboratory's Adaptive Sampling and Analysis Programs (ASAP) makes hazardous waste site characterization and remediation more effective and efficient by relying on real-time data collection and field-based decision-making within the framework of dynamic work plans. Argonne has documented cost savings of more than 50 percent as compared to more traditional sampling programs (U.S. DOE 2002).
- ASAP data collection efforts have been used at Sandia National Laboratories and Kirtland Air Force Base in New Mexico; Brookhaven National Laboratory in New York; Argonne National Laboratory and Joliet Army Ammunition Plant in Illinois; and several Formerly Utilized Sites Remedial Action Program (FUSRAP) sites. In addition to providing better characterizations than traditional approaches, these programs cost 30% to 70% less (U.S. DOE 2002).
- DOE reports that recent work at the Fernald site as part of its soil excavation program has shown that the use of real-time data collection technologies and decision support techniques will save the site more than $20 million over the life of the project. In addition to analysis cost savings, these approaches have resulted in reduced excavation schedules and soil disposal costs, and superior overall soil characterization compared with conventional sampling and analysis.
- DOE reports that a precision excavation project at the FUSRAP Ashland 2 site that used adaptive sampling and analysis techniques resulted in an estimated $10 million savings. Data collection efforts were particularly effective when integrated within remedial designs.

- The ability to reduce uncertainty in decisions can reduce the perceived financial risk of site owners, developers, and communities, thereby contributing to revitalization of many properties. The newer characterization approaches can reduce uncertainty by enabling site investigators to increase the sampling density at reasonable cost.
- Although real-time field measurement and analytical technologies, dynamic work strategies, and systematic planning techniques have been known for some time, their acceptance has been slow, primarily because of a conservative engineering and regulatory atmosphere that appears to favor the established methods for conducting site characterizations.

- To help overcome this inertia, EPA, DOE, DOD, and other organizations have been promoting the use of the new technologies and strategies for characterizing, cleaning up, and monitoring hazardous waste sites.

- The use of field analytical technologies is expected to increase relative to traditional approaches, for several reasons:

  ÷ EPA, DOE, DOD, and other organizations have been sponsoring research on and promoting the use of the newer approaches.
  ÷ Newer approaches have been shown to mitigate deficiencies in groundwater characterization at many sites that relied on conventional approaches, which have lead to inadequate remedial designs.
  ÷ The demand for revitalization of brownfields and UST sites implies a requirement to conduct many site assessments, often at small- and medium-size sites. These activities will lead to further site investigation and cleanup for some percentage of these sites.
  ÷ The demand for due diligence by property purchasers, developers, and lenders implies a significant demand for Phase I and, possibly, Phase II assessments.
  ÷ The demand to redevelop sites provides a powerful economic incentive for faster site assessments and cleanups. Developers, property owners, and investors are under serious time constraints to get plans approved and secure financing and insurance. The integration of field analytics, dynamic work strategies, and systematic planning will allow investors to more expeditiously proceed with their projects.

Based on these factors, it is expected that the newer technologies will replace older technologies at many future and some existing sites. Although some newer technologies may not be appropriate for all sites, they are likely to reduce overall remediation costs at many sites, thereby allowing more sites to be cleaned up. Most of the major remediation programs are constrained by budgets, and not by the amount of cleanup work. Thus, if average site cleanup costs are reduced, more cleanups would be possible.

13.4 Number of Sites That Will Need Characterization

All potential hazardous waste sites will require some sort of site characterization. In addition, there is a healthy market for site characterization resulting from due diligence investigations conducted in support of real estate and other business transactions. However, no single source provides definitive information on the number and characteristics of sites that may require site characterization. The type and amount of characterization work needed varies widely from one site to another, depending on the nature and extent of the contaminant release, geology and hydrogeology of the site and surrounding area, source of contamination, size of the site, and other factors.

Exhibit 13-4 presents estimates of the potential number of sites that may require site characterization under the Superfund, RCRA Corrective Action, and other remediation programs described earlier in this report. As described in Chapter 1 and subsequent chapters, the definition of the term "site" differs somewhat from one market segment to another. In this report, the term is used to indicate an individual area of contamination, which can be small or large. This term is not to be confused with the terms "facility" and "installation," which identify an entire tract, including all contiguous land within the borders of a property. A "facility" may contain one or more contaminated areas or "sites." For this exhibit, the Superfund sites are counted as operable units (OUs) rather than sites.

As described in Section 13.1, Phase One site assessments do not generally include sampling, chemical analysis, and similar activities. Nevertheless, sites undergoing these assessments are of interest to this study because they comprise the universe of sites from which sites needing further study will be drawn. This is the largest market, amounting to 11.8 million Phase One assessments over 30 years, and costing $23 billion. Most of these assessments are in support of due diligence responsibilities in real estate and business transactions.

The other phases are potential markets for both conventional and new sampling and analysis technologies. Over the next 30 years, it is estimated that 1.2-2.3 million Phase Two assessments and 285,000 Phase Three assessments will be conducted. Sampling and analysis will also be needed during 392,000 remedial actions. The sampling and analysis required during remedial actions can be quite variable. If unforseen conditions arise at a site, extensive supplemental sampling and analysis may be called for. The sampling and analysis during O&M is also highly variable, with some sites needing none or minimal amounts, while others such as the Superfund and RCRA sites, are likely to require more comprehensive sampling and analysis. Thus the estimate of 507,000 sites likely to need sampling and analysis during O&M represents the middle value of a wide range of activities among the sites.

Exhibit 13-4. Estimated Number of Sites to Require Sampling and Analysis

	Phase One	Phase Two	Phase Three	Remedial Action [a]	O&M [b]
Superfund (OUs) [c]	658	658	832	1,700	2,500
RCRA-CA [d]	0	1,269	< 3,827	3,800	3,800
UST [e]	NA	NA	125,000	223,000	320,000
DOD [f]	NA	1,425	4,774	8,800	18,400
DOE [g]	NA	NA	NA	5,000	8,000
Civ. Agencies	NA	NA	NA	NA	NA
States [h]	h	h	150,000	150,000	155,000
Private [i]	11.5 mil.	1.2 - 2.3 mil.	NA	NA	NA
Total [J]	11.8 mil.	1.2 - 2.3 mil.	285,433	392,300	507,700

NA Estimate not available;

[a] Assumes all sites will require at least some sampling and analysis during remedial action; however the amount needed will vary widely from site-to-site.

[b] Total number of sites cleaned up. Some, but not all, of these sites will require sampling and analysis on a continuing or periodic basis. Some will require only minimal amounts and some will require more.

[c] **Superfund:** Operable units (OUs) were counted rather than sites. **Phases 1 - 2** will only be needed at future sites to be listed (280 sites with an estimated 658 OUs). **Phase 3** will be needed at the same 658 OUs plus 174 OUs (from Exhibit 3-2) that have not begun remedial assessment (658 + 174 = 832). **Remedial action** (RA) from 2004-2013 will be needed at 1,731 (658+1073) OUs. (The 1,073 OUs are at the 456 already listed sites that have not begun RA (Exhibit 3-2)). The 1,731 estimate does not include sites already in RA. It is assumed that **O&M** will be needed by 80% of all completed OUs, based on the facts developed in Chapters 2 and 3 that 83% of NPL sites have contaminated groundwater and 95% of groundwater remediations use monitored natural attenuation (MNA), P&T, or both (0.83 X 0.95 = 0.8) Thus, combining the above figures, it is estimated that 2,523 OUs will need O&M (1,731 OUs plus 1,399 OUs that have completed or are in RA = 3,130 X 0.8 = 2,504).

[d] **RCRA:** The 1,269 RCRA Corrective Action sites have not yet received priority ranking. The 3,827 sites represent all those likely to require site investigation and/or cleanup. Some of these investigations have already begun, although only a small portion of the cleanups have actually begun.

[e] **UST:** It is assumed that tank sites to be reported in the future will not do **Phase 1 and 2** assessments, but will go straight to phase 3. **Phase 3** is assumed to include all future cleanups, which equals 35,000 already confirmed releases where cleanups have not been initiated (Exhibit 5-5) plus 90,000 (average of range in Exhibit 5-5) projected future releases. The **Remedial action** estimates are based on the assumption that 60% of all sites in RA will require some sort of confirmation sampling. This assumption is derived from the estimates in Chapter 5 that 79% of UST groundwater sites use MNA or P&T. Assuming that 80% of the sites have groundwater contamination, about 60% will need O&M. Adding sites yet to complete remediation (125,000 that will need Phase 3 + 98,000 initiated but not complete = 223,000) to sites with cleanups completed (311,000 from Chapter 5) and multiplying by 0.6 gives a total of 320,000 (534,000 X 0.6) sites that will ultimately require monitoring.

[f] **DOD:** Future investigation is planned at 1,425 sites, underway at 4,774 sites, and 2,775 sites are already in remediation. The O&M estimate includes all previously remediated sites times 0.8 (from the percentage of NPL sites that will require O&M).

[g] **DOE:** has completed construction at 5,000 release sites; and 8,000 sites (10,000 X 0.8) may need O&M.

[h] **States:** From Chapter 9, (estimated 5,000 sites annually X 30 years plus 44,000 with cleanups completed through 2003 = 194,000 X 0.8 = 155,000). Phase 1 and 2 figures are included with estimate for private sites.

[I] **Private Sites:** Industry sources have estimated that the number of Phase I (ASTM definition) site assessments averaged 235,000 per year between 1999 and 2001 (EAS 2002). Summing this amount over 30 years, and assuming a 3% annual growth rate (which is approximately the growth rate of the GDP over the past 50 years), this would total 11.5 million Phase 1s. It is assumed that 10-20% of Phase 1s will need a Phase 2, based on industry history. These figures incorporates brownfields and voluntary cleanup programs.

[J] Excludes civilian federal agency and some DOE sites, because data could not be disaggregated.

13.5 Estimated Site Characterization Costs

Any estimate of the value of the site characterization market is hampered by the extremely wide range of potential situations involving the use of sampling and analysis tools and the paucity of program-wide data on costs. Many cleanup programs do not record expenditures by type of action. For example, EPA has not kept track of its own Fund-lead expenditures on specific actions, such as RD or RA. The Agency has no simple way of determining how much is spent on specific types of actions, such as site investigation. Cost estimates in RODs, which are done prior to remedy design, are estimates which serve as only general indicators of potential cost.

A 2001 Resources for the Future study (Probst, 2001) used expenditure data from EPA's financial management system to estimate the average dollars spent for Fund-lead RI/FSs, RDs, and RAs at the operable unit level for sites between 1992 and 1999. These costs are primarily extramural costs and do not cover other site-specific costs such as community and state involvement, nor other program costs, such as rent. Nevertheless, they provide an approximation of the relationship of site investigation costs to remedial design and remedial action costs. These cost comparisons are shown in Exhibit 13-5. The average RI/FS expenditures over all Fund-lead Superfund sites averaged 10 percent of combined costs for RI/FS, RD, and RA, which together account for most site expenditures. Since this estimate does not include the sampling and analysis work that occurs during remedial action, long-term remedial actions, and O&M, it represents a conservative estimate of the extent of site characterization work needed.

Exhibit 13-5. Estimated Major Components of Superfund Costs

Expenditure Category	Cost per Fund-Lead Operable Unit ($000)	Percent of Total Expenditures
RI/FS	1,363	9.9
RD	1,331	9.7
RA	11,059	80.4
Total	13,753	100.0

Notes:
- RI/FS costs do not include site characterization work conducted during remediations, O&M and long-term remedial actions.
- Average for non-federal Superfund Fund-lead sites from 1992 to 1999. These data do not include costs for long-term remedial actions and O&M.

Source: Probst, Katherine N. & David M. Konisky, et. al., 2001. *Superfund's Future, What Will It Cost*, Resources For the Future, Washington, D.C. 2001.

The data also indicate that site characterization cost as a percent of total cleanup cost is larger for smaller sites, than for larger sites (Exhibit 3-6). Site investigation costs are 7 percent of total site costs for "mega" Superfund sites (those with over $50 million in cost) and 15.5 percent for non-mega Superfund sites. Data are also available for drycleaner sites, which are almost all small and provide a useful comparison. On average, 28.2 percent of drycleaner site cleanup costs are for site investigations. The drycleaner data, from a sample of 50 drycleaner sites from the State Coalition for Remediation of Drycleaners database, also indicate the extent of site investigation costs (See Chapter 12, Drycleaner Sites). The site investigation costs cited in this section do not include site characterization work that is often undertaken during remedial action and O&M. Almost 17 percent of drycleaner site cleanup costs were for O&M.

Exhibit 13-6. Remediation Cost and Site Size

Site Type	Average Total Cleanup Cost	Site Investigation Cost	Percent
Mega Superfund (per OU)	$36,652,000	$2,582	7.0%
Non-Mega Superfund (per OU)	$6,750.000	$1,047	15.5%
Drycleaner	$402,000	$113,000	28.2%

Notes:
- Includes Total market value over 30 years.
- Does not include site characterization work conducted during remediations and O&M.

Source: Probst, Katherine N. & David M. Konisky, et. al., 2001. *Superfund's Future, What Will It Cost*, Resources For the Future, Washington, D.C. 2001; and Exhibit 12-2.

Applying these ratios to the estimated 30–year market values of each of the seven major remediation programs, the site characterization market is likely to be $21 billion over the next 30 years (Exhibit 13-7). *Because this estimate does not include site characterization work that is undertaken during remedial action and O&M, it may underestimate the total amount of sampling and analysis work needed.*

Exhibit 13-7. Estimated Site Characterization Costs

Market Segment	Total Remediation Market		Percent for Site Investigation	Value of Site Characterization Market ($Billions) [a]
	Number of Sites	Value ($Billions)		
Medium and Large Sites (Superfund, RCRA Corrective Action, DOD, & DOE)	16,000	145	10	14.5
Small Sites (UST, Civilian Agencies, and States)	278,000	64	16	6.5
Total	294,000	209		21.0

[a] Because this estimate does not include site characterization work that is undertaken during remedial action and O&M, it may underestimate the total amount of sampling and analysis work needed.

Source: Exhibits 1-1, 1-2, 12-2, 13-6.

13.6 Market Entry Conditions

The characterization market can generally be divided into two vendor groups: architecture and engineering (A&E) firms who generally provide technical investigation expertise (e.g., geologists, chemists, project managers) and equipment and analytical vendors who provide the drill rigs, geophysical equipment, and analytical equipment use to carry out site characterization. Although the two types of firms usually operate differently, there is some overlap. Some A&E firms have their own equipment and some vendors that provide interpretation services for some of the innovative direct push probes. The exception to this generalization are very small specialized firms that might do site characterization only, or risk assessments only, and firms that primarily work in the UST area.

In recent years, there has been a great deal of consolidation in the A&E area. Firms that were once considered large players in the environmental characterization field have been merged into even larger firms. For example, URS-Griner acquired Woodward-Clyde, Dames and Moore, and EG&E. Consolidation is also occurring in the analytical laboratories sector. It has, however, not been as extensive in the heavy equipment operator business. Drill rigs and direct push rigs are generally supplied by large firms with many small offices around the country or small drilling firms that do environmental work as a supplement to their construction and water well business. Because of high mobilization costs, companies located closer to the site have a cost advantage.

Large corporations and government agencies (e.g., DOE and DOD) with large complex contaminated sites tend to rely on the large A&E firms. This is also true for some government agencies and companies that have many smaller sites around the country. Nevertheless, there are opportunities for smaller vendors to subcontract. Since the larger A&E firms generally view field equipment as a subcontract issue, companies that can provide services such as direct push with various ancillary detection equipment, as well as traditional drilling rigs, are more likely to prevail in contract award.

In the larger facility market, there is increasing regulatory pressure to perform better site characterizations than have been done in the past as well as pressure from the facility owners to keep costs down. This presents an excellent opportunity for new characterization technologies and site management approaches that are geared towards better and potentially less expensive site investigations and site management approaches (Section 3.2). The USEPA make this point in their Dynamic Field Activities and Triad initiatives (see web pages at http://www.epa.gov/superfund/programs/dfa/index.htm and http://www.epa.gov/tio/triad).

The cleanup market involving smaller hazardous waste handlers and generators, USTs, and commercial property transfers is somewhat more fragmented in terms of vendor participation. Smaller waste generators, such as drycleaners and independent UST owners (as opposed to those owned by the major oil companies), and real estate owners and developers are more likely to employ specialty firms (e.g., tank investigations only) or smaller A&E firms that can perform Phase 1 and Phase 2 assessments but are unlikely to have a robust RI/FS practice. In addition, many of the larger A&E firms are not interested in this type of work because of their higher overhead costs and the relatively small profit margin that smaller jobs entail.

The cleanup budgets for the smaller facilities are much smaller and their environmental problems are generally better defined, such as a leaking tank or a PCE release at a drycleaner. Innovative specialty tools such as LIF, MIP, or the halogen specific probe can, in most cases, perform a complete characterization for relatively little cost. These capabilities should be a good selling point for specialty contractors or the smaller A&E firms that undertake this type of work. Significant portions of this market can be accessed through local and state governments and prime contractors.

Finally, commercial property transactions, especially for those properties with a history of handling hazardous materials/wastes, generally have very low budgets for Phase 2 characterizations. Nevertheless, the characterization results often carry with them a high degree of financial liability. This market would be receptive to technologies that provide analytical results that are more representative of true site conditions at a reasonable cost.

Firms practicing dynamic field activities and the Triad approach need to bring together professionals with many disciplines, such as project management, statistical and geostatistical sampling design, and analytical chemistry. To achieve the appropriate disciplinary mix, some firms may partner with analytical service providers, statisticians, and other disciplines.

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Chapter 14
DNAPLs at Hazardous Waste Sites

Dense non-aqueous phase liquids (DNAPLs) are chemicals that are denser than water and are only slightly soluble. Because of their physical and chemical properties, characterization and remediation of DNAPL-contaminated sites can pose significant challenges to site managers. Contamination of soil and groundwater by DNAPLs is associated with many hazardous waste sites and many industries, and has posed serious environmental problems for many years. This chapter describes the nature of the DNAPL problem and estimates of the extent of the market for its remediation.

