Summary of Recent Improvements in Methods for the Study of Contaminated and Potentially Contaminated Sites

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SUMMARY OF RECENT IMPROVEMENTS IN METHODS FOR THE STUDY OF CONTAMINATED AND POTENTIALLY CONTAMINATED SITES

1.0 INTRODUCTION

The objective of this white paper is to summarize efforts undertaken by various agencies and organizations, including the American Society for Testing and Materials (ASTM), the U.S. Department of Energy (DOE), the Department of Defense (DoD), the U.S. Environmental Protection Agency (EPA), and others, to develop field methodologies and technologies that streamline and improve the study of contaminated and potentially contaminated sites.

This white paper was prepared as an initial activity within a project to develop a general template and four industry-specific fact sheets for conducting faster and cheaper investigations of sites. The fact sheets will describe strategies for sites that housed dry cleaning operations; manufactured gas plants; steel manufacturing operations; and paint shops.

Through the development of a general template and the industry-specific fact sheets, EPA intends to encourage the use of up-to-date field methodologies, sampling and analytical approaches, and cost-effective approaches for site characterization and assessment. These approaches could be used at urban redevelopment sites addressed by the Brownfields program, sites being cleaned up under the Resource Conservation and Recovery Act (RCRA), and state sites being cleaned up under voluntary cleanup programs conducted by state authorities. EPA's objective is to streamline and improve procedures for conducting site characterizations and assessments under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), at both the federal and the state levels. EPA would like to promote consistency among all parties conducting those activities.

2.0 METHODOLOGY AND RESULTS

This section describes the method by which the information for this white paper was collected and the methods that were used to summarize the information and conduct preliminary analyses of it. In addition, this section summarizes the information that was collected in the study and the results of the preliminary analyses.

2.1 METHODOLOGY

Tetra Tech’s methodology for this study consisted of the following four basic steps:

- Telephone contacts combined with extensive searches of the literature
- Identification and listing by source (for example, EPA, DOE, or DoD) of each new approach
- Analysis of the similarities and differences among new approaches to site characterization and assessment promoted by different sources
- Development of preliminary recommendations about which new approaches should be considered for use in a template for the study of contaminated and potentially contaminated sites.

The four steps are described more fully in the following subsections.

2.1.1 Telephone Contacts and Literature Searches

Tetra Tech interviewed a number of points of contact from organizations that were believed to have developed new approaches to the study of contaminated and potentially contaminated sites. In addition, Tetra Tech conducted extensive literature searches to identify recent literature that describes new approaches to the study of such sites. The two efforts were interrelated, since individuals contacted by telephone were asked to identify literature sources and the literature was scrutinized to identify additional telephone contacts. Described below are the details of the telephone interviews and the literature searches.

To obtain state-of-the-art information about strategies and technologies used by the various agencies to speed up the characterization and assessment of sites, Tetra Tech interviewed experts in site investigations from various agencies and organizations, including ASTM; DoD, including the Navy and the Air Force; DOE, including Argonne, Ames, and Oak Ridge national laboratories; and EPA. Appendix A presents the guide that was used for interviews with the points of contact. The guide reflects the purpose of this study, to obtain information on four specific industries of concern, including manufactured gas plants, dry cleaning operations, steel manufacturing operations, and paint shops. The EPA work assignment manager and other EPA staff identified the original points of contact. Additional contacts were identified during the initial interviews and from authors of key literature found during the literature search. Appendix B lists the persons contacted and interviewed for this survey and summarizes their responses and contributions to this effort.

Literature searches for the years 1995 to 1997 were conducted by key words, such as “expedited,” “accelerated,” “rapid,” “site characterization,” “site assessment,” “site investigations,” and “data quality objectives.” In addition, Tetra Tech conducted separate literature searches by additional keywords (such as “steelmaking,” “coal tar,” “paint wastes,” and “dry cleaning solvents”) designed to obtain information about the four specific industries of concern. Tetra Tech conducted the searches through the seven largest

search engines on the Internet (Magellan, Hotbot, Webcrawler, Lycos, Exite, Netsearch, and Yahoo) and numerous databases, including Knight/Ridder/Dialog databases; the Clean-Up Information (CLU-IN) home page and bulletin board system; and the Alternative Treatment Technology Information Center (ATTIC) and Vendor Field Analytical and Characterization Technologies System (Vendor FACTS) databases, as well as EPA's home page and the home page of the Federal Remediation Technology Roundtable.

