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Technical Approaches to Characterizing and Cleaning Up Automotive Repair Sites Under the Brownfields Initiative

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U.S. Environmental Protection Agency
Office of Research and Development
National Risk Management Research Laboratory
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Notice

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Foreword

The U.S. Environmental Protection Agency is charged by Congress with protecting the Nation's land, air, and water resources. Under a mandate of national environmental laws, the Agency strives to formulate and implement actions leading to a compatible balance between human activities and the ability of natural systems to support and nurture life. To meet this mandate, EPA's research program is providing data and technical support for solving environmental problems today and building a science knowledge base necessary to manage our ecological resources wisely, understand how pollutants affect our health, and prevent or reduce environmental risks in the future.

The National Risk Management Research Laboratory is the Agency's center for investigation of technological and management approaches for reducing risks from threats to human health and the environment. The focus of the Laboratory's research program is on methods for the prevention and control of pollution to air, land, water and subsurface resources; protection of water quality in public water systems; remediation of contaminated sites and groundwater; and prevention and control of indoor air pollution. The goal of this research effort is to catalyze development and implementation of innovative, cost-effective environmental technologies; develop scientific and engineering information needed by EPA to support regulatory and policy decisions; and provide technical support and information transfer to ensure effective implementation of environmental regulations and strategies.

This publication has been produced as part of the Laboratory's strategic long-term research plan. It is published and made available by EPA's Office of Research and Development to assist the user community and to link researchers with their clients.

E. Timothy Oppelt, Director

National Risk Management Research Laboratory

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Chapter 1
Introduction

Background

Many communities across the country contain brownfields sites, which are abandoned, idle, and under-used industrial and commercial facilities where expansion or redevelopment is complicated by real or perceived environmental contamination. Concerns about liability, cost, and potential health risks associated with brownfields sites often prompt businesses to migrate to "greenfields" outside the city. Left behind are communities burdened with environmental contamination, declining property values, and increased unemployment. The U.S. Environmental Protection Agency's (EPA's) Brownfields Economic Redevelopment Initiative was established to enable states, site planners, and other community stakeholders to work together in a timely manner to prevent, assess, safely clean up, and sustainably reuse brownfields sites (U.S. EPA Brownfields Home Page, http://www.epa.gov/brownfields).

The cornerstone of EPA's Brownfields Initiative is the Pilot Program. Under this program, EPA is funding more than 200 brownfields assessment pilot projects in states, cities, towns, counties, and tribes across the country. The pilots, each funded at up to $200,000 over two years, are bringing together community groups, investors, lenders, developers, and other affected parties to address the issues associated with assessing and cleaning up contaminated brownfields sites and returning them to appropriate, productive use. Information about the Brownfields Initiative may be obtained from the EPA's Office of Solid Waste and Emergency Response, Outreach/Special Projects Staff or any of EPA's regional brownfields coordinators. These regional coordinators can provide communities with technical assistance as targeted brownfields assessments. A description of these assistance activities is contained on the brownfields web page. In addition to the hundreds of brownfields sites being addressed by these pilots, over 40 states have established brownfields or voluntary cleanup programs to encourage municipalities and private sector organizations to assess, clean up, and redevelop brownfields sites.

Purpose

EPA has developed a set of technical guides, including this document, to assist communities, states, municipalities, and the private sector to more effectively address brownfields sites. Each guide in this series contains information on a different type of brownfields site (classified according to former industrial use). In addition, a supplementary guide contains information on cost-estimating tools and resources for brownfields sites. EPA has developed this "Automotive Repair" guide to provide decision-makers, such as city planners, private sector developers, and others who are involved in redeveloping brownfields, with a better understanding of the technical issues involved in assessing and cleaning up automotive repair sites so that they can make the most informed decisions possible.[1] Throughout the guide, the term "planner" is used; the term is intended be descriptive of the many different people who are referenced above and may use the information contained herein.

The overview presented in this guide of the technical process involved in assessing and cleaning up brownfields sites can assist planners in making decisions at various stages of the project. An understanding of land use and industrial processes conducted in the past at a site can help the planner to conceptualize the site and identify likely areas of contamination that may require cleanup. Numerous resources may be available to provide information that facilitates the characterization of the site, such as federal, state, and local agencies that provide soil, topographic, or groundwater maps or retain site-specific records (e.g., of prior contamination, discharges, underground storage tanks).

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[1] Because parts of this document are technical in nature, planners may want to refer to additional EPA guides for further information. *The Tool Kit of Technology Information Resources for Brownfields Sites*, published by EPA's Technology Innovation Office (TIO), contains a comprehensive list of relevant technical guidance documents (available from NTIS, No. PB97144828). EPA's *Road Map to Understanding Innovative Technology Options for Brownfields Investigation and Cleanup*, also by EPA's TIO, provides an introduction to site assessment and cleanup (EPA Order No. EPA 542-B-97-002).

Specifically, the objective of this document is to provide decision-makers with:

- An understanding of common activities at automotive repair shops and the relationship between such activities and potential releases of contaminants to the environment.

- Information on the types of contaminants likely to be present at an automotive repair site.

- A discussion of site assessment (also known as site characterization), screening and cleanup levels, and cleanup technologies that can be used to assess and clean up the types of contaminants likely to be present at automotive repair sites.

- A conceptual framework for identifying potential contaminants at the site, pathways by which contaminants may migrate off site, and environmental and human health concerns.

- Information on developing an appropriate cleanup plan for automotive repair sites where contamination levels must be reduced to ensure the reuse of the site.

- A discussion of the pertinent issues and factors that should be considered when developing such an assessment and cleanup plan and selecting appropriate technologies, given time and budget constraints.

Appendix A contains a list of relevant acronyms, and Appendix B is a glossary of key terms. Appendix C is a case study that illustrates some of the guidance provided in this document. Appendix D contains a bibliography.

Chapter 2
Industrial Processes and Contaminants at Automotive Repair Sites

Understanding the activities that occur during an automotive repair facility's active life, and therefore the types of contaminants that may be present, provides important information to guide planners in the assessment, cleanup, and restoration of the site to an acceptable condition for sale or reuse. This section provides a general overview of the activities performed and the chemicals and potential contaminants used or found at typical automotive repair sites. The specific activities and contaminants found at a particular automotive repair site may be different from those described here. **Planners should obtain facility-specific information on activities at their site whenever possible.** Repair shops may also have been used for other industrial/commercial activities in the past.

General Site Characteristics

Automotive repair shops tend to be geographically small, consisting of one or two buildings on one to two acres of land. While there are many possible automotive repair-related activities that could have taken place at the site, the most likely include:

- Automotive repair, using solvents for cleaning engine parts and metals from body works.
- Automotive maintenance, including the changing of automotive fluids such as oil, antifreeze, and transmission fluids.
- Recycling activities, including those involving automotive parts, solvents, and battery breaking.

The main building typically houses the automotive repair and maintenance operations ([A] in Figure 1). Common chemical wastes from automotive repair and maintenance operations include oil and grease, solvents from parts cleaning and repair work, volatile organics and semivolatile organics from automotive fluids, and metals from automotive body work, as listed in Table 1. Another common chemical may be ethylene glycol, associated with antifreeze. If the shop performed painting operations, they may have taken place in the same building or in another building on the site ([B] in Figure 1). It is also possible that painting operations were performed in a temporary or outdoor structure. Volatile organics, such as toluene and methylene chloride, are typical contaminants associated with painting operations.

An area of the site may have been used as a drum disposal area ([C] in Figure 1), which may contain old leaking drums, battery casings, and other containers used to store petroleum, paint products, and waste oil and sludges. These areas may contain chemicals such as petroleum hydrocarbons; metals, particularly lead, and cadmium, which have commonly been used in batteries; volatile organic compounds (VOCs) such as benzene and xylenes; and oil and grease.

Underground storage tanks (USTs) ([D] in Figure 1) were often used at automotive shops that had gas pumps. The UST was used to store the gasoline, diesel fuel, and/or fuel oil in bulk volume on the site, and the fuel may have leaked into the underlying soils and groundwater. Paved areas, such as parking areas and outside service bays, may have contributed to runoff of petroleum contaminants to nearby areas. Pump islands may be a secondary source of contamination from spilled gasoline. Additional areas might include scrap and used car storage areas, and tire storage areas. These areas generally are not sources of contaminants. Table 1 identifies the most common contaminants associated with automotive repair sites.

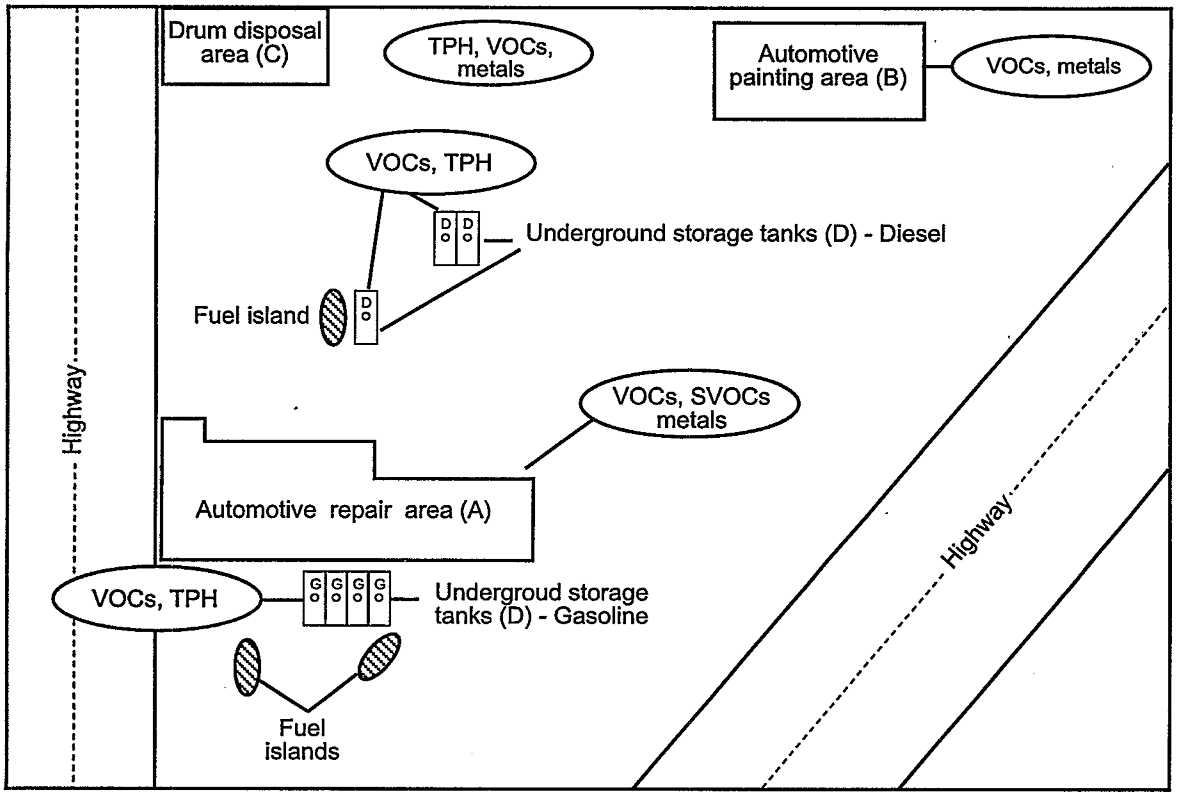

Figure 1. Typical automotive repair shop.

Table 1. Common Contaminants at Automotive Repair Shops

Contaminant Class	Contaminant
Volatile organic compounds (VOCs)	Benzene, toluene, ethyl benzene, xylene, trichloroethylene, methylene chloride, freon-113, methyl ethyl ketone, total petroleum hydrocarbons (TPH).
Semivolatile organics (SVOCs)	SVOCs in oil and grease, ethylene glycol, total petroleum hydrocarbons (TPH).
Metals	Lead, cadmium, chromium, aluminum.

Other Considerations

Many older structures contain lead paint and asbestos insulation and tiling. Any structure built before 1970 should be assessed for the presence of these materials. They can cause significant problems during demolition or renovation of the structures for reuse. Special handling and disposal requirements under state and local laws can increase significantly the cost of construction. Core or wipe samples can be analyzed for asbestos using polarized light microscopy (PLM). Laws pertaining to lead and asbestos may also affect the selection of data quality objectives (discussed later in this document), sampling, and analysis.

Chapter 3
Site Assessment

The purposes of a site assessment are to determine whether or not contamination is present and to assess the nature and extent of possible contamination and the risks to people and the environment that the contamination may pose. The elements of a site assessment are designed to help planners build a conceptual framework of the facility, which will aid site characterization efforts. The conceptual framework should identify:

- Potential contaminants that remain in and around the facility.
- Pathways along which contaminants may move.
- Potential risks to the environment and human health that exist along the migration pathways.

This section highlights the key role that state environmental agencies usually play in brownfields projects. The types of information that planners should attempt to collect to characterize the site in a Phase I site assessment (i.e., the facility's history) are discussed. Information is presented about where to find and how to use this information to determine whether or not contamination is likely. Additionally this section provides information to assist planners in conducting a Phase II site assessment, including sampling the site and determining the magnitude of contamination. Other considerations in assessing iron and steel sites are also discussed, and general sampling costs are included. This guide provides only a general approach to site evaluation; planners should expand and refine this approach for site-specific use at their own facilities.

The Central Role of the State Agencies

A brownfields redevelopment project involves partnerships among site planners (whether private or public sector), state and local officials, and the local community. State environmental agencies often are key decision-makers and a primary source of information for brownfields projects. Brownfields sites are generally cleaned up under state programs, particularly state voluntary cleanup or Brownfields programs; thus, planners will need to work closely with state program managers to determine their particular state's requirements for brownfields development. Planners may also need to meet additional federal requirements. Key state functions include:

- Overseeing brownfields site assessment and cleanup processes, including the management of voluntary cleanup programs.
- Providing guidance on contaminant screening levels.
- Serving as a source of site information, as well as legal and technical guidance.

State Voluntary Cleanup Programs (VCPs)

State VCPs are designed to streamline brownfields redevelopment, reduce transaction costs, and provide state liability protection for past contamination. Planners should be aware that state cleanup requirements vary significantly and should contact the state brownfield manager; brownfields managers from state agencies will be able to identify their state requirements for planners and will clarify how their state requirements relate to federal requirements.

Levels of Contaminant Screening and Cleanup

Identifying the level of site contamination and determining the risk, if any, associated with that contamination level is a crucial step in determining whether cleanup is needed. Some state environmental agencies, as well as federal and regional EPA offices, have developed screening levels for certain contaminants, which are incorporated into some brownfields programs. Screening levels represent breakpoints in risk-based concentrations of chemicals in soil, air, or water. If contaminant concentrations are below the screening level, no action is required; above the level, further investigation is needed.

In addition to screening levels, EPA regional offices and some states have developed cleanup standards; if contaminant concentrations are above cleanup standards, cleanup must be pursued. The section on "Performing a Phase II Site Assessment" in this document provides more information on screening levels, and the section on "Site Cleanup" provides more information on cleanup standards.

Performing a Phase I Site Assessment: Obtaining Facility Background Information from Existing Data

Planners should compile a history of the iron and steel manufacturing facility to identify likely site contaminants and their probable locations. Financial institutions typically require a Phase I site assessment prior to lending money to potential property buyers to protect the institution's role as mortgage holder (Geo-Environmental Solutions, n.d.). In addition, parties involved in the transfer, foreclosure, leasing, or marketing of properties recommend some form of site evaluation (The Whitman Companies, 1996). The site history should include[2]:

- A review of readily available records (e.g., former site use, building plans, records of any prior contamination events).
- A site visit to observe the areas used for various industrial processes and the condition of the property.
- Interviews with knowledgeable people (e.g., site owners, operators, and occupants; neighbors; local government officials).
- A report that includes an assessment of the likelihood that contaminants are present at the site.

The Phase I site assessment should be conducted by an environmental professional, and may take three to four weeks to complete. Site evaluations are required in part as a response to concerns over environmental liabilities associated with property ownership. A property owner needs to perform "due diligence," i.e. fully inquire into the previous ownership and uses of a property to demonstrate that all reasonable efforts to find site contamination have been made. Because brownfields sites often contain low levels of contamination and pose low risks, due diligence through a Phase I site assessment will help to answer key questions about the levels of contamination. Several federal and state programs exist to minimize owner liability at brownfields sites and facilitate cleanup and redevelopment; planners should contact their state environmental or regional EPA office for further information.

Information on how to review records, conduct site visits and interviews, and develop a report during a Phase I site assessment is provided below.

