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Office of Solid Waste and
Emergency Response
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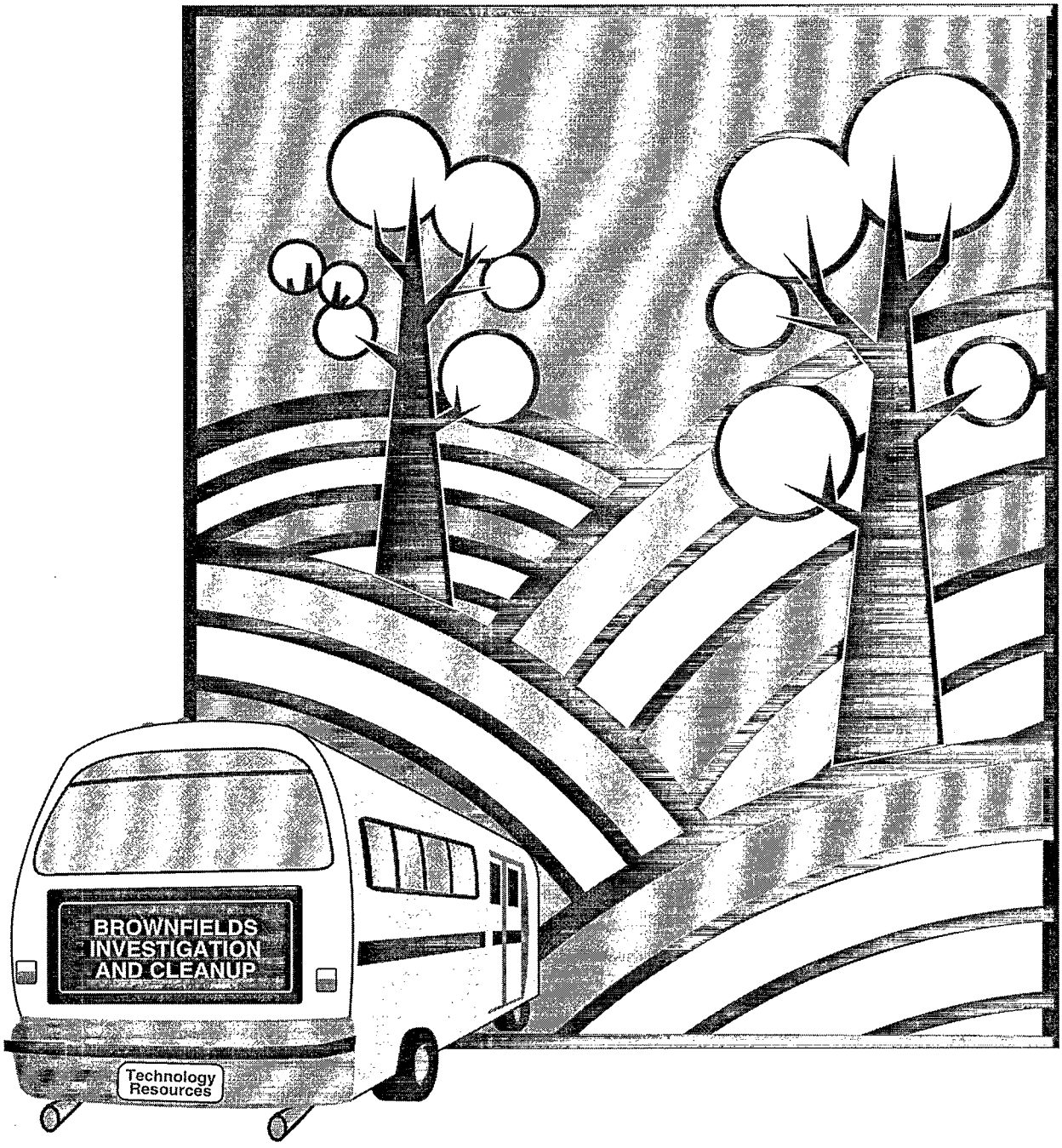
Road Map to Understanding Innovative Technology Options for Brownfields Investigation and Cleanup



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Road Map to Understanding Innovative Technology Options for Brownfields Investigation and Cleanup

U.S. Environmental Protection Agency
Office of Solid Waste and Emergency Response
Technology Innovation Office
Washington, DC 20460

NOTICE

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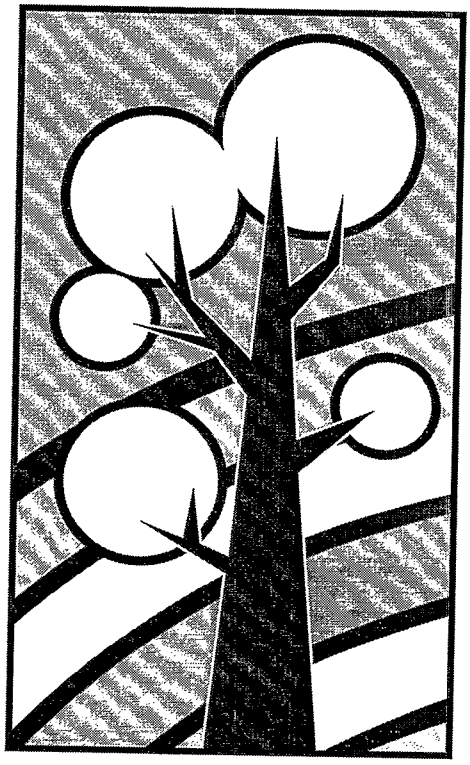
BACKGROUND

The U.S. Environmental Protection Agency (EPA) has defined Brownfields sites as "abandoned, idled, or under-used industrial and commercial facilities where expansion or redevelopment is complicated by real or perceived environmental contamination." EPA established its Brownfields Economic Redevelopment Initiative to empower states, communities, and other stakeholders involved in economic revitalization to work together to accomplish the redevelopment of such sites. Many states and local jurisdictions also help business and communities adapt environmental cleanup programs to the special needs of Brownfields sites.



Preparing Brownfields sites for productive reuse requires the integration of many elements—financial issues, community involvement, liability considerations, environmental assessment and cleanup, regulatory requirements, and more—as well as coordination among many groups of stakeholders. The assessment and cleanup of a site must be carried out in a way that integrates all those factors into the overall redevelopment process. In addition, the cleanup strategy will vary from site to site. At some sites, cleanup will be completed before the property is transferred to new owners. At other sites, cleanup may take place simultaneously with construction and redevelopment activities. Regardless of when and how cleanup is accomplished, the challenge to any Brownfields program is to clean up sites quickly and redevelop the land in ways that benefit communities and local economies.

Numerous technology options are available to assist those involved in Brownfields cleanup. EPA's Technology Innovation Office (TIO) encourages the use of innovative and cost-effective technologies to characterize and clean up contaminated sites. Innovative technologies for evaluating the nature and extent of contamination and for addressing the cleanup of Brownfields sites hold promise for reducing the cost of cleanup and accelerating the cleanup schedule—potentially producing significant benefits to Brownfields stakeholders by reducing barriers to redevelopment that add to costs, or time schedules, or create uncertainties. When such

factors as lower cost, increased environmental protection, and improved effectiveness are considered, innovative technologies frequently are more cost-effective and provide better and more efficient cleanup than established treatment technologies. Often, they also are more acceptable to communities.

Innovative does not mean unproven. EPA defines an innovative technology as one that has been used in the field but that is not yet considered routinely for use. In addition, cost and performance data on the technologies may be insufficient to encourage managers of cleanup projects to select those technologies over established methods. Nevertheless, innovative technologies are being used in many cleanup programs to assess contamination and to treat a variety of hazardous substances and petroleum products that have been released into the environment. For example, approximately 43 percent of Superfund sites that have contaminated soil are using "innovative" technologies (Innovative Treatment Technologies: Annual Status Report, Eighth Edition).

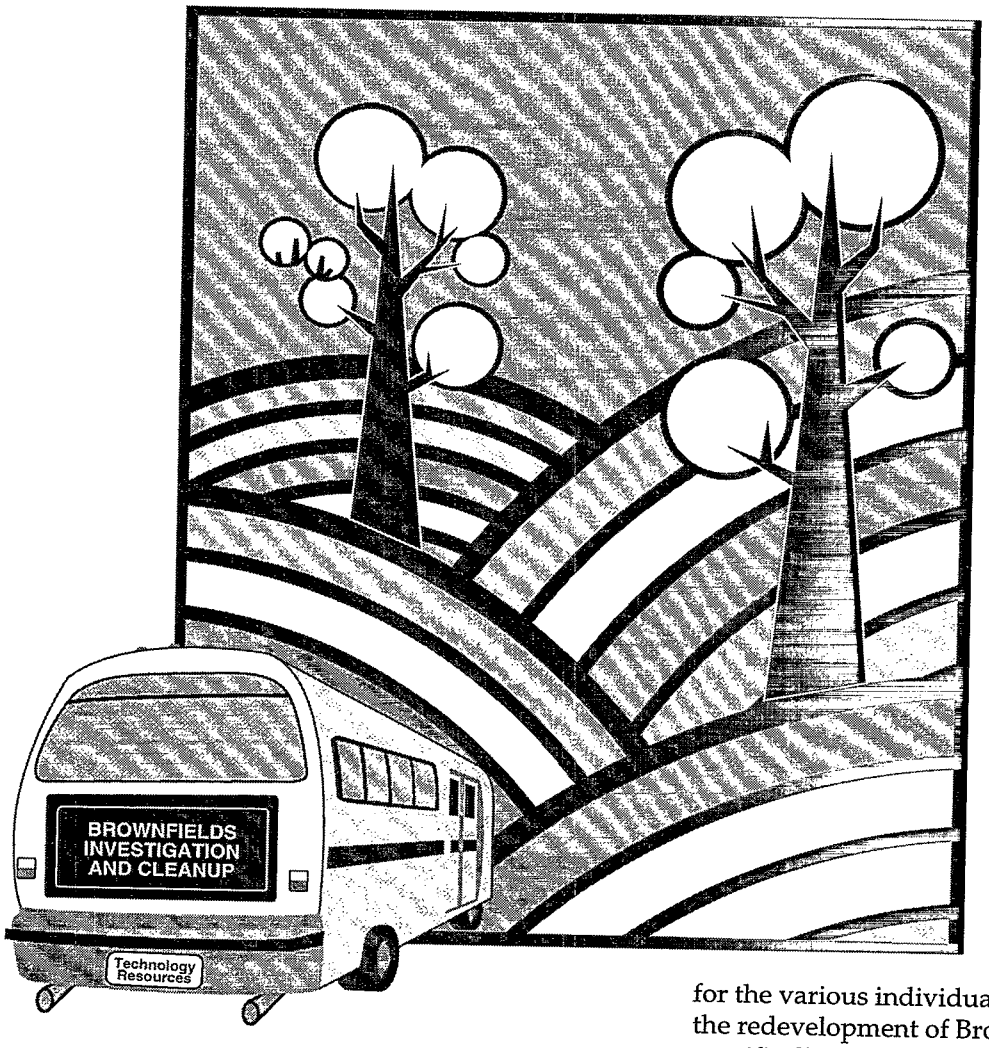
An Emerging Technology is an innovative technology that currently is undergoing bench-scale testing, in which a small version of the technology is tested in a laboratory.

An Innovative Technology is a technology that has been field-tested and applied to a hazardous waste problem at a site, but lacks a long history of full-scale use. Information about its cost and how well it works may be insufficient to support prediction of its performance under a wide variety of operating conditions.

An Established Technology is a technology for which cost and performance information is readily available. Only after a technology has been used at many different sites and the results fully documented is that technology considered established.

INTRODUCTION

The *Road Map to Understanding Innovative Technology Options for Brownfields Investigation and Cleanup* focuses on the site characterization and cleanup phase of Brownfields redevelopment. It introduces Brownfields stakeholders to the range of technology options and resources available to them. This Road Map also provides a framework of the logical steps involved in the characterization and cleanup of a Brownfields site in order to link technology options and resources to each of those steps. The Road Map is intended to assist Brownfields stakeholders involved in the selection of technologies in assessing, and, if necessary, addressing contamination at their site.



The Road Map is not an official guidance document. Instead, it draws upon EPA's experiences with Superfund sites, corrective action sites under the Resource Conservation and Recovery Act (RCRA), and UST sites. Specific conditions—such as the kinds and amount of contamination, the proposed reuses of the property, the financial resources available, and the level of support from neighboring communities—vary from site to site. Nevertheless, the Road Map provides a generally applicable outline of the steps involved in the cleanup of a site slated for redevelopment.

The Road Map is intended for the various individuals involved in or affected by the redevelopment of Brownfields sites. It specifically focuses on those who will make decisions about Brownfields sites but may not be familiar with many of the elements involved in cleaning them up. The document seeks to create an "educated consumer" by introducing the decision makers to the full range of available technology options. In addition, since most Brownfields sites will not be subject to the provisions of such Federally mandated

programs as Superfund, the Road Map introduces Brownfields stakeholders to the steps involved in implementing a cleanup. To better understand those steps, stakeholders should consult as early as possible with the appropriate regulators at the state and, if necessary, at the Federal level. Stakeholders can obtain additional information and assistance by contacting regulatory agencies, as well as by working with reputable technical and legal experts. A qualified site cleanup professional from a reputable consulting and engineering firm also may be employed.

It is important to understand that the cleanup process may not occur in the sequence outlined in the following chapters. At many sites, several activities may be undertaken concurrently with other phases. It is important to consider during each phase the activities and requirements described for subsequent phases, as well as to determine whether activities can be combined or implemented concurrently.

How to Use the Road Map

The four sections of the Road Map summarize the general phases of the cleanup of potentially contaminated sites: site assessment, site investigation, assessment of cleanup options, and design and implementation of the remedy. Each section describes the objective to be accomplished, outlines the key questions to be answered, summarizes the activities undertaken during that phase, lists several information resources available to assist in performing those activities, and points to specific actions to be taken at the completion of the phase. In addition, the section features a brief overview of technologies that can be used during that phase. **Please note that the key questions and activities to be conducted are intended to guide the reader in identifying issues that should be addressed; the Road Map seeks to answer the technology selection questions and is not intended to provide a response to each procedural question identified.** To serve as guideposts to the cleanup process, the questions take the point of view of the various groups involved in that process. They ask what stakeholders as a group working together—the "we" of each question—must do as cleanup progresses. The section "Other Important Considerations" discusses additional factors that affect the cleanup of Brownfields sites.

Several appendices also are included to help Brownfields stakeholders understand technical terms and issues related to cleanup. *Appendix A, Guide to Contaminants Found at Typical Brownfields Sites,* identifies activities that may have caused contamination at sites being considered for redevelopment. *Appendix B, Remediation Technologies Screening Matrix,* compares various cleanup technologies against a number of site conditions and considerations. *Appendix C, List of Acronyms and Glossary of Key Terms,* defines specialized terms and acronyms used in discussing and describing Brownfields cleanup efforts. *Appendix D, List of Brownfields and Technical Support Contacts,* provides information about state and EPA regional and technical points of contact. *Appendix E, How to Order Documents,* provides information about ordering the documents listed in the Road Map.

This Road Map is a companion guide to *A Tool Kit of Information Resources for Brownfields Investigation and Cleanup,* also developed by TIO. The Road Map identifies references in the Tool Kit and links them to specific steps in the site assessment, characterization, and cleanup process. The Tool Kit, in turn, describes the resources; provides information about how to obtain resources; introduces Brownfields stakeholders to new approaches and tools for implementing cleanup; and provides a "starter" supply of important information resources. These resources used in tandem should help Brownfields stakeholders understand better the range of technology options available to them.

How to Submit Comments

To help ensure that any future versions of the document meet the needs of its intended audience, EPA invites comments from the members of the Brownfields community. Please submit comments to:

Brownfields Cleanup Road Map
U.S. Environmental Protection Agency
Technology Innovation Office
401 M Street, SW (MC 5102G)
Washington, DC 20460
E-mail: *powell.dan@epamail.epa.gov*
Fax: (703) 603-9135

How to Obtain Additional Copies

Additional copies of this document can be obtained from:

National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161
(703) 487-4650

When ordering, refer to document number PB97-144810 for the Road Map and document number PB97-144828 for the Tool Kit.