The literature searches generally produced a list of document titles or a list of abstracts. Tetra Techs' methodology required that a Tetra Tech senior scientist review the results and obtain full copies of all documents that appeared to contain new information about the study of contaminated or potentially contaminated sites. After obtaining such documents, Tetra Tech summarized each one, according to the guide presented in Appendix C. Subsection 2.2 of this paper presents the results of this step in Tetra Tech's methodology.

2.1.2 Identification and Listing by Source of Each New Approach

Tetra Techs' methodology involved the compilation and summarization of major points in all literature and in transcripts of the interviews with experts. Next, literature sources and transcripts were analyzed subjectively to determine whether they contained approaches or technologies that were relatively new. In selecting such new information, Tetra Tech exercised a strong preference for new approaches or strategies, rather than technologies or resources. However, the process of selecting new information was flexible enough to include information that described only partial approaches or strategies and significant technologies or resources, even when no associated approach or strategy was involved. Literature or transcripts that were found not to contain new information were set aside, and those that were found to contain new information were placed on a list organized according to the organization considered to be the source of the new information. Although there were no strict criteria establishing limits on the age of an approach or idea, most of the literature selected had been published in the past two years and all of it had been published in the 1990s. In addition, it is important to note that, when similar new information was provided by more than one source, it was listed more than once, even if one source had published the new information more than one year before the other. Such double listing of new information was done so that Tetra Tech could 1) determine in later analyses whether the more recently published information included additional insights and 2) gauge the frequency with which specific types of new information were being discussed in the literature.

In addition to the listing of each new idea and its source, Tetra Tech's methodology included the preparation of a thorough summary. Therefore, each literature source and transcript of telephone interview was summarized in table format, with the purpose, applicability, and major components of the approach

described and recommended technologies listed. Subsection 2.2 of this paper presents the results of this step in Tetra Tech's methodology.

2.1.3 Analysis of Similarities and Differences Among New Approaches

After summarizing each approach, Tetra Tech compared them to identify similarities in their respective purposes, applicabilities, and major components and among the technologies recommended. The purpose of such comparisons was to identify those new approaches for improving the study of contaminated or potentially contaminated sites that 1) have common purposes and applications, 2) are promoted by more than one organization (source), 3) have major components or recommended technologies in common, and 4) are not fully accepted by specific organizations. In addition, such comparisons were deemed to be essential for the identification of elements to be included in a template for the study of contaminated and potentially contaminated sites. Subsections 2.2 and 3.1 through 3.3 of this paper present the results of this step in Tetra Tech's methodology.

2.1.4 Development of Preliminary Recommendations for Inclusion of New Approaches in a Template

The Tetra Tech methodology requires that, after careful examination of similarities and differences among the major components of each new approach to the study of contaminated and potentially contaminated sites, Tetra Tech senior staff nominate individual approaches (or major components thereof) for use in the template, of which this paper is the precursor. Such nomination must be accompanied by a description of the purpose and applicability of the approach, a thorough description of the strengths and limitations of the approach, and a discussion of any perceived weaknesses of the approach, accompanied by the organization(s) that perceives the weaknesses.

Section 4.0 of this paper presents the preliminary results of this step in Tetra Tech's methodology.

2.2 RESULTS AND DISCUSSION

This section presents the results obtained from the conduct of the first two steps of Tetra Tech's four-step methodology for this study. Section 2.2.1 presents the results of the telephone interviews that were conducted, and section 2.2.2 presents the results of the literature reviews, including the identification, listing, and summary by source (for example, EPA, DOE, or DoD) of each new approach.