Facility Records

Facility records are often the best source of information on former site activities. If past owners are not initially known, a local records office should have deed books that contain ownership history. Generally, records pertaining specifically to the site in question are adequate for Phase I review purposes. In some cases, however, records of adjacent properties may also need to be reviewed to assess the possibility of contaminants migrating from or to the site, based on geologic or hydrogeologic conditions. If the brownfields property resides in a low-lying area, in close proximity to other industrial facilities or formerly industrialized sites, or downgradient from current or former industrialized sites, an investigation of adjacent properties is warranted.

Other Sources of Recorded Information

Planners may need to use other sources in addition to facility records to develop a complete history. ASTM Standard 1527 identifies standard sources such as historical aerial photographs, fire insurance maps, property tax files, recorded land title records, topographic maps, local street directories, building department records, zoning/land use records, maps and newspaper archives. (ASTM, 1997).

Some iron and steel site managers have worked with state environmental regulators; these offices may be key sources of information. Federal (e.g., EPA) records may also be useful. The types of information provided by regulators include facility maps that identify activities and disposal areas, lists of stored pollutants, and the types and levels of pollutants released. State offices and other sources where planners can search for site-specific information:

- The state offices responsible for industrial waste management and hazardous waste should have a record

[2] The elements of a Phase I site assessment presented here are based in part on ASTM Standards 1527 and 1528.

of any emergency removal actions at the site (e.g., the removal of leaking drums that posed an "imminent threat" to local residents); any Resource Conservation and Recovery Act (RCRA) permits issued at the site; notices of violations issued; and any environmental investigations.

- The state office responsible for discharges of wastewater to water bodies under the National Pollutant Discharge Elimination System (NPDES) program will have a record of any permits issued for discharges into surface water at or near the site. The local publicly owned treatment works (POTW) will have records for permits issued for indirect discharges into sewers (e.g., floor drain discharges into sanitary drains).

- The state office responsible for underground storage tanks may also have records of tanks located at the site, as well as records of any past releases.

- The state office responsible for air emissions may be able to provide information on potential air pollutants associated with particular types of onsite contamination.

- EPA's Comprehensive Environmental Response, Compensation, and Liability Information System (CERCLIS) of potentially contaminated sites should have a record of any previously reported contamination at or near the site. For information, contact the Superfund Hotline (800-424-9346).

- EPA Regional Offices can provide records of sites that have released hazardous substances. Information is available from the federal National Priorities List (NPL); lists of treatment, storage, and disposal (TSD) facilities subject to corrective action under the Resource Conservation and Recovery Act (RCRA); RCRA generators; and the Emergency Response Notification System (ERNS). Contact EPA Regional Offices for more information.

- State environmental records and local library archives may indicate permit violations or significant contamination releases from or near the site.

- Residents who were former employees may be able to provide information on waste management practices, but these reports should be substantiated.

- Local fire departments may have responded to emergency events at the facility. Fire departments or city halls may have fire insurance maps[3] or other historical maps or data that indicate the location of hazardous waste storage areas at the site.

- Local waste haulers may have records of the shop's disposal of hazardous or other waste materials.

- Utility records.

- Local building permits.

Requests for federal regulatory information are governed by the Freedom of Information Act (FOIA), and the fulfilling of such requests generally takes a minimum of four to eight weeks. Similar freedom of information legislation does not uniformly exist on the state level; one can expect a minimum waiting period of four weeks to receive requested information (ASTM, 1997).

Identifying Migration Pathways and Potentially Exposed Populations

Offsite migration of contaminants may pose a risk to human health and the environment; planners should gather as much readily available information on the physical characteristics of the site as possible. Migration pathways, i.e., soil, groundwater, and air, will depend on site-specific characteristics such as geology and the physical characteristics of the individual contaminants (e.g., mobility). Information on the physical characteristics of the general area can play an important role in identifying potential migration pathways and focusing environmental sampling activities, if needed. Planners should collect three types of information to obtain a better understanding of migration pathways, including topographic, soil and subsurface, and groundwater data, as described below.

Gathering Topographic Information

In this preliminary investigation, topographic information will be helpful in determining whether the site may be subject to or the source of contamination by adjoining properties. Topographic information will help planners identify low-lying areas of the facility where rain and snowmelt (and any contaminants in them) may collect and contribute both water and contaminants to the underlying aquifer or surface runoff to nearby areas. The U.S. Geological Survey (USGS) of the Department of the Interior has topographic maps for nearly every part of the country. These maps are inexpensive and available through the following address:

[3] Fire insurance maps show, for a specific property, the locations of such items as USTs, buildings, and areas where chemicals have been used for certain industrial processes.

USGS Information Services
Box 25286
Denver, CO 80225
[http://www.mapping.usgs.gov/esic/to_order.hmtl]

Gathering Soil and Subsurface Information

Planners should know about the types of soils and subsurface soils at the site from the ground surface extending down to the water table because soil characteristics play a large role in how contaminants move in the environment. For example, clay soils limit downward movement of pollutants into underlying groundwater but facilitate surface runoff. Sandy soils, on the other hand, can promote rapid infiltration into the water table while inhibiting surface runoff. Soil information can be obtained through a number of sources.

- Local planning agencies should have soil maps to support land use planning activities. These maps provide a general description of the soil types present within a county (or sometimes a smaller administrative unit, such as a township).
- The Natural Resource Conservation Service and Cooperative Extension Service offices of the U.S. Department of Agriculture (USDA) are also likely to have soil maps.
- Well-water companies are likely to be familiar with local subsurface conditions, and local water districts and state water divisions may have well-logging information.
- Local health departments may be familiar with subsurface conditions because of their interest in septic drain fields.
- Local construction contractors are likely to be familiar with subsurface conditions from their work with foundations.

Soil characteristics can vary widely within a relatively small area, and it is common to find that the top layer of soil in urban areas is composed of fill materials, not native soils. While local soil maps and other general soil information can be used for screening purposes such as in a Phase I assessment, site-specific information will be needed in the event that cleanup is necessary.

Gathering Groundwater Information

Planners should obtain general groundwater information about the site area, including:

- State classifications of underlying aquifers
- Depth to the groundwater tables
- Groundwater flow direction and rate

This information can be obtained by contacting state environmental agencies or from several local sources, including water authorities, well drilling companies, health departments, and Agricultural Extension and Natural Resource Conservation Service offices.

Identifying Potential Environmental and Human Health Concerns

Identifying possible environmental and human health risks early in the process can influence decisions regarding the viability of a site for cleanup and the choice of cleanup methods used. A visual inspection of the area will usually suffice to identify onsite or nearby wetlands and water bodies that may be particularly sensitive to releases of contaminants during characterization or cleanup activities. Planners should also review available information from state and local environmental agencies to ascertain the proximity of residential dwellings, industrial/commercial activities, or wetlands/water bodies, and to identify people, animals, or plants that might receive migrating contamination; any particularly sensitive populations in the area (e.g., children; endangered species); and whether any major contamination events have occurred previously in the area (e.g., drinking water problems; groundwater contamination).

For environmental information, planners can contact the U.S. Army Corps of Engineers, state environmental agencies, local planning and conservation authorities, the U.S. Geological Survey, and the USDA Natural Resource Conservation Service. State and local agencies and organizations can usually provide information on local fauna and the habitats of any sensitive and/or endangered species.

For human health information, planners can contact:

- State and local health assessment organizations. Organizations such as health departments, should have data on the quality of local well water used as a drinking water source as well as any human health risk studies that have been conducted. In addition, these groups may have other relevant information, such as how certain types of contaminants might pose a health risk during site characterization. Information on exposures to particular contaminants and associated health risks can also be found in health profile documents developed by the Agency for Toxic Substances and Disease Registry (ATSDR). In addition, ATSDR may have conducted a health consultation or health assessment in the area if an environmental contamination event occurred in the past. Such an event and assessment should have been identified in the Phase I records review of prior contamination incidents at the site. For information, contact ATSDR's Division of Toxicology (404-639-6300).

- Local water and health departments. During the site visit (described below), when visually inspecting the area around the facility, planners should identify any residential dwellings or commercial activities near the facility and evaluate whether people there may come into contact with contamination along one of the migration pathways. Where groundwater contamination may pose a problem, planners should identify any nearby waterways or aquifers that may be impacted by groundwater discharge of contaminated water, including any drinking water wells downgradient of the site, such as a municipal well field. Local water departments will have a count of well connections to the public water supply. Planners should also pay particular attention to information on private wells in the area downgradient of the facility because they may be vulnerable to contaminants migrating offsite even when the public municipal drinking water supply is not vulnerable. Local health departments often have information on the locations of private wells.

Both groundwater pathways and surface water pathways should be evaluated because contaminants in groundwater can eventually migrate to surface waters and contaminants in surface waters can migrate to groundwater.

Involving the Community

Community-based organizations represent a wide range of issues, from environmental concerns to housing issues to economic development. These groups can often be helpful in educating planners and others in the community about local brownfields sites, which can contribute to successful brownfields site assessment and cleanup activities. In addition, most state voluntary cleanup programs require that local communities be adequately informed about brownfields cleanup activities. Planners can contact the local Chamber of Commerce, local philanthropic organizations, local service organizations, and neighborhood committees for community input. State and local environmental groups may be able to supply relevant information and identify other appropriate community organizations. Local community involvement in brownfields projects is a key component in the success of such projects.

Conducting A Site Visit

In addition to collecting and reviewing available records, a site visit can provide important information about the uses and conditions of the property and identify areas that warrant further investigation (ASTM, 1997). During a visual inspection, the following conditions should be noted:

- current or past uses of abutting property that may affect the property being evaluated
- evidence of hazardous substances migrating on or off the site
- odors
- wells
- pits, ponds or lagoons
- pooling of liquids on the surface
- drums or storage containers
- stained soil or pavement
- corrosion
- stressed vegetation
- solid waste
- drains, sewers, sumps or other pathways for offsite migrations

Conducting Interviews

Conducting interviews with the site owner and/or site manager, site occupants, and local officials is highly recommended to obtain information about the prior and/or current uses and conditions of the property and to inquire about any useful documents that might exist regarding the property. During inverviews, the interviewer should ask about environmental audit reports, environmental permits, registrations for storage tanks, material safety data sheets, community right-to-know plans, safety plans, government agency notices or correspondence, hazardous waste generator reports or notices, geotechnical studies, or any proceedings involving the property) (ASTM, 1997). Interviews with at least one staff person from the following local government agencies are recommended: the fire department, health agency, and the agency with authority for hazardous waste disposal or other environmental matters. Interviews can be conducted in person, by telephone, or in writing.

ASTM Standard 1528 provides a questionnaire that may be appropriate for use in interviews for certain sites. ASTM suggests that this questionnaire be posed to the current property owner, any major occupant of the property (or at least 10 percent of the occupants of the property if no major occupant exists), or "any occupant likely to be using, treating, generating, storing, or disposing of hazardous substances or petroleum products on or from the property." A user's guide accompanies the ASTM questionnaire to assist the investigator in conducting interviews, as well as researching records and making site visits.

Developing a Report

Towards the end of the Phase I assessment, planners should develop a report that includes all of the important information obtained during record reviews, the site visit, and interviews. Documentation, such as references and important exhibits, should be included, as well as the credentials of the environmental professional that conducted the Phase I environmental site assessment. The report should include all information regarding the presence or likely presence of hazardous substances or petroleum products on the property and any conditions that indicate an existing, past, or potential release of such substances into property structures or into the ground, groundwater, or surface water of the property (ASTM, 1997). The report should include the environmental professional's opinion of the impact of the presence or likely presence of any contaminants, and a findings and conclusion section that either indicates that the Phase I environmental site assessment revealed no evidence of contaminants in connection with the property, or discusses what evidence of contamination was found (ASTM, 1997).

Additional sections of the report might include a recommendation for a Phase II site assessment, if appropriate. Some states or financial institutions may require information on asbestos, lead paint, lead in drinking water, radon and wetlands.

If the Phase I site assessment adequately informs state and local officials, planners, community representatives, and other stakeholders that no contamination exists at the site, or that contamination is so minimal that it does not pose a health or environmental risk, then those involved may decide that adequate site assessment has been accomplished and the process of redevelopment may proceed. In some cases where evidence of contamination exists, stakeholders may decide that enough information is available from the Phase I site assessment to characterize the site and determine an appropriate approach for site cleanup of the contamination. In other cases, stakeholders may decide that additional site assessment is warranted, and a Phase II site assessment would be conducted, as described below.

Performing a Phase II Site Assessment

A Phase II site assessment typically involves taking soil, water, and air samples to identify the types, quantity, and extent of contamination in these various environmental media. The types of data collected in a Phase II site assessment can vary from already existing site data (if adequate), to limited sampling of the site, to more extensive contaminant-specific or site-specific sampling data. Planners should use knowledge of past facility operations whenever possible to focus the site evaluation on those process areas where pollutants were stored, handled, used, or disposed. These will be the areas where potential contamination will be most readily identified. Generally, to minimize costs, a Phase II site assessment will begin with limited sampling (assuming readily available data do not exist that adequately characterize the type and extent of contamination on the site) and will proceed to more comprehensive sampling if needed (e.g., if the initial sampling could not identify the geographical limits of contamination).

This section explains the importance of setting data quality objectives (DQOs) and provides brief guidance for doing so; describes screening levels to which sampling results can be compared; and provides an overview of environmental sampling and data analysis, including sampling methods and ways to increase data certainty.

Setting Data Quality Objectives

EPA has developed a guidance document that describes key principals and best practices for brownfields site assessment quality assurance and quality control based on program experience. The document, Quality Assurance Guidance for Conducting Brownfields Site Assessments (EPA 540-R-98-038), is intended as a reference for people involved in the brownfields site assessment process and serves to inform managers of important quality assurance concepts.

EPA has adopted the Data Quality Objectives (DQO) Process (EPA 540-R-93-071) as a framework for making decisions. The DQO Process is common-sense, systematic planning tool based on the scientific method. Using a systematic planning approach, such as the DQO Process, ensures that the data collected to support defensible site decision making will be of sufficient quality and quantity, as well as be generated through the most cost-effective means possible. DQOs, themselves, are statements that unambiguously communicate the following:

- What is the study objective?
- Define the most appropriate type of data to collect.
- Determine the most appropriate conditions under which to collect the data.
- Specify the amount of uncertainty that will be tolerated when making decisions.

It is important to understand the concept of uncertainty and its relationship to site decision making. Regulatory agencies, and the public they represent, want to be as confident as possible about the safety of reusing brownfields sites. Public acceptance of site decisions may depend on the site manager's being able to scientifically document the adequacy of site decisions. During negotiations with stakeholders, effective communication about the tradeoffs between project costs and confidence in the site decision can help set the stage for a project's successful completion. When the limits on uncertainty (e.g., only a 5, 10, or 20 percent chance of a particular decision error is permitted) are clearly defined in the project, subsequent activities can be planned so that data collection efforts will be able to support those confidence goals in a resource-effective manner. On the one hand, a manager would like to reduce the chance of making a decision error as much as possible, but on the other hand, reducing the chance of making that decision error requires collecting more data, which is, in itself, a costly process. Striking a balance between these two competing goals—more scientific certainty versus less cost—requires careful thought and planning, as well as the application of professional expertise.

The following steps are involved in systematic planning:

1. *Agree on intended land reuse.* All parties should agree early in the process on the intended reuse for the property because the type of use may strongly influence the choice of assessment and cleanup approaches. For example, if the area is to be a park, removal of all contamination will most likely be needed. If the land will be used for a shopping center, with most of the land covered by buildings and parking lots, it may be appropriate to reduce, rather than totally remove, contaminants to specified levels (e.g., state cleanup levels; see "Site Cleanup" later in this document).

2. *Clarify the objective of the site assessment.* What is the overall decision(s) that must be made for the site? Parties should agree on the purpose of the assessment. Is the objective to confirm that no contamination is present? Or is the goal to identify the type, level, and distribution of contamination above the levels which are specified, based on the intended land use. These are two fundamentally different goals that suggest different strategies. The costs associated with each approach will also vary.