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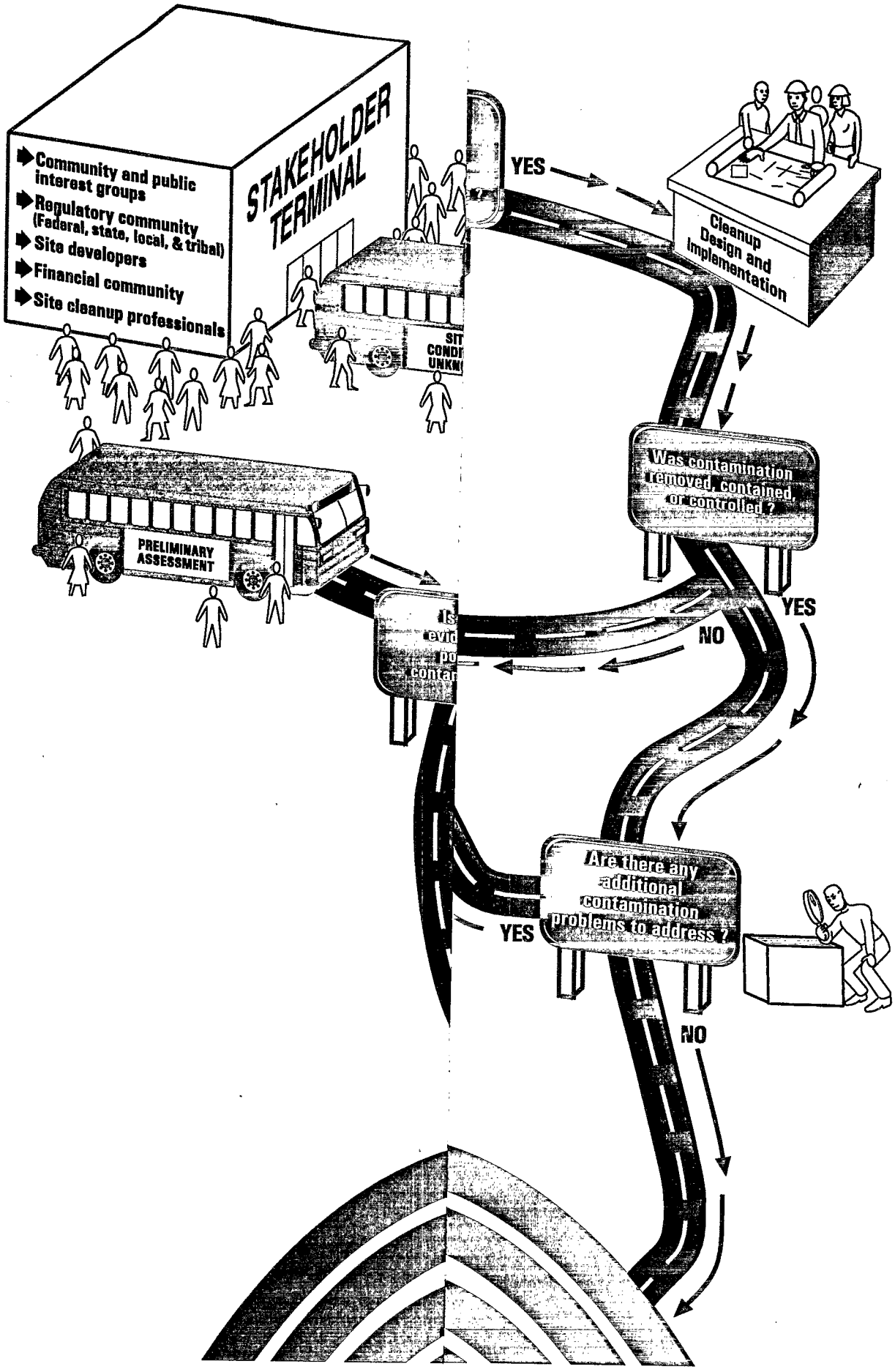
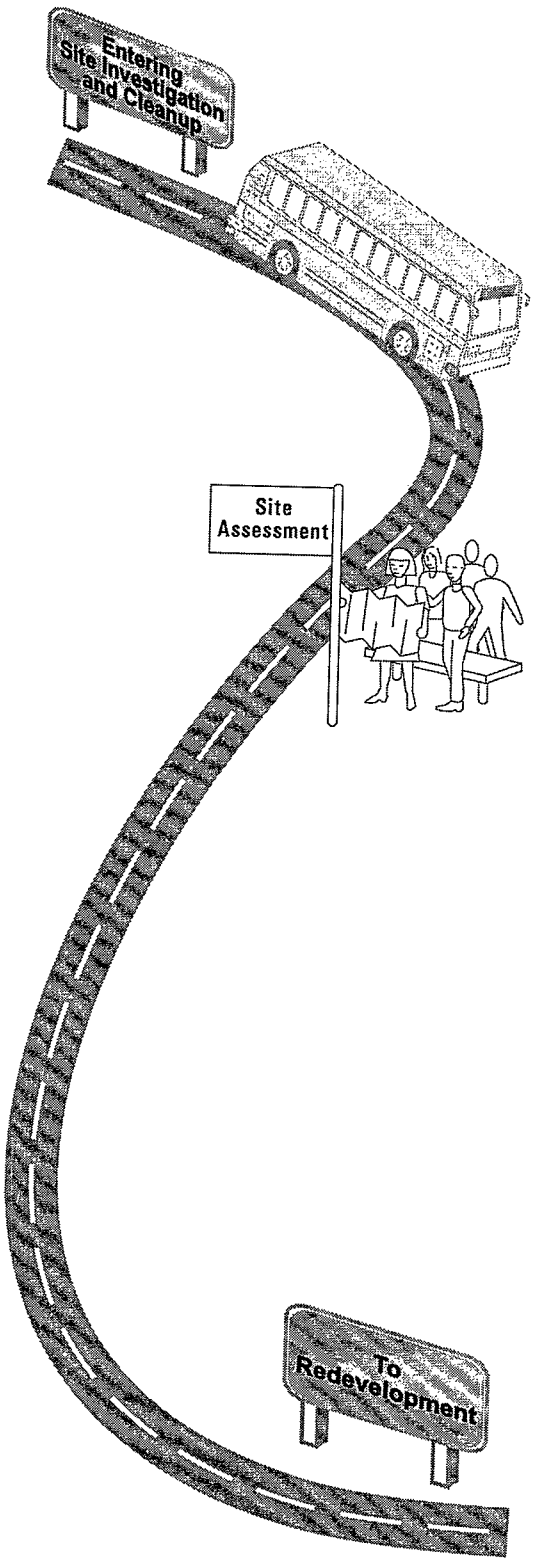

STAKEHOLDER TERMINAL
Community and public interest groups
Regulatory community (Federal, state, local, & tribal)
Site developers
Financial community
Site cleanup professionals
YES
Cleanup Design and Implementation
Was contamination removed, contained, or controlled ?
YES
NO
PRELIMINARY ASSESSMENT
Are there any additional contamination problems to address ?
YES
NO

SITE ASSESSMENT



Collect and Assess Information About the Brownfields Site

OBJECTIVE

The purpose of this step is to determine the likelihood of contamination at a particular site by collecting and reviewing applicable information about a site. This "environmental audit" is an initial investigation that usually is limited to a search of historical records. The data to be collected also include information about past and current environmental conditions and historical uses of the site.

During the site assessment phase, it is important to consider the activities and requirements described in the subsequent chapters and determine how they can be combined with or initiated during the site assessment. The collection of data during this initial step of the cleanup process is extremely important for use in identifying and evaluating the applicability of site assessment and cleanup technologies, as well as in determining whether the property can be cleaned to the level necessary for its intended reuse. It also is essential to assess and address the needs and concerns of the community (for example, the development of social and economic profiles and the identification of acceptable environmental risk).

To ensure that sufficient data are collected, the potential applicability of innovative technologies to the site also should be considered. Since much of the work at this stage involves a search of paper and electronic records, applicable technology options may be somewhat limited.

What Do We Need to Know?

KEY QUESTIONS

Factors that should be considered during this phase include:

1. What is known about the site? What records exist that indicate potential contamination and past use of the property? Have other environmental actions occurred (such as notices of violation)? Has an environmental audit been conducted? What level of site assessment is needed to identify the types and extent or the absence of contamination?

2. Is the site located in an area targeted for redevelopment? Is the site being considered for cleanup under a Federal or state Superfund cleanup initiative?

3. Are there Federal, state, local, or tribal regulatory requirements for site assessment? Is there a voluntary cleanup program (VCP)? What agency (Federal, state, local, or tribal)

would be responsible for managing oversight of cleanup?

4. What are the special needs and concerns of the community? How can we encourage community involvement? How will the community make its views known?

5. What environmental conditions will the community accept? What environmental conditions are unacceptable or will hinder redevelopment and the planned reuse?

6. If the site shows evidence of contamination, who and what will be affected? Who will pay for the cleanup?

How Do We Find the Answers?*

ANSWERS

Activities to be conducted during the initial survey of a site include:

- Determine whether contamination is likely; this process is similar to a Phase I site assessment or environmental audit, during which a records search is performed and the site is visited, but no sampling of soil or groundwater occurs:
  - *Identify past owners and the uses they made of the property*
  - *Review and analyze government and other historical records to identify past use or disposal of hazardous or other waste materials at the site*
  - *Review Federal and state lists that identify sites that may have environmental contamination; such lists include 1) EPA's Comprehensive Environmental Response, Compensation, and Liability Inventory System (CERCLIS) of potentially contaminated sites, 2) the National Pollutant Discharge Elimination System (NPDES) of permits issued for discharges into surface water, and 3) state records of "emergency removal" actions (for example, the removal of leaking drums or the excavation of explosive waste)*
  - *Interview property owners, occupants, and others associated with the site, such as previous employees, neighbors, and local planners*
  - *Perform a physical or visual examination of the site, including examination of existing structures for structural integrity and asbestos-containing material*
  - *Test for the presence of various contaminants; for example, lead paint, polychlorinated biphenyls (PCB), and radon*
- Review the applicability of government oversight programs:
  - *Identify and consult with the appropriate state, local, and tribal regulatory agencies to include them in the decision-making process as early as possible*
  - *Determine the approach (such as the Superfund program, property transfer laws, or VCPs) that is required or available to facilitate the cleanup of sites*
  - *Identify whether environmental incentives, such as benefits from state VCPs, can be obtained*
  - *Determine whether contamination has been identified previously*
  - *Contact the EPA regional Brownfields coordinator to identify and determine the availability of EPA support programs*
- Determine how to incorporate and encourage community participation:
  - *Identify regulatory requirements*
  - *Assess community interest in the project*
  - *Review any community plans for redevelopment*
- Identify future plans for reuse and redevelopment
- Identify factors that may impede redevelopment and reuse
- Begin identifying potential sources for funding site investigation and cleanup activities at the site, if necessary
- Examine unacceptable environmental conditions in terms of initial costs for site improvement and long-term costs for operation and maintenance — include potential cleanup options and constraints

Don't forget to review Other Important Considerations (see page 29)

** Please note that the Road Map seeks to answer the technology selection questions and is not intended to provide a response to each procedural question identified.*

that may affect redevelopment, such as project schedules, cost, and potential for achieving the desired reuse.

Where Do We Find Help To Our Technology Questions?

Examples of technology resources that are available to assist in assessing a site are listed below. Although many of the resources are more applicable in later stages of the cleanup process, it may be useful to begin thinking now about options and tools for investigation and cleanup. *Appendix E, How to Order Documents* includes order forms for the resources. Additional information about the resources can be found in the companion document, *A Tool Kit of Information Resources for Brownfields Investigation and Cleanup.*

A. Technology Survey Resources

- Clean-Up Information (CLU-IN) Bulletin Board System *(CLU-IN can be accessed by modem at (301) 589-8366 or by the Internet at http://clu-in.com)*
- National Exposure Research Laboratory (NERL) - Las Vegas, Site Characterization CD-ROM (EPA 600-C-96-001)

B. Site-Specific Resources

- Contaminants and Remedial Options at Pesticide Sites (EPA 600-R-94-202, PB95-103869)
- Contaminants and Remedial Options at Selected Metal-Contaminated Sites (EPA 540-R-95-512, PB95-271961)
- Contaminants and Remedial Options at Solvent-Contaminated Sites (EPA 600-R-94-203, PB95-177200)
- Contaminants and Remedial Options at Wood Preserving Sites (EPA 600-R-92-182, PB92-232222)
- Expedited Site Assessment Tools for Underground Storage Tank Sites: A Guide for Regulators (EPA 510-B-97-001)

C. Technology-Specific Resources

- Consortium for Site Characterization Technology—Innovative Technology Verification Reports:
  - *Cone Penetrometer/Laser Induced Fluorescence (LIF)*
    - *Rapid Optical Screening Tool (ROST) (EPA 600-R-97-020)*
    - *Site Characterization and Analysis Penetrometer System (SCAPS) (EPA 600-R-97-019)*
  - *Field-Portable X-Ray Fluorescence (FPXRF)*
  - *Portable Gas Chromatograph/Mass Spectrometers (GC/MS)*
- Vendor Field Analytical and Characterization Technologies System (Vendor FACTS), Version 2.0 (*Vendor FACTS can be downloaded from the Internet at http://www.ttemi.com/visitt or from the CLU-IN Web site at http://clu-in.com*) (Vendor Facts Bulletin EPA 542-N-97-007)

What Technologies Are Available?

The table presented on the next page summarizes several technologies that may be used during the site assessment phase. Because a site assessment focuses on determining the likelihood of contamination, technologies that detect contamination that may be in the air as vapor or particulate matter are listed. If other data indicate that contamination in soil or groundwater may exist, you may want to consider using analytical sampling techniques (as discussed in the next chapter). The information in the table was developed from data in EPA's Vendor FACTS database.

Specific information about the technologies, their effectiveness, and a summary of the contaminants monitored by the technologies can be found in the Vendor FACTS database. See *Appendix C, List of Acronyms and Glossary of Key Terms,* for descriptions of the technologies.

Contaminants Monitored	Applicable Technologies
Ammonia	Gas Monitors
Carbon Monoxide	Colorimetric Detector Tubes; Gas Monitors
Chlorine	Colorimetric Detector Tubes; Gas Monitors
Cyanide Compounds	Colorimetric Detector Tubes; Gas Monitors
Explosives, such as Hydrazine	Gas Monitors
Hydrogen Sulfide	Colorimetric Detector Tubes; Gas Monitors
Mercury	Mercury Vapor Analyzers
Methane	Gas Monitors
Nitrous Oxides	Gas Monitors
Pesticides	Gas Monitors
Radiation	Radiation Meters
Various Volatile Organic Compounds (VOC)	Colorimetric Detector Tubes; Hand-held Photoionization Detectors (PID) or Flame Ionization Detectors (FID)

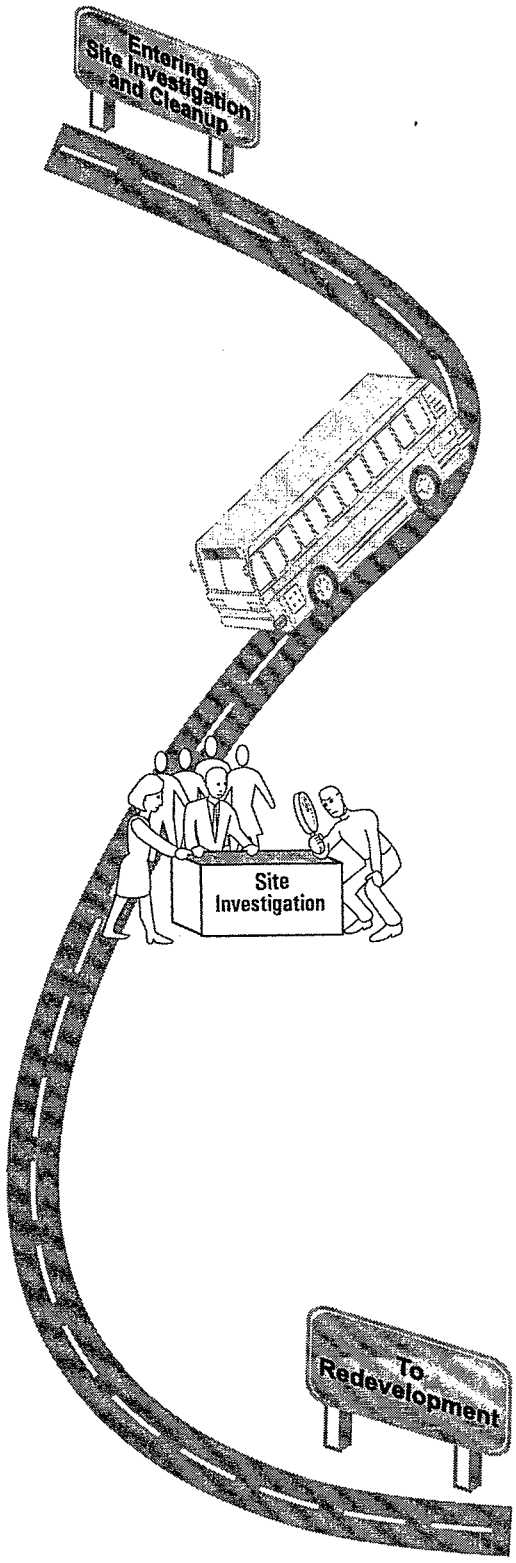
Where Do We Go From Here?

NEXT STEPS

After completing an initial assessment and survey of the environmental conditions at the site, you may take one of the following courses of action:

Result of Site Assessment		Course of Action
No apparent contamination is found and there is no reason to suspect other media are contaminated. Concerns of stakeholders have been addressed adequately.	➡	*Consult with appropriate regulatory officials before proceeding with redevelopment activities.*
Contamination is found that poses a significant risk to human health or the environment.	➡	*Contact the appropriate Federal, state, local, or tribal government agencies responsible for hazardous waste. Based on feedback of government agency, determine whether redevelopment is an option.*
Contamination possibly exists.	➡	*Proceed to the SITE INVESTIGATION phase.*
Contamination definitely exists, BUT no site investigation has been conducted.	➡	*Proceed to the SITE INVESTIGATION phase.*
Contamination definitely exists, AND a site investigation has been performed.	➡	*Proceed to the SITE INVESTIGATION phase if additional investigation is needed; otherwise, proceed to the CLEANUP OPTIONS phase.*

SITE INVESTIGATION



Identify the Source, Nature, and Extent of Contamination

OBJECTIVE

This phase focuses on identifying, locating, and characterizing the nature and extent of contamination at a site. It is essential that an appropriately detailed study of the site be performed to identify the cause, nature, and extent of contamination and the possible threats to the environment or to any people living or working nearby. For Brownfields sites, the results of such a study can be used in determining goals for cleanup, quantifying risks, determining acceptable and unacceptable risk, and developing cleanup plans that do not cause unnecessary delays in the redevelopment and reuse of property.

A site investigation is based on the results of the site assessment, which is discussed in the preceding section of the Road Map. The site investigation phase may include the analysis of samples of soil and soil gas, groundwater, surface water, and sediment. The migration pathways of contaminants also are examined during this phase, and a baseline risk assessment may be needed to calculate risk to human health and the environment.

What Do We Need to Know?

KEY QUESTIONS

If there is evidence of potential or actual contamination, factors that should be considered during the site investigation phase include:

1. Are there Federal, state, local, and tribal regulatory requirements for a site investigation? What agency would be responsible for managing oversight of this phase? What happens if the appropriate agency has not developed standards or guidelines that are suitable for the proposed redevelopment?
2. What technologies are available to facilitate site investigation?
3. Can the need for cleanup be assessed fully and accurately from the information gathered during the site assessment or from a previous site investigation?
4. What environmental conditions does the community consider unacceptable? What issues has the community raised that may affect the site investigation?

5. What are the potential exposure pathways? Who or what could be affected by the contamination or the efforts to clean up the contamination?

6. What happens if significant contamination is found? What happens if contamination poses a "significant threat" to local residents?

7. What happens if the contamination is originating from an adjacent or other off-site source? What happens if background sampling indicates that contamination is originating from a naturally occurring source?

8. Are the infrastructure systems (roads, buildings, sewers, and other facilities) contaminated? Could they be affected by efforts to clean up contamination?

How Do We Find the Answers?*

ANSWERS

Typical activities that may be conducted during the site investigation phase include:

- Identify the environmental conditions at the site (for example, by performing a Phase II environmental site assessment that includes tests to confirm the locations of and identities of environmental hazards):
  - *Conduct sampling and analysis to determine the nature, extent, source, and significance of the contamination that may be present at the site*
  - *Conduct sampling and analysis to fully assess the physical and geophysical conditions and characteristics of the site*
  - *Interpret the results of the analysis to characterize site conditions*
  - *Determine whether and how (if applicable) the infrastructure systems (including existing structures) are affected by contamination*
- Assess the risk the site may pose to human health and the environment. Consider the following exposure pathways:
  - *For soil and dust, direct contact, ingestion, or inhalation*
  - *For water, ingestion and inhalation*
  - *For air, inhalation or ingestion*
- Determine the proper mix of technologies (such as field measurement technologies that characterize the physical and chemical aspects of the site and fixed laboratory sampling methods) that can facilitate site investigations and meet the required level of data quality (see the definition of data quality objectives [DQO] in *Appendix C, List of Acronyms and Glossary of Key Terms*)
- Examine unacceptable environmental conditions in terms of initial costs for site improvement and long-term costs for annual operation and maintenance — include potential cleanup options and constraints that may affect redevelopment requirements, such as project schedules, costs, and potential for achieving the desired reuse
- Begin consideration of sources of funding for site investigation and cleanup activities
- Consider the use of site-specific risk assessment to determine cleanup levels or guidelines when standards or guidelines have not been developed
- Continue to work with appropriate regulatory agencies to ensure that regulatory requirements are being properly addressed:
  - *Identify and consult with the appropriate state, local, and tribal agencies to include them as early as possible in the decision-making process*
  - *Contact the EPA regional Brownfields coordinator to identify and determine the availability of EPA support programs*
- Educate members of the community about the site investigation process and actively involve them in decision making; consider risk communication techniques to facilitate those activities.