Because of their density and low solubility, DNAPLs are often present in the subsurface in an undissolved phase. Most DNAPLs undergo only limited degradation in the subsurface, and persist for long periods of time while slowly releasing soluble organic constituents to groundwater. The most frequently applied remediation approach has been to use groundwater pump-and-treat systems primarily to contain the dissolved phase plume and not treat the source zone.[1] However, it has been shown that this approach has not been successful in achieving cleanup goals at many sites (NRC 1994). Efforts to remove free-phase and residual DNAPLs face the challenge of our limited capability to delineate the source zones. If some of the free-phase or residual DNAPLs remain, the deposit may continue to dissolve into the groundwater. Whether to treat or remove free-phase or residual DNAPLs involves tradeoffs between long-term and short-term site management options and costs. There is a debate in the scientific and engineering community regarding how much mass must be removed to have an effect on the groundwater concentration profile and on the duration of post-treatment containment activities.

DNAPL compounds are encountered in most industries and under all the remediation programs, including Superfund, RCRA Corrective Action, UST, DOD, DOE, and other cleanup programs. Thus, the market estimates in this chapter should not be added to those in the previous chapters of this report. Adding these estimates would be double-counting sites and, therefore, overestimating the scope of the market.

14.1 Market Description

While no compilation of the number of sites with DNAPLs exists, the extent of the problem can be described in terms of the occurrence of DNAPL-related chemical compounds at waste sites, the types of industrial activities that have resulted in free-phase DNAPLs, and the frequency of occurrence of those chemicals in the seven major remediation market segments.

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1 A source zone is that portion of the subsurface where immiscible liquids (free-phase or residual DNAPLs) are present either above or below the water table. The contaminated material in the source zone acts as a reservoir for the continued migration of contamination to surrounding environmental media or as a source for direct exposure (ITRC 2002).

14.1.1 DNAPLs in the Environment

Because DNAPLs are marginally soluble in, and heavier than, water, they can migrate to depths well below the water table. As they migrate, they can leave behind ganglia or microglobules in pore spaces of the soil matrix. When the sinking DNAPLs encounter a low-permeability layer, such as clay or bedrock, they can accumulate, or "pool" and spread laterally, until they encounter a fracture or other path toward deeper zones. Globules can also enter pores and be held there in capillary suspension. All these forms of undissolved chemicals (ganglia, globules, and pools) effectively serve as long-term sources of groundwater pollution. They can slowly dissolve in the surrounding groundwater and form contamination plumes. These plumes can have varying levels of concentration, such as narrow bands of high-concentration and bands of low-concentration. Because DNAPLs have very low solubility points, they can continue to release small, but environmentally important, quantities of contaminants into the groundwater for centuries. As a result of this complex pattern of subsurface transport, the distribution of DNAPLs can be difficult to delineate. In addition, very few sites report direct observation of DNAPLs in the subsurface. Many DNAPLs are colorless liquids which, when present as residuals in soil pores, are difficult to visually observe.[2]

14.1.2 Chemical Compounds that are DNAPLs

DNAPLs include halogenated organic solvents such as trichloroethylene (TCE), 1,1,1-trichloroethane (TCA), perchloroethylene (PCE), carbon tetrachloride, substituted aromatics, phthalates, polychlorinated biphenyl (PCB) mixtures, coal and process tars, creosote, and some pesticides. Exhibit 14-1 shows some of the common DNAPLs. A more comprehensive list of chemical compounds that are DNAPLs are found in various sources (Cohen and Mercer 1993, EPA 1992, 1993). DNAPLs are often complex mixtures of the listed chemicals, and many sites are contaminated with various combinations of DNAPLs, LNAPLs, metals and/or radionuclides.

These compounds are also among the most common contaminants at Superfund, DOD, RCRA, and DOE sites. Specific data for the other market segments are not available. State and brownfield sites, which include many former industrial properties, are likely to have a similar profile of chemical usage.

The presence of these chemicals does not guarantee that DNAPLs are present in free or residual phase. The occurrence of DNAPLs is a function of whether compounds were discharged to the environment in dissolved or free-phase liquid form, the material, waste management practices, volume and pattern of releases, and hydrogeological characteristics. Many early site investigations may have missed the presence of DNAPLs or presumed that the source of any dissolved-phase DNAPLs was from points of discharge on the surface. The presence and location of DNAPLs are usually not obvious, and EPA has produced reports and fact sheets to help site investigators estimate the potential occurrence of DNAPLs (U.S. EPA 1992).

2 They can be identified through the use of reactive dyes that turn colors in the presence of DNAPLs or shaking a soil sample in a jar of water and observing DNAPLs as a second phase at the bottom of the jar.

Exhibit 14-1. Common DNAPL-Related Chemicals

Halogenated VOCs	Halogenated SVOCs	
Chlorobenzene	1,4-Dichlorobenzene	Napthalene
1,2,-Dichloropropane	1,2-Dichlorobenzene	Benzo(a)Anthracene
1,1,-Dichloroethane	Aroclor 1242, 1254, 1260	Fluorene
1,1,-Dichloroethylene	Chlordane	Acenapthene
1,2,-Dichloroethane	Diedrin	Anthracene
Trans-1,2,-Dichloroethylene	2,3,4,6-Tetrachlorophenol	Dibenzo(a,h)Anthracene
Cis-1,2,-Dichloroethylene	Pentachlorophenol	Fluoranthene
1,1,1-Trichloroethane		Pyrene
Methylene Chloride	**Non-Halogenated SVOCs**	Chrysene
1,1,2-Trichloroethane		2,4-Dinitrophenol
Trichloroethylene	2-Methyl Napthalene	Other polynuclear aromatic hydrocarbons
Chloroform	o-Cresol	
Carbon Tetrachloride	p-Cresol	**Miscellaneous**
1,1,2,2-Tetrachloroethane	2,4-Dimethylphenol	
Tetrachloroethylene	—Cresol	Coal tar
Ethylene Dibromide	Phenol	Creosote

Note: Many of these chemicals are found mixed with other chemicals or carrier oils.
Source: U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, Estimating Potential Occurrence of DNAPLs at Superfund Sites, Publication 9355.4-07S, January 1992.

14.1.3 Industrial Activities

One of the most accurate indicators of probable releases of DNAPLs at a site is the site's history—the types of industries that operated on the site, industrial processes, and waste management practices. The text box lists industries that have a high probability of DNAPL releases, based on the materials they use or discharge and historical industrial and waste management practices. Industrial or waste disposal processes with a high probability of DNAPL release include metal cleaning and degreasing, tool-and die operations; machinery, equipment, and instrument repair and maintenance; paint removing and stripping; storage of solvents in underground storage tanks; storage of drummed solvents in uncontained storage areas; solvents loading and unloading; disposal of mixed chemical waste in landfills; and treatment of mixed chemical waste in lagoons or ponds.

Industries With High Probability of Past DNAPLs Release

- Wood preservation
- Manufactured gas plants
- Electronics and electrical equipment manufacturing
- Transportation equipment manufacturing (e.g., aircraft, automobiles, and engines)
- Fabricated metal products manufacturing
- Solvent manufacturing, distribution, packaging, and recycling
- Pesticide and herbicide manufacturing, packaging, and distribution
- Organic chemical manufacturing, distribution, packaging, and recycling
- Equipment maintenance
- Drycleaning
- Instrument manufacturing
- Transformer oil production/reprocessing
- Coking operations
- Pipeline compressor stations
- Departments of Defense and Energy maintenance and training activities.

14.1.4 Hydrogeological Characteristics

Because of its tendency to migrate to the lowest possible level and pool, DNAPL transport in the subsurface is very sensitive to the geological media through which it passes. Site geology can affect many aspects of DNAPL contamination, including the likelihood that the DNAPL will reach the saturated zone, ultimate depth of the DNAPL travel, extent of lateral travel, likelihood that pools will form and their shape, and the spatial distribution of the dissolved-phase plume. These factors will also affect the nature and probable success of the site characterization and remediation work that will be needed. Previous research indicates that the nature of DNAPL deposits are most likely to be influenced by local and site-specific geological formations, rather than overall hydrogeological regions (U.S. EPA 1993a).

Approaches to DNAPL characterization and remediation differ significantly depending on whether DNAPL source zones are shallow or deep. Examples of situations encountered with *shallow source zones* are:

- Sites with installed pump-and-treat systems that have inadequately contained plumes, whether or not they have addressed the source zones. Additional characterization and decisions regarding revisions to the remedies may be called for, either to address the plume, the source zone, or both;

- A continuing market where pump and treat and permeable reactive barriers (PRBs) will be used as part of remediation;

- Old and new sites with undefined source zones. The remediation approaches used at these sites will depend on regulatory policy, available technology, and economics in affecting tradeoffs between source reduction and containment.

In all these situations, there appears to be an expanding market for the new technologies that provide on-site characterization.

It is likely that characterization of *deep source areas* and bedrock will continue to use "traditional" technologies, such as drilling rigs, in the near future. Research and development in this area is needed to develop more effective characterization and remediation approaches.

14.2 Factors Affecting Demand for Remediation Services

The proportion of DNAPL sites that will be subject to containment and how many will undergo source zone treatment is uncertain. A number of factors may affect the decision to attempt to strike a balance between remediating a source zone and long-term pump and treat at a DNAPL site, and hence the potential demand for remediation services. These factors, which are not mutually exclusive, include:

- Regulatory requirements at some sites may call for achieving groundwater MCLs in the source zone. In some cases, regulatory requirements may be so stringent that property owners and PRPs seek alternatives, such as technical impracticability waivers, to source reduction or removal.

- The CERCLA process of remedy selection includes a preference for remedies that provide "permanence and treatment" to the extent practicable. This implies that, to the extent practicable, contaminants are to be treated and/or destroyed.

- The ability to economically delineate the DNAPL source zones varies from site to site, and is especially difficult in fractured rock.

- The ability to show that source reduction will significantly reduce the long-term costs of containment also varies from one site to another.

- The effective combinations of technologies have the potential for performance and cost advantages. However, sometimes the need to apply more than one cleanup technology may increase the complexity, cost, and uncertainty of a remediation.

- Potential contamination at uncharacterized, or undiscovered sites, such as MGP sites, former drycleaners sites, or other brownfields sites, may increase the number of sites that need characterization and/or remediation.

- Development and acceptance of innovative remedial and characterization technologies. Effective technologies are especially needed for deep sources. Characterization and remediation of deep sources are more costly and usually produce less certain results than those of shallower sources.

- A number of states have recognized the need to consider newer site characterization and remediation technologies prior to granting waivers from ARARs for technical impracticability (ITRC 2002).

- Reuse considerations at a site may drive the type of remediation approach selected and/or generate a need for a faster cleanup at a site. For example, a developer may not be able to use a property that has pump-and-treat equipment in important locations on the property, or institutional controls that limit the property's intended use. In some situations, it may be possible to place treatment system features in locations more compatible with the intended reuse, or use a different treatment approach.

  Some prospective property purchasers may need the property cleaned up faster than is possible with a pump-and-treat system. An alternative, such as a protective cap may be installed more quickly than a groundwater treatment system, thereby enabling the property to be put into productive use more quickly. On the other hand, a cap may not be compatible with some reasonably anticipated future site uses, and usually will be accompanied by institutional controls.

14.3 Number and Types of Sites

Based on the types of contaminants found at hazardous waste sites and other factors, it is likely that a significant number of sites have a DNAPL problem. However, no single source provides definitive information on the number and characteristics of sites that may require DNAPL remediation. The type and amount of DNAPL remediation work needed vary widely from one site to another, depending on the nature and extent of the contaminant release, geology and hydrogeology of the area, source of contamination, size of the site, and other factors. Exhibit 14-2 summarizes data on the incidence of VOCs and SVOCs, many of which are DNAPL chemicals. About 78 percent of NPL sites contain VOCs (69 percent halogenated) and 71 percent contain SVOCs (44 percent PAHs, 28 percent pesticides, 27 percent PCBs, and 26 percent halogenated SVOCs). Many NPL sites have combinations of these compounds. About 64 percent of DOD sites contain VOCs (49 percent halogenated, 32 percent non-halogenated). Fifty-seven percent of DOD sites contain SVOCS, including PAHs (16 percent) organic pesticides or herbicides (15 percent), halogenated SVOCs (8 percent), and PCBs (6 percent) (Exhibit 14-2).

Based on data from 214 RCRA Corrective Action sites collected in the early 1990s, 60 percent contained halogenated VOCs, 18 percent PAHs, 11 percent non-halogenated SVOCs, 11 percent halogenated SVOCs, and 9 percent unspecified VOCs and SVOCs. Halogenated compounds are often DNAPLs. Based on a 1993 EPA evaluation of 79 treatment, storage, and disposal facilities, 9 of the 19 predominant constituents projected above action levels in groundwater are DNAPL chemicals (U.S. EPA 1994).

The use of DNAPL compounds at a site does not guarantee that DNAPLs are present in free-phase or residual form. The nature and extent of the DNAPL deposits also depend upon the form, pattern, and volume of release, hydrological conditions and other factors.

Exhibit 14-2. Occurrence of VOCs and SVOCs at Contaminated Sites

Remediation Program	VOCs	SVOCs
NPL	78%	71%
RCRA Corrective Action	60% +	18% +
DOD	64%	57%
DOE	38%*	38%*

- * DOE figure combines SVOCs and VOCs. This figure is based on data in early 1990s.
- About 69% of NPL sites contain halogenated VOCs, 44% PAHs, 28% pesticides, 27% PCBs, and 26% halogenated SVOCs.
- About 49% of DOD sites contain halogenated VOCs, 32% non-halogenated SVOCs, 16% PAHs, 15% organic pesticides or herbicides, 8% halogenated SVOCs, and 6% PCBs.
- The RCRA VOCs figure is for halogenated VOCs, since the data were not aggregated into major contaminant groups. About 32% of RCRA sites also contain other non-halogenated VOCs, and 11% contain BTEX. The SVOCs figure for RCRA Corrective Action sites is for PAHs, since the data were not aggregated into major contaminant groups. About 11% contained non-halogenated SVOCs, 11% halogenated SVOCs, 9% unspecified VOCs and SVOCs, and 36% contain other unspecified contaminants.

Source: Chapters 3, 4, and 6.

> 29-45% of NPL sites, or an average of 37%, are likely to have free-phase or residual DNAPLs present in the subsurface. These estimates incorporate several approximations and simplifying assumptions as described in the text.

Although the occurrence of halogenated compounds is a strong indication that the site may have DNAPLs, it does not guarantee that it will. The occurrence of DNAPLs is also influenced by industrial practices, form and volume of releases, and hydrogeological conditions, among other factors. A 1993 EPA study considered these factors to estimate the likelihood of free-phase DNAPL presence at NPL sites (U.S. EPA 1993a). This study concluded that approximately 57 percent of NPL sites with organics contamination in groundwater either have, or could be expected to have a medium to high potential of DNAPLs presence, which could provide a source of groundwater contamination in the subsurface. The remainder of the sites could be expected to fall within the category of "low to unlikely" to have DNAPLs present. (The percentages were: 100% potential = 5%, high potential = 32%, medium potential = 20%, low potential = 27%, and zero potential = 16%). Based on interpolation of data in this report (U.S. EPA 1993a), it is estimated that 29-45 percent of all NPL sites, or an average of 37 percent are likely to have free-phase or residual DNAPLs.

Many of the compounds found at these sites are also found at many non-Superfund sites, such as RCRA sites. Based on information about previous site uses, it is likely that these chemicals are also present at contaminated brownfields sites. Conclusions regarding UST sites are less certain. There are an estimated 25,000 USTs containing hazardous substances and many are likely to contain solvents. Although it is likely that a significant number of these contain solvents, there are no recent data regarding the specific chemicals contained in USTs. Petroleum-containing USTs are more likely to contribute to the presence of BTEX, which are LNAPLs.

DNAPL-related chemicals are also released to the environment by the drycleaning industry and were released by the now defunct manufactured gas industry. The characteristics of drycleaner sites are described in Chapter 12. Based on that discussion, over 15,000 active drycleaner sites will probably need site investigation and remediation. About 90 percent of these facilities use perchloroethylene (PCE) as their primary drycleaning solvent. In addition, there may be 9,000 to 90,000 "inactive" sites, which are former or closed drycleaning facilities. Older facilities used more drycleaning solvent than newer ones and tended to have more releases. Most of these sites tend to be remediated under a state mandated or voluntary control program. They are not counted separately in the above estimates, but are probably a component of the state site figure.

The cleanup of former manufactured gas plants (MGPs) and other coal tar sites may be addressed under any of the remediation programs, such as Superfund, RCRA, or a state environmental program, depending on the nature and extent of the contamination and other site-specific factors. The characteristics of MGPs and other coal tar sites are discussed in Chapter 10. Based on the estimates presented in that chapter, there may be 30,000 to 45,000 former MGP sites. These sites varied in size from less than one acre to approximately 200 acres. Because of the nature of the gas manufacturing process and the practices at the time, releases of contaminated materials to the environment were common. A small percentage of these sites have been, or are being, cleaned up under one or more of the seven major market segments. For example, 12 MGP sites are on the NPL and some have been reported under state cleanup programs. Because these sites may be managed under any of the remediation programs, the estimates of the MGP market should not be added to those of the seven major market segments above. Adding these estimates would be double-counting sites and cleanup costs, thereby overestimating the market's scope.

Summarizing this information, it is estimated that, 37 percent of non-federal NPL sites, 28 percent of RCRA, 28 percent of state, 30 percent of DOD, and 30 percent of DOE sites are likely to have a DNAPL problem. Although there are possibly thousands of UST sites with DNAPLs (e.g., tanks containing solvents), there are insufficient data on the number of tanks that contain them to make a meaningful estimate. These percentages result in the estimates presented in Exhibit 14-3. The estimated percentage of sites with DNAPLs is interpolated from data in the EPA study (U.S. EPA 1993a) and adjusted for the percentage of sites with groundwater contamination (83 percent). The NPL percentages are applied to the other market segments based on the occurrence of organics in those segments relative to the NPL segment.

In addition to sites that have not yet begun remediation, there may be old sites (those with ongoing or completed remedy construction) where a DNAPL problem has not yet been discovered, where operating pump-and-treat systems are not adequately containing the plumes, and/or where addressing the source zones have not been attempted. As new characterization and remediation approaches become practicable, the remedies at these sites may be revisited.