   As noted above, parties should also agree on the total amount of uncertainty allowable in the overall decision(s). Conducting a risk assessment involves identifying the levels of uncertainty associated with characterization and cleanup decisions. A risk assessment involves identifying potential contaminants and analyzing the pathways through which people, other species of concern, or the environment can become exposed to those contaminants (see EPA 600-R-93-039 and EPA 540-R095-132). Such an assessment can help identify the risks associated with varying the levels of acceptable uncertainty in the site decision and can provide decision-makers with greater confidence about their choice of land use decisions and the objective of the site assessment. If cleanup is required, a risk assessment can also help determine how clean the site needs to be, based on expected reuse (e.g., residential or industrial), to safeguard people from exposure to contaminants. For more information, see the section *Increasing the Certainty of Sampling Results* and the section *Site Cleanup.*

3. *Define the appropriate type(s) of data that will be needed to make an informed decision at the desired confidence level.* Parties should agree on the type of data to be collected by defining a preliminary list of suspected analytes, media, and analyte-specific ac-

tion levels (screening levels). Define how the data will be used to make site decisions. For example, data values for a particular analyte may or may not be averaged across the site for the purposes of reaching a decision to proceed with work. Are there maximum values which a contaminant(s) cannot exceed? If found, will concentrations of contaminants above a certain action level (hotspots) be characterized and treated separately? These discussions should also address the types of analyses to be performed at different stages of the project. Planners and regulators can reach an agreement to focus initial characterization efforts in those areas where the preliminary information indicates potential sources of contamination may be located. It may be appropriate to analyze for a broad class of contaminants by less expensive screening methods in the early stages of the project in order to limit the number of samples needing analysis by higher quality, more expensive methods later. Different types of data may be used at different stages of the project to support interim decisions that efficiently direct the course of the project as it moves forward.

4. *Determine the most appropriate conditions under which to collect the data.* Parties should agree on the timing of sampling activities, since weather conditions can influence how representative the samples are of actual conditions.

5. *Identify appropriate contingency plans/actions.* Certain aspects of the project may not develop as planned. Early recognition of this possibility can be a useful part of the DQO Process. For example, planners, regulators, and other stakeholders can acknowledge that screening-level sampling may lead to the discovery of other contaminants on the site than were originally anticipated. During the DQO Process, stakeholders may specify appropriate contingency actions to be taken in the event that contamination is found. Identifying contingency actions early in the project can help ensure that the project will proceed even in light of new developments. The use of a dynamic workplan combined with the use of rapid turnaround field analytical methods can enable the project to move forward with a minium of time delays and wasted effort.

6. *Develop a sampling and analysis plan that can meet the goals and permissible uncertainties described in the proceeding steps.* The overall uncertainty in a site decision is a function of several factors: the number of samples across the site (the density of sample coverage), the heterogeneity of analytes from sample to sample (spatial variability of contaminant concentrations), and the accuracy of the analytical method(s). Studies have demonstrated that analytical variability tends to contribute much less to the uncertainty of site decisions than does sample variability due to matrix heterogeneity. Therefore, spending money to increase the sample density across the site will usually (for most contaminants) make a larger contribution to confidence in the site decision, and thus be more cost-effective, than will spending money to achieve the highest data quality possible, but at a lower sampling density.

Examples of important consideration for developing a sampling and analysis plan include:

- Determine the sampling location placement that can provide an estimate of the matrix heterogeneity and thus address the desired certainty. Is locating hotspots of a certain size important? Can composite sampling be used to increase coverage of the site (and decrease overall uncertainty due to sample heterogeneity) while lowering analytical costs?

- Evaluate the available pool of analytical technologies/methods (both field methods and laboratory methods, which might be implemented in either a fixed or mobile laboratory) for those methods that can address the desired action levels (the analytical methods quantification limit should be well below the action level). Account for possible or expected matrix interferences when considering appropriate methods. Can field analytical methods produce data that will meet all of the desired goals when sampling uncertainty is also taken into account? Evaluate whether a combination of screening and definitive methods may produce a more cost-effective means to generate data. Can economy of scale be used? For example, the expense of a mobile laboratory is seldom cost-effective for a single small site, but might be cost-effective if several sites can be characterized sequentially by a single mobile laboratory.

- When the sampling procedures, sample preparation and analytical methods have been selected, design a quality control protocol for each procedure and method that ensures that the data generated will be of known, defensible quality.

7. *Through a number of iterations, refine the sampling and analysis plan to one that can most cost-effectively address the decision-making needs of the site planner.*

8. *Review agreements often.* As more information becomes available, some decisions that were based on earlier, limited information should be reviewed to see if they are still valid. If they are not, the parties can again use the DQO framework to revise and refine site assessment and cleanup goals and activities.

The data needed to support decision-making for brownfields sites generally are not complicated and are less extensive than those required for more heavily contaminated, higher-risk sites (e.g., Superfund sites). But data uncertainty may still be a concern at brownfields sites because knowledge of past activities at a site may be less than comprehensive, resulting in limited site characterization. Establishing DQOs can help address the issue of data uncertainty in such cases. Examples of DQOs include verifying the presence of soil contaminants, and assessing whether contaminant concentrations exceed screening levels.

Screening Levels

In the initial stages of a Phase II site assessment an appropriate set of screening levels for contaminants in soil, water, and/or air should be established. Screening levels are risk-based benchmarks which represent concentrations of chemicals in environmental media that do not pose an unacceptable risk. Sample analyses of soils, water, and air at the facility can be compared with these benchmarks. If onsite contaminant levels exceed the screening levels, further investigation will be needed to determine if and to what extent cleanup is appropriate.

Some states have developed generic screening levels for industrial and residential use. These levels may not account for site-specific factors that affect the concentration or migration of contaminants. Alternatively, screening levels can be developed using site-specific factors. While site-specific screening levels can more effectively incorporate elements unique to the site, developing site-specific standards is a time- and resource-intensive process. Planners should contact their state environmental offices and/or EPA regional offices for assistance in using screening levels and in developing site-specific screening levels.

Risk-based screening levels are based on calculations/models that determine the likelihood that exposure of a particular organism or plant to a particular level of a contaminant would result in a certain adverse effect. Risk-based screening levels have been developed for tap water, ambient air, fish, and soil. Some states or EPA regions also use regional background levels (or ranges) of contaminants in soil and Maximum Contaminant Levels (MCLs) in water established under the Safe Drinking Water Act as screening levels for some chemicals. In addition, some states and/or EPA regional offices[4] have developed equations for converting soil screening levels to comparative levels for the analysis of air and groundwater.

When a contaminant concentration exceeds a screening level, further site assessment (such as sampling the site at strategic locations and/or performing more detailed analysis) is needed to determine that: (1) the concentration of the contaminant is relatively low and/or the extent of contamination is small and does not warrant cleanup for that particular chemical, or (2) the concentration or extent of contamination is high, and that site cleanup is needed (see the section "Site Cleanup" for a discussion on cleanup levels).

Using state cleanup standards for an initial brownfields assessment may be beneficial if no industrial screening levels are available or if the site may be used for residential purposes. EPA's soil screening guidance is a tool developed by EPA to help standarize and accelerate the evaluation and cleanup of contaminated soils at sites on the NPL where future residential land use is anticipated. This guidance may be useful at corrective action or VCP sites where site conditions are similar. However, use of this guidance for sites where residential land use assumptions do not apply could result in overly conservative screening levels.

Environmental Sampling and Data Analysis

Environmental sampling and data analysis are integral parts of a Phase II site assessment process. Many different technologies are available to perform these activities, as discussed below.

Levels of Sampling and Analysis

There are two levels of sampling and analysis: screening and contaminant-specific. Planners are likely to use both at different stages of the site assessment.

[4] For example, EPA Region 6 Human Health Media-Specific Screening Levels include air and groundwater levels based on soil screening levels for some chemicals.

Screening. Screening sampling and analysis use relatively low-cost technologies to take a limited number of samples at the most likely points of contamination and analyze them for a limited number of parameters. Screening analyses often test only for broad classes of contaminants, such as total petroleum hydrocarbons, rather than for specific contaminants, such as benzene or toluene. Screening is used to narrow the range of areas of potential contamination and reduce the number of samples requiring further, more costly, analysis. Screening is generally performed on site, with a small percentage of samples (e.g., generally 10 percent) submitted to a state-approved laboratory for a full organic and inorganic screening analysis to validate or clarify the results obtained.

Some geophysical methods are used in site assessments because they are noninvasive (i.e., do not disturb environmental media as sampling does). Geophysical methods are commonly used to detect underground objects that might exist at a site, such as USTs, dry wells, and drums. The two most common and cost-effective technologies used in geophysical surveys are ground-penetrating radar and electromagnetics. An overview of geophysical methods is presented in Table 2. Geophysical methods are discussed in *Subsurface Characterization and Monitoring Techniques: A Desk Reference Guide* (EPA/625/R-93003a).

Contaminant-specific. For a more in-depth understanding of contamination at a site (e.g., when screening data are not detailed enough), it may be necessary to analyze samples for specific contaminants. With contaminant-specific sampling and analysis, the number of parameters analyzed is much greater than for screening-level sampling, and analysis includes more accurate, higher-cost field and laboratory methods. Such analyses may take several weeks.

Computerization, microfabrication and biotechnology have permitted the recent development of analytical equipment that can be generated in the field, on-site in a mobile laboratory and off-site in a laboratory. The same kind of equipment might be used in two or more locations

Increasing Certainty of Sampling Results

One approach to reducing the level of uncertainty associated with site data is to implement a statistical sampling plan. Statistical sampling plans use statistical principles to determine the number of samples needed to accurately represent the contamination present. With the statistical sampling method, samples are usually analyzed with highly accurate laboratory or field technologies, which increase costs and take additional time. Using this approach, planners can consult with regulators and determine in advance specific measures of allowable uncertainty (e.g., an 80 percent level of confidence with a 25 percent allowable error).

Another approach to increasing the certainty of sampling results is to use lower-cost technologies with higher detection limits to collect a greater number of samples. This approach would provide a more comprehensive picture of contamination at the site, but with less detail regarding the specific contamination. Such an approach would not be recommended to identify the extent of contamination by a specific contaminant, such as benzene, but may be an excellent approach for defining the extent of contamination by total organic compounds with a strong degree of certainty.

Site Assessment Technologies

This section discusses the differences between using field or laboratory technologies and provides an overview of applicable site assessment technologies. In recent years, several innovative technologies that have been field-tested and applied to hazardous waste problems have emerged, although these technologies lack a long history of full-scale use. In many cases, innovative technologies may cost less than conventional techniques and can successfully provide the needed data. Operating conditions may affect the cost and effectiveness of individual technologies.

Field vs. Laboratory Analysis

The principal advantages of performing field sampling and field analysis are that results are immediately available and more samples can be taken during the same sampling event; also, sampling locations can be adjusted immediately to clarify the first round of sampling results if warranted. This approach may reduce costs associated with conducting additional sampling events after receipt of laboratory analysis. Field assessment methods have improved significantly over recent years; however, while many field technologies may be comparable to laboratory technologies, some field technologies may not detect contamination at levels as low as laboratory methods, and may not be contaminant-specific. To validate the field results or to gain more information on specific contaminants, a small percentage of the samples can be sent for

Table 2. Non-Invasive Assessment Technologies

Applications	Strengths	Weaknesses	Typical Costs[1]
Infrared Thermography (IR/T)			
• Locates buried USTs. • Locates buried leaks from USTs. • Locates buried sludge pits. • Locates buried nuclear and nonnuclear waste. • Locates buried oil, gas, chemical and sewer pipelines. • Locates buried oil, gas, chemical and sewer pipeline leaks. • Locates water pipelines. • Locates water pipeline leaks. • Locates seepage from waste dumps. • Locates subsurface smoldering fires in waste dumps. • Locates unexploded ordinance on hundreds or thousands of acres. • Locates buried landmines.	• Able to collect data on large areas very efficiently (hundreds of acres per flight). • Able to collect data on long cross country pipelines very efficiently (300-500 miles per day). • Low cost for analyzed data per acre unit. • Able to prescreen and eliminate clean areas from further costly testing and unneeded rehabilitation. • Able to fuse data with other techniques for even greater accuracy in more situations. • Able to locate large and small leaks in pipelines and USTs. (Ultrasonic devices can only locate small, high pressure leaks containing ultrasonic noise.) • No direct contact with objects under test is required. (Ultrasonic devices must be in contact with buried pipelines or USTs.) • Has confirmed anomalies to depths greater than 38 feet with an accuracy of better than 80%. • Tests can be performed during both daytime and nighttime hours. • Normally no inconvenience to the public.	• Cannot be used in rainy conditions. • Cannot be used to determine depth or thickness of anomalies. • Cannot determine what specific anomalies are detected. • Cannot be used to detect a specific fluid or contaminant, but all items not native to the area will be detected.	• Depends upon volume of data collected and type of targets looked for. • Small areas < 1 acre: $1,000-$3,500. • Large areas > 1,000 acres: $10 - $200 per acre.
Ground Penetrating Radar (GPR)			
• Locates buried USTs. • Locates buried leaks from USTs. • Locates buried sludge pits. • Locates buried nuclear and nonnuclear waste. • Locates buried oil, gas, chemical and sewer pipelines. • Locates buried oil and chemical pipeline leaks. • Locates water pipelines. • Locates water pipeline leaks. • Locates seepage from waste dumps. • Locates cracks in subsurface strata such as limestone.	• Can investigate depths from 1 centimeter to 100 meters+ depending upon soil or water conditions. • Can locate small voids capable of holding contamination wastes. • Can determine different types of materials such as steel, fiberglass or concrete. • Can be trailed behind a vehicle and travel at high speeds.	• Cannot be used in highly conductive environments such as salt water. • Cannot be used in heavy clay soils. • Data are difficult to interpret and require a lot of experience.	• Depends upon volume of data collected and type of targets looked for. • Small areas < 1 acre: $3,500 - $5,000. • Large areas > 10 acres: $2,500 - $3,500 per acre.

(Continued)

laboratory analysis. The choice of sampling and analytical procedures should be based on DQOs established earlier in the process, which determine the quality (e.g., precision, level of detection) of the data needed to adequately evaluate site conditions and identify appropriate cleanup technologies.

Sample Collection and Analysis Technologies

Tables 3 and 4 list sample collection technologies for soil/subsurface and groundwater that are appropriate for automotive repair brownfields sites. Technology selection depends on the medium being sampled and the type of analysis required, based on DQOs (see the section on this

Table 2. Continued

Applications	Strengths	Weaknesses	Typical Costs[1]
Electromagnetic Offset Logging (EOL)			
• Locates buried hydrocarbon pipelines. • Locates buried hydrocarbon USTs. • Locates hydrocarbon tanks. • Locates hydrocarbon barrels. • Locates perched hydrocarbons. • Locates free floating hydrocarbons. • Locates dissolved hydrocarbons. • Locates sinker hydrocarbons. • Locates buried well casings.	• Produces 3D images of hydrocarbon plumes. • Data can be collected to depth of 100 meters. • Data can be collected from a single, unlined or nonmetal lined well hole. • Data can be collected within a 100 meter radius of a single well hole. • 3D images can be sliced in horizontal and vertical planes. • DNAPLs can be imaged.	• Small dead area around well hole of approximately 8 meters. This can be eliminated by using 2 complementary well holes from which to collect data.	• Depends upon volume of data collected and type of targets looked for. • Small areas < 1 acre: $10,000 - $20,000. • Large areas > 10 acres: $5,000 - $10,000 per acre.
Magnetometer (MG)			
• Locates buried ferrous materials such as barrels, pipelines, USTs, and buckets.	• Low cost instruments can be used that produce results by audio signal strengths. • High cost instruments can be used that produce hard copy printed maps of targets. • Depths to 3 meters. 1 acre per day typical efficiency in data collection.	• Non-relevant artifacts can be confusing to data analyzers. • Depth limited to 3 meters.	• Depends upon volume of data collected and type of targets looked for. • Small areas < 1 acre: $2,500 - $5,000. • Large areas > 10 acres: $1,500 - $2,500 per acre.

[1] Cost based on case study data in 1997 dollars.

subject earlier in this document). Soil samples are generally collected using spoons, scoops, and shovels. The selection of a subsurface sample collection technology depends on the subsurface conditions (i.e., consolidated materials and bedrock), the required sampling depth and level of analysis, and the extent of sampling anticipated. For example, if subsequent sampling efforts are likely, then installing semipermanent well casings with a well-drilling rig may be appropriate. If limited sampling is expected, direct push methods may be more cost-effective. The types of contaminants will also play a key role in the selection of sampling methods, devices, containers, and preservation techniques.

Table 5 lists analytical technologies that are appropriate for automotive brownfields sites, the types of contamination they can measure, applicable environmental media, and the relative cost of each. The final two columns of the table contain the applicability (e.g., field and/or laboratory) of the analytical method, and the technology's ability to generate quantitative versus qualitative results. Less expensive technologies that have rapid turnaround times and produce only qualitative results should be sufficient for many brownfields sites.

Additional Considerations for Assessing Automotive Repair Sites

Decisions regarding where to collect samples at automotive repair brownfields sites should be based on the conceptual framework developed for the site (discussed previously in "Site Assessment"), the activities that were conducted at the site (identified in the Phase I site assessment), and the chemicals used in those activities (identified in the Phase I assessment and in any screening sampling conducted). Using this information, the planner can focus sampling collection on the areas where past releases of contaminants are most likely. This section provides some general guidelines for planners to follow regarding the selection of the most likely areas of contamination. Samples should be taken both inside the shop and around the property, as described below.