Don't forget to review Other Important Considerations (see page 29)

** Please note that the Road Map seeks to answer the technology selection questions and is not intended to provide a response to each procedural question identified.*

Where Do We Find Help To Our Technology Questions?

Examples of technology resources that provide information to assist in identifying the environmental condition of the site are listed below. *Appendix E, How to Order Documents* includes order forms for the resources. Additional information about the resources can be found in this Road Map's companion document, *A Tool Kit of Information Resources for Brownfields Investigation and Cleanup.*

A. Technology Survey Resources

- National Exposure Research Laboratory (NERL) - Las Vegas, Site Characterization CD-ROM (EPA 600-C-96-001)
- Site Characterization and Monitoring: A Bibliography of EPA Information Resources (EPA 542-B-96-001)
- Status Report on Field Analytical Technologies Utilization: Fact Sheet (EPA 542-R-97-003)

B. Site-Specific Resources

- Expedited Site Assessment Tools for Underground Storage Tank Sites: A Guide for Regulators (EPA 510-B-97-001)

C. Technology-Specific Resources

- Abstract Proceedings: Superfund Technical Support Project General Meeting, Athens, GA, 12/3/90 - 12/6/90 (PB93-205862)
- Characterization of Chromium-Contaminated Soils Using Field-Portable X-ray Fluorescence (PB94-210457)
- Characterization Protocol for Radioactive Contaminated Soils (PB92-963354)
- Consortium for Site Characterization Technology—Innovative Technology Verification Reports:
  - *Cone Penetrometer/Laser Induced Fluorescence (LIF)*
    - *Rapid Optical Screening Tool (ROST) (EPA 600-R-97-020)*
    - *Site Characterization and Analysis Penetrometer System (SCAPS)* (EPA 600-R-97-019)
  - *Field-Portable X-Ray Fluorescence (FPXRF)*
  - *Portable Gas Chromatograph/Mass Spectrometers (GC/MS)*
- Development of a Battery-Operated Portable Synchronous Luminescence Spectrofluorometer (PB94-170032)
- DNAPL Site Evaluation (PB93-150217)
- Navy/EPA Technical Screening Matrix (*under development; available in September 1997*)
- Sampling of Contaminated Sites (PB92-110436)
- Superfund Innovative Technology Evaluation Program - Measuring and Monitoring Program Reports (*See Appendix A, Brownfields Site Cleanup "Starter Kit" in the companion document, A Tool Kit of Information Resources for Brownfields Investigation and Cleanup for a complete list of the reports and the publication numbers)*
- Vendor Field Analytical and Characterization Technologies System (Vendor FACTS), Version 2.0 *(Vendor FACTS can be downloaded from the Internet at http://www.ttemi.com/visitt or from the CLU-IN Web site at http://clu-in.com);* (Vendor Facts Bulletin EPA 542-N-97-007)

What Technologies Are Available?

The table presented on the next page summarizes several technologies that may be used during the site investigation phase. The information in the table was developed from information in EPA's Vendor FACTS database. Specific information about the technologies, their effectiveness, and their applicability in relation to detection limits, as well as a summary of the contaminants monitored, can be obtained from the database. EPA's *Superfund Innovative Technology Evaluation (SITE) Program: Technology Profiles* also provides summaries of more than 150 monitoring

Contaminants Monitored	Examples of Field Analytical Technologies
Soils, Sediments, and Sludges	
Geophysical Characteristics of Soil and Bedrock	In Situ Geophysics, Borehole Technologies; Downhole Sensors; Seismic Reflection/ Refraction
Buried Objects and Subsurface Anomalies	Ground-Penetrating Radar (GPR); Infrared Monitors; High-Frequency Electromagnetic (EM) Sounding; Subsurface EM; Subsurface Magnetrometry; Transient EM Geophysical Instruments
Benzene, Toluene, Ethylbenzene, and Xylene (BTEX)	Colorimetric Test Kits; Immunoassay Test Kits; Laser-induced Fluorescence/Cone Penetrometer; Portable Gas Chromatography/ Mass Spectrometry
Explosives	Colorimetric Test Kits; Immunoassay Test Kits; Gas Chromatography/Mass Spectrometry
Mercury	Immunoassay Test Kits; Laser-induced Fluorescence/Cone Penetrometer
Pentachlorophenol (PCP)	Immunoassay Test Kits; Portable Gas Chromatography/Mass Spectrometry
Pesticides	Immunoassay Test Kits
Polychlorinated Biphenyls (PCB)	Colorimetric Test Kits; Immunoassay Test Kits; Portable Gas Chromatography/Mass Spectrometry
Polynuclear Aromatic Hydrocarbons (PAH)	Immunoassay Test Kits; Portable Gas Chromatography/Mass Spectrometry; Soil Gas Analyzers; Chemical Reaction-based Indicators; Biosensors
Total Petroleum Hydrocarbons (TPH)	Colorimetric Test Kits; Immunoassay Test Kits; Laser-induced Fluorescence/Cone Penetrometer; Infrared Monitors
VOCs, Semi-Volatile Organic Compounds (SVOC), Dioxin, Furans	Portable Gas Chromatography/Mass Spectrometry
Groundwater, Surface Water, and Leachate	
Buried Objects	GPR; Transient EM Geophysical Instruments; Subsurface EM; High-Frequency EM Sounding; Subsurface Magnetrometry
Metals	X-ray Analyzers; Biosensors
PAHs	Immunoassay Test Kits
Pesticides	Immunoassay Test Kits; Portable Gas Chromatography/Mass Spectrometry; Chemical Reaction-based Indicators
PCBs	Colorimetric Test Kits; Immunoassay Test Kits; Portable Gas Chromatography/Mass Spectrometry
BTEX	Colorimetric Test Kits; Immunoassay Test Kits; Portable Gas Chromatography/Mass Spectrometry
VOCs, SVOCs	Portable Gas Chromatography/Mass Spectrometry
Soil Gas	
VOCs, SVOCs, PCBs, Pesticides, Dioxin, Furans	Portable Gas Chromatography/Mass Spectrometry; Soil Gas Analyzer

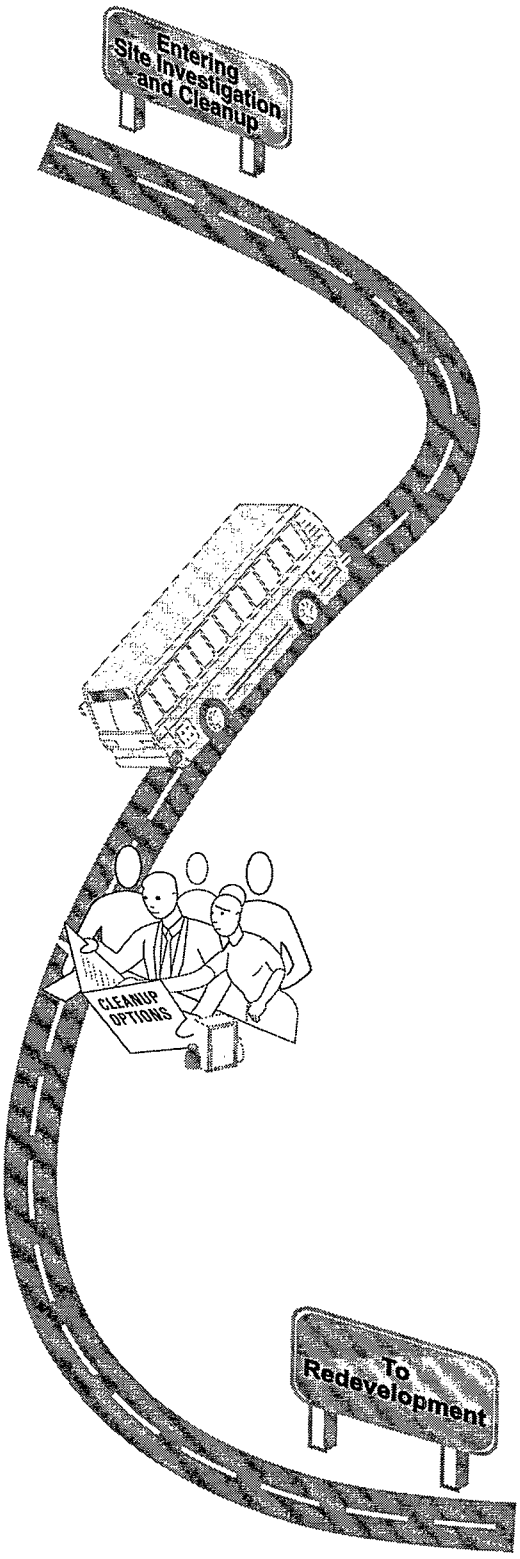
and measurement technologies. See *Appendix C, List of Acronyms and Glossary of Key Terms,* for a description of the technologies.

Where Do We Go From Here?

After you have completed your investigation of the environmental conditions at the site, you may take one of the following courses of action:

Results of the Site Investigation		Course of Action
No contamination is found.	➡	*Consult with appropriate regulatory officials before proceeding with redevelopment activities.*
Contamination is found BUT does not pose a significant risk to stakeholders' human health or the environment.	➡	*Consult with appropriate regulatory officials before proceeding with redevelopment activities.*
Cleanup of the contamination found probably will require a small expenditure of funds and time.	➡	*Proceed to the CLEANUP OPTIONS phase.*
Cleanup of the contamination found probably will require a significant expenditure of funds and time. However, contamination does not pose a significant threat to local residents.	➡	*Determine whether redevelopment continues to be practicable; if so, proceed to the CLEANUP OPTIONS phase.*
Contamination is found that poses a significant threat to local residents.	➡	*Contact the appropriate Federal, state, local, or tribal government agencies responsible for hazardous waste.*

CLEANUP OPTIONS



Evaluate Applicable Cleanup Alternatives for the Site

OBJECTIVE

The review and analysis of cleanup alternatives rely on the data collected during the site assessment and investigation phases, which are discussed in the preceding sections of the Road Map. The purpose of screening various technologies is to evaluate those technologies for their capability to meet specific cleanup and redevelopment objectives. For Brownfields sites, it also is important to consider budget requirements and to maintain a work schedule so that the project remains profitable.

The role of institutional controls, such as zoning and deed restrictions, posting of safety signs, and efforts to increase community awareness of the environmental conditions and cleanup activities at the site, also is an important consideration during this phase.

What Do We Need to Know?

KEY QUESTIONS

Factors that should be considered during the evaluation of cleanup options include:

1. How do we determine the appropriate and feasible level of cleanup? Are there Federal, state, local, and tribal requirements for cleanup? Are there prescribed standards for cleanup? Are there provisions for using presumptive remedies?

2. What factors are associated with the implementation of cleanup options? Will the cleanup facilitate or hinder the planned redevelopment? How long will cleanup take? What will cleanup cost? What are the short-term and long-term effects of the cleanup technologies under consideration?

3. Are the cleanup options compatible with regional or local planning and development goals and requirements? Can redevelopment activities (such as construction or renovation of buildings) be conducted concurrently with cleanup?

4. How can the community participate in the review and selection of cleanup options? Are the options acceptable in light of community concerns about protection during cleanup and reuse of the site?

5. Is there a need for institutional controls after cleanup? Are proposed institutional controls appropriate in light of community concerns and access to and use of the property?

How Do We Find the Answers?*

ANSWERS

The process of reviewing and analyzing cleanup options and technology alternatives usually follows these steps:

- Establish goals for cleanup
- Educate members of the community about the site cleanup selection process and actively involve them in decision making
- Review general information about technologies to become familiar with cleanup technologies that may be applicable to a particular site:
  - *Conduct searches of existing literature that further describes the technology alternatives*
  - *Analyze detailed technical information about the applicability of technology alternatives*
- Narrow the list of potential alternatives to those technologies that are most appropriate for addressing the contamination identified at the site and that are compatible with the specific conditions of the site and the proposed reuse of the property:
  - *Network with other Brownfields stakeholders and environmental professionals to learn about their experiences and to tap their expertise*
  - *Determine whether sufficient data are available to support identification and evaluation of cleanup alternatives*
  - *Evaluate the options against a number of factors, including toxicity levels, exposure pathways, associated risk, future land use, and economic considerations*
  - *Analyze the applicability of a particular technology to the contamination identified at a site*
  - *Determine the effects of various technology alternatives on redevelopment objectives*
- Continue to work with appropriate regulatory agencies to ensure that regulatory requirements are addressed properly:
  - *Consult with the appropriate state, local, and tribal regulatory agencies to include them in the decision-making process as early as possible*
  - *Contact the EPA regional Brownfields coordinator to identify and determine the availability of EPA support programs*
- Integrate cleanup alternatives with reuse alternatives to identify potential constraints on reuse and time schedules and to assess cost and risk factors
- Select an acceptable remedy that not only addresses the risk of contamination, but also best meets the objectives for redevelopment and reuse of the property and is compatible with the needs of the community
- Communicate information about the proposed cleanup option to Brownfields stakeholders, including the affected community.

Don't forget to review Other Important Considerations (see page 29)

Where Do We Find Help To Our Technology Questions?

HELP

Examples of resources that will assist in reviewing and analyzing cleanup options are listed below. *Appendix E, How to Order Documents* includes order forms for the resources. Additional information about the resources can be found in this Road Map's companion document, *A Tool Kit of Information Resources for Brownfields Investigation and Cleanup.*

A. General Technology Program Information

- Clean-Up Information (CLU-IN) Bulletin Board System *(CLU-IN can be accessed by modem at (301) 589-8366 or by the Internet at http://clu-in.com)*
- Clean-Up Information Home Page on the World Wide Web (EPA 542-F-96-011)

** Please note that the Road Map seeks to answer the technology selection questions and is not intended to provide a response to each procedural question identified.*

- Conducting Treatability Studies Under RCRA (OSWER Directive 9380.3-09FS, PB92-963501)
- Superfund Innovative Technology Evaluation Program: Emerging Technology Program (EPA 540-F-95-502)
- Superfund Innovative Technology Evaluation Program: Fact Sheet (EPA 542-F-95-009)
- Technology Transfer Highlights (EPA 625-N-96-001)

B. Technology Survey Resources

General

- Abstracts of Remediation Case Studies (EPA 542-R-95-001, PB95-201711)
- Accessing Federal Data Bases for Contaminated Site Clean-Up Technologies, Fourth Edition (EPA 542-B-95-005, PB96-141601)
- Alternative Treatment Technology Information Center (ATTIC) (*The ATTIC database can be accessed by modem at (703) 908-2138*)
- Bibliography for Innovative Site Clean-Up Technologies (EPA 542-B-96-003)
- Completed North American Innovative Technology Demonstration Projects (EPA 542-B-96-002, PB96-153127)
- Federal Publications on Alternative and Innovative Treatment Technologies for Corrective Action and Site Remediation, Fifth Edition (EPA 542-B-95-004, PB96-145099)
- Guide to Documenting Cost and Performance for Remediation Projects (EPA 542-B-95-002, PB95-182960)
- Innovative Treatment Technologies: Annual Status Report, Eighth Edition (EPA 542-R-96-010)
- Innovative Treatment Technologies: Annual Status Report Database (ITT Database) (*ITT can be downloaded from the CLU-IN Web site at http://clu-in.com or from ATTIC or America Online)*
- Remediation Case Studies: Fact Sheet and Order Form (EPA 542-F-95-003)
- Remediation Technologies Screening Matrix and Reference Guide, Second Edition (PB95-104782; Fact Sheet EPA 542-F-95-002)
- Selected Alternative and Innovative Treatment Technologies for Corrective Action and Site Remediation: A Bibliography of EPA Information Resources (EPA 542-B-95-001)
- Superfund Innovative Technology Evaluation Program: Technology Profiles, Ninth Edition (EPA 540-R-97-502)
- Synopses of Federal Demonstrations of Innovative Site Remediation Technologies, Third Edition (EPA 542-B-93-009, PB94-144565)
- Technology Preselection Data Requirements: Engineering Bulletin (EPA 540-S-92-009, PB93-105591)
- Vendor Information System for Innovative Treatment Technologies (VISITT), Version 5.0 *(VISITT can be downloaded from the Internet at http://www.ttemi.com/visitt or from the CLU-IN Web site at http://clu-in.com)* (VISITT Bulletin EPA 542-N-96-006)

Sites/Waste Types

METALS

- In Situ Treatment of Metal Contaminated Soils (EPA 542-R-96-001)
- Literature Review Summary of Metals Extraction Processes Used to Remove Lead From Soils: Project Summary (EPA 600-SR-94-006)
- Recent Developments for In Situ Treatment of Metal Contaminated Soils (EPA 542-R-97-004)
- Selection of Control Technologies for Remediation of Lead Battery Recycling Sites: Engineering Bulletin (EPA 540-S-91-014, PB93-121333)

POLYCHLORINATED BIPHENYLS (PCBs)

- Technology Alternatives for the Remediation of PCB-Contaminated Soil and Sediment (EPA 540-S-93-506)

UNDERGROUND STORAGE TANKS

- How to Effectively Recover Free Product at Leaking Underground Storage Tank Sites: A Guide for State Regulators (EPA 510-F-96-001; Fact Sheet EPA 510-F-96-005)
- How to Evaluate Alternative Cleanup Technologies for Underground Storage Tank Sites: A Guide for Corrective Action Plan Reviewers (EPA 510-B-94-003, S/N 055-000-00499-4; Pamphlet EPA 510-F-95-003)
- Introducing TANK Racer (EPA 510-F-96-001)
- Overview of UST Remediation Options (EPA 510-F-93-029)

WOOD PRESERVING/TREATMENT

- Superfund Innovative Technology Evaluation (SITE) Program: Technology Profiles, Seventh Edition (EPA 540-R-94-526, PB95-183919)

C. Technology-Specific Resources

Community Outreach

- Citizen's Guides to Understanding Innovative Treatment Technologies. *(The second document number listed after each title below is the document number for the guide in Spanish)*
  - *Bioremediation (EPA 542-F-96-007, EPA 542-F-96-023)*
  - *Chemical Dehalogenation (EPA 542-F-96-004, EPA 542-F-96-020)*
  - *In Situ Soil Flushing (EPA 542-F-96-006, EPA 542-F-96-022)*
  - *Innovative Treatment Technologies for Contaminated Soils, Sludges, Sediments, and Debris (EPA 542-F-96-001, EPA 542-F-96-017)*
  - *Phytoremediation (EPA 542-F-96-014, EPA 542-F-96-025)*
  - *Soil Vapor Extraction and Air Sparging (EPA 542-F-96-008, EPA 542-F-96-024)*
  - *Soil Washing (EPA 542-F-96-002, EPA 542-F-96-018)*
  - *Solvent Extraction (EPA 542-F-96-003, EPA 542-F-96-019)*
  - *Thermal Desorption (EPA 542-F-96-005, EPA 542-F-96-021)*
  - *Treatment Walls (EPA 542-F-96-016, EPA 542-F-96-027)*

Superfund Innovative Technology Evaluation (SITE) Program

See Appendix A, Brownfields Site Cleanup "Starter Kit" in the companion document, A Tool Kit of Information Resources for Brownfields Investigation and Cleanup for a complete list of the reports and the publication numbers.