Exhibit 14-3. Estimated Number of Sites With DNAPLs

Cleanup Market Segments	Estimated No. of Sites to be Cleaned up [a]	Estimated Percent With DNAPLs (%)		Estimated Number of Sites With DNAPLs	
		Range	Average	Range	Average
NPL (non-federal)	736	29 – 44	37	213 – 324	538
RCRA	3,800	22 – 34	28	836 – 1,292	1,052
UST	125,000	NA	NA	NA	NA
DOD	6,400	24 – 37	30	1,536 – 2,368	1,819
DOE	5000	24 – 37	30	1,200 – 1,850	1,469
Civilian Agencies	> 3,000	NA	NA	NA	NA
State & Private	150,000	22 – 34	28	33,000 – 51,000	41,200
Total	293,936			37,260 – 54,814	46,078

NA Not available
[a] From Exhibit 1-1.
Source: Analysis of data in *Evaluation of the Likelihood of DNAPL Presence at NPL Sites, National Results,* OSWER Publication 9335.4-13, EPA 540-R-93-073, PB93-963343, Office of Solid Waste and Emergency Response, September, 1993.

These estimates are approximations that incorporate a number of simplifying assumptions as described above. For example, evidence of discharge of a compound does not necessarily mean it remains in free-phase or residual form. The compounds could be dissolved, in which case this methodology would overstate the number of sites with free-phase or residual DNAPLs. On the other hand, since not all compounds associated with DNAPLs were included in previous studies, the estimate may be understating the extent of the DNAPL problem.

14.4 Estimated Remediation Costs

Any estimate of the value of the site characterization market is hampered by the extremely wide range of potential site conditions and the paucity of program-wide data on costs that pertain to specific DNAPL remediations. Most cleanup programs do not compile data on expenditures pertaining to specific contaminants or pollutants, or specific actions such as pump-and-treat operations, excavations, or laboratory analyses in a manner that can be aggregated or used to compute averages. Many sites are being remediated for more than one contaminant and medium. Even if total remediation cost for a site is known, the specific costs attributable to DNAPL remediation would be difficult to determine. Cost estimates in RODs, which are done prior to remedy design, are estimates which serve as only general indicators of potential cost.

Remediation costs for DNAPLs are primarily affected by costs involved in removing or reducing source zones and costs incurred in addressing dissolved phase plumes. Because pump-and-treat systems have often been a major part of both types of DNAPL remediations, it is useful to examine the historical experience with their costs. In reviewing historical cost data, it is important to bear in mind that the study of many existing sites is complicated by the fact that many previous pump-and-treat systems were installed and began operations before the existence of a subsurface DNAPL source zone was suspected. Thus, historical cost data from these sites may not be reflective of ultimate costs at future sites.

14.4.1 Pump-and-Treat System Costs

Historically, pump-and-treat systems have been the principal remedy at DNAPL sites. Information on the cost of pump-and-treat systems from three EPA studies provides useful insight into the potential magnitude and variability of these costs. In a 1999 study of 26 pump-and-treat remediations and two PRB systems, EPA estimated that the average capital cost for pump-and-treat systems was $3.5 million and the average annual operating cost was $670,000 (U.S. EPA 1999). Some of these expenditures may include costs for source control remedies, such as slurry walls, when the source control was an integral part of the groundwater cleanup. Comparing these costs on a per volume of water treated basis, the estimates were $250 capital and $31 O&M per 1,000 gallons per year, respectively (Exhibit 14-4). A 2001 EPA study indicated similar results (U.S. EPA 2001c).

Exhibit 14-4. Cleanup Costs for Selected Pump-and-Treat Projects

	Annual O&M Costs				Capital Costs				Millions of Gallons/Year	
	Mean (000)	Per 1,000 Gallons Annually	Median (000)	Per 1,000 Gallons Annually	Mean (000)	Per 1,000 Gallons Annually	Median (000)	Per 1,000 Gall. Ann	Mean	Med
26 Project Sample (U.S. EPA 1999) [b]										
All 26 Sites	670	31	190	18	3,500	250	1,900	96	63	21
32 Project Sample (U.S. EPA 2001c)										
All 32 sites	770	32	260	16	4,900	280	2,000	78	120	30
79 Project Sample (U.S. EPA 2001a)										
All 79 Sites	570	NA	350	NA	NA	NA	NA	NA	NA	NA
Sites with Observed NAPLs	736	NA	402	NA	NA	NA	NA	NA	NA	NA
Sites With Suspected NAPLs	568	NA	285	NA	NA	NA	NA	NA	NA	NA

b Does not include two sites where PRBs were used as the only remediation technology.
NA Not available

source: U.S. EPA. 1999. *Groundwater Cleanup: Overview of Operating Experience at 28 Sites,* EPA 542-R-99-006, Office of Solid Waste and Emergency Response, September 1999; U.S. EPA. 2001. *Groundwater Pump and Treat Systems: Summary of Selected Cost and Performance Information at Superfund-financed Sites,* EPA 542-R-01-021b, Office of Solid Waste and Emergency Response, December 2001; U.S. EPA. 2001. *Cost Analysis for Selected Groundwater Cleanup Projects: Pump and Treat Systems and Permeable Reactive Barriers,* EPA 542-R-01-013, Office of Solid Waste and Emergency Response, February 2001.

The 2001 study, which used data from the above 26 sites plus 6 additional pump-and-treat sites, indicated significant economies of scale, (decreasing cost per gallon of water treated) for systems that pump and treat up to 20 million gallons per year. As system sizes exceed 20 million gallons per year, there is little change in cost per gallon. However, because the systems studied represent several different technologies, contaminants, and site conditions, some of the variation in unit costs may be due to variations between sites using different technologies or treating for different contaminants. There were not enough data points to develop meaningful separate cost curves for each technology and set of site conditions. Nevertheless, these data imply a general tendency of decreasing unit costs up to a point. To the extent that economies of scale exist, it is likely that per gallon pump-and-treat costs at most state and private sites will probably be higher than at most Superfund, RCRA, DOD and DOE sites, which tend to be larger (Exhibit 14-5).

> Because of potential economies of scale in P&T systems, most smaller sites, such as most state sites, are likely to have higher unit P&T costs, on average, than most Superfund, RCRA, DOD, and DOE sites.

The exhibit also shows that the type of contaminant group and type of aboveground treatment affects the operating cost of a pump-and-treat system. Sites at which chlorinated solvents, alone or with other VOCs, were present had lower operating costs and capital costs than sites with other combinations of contaminants (average of $26 per 1,000 gallons per year compared to $53, and median of $12 compared to $39). Similarly, treating for chlorinated solvents, alone or with other VOCs, using air stripping or granulated activated carbon only, the average O&M cost was substantially lower than the average for sites treating for these contaminants plus other combinations of contaminants, such as solvents, BTEX, metals, PCBs, or PAHs (median of $3 per 1,000 gallons per year compared to $40).

Exhibit 14-5. Comparison of Pump-and-Treat Costs for Selected Projects

Site Characteristic	Ave. O&M Cost per Thous. Gal. Annually	Median O&M Cost per Thous. Gal. Annually	Ave. Capital Cost per Thous. Gal. Annually	Median Capital Cost per Thous. Gal. Annually
# 20 million gallons per year (14 sites)	62	42	580	440
$ 20 million gallons per year (18 sites)	10	5	49	24
Sites with chlorinated solvents alone or with other VOCs (18 sites)	26	12	3,600,000	1,900,000
Sites with other combinations of contaminants (solvents, BTEX, metals, PCBs, or PHBs) (9 sites)	53	39	8,900,000	7,400,000
Sites with chlorinated solvents alone or with other VOCs that use air stripping and/or GAC (11 sites)	NA	3	NA	NA
Sites with other combinations of treatment technologies (7 sites)	NA	40	NA	NA

Notes: GAC: Granulated activated carbon
NA: Data not available

These results should be interpreted with caution. First, the sites were not selected for this study to be a statistically representative sample of groundwater remediation projects, although they include a range of system types and situations at Superfund and RCRA Corrective Action sites. Second, the unit cost (per 1,000 gallons treated) is highly dependent on site-specific factors, such as the specific treatment technology used, complexity of the aquifer, types and mix of contaminants targeted for treatment, water and air discharge limits, and restoration goals. Third, the data are presented primarily as annual O&M costs and initial capital costs. These data are necessary, but insufficient to make decisions on selecting technologies for a given site. Decisions about which technology is less expensive are typically based on life-cycle costs. Estimating life-cycle costs requires information on the duration of the system and repair and replacement requirements in the out years, which were not available in these studies.

The third study, a 2001 EPA study of 79 Superfund-financed sites, estimated that the average annual O&M costs of a pump-and-treat system is approximately $570,000, and the median is $350,000 (U.S. EPA 2001a). This difference is due to a small number of systems with relatively high costs that raise the average. Factoring in estimated durations of the pump-and-treat systems obtained from an RPM survey, the study estimated average life-cycle cost to reach remediation completion for the average Fund-lead pump-and-treat system is approximately $10 million without discounting and $6 million with discounting (i.e., present value).[3] The study also indicated that average annual pump-and-treat cost for sites where NAPLs (the report did not differentiate between LNAPLs and DNAPLs) were observed is 29 percent higher than for all sites. Exhibit 14-4 displays the estimated average costs from these studies.

> The average life-cycle cost for pump-and-treat systems at Fund-lead sites has been estimated to be $10 million and have a net present value of $6 million. This average may be higher if systems continue to operate beyond 30 years, which is likely to be the case for sites with appreciable unaddressed NAPL contamination.
>
> The O&M costs per 1,000 gallons of water treated per year with pump-and-treat systems appears to decline with increasing volume of water treated until about 20 million gallons per year. Above 20 million gallons, there is little change in unit cost as volume increases.

In applying this information to understand the potential cost of DNAPL cleanups it is important to understand that these estimates *may understate* future costs of the systems studied. Regional staff surveyed may have assigned a default value of 30 years to systems for which the expected system duration was unknown. While the practice of using 30 years as a default value has been used in many engineering cost applications, some pump-and-treat systems may need to operate many decades, or centuries beyond. EPA guidance on cost analysis for feasibility studies states that the period of analysis "should not necessarily be limited to the commonly-used assumption of 30 years"(U.S. EPA 200b). There is an increased likelihood that, over long periods, additional maintenance and replacement of system components and reactive materials will be needed. In addition, the cost of replacing system components during the initial 30 years may have not been included. These uncounted costs may be significant.

Also not included in the above cost estimates is the potential cost of revising remedies at older sites where the original remedy design did not adequately consider the existence of free-phase or residual DNAPLs in the subsurface. The case studies indicate that there may be such situations, because the groundwater pump-and-treat systems at some sites began before the existence of subsurface DNAPL source zones were suspected.

Knowledge about the present value of the future O&M costs is an important factor in determining the balance between containment and treatment at a site. Present value estimates can be compared to the cost of additional source removal in the short term (which is usually not discounted since it is an early, short-term cost). Similar calculations might be used by state or federal regulators in ensuring that adequate funds are available to continue O&M at a site. In

[3] Because funds not spent at present can be invested at a rate that exceeds inflation, current funds can yield additional money for future expenditures, thereby making present-day dollars worth more than future dollars. As a result, future costs are often discounted and reported as present value. The discount rate, which is similar to an interest rate and differs from project to project, is primarily a function of the cost of capital to the responsible entity, or, in the case of some federal rulemakings and expenditures, a "social discount rate." The discount rate used in the 2001 study is 5 percent and all figures are reported in 2001 dollars.

addition to examining discounted costs and performance, decision makers are also advised to examine undiscounted costs in comparing alternative remedies.

The data in these studies demonstrate the highly variable nature of the costs among sites. Because of this variability and because of the small sample sizes, the estimates are presented as a general overview of pump-and-treat costs, and are not meant to be used to guide cost estimates for any specific project.

14.5 Remediation Technologies and R&D

Effectively remediating DNAPLs requires adequate means of finding and delineating them (characterization) and treating them (remediation). In the past, both characterization and remediation have tended to be expensive. As a result, many potentially responsible parties have not characterized source zones but rather have chosen dissolved plume containment while seeking a "technical impracticability waiver" for the actual cleanup of the source zone. The dissolved plume containment has generally consisted of a groundwater pump-and-treat system and more recently of some form of permeable reactive barrier (PRB) such as zero valent iron for TCE. A pump-and-treat system is relatively inexpensive to install but incurs relatively high operation and maintenance costs over the life of the system. PRBs are relatively expensive to install and their effective lifetime before requiring replacement is uncertain.

Despite the many groundwater pump-and-treat projects, many sites have not achieved cleanup goals, largely due to the infeasibility of recovering more mass by continued pump and treat. A 1994 study by the National Academy of Sciences concluded that 42 of 77 sites examined, were unlikely to achieve cleanup to drinking water standards. At 29 sites, cleanup to drinking water standards is possible but subject to significant uncertainties. For these later sites, partial cleanup was offered as a possibly more realistic scenario (NRC 1994). Without treatment of the source zone, these systems will be required to function for many years, perhaps decades or centuries at some DNAPL sites, as the sources slowly dissolve into the groundwater.

14.5.1 Site Characterization Technologies

Characterization of a DNAPL source zone has traditionally been problematic. For the most part, characterization in unconsolidated formations calls for a relatively refined description of the site stratigraphy and vertical and horizontal profiling of dissolved DNAPL concentrations in the groundwater. This characterization information, in conjunction with a knowledge of the site history, is then used to determine where to drill for the DNAPLs. Since DNAPL subsurface architecture can be very complex, with many thin lenses of pure phase with randomly occurring residual areas, continuous coring and screening/testing of the cores is a prevalent practice. When the coring is done using a hollow stem auger it is slow and costly. This cost of characterization has in some cases led to an inadequate delineation of the source area and dissolved plume and, subsequently, to the installation of containment systems that inadvertently do not address the source area nor the entire plume.

In the past ten years a number of characterization technologies have become available that greatly reduce the difficulty, and sometimes cost, of finding DNAPLs in the shallow (less than

60 feet) subsurface. Most of these advances have come as a result of direct push technology (DPT) and provide either direct in-situ sampling (near continuous groundwater sampling for vertical profiling, membrane interface probe for near continuous contaminant sampling) or in-situ measurement of contaminants (e.g., induced fluorescence, halogen probe). Also, dual tube DPT rigs can provide a relatively inexpensive way to collect continuous cores for surface contaminant screening by portable instruments and hydrophobic dye tests. The degree of characterization needed also depends on the remediation technology under consideration. However, the corollary is also true: Because they make possible more accurate delineation of contamination plumes and DNAPL source areas, the newer characterization technologies can improve the effectiveness of some of the older remediation technologies and enable the application of the newer approaches.

14.5.2 Treatment Technologies

A number of in-situ remediation technologies have recently been developed to address DNAPL contamination. These technologies generally fall into one of three categories: thermal, oxidation, or surfactant and cosolvent flushing. Thermal technologies (steam and electrical) rely on elevating the temperature of the subsurface to make the contaminants more mobile so they can be captured by collection devices. The elevated heat can also cause direct chemical destruction or destruction by hydrous pyrolysis. Since thermal technologies treat general areas, the precise location of DNAPL masses is not as important as it is for the other technologies.

Oxidation techniques rely on the injection of oxidizing chemicals, such as permanganates or hydrogen peroxide, into the subsurface where they react with the DNAPLs and destroy them. Since the main expense with oxidizing technologies is the cost of the oxidant, information on quantities of contamination and the extent of naturally-occurring oxidant demand (NOD) are important. There is a growing body of full-scale remedial experience where this very approach has been approved by regulators and resulted in the issuance of no-further action letters. Nevertheless, contact between oxidizing agents and contaminants is required for effective treatment and achieving adequate contact is problematic in low-permeability and /or heterogenous media.

Finally, flushing can be accomplished using cosolvents (alcohols), surfactants, or hot/cold water. Otherwise stationary contaminant masses are mobilized by the flushing agent and both are captured by a collection well(s). With the exception of hot/cold flushing, the above technologies have been shown to be able to capture or destroy between 60 and 90 percent of the contamination.

There is a great deal of discussion in the remediation community as to whether removal of 60 to 90 percent of a DNAPL mass is worth the cost. Because the remaining mass will continue to be a source of groundwater contamination, containment may still be needed to prevent risk of exposure. Some argue that by creatively structuring a treatment train across a site using aggressive source removal followed by downstream passive polishing techniques, such as bioremediation, natural attenuation could then be used instead of pump and treat to address the dissolved phase plume. This is an area where more research is required to determine which sources might be amenable to this approach. The research is needed to better define mass flux rates from reduced source zones and the potential for early shut down of pump-and-treat systems. There is also a need to develop better tools for both characterizing and remediating deep DNAPL sources, particularly those found in fractured bedrock.

14.5.3 Balancing Source Removal/Treatment vs. Containment

The extent to which site managers will continue to rely on containment approaches compared to source zone reduction will depend on decisions made at individual sites. These decisions will be based on technical, financial, and reuse considerations for the site, as well as regulatory requirements and policy.

Through most of the 1990s, EPA policy recognized the difficulties of remediating sites containing DNAPL source zones and associated groundwater plumes, although the Agency continued to encourage aggressive cleanup of DNAPL source areas to the extent feasible. As a result, EPA policy has incorporated an implicit presumption that removal of DNAPLs from the subsurface is not practicable in many situations. In its 1993 guidance on "technical impracticability" EPA recognized that current technology was not capable of removing DNAPL mass (U.S. EPA 1993b). EPA policy has also suggested that waivers due to technical impracticability would be a presumptive remedy at DNAPL sites (U.S. EPA 1995 and 1996). Since then, progress has been made in both site characterization and remediation technologies that can affect DNAPL site management. Improved site characterization approaches may be used to improve the effectiveness and cost of plume management and treatment and treatment of the source zone. Thus, there is a growing awareness that accelerated groundwater restoration may be cost effective at many sites.

A number of states have recognized the potential of the newer characterization and treatment tools in their regulatory policies regarding DNAPLs (ITRC 2002). They encourage the use of these tools to reduce the DNAPL source zone through removal and/or treatment of free-phase or residual DNAPLs. Their policy is to not grant ARAR waivers due to technical impracticability without serious consideration of innovative and emerging source reduction technologies.