Indoor Sampling

Inside the shop, samples should be collected from drains and sumps and analyzed for volatile organics. Photo ionization detectors (PID) or colorimetric detectors can often be used with sufficient accuracy to support a brownfields Phase II site assessment. Samples from shop areas used for paint operations should also be screened

Table 3. Soil and Subsurface Sampling Tools

Technique/ Instrumentation	Media: Soil	Media: Ground-water	Relative Cost per Sample	Sample Quality
Drilling Methods				
Cable Tool	X	X	Mid-range expensive	Soil properties will most likely be altered
Casing Advancement	X	X	Most expensive	Soil properties will likely be altered
Direct Air Rotary with Rotary Bit/ Downhole Hammer	X	X	Mid-range expensive	Soil properties will most likely be altered
Direct Mud Rotary	X	X	Mid-range expensive	Soil properties may be altered
Directional Drilling	X	X	Most expensive	Soil properties may be altered
Hollow-Stem Auger	X	X	Mid-range expensive	Soil properties may be altered
Jetting Methods	X	X	Least expensive	Soil properties may be altered
Rotary Diamond Drilling	X	X	Most expensive	Soil properties may be altered
Rotating Core	X		Mid-range expensive	Soil properties may be altered
Solid Flight and Bucket Augers	X	X	Mid-range expensive	Soil properties will likely be altered
Sonic Drilling	X	X	Most expensive	Soil properties will most likely not be altered
Split and Solid Barrel	X		Least expensive	Soil properties may be altered
Thin-Wall Open Tube	X		Mid-range expensive	Soil properties will most likely not be altered
Thin-Wall Piston/ Specialized Thin Wall	X		Mid-range expensive	Soil properties will most likely not be altered
Direct Push Methods				
Cone Penetrometer	X	X	Mid-range expensive	Soil properties may be altered
Driven Wells		X	Mid-range expensive	Soil properties may be altered
Hand-Held Methods				
Augers	X	X	Least expensive	Soil properties may be altered
Rotating Core	X		Mid-range expensive	Soil properties may be altered
Scoop, Spoons, and Shovels	X		Least expensive	Soil properties may be altered
Split and Solid Barrel	X		Least expensive	Soil properties may be altered
Thin-Wall Open Tube	X		Mid-range expensive	Soil properties will most likely not be altered
Thin-Wall Piston/ Specialized Thin Wall	X		Mid-range expensive	Soil properties will most likely not be altered
Tubes	X		Least expensive	Soil properties will most likely not be altered

Bold—Most commonly used field techniques.

for metals, particularly chromium and lead. Some cost-effective analytical technologies for these analyses include x-ray fluorescence (XRF) and chemical reaction-based test papers. If there is evidence that solvents were used in significant amounts in the repair shop, taking samples of the concrete floor may be appropriate; consult a professional engineer when making this decision. Planners may also consider collecting wipe samples from the walls. These samples should be screened for organic and inorganic compounds. Samples should also

Table 4. Groundwater Sampling Tools

Technique/ Instrumentation	Contaminants[1]	Relative Cost per Sample	Sample Quality
Portable Groundwater Sampling Pumps			
Bladder Pump	SVOCs, metals, TPH	Mid-range expensive	Liquid properties will most likely not be altered
Gas-Driven Piston Pump	SVOCs, metals, TPH	Most expensive	Liquid properties will most likely not be altered by sampling
Gas-Driven Displacement Pumps	SVOCs, metals, TPH	Least expensive	Liquid properties will most likely not be altered by sampling
Gear Pump	SVOCs, metals, TPH	Mid-range expensive	Liquid properties may be altered
Inertial-Lift Pumps	SVOCs, metals, TPH	Least expensive	Liquid properties will most likely not be altered
Submersible Centrifugal Pumps	SVOCs, metals, TPH	Most expensive	Liquid properties may be altered
Submersible Helical-Rotor Pump	SVOCs, metals, TPH	Most expensive	Liquid properties may be altered
Suction-Lift Pumps (peristaltic)	SVOCs, metals, TPH	Least expensive	Liquid properties may be altered
Portable Grab Samplers			
Bailers	VOCs, SVOCs, metals, TPH	Least expensive	Liquid properties may be altered
Pneumatic Depth-Specific Samplers	VOCs, SVOCs, metals, TPH	Mid-range expensive	Liquid properties will most likely not be altered
Portable *In Situ* Groundwater Samplers/Sensors			
Cone Penetrometer Samplers	VOCs, SVOCs, metals, TPH	Least expensive	Liquid properties will most likely not be altered
Direct Drive Samplers	VOCs, SVOCs, metals, TPH	Least expensive	Liquid properties will most likely not be altered
Hydropunch	VOCs, SVOCs, metals, TPH	Mid-range expensive	Liquid properties will most likely not be altered
Fixed *In Situ* Samplers			
Multilevel Capsule Samplers	VOCs, SVOCs, metals, TPH	Mid-range expensive	Liquid properties will most likely not be altered
Multiple-Port Casings	VOCs, SVOCs, metals, TPH	Least expensive	Liquid properties will most likely not be altere
Passive Multilayer Samplers	VOCs	Least expensive	Liquid properties will most likely not be altered

Bold Most commonly used field techniques
VOCs Volatile Organic Compounds
SVOCs Semivolatile Organic Compounds (may be present in oil and grease)
TPH Total Petroleum Hydrocarbons
[1] See Figure 1 for an overview of site locations where these contaminants may typically be found.

be taken from the insulation in the ceiling and around pipes and analyzed for asbestos if the shop was built before 1970.

Outdoor Sampling

Outdoor sampling activities will depend on the specific characteristics of each automotive repair brownfields site,

Table 5. Sample Analysis Technologies

Technique/ Instrumentation	Analytes	Media: Soil	Media: Ground-water	Media: Gas	Relative Detection	Relative Cost per Analysis	Application**	Produces Quantitative Data
Metals								
Laser-Induced Breakdown Spectrometry	Metals	X			ppb	Least expensive	Usually used in field	Additional effort required
Titrimetry Kits	Metals	X	X		ppm	Least expensive	Usually used in laboratory	Additional effort required
Particle-Induced X-ray Emissions	Metals	X	X		ppm	Mid-range expensive	Usually used in laboratory	Additional effort required
Atomic Adsorption Spectrometry	Metals	X*	X	X	ppb	Most expensive	Usually used in laboratory	Yes
Inductively Coupled Plasma—Atomic Emission Spectroscopy	Metals	X*	X	X	ppb	Most expensive	Usually used in laboratory	Yes
Field Bioassessment	Metals	X	X			Most expensive	Usually used in field	No
X-Ray Fluorescence	Metals	X	X	X	ppm	Least expensive	Laboratory and field	Yes (limited)
TPH, VOCs, and SVOCs								
Laser-Induced Fluorescence (LIF)	TPH VOCs	X	X		ppm	Least expensive	Usually used in field	Additional effort required
Solid/Porous Fiber Optic	TPH VOCs	X*	X	X	ppm	Least expensive	Immediate, can be used in field	Additional effort required
Free Product Sensor	TPH VOCs		X		100-1,000 ppm	Least expensive	Usually used in field	No
Chemical Calorimetric Kits	VOCs, SVOCs, TPH	X	X		ppm	Least expensive	Can be used in field, usually used in laboratory	Additional effort required
VOCs and SVOCs								
Flame Ionization Detector (hand-held)	VOCs	X*	X*	X	ppm	Least expensive	Immediate, can be used in field	No
Explosimeter	VOCs	X*	X*	X	ppm	Least expensive	Immediate, can be used in field	No
Photo Ionization Detector (hand-held)	VOCs, SVOCs	X*	X*	X	ppm	Least expensive	Immediate, can be used in field	No
Catalytic Surface Oxidation	VOCs	X*	X*	X	ppm	Least expensive	Usually used in laboratory	No
Near IR Reflectance/Trans Spectroscopy	VOCs	X			100-1,000 ppm	Mid-range expensive	Usually used in laboratory	Additional effort required

VOCs Volatile Organic Compounds
SVOCs Semivolatile Organic Compounds (may be present in oil and grease)
TPH Total Petroleum Hydrocarbons
X* Indicates there must be extraction of the sample to gas or liquid phase
** Samples sent to laboratory require shipping time and usually 14 to 35 days turnaround time for analysis. Rush orders cost an additional amount per sample.

(Continued)

Table 5. Continued

Technique/ Instrumentation	Analytes	Media: Soil	Media: Ground-water	Media: Gas	Relative Detection	Relative Cost per Analysis	Application**	Produces Quantitative Data
Ion Mobility Spectrometer	VOCs, SVOCs	X*	X*	X	100-1,000 ppb	Mid-range expensive	Usually used in laboratory	Yes
Raman Spectroscopy/SERS	VOCs, SVOCs	X	X	X*	ppb	Mid-range expensive	Usually used in laboratory	Additional effort required
Infrared Spectroscopy	VOCs, SVOCs	X	X	X	100-1,000 ppm	Mid-range expensive	Usually used in laboratory	Additional effort required
Scattering/Absorption Lidar	VOCs	X*	X*	X	100-1,000 ppm	Mid-range expensive	Usually used in laboratory	Additional effort required
FTIR Spectroscopy	VOCs	X*	X*	X	ppm	Mid-range expensive	Laboratory and field	Additional effort required
Synchronous Luminescence/ Fluorescence	VOCs, SVOCs	X*	X		ppb	Mid-range expensive	Usually used in laboratory, can be used in field	Additional effort required
Gas Chromatography (GC) (can be used with numerous detectors)	VOCs, SVOCs	X*	X	X	ppb	Mid-range expensive	Usually used in laboratory, can be used in field	Yes
UV-Visible Spectrophotometry	VOCs	X*	X	X	ppb	Mid-range expensive	Usually used in laboratory	Additional effort required
UV Fluorescence	VOCs	X	X	X	ppb	Mid-range expensive	Usually used in laboratory	Additional effort required
Ion Trap	VOCs, SVOCs	X*	X*	X	ppb	Most expensive	Laboratory and field	Yes
Other								
Chemical Reaction-Based Test Papers	VOCs, SVOCs, Metals	X	X		ppm	Least expensive	Usually used in field	Yes
Immunoassay and Colorimetric Kits	VOCs, SVOCs, Metals	X	X		ppm	Least expensive	Usually used in laboratory, can be used in field	Additional effort required
Polarized Light Microscopy	Asbestos	X	Under Structure	Under Structure	Not applicable	Least expensive	Always in laboratory	Not applicable

VOCs Volatile Organic Compounds
SVOCs Semivolatile Organic Compounds (may be present in oil and grease)
TPH Total Petroleum Hydrocarbons
X* Indicates there must be extraction of the sample to gas or liquid phase
** Samples sent to laboratory require shipping time and usually 14 to 35 days turnaround time for analysis. Rush orders cost an additional amount per sample.

but should be directed at assessing both onsite soil contamination and contamination along surface water runoff pathways. Onsite samples should be taken in areas where soils are visibly stained, including outdoor maintenance bays and painting booths. Offsite samples should be taken around paved areas to detect petroleum contamination that may have accumulated from rainwater and snowmelt runoff. Samples should then be taken along surface water runoff pathways to assess potential contaminant migration offsite. If wetlands or other waterways are downgradient from the facility, all logical points of entry should be sampled, including points where wastes may have been discharged from the shop. All outdoor samples should be screened for TPH and solvents using field screening technologies such as PID, colorimetric kits, or portable gas chromatography.

Underground Screening

Geophysical methods can be used to detect the presence of USTs or other buried objects. If such objects are found, planners must determine if they contain contaminants, and if those contaminants have entered the environment. USTs should be excavated and removed. Several technologies can sample soil gas around the USTs before their removal to determine if they have leaked. To obtain these samples, soil borings can be collected at and below the tanks' depths and screened for TPH using technologies such as PID, colorimetric kits, or portable gas chromatography. Old drums and battery casings often are found in unpermitted disposal areas at automotive repair sites. These may have been buried many years ago, and any potential contaminants that they contained are likely to have leaked into the underlying soils. As with USTs, soil borings should be taken in and around these disposal areas and screened for TPH, lead, nickel, and cadmium.

It is also important to determine the depth to the water table and the composition of subsurface soils at the site, which will be key factors regarding whether contaminants have migrated off site and possibly contaminated groundwater. The more shallow the water table, the more likely that contaminants may have reached groundwater. Subsurface soils that are clayey in nature or relatively nonporous may prevent contaminants from reaching the water table; more porous subsurface soils, such as sand, allows water and contaminants to migrate more quickly into groundwater.

Groundwater Screening

In some instances, contaminants from soils, USTs, or disposal areas at the automotive repair site may have migrated into groundwater. In addition, waste oils and solvents may have been disposed of in dry wells, from which they may have entered the groundwater table. At sites where soils and subsoils are relatively porous (i.e., sandy or gravelly soils) or where the water table is near the surface, planners should have groundwater samples screened for TPH and solvents. The costs associated with collecting groundwater samples has declined substantially since the development of cone penetrometer technology (CPT), which does not depend on drilling and installing well casings but instead uses a steel rod that is driven into the ground. Several types of detectors can be used in conjunction with CPT to collect information on soil and groundwater conditions and analyze them for contamination; one such innovative technology, Rapid Optical Sensing Tool (ROST™) uses laser-induced fluorescence technology to screen for TPH in subsurface soils and groundwater. Table 4 discusses groundwater sampling technologies.

General Sampling Costs

Site assessment costs vary widely, depending on the nature and extent of the contamination and the size of the sampling area. The sample collection costs discussed below are based on an assumed labor rate of $35 per hour plus $10 per sample for shipping and handling.

Soil Collection Costs

Surface soil samples can be collected with tools as simple as a stainless steel spoon, shovel, or hand auger. Samples can be collected using hand tools in soft soil for as low as $10 per sample (assuming that a field technician can collect 10 samples per hour). When soils are hard, or deeper samples are required, a hammer-driven split spoon sampler or a direct push rig is needed. Using a drill rig equipped with a split spoon sampler or a direct push rig typically costs more than $600 per day for rig operation (Geoprobe, 1998), with the cost per sample exceeding $30 (assuming that a field technician can collect 2 samples per hour). Labor costs generally increase when heavy machinery is needed.

Groundwater Sampling Costs

Groundwater samples can be extracted through conventional drilling of a permanent monitoring well or using the direct push methods listed in Table 3. The conventional, hollow-stem auger-drilled monitoring well is more widely accepted but generally takes more time than direct push methods. Typical quality assurance protocols for the conventional monitoring well require the well to be drilled, developed, and allowed to achieve equilibrium for 24 to 48 hours. After the development period, a groundwater sample is extracted. With the direct push sampling method, a probe is either hydraulically pressed or vibrated into the ground, and groundwater percolates into a sampling container attached to the probe. The direct push method costs are contingent upon the hardness of the subsurface, depth to the water table, and permeability of the aquifer. Costs for both conventional and direct push techniques are generally more than $40 per sample (assuming that a field technician can collect 1 sample per hour); well installation costs must be added to that number.

Surface Water and Sediment Sampling Costs

Surface water and sediment sampling costs depend on the location and depth of the required samples. Obtaining surface water and sediment samples can cost as little as $30 per sample (assuming that a field technician can collect 2 samples per hour). Sampling sediment in deep water or sampling a deep level of surface water, however, requires the use of larger equipment, which drives up the cost. Also, if surface water presents a hazard during sampling and protective measures are required, costs will increase greatly.

Sample Analysis Costs

Costs for analyzing samples in any medium can range from as little as $27 per sample for a relatively simple test (e.g., an immunoassay test for metals) to greater than $400 per sample for a more extensive analysis (e.g., for semivolatiles) and up to $1,200 per sample for dioxins (Robbat, 1997). Major factors that affect the cost of sample analysis include the type of analytical technology used, the level of expertise needed to interpret the results, and the number of samples to be analyzed. Planners should make sure that laboratories that have been certified by state programs are used; contact your state environmental agency for a list of state-certified laboratories.

Chapter 4
Site Cleanup

The purpose of this section is to guide planners in the selection of appropriate cleanup technologies. The principal factors that will influence the selection of a cleanup technology include:

- Types of contamination present
- Cleanup and reuse goals
- Length of time required to reach cleanup goals
- Post-treatment care needed
- Budget

The selection of appropriate cleanup technologies often involves a trade-off between time and cost. A companion EPA document to this guide, entitled *Cost Estimating Tools and Resources for Addressing Sites Under the Brownfields Initiative*, provides information on cost factors and developing cost estimates. In general, the more intensive the cleanup approach, the more quickly the contamination will be mitigated and the more costly the effort. In the case of brownfields cleanup, both time and cost can be major concerns, considering the planner's desire to return the facility to reuse as quickly as possible. Thus, the planner may wish to explore a number of options and weigh carefully the costs and benefits of each. One effective method of comparison is the cleanup plan, as discussed below; planners should involve stakeholders in the community in the development of the plan.