- Superfund Innovative Technology Evaluation Program - Demonstration Program Reports
- Superfund Innovative Technology Evaluation Program - Measuring and Monitoring Program Reports

Bioremediation

- Bioremediation Field Evaluation: Champion International Superfund Site, Libby, Montana (EPA 540-R-96-500)
- Bioremediation Field Evaluation: Eielson Air Force Base, Alaska (EPA 540-R-95-533)
- Bioremediation Field Initiative Site Profiles:
  - *Libby Ground Water Superfund Site, Montana (EPA 540-F-95-506A)*
  - *Eielson Air Force Base, Alaska (EPA 540-F-95-506B)*
  - *Escambia Wood Preserving Site, Florida (EPA 540-F-95-506G)*

- *Hill Air Force Base Superfund Site, Utah (EPA 540-F-95-506C)*
- *Public Service Company of Colorado, Colorado (EPA 540-F-95-506D)*
- *Reilly Tar and Chemical Corporation, Minnesota (EPA 540-F-95-506H)*

- Bioremediation in the Field Search System (EPA 540-F-95-507; Fact Sheet EPA 540-F-94-506)
- Bioremediation Resource Guide (EPA 542-B-93-004, PB94-112307)
- EPA Engineering Bulletins:
  - *Composting (EPA 540-S-96-502)*
  - *In Situ Biodegradation Treatment (EPA 540-S-94-502, PB94-190469)*
  - *Rotating Biological Contactors (EPA 540-S-92-007)*
  - *Slurry Biodegradation (EPA 540-2-90-016, PB91-228049)*
- In Situ Bioremediation of Contaminated Ground Water (EPA 540-S-92-003, PB92-224336)
- In Situ Bioremediation of Ground Water and Geological Material: A Review of Technologies (EPA 600-SR-93-124, PB93-215564)
- Remediation Case Studies: Bioremediation (EPA 542-R-95-002, PB95-182911)

Groundwater Treatment

- Emerging Abiotic In Situ Remediation Technologies for Ground Water and Soil: Summary Report (EPA 542-S-95-001, PB95-239299)
- Evaluation of Technologies for In Situ Cleanup of DNAPL Contaminated Sites (EPA 600-R-94-120, PB94-195039)
- Ground-Water Remediation Technologies Analysis Center (GWRTAC) (*GWRTAC can be accessed by the Internet at http://www.gwrtac.org*)
- Ground-Water Treatment Technology Resource Guide (EPA 542-B-94-009, PB95-138657)
- In Situ Bioremediation of Contaminated Ground Water (EPA 540-S-92-003, PB92-224336)
- In Situ Bioremediation of Ground Water and Geological Material: A Review of Technologies (EPA 600-SR-93-124, PB93-215564)
- Light Nonaqueous Phase Liquids (EPA 540-S-95-500, PB95-267738)
- Remediation Case Studies: Groundwater Treatment (EPA 542-R-95-003, PB95-182929)
- Status Reports on In Situ Treatment Technology Demonstration and Applications:
  - *Altering Chemical Conditions (EPA 542-K-94-008)*
  - *Cosolvents (EPA 542-K-94-006)*
  - *Electrokinetics (EPA 542-K-94-007)*
  - *Hydraulic and Pneumatic Fracturing (EPA 542-K-94-005)*
  - *Surfactant Enhancements (EPA 542-K-94-003)*
  - *Thermal Enhancements (EPA 542-K-94-009)*
  - *Treatment Walls (EPA 542-K-94-004)*

Physical and Chemical Treatment

- EPA Engineering Bulletins:
  - *Chemical Dehalogenation Treatment: APEG Treatment (EPA 540-2-90-015, PB91-228031)*
  - *Chemical Oxidation Treatment (EPA 540-2-91-025, PB92-180066)*
  - *In Situ Soil Flushing (EPA 540-2-91-021, PB95-180025)*
  - *In Situ Vitrification Treatment (EPA 540-S-94-504, PB95-125499)*
  - *Solidification/Stabilization of Organics and Inorganics (EPA 540-S-92-015)*
  - *Supercritical Water Oxidation (EPA 540-S-92-006, PB92-224088)*
- Physical/Chemical Treatment Technology Resource Guide (EPA 542-B-94-008, PB95-138665)

- Remediation Case Studies: Thermal Desorption, Soil Washing, and In Situ Vitrification (EPA 542-R-95-005, PB95-182945)
- Soil Washing Treatment: Engineering Bulletin (EPA 540-2-90-017, PB91-228056)
- Solvent Extraction Treatment: Engineering Bulletin (EPA 540-S-94-503, PB94-190477)

Soil Vapor Extraction and Enhancements

- EPA Engineering Bulletins:
  - *In Situ Soil Vapor Extraction Treatment (EPA 540-2-91-006, PB91-228072)*
  - *In Situ Steam Extraction Treatment (EPA 540-2-91-005, PB91-2228064)*
- Remediation Case Studies: Soil Vapor Extraction (EPA 542-R-95-004, PB95-182937)
- Soil Vapor Extraction (SVE) Enhancement Technology Resource Guide: Air Sparging, Bioventing, Fracturing, and Thermal Enhancements (EPA 542-B-95-003)
- Soil Vapor Extraction (SVE) Treatment Technology Resource Guide (EPA 542-B-94-007)

Thermal Treatment

- EPA Engineering Bulletins:
  - *Mobile/Transportable Incineration Treatment (EPA 540-2-90-014, PB91-228023)*
  - *Pyrolysis Treatment (EPA 540-S-92-010)*
  - *Thermal Desorption Treatment (EPA 540-S-94-501, PB94-160603)*
- Remediation Case Studies: Thermal Desorption, Soil Washing, and In Situ Vitrification (EPA 542-R-95-005, PB95-182945)

What Technologies Are Available?

The table to the right identifies several innovative technologies used to treat soil and groundwater. The technologies identified treat contaminants in very different ways. In addition, a site often is contaminated by more than one type of contaminant. As such, the table is designed to facilitate comparisons between different technologies and different types of contaminants.

The information in the table is based on data in EPA's VISITT database as well as the Remediation Technologies Screening Matrix and Reference Guide (see *Appendix B* for a copy of the complete matrix). The technologies listed in the table were rated "better" in treating the selected contaminant groups. See *Appendix C, List of Acronyms and Glossary of Key Terms,* for descriptions of the technologies.

Contaminants Monitored	Examples of Technologies
Soils, Sediments, and Sludges	
VOCs	Ex Situ Bioremediation; In Situ Bioremediation (Biodegradation); In Situ Soil Flushing; Soil Vapor Extraction
SVOCs	Incineration; In Situ Bioremediation (Biodegradation); Soil Washing; Solvent Extraction; Thermal Desorption
Fuels	Ex Situ Bioremediation; Incineration; In Situ Bioremediation (Biodegradation); Soil Washing; Soil Vapor Extraction
Inorganic Compounds	Ex Situ Soil Flushing; Soil Washing; Solidification/ Stabilization
Explosives	Ex Situ Bioremediation; Incineration; In Situ Bioremediation (Biodegradation); Soil Washing; Solvent Extraction
Groundwater, Surface Water, and Leachate	
VOCs	Air Sparging; Dual-Phase Extraction; In Situ Air Sparging; In Situ Bioremediation Oxygen Enhancement with Air Sparging; In Situ Bioremediation Oxygen Enhancement with H_2O_2; Passive Treatment Wall; Pump and Treat Air Stripping; Pump and Treat Biological Reactor; Pump and Treat Carbon Adsorption
SVOCs	In Situ Bioremediation Oxygen Enhancement with Air Sparging; In Situ Bioremediation Oxygen Enhancement with H_2O_2; Passive Treatment Wall; Pump and Treat Biological Reactor; Pump and Treat Carbon Adsorption
Fuels	Air Sparging; Dual-Phase Extraction; In Situ Air Sparging; In Situ Bioremediation Oxygen Enhancement with Air Sparging; In Situ Bioremediation Oxygen Enhancement with H_2O_2; Pump and Treat Biological Reactor
Inorganic Compounds	Passive Treatment Wall; Pump and Treat Filtration; Pump and Treat Ion Exchange
Explosives	Passive Treatment Wall; Pump and Treat Carbon Adsorption

Where Do We Go From Here?

After you have reviewed options for cleanup, you may take any of the following courses of action:

Result of the Review of Cleanup Options		Course of Action
The proposed cleanup option appears feasible.	➡	*Proceed to the CLEANUP DESIGN AND IMPLEMENTATION phase.*
No cleanup option appears feasible in light of the proposed redevelopment and land reuse needs (such as project milestones and cost and intended reuse).	➡	*Determine whether revising redevelopment plans remains a practicable option; if so, proceed to the CLEANUP DESIGN AND IMPLEMENTATION phase. If contamination exists at considerable levels, consider other waste programs.*

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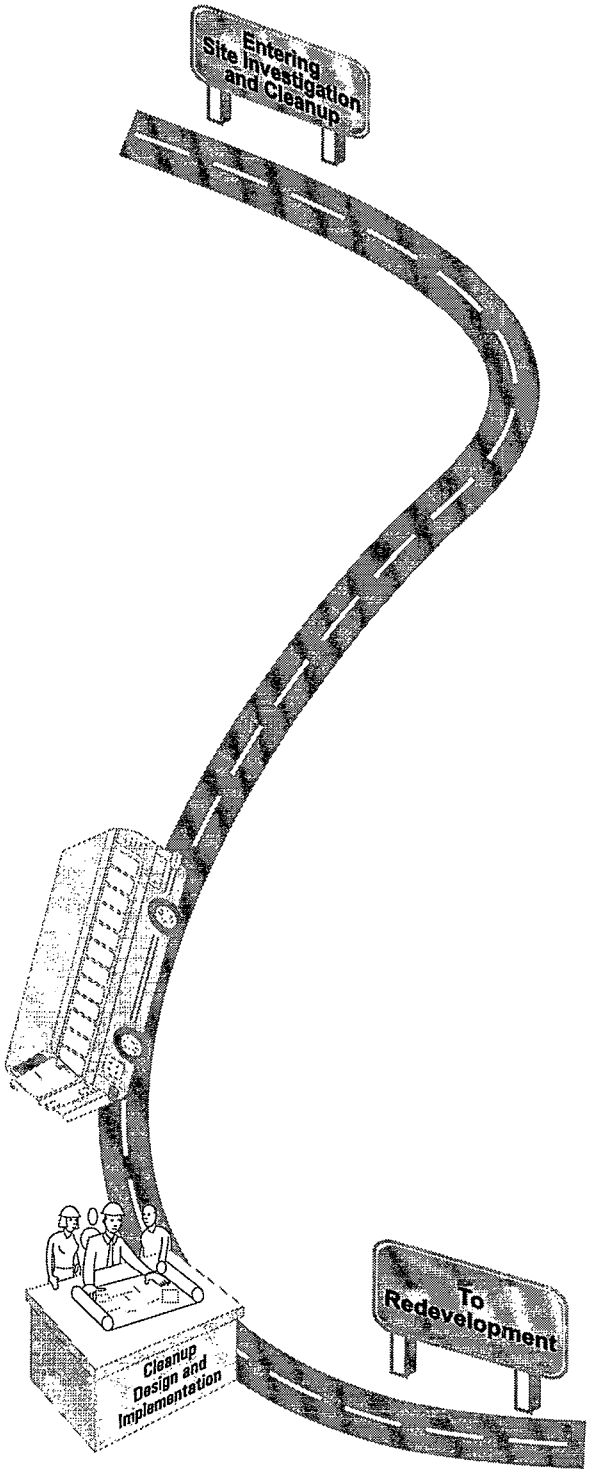
CLEANUP DESIGN AND IMPLEMENTATION



Develop and Carry Out Detailed Cleanup Plans for the Site

OBJECTIVE

This phase focuses on the design and implementation of a cleanup plan to prepare the property for redevelopment and reuse. The design of the cleanup plan and implementation of the technology options selected in the previous phase involves close coordination with all other redevelopment efforts in the immediate vicinity of the site.

What Do We Need to Know?

KEY QUESTIONS

Factors that should be considered during the design and implementation of cleanup activities include:

1. Are there Federal, state, local, and tribal requirements for conducting cleanup activities?
2. How will cleanup be monitored so that work can be stopped when cleanup goals are reached?
3. How best can the community participate in the design and implementation of the cleanup plan?
4. What can be done to protect the community and other property during cleanup?
5. What are the tradeoffs between cost and meeting redevelopment project deadlines? Can redevelopment activities (such as renovation of existing buildings and construction of roads and sewage systems) be performed concurrently with cleanup activities?
6. Will institutional controls facilitate or hinder redevelopment?

How Do We Find the Answers?*

ANSWERS

Typical activities that may be conducted during this phase include:

- Review all applicable Federal, state, local, and tribal regulatory guidelines and regulations to

**Please note that the Road Map seeks to answer the technology selection questions and is not intended to provide a response to each procedural question identified.*

ensure compliance, including guidelines for state VCPs

- Continue to work with the appropriate regulatory agencies to ensure that regulatory requirements are being properly addressed
  - *Consult with the appropriate state, local, and tribal regulatory agencies to include them in the decision-making process as early as possible*
  - *Contact the EPA regional Brownfields coordinator to identify and determine the availability of EPA support programs*
- Identify all environmental requirements that must be met and the levels of environmental incentives that apply
- Develop one or more conceptual plans for cleanup and subsequent monitoring that incorporate technology options and consider the effect of any cleanup activities on the proposed reuse of the property and the schedule for project design or construction:
  - *Develop or review the schedule for completion of the project*
  - *Obtain a final figure for the funds available for project development*
  - *Coordinate the renovation and construction of infrastructure with cleanup activities*
  - *Coordinate activities with developers, financiers, construction firms, and members of the local community*
- Establish contingency plans to address the discovery of additional contamination during cleanup
- Develop procedures for community participation, for example, by working with community advisory boards or local redevelopment authorities
- Implement and monitor the cleanup plan and performance of the remedy selected
- Work with county or local officials to facilitate the placement and implementation of institutional controls, including ongoing monitoring and enforcement of these controls.

Don't forget to review Other Important Considerations *(see page 29)*

Where Do We Find Help To Our Technology Questions?

Examples of technology resources that provide information about applicable regulatory guidelines and regulations and community outreach materials are listed below. In addition, technologies identified during the site investigation phase may be appropriate to monitor cleanup performance and close-out. *Appendix E, How to Order Documents* includes order forms for the resources. Additional information about the resources can be found in the Road Map's companion document, *A Tool Kit of Information Resources for Brownfields Investigation and Cleanup.*

A. General Technology Program Information

- Initiatives to Promote Innovative Technology in Waste Management Programs (OSWER Directive 9380.0-25, EPA 540-F-96-012)
- State Policies Concerning the Use of Injectants for In Situ Ground Water Remediation (EPA 542-R-96-001, PB96-164538)

B. Technology Survey Resources

- Vendor Information System for Innovative Treatment Technologies (VISITT), Version 5.0 *(VISITT can be downloaded from the Internet at http://www.ttemi.com/visitt or from the CLU-IN Web site at http://clu-in.com)*

C. Technology-Specific Resources

- Citizen's Guides to Understanding Innovative Treatment Technologies. *(The second document number listed after each title below is the document number for the guide in Spanish)*
  - *Bioremediation (EPA 542-F-96-007, EPA 542-F-96-023)*
  - *Chemical Dehalogenation (EPA 542-F-96-004, EPA 542-F-96-020)*
  - *In Situ Soil Flushing (EPA 542-F-96-006, EPA 542-F-96-022)*

- *Innovative Treatment Technologies for Contaminated Soils, Sludges, Sediments, and Debris (EPA 542-F-96-001, EPA 542-F-96-017)*
- *Phytoremediation (EPA 542-F-96-014, EPA 542-F-96-025)*
- *Soil Vapor Extraction and Air Sparging (EPA 542-F-96-008, EPA 542-F-96-024)*
- *Soil Washing (EPA 542-F-96-002, EPA 542-F-96-018)*
- *Solvent Extraction (EPA 542-F-96-003, EPA 542-F-96-019)*
- *Thermal Desorption (EPA 542-F-96-005, EPA 542-F-96-021)*
- *Treatment Walls (EPA 542-F-96-016, EPA 542-F-96-027)*

➲ Technology Resource Guides:

- *Bioremediation Resource Guide (EPA 542-B-93-004, PB94-112307)*
- *Ground-Water Treatment Technology Resource Guide (EPA 542-B-94-009, PB95-138657)*
- *Physical/Chemical Treatment Technology Resource Guide (EPA 542-B-94-008, PB95-138665)*
- *Soil Vapor Extraction (SVE) Enhancement Technology Resource Guide: Air Sparging, Bioventing, Fracturing, and Thermal Enhancements (EPA 542-B-95-003)*
- *Soil Vapor Extraction (SVE) Treatment Technology Resource Guide (EPA 542-B-94-007)*

➲ WASTECH Series of Innovative Site Remediation Technology Engineering Monographs:

- *Bioremediation*
- *Chemical Treatment*
- *Soil Washing/Soil Flushing*
- *Solidification/Stabilization*
- *Solvent/Chemical Extraction*
- *Thermal Desorption*
- *Thermal Destruction*
- *Vacuum Vapor Extraction*

Where Do We Go From Here?