In conjunction with the state and federal regulatory policies, remediation professionals generally compare the costs and relative effectiveness of alternative approaches to reducing risks. For most DNAPL sites, the choice will be between a high initial cost and low future annual cost, on the one hand, and lower initial costs and moderate annual O&M costs for many years, perhaps decades or centuries, on the other. This tradeoff will be influenced by the discount rate used to compare future expenses to current expenses. Although EPA guidance provides "rules of thumb" for the selection of the discount rate, decision makers may use a lower or higher discount rate if there is justification for it (U.S. EPA 2000b). Some additional critical factors to be considered include life-cycle cost of all alternatives in both discounted and undiscounted dollars, including all probable costs, such as replacement of equipment and reactive materials, projected repairs, and O&M; and probable performance of each technology considered, given the site's history, type and form of contaminants, manner and form of contaminant releases, and hydrogeologic characteristics. Regulators, responsible parties, and site owners will need to carefully structure these evaluations to ensure that funds will be available to continue O&M as long as necessary to protect human health and the environment.

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Web Sites

Chemical Oxidation Site Profiles
http://www.cluin.org/products/chemox/search/chem_search.cfm

Fractured Bedrock Site Profiles and Other Links
http://www.cluin.org/fracrock/

In Situ Thermal Treatment Site Profiles
http://www.cluin.org/products/thermal/

Remediation Technology Cost and Performance Information
http://www.frtr.gov/costperf.htm

Field Analytic Technologies Information
http://fate.clu-in.org/

Appendix A

Supporting Data for Analysis of

National Priority List Sites

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Exhibit A-1. Contaminant Groups and Subgroups for the Analysis of Contaminants at NPL and DOD Sites

This appendix contains the definitions of the chemical groups and subgroups used for the analyses of chemicals of concern found at NPL and DOD sites in chapters 3 and 6 of this report. The table on this page indicates the major chemical groups and subgroups, and the following pages list the individual chemicals that belong to each group and subgroup. This taxonomy was developed by grouping chemicals and elements in accordance with EPA test methods for evaluating solid waste and other standard chemical references listed on page A-11 of this appendix.

Breakdown of Contaminant Groups and Subgroups

Contaminant Group	Contaminant Subgroup	Individual Contaminants
1. Volatile organic compounds (VOCs)	Halogenated Non-halogenated BTEX	See pages A-4 and A-5
2. Semivolatile organic compounds (SVOCs)	Halogenated Non-halogenated PAHs Pesticides Phenols PCBs	See pages A-6 through A-10
3. Metals	No subgroup	See page A-10
4. Fuels & other petroleum distillates	Fuels and distillates Solvents	See page A-10
5. Explosives & propellants	No subgroup	See page A-11
6. Other	Miscellaneous inorganic elements and compounds Radioactive materials Other Organic (coal tar, creosote) Unspecified Solvents	See page A-11
Sources: See page A-11		

1. VOLATILE ORGANIC COMPOUNDS (VOCs)

Halogenated VOCs

1,1-Dichloroethane 75-34-3
1,1-Dichloroethene 75-35-4
1,1,1-Trichloroethane 71-55-6
1,1,1,2-Tetrachloroethane 630-20-6
1,1,2-Trichloro-1,2,2-Trifluoroethane 76-13-1
1,1,2-Trichloroethane 79-00-5
1,1,2,2-Tetrachloro-1,2-difluoroethane 76-12-0
1,1,2,2-Tetrachloroethane 79-34-5
1,2-Dibromo-3-chloropropane 96-12-8
1,2-Dibromoethane 106-93-4
1,2-Dichloro-1,1,2,2-Tetrafluoroethane 76-14-2
1,2-Dichlorobenzene 95-50-1
1,2-Dichloroethane 107-06-2
1,2-Dichloropropane 78-87-5
1,2,3-Trichloropropane 96-18-4
1,2,3-Trichlorbenzene 87-61-6
1,2,4-Trichlorobenzene 120-82-1
1,3-Dichloro-2-propanol 96-23-1
1,3-Dichlorobenzene 541-73-1
1,4-Dichlorobenzene 106-46-7
1,4-Difluorobenzene (IS) 540-36-3
2-Chloroethanol 107-07-3
2-Chloroethyl vinyl ether 110-75-8
2-Picoline 109-06-8
3-Chloropropionitrile 542-76-7 I
4-Bromofluorobenzene (surr) 460-00-4
4-Chlorophenyl phenyl ether 7005-72-3
Allyl chloride 107-05-1
Benzyl chloride 100-44-7
Bis(2-chloroethoxy)methane 111-91-1
Bis(2-chloroethyl) ether 111-44-4
Bis(2-chloroethyl)sulfide 505-60-2
Bis(2-chloroisopropyl) ether 108-60-1
Bromoacetone 598-31-2
Bromochloromethane 74-97-5
Bromodichloromethane 75-27-4
Bromoform 75-25-2
Bromomethane 74-83-9
Carbon tetrachloride 56-23-5
Chloral hydrate 302-17-0
Chlorobenzene 108-90-7
Chlorodibromomethane 124-48-1
Chloroethane 75-00-3
Chloroform 67-66-3
Chloromethane 74-87-3
Chloroprene 126-99-8
cis-1,3-Dichloropropene 10061-01-5
cis-1,4-Dichloro-2-butene 1476-11-5
cis-1,2-Dichloroethene 156-59-2
Dibromochloromethane 124-48-1
Dibromomethane 74-95-3
Dichlorodifluoromethane 75-71-8
Difluoromethane
Epichlorohydrin 106-89-8 I
Fluorobenzene (IS) 462-06-6
Hexachlorobutadiene 87-68-3
Hexachloroethane 67-72-1 I
Iodomethane 74-88-4
Methylene chloride 75-09-2
Pentachloroethane 76-01-7 I
Tetrachloroethene 127-18-4
trans-1,2-Dichloroethene 156-60-5
trans-1,3-Dichloropropene 10061-02-6
trans-1,4-Dichloro-2-butene 110-57-6
Trichloroethene 79-01-6
Trichlorofluoromethane 75-69-4
Vinyl chloride 75-01-4

Non-halogenated VOCs

110-86-1 I β-Propiolactone 57-57-8
1-Propanol 71-23-8
1,2,3,4-Diepoxybutane 1464-53-5
1,4-Dioxane 123-91-1
2-Butanone (MEK) 78-93-3
2-Hexanone 591-78-6
2-Hydroxypropionitrile 78-97-7 I
2-Nitropropane 79-46-9
2-Pentanone 107-87-9
2-Propanol 67-63-0
2,5-Dimethylbenzaldehyde 5779-94-2
4-Methyl-2-pentanone (MIBK) 108-10-1
Acetone 67-64-1
Acetonitrile 75-05-8
Acrolein (Propenal) 107-02-8
Acrylonitrile 107-13-1
Allyl alcohol 107-18-6
Benzaldehyde 100-52-7
Butanal (Butyraldehyde) 123-72-8
Carbon disulfide 75-15-0
Croton aldehyde 4170-30-3
Croton aldehyde 123-73-9
Cyclohexene 110-82-7
Cyclohexanone 108-94-1
Decanal 112-31-2
Diethyl ether 60-29-7
Ethanol 64-17-5 I
Ethyl methacrylate 97-63-2
Ethyl acetate 141-78-6 I
Ethylene oxide 75-21-8
Formaldehyde 50-00-0
Heptanal 111-71-7

Hexanal (Hexaldehyde) 66-25-1
Isobutyl alcohol 78-83-1
Isopropylbenzene 98-82-8
Isovaleraldehyde 590-86-3
m-Tolualdehyde 620-23-5
Malononitrile 109-77-3
Methacrylonitrile 126-98-7
Methane 74-82-8
Methanol 67-56-1 I
Methyl Acetate 79-20-9
Methylcyclohexane 108-87-2
Methyl methacrylate 80-62-6
Methyl-tert-butyl ether 1634-04-4
n-Butanol 71-36-3
N-Nitroso-di-n-butylamine 924-16-3
n-Propylamine 107-10-8
Naphthalene 91-20-3
Nitrobenzene 98-95-3
Nonanal 124-19-6
o-Tolualdehyde 529-20-4
o-Toluidine 95-53-4
Octanal 124-13-0
p-Tolualdehyde 104-87-0Paraldehyde 123-63-7
Pentanal (Valeraldehyde) 110-62-3
Propanal (Propionaldehyde) 123-38-6
Propargyl alcohol 107-19-7
Propionitrile (ethyl cyanide) 107-12-0
Pyridine
Styrene 100-42-5
Tetrahydrofuran 109-99-9
t-Butyl alcohol 75-65-0
Vinyl acetate 108-05-4

BTEX

Benzene 71-43-2
Toluene 108-88-3
Ethylbenzene 100-41-4
m-Xylene 108-38-3
o-Xylene 95-47-6
p-Xylene 106-42-3

Notes (VOCs):
List compiled from SW-846, CLP Target Compound List, Drinking Water Standard, Priority Pollutant List.

2. SEMIVOLATILE ORGANIC COMPOUNDS (SVOCs)

Halogenated SVOCs

1-Chloronaphthalene 90-13-1
1,2-Dibromo-3-chloropropane 96-12-8
1,2-Dichlorobenzene 95-50-1
1,2,3,4,5,6,7,8-Octachlorodibenzofuran (OCDF) 39001-02-0
1,2,3,4,5,6,7,8-Octachlorodibenzo-*p*-dioxin (OCDD) 3268-87-9
1,2,3,4,6,7,8-Heptachlorodibenzo-*p*-dioxin (HpCDD) 35822-46-9
1,2,3,4,6,7,8-Heptachlorodibenzofuran (HpCDF) 67562-39-4
1,2,3,4,7,8-Hexachlorodibenzo-*p*-dioxin (HxCDD) 39227-28-6
1,2,3,4,7,8-Hexachlorodibenzofuran (HxCDF) 70648-26-9
1,2,3,4,7,8,9-Heptachlorodibenzofuran (HpCDF) 55673-89-7
1,2,3,6,7,8-Hexachlorodibenzofuran (HxCDF) 57117-44-9
1,2,3,6,7,8-Hexachlorodibenzo-*p*-dioxin (HxCDD) 57653-85-7
1,2,3,7,8-Pentachlorodibenzo-*p*-dioxin (PeCDD) 40321-76-4
1,2,3,7,8-Pentachlorodibenzofuran (PeCDF) 57117-41-6
1,2,3,7,8,9-Hexachlorodibenzofuran (HxCDF) 72918-21-9
1,2,3,7,8,9-Hexachlorodibenzo-*p*-dioxin (HxCDD) 19408-74-3
1,2,4-Trichlorobenzene 120-82-1
1,2,4,5-Tetrachlorobenzene 95-94-3
1,3-Dichlorobenzene 541-73-1
1,4-Dichlorobenzene 106-46-7
2-Chloroaniline 101-14-4
2-Chloronaphthalene 91-58-7
2,3,4,6-Tetrachlorophenol 58-90-2
2,3,4,6,7,8-Hexachlorodibenzofuran (HxCDF) 60851-34-5
2,3,4,7,8-Pentachlorodibenzofuran (PeCDF) 57117-31-4
2,3,7,8-Tetrachlorodibenzo-*p*-dioxin (TCDD) 1746-01-6
2,3,7,8-Tetrachlorodibenzofuran (TCDF) 51207-31-9
3-(Chloromethyl)pyridine 6959-48-4
3-Methylcholanthrene 56-49-5
3,3'-Dichlorobenzidine 91-94-1
4-Bromophenyl phenyl ether 101-55-3
4-Chloro-1,2-phenylenediamine 95-83-0
4-Chloro-1,3-phenylenediamine 5131-60-2
4-Chloroaniline 106-47-8
4-Chlorophenyl phenyl ether 7005-72-3
4,4'-Methylenebis (2-chloroaniline) 101-14-4
5-Chloro-2-methylaniline 95-79-4
Bis(2-chloroethoxy)methane 111-91-1
Bis(2-chloroethyl) ether 111-44-4
Bis(2-chloroisopropyl) ether 108-60-1
Chlorobenzilate 510-15-6
p-Chloro-m-creosol
Hexachlorobenzene 118-74-1
Hexachlorobutadiene 87-68-3
Hexachlorocyclopentadiene 77-47-4
Hexachloroethane 67-72-1
Hexachlorophene 70-30-4
Hexachloropropene 1888-71-7
Hexamethylphosphoramide 680-31-9

Hydrochloride 6959-48-4
Pentachlorobenzene 608-93-5
Pentachloronitrobenzene 82-68-8
Total Heptachlorodibenzo-*p*-dioxin (HpCDD) 37871-00-4
Total Tetrachlorodibenzo-*p*-dioxin (TCDD) 41903-57-5
Total Pentachlorodibenzo-*p*-dioxin (PeCDD) 36088-22-9
Total Hexachlorodibenzo-*p*-dioxin (HxCDD) 34465-46-8
Total Tetrachlorodibenzofuran (TCDF) 55722-27-5
Total Pentachlorodibenzofuran (PeCDF) 30402-15-4
Total Hexachlorodibenzofuran (HxCDF) 55684-94-1
Total Heptachlorodibenzofuran (HpCDF) 38998-75-3
Tris(2,3-dibromopropyl) phosphate 126-72-7

Non-halogenated SVOCs

N,N-dimethylaniline 101-61-1
α,α-Dimethylphenethylamine 122-09-8
1-Acetyl-2-thiourea 591-08-2
1-Naphthylamine 134-32-7
1,2-Dinitrobenzene 528-29-0
1,2-Diphenylhydrazine 122-66-7
1,3-Dinitrobenzene 99-65-0
1,3,5-Trinitrobenzene 99-35-4
1,4-Dinitrobenzene 100-25-4
1,4-Naphthoquinone 130-15-4
1,4-Phenylenediamine 106-50-3
2-Acetylaminofluorene 53-96-3
2-Amino-4, 6-dinitrotoluene 35572-78-2
2-Aminoanthraquinone 117-79-3
4-Bromophenyl phenyl ether 101-55-3
2-Naphthylamine 91-59-8
2-Nitroaniline 88-74-4
2-Nitrotoluene 88-72-2
2-Picoline (2-Methylpyridine) 109-06-8
2,4-Diaminotoluene 95-80-7
2,4-Dinitrotoluene 121-14-2
2,4,5-Trimethylaniline 137-17-7
2,4,6-Trinitrotoluene 118-96-7
2,6-Dinitrotoluene 606-20-2
3-Amino-9-ethylcarbazole 132-32-1
3-Nitroaniline 99-09-2
3-Nitrotoluene 99-08-1
3,3'-Dimethoxybenzidine 119-90-4
3,3'-Dimethylbenzidine 119-93-7
4-Amino-2,6-dinitrotoluene 1946-51-0
4-Aminobiphenyl 92-67-1
4-Nitroaniline 100-01-6
4-Nitrobiphenyl 92-93-3
4-Nitrotoluene 99-99-0
4,4'-Methylenebis (2-chloroaniline) 101-14-4
4,4'-Oxydianiline 101-80-4
4,6-Dinitro-2-methylphenol 534-52-1
5-Nitro-o-anisidine 99-59-2
5-Nitro-o-toluidine 99-55-8
5-Nitroacenaphthene 602-87-9
5,5-Diphenylhydantoin 57-41-0
Acetophenone 98-86-2
Aminoazobenzene 60-09-3
Anilazine 101-05-3
Aniline 62-53-3
Benzidine 92-87-5
Benzoic acid 65-85-0
Benzyl alcohol 100-51-6
Bis(2-chloroethoxy)methane 111-91-1
Bis(2-chloroethyl)ether 111-44-4
Bis(2-chloroisopropyl)ether 108-60-1
Bis(2-ethylhexyl) phthalate 117-81-7
Butyl benzyl phthalate 85-68-7
Carbazole 86-74-8
Di-n-butyl phthalate 84-74-2
Di-n-octyl phthalate 117-84-0
Dibenzofuran 132-64-9
Diethyl phthalate 84-66-2
Diethyl sulfate 64-67-5
Diethylstilbestrol 56-53-1
Dihydrosaffrole 56312-13-1
Dimethyl phthalate 131-11-3
Dimethylaminoazobenzene 60-11-7
Diphenylamine 122-39-4
Ethyl methanesulfonate 62-50-0
Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX) 121-82-4
Hydroquinone 123-31-9
Isophorone 78-59-1
Isosafrole 120-58-1

Non-halogenated SVOCs (Continued)

Maleic anhydride 108-31-6
Mestranol 72-33-3
Methapyrilene 91-80-5
Methyl methanesulfonate 66-27-3
Methyl-2,4,6-trinitrophenylnitramine (Tetryl) 479-45-8
N-Nitrosodi-n-butylamine 924-16-3
N-Nitrosodi-n-propylamine 621-64-7
N-Nitrosodiethylamine 55-18-5
N-Nitrosodimethylamine 62-75-9
N-Nitrosodiphenylamine 86-30-6
N-Nitrosomethylethylamine 10595-95-6
N-Nitrosomorpholine 59-89-2
N-Nitrosopiperidine 100-75-4
N-Nitrosopyrrolidine 930-55-2
Nicotine 54-11-5
Nitrobenzene 98-95-3
Nitroquinoline-1-oxide 56-57-5
o-Anisidine 90-04-0
o-Toluidine 95-53-4
Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (HMX) 2691-41-0
Octamethyl pyrophosphoramide 152-16-9
O,O,O-Triethyl phosphorothioate 126-68-1
p-Benzoquinone 106-51-4
p-Cresidine 120-71-8
Phenacetin 62-44-2Phenobarbital 50-06-6
Phthalic anhydride 85-44-9
Piperonyl sulfoxide 120-62-7
Pronamide 23950-58-5
Propylthiouracil 51-52-5
Pyridine 110-86-1
Resorcinol 108-46-3
Tetraethyl dithiopyrophosphate 3689-24-5
Tetraethyl pyrophosphate 107-49-3
Toluene diisocyanate 584-84-9
Tri-p-tolyl phosphate 78-32-0
Trimethyl phosphate 512-56-1

Polynuclear Aromatic Hydrocarbons (PAHs)