The intended future use of a brownfields site will drive the level of cleanup needed to make the site safe for redevelopment and reuse. Brownfields sites are by definition not Superfund NPL sites; that is, brownfields sites usually have lower levels of contamination present and therefore generally require less extensive cleanup efforts than Superfund NPL sites. Nevertheless, all pathways of exposure, based on the intended reuse of the site, must be addressed in the site assessment and cleanup; if no pathways of exposure exist, less cleanup (or possibly none) may be required.

Some regional EPA and state offices have developed cleanup standards for different chemicals, which may serve as guidelines or legal requirements for cleanups. It is important to understand that screening levels (discussed previously in "Performing a Phase II Site Assessment: Sampling the Site") are different from cleanup (or corrective action) levels. Whereas screening levels indicate whether further site investigation is warranted for a particular contaminant, cleanup levels indicate whether cleanup action is needed and how extensive it needs to be. Planners should check with their state environmental office for guidance and/or requirements for cleanup standards.

This section contains information on developing a cleanup plan and discusses various alternatives for addressing contamination at the automotive repair site (i.e., institutional controls; containment and cleanup technologies). A table that summarizes cleanup technologies applicable to automotive repair sites is presented, followed by a discussion of post-construction care issues that planners need to consider when selecting cleanup alternatives.

Developing a Cleanup Plan

If the results of the site evaluation indicate the presence of contamination above acceptable levels, planners will need to have a cleanup plan developed by a professional environmental engineer that describes the approach that will be used to contain and possibly cleanup contamination. In developing this plan, planners and their engineers should consider a range of possible options, with the intent of identifying the most cost-effective approaches for cleaning up the site, considering time and cost concerns. The cleanup plan can include the following elements:

- A clear delineation of environmental concerns at the site. Areas should be discussed separately if the cleanup approach for one area is different from that for other areas of the site. Clear documentation of existing conditions at the site and a summarized assessment of the nature and scope of contamination should be included.

- A recommended cleanup approach for each environmental concern that takes into account expected land reuse plans and the adequacy of the technology selected.

- A cost estimate that reflects both expected capital and operating/maintenance costs.

- Post-construction maintenance requirements for the recommended approach.

- A discussion of the assumptions made to support the recommended cleanup approach, as well as the limitations of the approach.

Planners can use the framework developed during the initial site evaluation (see the "Site Assessment" section) and the controls and technologies described below to compare the effectiveness of the least costly approaches for meeting the required cleanup goals established in the DQOs. These goals should be established at levels that are consistent with the expected reuse plans. A final cleanup plan may include a combination of actions, such as institutional controls, containment technologies, and cleanup technologies, as discussed below.

Institutional Controls

Institutional controls may play an important role in returning an automotive repair shop brownfields site to a marketable condition. Institutional controls are mechanisms that help control the current and future use of, and access to, a site. They are established, in the case of brownfields, to protect people from possible contamination. Institutional controls range from a security fence prohibiting access to certain portions of the site to deed restrictions imposed on the future use of the facility. If the overall cleanup approach does not include the complete cleanup of the facility (i.e., the complete removal or destruction of onsite contamination), a deed restriction will likely be required that clearly states that hazardous waste is being left in place within the site boundaries. Many state brownfields programs include institutional controls.

The exclusive use of institutional controls at automotive repair brownfields sites may be insufficient because of the mobile and toxic nature of the common contaminants (i.e., TPH and solvents). Nonetheless, planners and regulators should determine if such controls could play a limited role, thereby reducing the amount of cleanup necessary. Even if regulators do accept some application of institutional controls, they will most likely require long-term groundwater monitoring to ensure that contaminants are not migrating from the site if full cleanup is not conducted. The cost of such monitoring may be greater than the cost of full cleanup if cleanup activities are relatively limited in scope.

Containment Technologies

Containment technologies are designed to prevent contaminants from moving off the site. Containment technologies include engineered barriers such as caps for contaminated soils, sheet piles, slurry walls, and hydraulic containment. Like institutional controls, containment technologies do not remove or destroy contamination, but mitigate potential risk by limiting contaminant migration and contact by people and the environment.

A cleanup approach using containment technologies may be appropriate at an automotive repair brownfields site, particularly if assessment activities show the disposal of large volumes of batteries and drums. If soil contamination in these areas is limited to metals and small amounts of TPH or solvents, a cost-effective approach may be to excavate the drums and battery casings, and then seal the area with an engineered cap made of asphalt or soil material. Both drums and batteries should be disposed of at an EPA-approved facility. Planners should be aware that engineered caps require periodic maintenance to ensure their effectiveness. In addition, if the levels of TPH or solvents in the capped material are moderate or high, regulators may require periodic groundwater monitoring to ensure that contaminants are not migrating underneath the cap. The cost of the maintenance and monitoring associated with a cap should be weighed against the cost of excavating the soils and disposing of them in an EPA-approved landfill.

Types of Cleanup Technologies

Cleanup may be required to remove or destroy onsite contamination if regulators are unwilling to accept the level of contamination present or if the types of contamination prevent the use of institutional controls or containment technologies. Cleanup technologies fall broadly into two categories—*ex situ* and *in situ*, as described below.

- *Ex Situ.* An *ex situ* technology treats contaminated materials after they have been removed and transported to another location. After treatment, if the remaining materials, or residuals, meet cleanup goals, they can be returned to the site. If the residuals do not yet meet cleanup goals, they can be subjected to further treatment, contained on site, or moved to another location for storage or further treatment.

- *In Situ.* The use of *in situ* technologies has increased dramatically in recent years. *In situ* technologies treat contamination in place and are often innovative technologies. Examples of *in situ* technologies include bioremediation, soil flushing, oxygen-releasing compounds, air sparging, and treatment walls. In some cases, *in situ* technologies are feasible, cost-effective choices for the types of contamination that are likely at automotive repair sites. Planners, however, do need to be aware that cleanup with *in situ* technologies is likely to take longer than with *ex situ* technologies.

Maintenance requirements associated with *in situ* technologies depend on the technology used and vary widely in both effort and cost. For example, containment technologies such as caps and liners will require regular maintenance, such as maintaining the vegetative cover and performing periodic inspections to ensure the long-term integrity of the cover system. Groundwater treatment systems will require varying levels of post-cleanup care. If an *ex situ* system is in use at the site, it will require regular operations support and periodic maintenance to ensure that the system is operating as designed.

Cleanup Technologies for Automotive Repair Sites

Table 6 presents cleanup technologies that may be appropriate, based on their capital and operating costs, for use at automotive repair sites. In addition to more conventional technologies, a number of innovative technology options are listed. Many cleanup approaches use institutional controls and one or a combination of the technologies described in Table 6. Whatever cleanup approach is ultimately chosen, planners should explore a number of cost-effective options. This section discusses some cleanup alternatives for automotive repair sites based on the technologies described in Table 6.

Cleanup Options for Contaminated Soils

For areas where contamination is primarily composed of TPH and low levels of solvents, several innovative technologies may be cost-effective options, including soil vapor extraction (SVE), augmented bioremediation, and oxygen-releasing compounds. All these technologies treat contaminants in place, require no excavation, and may reinforce the natural processes that lead to the breakdown of volatile organics in soils, known as bioremediation. Table 6 describes these and other cleanup technologies in more detail, including technology limitations. Technologies to consider include:

- *SVE:* SVE is widely used to remove volatile organics, including TPH, from subsurface soils. SVE uses vacuum pressure to extract volatile organics from soils and collects the gas with carbon filters.

- *Augmented Bioremediation:* Augmented bioremediation uses nutrient treatments to enhance the activity of native microorganisms in the soils that break down organic contamination. This approach is slow relative to other cleanup approaches.

- *Oxygen-Releasing Compounds (ORC):* ORC technologies inject nontoxic compounds into subsurface contamination areas, where they react with the contamination, releasing oxygen that enhances natural bioremediation. ORC has shown dramatic results in pilot and full-scale projects nationwide in cleaning up the types of contaminants associated with petroleum products.

Cleanup Options for Contaminated Groundwater

If groundwater at the automotive repair site is contaminated, several approaches may be taken to achieve cleanup goals. The choice of technology will depend on many site-specific factors, such as hydraulic conductivity of soils, the mass of contamination, and the size of the groundwater plume. The most conventional groundwater cleanup technology is pump-and-treat; however, it is also likely to be an expensive approach. Some innovative technologies, such as air sparging, have also been used successfully to cleanup benzene, toluene, ethylbenzene, and xylene (BTEX) in groundwater.

Post-Construction Care

Many of the cleanup technologies that leave contamination onsite, either in containment systems or because of the long periods required to reach cleanup goals, will require long-term maintenance and possibly operation. If waste is left on site, regulators will likely require long-term monitoring of applicable media (i.e., soil, water, or air) to ensure that the cleanup approach selected is continuing to function as planned (e.g., residual contamination, if any, remains at acceptable levels and is not migrating). If long-term monitoring is required (e.g., by the state), periodic sampling, analysis, and reporting requirements will also be involved. Planners should be aware of these requirements and provide for them in cleanup budgets.

Table 6. Cleanup Technologies for Automotive Repair Brownfields Sites

Applicable Technology	Description	Examples of Applicable Land/Process Areas[1]	Contaminants Treated by This Technology	Limitations	Cost
Containment Technologies					
Capping	• Used to cover buried waste materials to prevent migration. • Made of a relatively impermeable material that will minimize rainwater infiltration. • Waste materials can be left in place. • Requires periodic inspections and routine monitoring. • Contaminant migration must be monitored periodically.	• Painting operations, drum disposal area, repair operations.	• Metals.	• Costs associated with routine sampling and analysis may be high. • Long-term maintenance may be required to ensure impermeability. • May have to be replaced after 20 to 30 years of operation. • May not be effective if groundwater table is high.	• $11 to $40 per square yard.[2]
Sheet Piling	• Steel or iron sheets are driven into the ground to form a subsurface barrier. • Low-cost containment method. • Used primarily for shallow aquifers.	• Painting operations, drum disposal area, UST.	• Not contaminant-specific.	• Not effective in the absence of a continuous aquitard. • Can leak at the intersection of the sheets and the aquitard, or through pile wall joints.	• $8 to $17 per square foot.[3]
Grout Curtain	• Grout curtains injected into subsurface soils and bedrock. • Forms an impermeable barrier in the subsurface.	• Painting operations, drum disposal area, UST.	• Not contaminant-specific.	• Difficult to ensure a complete curtain without gaps through which the plume can escape; however new techniques have improved continuity of curtain.	• $6 to $14 per square foot.[3]

(Continued)

Table 6. Continued

Applicable Technology	Description	Examples of Applicable Land/Process Areas[1]	Contaminants Treated by This Technology	Limitations	Cost
***Ex situ* Technologies**					
Excavation/ Offsite Disposal	• Removes contaminated material to an EPA-approved landfill.	• Painting operations, disposal area, UST.	• Not contaminant- specific.	• Generation of fugitive emissions may be a problem during operations. • The distance from the contaminated site to the nearest disposal facility will affect cost. • Depth and composition of the media requiring excavation must be considered. • Transportation of the soil through populated areas may affect community acceptability. • Disposal options for certain waste (e.g., mixed waste or transuranic waste) may be limited. There is currently only one licensed disposal facility for radioactive and mixed waste in the United States.	• $270 to $460 per ton.[3]
Liquid Phase Carbon Adsorption	• Groundwater is pumped through a series of vessels containing activated carbon, to which dissolved contaminants adsorb. • Effective for polishing water discharges from other remedial technologies to attain regulatory compliance. • Can be quickly installed. • High contaminant-removal efficiencies.	• Wastes from automotive repair, drum disposal, UST, painting operations, fuel island.	• Low levels of metals. • VOCs. • SVOCs.	• The presence of multiple contaminants can affect process performance. • Metals can foul the system. Costs are high if used as the primary treatment on waste streams with high contaminant concentration levels. • Type and pore size of the carbon, and operating temperature will affect process performance. • Transport and disposal of spent carbon can be expensive. • Water soluble compounds and small molecules are not adsorbed well.	• $1.20 to 6.30 per 1,000 gallons treated at flow rates of 0.1 mgd.[4] • Costs decrease with increasing flow rates and decreasing concentrations. • Costs are dependent on waste stream flow rates, type of contaminant, concentration and timing requirements.

(Continued)

Table 6. Continued

Applicable Technology	Description	Examples of Applicable Land/Process Areas[1]	Contaminants Treated by This Technology	Limitations	Cost
***In situ* Technologies**					
Natural Attenuation	• Natural subsurface processes such as dilution, volatilization, biodegradation, adsorption, and chemical reactions with subsurface media that reduce contaminant concentrations to acceptable levels. • Consideration of this option requires modeling and evaluation of contaminant degradation rates and pathways. • Sampling and analyses must be conducted throughout the process to confirm that degradation is proceeding at sufficient rates to meet cleanup objectives. • Used for remediation of non halogenated VOCs and SVOCs.	• Painting operations, drum disposal area, UST, automotive repair area, fuel island.	• TPH. • VOCs.	• Intermediate degradation products may be more mobile and more toxic than original contaminants. • Contaminants may migrate before they are degraded. • The site may have to be fenced and may not be available for reuse until hazard levels are reduced. • Source areas may require removal for natural attenuation to be effective. • Modeling contaminant degradation rates and sampling and analyzing to confirm modeled predictions extremely expensive.	• Not available.
Soil Vapor Extraction	• Application of vacuum to the soil to induce controlled air flow and remove contaminants from the unsaturated (vadose) zone of the soil. • The gas leaving the soil may be treated to recover or destroy the contaminants. • The continuous air flow promotes *in-situ* biodegradation of low volatility organic compounds that may be present.	• Painting operations, drum disposal area, UST, automotive repair area, fuel island.	• VOCs • TPH	• Tight or extremely moist (>50%) soil has a reduced permeability to air, requiring higher vacuums. • Large screened intervals are required in extraction wells for soil with highly variable permeabilities. • Air emissions may require treatment to eliminate possible harm to the public or environment. • Off-gas treatment residual liquids and spent activated carbon may require treatment or disposal. • Not effective in the saturated zone.	• \$10 to \$50 per cubic meter of soil.[4] • Cost is site specific, depending on the size of the site, the nature and amount of contamination, and the hydrogeologic setting, which affect the number of wells, the blower capacity and vacuum level required, and the length of time required to remediate the site. Off-gas treatment signfiicantly adds to the cost.

(Continued)

Table 6. Continued

Applicable Technology	Description	Examples of Applicable Land/Process Areas[1]	Contaminants Treated by this Technology	Limitations	Cost
Air Sparging	• *In situ* technology in which air is injected under pressure below the water table to increase ground-water oxygen concentrations and enhance the rate of biological degradation of contaminants by naturally occurring microbes. • Increases the mixing in the saturated zone, which increases the contact between groundwater and soil. • Air bubbles traverse horizontally and vertically through the soil column, creating an underground stripper that volatilizes contaminants. • Air bubbles travel to a soil vapor extraction system. • Air sparging is effective for facilitating extraction of deep contamination, contamination in low-permeability soils, and contamination in the saturated zone.	• Painting operations, drum disposal area, UST, auto repair area, fuel island.	• VOCs.	• Depth of contaminants and specific site geology must be considered. • Air flow through the saturated zone may not be uniform. A permeability differential such as a clay • layer above the air injection zone can reduce the effectiveness. • Vapors may rise through the vadose zone and be released into the atmosphere. • Increased pressure in the vadose zone can build up vapors in building basements, which are generally low-pressure areas.	• $50 to $100 per 1,000 gallons of groundwater treated.[4]
Bioventing	• Stimulates the natural *in situ* biodegradation of petroleum hydrocarbons (TPH) and volatile organics in soil by providing oxygen to existing soil microorganisms. • Oxygen commonly supplied through direct air injection. • Uses low air flow rates to provide only enough oxygen to sustain microbial activity. • Volatile compounds are biodegraded as vapors and move slowly through the biologically active soil.	• Painting operations, drum disposal area, UST, auto repair area, fuel island.	• VOCs. • TPH.	• Low soil-gas permeability. • High water table or saturated soil layers. • Vapors can build up in basements within the radius of influence of air injection wells. • Low soil moisture content may limit biodegradation by drying out the soils. • Low temperatures slow remediation. • Vapors may need treatment, depending on emission level and state regulations. • Chlorinated solvents may not degrade fully under certain surface conditions.	• $10 to $70 per cubic meter of soil.[4] • Cost affected by conaminant type and concentration, soil permeaility, well spacing and number, pumping rate, and off-gas treatment.