NEXT STEPS

After you have completed cleanup, you may take one of the following courses of action:

Result of Cleanup		Course of Action
Contamination has been removed, contained, or controlled.	➡	*Consult with the appropriate regulatory officials before proceeding with redevelopment activities.*
Additional contamination has been discovered.	➡	*Continue cleanup activities. However, you may have to return to the SITE INVESTIGATION phase to determine the extent and nature of the contamination.*
Long-term monitoring of cleanup and performance of the technology is required.	➡	*Return to the SITE INVESTIGATION phase to collect after-performance samples for monitoring cleanup.*

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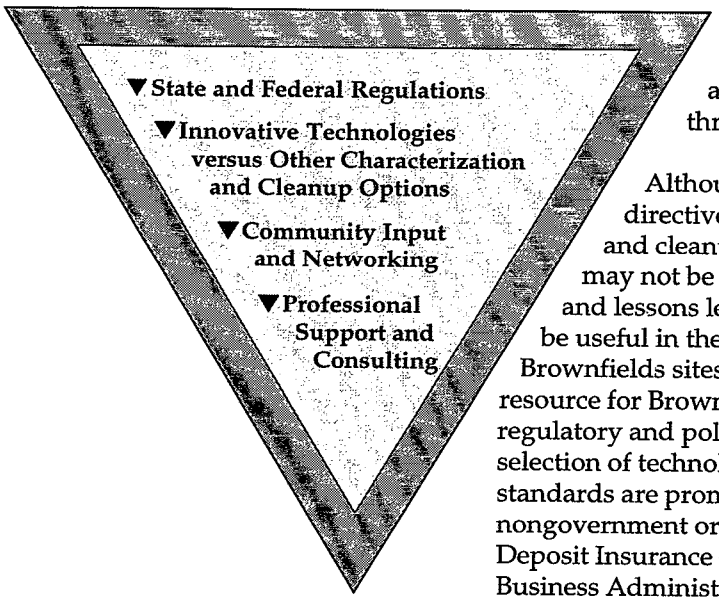
OTHER IMPORTANT CONSIDERATIONS

Understanding Regulatory Guidelines and Regulations

Understanding the applicable regulatory guidelines and regulations is crucial to selecting the appropriate technologies for cleaning up a Brownfields site. It is important to note that many Brownfields sites will be managed under state regulatory authorities. Therefore, the state regulatory authority will specify many of the requirements for, and steps in, site assessment, site investigation, the selection of cleanup options, and the design and implementation of cleanup. State regulatory agencies should be consulted to determine what, if any, site specific-requirements may exist. State regulators also can help to identify other regulatory guidelines and regulations (such as applicable Federal statutes) that also may affect the site. For these reasons, it is important to remain in constant contact with state regulatory agencies, as well as any other appropriate regulatory agencies, throughout the cleanup process.



Although compliance with official policy directives under other Federal regulatory and cleanup programs, such as Superfund, may not be required, some of the information and lessons learned under such programs may be useful in the investigation and cleanup of Brownfields sites. EPA also can be a valuable resource for Brownfields stakeholders by providing regulatory and policy support to facilitate the selection of technologies. Other guidance and standards are promulgated by government and nongovernment organizations, such as the Federal Deposit Insurance Corporation (FDIC) the Small Business Administration (SBA), and the American Society for Testing and Materials (ASTM). The box on the next page provides descriptions of the various EPA hotlines for statutory and regulatory programs.

HOTLINES AND OTHER SERVICES

Center for Environmental Research Information (CERI).
CERI is the focal point for the exchange of scientific and technical environmental information produced by EPA. CERI publishes brochures, capsule and summary reports, handbooks, newsletters, project reports, and manuals. The center operates daily, Monday through Friday, 8:00 a.m. to 4:30 p.m. eastern standard time (EST). The center can be reached by telephone at 513-569-7391.

Resource Conservation and Recovery Act/Underground Storage Tanks (RCRA/UST), Superfund, and Emergency Planning and Community Right-to-Know Act (EPCRA) Hotline.
This hotline provides information about the RCRA/UST, Superfund, and EPCRA programs. The hotline handles information about EPA's RCRA regulations and programs implemented under RCRA, the Comprehensive Environmental Response Compensation and Liability Act (CERCLA), EPCRA, and the Superfund Amendments Reauthorization Act (SARA) Title III. The hotline also provides referrals for obtaining related documents concerning the RCRA, UST, Superfund/CERCLA, and Pollution Prevention/Waste Minimization programs. Translation is available for Spanish-speaking callers. The hotline operates daily Monday through Friday, 9:00 a.m. to 6:00 p.m. EST. The hotline can be reached by telephone at 800-424-9346 for all nongovernment locations outside the Washington, DC metropolitan local calling area, or 703-412-9810 for all locations in the Washington, DC metropolitan local calling area.

Resource Conservation and Recovery Act Docket and Information Center (RIC).
The RIC provides public access to all regulatory materials supporting EPA's actions under RCRA and disseminates publications from EPA's Office of Solid Waste and Emergency Response. The information center operates daily, Monday through Friday, 9:00 a.m. to 4:00 p.m. EST. The information center can be reached by telephone at 703-603-9230.

Superfund Docket and Information Center.
The Superfund Docket and Information Center provides access to Superfund regulatory documents, Superfund Federal Register Notices, and Records of Decision (ROD). The center operates daily, Monday through Friday, 9:00 a.m. to 4:00 p.m. EST. The center can be reached by telephone at 703-603-8917 or by facsimile at 703-603-9133.

TechDirect.
TechDirect is a free electronic mail service that highlights new publications and events of interest to site cleanup professionals. Approximately once a month, EPA's Technology Innovation Office (TIO) sends subscribers an e-mail message announcing the availability of publications and the scheduling of events. The message also directs subscribers to sources from which they can obtain more information. Contact Mr. Jeff Heimerman at 703-603-7191 or by e-mail at *heimerman.jeff@epamail.epa.gov* for more information.

Toxic Substances Control Act (TSCA) Assistance Information Service.
The information service provides information about regulations under TSCA to the chemical industry, labor and trade organizations, environmental groups, and the general public. Technical as well as general information is available. The information service operates daily, Monday through Friday, 8:30 a.m. to 5:00 p.m. EST. The information service can be reached by telephone at 202-554-1404.

Comparing Innovative Technologies to Other Characterization and Cleanup Options

The Road Map focuses on innovative characterization and treatment options. Although the Road Map emphasizes the use of innovative technologies to address contamination, the use of other technologies also should be considered. For example, containment or more standard technology options also may be appropriate to address contamination at Brownfields sites. Examples of containment technologies include dynamic compaction, landfill reuse, and stabilization or solidification of contaminated material. Established technologies, such as incineration and pump-and-treat processes for groundwater contamination, also are alternatives to innovative technologies for use in addressing contamination.

When deciding between innovative and established technologies or between treatment and containment technologies, Brownfields stakeholders should compare the effectiveness and efficiency of each technology against the specific needs of the individual site and stakeholders. During this analysis, one should remember that technologies, or at least our understanding of them, change constantly.

Seeking External Support (Community Relations and Professional Support)

A wealth of information and expertise related to site cleanup is readily available. It is important that members of the Brownfields community have access to that information and are able to draw upon lessons learned to benefit from the experience of others.

Most decision makers at Brownfields sites will require technical and legal assistance to fully understand the complexities of investigating and cleaning up a contaminated site. In fact, some states may require the participation of certified or licensed professionals to help guide the site investigation and cleanup process. State regulatory agencies should be consulted to determine the requirements, if any, for the participation of certified or licensed cleanup professionals. It is recommended that site cleanup professionals and legal and other experts be recruited as members of the Brownfields team.

The Brownfields community can benefit from EPA's assistance in directing its members to appropriate resources and providing opportunities to network and participate in the sharing of information. A number of electronic bulletin boards and databases, newsletters, and reports provide opportunities for Brownfields stakeholders to network with other stakeholders to identify information about site cleanup and technology options.

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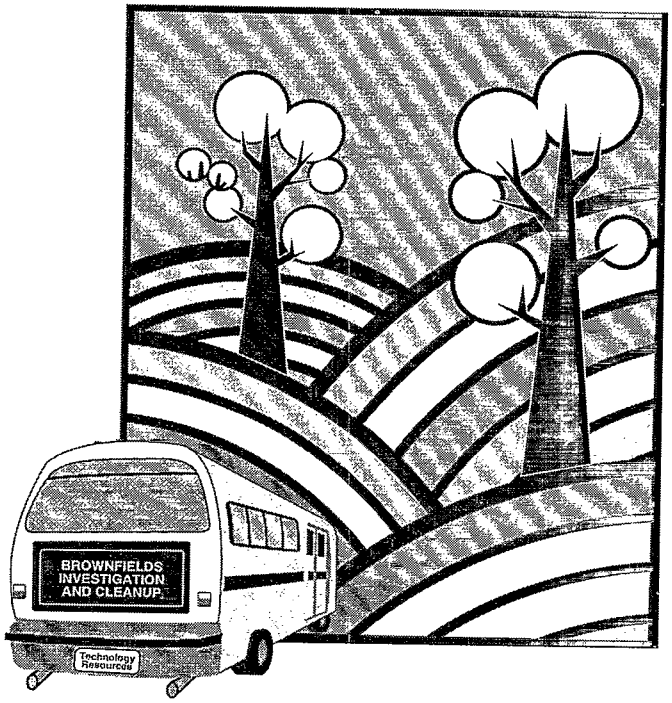
APPENDICES


BROWNFIELDS
INVESTIGATION
AND CLEANUP
Technology
Resources

APPENDIX A

Appendix A

GUIDE TO CONTAMINANTS FOUND AT TYPICAL BROWNFIELDS SITES

The following table identifies several activities that may have caused contamination at Brownfields sites. The table summarizes contaminants that are related to such activities and identifies sources for the contaminants; however, it is not an exhaustive list of contaminants that can be found at a Brownfields site. Identifying contaminants that may be present should be determined on a site-by-site basis. Such a determination should be conducted thoroughly and carefully. Information for this table was compiled from several sources, including various EPA *Guides to Pollution Prevention* for selected industries. A list of the specific citations used is provided on page A-2.

Past Activities Typically Conducted at Brownfields Sites	Typical Contaminants and Typical Sources
Agriculture	Volatile organic compounds (VOC); arsenic, copper, carbon tetrachloride, ethylene dibromide, and methylene chloride; pesticides; insecticides; herbicides; grain fumigants
Automotive refinishing and repair	Some metals and metal dust; various organic compounds; solvents; paint and paint sludges; scrap metal; waste oils
Battery recycling and disposal	Lead; cadmium; acids
Chloro-alkali manufacturing	Chlorine compounds; mercury
Coal gasification	Polynuclear aromatic hydrocarbons (PAH)
Cosmetics manufacturing	Heavy metals; dusts; solvents; acids
Dry cleaning activities	VOCs such as chloroform and tetrachloroethane; various solvents; spot removers; fluorocarbon 113
Electroplating operations	Various metals such as cadmium, chromium, cyanide, copper, and nickel
Glass manufacturing	Arsenic; lead
Herbicide manufacturing and use	Dioxin; metals; herbicides
Hospitals	Formaldehyde; radionuclides; photographic chemicals; solvents; mercury; ethylene oxide; chemotherapy chemicals
Incinerators	Dioxin; various municipal and industrial waste
Landfills—municipal and industrial	Metals; VOCs; polychlorinated biphenyl (PCB); ammonia; methane; household products and cleaners; pesticides; various wastes
Leather manufacturing	Toluene; benzene
Machine shops/metal fabrication	Metals; VOCs; dioxin; beryllium; degreasing agents; solvents; waste oils
Marine maintenance industry	Solvents; paints; cyanide; acids; VOC emissions; heavy metal sludges; degreasers
Munitions manufacturing	Lead; explosives; copper; antimony
Paint/ink manufacturing	Metals (such as chromium, cadmium, lead, and zinc); VOCs; chloroform; ethyl benzene; solvents; paints; inks
Pesticide manufacturing	VOCs; arsenic; copper; pesticides; insecticides; herbicides; fungicides; xylene; chlorinated organic compounds; solvents
Petroleum refining and reuse	Petroleum hydrocarbons; benzene, toluene, ethylbenzene, xylene (BTEX); fuels; oil and grease
Pharmaceutical manufacturing	Lead; various organic chemicals; organic solvents
Photographic manufacturing and uses	Silver bromide; methylene chloride; solvents; photographic products
Plastics manufacturing	Polymers; phthalates; cadmium; solvents; resins; chemical additives; VOCs

Past Activities Typically Conducted at Brownfields Sites (continued)	Typical Contaminants and Typical Sources
Printing industry	Silver; solvents; acids; waste oils; inks and dyes; photographic chemicals
Railroad yards	Petroleum hydrocarbons; VOCs; BTEX; solvents; fuels; oil and grease; lead; PCBs
Research and educational institutions	Inorganic acids; organic solvents; metals and metal dust; photographic waste; waste oil; paint; heavy metals; pesticides
Scrap metal operations	Various metals (such as lead and nickel); PCBs; dioxin; transformers
Smelter operations	Metals (such as lead, copper, and arsenic)
Semiconductor manufacturing	Metals; VOCs; carbon tetrachloride; degreasing agents; solvents
Wood pulp and paper manufacturing	Chlorinated organic compounds; dioxin; furans; chloroform; resin acids
Wood preserving	Creosote; pentachlorophenol (PCP); arsenic; chromium; copper; PCB; PAHs; beryllium; dioxin; wood preservatives

LIST OF CITATIONS USED TO IDENTIFY COMMON CONTAMINANTS

- Contaminants and Remedial Options at Selected Metal-Contaminated Sites (EPA 540-R-95-512, PB95-271961)
- Dry Cleaning and Laundry Plants, Fact Sheet (EPA 530-SW-90-027b)
- Guidelines for Waste Reduction and Recycling: Metal Finishing, Electroplating, Printed Circuit Board Manufacturing, Hazardous Waste Reduction Program, Oregon Department of Environmental Quality (No document number)
- Guides to Pollution Prevention:
  - *Research and Educational Institutions (EPA 625-7-90-010)*
  - *Selected Hospital Waste Streams (EPA 625-7-90-009)*
  - *The Automotive Refinishing Industry (EPA 625-7-91-016)*
  - *The Automotive Repair Industry (EPA 625-7-91-013)*
  - *The Commercial Printing Industry (EPA 625-7-90-008)*
  - *The Fiberglass-Reinforced and Composite Plastics Industry (EPA 625-7-91-014)*
  - *The Marine Maintenance and Repair Industry (EPA 625-7-91-015)*
  - *The Mechanical Equipment Repair Industry (EPA 625-R-92-008)*
  - *The Pesticide Formulating Industry (EPA 625-7-90-004)*
  - *The Pharmaceutical Industry (EPA 625-7-91-017)*
- Innovative Treatment Technologies: Annual Status Report (EPA 542-R-95-008)
- Low-Level Mixed Waste: A RCRA Perspective for NRC Licenses (EPA 530-SW-90-057)
- Pollution Prevention Technologies for the Bleached Kraft Segment of the U.S. Pulp and Paper Industry (EPA 600-R-93-110)
- Solving the Hazardous Waste Problem: EPA's RCRA Program (EPA 530-SW-86-037)
- Waste Minimization Audit Report: Case Studies of Minimization of Mercury-Bearing Wastes at a Mercury Cell Chloralkali Plant: Project Summary (EPA 600-S2-88-011)
- Waste Minimization Opportunity Assessment: Philadelphia Naval Shipyard: Project Summary (EPA 600-S2-90-046)
- Waste Reduction for the Aerospace Industry: Fact Sheet, California Department of Health Services Technology Clearinghouse (no document number)

APPENDIX B

Remediation Technologies Screening Matrix

NOTE: Specific site and contaminant characteristics may limit the applicability and effectiveness of any of the technologies and treatments listed below. This matrix is optimistic in nature and should always be used in conjunction with the *referenced text sections*, which contain additional information that can be useful in identifying potentially applicable technologies.

	Development Status	Availability	Residuals Produced	Treatment Train (excludes off-gas treatment)	Contaminants Treated: VOCs	SVOCs	Fuels	Inorganic	Explosives	System Reliability/ Maintainability	Cleanup Time	Overall Cost	O&M or Capital Intensive
SOIL, SEDIMENT, AND SLUDGE													
3.1 In Situ Biological Treatment													
4.1 Biodegradation	Full	■	None	No	■	■	■	△	■	△	△	●	O&M
4.2 Bioventing	Full	■	None	No	■	■	■	△	I	■	●	■	Neither
4.3 White Rot Fungus	Pilot	△	None	No	△	△	△	△	■	△	△	●	O&M
3.2 In Situ Physical/Chemical Treatment													
4.4 Pneumatic Fracturing (enhancement)	Pilot	△	None	Yes	●	●	●	●	●	■	NA	■	Neither
4.5 Soil Flushing	Pilot	■	Liquid	No	■	●	●	■	△	●	△	I	O&M
4.6 Soil Vapor Extraction (In Situ)	Full	■	Liquid	No	■	●	■	△	△	■	●	■	O&M
4.7 Solidification/Stabilization	Full	■	Solid	No	△	●	△	■	△	■	■	■	CAP
3.3 In Situ Thermal Treatment													
4.8 Thermally Enhanced SVE	Full	●	Liquid	No	●	■	●	△	△	●	■	●	Both
4.9 Vitrification	Pilot	△	Liquid	No	●	●	●	■	△	△	■	△	Both
3.4 Ex Situ Biological Treatment (assuming excavation)													
4.10 Composting	Full	■	None	No	■	●	■	△	■	■	●	■	Neither
4.11 Controlled Solid Phase Bio. Treatment	Full	■	None	No	■	●	■	△	■	■	●	■	Neither
4.12 Landfarming	Full	■	None	No	■	●	■	△	●	■	△	■	Neither
4.13 Slurry Phase Bio. Treatment	Full	●	None	No	■	●	■	△	■	●	●	●	Both
3.5 Ex Situ Physical/Chemical Treatment (assuming excavation)													
4.14 Chemical Reduction/Oxidation	Full	■	Solid	Yes	●	●	●	■	△	■	■	●	Neither
4.15 Dehalogenation (BCD)	Full	△	Vapor	No	●	■	△	△	△	I	I	I	I
4.16 Dehalogenation (Glycolate)	Full	●	Liquid	No	●	■	△	△	△	△	△	△	Both
4.17 Soil Washing	Full	●	Solid, Liquid	Yes	●	■	■	■	■	●	■	●	Both
4.18 Soil Vapor Extraction (Ex Situ)	Full	■	Liquid	No	■	●	●	△	△	■	●	■	Neither
4.19 Solidification/Stabilization	Full	■	Solid	No	△	●	△	■	△	■	■	■	CAP
4.20 Solvent Extraction (chemical extraction)	Full	●	Liquid	Yes	●	■	●	△	■	●	△	△	Both
3.6 Ex Situ Thermal Treatment (assuming excavation)													
4.21 High Temperature Thermal Desorption	Full	■	Liquid	Yes	●	■	●	△	△	●	■	●	Both
4.22 Hot Gas Decontamination	Pilot	●	None	No	△	△	△	△	■	■	■	■	Both
4.23 Incineration	Full	■	Liquid,Solid	No	●	■	■	△	■	●	■	△	Both
4.24 Low Temperature Thermal Desorption	Full	■	Liquid	Yes	■	●	■	△	■	●	■	■	Both
4.25 Open Burn/Open Detonation	Full	■	Solid	No	△	△	△	△	■	■	■	■	Both
4.26 Pyrolysis	Full	△	Liquid,Solid	No	●	■	●	△	I	I	■	△	Both
4.27 Vitrification	Full	●	Liquid	No	●	●	●	■	△	●	●	△	Both
3.7 Other Treatment													
4.28 Excavation, Retrieval, and Off-Site Disposal	NA	■	NA	No	●	●	●	●	●	■	■	△	Neither
4.29 Natural Attenuation	NA	■	None	No	■	■	■	△	△	■	△	■	Neither

Rating Codes (See Table 3-1)

- ■ Better
- ● Average
- △ Worse
- I Inadequate Information
- NA Not Applicable

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Source: Remediation Technologies Screening Matrix and Reference Guide (PB95-104782)

Remediation Technologies Screening Matrix (Continued)

NOTE: Specific site and contaminant characteristics may limit the applicability and effectiveness of any of the technologies and treatments listed below. This matrix is optimistic in nature and should always be used in conjunction with the *referenced text sections*, which contain additional information that can be useful in identifying potentially applicable technologies.