Acenaphthene 83-32-9
Acenaphthylene 208-96-8
Anthracene 120-12-7
Benzo(a)anthracene 56-55-3
Benzo(a)pyrene 50-32-8
Benzo(b)fluoranthene 205-99-2
Benzo(j)fluoranthene 205-83-3
Benzo(k)fluoranthene 207-08-9
Benzo(ghi)perylene 191-24-2
Chrysene 218-01-9
Dibenz(a,h)acridine 226-36-8
Dibenz(a,j)acridine 224-42-0
Dibenzo(a,h)anthracene 53-70-3
Dibenzo(a,e)pyrene 192-65-4
Dibenzo(a,h)pyrene 189-64-0
Dibenzo(a,i)pyrene 189-55-9
Fluoranthene 206-44-0
Fluorene 86-73-7
Indeno(1,2,3-cd)pyrene 193-39-5
3-Methylcholanthrene 56-49-5
Naphthalene 91-20-3
Phenanthrene 85-01-8
Pyrene 129-00-0
7,12-Dimethylbenz(a)anthracene 57-97-6
2-Methylnaphthalene 91-57-6

Pesticides

α-BHC 319-84-6
α-Chlordane 5103-71-9
β-BHC 319-85-7
γ-BHC (Lindane) 58-89-9
γ-Chlordane 5103-74-2
δ-BHC 319-86-8
2,4-D 94-75-7
2,4-DB 94-82-6
2,4,5-T 93-76-5
2,4,5-TP (Silvex) 93-72-1
3-Hydroxycarbofuran 16655-82-6
4-Nitrophenol 100-02-1
4,4'-DDD 72-54-8
4,4'-DDE 72-55-9
4,4'-DDT 50-29-3
Aldicarb
Aldicarb (Temik) 116-06-3
Aldicarb Sulfone 1646-88-4
Aldicarb Sulfoxide
Aldrin 309-00-2
Aramite 140-57-8
Aspon, 3244-90-4
Atrazine 1912-24-9
Azinphos-ethyl 2642-71-9
Azinphos-methyl 86-50-0
Barban 101-27-9
Bolstar (Sulprofos) 35400-43-2
Bromoxynil 1689-84-5
Captafol 2425-06-1
Captan 133-06-2
Carbaryl (Sevin) 63-25-2
Carbofuran (Furadan) 1563-66-2
Carbophenothion 786-19-6
Chlordane - not otherwise specified 57-74-9
Chlorfenvinphos 470-90-6

Pesticides (Continued)

Chlorobenzilate 510-15-6
Chlorpyrifos 2921-88-2
Chlorpyrifos methyl 5598-13-0
Coumaphos 56-72-4
Crotoxyphos 7700-17-6
Dalapon 75-99-0
Dibromochloropropane (DBCP) 96-12-8
Demeton 8065-48-3
Diallate (cis or trans) 2303-16-4
Diazinon 333-41-5
Dicamba 1918-00-9
Dichlone 117-80-6
Dichlorofenthion 97-17-6
Dichloroprop 120-36-5
Dichlorvos (DDVP) 62-73-7
Dicrotophos 141-66-2
Dieldrin 60-57-1
Dimethoate 60-51-5
Dinocap 39300-45-3
Dinoseb 88-85-7
Dioxacarb 6988-21-2
Dioxathion 78-34-2
Diquat 2764-72-9
Diuron 330-54-1
Disulfoton 298-04-4
Endosulfan I 959-98-8
Endosulfan sulfate 1031-07-8
Endosulfan II 33213-65-9
Endrin 72-20-8
Endrin ketone 53494-70-5
Endrin aldehyde 7421-93-4
EPN 2104-64-5
Ethion 563-12-2
Ethoprop 13194-48-4
Ethyl carbamate 51-79-6
Ethyl parathion 56-38-2
Famphur 52-85-7 a
Fenitrothion 122-14-5
Fensulfothion 115-90-2
Fenthion 55-38-9
Fluchloralin 33245-39-5
Fonophos 944-22-9
Heptachlor epoxide 1024-57-3
Heptachlor 76-44-8
Hexachlorobenzene 118-74-1
Hexachlorocyclopentadiene 77-47-4
Hexamethylphosphoramide (HMPA) 680-31-9
Isodrin 465-73-6
Kepone 143-50-0
Leptophos 21609-90-5
Linuron 330-55-2
Malathion 121-75-5
MCPA 94-74-6
MCPP 93-65-2
Merphos 150-50-5
Methiocarb (Mesurol) 2032-65-7
Methomyl (Lannate) 16752-77-5
Methoxychlor 72-43-5
Methyl parathion 298-00-0
Mevinphos 7786-34-7
Mexacarbate 315-18-4
Mirex 2385-85-5
Monocrotophos 6923-22-4
Monuron 150-68-5
Naled 300-76-5
Nitrofen 1836-75-5
Parathion 56-38-2
Parathion, methyl 298-00-0
Pentachlorophenol 87-86-5
Phorate 298-02-2
Phosalone 2310-17-0
Phosmet 732-11-6
Phosphamidon 13171-21-6
Picloram 1918-02-1
Promecarb 2631-37-0
Propoxur (Baygon) 114-26-1
Ronnel 299-84-3
Rotenone 83-79-4
Safrole 94-59-7
Siduron 1982-49-6
Simazine 122-34-9
Stirophos (Tetrachlorovinphos) 22248-79-9
Strychnine 57-24-9
Sulfallate 95-06-7
Sulfotepp 3689-24-5
TEPP 21646-99-1
Terbufos 13071-79-9
Tetrachlorvinphos 961-11-5
Tetraethyl dithiopyrophosphate 3689-24-5
Tetraethyl pyrophosphate 107-49-3
Thionazin (Zinophos) 297-97-2
Thiophenol (Benzenethiol) 108-98-5
Tokuthion (Protothiofos) 34643-46-4
Toxaphene 8001-35-2
Tri-o-cresylphosphate (TOCP) 78-30-8
Triazine Herbicides (NPD only)
Trichlorfon 52-68-6
Trichloronate 327-98-0
Trifluralin 1582-09-8

Phenols

2-Chlorophenol 95-57-8
2-Cyclohexyl-4,6-dinitrophenol 131-89-5
2-Methyl-4,6-dinitrophenol 534-52-1
2-Methylphenol (o-Cresol) 95-48-7
2-Nitrophenol 88-75-5
2,3,4,5-Tetrachlorophenol 4901-51-3
2,3,4,6-Tetrachlorophenol 58-90-2
2,3,5,6-Tetrachlorophenol 935-95-5
2,4-Dichlorophenol 120-83-2
2,4-Dimethylphenol 105-67-9
2,4-Dinitrophenol 51-28-5
2,4,5-Trichlorophenol 95-95-4
2,4,6-Trichlorophenol 88-06-2
2,6-Dichlorophenol 87-65-0
3-Methylphenol (m-Cresol) 108-39-4
4-Chloro-3-methylphenol 59-50-7
4-Methylphenol (p-Cresol) 106-44-5
4-Nitrophenol 100-02-7
Dinoseb (DNBP) 88-85-7
(2-(Sec-butyl)-4,6-dinitrophenol)
Pentachlorophenol 87-86-5
Phenol 108-95-2 DC(28)

Polychlorinatedbiphenyls (PCBs)

Aroclor 1016 12674-11-2 -
Aroclor 1221 11104-28-2 -
Aroclor 1232 11141-16-5 -
Aroclor 1242 53469-21-9 -
Aroclor 1248 12672-29-6 -
Aroclor 1254 11097-69-1 -
Aroclor 1260 11096-82-5 -
2-Chlorobiphenyl 2051-60-7 1
2,3-Dichlorobiphenyl 16605-91-7 5
2,2',5-Trichlorobiphenyl 37680-65-2 18
2,4',5-Trichlorobiphenyl 16606-02-3 31
2,2',3,5'-Tetrachlorobiphenyl 41464-39-5 44
2,2',5,5'-Tetrachlorobiphenyl 35693-99-3 52
2,3',4,4'-Tetrachlorobiphenyl 32598-10-0 66
2,2',3,4,5'-Pentachlorobiphenyl 38380-02-8 87
2,2',4,5,5'-Pentachlorobiphenyl 37680-73-2 101
2,3,3',4',6-Pentachlorobiphenyl 38380-03-9 110
2,2',3,4,4',5'-Hexachlorobiphenyl 35065-28-2 138
2,2',3,4,5,5'-Hexachlorobiphenyl 52712-04-6 141
2,2',3,5,5',6-Hexachlorobiphenyl 52663-63-5 151
2,2',4,4',5,5'-Hexachlorobiphenyl 35065-27-1 153
2,2',3,3',4,4',5-Heptachlorobiphenyl 35065-30-6 170
2,2',3,4,4',5,5'-Heptachlorobiphenyl 35065-29-3 180
2,2',3,4,4',5',6-Heptachlorobiphenyl 52663-69-1 183
2,2',3,4',5,5',6-Heptachlorobiphenyl 52663-68-0 187
2,2',3,3',4,4',5,5',6-Nonachlorobiphenyl 40186-72-9

3. METALS

Aluminum
Antimony
Arsenic
Barium
Beryllium
Boron
Cadmium
Calcium
Chromium
Cobalt
Copper
Iron
Lead
Lithium
Magnesium
Manganese
Mercury
Molybdenum
Nickel
Potassium
Selenium
Silver
Sodium
Strontium
Thallium
Tin
Vanadium
Zinc

Note (metals):
The above are either TAL metals, drinking water primary or secondary metals, or have toxicity values associated with the Region 9 preliminary cleanup goals list

4. FUELS AND OTHER PETROLEUM DISTILLATES

Diesel Fuel
Gasoline
JP-4
JP-5
Kerosene
No. 2 Fuel oil
Unspecified fuel

Solvents

Mineral Spirits
Stoddard solvent

5. EXPLOSIVES AND PROPELLANTS

Explosives
Propellants

6. OTHER WASTES

Miscellaneous Inorganic Elements and Compounds (Misc. Organics)

Ammonia
Asbestos
Copper Chromated Arsenic
Chloride
Hydrazine
Hydrofluoric acid
Inorganic cyanides
Nitrate
Nitrite
Perchlorate
Phosphine
Phosphorus
Silicon tetrafluoride
Sulfides

Radioactive Materials

Americium
Cesium 137 Cobalt 60
Curium
Iodine 131
Lead 210
Neptunium
Plutonium
Polonium 210
Radium
Radon
Strontium 90
Technetium
Thorium
Tritium
Uranium

Other Organic Substances

Coal Tar
Creosote
Unspecified organic materials
Unspecified solvents

7. REFERENCES

Greenberg, A. et al., editors. 1985. *Standard Methods for the Examination of Water and Wastewater*, American Public Health Association.

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Exhibit A-2. Superfund Remedial Action Contractors (RACs)

Region 1

Tetra Tech NUS, Inc.
55 Jonspin Road
Wilmington, MA 01887
Contact: George Gardner
508-658-7899
email: bbrd680@b-r.com

Metcalf and Eddy, Inc.
30 Harvard Mill Square
P.O. Box
Wakefield, MA 01880
Contact: Neville Chung
617-224-6385
email: neville_chung@metcalfeddy.com

Region 2

Foster Wheeler Environmental Corp.
1000 The American Road
Morris Plains, NJ 07950
Contact: William Colvin
973-630-8554
email: wcolvin@fwenc.com

CDM Federal Programs Corp.
125 Maiden Lane - 5th Floor
New York, NY 10038
Contact: Robert Goltz
212-785-9123
email: goltz.rd@cdm.com

Region 3

Tetra Tech NUS, Inc.
661 Andersen Drive
Pittsburgh, PA 15220
Contact: Don Senovich
412-921-7090
email: dsenovich@b-r.com

Tetra Tech/Black and Veatch (joint venture)
56 West Main Street
Christiana, DE 19702
Contact: Dr. Carl Hsu
302-738-7551
email: carl.hsu@tetratech.com

CDM Federal Programs Corp.
13135 Lee Jackson Memorial Highway
Suite 200
Fairfax, VA 22033
Contact: Joan Knapp
703-968-0200 ex. 358
email: knappjo@cdm.com

Region 4

Black & Veatch Special Project Corp.
1145 Sanctuary Parkway, Suite 475
Alpharetta, GA 30004
Contact: Harvey B. Coppage
770-751-7517
email: coppagehb@bv.com

Region 5

CH2MHILL
135 South 84th St., Suite 325
Milwaukee, WI 53214
Contact: Isaac Johnson
414-272-2426
email: ijohnson@ch2m.com

Weston Solutions, Inc.
750 E. Bunker Court, Suite 500
Vernon Hills, IL 60061-1450
Contact: James M. Burton
847-918-4000
email: james.burton@westonsolutions.com

Region 6

CH2MHILL
10th Floor
12377 Merit Drive
Dallas, TX 75251
Contact: Al Sloan
972-980-2170
email: asloan@ch2m.com

Tetra Tech Environmental Management, Inc.
1 Dallas Center
350 N. St. Paul St., Suite 2600
Dallas, TX 75201
Contact: Lou Barinka
214-740-2014
email: barinkal@ttemi.com

Region 7

Black & Veatch
6601 College Blvd.
Overland Park, KS 66211
Contact: Ray Herzog
913-458-6600
email: herzogrh@bv.com

Region 8

CDM Federal Programs
1331 17th Street, Suite 1050
Denver, CO 80202
Contact: Richard Culver
303-295-1237
email: culverrl@cdm.com

Region 9

CH2MHILL
155 Grand Avenue, Suite 1000
Oakland CA 94612
Contact: Udai Singh
510-587-7555
email: usingh@ch2m.com

Region 10

URS Greiner, Inc.
2401 4th Avenue, Suite 1000
Seattle, WA 98121-1459
Contact: Vivianne Larkin
206-674-1871
email: vivianne_larkin@urscorp.com

Appendix B

Supporting Data for Analysis of

Underground Storage Tank Sites

Exhibit B-1. UST Corrective Action Measures Mid-Year FY 2004 (As of March 31, 2004)

Region/ State	Active Tanks	Closed Tanks	Confirmed Released	Cleanups Initiated	Cleanups Completed	Cleanup Backlog	Emergency Responses
Region One							
CT	12,358	191 49	2,388	2,344	1,538	850	110
MA	11,489	21,689	5,958	5,745	4,525	1,433	4,868
ME	3,443	11,963	2,080	2,029	1,948	132	370
NH	3,027	10,639	2,141	2,141	1,292	849	606
RI	1,720	7,041	1,199	1,199	942	257	26
VT	2,967	5,104	1,897	1,885	1,086	811	261
Subtotal	35,004	75,585	15,663	15,343	11,331	4,332	6,241
Region Two							
NJ	18,836	52,720	9,257	8,400	5,466	3,791	51
NY	29,683	78,126	19,719	19,130	17,264	2,455	410
PR	4,684	5,202	999	843	380	619	168
VI	124	278	14	14	0	14	14
Subtotal	53,327	136,326	29,989	28,387	23,110	6,879	643
Region Three							
DC	723	2,998	781	781	528	253	228
DE	1,560	6,378	2,204	2,142	1,889	315	390
MD	9,369	27,639	11,999	10,420	8,661	3,338	330
PA	26,739	57,841	13,445	13,331	9,090	4,355	28
VA	28,024	48,907	9,988	9,714	9,083	905	63
WV	6,267	18,198	2,801	2,632	1,584	1,217	9
Subtotal	72,682	161,961	41,218	39,020	30,835	10,383	1,048
Region Four							
AL	18,194	28,236	10,688	10,587	8,987	1,701	276
FL	32,786	91,252	25,220	14,012	7,606	17,614	204
GA	38,725	43,707	10,443	9,904	7,321	3,122	10
KY	13,452	34,284	12,744	12,739	10,176	2,568	148
MS	8,994	21,351	6,357	6,207	6,061	296	114
NC	30,932	61,902	23,090	22,290	16,053	7,037	503
SC	12,325	30,999	8,490	8,101	4,912	3,578	94
TN	16,550	31,726	12,359	11,697	11,092	1,267	68
Subtotal	171,958	343,457	109,391	95,537	72,208	37,183	1,417

Exhibit B-1. UST Corrective Action Measures (Continued) Mid-Year FY 2004 (As of March 31, 2004)

Region/ State	Active Tanks	Closed Tanks	Confirmed Released	Cleanups Initiated	Cleanups Completed	Cleanup Backlog	Emergency Responses
Region Five							
IL	23,373	60,961	21,895	20,499	13,158	8,737	1,755
IN	14,299	34,673	7,943	6,994	4,347	3,596	226
MI	21,493	63,453	20,242	19,867	11,296	8,946	87
MN	14,077	28,025	9,311	8,816	8,054	1,257	432
OH	24,758	41,311	23,288	22,891	19,698	3,590	417
WI	14,149	63,672	18,038	17,123	14,464	3,574	388
Subtotal	112,149	292,095	100,717	96,190	71,017	29,700	3,305
Region Six							
AR	9,952	19,554	1,205	927	877	328	12
LA	14,913	30,709	2,595	1,894	1,584	1,011	691
NM	4,189	12,086	2,419	1,660	1,502	917	79
OK	11,890	23,908	3,902	3,902	3,395	507	89
TX	58,218	106,926	23,585	21,499	18,186	5,399	500
Subtotal	99,162	193,183	33,706	29,882	25,544	8,162	1,371
Region Seven							
LA	7,846	21,699	5,708	5,492	3,603	2,105	0
KS	7,556	19,055	4,526	4,255	2,438	2,088	115
MO	10,328	27,847	5,995	5,621	4,562	1,433	329
NE	6,962	13,926	5,890	3,837	3,524	2,366	10
Subtotal	32,692	82,527	22,119	19,205	14,127	7,992	454
Region Eight							
CO	8,225	20,453	6,291	6,066	5,241	1,050	41
MT	3,584	12,894	3,045	2,289	1,880	1,165	48
ND	2,194	6,892	811	800	756	55	3
SD	3,084	6,522	2,307	2,258	2,039	268	21
UT	4,042	12,355	4,038	3,852	3,518	520	3
WY	2,073	7,695	1,978	1,212	955	1,023	62
Subtotal	23,202	66,811	18,470	16,477	14,389	4,081	178