(Continued)

Table 6. Continued

Applicable Technology	Description	Examples of Applicable Land/Process Areas[1]	Contaminants Treated by This Technology	Limitations	Cost
Biodegradation	• Indigenous or introduced microorganisms degrade organic contaminants found in soil and groundwater. • Used successfully to remediate soils, sludges, and groundwater. • Especially effective for remediating low-level residual contamination in conjunction with source removal.	• Painting operations, drum disposal area, UST, automotive repair area, fuel island.	• VOCs. • TPH.	• Cleanup goals may not be attained if the soil matrix prevents sufficient mixing. • Circulation of water-based solutions through the soil may increase contaminant mobility and necessitate treatment of underlying groundwater. • Injection wells may clog and prevent adequate flow rates. • Preferential flow paths may result in nonuniform distribution of injected fluids. • Should not be used for clay, highly layered, or heterogeneous subsurface environments. • High concentrations of heavy metals, highly chlorinated organics, long chain hydrocarbons, or inorganic salts are likely to be toxic to microorganisms. • Low temperatures slow bioremediation. • Chlorinated solvents may not degrade fully under certain surface conditions.	• $30 to $100 per cubic meter of soil.[4] • Cost affected by the nature and depth of the contaminants, use of bioaugmentation or hydrogen peroxide addition, and groundwater pumping rates.
Oxygen Releasing Compounds	• Based on Fenton's Reagent Chemistry. • Stimulates the natural *in situ* biodegradation of petroleum hydrocarbons in soil and groundwater by providing oxygen to existing microorganisms. • Oxygen supplied through the controlled dispersion and diffusion of active reagents, such as hydrogen peroxide. • Active reagents are injected into the affected area using semi-permanent injection wells.	• Painting operations, drum disposal area, UST, automotive repair area, fuel island.	• TPH. • VOCs.	• Low soil permeability limits dispersion. • Low soil moisture limits reaction time. • Low temperatures slow reaction. • Not cost-effective in the presence of unusually thick layers of free product.	• Relatively low cost in applications on small areas of contamination. • Cost depends on size of treatment area and amount of contaminant present as free product.

[1]The cleanup of any one area is likely to affect the cleanup of other areas in close proximity; cleanup decisions are often made for larger areas than those presented here, and combinations of technologies may be selected.
[2]Interagency Cost Workgroup, 1994.
[3]Costs of Remedial Actions at Uncontrolled Hazardous Wastes Sites, U.S. EPA, 1986.
[4]Federal Remediation Technology Roundtable. http://www.frtr.gov/matrix/top_page.html
[5]Road Map to Understanding Innovative Technology Options for Brownfields Sites, U.S. EPA, 1997.

UST = underground storage tank
VOCs = volatile organic compounds
SVOCs = semivolatile organic compounds
TPH = total petroleum hydrocarbons

Chapter 5
Conclusion

Brownfields redevelopment contributes to the revitalization of communities across the United States Reuse of these abandoned, contaminated sites spurs economic growth, builds community pride, protects public health, and helps maintain our nation's "greenfields," often at a relatively low cost. This document provides brownfields planners with an overview of the technical methods that can be used to achieve successful site assessment and cleanup, which are two key components in the brownfields redevelopment process.

While the general guidance provided in this document will be applicable to many brownfields projects, it is important to recognize that no two brownfields sites will be identical, and planners will need to base site assessment and cleanup activities on the conditions at their particular site. Some of the conditions that may vary by site include: the type of contaminants present, the geographic location and extent of contamination, the availability of site records, hydrogeologic conditions, and state and local regulatory requirements. Based on these factors, as well as financial resources and desired time-frames, planners will find different assessment and cleanup approaches appropriate.

Consultation with state and local environmental officials and community leaders, as well as careful planning early in the project, will assist planners in developing the most appropriate site assessment and cleanup approaches. Planners should also determine early on if they are likely to require the assistance of environmental engineers. A site assessment strategy should be agreeable to all stakeholders and should address:

- The type and extent of contamination present at the site
- The types of data needed to adequately assess the site
- Appropriate sampling and analytical methods for characterizing contamination
- An acceptable level of data uncertainty

When used appropriately, the site assessment methods described in this document will help to ensure that a good strategy is developed and implemented effectively.

Once the site has been assessed and stakeholders agree that cleanup is needed, planners will need to consider cleanup options. Many different types of cleanup technologies are available. The guidance provided in this document on selecting appropriate methods directs planners to base cleanup initiatives on site- and project-specific conditions. The type and extent of cleanup will depend in large part on the type and level of contamination present, reuse goals, and the budget available. Certain cleanup technologies are used onsite, while others require offsite treatment. Also, in certain circumstances, containment of contamination onsite and the use of institutional controls may be important components of the cleanup effort. Finally, planners will need to include budgetary provisions and plans for post-cleanup and post-construction care if it is required at the brownfields site. By developing a technically sound site assessment and cleanup approach that is based on site-specific conditions and addresses the concerns of all project stakeholders, planners can achieve brownfields redevelopment and reuse goals effectively and safely.

Appendix A
Acronyms

ACM	Asbestos Contaminated Media
ASTM	American Society for Testing and Materials
ATSDR	Agency for Toxic Substances and Disease Registry
BTEX	Benzene, Toluene, Ethylbenzene, and Xylene
CDM	CDM Federal Programs Corporation
CERCLIS	Comprehensive Environmental Response, Compensation, and Liability Information System
CERI	Center for Environmental Research Information
CPT	Cone Penetrometer Technology
DQO	Data Quality Objective
EPA	U.S. Environmental Protection Agency
ERNS	Emergency Response Notification System
FOIA	Freedom of Information Act
FWS	U.S. Fish and Wildlife Service
MCL	Maximum Contaminant Levels
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
O&M	Operations and Maintenance
ORC	Oxygen-Releasing Compounds
ORD	Office of Research and Development
OSWER	Office of Solid Waste and Emergency Response
PAH	Polyaromatic Hydrocarbon
PCB	Polychlorinated Biphenyl
PCP	Pentachlorophenol
PID	Photoionization Detector
PLM	Polarized Light Microscopy
POTW	Publicly Owned Treatment Works
RCRA	Resource Conservation and Recovery Act
SVE	Soil Vapor Extraction
SVOC	Semivolatile Organic Compound
TCE	Trichloroethylene
TIO	Technology Innovation Office
TPH	Total Petroleum Hydrocarbon
TSD	Treatment, Storage, and Disposal
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
UST	Underground Storage Tank
VCP	Voluntary Cleanup Program
VOC	Volatile Organic Compound
XRF	X-ray Fluorescence

Appendix B[1]
Glossary

The following is a list of specialized terms used during the assessment and cleanup of brownfields sites.

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 (VOCs). See also *Soil Vapor Extraction* and *Volatile Organic Compound.*

Air Stripping—Air stripping is a treatment method 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.

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 cleanup 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.*

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.

Bioventing—Bioventing is an *in situ* cleanup 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 cleaning up 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.

[1]Adapted from EPA's *Road Map to Understanding Innovative Technology Options for Brownfields Investigation and Cleanup* (EPA, 1997).

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

Carbon Adsorption—Carbon adsorption is a treatment method 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 (PCBs), dioxins (DDT), and certain chlorinated pesticides, which may be present in soil and oils. 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.

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.

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 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.

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.

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 onsite 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. The technology is continually improved as it is used and evaluated at different sites. See also *Established Technology* and *Innovative Technology.*

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.

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)—An 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, polyaromatic hydrocarbons (PAH), VOCs, and petroleum hydrocarbons. See also *Volatile Organic Compounds*.

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.

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 considered innovative are portable, weatherproof units that have self-contained power supplies. See also *Semivolatile Organic Compound.*

Ground-Penetrating Radar (GPR)—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.*

Hazardous Substance—A hazardous substance is any material that poses a threat to public health or the environment. 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 certain federal legislation, the term excludes petroleum, crude oil, natural gas, natural gas liquids, or synthetic gas usable for fuel.

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.

High-Frequency Electromagnetic (EM) Sounding—High-frequency EM sounding, the technology used for non-intrusive 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*.

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

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.

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 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, 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 are usually conducted in the field or the laboratory; they 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*.

In Situ—The term *in situ*, "in its original place," or "onsite", 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), aromatics, and PCBs. See also *Aromatics* and *Heavy Metal*.

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.

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.

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.*

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 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 the Resource Conservation and Recovery Act (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.

Monitored 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, 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.

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 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 cleanup under Superfund. Inclusion of a site on the list is based primarily on the score the site receives under the Hazard Ranking System (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.

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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 cleanup and to ensure that no new threat to human health or the environment arises. O&M 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.

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.

Phase I Site Assessment—A Phase I site assessment 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 assessment includes a site visit but does not include any sampling. If such an assessment identifies no significant concerns, a Phase II assessment is not necessary.

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

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 is also used to detect VOCs and petroleum hydrocarbons.

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 hydrocarbons, 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.

Pump and Treat—Pump and treat is a general term used to describe cleanup 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.

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.*

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.*

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.

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.

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.

Semivolatile Organic Compound (SVOC)—SVOCs, composed primarily of carbon and hydrogen atoms, have boiling points greater than 200°C. Common SVOCs include pentachlorophenols (PCPs) and phenol. See also *Phenol.*

Site Assessment—A site assessment is the process by which it is determined whether contamination is present on a site.

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 (PCPs), and polychlorinated bephenyls (PCBs). See also *Semivolatile Organic Compound.*

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. See also *Semivolatile Organic Compound* and *Volatile Organic Carbon.*

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 *Volatile Organic Compound.*

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 above-ground.

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 significantly hazardous substances released into the environment, regardless of fault. The Superfund was established under Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and subsequent amendments to CERCLA. The term Superfund is also used to refer to cleanup programs designed and conducted under CERCLA and its subsequent amendments.

Superfund Amendment and Reauthorization Act (SARA)—SARA is the 1986 act amending Comprehensive Environmental Response, Compensation, and Liability Act (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.

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 are then 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 *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 determining the 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 an 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.

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.

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 aquifer 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.

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 National Priorities List (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.

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.

Appendix C
Powers Junction Example

Introduction

The information in this appendix is excerpted from the report "Technical Assistance for Sampling and Analytical Support; Powers Junction Brownfield Site, New Orleans, Louisiana; Brownfield Assessment and Recommendations Report" prepared for the Region 6 office of the U.S. Environmental Protection Agency (EPA) in Dallas, Texas, by PRC Environmental Management, Inc. received under Work Assignment No. 008-AN-SP-0600, under Response Action Contract (RAC) No. 68-W6-0037. Some of the information was edited for the purposes of this guide. While not explicitly based on the information presented in this guide, this case study shows how a site assessment and comparison of cleanup alternatives were done. Tables C1 through C4 itemize costs for the cleanup options. Figure C1 is a map of the Powers Junction site that shows sampling locations. References for Appendix C are listed at the end of this example.

A) Site Description And History

The Powers Junction site was designated as a pilot project under the EPA Brownfields Economic Redevelopment Initiative. The Powers Junction site is located at 19001 Chef Menteur Highway, New Orleans, Louisiana. The 3-acre site is composed of several parcels, with the largest parcel having dimensions of 388 feet by 350 feet by 624 feet. The privately owned site is surrounded by the Bayou Sauvage National Wildlife Refuge. Until the early 1970s, a truck stop and service station operated at the site. From the early 1970s to 1995, a truck repair facility operated at the site. According to local U.S. Fish and Wildlife Service (FWS) representatives, some maintenance activities associated with the former truck repair facility were conducted in the northeast sector of the site, next to a former motel.

PRC Environmental Management, Inc. (PRC) served as the environmental contractor on the site. PRC performed sampling and analytical services at the Powers Junction brownfield site during February 1997. The purposes of the sampling and analytical work were to (1) determine whether contaminants are present at the site, and (2) if they are present, determine the locations, levels, and extent of contamination.

Current site conditions

The former truck stop and service station building (which is the only remaining permanent structure onsite) and a small inhabited mobile trailer are on the site. A concrete foundation is all that remains of a recently demolished motel. Seven underground storage tanks (USTs) are located at the site. Four gasoline USTs are located in the fueling area in front of, and south of, the existing building. A 4-inch-thick concrete pad covers the surface of the front fueling area. Three diesel fuel USTs are located behind, and north of, the existing building. Gravel and shell cover the surface of the rear fueling area. Surface soil (0 to 2 feet below ground surface [bgs]) characteristics varied horizontally and vertically at the site. The southern half of the site, where most of the fueling operations were conducted, consisted of (1) gravelly fill mixed with sand, shell, and some asphalt from 0 to 1 foot bgs, and (2) a grey silty clay mixed with sand and gravel from 1 to 2 feet bgs. The northern half of the site consisted of (1) a grey sandy clay mixed with shell and organic material near the surface, and (2) an olive brown to gray clay from 1 to 2 feet bgs. According to local FWS officials, the water table is at about 4 feet bgs at the site, and local shallow groundwater flow is to the south and southeast. A surface water body, identified as a borrow canal, is located next to the site to the north.

B) Field Sampling Investigation

During the sampling investigation, PRC collected samples from the following: (1) surface and subsurface soil, (2) shallow water table, (3) USTs, (4) borrow canal sediments, and (5) building materials from the existing building.

(1) Surface and Subsurface Soil Investigation

PRC conducted soil sampling at 28 of 30 probe locations for field analyses by using a sampling grid layout. A

Table C1. Cost Estimate for Cleanup Option 1: Excavation and Offsite Treatment and Disposal (Risk-Based Approach)

Item/Description	Unit	Unit Cost	Industrial Quantity	Industrial Cost ($)
Site Preparation				
Demolish reinforced concrete	CY	51.06	100	5,106
Demolish existing building	CF	0.06	60,000	3,600
Load and haul debris	CY	3.57	1,000	3,570
Fertilize, seed, and sprig surface soil	SY	1.10	1,350	1,485
Preparation Subtotal				**$13,761**
UST Decomissioning				
Excavate and load on trailer, 3000-gallon	Each	465.00	7	3,255
Remove sludge	Each	172.00	7	1,204
Dispose of sludge	Gallon	2.45	200	490
Known leaking UST excavation	Each	465.00	1	465
Haul tank to salvage dump, 100-mile RT	Each	525.00	7	3,675
UST Subtotal				**$9,089**
Site Earthwork				
1 CY hydraulic excavator	CY	3.14	600	1,884
Loading into truck	CY	1.55	600	930
Backfill, unclassified fill, 6-inch lift, offsite	CY	7.35	675	4,961
Earthwork Subtotal				**$7,775**
Sampling, Testing, and Analysis				
Soil lab analysis: TCLP metals	Sample	693.81	5	3,469
Soil lab analysis: BTEX	Sample	123.69	10	1,237
Soil lab analysis: PAHs	Sample	298.37	10	2,984
Soil lab analysis: metals, each (8)	Sample	148.41	5	742
Analytical Subtotal				**$8,432**
Disposal				
Transportation 100-mile RT, 20-CY loads	Mile	3.38	3,000	10,140
Waste stream evaluation fee	Each	494.71	1	495
Low-temperature thermal desorption	Ton	69.41	810	56,222
Dump charges for construction debris	CY	18.42	1,000	18,420
Landfill nonhazardous waste disposal	CY	44.00	600	26,400
Disposal Subtotal				**$111,677**
Total Cost				**$150,734**

Notes
Unit costs were obtained from the ECHOS Environmental Restoration Unit Cost Book and vendor price quotes.
Hazardous waste disposal at Class I Landfill.
Soil density is assumed to be 100 pounds/CF.

BTEX	Benzene, ethylbenzene, toluene, and xylenes.
CF	Cubic foot.
CY	Cubic yard.
ECHOS	Environmental cost handling options and solutions.
PAH	Polycyclic aromatic hydrocarbons.
RT	Round trip.
SY	Square yard.
TCLP	Toxicity characteristic leaching procedure.
UST	Underground storage tank.

Geoprobe was used to probe at each intersection of the sampling grid. PRC conducted field analyses of each soil increment for the following parameters:

- Volatile organic compounds (VOCs)
  - Benzene, toluene, ethylbenzene, xylenes (BTEX)
  - Methyl tertiary-butyl ether (MTBE)
  - 1,2,4-Trimethylbenzene and 1,3,5-trimethylbenzene
  - Total petroleum hydrocarbons for gasoline (TPH-gasoline)
- Semivolatile organic compounds (SVOCs)
  - Polynuclear aromatic hydrocarbons (PAH)
  - TPH for diesel fuel (TPH-diesel)
- Total metals

Field analysis for organics was conducted by using gas chromatography (GC). Field analysis for total metals was conducted by using X-ray fluorescence (XRF) spectrometry. Nine confirmatory split samples including one duplicate sample were collected at eight soil probe locations and shipped to Contract Laboratory Program (CLP) laboratories to compare field analytical results to CLP laboratory analytical results.