	Development Status	Availability	Residuals Produced	Treatment Train (excludes off-gas treatment)	Contaminants Treated: VOCs	SVOCs	Fuels	Inorganic	Explosives	System Reliability/ Maintainability	Cleanup Time	Overall Cost	O&M or Capital Intensive
GROUNDWATER, SURFACE WATER, AND LEACHATE													
3.8 In Situ Biological Treatment													
4.30 Co-metabolic Treatment	Pilot	△	None	No	■	■	●	△	●	△	●	●	O&M
4.31 Nitrate Enhancement	Pilot	△	None	No	■	■	■	△	●	●	●	■	Neither
4.32 Oxygen Enhancement with Air Sparging	Full	■	None	No	■	■	■	△	●	■	●	■	Neither
4.33 Oxygen Enhancement with H_2O_2	Full	■	None	No	■	■	■	△	●	△	●	●	O&M
3.9 In Situ Physical/Chemical Treatment													
4.34 Air Sparging	Full	■	Vapor	Yes	■	△	■	△	△	■	■	■	Neither
4.35 Directional Wells (enhancement)	Full	△	NA	Yes	●	●	●	●	●	●	■	I	Neither
4.36 Dual Phase Extraction	Full	■	Liquid,Vapor	Yes	■	△	■	△	△	●	●	●	O&M
4.37 Free Product Recovery	Full	■	Liquid	No	△	■	■	△	△	●	■	■	Neither
4.38 Hot Water or Steam Flushing/Stripping	Pilot	●	Liquid,Vapor	Yes	●	■	■	△	△	△	■	●	CAP
4.39 Hydrofracturing (enhancement)	Pilot	I	None	Yes	●	●	●	●	●	■	■	●	Neither
4.40 Passive Treatment Walls	Pilot	△	Solid	No	■	■	●	■	■	I	△	I	CAP
4.41 Slurry Walls (containment only)	Full	■	NA	NA	●	●	●	●	●	■	■	■	CAP
4.42 Vacuum Vapor Extraction	Pilot	△	Liquid,Vapor	No	■	●	■	I	△	■	●	●	CAP
3.10 Ex Situ Biological Treatment (assuming pumping)													
4.43 Bioreactors	Full	■	Solid	No	■	■	■	△	●	●	NA	■	CAP
3.11 Ex Situ Physical/Chemical Treatment (assuming pumping)													
4.44 Air Stripping	Full	■	Liquid,Vapor	No	■	●	●	△	△	■	NA	■	O&M
4.45 Filtration	Full	■	Solid	Yes	△	△	△	■	●	■	■	■	Neither
4.46 Ion Exchange	Full	■	Solid	Yes	△	△	△	■	△	■	●	■	Neither
4.47 Liquid Phase Carbon Adsorption	Full	■	Solid	No	■	■	●	●	■	■	NA	△	O&M
4.48 Precipitation	Full	■	Solid	Yes	△	△	△	■	I	■	●	■	Neither
4.49 UV Oxidation	Full	■	None	No	■	■	■	△	■	△	NA	●	Both
3.12 Other Treatment													
4.50 Natural Attenuation	NA	■	None	No	■	■	■	△	△	■	△	■	Neither
3.13 AIR EMISSIONS/OFF-GAS TREATMENT													
4.51 Biofiltration	Full	●	None	NA	■	●	■	△	●	△	NA	●	Neither
4.52 High Energy Corona	Pilot	△	None		■	■	■	●	△	△	NA	●	I
4.53 Membrane Separation	Pilot	△	None		■	●	●	△	●	△	NA	●	I
4.54 Oxidation	Full	■	None		■	■	■	△	●	■	NA	■	Neither
4.55 Vapor Phase Carbon Adsorption	Full	■	Solid		■	■	■	●	■	■	NA	■	Neither

Rating Codes (See Table 3-1)

- ■ Better
- ● Average
- △ Worse
- I Inadequate Information
- NA Not Applicable

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Source: Remediation Technologies Screening Matrix and Reference Guide (PB95-104782)

APPENDIX C

Appendix C

LIST OF ACRONYMS and GLOSSARY OF KEY TERMS

ARAR	Applicable or Relevant and Appropriate Requirement
ASTM	American Society for Testing and Materials
BDAT	Best Demonstrated Achievable Technology
BTEX	Benzene, Toluene, Ethylbenzene, and Xylene
CAA	Clean Air Act
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CERCLIS	Comprehensive Environmental Response, Compensation, and Liability Information System
CWA	Clean Water Act
DDT	Dioxin
DNAPL	Dense Nonaqueous Phase Liquid
DQO	Data Quality Objective
EPA	U.S. Environmental Protection Agency
ESA	Environmental Site Assessment
HRS	Hazard Ranking System
HSWA	Hazardous and Solid Waste Amendments
IRIS	Integrated Risk Information System
ITT	Innovative Treatment Technology
LDR	Land Disposal Restrictions
LNAPL	Light Nonaqueous Phase Liquid
LUST	Leaking Underground Storage Tank
NAPL	Nonaqueous Phase Liquid
NCP	National Contingency Plan
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
NRC	National Response Center
O&M	Operations and Maintenance
ORD	Office of Research and Development
OSWER	Office of Solid Waste and Emergency Response
PAH	Polynuclear Aromatic Hydrocarbon
PA/SI	Preliminary Assessment and Site Inspection
PCB	Polychlorinated Biphenyl
PCP	Pentachlorophenol
PRP	Potentially Responsible Party
QA/QC	Quality Assurance and Quality Control
RCRA	Resource Conservation and Recovery Act
RD/RA	Remedial Design and Remedial Action
RI/FS	Remedial Investigation and Feasibility Study
ROD	Record of Decision
RQ	Reportable quantity
SARA	Superfund Amendments and Reauthorization Act
SITE	Superfund Innovative Technology Evaluation Program
SVE	Soil Vapor Extraction
SVOC	Semi-Volatile Organic Compound
TCE	Trichloroethylene
TIO	Technology Innovation Office
TPH	Total Petroleum Hydrocarbon
TSCA	Toxic Substances Control Act
TSDF	Treatment, Storage, and Disposal Facility
UST	Underground Storage Tank
VCP	Voluntary Cleanup Program
VOC	Volatile Organic Compound

The following is a list of specialized terms used during the cleanup of Brownfields sites.

Absorption
Absorption is the passage of one substance into or through another.

Adsorption
Adsorption is the adhesion of molecules of gas, liquid, or dissolved solids to a surface. The term also refers to a method of treating wastes in which activated carbon removes organic matter from wastewater.

Air Sparging
In air sparging, air is injected into the ground below a contaminated area, forming bubbles that rise and carry trapped and dissolved contaminants to the surface where they are captured by a soil vapor extraction system. Air sparging may be a good choice of treatment technology at sites contaminated with solvents and other volatile organic compounds (VOC). *See also Soil Vapor Extraction and Volatile Organic Compound.*

Air Stripping
Air stripping is a treatment system that removes or "strips" VOCs from contaminated groundwater or surface water as air is forced through the water, causing the compounds to evaporate. *See also Volatile Organic Compound.*

American Society for Testing and Materials (ASTM)
The ASTM sets standards for many services, including methods of sampling and testing of hazardous waste and media contaminated with hazardous waste.

Applicable or Relevant and Appropriate Requirement (ARAR)
As defined under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), ARARs are cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limits promulgated under Federal or state law that specifically address problems or situations present at a CERCLA site. ARARs are major considerations in setting cleanup goals, selecting a remedy, and determining how to implement that remedy at a CERCLA site. ARARs must be attained at all CERCLA sites unless a waiver is attained. ARARs are not national cleanup standards for the Superfund program. *See also Comprehensive Environmental Response, Compensation, and Liability Act and Superfund.*

Aquifer
An aquifer is an underground rock formation composed of such materials as sand, soil, or gravel that can store groundwater and supply it to wells and springs.

Aromatics
Aromatics are organic compounds that contain 6-carbon ring structures, such as creosote, toluene, and phenol, that often are found at dry cleaning and electronic assembly sites.

Baseline Risk Assessment
A baseline risk assessment is an assessment conducted before cleanup activities begin at a site to identify and evaluate the threat to human health and the environment. After remediation has been completed, the information obtained during a baseline risk assessment can be used to determine whether the cleanup levels were reached.

Bedrock
Bedrock is the rock that underlies the soil; it can be permeable or non-permeable. *See also Confining Layer and Creosote.*

Best Demonstrated Achievable Technology (BDAT)
A BDAT is a technology that has demonstrated the ability to reduce a particular contaminant to a lower concentration than other currently available technologies. BDATs can change with time as technologies evolve.

Bioremediation
Bioremediation refers to treatment processes that use microorganisms (usually naturally occurring) such as bacteria, yeast, or fungi to break down hazardous substances into less toxic or nontoxic substances. Bioremediation can be used to clean up contaminated soil and water. In situ bioremediation treats the contaminated soil or groundwater in the location in which it is found. For ex situ bioremediation processes, contaminated soil must be excavated or groundwater pumped before they can be treated.

Biosensor
A biosensor is a portable device that uses living organisms, such as enzymes, tissues, microbes, and antibodies, to produce reactions to analytes.

Bioventing
Bioventing is an in situ remediation technology that combines soil vapor extraction methods with bioremediation. It uses vapor extraction wells that induce air flow in the subsurface through air injection or through the use of a vacuum. Bioventing can be effective in remediating releases of petroleum products, such as gasoline, jet fuels, kerosene, and diesel fuel. *See also Bioremediation and Soil Vapor Extraction.*

Borehole
A borehole is a hole cut into the ground by means of a drilling rig.

Borehole Geophysics
Borehole geophysics are nuclear or electric technologies used to identify the physical characteristics of geologic formations that are intersected by a borehole.

Brownfields
Brownfields sites are abandoned, idled, or under-used industrial and commercial facilities where expansion or redevelopment is complicated by real or perceived environmental contamination.

BTEX
BTEX is the term used for benzene, toluene, ethylbenzene, and xylene-volatile aromatic compounds typically found in petroleum products, such as gasoline and diesel fuel.

Cadmium
Cadmium is a heavy metal that accumulates in the environment. *See also Heavy Metal.*

Carbon Adsorption
Carbon adsorption is a treatment system that removes contaminants from groundwater or surface water as the water is forced through tanks containing activated carbon.

Chemical Dehalogenation
Chemical dehalogenation is a chemical process that removes halogens (usually chlorine) from a chemical contaminant, rendering the contaminant less hazardous. The chemical dehalogenation process can be applied to common halogenated contaminants such as polychlorinated biphenyls (PCB) and dioxins (DDT), which may be present in soil and oils. Dehalogenation can be effective in removing halogens from hazardous organic compounds, such as dioxins, PCBs, and certain chlorinated pesticides. The treatment time is short, energy requirements are moderate, and operation and maintenance costs are relatively low. This technology can be brought to the site, eliminating the need to transport hazardous wastes. *See also Polychlorinated Biphenyl and Dioxin.*

Chlorinator
A chlorinator is a device that adds chlorine, in gas or liquid form, to water or sewage to kill bacteria.

Clean Air Act (CAA)
The CAA is a Federal law passed in 1970 that requires the U.S. Environmental Protection Agency (EPA) to establish regulations to control the release of contaminants to the air to protect human health and environment.

Cleanup
Cleanup is the term used for actions taken to deal with a release or threat of release of a hazardous substance that could affect humans and or the environment. The term sometimes is used interchangeably with the terms remedial action, removal action, response action, or corrective action.

Clean Water Act (CWA)
CWA is a 1977 amendment to the Federal Water Pollution Control Act of 1972, which set the basic structure for regulating discharges of pollutants to U.S. waters. This law gave EPA the authority to set effluent standards on an industry-by-industry basis and to set water quality standards for all contaminants in surface waters.

Colorimetric
Colorimetric refers to chemical reaction-based indicators that are used to produce compound reactions to individual compounds, or classes of compounds. The reactions, such as visible color changes or other easily noted indications, are used to detect and quantify contaminants.

Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)
CERCLA is a Federal law passed in 1980 that created a special tax that funds a trust fund, commonly known as Superfund, to be used to investigate and clean up abandoned or uncontrolled hazardous waste sites. CERCLA required for the first time that EPA step beyond its traditional regulatory role and provide response authority to clean up hazardous waste sites. EPA has primary responsibility for managing cleanup and enforcement activities authorized under CERCLA. Under the program, EPA can pay for cleanup when parties responsible for the contamination cannot be located or are unwilling or unable to perform the work, or take legal action to force parties responsible for contamination to clean up the site or reimburse the Federal government for the cost of the cleanup. *See also Superfund.*

Comprehensive Environmental Response, Compensation, and Liability Information System (CERCLIS)
CERCLIS is a database that serves as the official inventory of Superfund hazardous waste sites. CERCLIS also contains information about all aspects of hazardous waste sites, from initial discovery to deletion from the National Priorities List (NPL). The database also maintains information about planned and actual site activities and financial information entered by EPA regional offices. CERCLIS records the targets and accomplishments of the Superfund program and is used to report that information to the EPA Administrator, Congress, and the public. *See also National Priorities List and Superfund.*

Confining Layer
A "confining layer" is a geological formation characterized by low permeability that inhibits the flow of water. *See also Bedrock and Permeability.*

Contaminant
A contaminant is any physical, chemical, biological, or radiological substance or matter present in any media at concentrations that may result in adverse effects on air, water, or soil.

Corrective Measure Study (CMS)
If the potential need for corrective measures is verified during a RCRA Facility Investigation (RFI), the owner or operator of a facility is then responsible for performing a CMS. A CMS is conducted to identify, evaluate, and recommend specific corrective measures based on a detailed engineering evaluation. Using data collected during the RFI, the CMS demonstrates that proposed measures will be effective in controlling the source of contamination, as well as problems posed by the migration of substances from the original source into the environment. The measures also must be assessed in terms of technical feasibility, ability to meet public health protection requirements and protect the environment, possible adverse environmental effects, and institutional constraints. *See also RCRA Facility Investigation.*

Corrosivity
Corrosive wastes include those that are acidic and capable of corroding metal such as tanks, containers, drums, and barrels.

Creosote
Creosote is an oily liquid obtained by the distillation of wood that is used as a wood preservative and disinfectant and often is found at wood preserving sites. *See also Aromatics and Light Nonaqueous Phase Liquid.*

Data Quality Objective (DQO)
DQOs are qualitative and quantitative statements specified to ensure that data of known and appropriate quality are obtained. The DQO process is a series of planning steps, typically conducted during site assessment and investigation, that is designed to ensure that the type, quantity, and quality of environmental data used in decision making are appropriate. The DQO process involves a logical, step-by-step procedure for determining which of the complex issues affecting a site are the most relevant to planning a site investigation before any data are collected.

Dechlorination
Dechlorination, the process used primarily to treat and destroy halogenated aromatic contaminants, is the chemical reaction that removes halogens (usually chlorine) from the primary structure of the contaminating organic chemical. Dechlorination can treat contaminated liquids, soils, sludges, and sediments, as well as halogenated organics and PCBs, pesticides, and some herbicides.

Dense Nonaqueous Phase Liquid (DNAPL)
A DNAPL is one of a group of organic substances that are relatively insoluble in water and more dense than water. DNAPLs tend to sink vertically through sand and gravel aquifers to the underlying layer.

Dioxin (DDT)
A dioxin is any of a family of compounds known chemically as dibenzo-p-dioxins. They are chemicals released during combustion. Concern about them arises from their potential toxicity and the risk posed by contamination in commercial products. Boilers and industrial furnaces are among the sources of dioxins.

Disposal
Disposal is the final placement or destruction of toxic, radioactive or other wastes; surplus or banned pesticides or other chemicals; polluted soils; and drums containing hazardous materials from removal actions or accidental release. Disposal may be accomplished through the use of approved secure landfills, surface impoundments, land farming, deep well injection, ocean dumping, or incineration.

Dual-Phase Extraction
Dual-phase extraction is a technology that extracts contaminants simultaneously from soils in saturated and unsaturated zones by applying soil vapor extraction techniques to contaminants trapped in saturated zone soils. *See also Soil Vapor Extraction.*

Electromagnetic (EM) Geophysics
EM geophysics refers to technologies used to detect spatial (lateral and vertical) differences in subsurface electromagnetic characteristics. The data collected provide information about subsurface environments.

Electromagnetic (EM) Induction
EM induction is a geophysical technology used to induce a magnetic field beneath the earth's surface, which in turn causes a secondary magnetic field to form around nearby objects that have conductive properties, such as ferrous and nonferrous metals. The secondary magnetic field is then used to detect and measure buried debris.

Emergency Removal
An emergency removal is an action initiated in response to a release of a hazardous substance that requires on-site activity within hours of a determination that action is appropriate.

Emerging Technology
An emerging technology is an innovative technology that currently is undergoing bench-scale testing. During bench-scale testing, a small version of the technology is built and tested in a laboratory. If the technology is successful during bench-scale testing, it is demonstrated on a small scale at field sites. If the technology is successful at the field demonstrations, it often will be used full scale at contaminated waste sites. As the technology is used and evaluated at different sites, it is improved continually. *See also Established Technology and Innovative Technology.*

Enforcement Action
An enforcement action is an action undertaken by EPA under its authority granted under various Federal environmental statutes, such as CERCLA, RCRA, CAA, CWA, the Toxic Substances Control Act (TSCA), and others. For example, under CERCLA, EPA may obtain voluntary settlement or compel potentially responsible parties (PRP) to implement removal or remedial actions when releases of hazardous substances have occurred. *See also Comprehensive Environmental Response, Compensation, and Liability Act, Potentially Responsible Party, and Removal Action.*

Engineered Control
An engineered control, such as barriers placed between contamination and the rest of a site, is a method of managing environmental and health risks. Engineered controls can be used to limit exposure pathways.