Exhibit B-1. UST Corrective Action Measures (Continued)
Mid-Year FY 2004 (As of March 31, 2004)

Region/ State	Tanks	Closed Tanks	Confirmed Released	Cleanups Initiated	Cleanups Completed	Cleanup Backlog	Emergency Responses
Region Nine							
AZ	8,303	19,584	8,085	5,550	5,512	2,573	2
CA	41,005	117,655	42,487	42,487	27,245	15,242	0
HI	1,835	4,921	1,776	1,680	1,414	362	0
NV	3,695	6,613	2,420	2,410	2,133	287	52
CNMI	79	19	9	8	2	7	0
GU	280	398	132	132	108	24	0
AS	12	52	7	7	6	1	1
Subtotal	55,209	149,242	54,916	52,274	36,420	18,496	55
Region Ten							
AK	1,086	6,151	2,300	2,163	1,292	1,008	95
ID	3,527	9,169	1,315	1,284	1,135	180	12
OR	6,629	25,861	6,760	6,407	5,167	1,593	56
WA	9,939	35,014	5,977	5,742	3,956	2,021	37
Subtotal	21,181	76,195	16,352	15,596	11,550	4,802	200
Regional Corrective Actions for Indian Country							
Region 1	4	2	0	0	0	0	0
Region 2	179	21	7	1	0	7	2
Region 3	NA	NA	NA	NA	NA	NA	NA
Region 4	58	55	10	10	4	6	0
Region 5	374	996	191	188	124	67	0
Region 6	301	195	34	34	30	4	1
1Region 7	88	91	20	15	8	12	0
Region 8	571	1,885	436	397	215	221	5
Region 9	708	1,165	181	136	101	80	0
Region 10	400	846	148	142	112	36	0
Subtotal	2,683	5,256	1,027	923	594	433	8

National Totals

	Active Tanks	Closed Tanks	Confirmed Released	Cleanups Initiated	Cleanups Completed	Cleanup Backlog	Emergency Responses
National Total	679,249	1,582,638	443,568	408,834	311,125	132,443	14,920

Source: U.S. Environmental Protection Agency, Office of Underground Storage Tanks, *Semi-Annual Activity Report, First Half (March 31, 2004)*. http://www.epa.gov/swerust1/cat/camarchv.htm

Appendix C

Supporting Data for Analysis of

Department of Defense Sites

Exhibit C-1: Location of DOD Sites Needing Cleanup

EPA Region	State	DOD Installations	DOD Sites	Army Sites	Navy Sites	Air Force Sites	DLA Sites	FUDS Sites
One	CT	16	51	7	27	8	0	9
	MA	56	153	34	10	56	0	53
	ME	39	67	1	9	15	0	42
	NH	9	36	6	10	17	0	3
	RI	27	60	9	15	1	0	35
	VT	5	10	0	0	5	0	5
	Subtotal	152	377	57	71	102	0	147
Two	NJ	44	268	173	32	19	1	4
	NY	89	260	60	6	80	8	106
	PR	12	60	0	48	2	0	10
	VI	1	1	0	0	0	0	1
	Subtotal	146	589	233	86	101	9	160
Three	DC	29	63	3	26	7	0	27
	DE	7	44	0	0	39	0	5
	MD	30	357	174	140	26	4	13
	PA	34	135	73	19	10	10	23
	VA	43	318	62	202	20	9	25
	WV	6	39	0	13	0	1	25
	Subtotal	149	956	312	400	102	24	118
Four	AL	24	217	180	0	18	0	19
	FL	96	462	0	161	217	0	84
	GA	26	163	75	10	64	0	14
	KY	8	74	63	3	0	0	8
	MS	24	61	0	16	25	0	20
	NC	31	168	15	82	45	0	26
	SC	29	163	19	68	53	0	23
	TN	21	140	46	16	24	39	15
	Subtotal	259	1,448	398	356	446	39	209
Five	IL	55	247	89	23	69	0	66
	IN	18	124	62	33	10	0	19
	MI	31	120	0	0	80	0	40
	MN	10	37	20	3	5	0	9
	OH	33	148	35	0	50	1	62
	WI	19	36	9	0	11	0	16
	Subtotal	166	712	215	59	225	1	212
Six	AR	11	49	12	0	19	0	18
	LA	13	31	5	1	11	7	7
	NM	124	184	20	0	32	0	132
	OK	41	123	25	0	47	0	51
	TX	125	359	67	48	122	1	121
	Subtotal	314	746	129	49	231	8	329

Exhibit C-1: Location of DOD Sites Needing Cleanup (Continued)

EPA Region	State	DOD Installations	DOD Sites	Army Sites	Navy Sites	Air Force Sites	DLA Sites	FUDS Sites
Seven	IA	8	33	23	0	2	0	8
	KS	55	164	83	0	8	0	73
	MO	24	85	22	0	37	0	26
	NE	41	69	3	0	17	0	49
	Subtotal	128	351	131	0	64	0	156
Eight	CO	28	226	154	1	47	0	24
	MT	6	18	0	0	12	0	6
	ND	3	6	1	0	5	0	0
	SD	19	30	0	0	11	0	19
	UT	24	227	159	0	35	6	27
	WY	21	37	0	0	17	0	20
	Subtotal	101	544	314	1	127	6	96
Nine	AS	6	6	0	0	0	0	6
	AZ	87	140	39	2	20	0	79
	CA	402	2,011	68	653	830	44	416
	CN	15	18	0	0	0	0	18
	GM	13	14	0	0	0	0	14
	GU	8	49	0	28	21	0	0
	HI	73	251	12	109	67	0	63
	JQ	2	8	0	0	7	0	0
	MQ	1	1	0	1	0	0	0
	NV	29	78	18	20	11	0	29
	WQ	1	37	0	0	37	0	0
	Subtotal	637	2,613	137	813	993	44	625
Ten	AK	120	454	24	0	293	0	137
	ID	9	32	0	17	8	0	7
	OR	17	33	4	0	14	0	15
	WA	36	119	25	41	31	0	22
	Subtotal	182	638	53	58	346	0	181
Total		2,234	8,974	1,979	1,893	2,737	131	2,233

Notes:
- Needing Cleanup means sites that have not achieved Response Complete (RC) status.
- The column for DOD Installations and Sites includes one Defense Threat Reduction Agency (DTRA) site at Johnston Atoll (JQ).
- JQ = Johnston Atoll; AS = American Samoa; GM/GU = Guam; WQ = Wake Island; MQ = Midway; CN = Marianas; VI = Virgin Islands.

Source: DOD, Office of the Under Secretary of Defense (Installations & Environment), Restoration Management Information System (RMIS), data as of September 2001.

Exhibit C-2: Definitions of DOD Site Types

Site Type	Site Description	Primary Contaminants
Underground Storage Tank	Underground storage tank sites result from the release of substances from underground storage tanks and any associated piping.	• POLs • Solvents • POL sludges • Metals
Spill Area	Spill areas are small areas where spills from drums, tanks, and other waste units have taken place.	• POLs • Sludge • PCBs • Metals • Solvents
Landfill	Landfill sites are typically areas formerly used to dispose of both domestic and industrial hazardous waste.	• POLs • Pesticides • Solvents • Metals Paint • Ord. compounds
Unexploded Munitions/Ordnance Area	Unexploded munitions and ordnance areas are areas that have been used for munitions and ordnance training.	• UXO • Explosive chemicals • Metals • Ord. compounds
Surface Disposal Area	Surface disposal area sites consist of small areas formerly used for disposal of solid wastes with little or no free liquids. Typical materials include rags, filters, paint cans, small capacitors, and batteries.	• POLs • Metals • Solvents • Acids • Paints • PCBs • Pesticides
Disposal Pit/Dry Well	Disposal pit/dry well sites consist of small unlined excavations and structures that were used over a period of time to dispose of small quantities of liquid wastes.	• POLs • Acids • Metals • Solvents • Ordnance compounds • Explosive chemicals
Storage Area	Storage areas are areas where spills and leaks occurred from stored containers or equipment.	• POLs • Metals • Solvents • Acid • POL sludge • PCBs
Contaminated Groundwater	Contaminated groundwater results from various types of releases of known or unknown origin, such as migration of leachate from disposal areas and migration of substances from contaminated surface and subsurface soils.	• Metals • POLs • Chlorinated solvents • Explosive chemicals • Non-chlorinated solvents

Exhibit C-2: Definitions of DOD Site Types (Continued)

Site Type	Site Description	Primary Contaminants
Fire/Crash Training Area	Fire and crash rescue training areas consist of trenches and/or pits where flammable materials were ignited periodically for demonstrations and training exercises.	• POLs • Solvents • POL sludges • Metals
Building Demolition/ Debris Removal	Building demolition and debris removal sites consist of buildings and/or debris that are unsafe or must be removed.	• Asbestos • Lead paint • Construction debris
Surface Impoundment/ Lagoon	Surface impoundments and lagoons consist of unlined depressions, excavations, or diked areas which were used to accumulate liquid waste, waste containing free liquid, or industrial wastewaters.	• POLs • Solvents • Metals • Ord. compounds • Explosive chemicals • Industrial wastewater
Aboveground Storage Tanks	Aboveground storage tank sites result from release of substances to surrounding areas from aboveground tanks, containers, and any associated piping.	• POLs
Contaminated Fill	Contaminated fill areas consist of contaminated material resulting from excavations for construction, tanks, and other purposes.	• POLs • Metals • Explosive chem. • Paint waste • Ordnance compounds
Contaminated Building	Contaminated building sites result from releases within or on the outside of a structure of a substance that has been contained within the building.	• POL • Plating waste • Metals • POL sludge • PCBs • Asbestos • Propellants • Pesticides • Solvents • Acids
Burn Area	Burn area sites consist of pits or surface areas that were used for open-air incineration of waste.	• POLs • Propellants • Solvents • Explosives • Ordnance
Contaminated Sediments	Contaminated sediments include sediments of bodies of water that have been contaminated by surface runoff, subsurface migration, or direct discharge of contaminants.	• POLs • PCBs • Pesticides • Metals • Solvents • Explosive chem.

Exhibit C-2: Definitions of DOD Site Types (Continued)

Site Type	Site Description	Primary Contaminants
Explosive/Ordnance Disposal Area	Explosive ordnance disposal areas consist of open-air areas that were used to detonate, demilitarize, bury, or dispose of explosives.	• Unexploded • Ordnance (UXO) • Ordnance compounds • Explosive chemicals • Metals
Waste Line	Waste lines are underground piping used to carry industrial wastes from shop facilities to a wastewater treatment plant.	• Solvents • Plating sludges • Explosive chemicals • Metals • Pesticides
Waste Treatment Plant	Wastewater treatment plant sites result from releases of substances at plants that were used to treat and dispose of domestic and/or industrial wastewater.	• POLs • Solvents • Plating sludges • Explosive chemicals • Industrial wastewater
Sewage Treatment Plant	Sewage treatment plants typically consist of a complex of tanks, piping, and sludge management areas used to treat sanitary sewage generated at an installation. The unit may use chemical or biological treatment methods. Lagoons associated with the biological treatment of sewage currently may be considered to be separate units.	• Metals • Industrial wastewater • Solvents • POLs
Petroleum, Oil, Lubricant (POL) Distribution Line	Petroleum, oil, lubricant distribution lines are used to transport POL products from storage to dispensing facilities.	• POLs • POL sludge
Underground Storage Tank Farm	Underground storage tank farm sites result from the release of substances from multiple, typically large, underground storage tanks and associated piping which make up a tank farm complex.	• POLs • POL sludges • Solvents • Metals
Firing Range	Firing ranges consist of large areas of land used for practice firing of large artillery or mortars, or as a practice bombing range for aircraft. These areas are typically contaminated with unexploded ordnance, which may be found on and below the ground surface.	• Metals • Ord. compounds • Explosives • Radionuclides • UXO
Soil Contaminated After Tank Removal	This unit consists of soil that has been removed during a tank removal operation and staged prior to treatment.	• POLs • POL sludge

Exhibit C-2: Definitions of DOD Site Types (Continued)

Site Type	Site Description	Primary Contaminants
Storm Drain	Storm drains typically consist of a natural or man-made drain used as a runoff control structure for rainfall. The unit also may be used from runoff from other sources such as process operations. Man-made units may be concrete lined.	• POLs • Metals • POL sludge • Pesticides • Industrial wastewater • Solvents
Oil/Water Separator	Oil/water separators are typically small units that skim oil from storm-water runoff. The oil/water separator consists of the unit, and any associated piping.	• POLs • Solvents • Industrial wastewater • PCBs
Maintenance Yard	Maintenance yards consist of paved or unpaved areas where vehicles and other maintenance equipment is stored and often serviced. Typically, maintenance supplies are stored at these units.	• POLs • Metals • Solvents
Low-level Radioactive Waste Area	Low-level radioactive waste areas consist of areas used to store or dispose of low-level radioactive materials of various types (for example, radium paint, and radioactive instruments and propellants).	• Low-level radioactive waste
Washrack	Washrack sites typically consist of a building designed for washing vehicles such as tanks, aircraft, and other military vehicles. This unit also may consist of a paved area where washing of vehicles occurs.	• POLs
Drainage Ditch	Drainage units typically consist of a natural or a man-made ditch used as a runoff control structure for rainfall. The unit also may be used for runoff from other sources such as process operations. Man-made units may be concrete lined.	• POLs • Solvents • Explosive chemicals • Metals • PCBs
Small Arms Range	Small arms ranges are typically located outdoors and used for target practice of small arms, usually 50 caliber or less. The unit may include a soil or sandbag berm, or hill located behind the targets to prevent bullets from traveling outside the range area.	• Metals • Ordnance compounds
Incinerator	Incinerators typically consist of a furnace and stack unit used for a variety of disposal activities including the incineration of medical waste, or an installation's dunnage. These units vary in size and may either be freestanding or part of other operations such as hospitals.	• Ash • Metals • Ordnance compounds

Exhibit C-2: Definitions of DOD Site Types (Continued)

Site Type	Site Description	Primary Contaminants
Contaminated Soil Piles	This unit consists of soil that has been staged after an excavation activity.	• POLs • Sludge • Metals • Solvents • PCBs • Ord. compounds
Mixed Waste Area	Mixed waste areas consist of areas used to store or dispose of hazardous wastes that have been mixed with or contaminated by radioisotopes.	• Solvents • Mixed waste
Pistol Range	Pistol ranges may be located indoors or outdoors and are used for target practice. Outdoor units include a soil or sandbag berm located behind the targets to prevent bullets from traveling outside the range area.	• Metals
Chemical Disposal	Chemical disposal units are areas that have been used for the disposal of chemicals, typically of an unknown type. The unit may be a burial area where bottles or packages of chemicals were placed or an area where liquids were disposed of on the soil.	• POLs • Metals • Solvents • Explosive chemicals
Pesticide Shop	Pesticide shops typically are used to store and prepare large volumes of pesticides and solvents for maintenance. The units may be located in a freestanding building or attached to another building. Areas near the unit may have been used for the disposal of off-specification pesticides.	• Pesticides • Metals • POLs
Industrial Discharge	Industrial discharge units consist of a pipe system used to discharge industrial effluent to the environment. The unit may discharge to a natural or man-made water body, dry creek bed or some other natural feature.	• Metals • Industrial wastewater
Surface Runoff	Surface runoff is an area with runoff from rain which may occur anywhere within a facility, particularly adjacent to industrial areas and airfield aprons.	• POLs • Metals • Solvents • Explosive chemicals
Leach Field	Leach fields typically consist of a subsurface area generally associated with septic tanks. The unit serves the purpose of biologically treating sanitary sewage, however, in cases where these units were used at industrial facilities, there also is contamination from non-biodegradable industrial contaminants.	• Metals • Solvents

Exhibit C-2: Definitions of DOD Site Types (Continued)

Site Type	Site Description	Primary Contaminants
Plating Shop	Plating shops typically consist of a building or room within a building used for coating metal parts. The unit contains several tanks of solvents which are used in the plating process.	• Metals • Solvents • Acids • Industrial wastewater
Sewage Effluent Settling Pond	Sewage effluent settling ponds consist of a lagoon used for the settling of solids and/or biological treatment of sewage. The units also may be used as infiltration galleries.	• Metals • Ordnance compounds • Solvents
Dip Tank	Dip tanks are typically metal or concrete units located in coating shops that range in size from 50 to more than 500 gallons. The tanks are used to clean parts prior to treatment, or to coat parts with various materials including metals and plastics.	• POLs • Chlorinated solvents • Metals • Acids

Notes: POLs = Petroleum, oil, lubricants and POL sludge; PCB = Polychlorinated Biphenyls; Ord. = Ordnance

Source: DOD, Office of the Deputy Under Secretary of Defense (Environmental Security), Defense Environmental Restoration Program Annual Report to Congress, for Fiscal Year 2001, Appendix G.