Table C2. Cost Estimate for Cleanup Option 2: Excavation and Offsite Treatment and Disposal

Item/Description	Unit	Unit Cost	Industrial Quantity	Industrial Cost ($)	Residential Quantity	Residential Cost ($)
Site Preparation						
Demolish reinforced concrete	CY	51.06	100	5,106	100	5,106
Demolish existing building	CF	0.06	60,000	3,600	60,000	3,600
Load and haul debris	CY	3.57	1,000	3,570	1,000	3,570
Fertilize, seed, and sprig surface soil	SY	1.10	450	495	0	0
Preparation Subtotal				**$12,771**		**$12,276**
UST Decomissioning						
Excavate and load on trailer, 3000-gallon	Each	465.00	7	3,255	7	3,255
Remove sludge	Each	172.00	7	1,204	7	1,204
Dispose of sludge	Gallon	2.45	200	490	200	490
Known leaking UST excavation	Each	465.00	1	465	1	465
Haul tank to salvage dump, 100-mile RT	Each	525.00	7	3,675	7	3,675
UST Subtotal				**$9,089**		**$9,089**
Site Earthwork						
1-CY hydraulic excavator	CY	3.14	1,200	3,768	3,600	11,304
Loading into truck	CY	1.55	1,200	1,860	3,600	5,580
Backfill, unclassified fill, 6-inch lift, offsite	CY	7.35	1,425	10,474	4,450	32,708
Earthwork Subtotal				**$16,102**		**$49,592**
Sampling, Testing, and Analysis						
Soil lab analysis: TCLP metals	Sample	693.81	5	3,469	5	3,469
Soil lab analysis: BTEX	Sample	123.69	10	1,237	10	1,237
Soil lab analysis: PAHs	Sample	298.37	10	2,984	10	2,984
Soil lab analysis: metals, each (8)	Sample	148.41	5	742	5	742
Total petroleum hydrocarbons	Sample	116.67	0	0	10	1,167
Analytical Subtotal						**$ 9,598**
Disposal						
Transportation 100-mile RT, 20-CY loads	Mile	3.38	6,000	20,280	16,000	54,080
Waste stream evaluation fee	Each	494.71	1	495	2	989
Low-temperature thermal desorption	Ton	69.41	1,620	112,444	2,025	140,555
Dump charges for construction debris	CY	18.42	1,000	18,420	1,000	18,420
Landfill nonhazardous waste disposal	CY	44.00	1,200	52,800	1,500	66,000
Landfill hazardous waste disposal	Ton	233.32	0	0	2,835	661,462
Disposal Subtotal				**$204,439**		**$941,507**
Total Cost				**$250,832**		**$1,022,062**

Notes
Unit costs were obtained from the ECHOS Environmental Restoration Unit Cost Book and vendor price quotes.
Hazardous waste disposal at Class I Landfill.
Soil density is assumed to be 100 pounds/CF.

BTEX	Benzene, ethylbenzene, toluene, and xylenes.
CF	Cubic foot.
CY	Cubic yard.
ECHOS	Environmental cost handling options and solutions.
PAH	Polycyclic aromatic hydrocarbons.
RT	Round trip.
SY	Square yard.
TCLP	Toxicity characteristic leaching procedure.
UST	Underground storage tank.

(2) Shallow water table investigation

PRC collected a groundwater grab sample for field analysis to determine whether TPH fuels were present in the shallow water table.

(3) Borrow canal investigation

On February 21, 1997, PRC collected a sediment grab sample designated C6-Sediment from the shoreline of the borrow canal at a location east-northeast of Probe C6, for field analysis to determine whether site runoff had impacted the surface water body and potentially contaminated the sediments (Figure 3). Section 4.3 discusses the analytical results.

(4) Underground Storage Tanks Investigation

PRC inspected the seven USTs through their fill ports (access ports) by using a water level indicator, Kolor Kut™ colorimetric fuel gauging paste, and Sludge Judges™. PRC determined that each of the four gasoline USTs was a 3000-gallon horizontal tank, 18 feet long and 64 inches in diameter. PRC collected a grab sample from one of the gasoline USTs for field GC analysis to confirm the presence of TPH fuels.

The three diesel fuel USTs were not labeled; however, based on the location of the USTs (behind the store) and

Table C3. Cost Estimate for Cleanup Option 3: Excavation, Onsite Bioremediation (Landfarming) and Offsite Disposal

Item/Description	Unit	Unit Cost	Industrial Quantity	Industrial Cost ($)	Residential Quantity	Residential Cost ($)
Site Preparation						
Demolish reinforced concrete	CY	51.06	100	5,106	100	5,106
Demolish existing building	CF	0.06	60,000	3,600	60,000	3,600
Load and haul debris	CY	3.57	1,000	3,570	1,000	3,570
Fertilize, seed, and sprig surface soil	SY	1.10	450	495	0	0
Preparation Subtotal				**$12,276**		**$12,276**
UST Decomissioning						
Excavate and load on trailer, 3000-gallon	Each	465.00	7	3,255	7	3,255
Remove sludge	Each	172.00	7	1,204	7	1,204
Dispose of sludge	Gallon	2.45	200	490	200	490
Known leaking UST excavation	Each	465.00	1	465	1	465
Haul tank to salvage dump, 100-mile RT	Each	525.00	7	3,675	7	3,675
UST Subtotal				**$9,089**		**$9,089**
Site Earthwork						
1-CY hydraulic excavator	CY	3.14	1,200	3,768	3,600	11,304
Loading into truck	CY	1.55	1,200	1860	3,600	5,580
Backfill, unclassified fill, 6-inch lift, offsite	CY	7.35	0	0	2,600	19,110
Earthwork Subtotal				**$5,628**		**$35,994**
Sampling, Testing, and Analysis						
Soil lab analysis: TCLP metals	Sample	693.81	5	3,469	5	3,469
Soil lab analysis: BTEX	Sample	123.69	10	1,237	10	1,237
Soil lab analysis: PAHs	Sample	298.37	10	2,984	10	2,984
Soil lab analysis: metals, (8)	Sample	148.41	5	742	5	742
Total petroleum hydrocarbons	Sample	116.67	0	0	10	1,167
Analytical Subtotal				**$8,432**		**$9,598**
Disposal						
Transportation 100-mile RT, 20-CY loads	Mile	3.38	0	0	10,500	35,490
Waste stream evaluation fee	Each	494.71	0	0	1	495
Dump charges for construction debris	CY	18.42	1,000	18,420	1,000	18,420
Landfill hazardous waste disposal	Ton	233.32	0	0	2,835	661,462
Disposal Subtotal				**$18,420**		**$715,867**
Onsite Bioremediation						
Land treatment, 2 feet deep	Acre	8,762.22	0.40	3,505	0.50	1,752
Backfill, unclassified fill, 6-inch lift, onsite	CY	4.78	1,500	7,170	1,800	8,604
Onsite Bioremediation Subtotal				**$10,675**		**$10,356**
Total Cost				**$64,520**		**$793,181**

Notes

Unit costs were obtained from the ECHOS Environmental Restoration Unit Cost Book and vendor price quotes.
Hazardous waste disposal at Class I Landfill.
Soil density is assumed to be 100 pounds/CF.

BTEX	Benzene, ethylbenzene, toluene, and xylenes.
CF	Cubic foot.
CY	Cubic yard.
ECHOS	Environmental cost handling options and solutions.
PAH	Polycyclic aromatic hydrocarbons.
RT	Round trip.
SY	Square yard.
TCLP	Toxicity characteristic leaching procedure.
UST	Underground storage tank.

the nature of their contents (diesel fuel odor), PRC assumed that the USTs stored diesel fuel. Based on field measurements and industry standards, PRC determined that two of the three diesel USTs were 3000-gallon horizontal tanks, measuring 18 feet long and 64 inches in diameter. PRC could not determine the dimensions of UST No. 7 on the basis of field measurements.

(5) Existing Truck Stop and Service Station Building Investigation

CDM Federal Programs Corporation (CDM) assisted the Louisiana Department of Environmental Quality (LDEQ) in collecting 14 asbestos samples from uniform areas within, and outside of, the existing building. CDM also tested 18 different areas within the existing building for lead-based paint.

C) Investigation Results

This section summarizes the analytical results for the samples collected at the Powers Junction site. PRC followed analytical guidelines outlined in the site-specific quality assurance project plan. Analytical data were compared to EPA screening levels and LDEQ risk-based cor-

Table C4. Cost Estimate for Cleanup Option 4: Excavation, *In situ* Bioremediation (Bioventing) and Offsite Disposal

Item/Description	Unit	Unit Cost	Industrial Quantity	Industrial Cost ($)	Residential Quantity	Residential Cost ($)
Site Preparation						
Demolish reinforced concrete	CY	51.06	100	5,106	100	5,106
Demolish existing building	Cubic foot	0.06	60,000	3,600	60,000	3,600
Load and haul debris	CY	3.57	1,000	3,570	1,000	3,570
Fertilize, seed, and sprig surface soil	SY	1.10	450	495	0	0
Preparation Subtotal				**$12,771**		**$12,276**
UST Decomissioning						
Excavate and load on trailer, 3000-gallon	Each	465.00	7	3,255	7	3,255
Remove sludge	Each	172.00	7	1,204	7	1,204
Dispose of sludge	Gallon	2.45	200	490	200	490
Known leaking UST excavation	Each	465.00	1	465	1	465
Haul tank to salvage dump, 100-mile RT	Each	525.00	7	3,675	7	3,675
UST Subtotal				**$9,089**		**$9,089**
Site Earthwork						
1-CY hydraulic excavator	CY	3.14	600	1,884	2,700	8,478
Loading into truck	CY	1.55	600	930	2,700	4,185
Backfill, unclassified fill, 6-inch lift, offsite	CY	7.35	750	5,513	3,370	24,770
Earthwork Subtotal				**$8,327**		**$37,433**
Sampling, Testing, and Analysis						
Soil lab analysis: TCLP metals	Sample	693.81	5	3,469	5	3,469
Soil lab analysis: BTEX	Sample	123.69	10	1,237	10	1,237
Soil lab analysis: PAHs	Sample	298.37	10	2,984	10	2,984
Soil lab analysis: metals, (8)	Sample	148.41	5	742	5	742
Total petroleum hydrocarbons	Sample	116.67	0	0	10	1,167
Analytical Subtotal				**$8,432**		**$9,598**
Disposal						
Transportation 100-mile RT, 20-CY loads	Mile	3.38	3,000	10,140	13,500	45,630
Waste stream evaluation fee	Each	494.71	1	495	2	989
Low-temperature thermal desorption	Ton	69.41	810	56,222	810	56,222
Dump charges for construction debris	CY	18.42	1,000	18,420	1,000	18,420
Landfill nonhazardous waste disposal	CY	44.00	600	26,400	0	0
Landfill hazardous waste disposal	Ton	233.32	0	0	3,645	850,451
Disposal Subtotal				**$111,677**		**$971,713**
***In situ* Bioremediation**						
Bioventing, 5 feet deep	Lump sum	12,163.08	1.00	12,163	1.00	12,163
***In situ* Bioremediation Subtotal**				**$12,163**		**$12,163**
Total Cost				**$162,458**		**$1,052,272**

Notes
Unit costs were obtained from the ECHOS Environmental Restoration Unit Cost Book and vendor price quotes.
Hazardous waste disposal at Class I Landfill.
Soil density is assumed to be 100 pounds/CF.
BTEX Benzene, ethylbenzene, toluene, and xylenes.
CY Cubic yard.
ECHOS Environmental cost handling options and solutions.
PAH Polycyclic aromatic hydrocarbons.
RT Round trip.
SY Square yard.
TCLP Toxicity characteristic leaching procedure.
UST Underground storage tank.

rective action levels (CAL) to determine areas of concern.

(1) Surface and Subsurface Soil Investigation Results

Analytical results indicate that there are three distinct areas of soil contamination: (1) the gasoline fueling area in the vicinity of the gasoline USTs, which is contaminated with benzene and TPH gasoline; (2) the diesel fueling area, in the vicinity of the diesel USTs, which is contaminated with TPH-diesel, PAHs, and lead; and (3) the former truck repair area in the northeast sector of the site, which is contaminated with metals.

Analytical results indicated that one or more of the four gasoline USTs were leaking into the shallow water table. Contamination appeared to be vertically limited to the water table (4 feet bgs) and top 4 feet of soil, and horizontally limited to the gasoline fueling area. In the vicinity of the diesel fueling area, several PAHs were

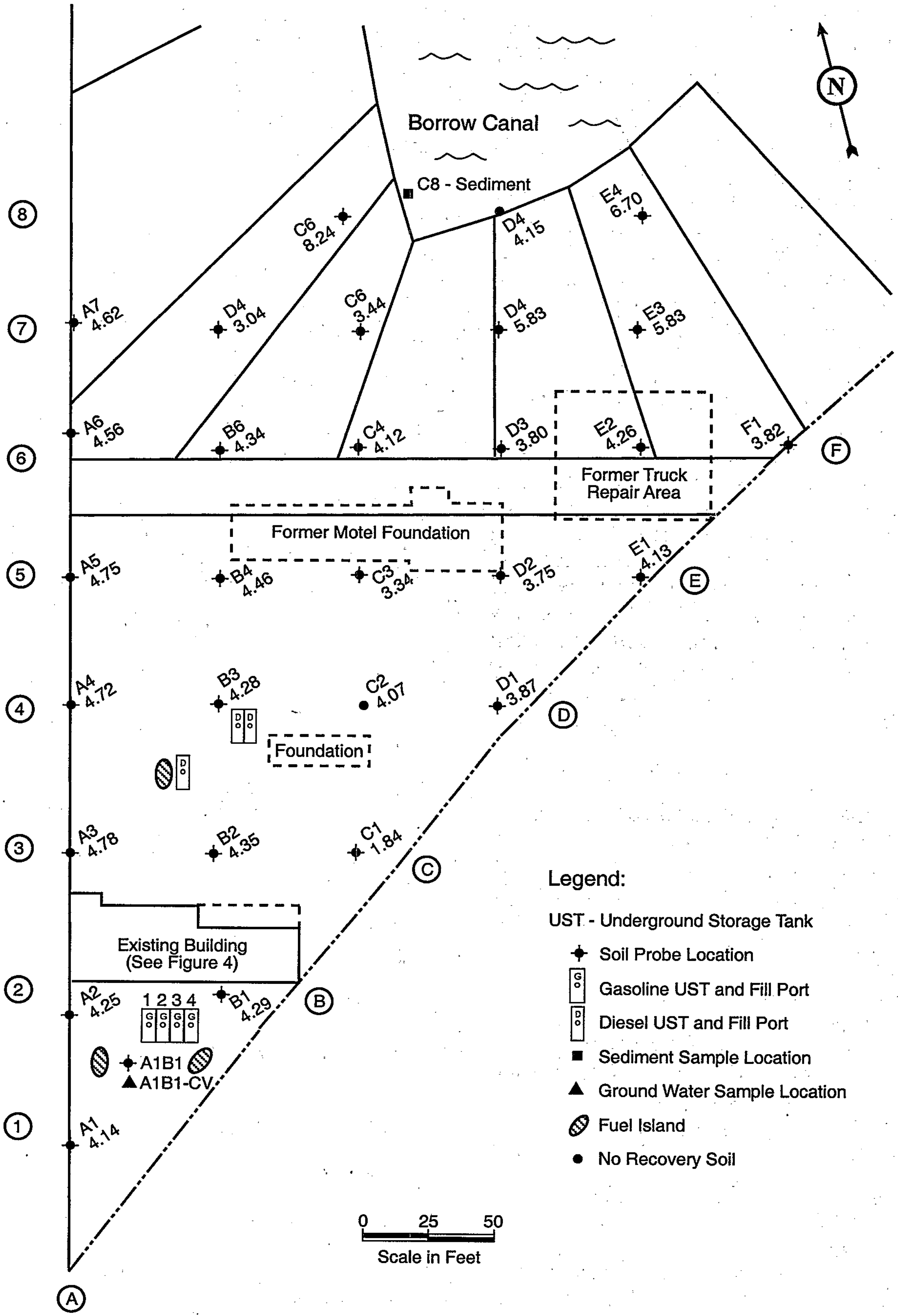

Figure C1. Soil probe location map.

detected at (1) concentrations exceeding the EPA Region 6 Human Health Media-Specific Screening Levels for residential, and in some cases industrial, soil from 0 to 1 foot bgs, and (2) decreasing concentrations from 1 to 2 feet bgs. No PAHs were detected at 4 feet bgs. Field and CLP analysis indicated that the diesel USTs were not leaking. Surface PAH and TPH-diesel contamination may be attributable to historical diesel fuel spillage, overflow from one of the tanks, or proximity to a highway. Analysis of soil samples in the vicinity of the former truck repair area detected chromium and lead at concentrations exceeding the EPA Region 6 Human Health Media Specific Screening Levels for residential soil.