2.2.1 Telephone Contacts

As Appendix B shows, Tetra Tech interviewed 102 contacts by telephone, 31 initial contacts and 71 second-round contacts. The second-round contacts were individuals identified by initial contacts and authors of key literature. Only three new approaches were identified through the interviews that were not yet described in greater detail in the published literature. (Reference to these approaches are identified as draft documents in this paper.) However, a great deal of the literature used in this study was identified by the points of contact.

The telephone interviews indicated, and the literature search later confirmed, that there is a widely accepted and rather narrow definition of the term "expedited site characterization." This term refers to a two-phase process, first developed by DOE and later modified and expanded by ASTM, by which an interdisciplinary team of senior professionals fully characterize (first in terms of hydrogeologic pathways and then in terms of mass transport of hazardous constituents) a site at which previous investigations have failed.

The telephone interviews also revealed that the terms "assessment" and "characterization" generally are viewed as the initial and subsequent stages, respectively, in the study of a contaminated or potentially contaminated site. It appears that most of the persons who were contacted during the study view assessments as the use of semiquantitative data to determine the existence of contamination or to provide some indication of the extent of contamination at a site. Most contacts interviewed considered site characterization to involve a thorough description of both the types and distributions of all contaminants at a site. However, a number of persons stated they would not consider a site fully characterized until enough data had been collected to fulfill one or more of the following objectives that commonly are used to define the scopes of various site studies:

- Calculate present risks to human health
- Calculate present ecological risks
- Determine compliance with regulatory levels (ARARs), which sometimes are unrelated to risks
- Address site-specific community concerns
- Identify uncontaminated areas and eliminate them from further consideration
- Establish cleanup levels
- Select and design cleanup technologies

Another term used among the persons contacted is "field screening methods" or "field screening

technology." These terms generally are applied to portable equipment that is capable of rapid on-site sampling or analysis at low but definable (especially in terms of detection limits, interferences, and contaminant specificity) levels of data quality. In general, such screening equipment is well suited for site assessments, removal actions, and initial remedial activities.

2.2.2 Literature Searches and Summarization of Approaches

The literature searches resulted in the initial selection of 76 documents. Of those, 30 were found to include new information about the study of contaminated and potentially contaminated sites. The 30 literature sources were listed by source and summarized, with the purpose, applicability, and major components of each described and the recommended technologies listed. Table 1 presents the results of that effort. The data in Table 1 also reveal that 24 of the selected approaches involve strategies; only one is strongly oriented to a particular technology (Site characterization and analysis penetrometer system [SCAPS]), and only five can be considered major resources that do not involve strategies. As stated in the previous section of this paper, the preference for approaches based on strategies was intentional, mainly because a number of current studies funded by EPA focus on technologies and resources. The data in Table 1 also indicate that three government agencies (EPA, DOE, and DoD), ASTM, four states