Exhibit C-3: DOD Site Types Needing Cleanup

Site Type	Army	Navy	Air Force	DLA	FUDS	Total
Spill Site Area	145	151	789	9	12	1,107
Landfill	300	231	373	8	62	974
Underground Storage Tanks	75	237	311	14	203	840
Other	25	38	1	4	666	734
Unexploded Munitions and Ordnance Area	48	24	17	0	499	588
Surface Disposal Area	110	246	179	8	20	563
Storage Area	171	190	77	21	18	477
Contaminated Groundwater	143	65	44	16	150	418
Disposal Pit and Dry Well	97	65	216	24	12	414
Fire/Crash Training Area	29	59	153	1	7	249
Surface Impoundment/Lagoon	97	37	25	2	13	174
Aboveground Storage Tank	26	52	40	1	48	167
Explosive Ordnance Disposal Area	51	32	12	0	68	163
Burn Area	93	31	10	0	20	159
Contaminated Buildings	105	32	5	2	12	156
Building Demolition/Debris Removal	7	11	22	5	111	151
Contaminated Sediments	38	63	16	0	33	150
POL (Petroleum/Oil/Lubricants) Lines	12	38	77	2	8	137
Firing Range	17	3	8	0	76	104
Contaminated Fill	18	12	5	3	61	99
Industrial Discharge	66	11	11	0	3	91
Storm Drain	2	13	70	1	2	88
Waste Lines	22	38	25	0	2	87
Chemical Disposal	48	6	20	0	6	80
Soil Contamination After Tank Removal	10	7	6	5	52	80
Maintenance Yard	26	31	18	1	2	78
Underground Tank Farm	14	43	14	0	7	78
Waste Treatment Plant	29	18	26	0	3	76
Oil/Water Separator	10	13	30	0	0	53
Sewage Treatment Plant	11	5	26	0	2	44
Drainage Ditch	13	11	18	1	1	44
Small Arms Range	10	4	12	0	17	43
Mixed Waste Area	5	20	8	0	8	41
Washrack	23	4	13	0	1	41
Radioactive Waste Area	5	2	26	0	6	39
Contaminated Soil Piles	14	7	4	0	12	37

Exhibit C-3: DOD Site Types Needing Cleanup (Continued)

Site Type	Army	Navy	Air Force	DLA	FUDS	Total
Leach Field	19	8	7	1	0	35
Incinerator	18	6	2	0	3	29
Pesticide Shop	10	9	5	0	1	25
Surface Runoff	5	1	8	1	2	17
Plating Shop	2	13	2	0	0	17
Dip Tank	3	4	4	0	0	11
Pistol Range	6	1	1	1	2	1
Sewage Effluent Settling Ponds	1	1	1	0	2	5
Total	1,979	1,893	2,737	131	861	8,974

Note 1: The column for Total DOD includes one Defense Threat Reduction Agency (DTRA) site at Johnston Atoll (JQ).
Note 2: Needing cleanup is interpreted as sites that have not achieved Response Complete (RC) status.

Source: DOD, Office of the Deputy Under Secretary of Defense (Installations & Environment), Restoration Management Information System (RMIS), data as of September 2001

Exhibit C-4: Frequency of Matrices by DOD Site Type

Site Type	No. of Sites with Data	Ground-water	Soil	Surface Water	Sediment
Spill Site Area	874	507	681	105	114
Landfill	850	629	630	229	217
Surface Disposal Area	512	271	420	82	112
Underground Storage Tanks	459	366	280	23	32
Storage Area	417	176	379	41	57
Disposal Pit and Dry Well	352	223	266	54	74
Contaminated Groundwater	321	288	172	53	45
Fire/Crash Training Area	208	176	176	40	40
Surface Impoundment/Lagoon	156	105	110	44	62
Burn Area	146	89	133	30	35
Contaminated Buildings	145	68	131	11	23
Contaminated Sediments	132	49	70	39	73
Other	121	56	102	16	20
Aboveground Storage Tank	106	51	94	7	8
POL (Petroleum/Oil/Lubricants) Lines	103	75	69	3	9
Explosive Ordnance Disposal Area	91	49	81	19	14
Contaminated Fill	85	44	80	13	16
Industrial Discharge	79	60	60	19	30
Waste Lines	76	51	56	6	12
Waste Treatment Plant	68	41	52	4	13
Maintenance Yard	68	33	60	4	10
Chemical Disposal	67	38	57	6	11
Underground Tank Farm	66	61	37	7	9
Storm Drain	63	44	28	14	17
Soil Contamination After Tank Removal	57	43	48	5	3
Unexploded Munitions and Ordnance Area	54	30	44	12	10
Oil/Water Separator	45	25	39	3	7
Drainage Ditch	38	16	23	10	10
Washrack	36	26	30	6	5
Contaminated Soil Piles	35	16	34	3	2
Sewage Treatment Plant	34	19	31	6	6
Mixed Waste Area	32	15	26	5	7
Leach Field	28	20	20	2	2
Incinerator	27	9	26	2	3
Radioactive Waste Area	23	12	22	3	2
Pesticide Shop	23	12	23	1	4
Firing Range	23	5	22	2	0

Exhibit C-4: Frequency of Matrices by DOD Site Type (Continued)

Site Type	No. of Sites with Data	Ground-water	Soil	Surface Water	Sediment
Small Arms Range	22	7	20	1	2
Building Demolition/Debris Removal	22	6	20	1	2
Plating Shop	16	16	15	2	2
Surface Runoff	14	8	9	4	4
Dip Tank	11	3	11	0	0
Pistol Range	9	3	8	0	2
Sewage Effluent Settling Ponds	5	5	4	1	1
Total	6,119	3,846	4,699	938	1,127

Notes: The numbers in this table represent only those sites for which media data is available. The total count for a site type may exceed the number of sites with data for the site type because a site may have more than one contaminated matrix. The total includes 1 DTRA site.

Source: OD, Office of the Deputy Under Secretary of Defense (Installations & Environment), Restoration Management Information System (RMIS), Data as of September 2001.

Exhibit C-5: Frequency of Major Contaminant Groups by Matrix and DOD Component

Component	Contaminant Group	Ground-water	Sediment	Soil	Surface Water	Total All Media	% Sites w/Data
Army	VOCs	696	80	389	114	900	49%
	SVOCs	410	217	792	110	1065	57%
	Metals	724	315	1135	225	1447	78%
	Other	345	118	340	86	672	36%
	Explosives and Propellants	124	17	142	28	234	13%
	No Group Determined	0	0	0	0	0	0%
	VOCs & SVOCs	74	11	63	10	140	8%
	VOCs & Metals	197	17	61	32	279	15%
	SVOCs & Metals	90	123	362	49	519	28%
	VOCs, SVOCs, & Metals	180	43	188	44	331	18%
	No. Sites with Data	1114	389	1458	279	1854	
Navy	VOCs	877	147	734	108	1240	68%
	SVOCs	610	249	862	115	1165	64%
	Metals	785	295	1043	192	1341	74%
	Other	587	218	638	123	930	51%
	Explosives and Propellants	44	15	49	13	90	1%
	No Group Determined	0	1	7	0	8	0%
	VOCs & SVOCs	95	9	81	8	169	9%
	VOCs & Metals	172	16	84	34	269	15%
	SVOCs & Metals	70	116	268	35	418	23%
	VOCs, SVOCs & Metals	419	118	397	58	649	36%
	No. Sites with Data	1096	331	1417	229	1812	
Air Force	VOCs	1059	117	784	204	1458	75%
	SVOCs	447	192	680	108	947	49%
	Metals	699	222	859	213	1231	63%
	Other	441	91	329	87	690	35%
	Explosives and Propellants	15	2	11	3	27	1%
	No Group Determined	2	0	0	0	2	0%
	VOCs & SVOCs	132	21	113	17	249	13%
	VOCs & Metals	227	12	124	70	374	19%
	SVOCs & Metals	44	105	178	43	308	16%
	VOCs, SVOCs, & Metals	242	58	268	42	470	24%
	No. Sites with Data	1321	305	1385	321	1945	

Exhibit C-5. Frequency of Major Contaminant Groups by Matrix and DOD Component (Continued)

Component	Contaminant Group	Ground-water	Sediment	Soil	Surface Water	Total All Media	% Sites w/Data
DLA	VOCs	21	2	16	1	33	41%
	SVOCs	5	9	33	1	41	51%
	Metals	8	2	52	4	59	74%
	Other	6	1	8	1	15	19%
	Explosives and Propellants	0	0	1	0	1	1%
	No Group Determined	0	0	0	0	0	0%
	VOCs & SVOCs	4	2	1	0	7	9%
	VOCs & Metals	5	0	3	1	8	10%
	SVOCs & Metals	0	1	20	1	22	28%
	VOCs, SVOCs, & Metals	1	0	6	0	7	9%
	No. Sites with Data	23	10	65	4	80	
FUDS	VOCs	211	29	181	33	290	68%
	SVOCs	119	51	208	34	263	62%
	Metals	207	79	295	93	337	79%
	Other	87	23	99	26	155	36%
	Explosives and Propellants	25	4	31	7	45	11%
	No Group Determined	0	0	0	0	0	0%
	VOCs & SVOCs	33	2	31	2	57	13%
	VOCs & Metals	68	4	41	11	110	26%
	SVOCs & Metals	18	36	76	22	117	27%
	VOCs, SVOCs & Metals	63	21	81	13	123	29%
	No. Sites with Data	292	91	373	104	427	
Total DOD	VOCs	2864	375	2104	460	3921	64%
	SVOCs	1591	718	2575	368	3481	57%
	Metals	2423	913	3384	727	4415	72%
	Other	1466	451	1414	323	2462	40%
	Explosives and Propellants	208	38	234	51	397	6%
	No Group Determined	2	1	7	0	10	0%
	VOCs & SVOCs	338	45	289	37	622	10%
	VOCs * Metals	669	49	313	148	1040	17%
	VOCs, SVOCs & Metals	905	240	940	157	1580	26%
	No. Sites with Data	3846	1126	4698	937	6118	

Notes:
- FUDS = Formerly Used Defense Sites; DLA - Defense Logistics Agency; VOCs - Volatile Organic Compounds; SVOCs = Semivolatile Organic Compounds.
- The total amount for a matrix or contaminant groups may exceed the number of sites with data, because a site may have more than one contaminant group or contaminated matrix.
- Source: DOD, Office of the Deputy Under Secretary of Defense (Installations & Environment), Restoration Management Information System (RMIS), data as of September 2001.

Exhibit C-6: Frequency of Major Contaminant Groups by DOD Site Type

Site Type	Total No. of Sites	No. of Sites w/Data	VOCs	Metals	SVOCs	Other	Explosives & Propellants	No Group Determined
Spill Site Area	1,107	874	619	478	462	274	35	0
Landfill	974	850	535	748	516	444	45	1
Underground Storage Tanks	840	459	408	219	213	130	4	1
Other	734	121	75	90	74	45	12	0
Unexploded Munitions and Ordnance Area	588	54	26	47	34	28	18	0
Surface Disposal Area	563	512	289	402	282	225	25	0
Storage Area	477	417	215	300	266	161	10	2
Contaminated Groundwater	418	321	271	203	143	127	15	0
Disposal Pit and Dry Well	414	352	231	273	208	154	14	0
Fire/Crash Training Area	249	208	178	168	153	118	7	1
Surface Impoundment/Lagoon	174	156	83	142	95	90	34	0
Aboveground Storage Tank	167	106	77	60	53	27	3	0
Explosive Ordnance Disposal Area	163	91	26	79	53	35	33	0
Burn Area	159	146	82	120	99	68	41	0
Contaminated Buildings	156	145	53	111	101	43	25	0
Building Demolition/Debris Removal	151	22	4	20	16	11	2	0
Contaminated Sediments	150	132	52	110	87	57	12	0
POL (Petroleum/Oil/Lubricants) Lines	137	103	89	56	63	30	2	0
Firing Range	104	23	5	21	8	7	2	0
Contaminated Fill	99	85	46	67	54	25	2	0
Industrial Discharge	91	79	44	55	56	31	18	2
Storm Drain	88	63	47	46	28	32	0	1
Waste Lines	87	76	42	65	43	31	10	1
Chemical Disposal	80	67	32	54	18	16	5	0
Soil Contamination After Tank Removal	80	57	48	33	31	22	2	0
Maintenance Yard	78	68	50	44	34	31	0	0
Underground Tank Farm	78	66	64	40	43	18	0	0
Waste Treatment Plant	76	68	40	56	48	31	6	0
Oil/Water Separator	53	45	35	35	26	22	0	0
Drainage Ditch	44	38	19	26	22	9	3	0
Sewage Treatment Plant	44	34	20	24	18	8	0	0
Small Arms Range	43	22	4	22	4	8	0	0
Mixed Waste Area	41	32	17	27	21	16	0	0
Washrack	41	36	23	30	19	13	1	0

Exhibit C-6: Frequency of Major Contaminant Groups by DOD Site Type (Continued)

Site Type	Total No. of Sites	No. of Sites w/Data	VOCs	Metals	SVOCs	Other	Explosives & Propellants	No Group Determined
Radioactive Waste Area	39	23	4	8	7	20	1	0
Contaminated Soil Piles	37	35	11	31	15	12	2	0
Leach Field	35	28	12	22	12	8	1	1
Incinerator	29	27	7	21	8	7	3	0
Pesticide Shop	25	23	8	16	21	8	1	0
Plating Shop	17	16	12	16	9	12	1	0
Surface Runoff	17	14	8	9	9	3	1	0
Dip Tank	11	11	5	10	4	3	0	0
Pistol Range	11	9	1	9	2	2	0	0
Sewage Effluent Settling Ponds	5	5	4	2	3	1	1	0
TOTAL	8,974	6,119	3,921	4,415	3,481	2,463	397	10

Notes [a] Number of sites needing remediation; data were available for 6,119 of the sites needing remediation, including 1 DTRA site.
POL = petroleum, oil, lubricant
The total count for a site type may exceed the number of sites with data for the site type, because a site may have more than one contaminant group.

Source: DOD, Office of the Deputy Under Secretary of Defense (Installations & Environment), Restoration Management Information System (RMIS), data as of September 2001.

Exhibit C-7. Frequency of Contaminant Subgroup by Matrix Percent of Sites With Data

Contaminant Sub Group	Ground-water	GW %	Sediment	Sediment %	Soil	Soil %	Surface Water	SW %
Metals	2423	63.00	913	81.01	3384	72.02	727	77.51
Halogenated VOCs	2151	55.93	211	18.72	1052	22.39	333	35.50
BTEX	1465	38.09	151	13.40	1218	25.92	144	15.35
Miscellaneous Inorganic Elements and Compounds (Misc. Organics)	1418	36.87	449	39.84	1361	28.96	316	33.69
Non-halogenated VOCs	1307	33.98	263	23.34	1282	27.28	184	19.62
Non-halogenated SVOCs	847	22.02	242	21.47	973	20.71	189	20.15
Polynuclear Aromatic Hydrocarbons (PAHs)	638	16.59	445	39.49	1450	30.86	80	8.53
Pesticides	458	11.91	369	32.74	988	21.03	147	15.67
Phenols	315	8.19	84	7.45	218	4.64	62	6.61
Halogenated SVOCs	288	7.49	58	5.15	214	4.55	27	2.88
Explosives and Propellants	208	5.41	38	3.37	234	4.98	51	5.44
Polychlorinated biphenyls (PCBs)	84	2.18	165	14.64	602	12.81	29	3.09
Radioactive Materials	46	1.20	3	0.27	42	0.89	6	0.64
Other	18	0.47	2	0.18	25	0.53	1	0.11
Other Organic (Coal Tar, Creosote)	10	0.26	4	0.35	6	0.13	4	0.43
No Group Determined	2	0.05	1	0.09	7	0.15	0	0.00

Notes: VOC = Volatile Organic Compound; SVOC - Semivolatile Organic Compound; BTEX = Benzene, Toluene, Ethylbenzene, Xylenes; Data were available for 6,119 sites

Source: DOD, Office of the Under Secretary of Defense (Installations & Environment), Restoration Management Information System (RMIS), data as of September 2001.

Appendix D

Supporting Data for Analysis of

Manufactured Gas Plant Sites

Exhibit D-1. Estimated Disposition of Former Manufactured Gas Plants & Other Coal Tar Sites in the U.S.

Site Type [a]	Number of Sites						Estimated Current Land Use of Site			
	Original Sites	Sites With Releases	Sites Previously NFRAPD[b]	In State Cleanup Program	Studied and Rem-ediated	Not Yet Inves-tigated	Industrial/ Commercial	Resi-dential	Recrea-tional	Vacant
Commercial MGPs	3,500	3,500	<700	>175	<350	2,275+	2,450	350	350	350
District Gas Holders	500-1,500	500-1,500	25-75+	0	<25-75	450-1,350+	300-900+	75-225	75-225	<50-150
Rail Yard Pintsch Oil-Gas Plants	100-150	100-150	<5-7	<5-7	<5-7	>85-129	85-127+	<5-7	<5-7	<5-7
Military Gas Plants	150-250	150-250	0	0	0	150-250-	120-200+	<7-12	<15-25	<7-12
Ice & Refrigeration Plants w/Gas Producer	200-400	150-300	7-15	0	0	143-285	90+	<5	0+	<5
Institutional Gas Machines	5,000-10,000	2,500-5,000	125-250	0	0+	2,375-4,750	>75	<10	<5	5
Domestic/Residen-tial Gas Machines	10,000-15,000	10,000-15,000	0	0	<200-300	9,800-14,700+	0	9,000-13,500	<500-750	500-750
Captive Gas Producers - Pressure & Suction	11,000-15,000	11,000-15,000	<550-750	0	<550-750	9,900-13,500	>8,800-12,000	<550-750	<550-750	1,100-1,500
Bottled Gas Plants	100	50	0	0	<2	50	>80	<5	<5	10
Kerosene Refiners	100-150	100-150	<5-7	0	<2-3	93-140+	>90-135	<5-7	0+	10-15
Compressed Fuel Briquette Plants	100	50	0	0	0	50	>95	0	0	<5
Beehive Coke Works	2,000-4,000	2,000-4,000	<100-200	0	<100-200	>1,800-3,600	200-400	100-200	100-200	1,400-2,800

Exhibit D-1. Estimated Disposition of Former Manufactured Gas Plants & Other Coal Tar Sites in the U.S. (Continued)

Site Type [a]	Number of Sites						Estimated Current Land Use of Site			
	Original Sites	Sites With Releases	Sites Previously NFRAPD[b]	in State Cleanup Program	Studied and Remediated	Sites Not Yet Investigated	Industrial/ Commercial	Residential	Recreational	Vacant
Merchant & Utility Coke Works	250-300	250-300	25-30	25-30	75-90	125-150	225-285	0	0	<12-15
Charcoal Plants	2,000-3,000	2,000-3,000	<100-150	0	<100-150	1,800-2,700	900-1,350	100-150	100-150	900-1,350
Tar Distilleries	200-400	200-400	20-40	10-20	10-20	160-320	160-320	10-20	10-20	20-40
WWI Federal Wood Tar Distillation Plants	11	11	0	0	<5	6	95	<5	<5	<5
WWI Federal Toluene Plants	10	10	0	0	<5	5	95	<5	<5	<5
Wood Preservation Plants	800-1,000	800-1,000	240-300	<80-100	<40-50	440-550	640-800	40-50	40-50	80-100
U.S. BOM Coal Gasification Plants	37-55	37-55	2-3	2-3	0	33-49	17-25	0	0	17-25
U.S. DOE Coal Gasification Plants	63-75	63-75	3-4	3-4	0	57-67	28-34	0	0	28-34
Total	36,121-55,001	33,471-49,801	1,907-2,531	300-339	1,469-2,007	29,975-44,926	14,545-19,556	10,272-15,300	1,765-2,547	4,509-7,291

Notes: Volume of releases includes present-day bodies of contaminated soil in the subsurface, not otherwise visible at ground surface

a See Exhibit 10-1 for definitions

b No Further Remedial Action Planned

Source: Allen W. Hatheway, "Estimated Number of Manufactured Gas and Other Coal-Tar Sites in the United States," *Environmental Engineering Geoscience*, Vol. III, No. 1, Spring 1997, pp. 141-142 and personal communication with the author, February-March 2003. The data are based on Dr. Hatheway's database on MGPs which includes information on approximately 7,000 sites, assembled from *Brown's Directory of North American Gas Plants*, historic gas industry literature, Sandborn Fire Insurance maps, state agencies, and direct on-site observations.