Environmental Audit
See Phase I Environmental Audit.

Environmental Site Assessment (ESA)
An ESA is the process by which it is determined whether contamination is present on a site.

Established Technology
An established technology is a technology for which cost and performance information is readily available. Only after a technology has been used at many different sites and the results fully documented is that technology considered established. The most frequently used established technologies are incineration, solidification and stabilization, and pump-and-treat technologies for groundwater. *See also Emerging Technology and Innovative Technology.*

Exposure Pathway
An exposure pathway is the route of contaminants from the source of contamination to potential contact with a medium (air, soil, surface water, or groundwater) that represents a potential threat to human health or the environment. Determining whether exposure pathways exist is an essential step in conducting a baseline risk assessment. *See also Baseline Risk Assessment.*

Ex Situ
The term ex situ or "moved from its original place," means excavated or removed.

Filtration
Filtration is a treatment process that removes solid matter from water by passing the water through a porous medium, such as sand or a manufactured filter.

Flame Ionization Detector (FID)
A FID is an instrument often used in conjunction with gas chromatography to measure the change of signal as analytes are ionized by a hydrogen-air flame. It also is used to detect phenols, phthalates, polynuclear aromatic hydrocarbons (PAH), VOCs, and petroleum hydrocarbons. *See also Portable Gas Chromatography.*

Fourier Transform Infrared Spectroscopy
A fourier transform infrared spectroscope is an analytical air monitoring tool that uses a laser system chemically to identify contaminants.

Fumigant
A fumigant is a pesticide that is vaporized to kill pests. They often are used in buildings and greenhouses. *See also Dioxin.*

Furan
Furan is a colorless, volatile liquid compound used in the synthesis of organic compounds, especially nylon.

Gas Chromatography
Gas chromatography is a technology used for investigating and assessing soil, water, and soil gas contamination at a site. It is used for the analysis of VOCs and semivolatile organic compounds (SVOC). The technique identifies and quantifies organic compounds on the basis of molecular weight, characteristic fragmentation patterns, and retention time. Recent advances in gas chromatography that are considered innovative are portable, weather-proof units that have self-contained power supplies.

Ground-Penetrating Radar
GPR is a technology that emits pulses of electromagnetic energy into the ground to measure its reflection and refraction by subsurface layers and other features, such as buried debris.

Groundwater
Groundwater is the water found beneath the earth's surface that fills pores between such materials as sand, soil, or gravel and that often supplies wells and springs. *See also Aquifer.*

Halogenated Organic Compound
A halogenated organic compound is a compound containing molecules of chlorine, bromine iodine, and or fluorine. Halogenated organic compounds were used in high-voltage electrical transformers because they conducted heat well while being fire resistant and good electrical insulators. Many herbicides, pesticides, and degreasing agents are made from halogenated organic compounds.

Hazard Ranking System (HRS)
The HRS is the primary screening tool used by EPA to assess the risks posed to human health or the environment by abandoned or uncontrolled hazardous waste sites. Under the HRS, sites are assigned scores on the basis of the toxicity of hazardous substances that are present and the potential that those substances will spread through

the air, surface, water, or groundwater, taking into account such factors as the proximity of the substance to nearby populations. Scores are used in determining which sites should be placed on the NPL. *See also National Priorities List.*

Hazardous Substance
As defined under CERCLA, a hazardous substance is any material that poses a threat to public health or the environment. The term also refers to hazardous wastes as defined under the Resource Conservation and Recovery Act (RCRA). Typical hazardous substances are materials that are toxic, corrosive, ignitable, explosive, or chemically reactive. If a certain quantity of a hazardous substance, as established by EPA, is spilled into the water or otherwise emitted into the environment, the release must be reported. Under the legislation cited above, the term excludes petroleum, crude oil, natural gas, natural gas liquids, or synthetic gas usable for fuel.

Hazardous and Solid Waste Amendments (HSWA)
HSWA are 1984 amendments to RCRA which required phasing out land disposal of hazardous waste and added minimum technology requirements. *See also Resource Conservation and Recovery Act.*

Heavy Metal
The term heavy metal refers to a group of toxic metals including arsenic, chromium, copper, lead, mercury, silver, and zinc. Heavy metals often are present at industrial sites at which operations have included battery recycling and metal plating.

Herbicide
A herbicide is a chemical pesticide designed to control or destroy plants, weeds, or grasses.

High-Frequency Electromagnetic (EM) Sounding
High-frequency EM sounding, the technology used for nonintrusive geophysical exploration, projects high-frequency electromagnetic radiation into subsurface layers to detect the reflection and refraction of the radiation by various layers of soil. Unlike ground-penetrating radar, which uses pulses, the technology uses continuous waves of radiation. *See also Ground-Penetrating Radar.*

Hydrazine
Hydrazine is a highly toxic liquid used in rocket propellant, agricultural chemicals, drugs, spandex fibers, antioxidants, plating metals on glass and plastic, explosives, and in boiler feedwater. The chemical compound causes a severe explosion hazard when exposed to heat.

Hydrocarbon
A hydrocarbon is an organic compound containing only hydrogen and carbon, often occurring in petroleum, natural gas, and coal.

Hydrogen Sulfide (HS)
HS is a gas emitted during decomposition of organic compounds. It also is a byproduct of oil refining and burning.

Hydrogeology
Hydrogeology is the study of groundwater, including its origin, occurrence, movement, and quality.

Hydrology
Hydrology is the science that deals with the properties, movement, and effects of water found on the earth's surface, in the soil and rocks beneath the surface, and in the atmosphere.

Ignitability
Ignitable wastes can create fires under certain conditions. Examples include liquids, such as solvents that readily catch fire, and friction-sensitive substances.

Immunoassay
Immunoassay is an innovative technology used to measure compound-specific reactions (generally colorimetric) to individual compounds or classes of compounds. The reactions are used to detect and quantify contaminants. The technology is available in field-portable test kits.

Incineration
Incineration is a treatment technology that involves the burning of certain types of solid, liquid, or gaseous materials under controlled conditions to destroy hazardous waste.

Information Repository
An information repository is a location in a public building that is convenient for local residents, such as a public school, city hall, or library, that contains information about a Superfund site, including technical reports and reference documents.

Infrared Monitor
An infrared monitor is a device used to monitor the heat signature of an object, as well as to sample air. It may be used to detect buried objects in soil.

Inorganic Compound
An inorganic compound is a compound that generally does not contain carbon atoms (although carbonate and bicarbonate compounds are notable exceptions), tends to be more soluble in water, and tends to react on an ionic rather than on a molecular basis. Examples of inorganic compounds include various acids, potassium hydroxide, and metals.

Innovative Technology
An innovative technology is a process that has been tested and used as a treatment for hazardous waste or other contaminated materials, but lacks a long history of full-scale use and information about its cost and how well it works sufficient to support prediction of its performance under a variety of operating conditions. An innovative technology is one that is undergoing pilot-scale treatability studies that usually are conducted in the field or the laboratory and require installation of the technology, and provide performance, cost, and design objectives for the technology. Innovative technologies are being used under many Federal and state cleanup programs to treat hazardous wastes that have been improperly released. For example, innovative technologies are being selected to manage contamination (primarily petroleum) at some leaking underground storage sites. *See also Emerging Technology and Established Technology.*

Ion Exchange
Ion exchange, a common method of softening water, depends on the ability of certain materials to remove and exchange ions from water. These ion exchange materials, generally composed of unsoluble organic polymers, are placed in a filtering device. Water softening exchange materials remove calcium and magnesium ions, replacing them with sodium ions.

Insecticide
An insecticide is a pesticide compound specifically used to kill or control the growth of insects. *See also Dioxin.*

In Situ
The term in situ, "in its original place," or "on-site", means unexcavated and unmoved. In situ soil flushing and natural attenuation are examples of in situ treatment methods by which contaminated sites are treated without digging up or removing the contaminants.

In Situ Oxidation
In situ oxidation is an innovative treatment technology that oxidizes contaminants that are dissolved in groundwater and converts them into insoluble compounds.

In Situ Soil Flushing
In situ soil flushing is an innovative treatment technology that floods contaminated soils beneath the ground surface with a solution that moves the contaminants to an area from which they can be removed. The technology requires the drilling of injection and extraction wells on site and reduces the need for excavation, handling, or transportation of hazardous substances. Contaminants considered for treatment by in situ soil flushing include heavy metals (such as lead, copper, and zinc), halogenated organic compounds, aromatics, and PCBs. *See also Aromatics, Halogenated Organic Compound, Heavy Metal, and Polychlorinated Biphenyl.*

In Situ Vitrification
In situ vitrification is a soil treatment technology that stabilizes metal and other inorganic contaminants in place at temperatures of approximately 3000°F. Soils and sludges are fused to form a stable glass and crystalline structure with very low leaching characteristics.

Institutional Controls
An institutional control is a legal or institutional measure which subjects a property owner to limit activities at or access to a particular property. They are used to ensure protection of human health and the environment, and to expedite property reuse. Fences, posting or warning signs, and zoning and deed restrictions are examples of institutional controls.

Integrated Risk Information System (IRIS)
IRIS is an electronic database that contains EPA's latest descriptive and quantitative regulatory information about chemical constituents. Files on chemicals maintained in IRIS contain information related to both noncarcinogenic and carcinogenic health effects.

Joint and Several Liability
Under CERCLA, joint and several liability is a concept based on the theory that it may not be possible to apportion responsibility for the harm caused by hazardous waste equitably among potentially responsible parties (PRP) from that dependant. Joint liability means that more than one defendant is liable to the plaintiff. Several liability means that the plaintiff may choose to sue only one of the defendants and recover the entire amount. One PRP therefore can be held liable for the entire cost of cleanup, regardless of the share of waste that PRP contributed. Joint and several liability is used only when harm is indivisible. If defendants can apportion harm, there is no several liability. *See also Potentially Responsible Party and Strict Liability.*

Land Disposal Restrictions (LDR)
LDRs is a RCRA program that restricts the land disposal of RCRA hazardous wastes and requires treatment to promulgated treatment standards. The LDRs may be an important Applicable or Relevant and Appropriate Requirement (ARAR) for Superfund actions. *See also Applicable or Relevant and Appropriate Requirement and Resource Conservation and Recovery Act.*

Landfarming
Landfarming is the spreading and incorporation of wastes into the soil to initiate biological treatment.

Landfill
A sanitary landfill is a land disposal site for nonhazardous solid wastes at which the waste is spread in layers compacted to the smallest practical volume.

Laser-Induced Fluorescence/Cone Penetrometer
Laser-induced fluorescence/cone penetrometer is a field screening method that couples a fiber optic-based chemical sensor system to a cone penetrometer mounted on a truck. The technology can be used for investigating and assessing soil and water contamination.

Leachate
A leachate is a contaminated liquid that results when water collects contaminants as it trickles through wastes, agricultural pesticides, or fertilizers. Leaching may occur in farming areas and landfills and may be a means of the entry of hazardous substances into soil, surface water, or groundwater.

Lead
Lead is a heavy metal that is hazardous to health if breathed or swallowed. Its use in gasoline, paints, and plumbing compounds has been sharply restricted or eliminated by Federal laws and regulations. *See also Heavy Metal.*

Leaking Underground Storage Tank (LUST)
LUST is the acronym for "leaking underground storage tank." *See also Underground Storage Tank.*

Light Nonaqueous Phase Liquid (LNAPL)
An LNAPL is one of a group of organic substances that are relatively insoluble in water and are less dense than water. LNAPLs, such as oil, tend to spread across the surface of the water table and form a layer on top of the water table.

Magnetrometry
Magnetrometry is a geophysical technology used to detect disruptions that metal objects cause in the earth's localized magnetic field.

Mass Spectrometry
Mass spectrometry is an analytical process by which molecules are broken into fragments to determine the concentrations and mass/charge ratio of the fragments. Innovative mass spectroscopy units, developed through modification of large laboratory instruments, are sometimes portable, weatherproof units with self-contained power supplies.

Medium
A medium is a specific environment--air, water, or soil–which is the subject of regulatory concern and activities.

Mercury
Mercury is a heavy metal that can accumulate in the environment and is highly toxic if breathed or swallowed. Mercury is a highly toxic substance found in thermometers, measuring devices, pharmaceutical and agricultural chemicals, chemical manufacturing, and electrical equipment. *See also Heavy Metal.*

Mercury Vapor Analyzer
A mercury vapor analyzer is an instrument that provides real-time measurements of concentrations of mercury in the air.

Methane
Methane is a colorless, nonpoisonous, flammable gas created by anaerobic decomposition of organic compounds.

Migration Pathway
A migration pathway is a potential path or route of contaminants from the source of contamination to contact with human populations or the environment. Migration pathways include air, surface water, groundwater, and land surface. The existence and identification of all potential migration pathways must be considered during assessment and characterization of a waste site.

Mixed Waste
Mixed waste is low-level radioactive waste contaminated with hazardous waste that is regulated under RCRA. Mixed waste can be disposed only in compliance with the requirements under RCRA that govern disposal of hazardous waste and with the RCRA land disposal restrictions, which require that waste be treated before it is disposed of in appropriate landfills.

Monitoring Well
A monitoring well is a well drilled at a specific location on or off a hazardous waste site at which groundwater can be sampled at selected depths and studied to determine the direction of groundwater flow and the types and quantities of contaminants present in the groundwater.

National Contingency Plan (NCP)
The NCP, formally the National Oil and Hazardous Substances Contingency Plan, is the major regulatory framework that guides the Superfund response effort. The NCP is a comprehensive body of regulations that outlines a step-by-step process for implementing Superfund responses and defines the roles and responsibilities of EPA, other Federal agencies, states, private parties, and the communities in response to situations in which hazardous substances are released into the environment. *See also Superfund.*

National Pollutant Discharge Elimination System (NPDES)
NPDES is the primary permitting program under the Clean Water Act, which regulates all discharges to surface water. It prohibits discharge of pollutants into waters of the United States unless EPA, a state, or a tribal government issues a special permit to do so.

National Priorities List (NPL)
The NPL is EPA's list of the most serious uncontrolled or abandoned hazardous waste sites identified for possible long-term remedial response under Superfund. Inclusion of a site on the list is based primarily on the score the site receives under the HRS. Money from Superfund can be used for cleanup only at sites that are on the NPL. EPA is required to update the NPL at least once a year. *See also Hazard Ranking System and Superfund.*

National Response Center (NRC)
The NRC, staffed by the U.S. Coast Guard, is a communications center that receives reports of discharges or releases of hazardous substances into the environment. The U.S. Coast Guard in turn, relays information about such releases to the appropriate Federal agency.

Natural Attenuation
Natural attenuation is an approach to cleanup that uses natural processes to contain the spread of contamination from chemical spills and reduce the concentrations and amounts of pollutants in contaminated soil and groundwater. Natural subsurface processes, such as dilution, volatilization, biodegradation, adsorption, and chemical reactions with subsurface materials, are allowed to reduce concentrations of contaminants to acceptable levels. An in situ treatment method that leaves the contaminants in place while those processes occur, natural attenuation is being used to clean up petroleum contamination from leaking underground storage tanks (LUST) across the country.

Nitric Oxide
Nitric oxide is a gas formed by combustion under high temperature and high pressure in an internal combustion engine.

Nonaqueous Phase Liquid (NAPL)
NAPLs are organic substances that are relatively insoluble in water and are less dense than water. *See also Dense Nonaqueous Phase Liquid and Light Nonaqueous Phase Liquid.*

Non-Point Source
The term non-point source is used to identify sources of pollution that are diffuse and do not have a point of origin or that are not introduced into a receiving stream from a specific outlet. Common non-point sources are rain water, runoff from agricultural lands, industrial sites, parking lots, and timber operations, as well as escaping gases from pipes and fittings.

Operation and Maintenance (O&M)
O&M refers to the activities conducted at a site, following remedial actions, to ensure that the cleanup methods are working properly. O&M activities are conducted to maintain the effectiveness of the remedy and to ensure that no new threat to human health or the environment arises. The state or PRP assumes responsibility for O&M, which may include such activities as groundwater and air monitoring, inspection and maintenance of the treatment equipment remaining on site, and maintenance of any security measures or institutional controls.

Organic Chemical or Compound
An organic chemical or compound is a substance produced by animals or plants that contains mainly carbon, hydrogen, and oxygen.

Ozone
Ozone is a form of oxygen found naturally which provides a protective layer shielding the earth from the harmful health effects on human health and the environment from ultraviolet radiation. Ozone is a chemical oxidant and a major component of smog in the troposphere, the earth's atmospheric layer extending 7 to 10 miles from the earth's surface. Ozone can have a serious effect on the human respiratory system and is one of the most prevalent and widespread of all the criteria pollutants for which the Clean Air Act required EPA to set standards.

Pentachlorophenol (PCP)
PCP, a chemical compound containing carbon, chlorine, oxygen, and hydrogen, is a contaminant used in feed stock material and chemical manufacturing.

Permeability
Permeability is a characteristic that represents a qualitative description of the relative ease with which rock, soil, or sediment will transmit a fluid (liquid or gas).

Pesticide
A pesticide is a substance or mixture of substances intended to prevent or mitigate infestation by, or destroy or repel, any pest. Pesticides can accumulate in the food chain and or contaminate the environment if misused. *See also Dioxin.*

Phase I Environmental Audit
A Phase I environmental audit is an initial environmental investigation that is limited to a historical records search to determine ownership of a site and to identify the kinds of chemical processes that were carried out at the site. A Phase I audit includes a site visit, but does not include any sampling. If such an audit identifies no significant concerns, Phase II and III audits are not necessary.

Phase II Environmental Audit
A Phase II environmental audit is an investigation that includes tests performed at the site to confirm the location and identity of environmental hazards. The audit includes preparation of a report that includes recommendations for cleanup alternatives.

Phase III Environmental Audit
A Phase III environmental audit is the third-step in the audit that includes the removal of contaminated materials from a site and their legal disposal.

Phenols
A phenol is one of a group of organic compounds that are byproducts of petroleum refining, tanning, and textile, dye, and resin manufacturing. Low concentrations of phenols cause taste and odor problems in water; higher concentrations may be harmful to human health or the environment.