(2) Shallow Water Table Investigation Results

Analysis of a groundwater sample collected from the area immediately south of the gasoline USTs, detected benzene, ethylbenzene, and TPH-gasoline. Benzene and ethylbenzene concentrations exceeded EPA drinking water maximum contaminant levels (MCLs) for these VOCs. The TPH gasoline concentration exceeded the proposed LDEQ CAL for groundwater. The shallow groundwater is not used locally as a drinking water source; therefore the MCLs may not apply to the shallow water table. Analytical results indicated that one or more of the four gasoline USTs are leaking into the shallow water table.

(3) Borrow Canal Investigation Results

Analysis of a sediment sample collected from the southern shore of the borrow canal did not detect organic contaminants at concentrations above EPA Region 6 Human Health Media-Specific Screening Levels for soil. No metals analysis was conducted.

(4) Underground Storage Tanks Investigation Results

Analysis of the contents of the USTs confirmed that: (1) the four USTs in front of the existing building contained gasoline or a mixture of gasoline and water, and (2) the three USTs behind the existing building contained diesel fuel or a mixture of diesel fuel and water.

(5) Existing Truck Stop and Service Station Building Investigation Results

Asbestos was detected in five of 14 building material samples. Lead was detected in three of 18 paint surfaces tested.

D) Analytical Results

Analytical results were compared to (1) EPA Region 6 Human Health Media-Specific Screening Levels for industrial and residential soil and (2) proposed LDEQ risk-based CALs for petroleum hydrocarbons in industrial and non-industrial soil, in order to establish remedial action levels for the Powers Junction site.

Analytical results indicate that the contents of one or more of the four gasoline USTs are leaking into the shallow water table. Contamination appears to be (1) vertically limited to the water table (4 feet bgs) and top 4 feet of soil, and (2) horizontally limited to the gasoline fueling area. The data indicated the following exceedances in soils within the gasoline fueling area:

- EPA Region 6 screening levels and LDEQ CALs for industrial soil
  - Benzene at Probe A1B1
- EPA Region 6 screening levels and LDEQ CALs for residential or nonindustrial soil
  - Benzene at Probes A1 and A2
  - TPH-gasoline at Probe A1B1

Analytical data indicate that the diesel USTs are not leaking. Diesel fuel contamination appears to be limited to the top 2 feet of soil and to the area defined by Probes A3, A4, and B3. Analyses of soil from Probes B2 and C1 revealed no diesel-related contamination. The data indicated the following exceedances in soils within the diesel fueling area:

- EPA Region 6 screening levels and LDEQ CALs for industrial soil
  - PAHs at Probes A3 and A4
- EPA Region 6 screening levels and LDEQ CALs for residential or nonindustrial soil
  - PAHs at Probes A3 and A4
  - TPH-diesel at Probe B3
  - Lead at Probe A4

Surface PAH and diesel fuel contamination within the diesel fueling area may be attributable to (1) historical diesel fuel spillage from the nearby fueling island, (2) overflow from diesel UST No. 7, which has an open fill port, and/or (3) the proximity of U.S. Highway 11 and its associated roadway paving activities, including asphalt resurfacing and road surface runoff.

Analytical results indicate the presence of chromium, lead, and TPH-diesel from 0 to 1 foot bgs in the vicinity of the former truck repair area. No organic constituents were detected at concentrations above the EPA Region 6 Human Health Media-Specific Screening Levels for industrial and residential soil. The data indicated the following exceedances in soils within the former truck repair area:

- No exceedances in soils of EPA Region 6 screening levels and LDEQ CALs for industrial soil
- EPA Region 6 screening levels and LDEQ CALs for residential or nonindustrial soil
  - Chromium at Probes E2 and E3
  - Lead at Probe E1

Analytical results indicate chromium at Probes A6, B6, and D1 which are not associated with the gasoline and diesel fueling areas, or the former truck repair area at concentrations exceeding EPA Region 6 screening level for residential soil. At Probe D1, the chromium concentration also exceeds the EPA Region 6 screening level for industrial soil.

Lead-based paint and asbestos contaminated media (ACMs) are in the existing building.

Before remedial activities can begin, additional sampling and subsurface investigation may be required at the site, including the following:

- Determine the extent of contamination, in the shallow water table and subsurface soil, resulting from one or more leaking gasoline USTs.
- Determine the orientation of the diesel fuel USTs to facilitate removal, and evaluate surrounding soils for any potential contamination resulting from leaks.
- Before the existing building is demolished, conduct a thorough assessment for asbestos and lead-based paint.
- If the site is to be developed for residential use, collect and analyze additional confirmatory samples from hot spot locations, such as Probes A6 and B6, to confirm these areas of potential remedial concern, which are not associated with historical fueling and truck repair activities.
- For remedial options other than excavation and offsite disposal, characterize the soil matrices to determine their compatibility with remedial processes.
- In the case of excavation and offsite disposal, the disposal facility may require that soils be analyzed for toxicity characteristic leaching procedure (TCLP) metals or other offsite disposal requirements.

E) Cleanup Alternatives and Associated Costs

FWS is interested in redeveloping the site as an environmental education center (industrial use) for the Bayou Sauvage Wildlife Refuge area. However, as directed by EPA Region 6, PRC evaluated cleanup options for the site on the basis of both industrial and residential soil screening levels.

Based on current site conditions, and analytical results from the field investigation, PRC proposes the following four cleanup alternatives:

- Cleanup Option 1: Excavation and Offsite Treatment and Disposal (Risk-Based approach)
  - UST removal and decommissioning
  - Demolition of existing building
  - Excavation and offsite treatment and disposal of soils contaminated with benzene and TPH-gasoline
  - Risk-based cleanup approach to remaining surface soil contaminated with TPH-diesel, PAHs, and chromium (industrial use scenario)
- Cleanup Option 2: Excavation and Offsite Treatment and Disposal
  - UST removal and decommissioning
  - Demolition of existing building
  - Excavation and offsite treatment and disposal of soils contaminated with benzene and PAHs
  - Excavation and offsite disposal of soils contaminated with metals (residential use scenario); for

the industrial use scenario, surface soil areas contaminated with chromium will be revegetated.

- Cleanup Option 3: Excavation, Onsite Bioremediation (Landfarming) and Offsite Disposal
  - UST removal and decommissioning
  - Demolition of existing building
  - Excavation and onsite bioremediation (landfarming) of soils contaminated with TPH fuels and PAHs; for the industrial use scenario, chromium contaminated soils will be revegetated.
  - Excavation and offsite disposal of soils contaminated with metals (residential use scenario)
- Cleanup Option 4: Excavation, *In situ* Bioremediation (Bioventing) and Offsite Disposal
  - UST removal and decommissioning
  - Demolition of existing building
  - *In situ* bioremediation (bioventing) of soils contaminated with TPH-gasoline and benzene
  - Revegetation of surface areas of soil contaminated with chromium (industrial use scenario)
  - Excavation and offsite disposal of soils contaminated with TPH-diesel, PAHs, and metals (residential use scenario)

PRC estimated preliminary costs for the proposed cleanup options by using (1) the Environmental Cost Handling Options Solution (ECHOS) Cost Data Book (Delta Technologies Group 1995), and (2) vendor price quotes. Tables 1, 2, 3, and 4 present the cost estimate for each of the proposed cleanup options.

The following assumptions apply to all of the proposed remedial options:

- Concrete to be removed is nonhazardous.
- All remedial options include demolition of the existing building (120 feet long by 50 feet wide by 10 feet high) and concrete (about 100 cubic yards [yd^3]), and removal of the seven 3000-gallon USTs.
- Radius of influence (about 4,000 square feet [ft^2]) for contamination at a probe location is one-half the distance between probe locations.
- Areas requiring remediation were estimated on the basis of EPA Region 6 Human Health Screening Levels for industrial and residential soils; TPH gasoline, TPH-diesel, and PAH cleanup levels are based on proposed LDEQ risk based CALs for industrial and nonindustrial soil.
- There is natural attenuation of contaminated shallow water table (4 feet bgs); therefore, groundwater remediation will not be considered in any of the proposed remedial options.
- The existing building will be demolished and disposed of as nonhazardous solid waste (construction debris); however, special precautions will be taken to minimize airborne distribution of lead-based paint and ACMs during the demolition.
- The treatment, storage, and disposal facilities for hazardous and nonhazardous waste are within a 100-mile round trip of the Powers Junction site.

Cleanup Option 1: Excavation and Offsite Treatment and Disposal (Risk-Based Approach)

Cleanup Option 1 involves the following tasks for industrial cleanup requirements:

- Demolish and dispose of the existing building and concrete (Site Preparation).
- Excavate and decommission the seven 3000-gallon USTs, including at least one leaking gasoline UST (UST Decommissioning).
- Excavate an estimated 600 yd^3 of benzene-contaminated soil (0 to 4 feet bgs) associated with the leaking gasoline UST(s) (Probe A1B1) (Site Earthwork).
- Treat the 600 yd^3 of benzene-contaminated soil offsite by using low-temperature thermal desorption, followed by offsite landfill disposal as nonhazardous waste (Disposal).
- Backfill the excavated area with of unclassified fill from an offsite source (Site Earthwork).

A risk-based industrial cleanup approach including revegetation of contaminated surface soils will be applied to the remaining areas of soil contaminated with PAHs and chromium from 0 to 2 feet bgs (surface contamination) (Probes A3, A4, and D1), which will consider the following factors:

- Proposed LDEQ Risk-Based Corrective Action Plan approach
- Natural attenuation of surface soil contamination with consideration of any potential migration to receptors
- Future land use and proximity of receptors

Cleanup under Option 1 would require about 1 to 2 months to complete.

Cleanup Option 2: Excavation and Offsite Treatment and Disposal

Cleanup Option 2 involves the following tasks for industrial cleanup levels:

- Demolish and dispose of the existing building and concrete (Site Preparation).
- Excavate and decommission the seven 3000-gallon USTs, including at least one leaking gasoline UST (UST Decommissioning).
- Excavate an estimated 1,200 yd^3 of PAH- and benzene-contaminated soil associated with the fueling areas (Probes A3, A4, and A1B1) (Site Earthwork).
- Treat the 1,200 yd^3 of PAH- and benzene-contaminated soil offsite by using low temperature thermal desorption, followed by offsite landfill disposal as nonhazardous waste (Disposal).
- Fertilize, seed, and sprig the 4000-square foot (ft^2) area of chromium-contaminated soil (0-2 feet bgs) (Probe D1) (Site Preparation).
- Backfill the excavated area with unclassified fill from an offsite source (Site Earthwork).

Costs will increase considerably to meet residential cleanup levels, based on the following variations:

- Excavate an estimated 1,500 yd^3 of TPH-, PAH-, and benzene-contaminated soil associated with the fueling areas (Probes A3, A1B1, and B3) (Site Earthwork).
- Treat the 1,500 yd^3 of TPH-, PAH-, and benzene-contaminated soil offsite by using low-temperature thermal desorption, followed by offsite landfill disposal as nonhazardous waste (Disposal).
- Excavate an estimated 2,100 yd^3 of soil (0 to 2 feet bgs) contaminated with PAHs, chromium, and lead (Probes A4, A6, B6, D1, E1, E2, and E3) (Site Earthwork).
- Dispose of the 2,100 yd^3 metals-contaminated soil offsite, in a Class I hazardous waste landfill (Disposal).
- Backfill the excavated area with unclassified fill from an offsite source (Site Earthwork).

If the metals-contaminated soil passes TCLP analysis for barium, chromium, and lead, disposal costs will be substantially lower, based on offsite treatment for TPH-diesel and PAHs, followed by disposal as nonhazardous waste.

Cleanup under Option 2 would require about 1 to 2 months to complete.

Cleanup Option 3: Excavation, Onsite Bioremediation and Offsite Disposal

Cleanup Option 3 involves the following tasks for industrial cleanup levels:

- Demolish and dispose of the existing building and concrete (Site Preparation).
- Excavate and decommission the seven 3000-gallon USTs, including at least one leaking gasoline UST (UST Decommissioning).
- Excavate an estimated 1,200 yd^3 of PAH- and benzene-contaminated soil associated with the fueling areas (Probes A3, A4, and A1B1) (Site Earthwork).
- Fertilize, seed, and sprig the 4000 ft^2 area of chromium-contaminated soil (0 to 2 feet bgs) (Probe D1) (Site Preparation).
- Treat the 1,200 yd^3 of PAH- and benzene-contaminated soil onsite by using bioremediation (land treatment 2 feet deep by 0.4 acre) (Onsite Bioremediation).
- Backfill the excavated areas with 1,500 yd^3 of bioremediated soil (soil volume increases 20 percent

[+300 yd^3] after land treatment) (Onsite Bioremediation).

Costs will increase considerably to meet residential cleanup levels, based on the following variations:

- Excavate an estimated 1,500 yd^3 of TPH-, PAH-, and benzene-contaminated soil associated with the fueling areas (Probes A3, A1B1, and B3) (Site Earthwork).
- Treat the TPH-, PAH-, and benzene-contaminated soil onsite by using bioremediation (landfarming) (Onsite Bioremediation).
- Excavate an estimated 2,100 yd^3 of soil (0 to 2 feet bgs) contaminated with PAHs, chromium, and lead (Probes A4, A6, B6, D1, E1, E2, and E3) (Site Earthwork).
- Dispose of the 2,100 yd^3 of metals-contaminated soil offsite in a Class I hazardous waste landfill (Disposal).
- Backfill the excavated areas with the 1,800 yd^3 of bioremediated soil (soil volume increases 20 percent [+300 yd^3] after land treatment) (Site Earthwork).
- Use offsite unclassified fill to supplement backfilling any remaining areas (Site Earthwork).

Chromium concentrations are not reduced by using this method; however, mixing with soils not contaminated with chromium may reduce the metals concentration by dilution. Treated soils are returned to the excavation from where they originated. Duration of treatment can last from 6 to 18 months, depending on the degradation rates of the contaminants that are being treated.

Cleanup Option 4: Excavation, *In Situ* Bioremediation and Offsite Disposal

Cleanup Option 4 involves the following tasks for industrial cleanup levels:

- Demolish and dispose of the existing building and concrete (Site Preparation).
- Excavate and decommission the seven 3000-gallon USTs, including at least one leaking gasoline UST (UST Decommissioning).
- Excavate an estimated 600 yd^3 of PAH-contaminated soil from the diesel fueling area (Probes A3 and A4) (Site Earthwork).
- Treat the 600 yd^3 of PAH-contaminated soil offsite by using low-temperature thermal desorption, followed by disposal as nonhazardous waste (Disposal).
- Fertilize, seed, and sprig the 4,000 ft^2 area of chromium-contaminated soil (0-2 feet bgs) (Probe D1) (Site Preparation).
- Treat the area contaminated with TPH-gasoline and benzene (Probe A1B1) by using *in situ* bioremediation (bioventing) (*In Situ* Bioremediation).

As an alternative, land treatment may be used to treat, on site, the soil contaminated with PAHs.

Costs will increase considerably to meet residential cleanup levels, based on the following variations:

- Excavate an estimated 600 yd^3 of soil contaminated with TPH-diesel and PAHs from the diesel fueling area (Probes A3 and B3) (Site Earthwork).
- Treat the 600 yd^3 of TPH- and PAH-contaminated soil offsite by using low temperature thermal desorption, followed by disposal as nonhazardous waste (Disposal).
- Excavate an estimated 2,100 yd^3 of soil (0 to 2 feet bgs) contaminated with TPH diesel, PAHs, chromium, and lead (Probes A4, A6, B6, D1, E1, E2, and E3) (Site Earthwork).
- Dispose of the 2,100 yd^3 of metals-contaminated soil offsite in a Class I hazardous waste landfill (Disposal).
- Treat the area contaminated with TPH-gasoline and benzene (Probe A1B1) by using *in situ* bioremediation (bioventing) (*In Situ* Bioremediation).
- Backfill excavated area with of unclassified fill from an offsite source (Site Earthwork).

If the metals-contaminated soil passes TCLP analysis for barium, chromium, and lead, disposal costs will be substantially lower, based on disposal as nonhazardous waste. As an alternative, land treatment may be used, on site, to bioremediate the soil contaminated with TPH-diesel, PAHs, and metals; this will eliminate the costs of transportation, offsite disposal, and offsite backfill. Metals concentrations are not reduced by using this method; however, mixing with soils not contaminated with chromium may reduce the metals concentration by dilution.

Duration of treatment can last from 6 to 18 months, depending on the degradation rates of the contaminants that are being treated.

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