Exhibit D-2
Estimated Typical Remediation Cost by Site Type

Site Type	Range of Site Size	Number of Sites Not Investigated	Typical Contaminants &Contaminated Media [a]	Release Volume Per Site (000) [b]	Ave. Remediation Cost Per Site ($ Millions)
Commercial MGPs	small - 1-3 acres medium - 3-10 acres large - 10-100 acres	2,275+	Soil: Tars stored in subsurface vessels or discharged to surface/subsurf. Spent Box Waste. PAH- cont. solid waste.	2,000-50,000 m^3	small - 3.0 - 5.0 medium - 4.0 - 10.0 large - 10.0 - 100.0
District Gas Holders	1-4 acres	450-1350+	Soil: Leaks in below-ground holders. Tars in abandoned subsurface. Holder tanks - basins pits.	100-500 m^3	0.25 - 1.5
Rail Yard Pintsch Oil-Gas Plants	0.5-1.5 acre	95-142	Soil: Dumped sludge & lampblack	500-10,000 m^3	0.5 - 5.0
Military Gas Plants	0.5-1.5 acre	150-250	Soil: Tars stored in subsurface vessels and discharged to surface/subsurf. . Spent Box Waste. PAH - cont. solid waste.	500-1,000 m^3	1.0 - 4.0
Ice & Refrigeration Plants with Gas Producers	1-2 acres	147-294	Soil: Tars stored in subsurface vessels and discharged to surface/subsurf.	500-1,000 m^3	0.5 - 1.5
Institutional Gas Machines	500-1500 ft^2	2,450-4,900	Soil	<100 m^3	0.2 - 0.75
Domestic Residential Gas Machines	400-1000 ft^2	9,800-14,700	Soil	<50 m^3	0.05

Exhibit D-2
Estimated Typical Remediation Cost by Site Type (Continued)

Site Type	Range of Site Size	Number of Sites Not Investigated	Typical Contaminants &Contaminated Media [a]	Release Volume Per Site (000) [b]	Ave. Remediation Cost Per Site ($ Millions)
Captive Gas Producers (Pressure & Suction)	20/30 to 50x600 ft	10,450-14,250	Soil: Tars stored in subsurface vessels and discharged to surface/subsurf. Spent Box Waste. PAH cont. solid waste.	100-10,000 m^3	1.0 - 10.0
Bottled Manufactured Gas Plants	1-3 acres	50	Soil: Tars stored in subsurface vessels & discharged to surface/subsurf. Spent Box Waste.	100-500 m^3	0.2 - 0.5
Kerosene Refiners	1-2 acres	95-142	Soil: Tars stored in subsurface vessels & discharge to surface/subsurf.. Filtration sludges from recovery	100-1,000 m^3	1.0 -5.0
Compressed Fuel Briquette Plants	1-2 acres	50	Soil: Tars stored in subsurface vessels & discharged to surface/subsurf.. Coal, coke, lampblack, fines secondarily cont. w/PAH.	100-1,000 m^3	0.5 - 1.0
Beehive Coke Works	40-100 acres	1,900-3,800	Tar &/or light oil in soil. PAH-cont. solid waste.	1,000-10,000 m^3	0.5 - 2.0
Merchant & Utility Coke Works	40-100 acres	100-120	Soil: Tars stored in subsurface vessels & discharged to surface/subsurface. Spent Box Waste. PAH-contaminated solid waste.	5,000-100,000 m^3	10.0 - 100.0

Exhibit D-2
Estimated Typical Remediation Cost by Site Type (Continued)

Site Type	Range of Site Size	Number of Sites Not Investigated	Typical Contaminants &Contaminated Media [a]	Release Volume Per Site (000) [b]	Ave. Remediation Cost Per Site ($ Millions)
Charcoal Plants	10-100 acres	1,900-2,850	Tars and/or light oil in soil. PAH-contaminated solid waste.	1,000-5,000 m^3	0.5 - 2.0
Tar Distilleries	10-100 acres	150-300	Soil: Tars stored in subsurface vessels & discharged to surface/subsurf. Filtration sludges from recovery process.	1,000-100,000 m^3	10.0 - 100.0
WWI Federal Wood Tar Distillation Plants[c,,d]	40-200 acres	11	Soil: Tars stored in subsurface vessels & discharged to surface/subsurf. Filtration sludges from recovery process.	1,000-10,000 m^3	1.01 - 2.0
WWI Federal Toluene Plants[c,d]	80-200 acres	10	Soil: Tars stored in subsurface vessels & discharged to surface/subsurf. Filtration sludges from recovery process. PAH-contaminated solid waste.	1,000-10,000 m^3	1.0 - 5.0
Wood Preservation Plants	10-200 acres	480-600	Soil: Tars stored in subsurface vessels, discharged to surface/subsurf, or in abandoned lagoons; PAH-contaminated solid waste.	1,000-10,000 m^3	5.0 - 20.0

Exhibit D-2
Estimated Typical Remediation Cost by Site Type (Continued)

Site Type	Range of Site Size	Number of Sites Not Investigated	Typical Contaminants &Contaminated Media [a]	Release Volume Per Site (000) [b]	Ave. Remediation Cost Per Site ($ Millions)
U.S. Bureau of Mines - Coal Gasification Plants[c]	10-40 acres	33-49	Soil: Tars stored in subsurface vessels. Tars discharged to surface/subsurface. PAH-contaminated solid waste.	500-1,000 m^3	1.0 - 2.0
U.S. Department of Energy - Coal Gasification Plants[c]	10-40 acres	57-67	Soil: Tars stored in subsurface vessels. Tars discharged to surface/subsurface. PAH-contaminated solid waste.	500-1,000 m^3	1.0 - 2.0

Assumptions:
- Cleanup cost estimates are inferred from sites that have been fully characterized, based on knowledge of actual site operation history and reasonable exploration of depth and breadth of subsurface conditions reflecting the presence of MGP residuals.
- Estimates do not consider the presence of post-operational contaminants not typically associated with MGP operations.
- Estimates do not reflect the costs of litigation judgements involving human health and gas works hazardous or toxic residuals at sites.
- It is assumed that 35% of the commercial plants are small, 35% are medium, and 30% are large, and that the average high-estimate costs for these size groups are $4 million, $7 million, and $13 million, respectively.

Footnotes:

a This table includes nominal groundwater contamination primarily associated with LNAPLs. It does not include solids lodged in the matrix of an aquifer (DNAPLs). Sites with solids lodged in the aquifer are difficult to predict, highly site specific, and potentially very costly to remediate.

b Volume of releases consider only highly-contaminated soil requiring direct or indirect treatment on site or placement in a RCRA Class C facility. Other more lightly contaminated soils are expected to be present and possibly subject to placement in a RCRA Class D facility.

c Estimates are based on analogous sites.

d These plants were constructed as a WWI emergency measure. Some were barely operational at war's end. Others were operated after the war for commercial purposes and will bear higher remediation costs.

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Appendix E

Federal and State Agency Programs

State and Federal Agency Contacts

EPA Regional Offices

EPA Region 1 (ME, NH, VT, MA, RI, CT)
http://www.epa.gov/region01/

EPA Region 2 (NY, NJ, PR, VI).
http://www.epa.gov/Region2/

Region 3 (PA, DE, DC, MD, VA, WV).
http://www.epa.gov/region03/

EPA Region 4 (KY, TN, NC, SC, MS, AL, GA, FL). http://www.epa.gov/region4/

EPA Region 5 (MN, WI, IL, MI, IN, OH).
http://www.epa.gov/Region5/

EPA Region 6 (NM, TX, OK, AR, LA).
http://www.epa.gov/earth1r6/

EPA Region 7 (NE, KS, IA, MO).
http://www.epa.gov/region07/

EPA Region 8 (MT, ND, WY, SD, UT, CO). http://www.epa.gov/region08/

EPA Region 9 (CA, NV, AZ, HI).
http://www.epa.gov/region09/

EPA Region 10 (WA, OR, ID, AK).
http://www.epa.gov/r10earth/

State Agencies

Links to U.S. states and territories
http://www.epa.gov/epaoswer/osw/stateweb.htm

RCRA State Authorizaton Status
http://www.epa.gov/epaoswer/hazwaste/state/stats/stats_bystate.htm

UST State and Territory Program Directory
http://www.epa.gov/swerust1/states/statcon1.htm

Civilian Federal Agencies

Department of Agriculture
http://www.nrcs.usda.gov/

Agricultural Research Service
http://www.ars.usda.gov/

U.S. Forest Services
http://www.fs.fed.us/

National Resources Conservation Service
http://www.nrcs.usda.gov

United States Geological Survey
http://toxics.usgs.gov/topics/remediation.html

Department of Interior
National Park Service
http://www.nps.gov/

Fish and Wildlife Service
http://www.fws.gov/

Bureau of Land Management
http://www.blm.gov/nhp/index.htm

Office of Surface Mining
http://www.osmre.gov/

Bureau of Reclamation
http://www.usbr.gov/main/index.html

Bureau of Indian Affairs
http://www.doi.gov/bureau-indian-affairs.html

Office of Environmental Policy and Compliance
Solid and Hazardous Materials Management Team
http://www.doi.gov/oepc/shazmat.html

Natural Resource Damage Assessment and Restoration Program
http://restoration.doi.gov/

United States postal Service
http://www.usps.com/

National Aeronautics and Space Administration (NASA)
http://www.hq.nasa.gov/office/codej/codeje/je_site/about_us/about_us.html

Tennessee Valley Authority
http://www.tva.gov/environment/envservices/index.htm

Department of Transportation
http://www.dot.gov/

Department of the Treasury
http://www.treas.gov/

Department of Veterans Affairs
http://www.va.gov/

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Appendix F
Acronyms

ACSIM	Assistant Chief of Staff for Installation Management (DOD)
A&E	Architectural and Engineering
AFCEE	Air Force Center for Environmental Excellence
AFSBED	Air Force Small Business Environmental Database
ANPR	Advanced Notice of Public Rulemaking
ARARs	Applicable or relevant and appropriate requirements
ASTM	American Society of Testing Materials
ASTSWMO	Association of State and Territorial Solid Waste Management Officials
ATSDR	Agency for Toxic Substances and Disease Registry
BCP BRAC	Cleanup Plan
BCT BRAC	Cleanup Team
BEMR	Baseline Environmental Management Report
BLM	Bureau of Land Management
BRAC	Base Realignment and Closures
BTEX	Benzene, Toluene, Ethylbenzene, and Xylene
CA	Cooperative Agreement
CA RCRA	Corrective Action Program under the Resource Conservation and Recovery Act
CAMU	Corrective Action Management Unit
CBO	Congressional Budget Office
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CERCLIS	CERCLA Information System
CERFA	Community Environmental Response Facilitation Act
CFAs	Civilian Federal Agencies
CFR	Code of Federal Regulations
CHF	Central Hazardous Materials Fund (DOI)
CHP	Central Hazardous Materials Fund
CIC	Community Involvement Coordinator
CID	Central Internet Database (DOE)
CLU-IN	Clean-Up Information System
CMI	Corrective Measures Implementation (RCRA)
CMS	Corrective Measures Study (RCRA)
CSM	Conceptual Site Model
CRADA	Cooperative Research and Development Agreement (DOE)
CWA	Clean Water Act
D&D	Deactivation and Decommissioning
DERA	Defense Environmental Restoration Account
DERP	Defense Environmental Restoration Program
DLA	Defense Logistics Agency
DNAPL	Dense Non-Aqueous Phase Liquid
DOD	Department of Defense
DOE	Department of Energy
DOI	Department of Interior
DOT	Department of Transportation
DQO	Data Quality Objectives
DRE	Destruction and Removal Efficiency

DSMOA	Defense and State Memorandum of Agreement
DTRA	Defense Threat Reduction Agency
EBS	Environmental Baseline Survey
ECR	Environmental Compliance and Restoration Program (NASA)
EM	Environmental Management
EMSP	Environmental Management Science Program
EOU	Excess, Obsolete or Unserviceable
EPA	Environmental Protection Agency
ERRS	Emergency and Rapid Response Services
ESTCP	Environmental Security Technology Certification Program
FAA	Federal Aviation Administration
FR	Federal Register
FRTR	Federal Remediation Technologies Roundtable
FUDS	Formerly Used Defense Sites
FUSRAP	Formerly Utilized Sites Remedial Action Program
FY	Fiscal Year
GAC	Granulated Activated Carbon
GAO	General Accounting Office
GPRA	Government Performance and Results Act
GWRTAC	Groundwater Remediation Technologies Analysis Center
HMMA	Hazardous Materials Management Appropriations
HMMP	Hazardous Materials Management Program (USDA)
HMPC	Hazardous Materials Policy Council (USDA)
HRS	Hazard Ranking System (Superfund)
HSWA	Hazardous and Solid Waste Amendments of RCRA
HWIR-Media	Hazardous Waste Identification Rule - Media
IAG	Interagency Agreement
IRP	Installation Restoration Program (DOD)
LDRs	Land Disposal Restrictions
LM	Office of Legacy Management (DOE)
LNAPLs	Light Non-Aqueous Phase Liquids
LTTD	Low Temperature Thermal Desorption
LUSTs	Leaking Underground Storage Tanks
MAP	Management Action Plan
MCL	Maximum Contaminant Level
MGP	Manufactured Gas Plant
MMRP	Military Munitions Response Program
MNA	Monitored Natural Attentuation
MTBE	Methyl Tertiary-butyl Ether
MTRs	Minimum Technology Requirements
MWTP	Mine Waste Technology Program
NABIR	Natural and Accelerated Bioremediation Research Program
NACEPT	National Advisory Council for Environmental Policy and Technology
NAPLs	Non-Aqueous Phase Liquids
NASA	National Aeronautics and Space Administration
NAVFAC	Naval Facilities Engineering Command
NCP	National Oil and Hazardous Substances Contingency Plan

NELP	Naval Environmental Leadership Program
NEPA	National Environmental Policy Act
NETAC	National Environmental Technologies Applications Center
NETL	National Energy Technologies Laboratory
NETTS	National Environmental Technology Test Sites Program
NFESC	Naval Facilities Engineering Service Center
NFRAP	No Further Action Planned
NMLRC	National Mine Land Reclamation Center
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
NTIS	National Technical Information Services
O&M	Operations and Maintenance
OB	Open Burn
OD	Open Detonation
ODUSD (I&E)	Office of Deputy Undersecretary of Defense (Installations & Environment)
OERR	Office of Emergency and Remedial Response
OPA	Oil Pollution Act
ORD	Office of Research and Development
OSM	Office of Surface Mining
OSMRE	Office of Surface Mining Reclamation and Enforcement
OSW	Office of Solid Waste
OSWER	Office of Solid Waste and Emergency Response
OU	Operable Unit
OUST	Office of Underground Storage Tanks
PA	Preliminary Assessment
PAHs	Polynuclear Aromatic Hydrocarbons
PCBs	Polychlorinated Biphenyls
PCE	Perchloroethylene
PFP	Pay for Performance
POL	Petroleum, Oil, and Lubricants
PRP	Potentially Responsible Party
P&T	Pump and Treat
RA	Remedial Action
RAB	Restoration Advisory Board
RACS	Remedial Action Contracting Strategy
RAP	Remedial Action Plan
RBCA	Risk-Based Corrective Action
RC	Response Complete (DOD)
RCAID	RCRA Action Implementation Database
RCRA	Resource Conservation and Recovery Act of 1976
RCRA CA	RCRA Corrective Action Program
RD	Remedial Design
RD&D	Research, Development and Demonstrations
RFA	RCRA Facility Assessment
RFI	RCRA Facility Investigation
RFP	Request for Proposals
RIA	Regulatory Impact Analysis
RI/FS	Remedial Investigation and Feasibility Study
RIP	Remedy In Place (DoD)
RIS	RCRA Implementation Study
RMIS	Restoration Management Information System (DOD)
ROD	Record of Decision

RP	Responsible Party
RPM	Remedial Project Manager
RTDF	Remediation Technologies Development Forum
SARA	Superfund Amendment and Reauthorization Act of 1986
SBIR	Small Business Innovation Research
SCRD	State Coalition for Remediation of Drycleaners
SERDP	Strategic Environmental Research and Development Program
SI	Site Inspection
SITE	Superfund Innovative Technology Evaluation
S&M	Surveillance and Maintenance
SMCRA	Surface Mining Control and Reclamation Act
S/S	Solidification/Stabilization
StATS	State Authorization Tracking System
STTR	Small Business Technology Transfer
SVE	Soil Vapor Extraction
SVOC	Semi-Volatile Organic Compound
SWMU	Solid Waste Management Unit
TCE	Trichloroethylene
TIO	Technology Innovation Office
T&M	Time and Materials
TRU	Transuranic
TSDF	Treatment, Storage, and Disposal Facility
UMTRA	Uranium Mill Tailings Remedial Action
USACE	United States Army Corps of Engineers
USAEC	United States Army Environmental Center
USDA	United Department of Agriculture
USFS	United States Forest Service
USGS	United States Geological Survey
UST	Underground Storage Tanks
UV	Ultraviolet
UXO	Unexploded Ordnance
VCP	Voluntary Cleanup Program
VEB	Vertical Engineered Barrier
VOC	Volatile Organic Compound
WFO	Work for Others
WMM	Waste Military Munitions