Photoionization Detector (PID)
A PID is a nondestructive detector, often used in conjunction with gas chromatography, that measures the change of signal as analytes are ionized by an ultraviolet lamp. The PID also is used to detect VOCs and petroleum hydrocarbons. *See also Portable Gas Chromatography.*

Phytoremediation
Phytoremediation is an innovative treatment technology that uses plants and trees to clean up contaminated soil and water. Plants can break down, or degrade, organic pollutants or stabilize metal contaminants by acting as filters or traps. Phytoremediation can be used to clean up metals, pesticides, solvents, explosives, crude oil, polyaromatic carbons, and landfill leachates. Its use generally is limited to sites at which concentrations of contaminants are relatively low and contamination is found in shallow soils, streams, and groundwater.

Plasma High-Temperature Metals Recovery
Plasma high-temperature metals recovery is a thermal treatment process that purges contaminants from solids and soils such as metal fumes and organic vapors. The vapors can be burned as fuel, and the metal fumes can be recovered and recycled. This innovative treatment technology is used to treat contaminated soil and groundwater.

Plume
A plume is a visible or measurable emission or discharge of a contaminant from a given point of origin into any medium. The term also is used to refer to measurable and potentially harmful radiation leaking from a damaged reactor.

Point Source
A point source is a stationary location or fixed facility from which pollutants are discharged or emitted or any single, identifiable discharge point of pollution, such as a pipe, ditch, or smokestack.

Polychlorinated Biphenyl (PCB)
PCBs are a group of toxic, persistent chemicals, produced by chlorination of biphenyl, that once were used in high voltage electrical transformers because they conducted heat well while being fire resistant and good electrical insulators. These contaminants typically are generated from metal degreasing, printed circuit board cleaning, gasoline, and wood preserving processes. Further sale or use of PCBs was banned in 1979.

Polynuclear Aromatic Hydrocarbon (PAH)
A PAH is a chemical compound that contains more than one fused benzene ring. They are commonly found in petroleum fuels, coal products, and tar.

Potentially Responsible Party (PRP)
A PRP is an individual or company (such as owners, operators, transporters, or generators of hazardous waste) that is potentially responsible for, or contributing to, the contamination problems at a Superfund site. Whenever possible, EPA requires PRPs, through administrative and legal actions, to clean up hazardous waste sites they have contaminated. *See also Superfund.*

Preliminary Assessment and Site Investigation (PA/SI)
A preliminary assessment (PA) is the process of collecting and reviewing available information about a known or suspected hazardous waste site or release. The PA usually includes a visit to the site.

Presumptive Remedies
Presumptive remedies are preferred technologies for common categories of CERCLA sites that have been identified through historical patterns of remedy selection and EPA's scientific and engineering evaluation of performance data on technology implementation.

Pump and Treat
Pump and treat is a general term used to describe remediation methods that involve the pumping of groundwater to the surface for treatment. It is one of the most common methods of treating polluted aquifers and groundwater.

Quality Assurance and Quality Control (QA/QC)
QA/QC is a system of procedures, checks, audits, and corrective actions applied to ensure that all EPA research design and performance, environmental monitoring and sampling, and other technical and reporting activities are of the highest achievable quality.

Radioactive Waste
Radioactive waste is any waste that emits energy as rays, waves, or streams of energetic particles. Sources of such wastes include nuclear reactors, research institutions, and hospitals.

Radionuclide
A radionuclide is a radioactive element characterized according to its atomic mass and atomic number, which can be artificial or naturally occurring. Radionuclides have a long life as soil or water pollutants. Radionuclides cannot be destroyed or degraded; therefore, applicable technologies involve separation, concentration and volume reduction, immobilization, or vitrification. *See also Solidification and Stabilization.*

Radon
Radon is a colorless, naturally occurring, radioactive, inert gaseous element formed by radioactive decay of radium atoms. *See also Radioactive Waste and Radionuclide.*

RCRA Facility Assessment (RFA)
A RFA is performed at a facility to determine the existence of any continuous or non-continuous releases of wastes. During the RFA, EPA or state regulators gather information on solid waste management units and other areas of concern at RCRA facilities, evaluate this information to determine whether there are releases that warrant further investigation and action, and determine the need to proceed to a RCRA Facility Investigation. *See also Resource Conservation and Recovery Act.*

RCRA Facility Investigation (RFI)
The purpose of a RFI is to gather sufficient data at a facility to fully characterize the nature, extent, and rate of migration of contaminant releases identified in the RCRA Facility Assessment. The data generated during the RFI is used to determine the potential need for corrective measures and to aid in the selection and implementation of these measures. *See also Corrective Measure Study and Resource Conservation and Recovery Act.*

Reactivity
Reactive wastes are unstable under normal conditions. They can create explosions and or toxic fumes, gases, and vapors when mixed with water.

Record of Decision (ROD)
A record of decision (ROD) is a legal, technical, and public document that explains which cleanup alternative will be used at a site. The ROD is based on information and technical analysis generated during the remedial investigation and feasibility study (RI/FS) and consideration of public comments and community concerns. *See also Preliminary Assessment and Site Investigation and Remedial Investigation and Feasibility Study.*

Release
A release is any spilling, leaking, pumping, pouring, emitting, emptying, discharging, injecting, leaching, dumping, or disposing into the environment of a hazardous or toxic chemical or extremely hazardous substance, as defined under RCRA. *See also Resource Conservation and Recovery Act.*

Remedial Design and Remedial Action (RD/RA)
The RD/RA is the step in the cleanup process that follows the remedial investigation and feasibility study (RI/FS) and selection of a remedy. A remedial design (RD) is the preparation of engineering plans and specifications to properly and effectively implement the remedy. The remedial action (RA) is the actual construction or implementation of the remedy. *See also Remedial Investigation and Feasibility Study.*

Remedial Investigation and Feasibility Study (RI/FS)
The RI/FS is the step in the cleanup process that is conducted to gather sufficient information to support the selection of a site remedy that will reduce or eliminate the risks associated with contamination at the site. The remedial investigation (RI) involves site characterization -- collection of data and information necessary to characterize the nature and extent of contamination at the site. The RI also determines whether the contamination presents a significant risk to human health or the environment. The feasibility study (FS) focuses on the development of specific response alternatives for addressing contamination at a site.

Removal Action
A removal action usually is a short-term effort designed to stabilize or clean up a hazardous waste site that poses an immediate threat to human health or the environment. Removal actions include removing tanks or drums of hazardous substances

that were found on the surface and installing drainage controls or security measures, such as a fence at the site. Removal actions also may be conducted to respond to accidental releases of hazardous substances. CERCLA places time and money constraints on the duration of removal actions. *See also Comprehensive Environmental Response, Compensation, and Liability Act.*

Reportable Quantity (RQ)
The RQ is the quantity of hazardous substances that, when released into the environment, can cause substantial endangerment to public health or the environment. Under CERCLA, the Federal government must be notified when quantities equaling or exceeding RQs specified in regulations are released.

Resin
Resins are solids or semi-solids of plant origin used principally in lacquers, varnishes, inks, adhesives, synthetic plastics, and pharmaceuticals.

Resource Conservation and Recovery Act (RCRA)
RCRA is a Federal law enacted in 1976 that established a regulatory system to track hazardous substances from their generation to their disposal. The law requires the use of safe and secure procedures in treating, transporting, storing, and disposing of hazardous substances. RCRA is designed to prevent the creation of new, uncontrolled hazardous waste sites.

Response Action
A response action is a short-term removal action or a long-term remedial response, authorized under CERCLA that is taken at a site to address releases of hazardous substances.

Risk Communication
Risk communication, the exchange of information about health or environmental risks among risk assessors, risk managers, the local community, news media and interest groups, is the process of informing members of the local community about environmental risks associated with a site and the steps that are being taken to manage those risks.

Sanborn Map
A Sanborn map is a record kept for insurance purposes that shows, for a specific property, the locations of such items as underground storage tanks (UST), buildings, and areas where chemicals have been used for certain industrial processes. A Phase I environmental audit includes a review of Sanborn maps. *See also Phase I Environmental Audit.*

Saturated Zone
The saturated zone is the area beneath the surface of the land in which all openings are filled with water at greater than atmospheric pressure.

Seismic Reflection and Refraction
Seismic reflection and refraction is a technology used to examine the geophysical features of soil and bedrock, such as debris, buried channels, and other features.

Semi-Volatile Organic Compound (SVOC)
SVOCs, composed primarily of carbon and hydrogen atoms, have boiling points greater than 200°C. Common SVOCs include PCPs and phenol. *See also Phenol and Polychlorinated Biphenyl.*

Sludge
Sludge is a semisolid residue from air or water treatment processes. Residues from treatment of metal wastes and the mixture of waste and soil at the bottom of a waste lagoon are examples of sludge, which can be a hazardous waste.

Slurry-Phase Bioremediation
Slurry-phase bioremediation, a treatment technology that can be used alone or in conjunction with other biological, chemical, and physical treatments, is a process through which organic contaminants are converted to innocuous compounds. Slurry-phase bioremediation can be effective in treating various SVOCs and nonvolatile organic compounds, as well as fuels, creosote, pentachlorophenols (PCP), and PCBs.

Soil Boring
Soil boring is a process by which a soil sample is extracted from the ground for chemical, biological, and analytical testing to determine the level of contamination present.

Soil Gas
Soil gas consists of gaseous elements and compounds that occur in the small spaces between particles of the earth and soil. Such gases can move through or leave the soil or rock, depending on changes in pressure.

Soil Vapor Extraction (SVE)
SVE, the most frequently selected innovative treatment at Superfund sites, is a process that physically separates contaminants from soil in a vapor form by exerting a vacuum through the soil formation. Soil vapor extraction removes VOCs and some SVOCs from soil beneath the ground surface.

Soil Washing
Soil washing is an innovative treatment technology that uses liquids (usually water, sometimes combined with chemical additives) and a mechanical process to scrub soils, removes hazardous contaminants, and concentrates the contaminants into a smaller volume. The technology is used to treat a wide range of contaminants, such as metals, gasoline, fuel oils, and pesticides. Soil washing is a relatively low-cost alternative for separating waste and minimizing volume as necessary to facilitate subsequent treatment. It is often used in combination with other treatment technologies. The technology can be brought to the site, thereby eliminating the need to transport hazardous wastes.

Solidification and Stabilization
Solidification and stabilization are the processes of removing wastewater from a waste or changing it chemically to make the waste less permeable and susceptible to transport by water. Solidification and stabilization technologies can immobilize many heavy metals, certain radionuclides, and selected organic compounds, while decreasing the surface area and permeability of many types of sludge, contaminated soils, and solid wastes.

Solvent
A solvent is a substance, usually liquid, that is capable of dissolving or dispersing one or more other substances.

Solvent Extraction
Solvent extraction is an innovative treatment technology that uses a solvent to separate or remove hazardous organic contaminants from oily-type wastes, soils, sludges, and sediments. The technology does not destroy contaminants, but concentrates them so they can be recycled or destroyed more easily by another technology. Solvent extraction has been shown to be effective in treating sediments, sludges, and soils that contain primarily organic contaminants, such as PCBs, VOCs, halogenated organic compounds, and petroleum wastes. Such contaminants typically are generated from metal degreasing, printed circuit board cleaning, gasoline, and wood preserving processes. Solvent extraction is a transportable technology that can be brought to the site. *See also Halogenated Organic Compound, Polychlorinated Biphenyl, and Volatile Organic Compound.*

Strict Liability
Strict liability is a concept under CERCLA that empowers the Federal government to hold PRPs liable without proving that the PRPs were at fault and without regard to a PRP's motive. PRPs can be found liable even if the problems caused by the release of a hazardous substance were unforeseeable, the PRPs acted in good faith, and state-of-the-art hazardous waste management practices were used at the time the materials were disposed of. *See also Potentially Responsible Party.*

Surfactant Flushing
Surfactant flushing is an innovative treatment technology used to treat contaminated groundwater. Surfactant flushing of NAPLs increases the solubility and mobility of the contaminants in water so that the NAPLs can be biodegraded more easily in an aquifer or recovered for treatment aboveground. *See also Nonaqueous Phase Liquid.*

Surface Water
Surface water is all water naturally open to the atmosphere, such as rivers, lakes, reservoirs, streams, and seas.

Superfund
Superfund is the trust fund that provides for the cleanup of hazardous substances released into the environment, regardless of fault. The Superfund was established under CERCLA and subsequent amendments to CERCLA. The term Superfund also is used to refer to cleanup programs designed and conducted under CERCLA and its subsequent amendments. *See also Comprehensive Environmental Response, Compensation, and Liability Act.*

Superfund Amendment and Reauthorization Act (SARA)
SARA is the 1986 act amending CERCLA that increased the size of the Superfund trust fund and established a preference for the development and use of permanent remedies, and provided new enforcement and settlement tools. *See also Comprehensive Environmental Response, Compensation, and Liability Act.*

Superfund Innovative Technology Evaluation (SITE) Program
The SITE program is an effort established by EPA in 1986 to advance the development, evaluation, and commercialization of innovative treatment technologies for assessing and cleaning up hazardous waste sites. The program provides an opportunity for technology developers to demonstrate their technologies' ability to successfully process and remediate hazardous waste. The SITE program has four components—the Emerging Technology Program, the Demonstration Program, the Monitoring and Measurement Technologies Program, and the Technology Transfer Program.

Thermal Desorption
Thermal desorption is an innovative treatment technology that heats soils contaminated with hazardous wastes to temperatures from 200 to 1,000°F so that contaminants that have low boiling points will vaporize and separate from the soil. The vaporized contaminants then are collected for further treatment or destruction, typically by an air emissions treatment system. The technology is most effective at treating VOCs, SVOCs and other organic contaminants, such as PCBs, PAHs, and pesticides. It is effective in separating organics from refining wastes, coal tar wastes, waste from wood treatment, and paint wastes. It also can separate solvents, pesticides, PCBs, dioxins, and fuel oils from contaminated soil. *See also Polyaromatic Hydrocarbon, Polychlorinated Biphenyl, Semivolatile Organic Compound, and Volatile Organic Compound.*

Total Petroleum Hydrocarbon (TPH)
TPH refers to a measure of concentration or mass of petroleum hydrocarbon constituents present in a given amount of air, soil, or water.

Toxicity
Toxicity is a quantification of the degree of danger posed by a substance to animal or plant life.

Toxicity Characteristic Leaching Procedure (TCLP)
The TCLP is a testing procedure used to identify the toxicity of wastes and is the most commonly used test for degree of mobilization offered by a solidification and stabilization process. Under this procedure, a waste is subjected to a process designed to model the leaching effects that would occur if the waste was disposed of in a RCRA Subtitle D municipal landfill. *See also Solidification and Stabilization.*

Toxic Substance
A toxic substance is a chemical or mixture that may present an unreasonable risk of injury to health or the environment.

Toxic Substances Control Act (TSCA)
TSCA was enacted in 1976 to test, regulate, and screen all chemicals produced or imported into the U.S. TSCA requires that any chemical that reaches the consumer marketplace be tested for possible toxic effects prior to commercial manufacture. Any existing chemical that poses health and environmental hazards is tracked and reported under TSCA.

Treatment, Storage, and Disposal Facility (TSD)
TSDs are sites at which hazardous substances are treated, stored, or disposed. TSD facilities are regulated by EPA and states under RCRA. *See also Resource Conservation and Recovery Act.*

Treatment Wall (also Passive Treatment Wall)
A treatment wall is a structure installed underground to treat contaminated groundwater found at hazardous waste sites. Treatment walls, also called passive treatment walls, are put in place by constructing a giant trench across the flow path of contaminated groundwater and filling the trench

with one of a variety of materials carefully selected for the ability to clean up specific types of contaminants. As the contaminated groundwater passes through the treatment wall, the contaminants are trapped by the treatment wall or transformed into harmless substances that flow out of the wall. The major advantage of using treatment walls is that they are passive systems that treat the contaminants in place so the property can be put to productive use while it is being cleaned up. Treatment walls are useful at some sites contaminated with chlorinated solvents, metals, or radioactive contaminants.

Trichloroethylene (TCE)
TCE is a stable, low-boiling colorless liquid that is used as a solvent, metal degreasing agent, and in other industrial applications.

Underground Storage Tank (UST)
A UST is a tank located entirely or partially underground that is designed to hold gasoline or other petroleum products or chemical solutions.

Unsaturated Zone
The unsaturated zone is the area between the land surface and the uppermost aquifer (or saturated zone). The soils in an unsaturated zone may contain air and water.

Vadose Zone
The vadose zone is the area between the surface of the land and the equifer water table in which the moisture content is less than the saturation point and the pressure is less than atmospheric. The openings (pore spaces) also typically contain air or other gases.

Vapor
Vapor is the gaseous phase of any substance that is liquid or solid at atmospheric temperatures and pressures. Steam is an example of a vapor.

Volatile Organic Compound (VOC)
A VOC is one of a group of carbon-containing compounds that evaporate readily at room temperature. Examples of volatile organic compounds include trichloroethane, trichloroethylene, benzene, toluene, ethylbenzene, and xylene (BTEX). These contaminants typically are generated from metal degreasing, printed circuit board cleaning, gasoline, and wood preserving processes.

Volatilization
Volatilization is the process of transfer of a chemical from the aqueous or liquid phase to the gas phase. Solubility, molecular weight, and vapor pressure of the liquid and the nature of the gas-liquid affect the rate of volatilization.

Voltammetric Stripping
Voltammetric stripping is a field-portable technology that uses electrochemistry to detect and quantify metals in environmental samples. Specific metals can be targeted for detection and quantification by the technology, which generally is applied to water samples.

Voluntary Cleanup Program (VCP)
A VCP is a formal means established by many states to facilitate assessment, cleanup, and redevelopment of Brownfields sites. VCPs typically address the identification and cleanup of potentially contaminated sites that are not on the NPL. Under VCPs, owners or developers of a site are encouraged to approach the state voluntarily to work out a process by which the site can be readied for development. Many state VCPs provide technical assistance, liability assurances, and funding support for such efforts. *See also National Priorities List.*

Wastewater
Wastewater is spent or used water from an individual home, a community, a farm, or an industry that contains dissolved or suspended matter.

Water Table
A water table is the boundary between the saturated and unsaturated zones beneath the surface of the earth, the level of groundwater, and generally is the level to which water will rise in a well. *See also Aquifer and Groundwater.*

X-Ray Fluorescence Analyzer
An x-ray fluorescence analyzer is a self-contained, field-portable instrument, consisting of an energy dispersive x-ray source, a detector, and a data processing system that detects and quantifies individual metals or groups of metals.

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APPENDIX D

Appendix D

LIST OF BROWNFIELDS AND TECHNICAL SUPPORT CONTACTS

The lists included in this appendix identify contacts at the state and EPA regional levels, as well as EPA technical support staff in the Technology Innovation Office and the Office of Research and Development. The individuals are available to assist cleanup and redevelopment efforts at Brownfields sites.

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EPA Regional Brownfields Coordinators D-6

EPA Technical Support D-7

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APPENDIX E

Appendix E

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