Table 1
Approaches to Improving Methods for the Study of Contaminated and Potentially Contaminated Sites
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SOURCE	APPROACH [a]	PURPOSE	APPLICABILITY [b]	MAJOR COMPONENTS	RECOMMENDED TECHNOLOGIES
A&WMA and EPA • VIP-33 Volumes I & II (1993) • VIP-47 Volumes I & II (1995)	Field Screening Methods for Hazardous Wastes and Toxic Chemicals [R]	Document state-of-the-art research on rapid, low-cost field screening methods; sampling technologies; and, to a lesser extent, conceptual approaches that improve the efficiency of site investigations	Varies with technology or conceptual approach [A & C]	Several published volumes that describe technologies and conceptual approaches to reduce costs, reduce data turnaround time, and increase scientific confidence in decisions based upon site investigation data; emphasis on good scientific investigation principles; promotes documentation of latest research findings and technology improvements; integration of risk-based criteria in several documents	Numerous technologies and approaches are presented in each published volume
ASCE • Manual No. 83 (1996)	Environmental Site Investigation (ESI) Guidance Manual [S]	Describes appropriate procedures for investigating and characterizing a site that is or may be contaminated with hazardous materials	Potentially contaminated or identified hazardous waste sites [A & C]	Conventional four-phase engineering approach, including preliminary site assessment, site investigation, remedial investigation, remedial planning, design and implementation; provides selection criteria for investigative methods and sample selection, as well as legal and regulatory justification for process integration of risk-based criteria (phase III)	Geophysical and soil gas surveys; GPR; electromagnetics; resistivity sounding; seismic refraction; magnetometer
ASTM • PS 3-95 (1996) (also see listing under EPA Source)	Accelerated Site Characterization (ASC) [S]	Rapid and accurate characterization of confirmed or suspected petroleum releases	Sites at which releases of petroleum are known or suspected, may also be applicable to sites at which releases of chlorinated solvents are known or suspected [C]	On-site iterative process that provides a comprehensive site characterization in one mobilization; promotes use of “rapid sampling” tools and techniques, field-generated analytical data, and on-site interpretation of results; use of dynamic work plan; on-site decision making; and real-time analyses; integration of risk-based criteria	Examples of rapid sampling tools include PID or FID headspace analyzers; pH, redox, dissolved oxygen, conductivity, and ion-specific meters; IR spectrometers; colorimetric and immunoassay kits; portable and on-site laboratory-grade GC/MS, and others
ASTM • PS 85-96 (1997) (also see listing under DOE Source)	Expedited Site Characterization (ESC) [S]	Collect only information required to meet all well-defined objectives for comprehensive site characterization	“Large-scale” projects, such as CERCLA remedial and RCRA facility investigations; complex hydrogeologic areas; PA/SIs and RFAs generally are required [C]	Experienced scientific professional staff in field; use of dynamic work plans, real-time data analyses, and on-site decision making; development of conceptual site models; emphasis on good scientific investigation principles; extensive study of pathways, followed by extensive study of contaminant concentration; characterization ceases when objectives are met	When feasible, noninvasive and minimally invasive methods are performed, but not individually specified

a = Category contains mostly approaches that involve strategies, but also includes major resources and technology dominated methods with emphasis on approach. The letters within the brackets inform the reader if a listing involves strategy [S], is a major resource [R], or is dominated by a technology [T].

b = The letters within the brackets inform the reader if a listing focuses predominantly on characterization [C], assessment [A], or a combination of both.

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SOURCE	APPROACH [a]	PURPOSE	APPLICABILITY [b]	MAJOR COMPONENTS	RECOMMENDED TECHNOLOGIES
ASTM • E 1527-93 (1993)	Phase I - Environmental Site Assessments (ESA) [S]	Provide a method for users to satisfy one of the due diligence requirements to qualify for the innocent landowner defense against CERCLA liability ("all appropriate inquiry into the previous ownership and uses of the property consistent with good commercial and customary practice")	Intended for specific parcels of commercial real estate; not limited to CERCLA sites [A]	Thorough review of records; visit to the property; interviews with current owners and occupants of the property and local government officials; evaluation and report; no testing or sampling; does not require high-level technical expertise of an environmental professional	Not applicable
ASTM • Draft (1996) PCN: 06-055002-65	Phase II - ESA [S]	Confirm or deny problems identified in Phase I - ESA (or transaction screening process); quantify the problem, if one exists	Same as Phase I - ESA [A &C]	Investigative activities that range from field screening methods to intrusive multimedia sampling and laboratory analysis, evaluation and presentation of data, and documentation of results; use of informal but detailed work plan; iterative approach that allows user to terminate the Phase II - ESA at the point at which sufficient data have been generated to meet the user's objective	Specific practices in the implementation of Phase II - ESA are not indicated; practices and methods accepted by government and industry are recommended
ASTM • E 1739-95` (1995)	Risk-Based Corrective Action (RBCA) [S]	Integration of site assessment, selection of remedial action, and monitoring with EPA-recommended risk and exposure assessment practices, so that corrective action decisions are made in a consistent manner that is protective of human health and the environment	Emphasis is on sites at which releases of petroleum products have occurred; process is not limited to a particular class of compounds [C]	Site assessment and classification provides an approach for clearly defining the types and amounts of data needed during site characterization; activities focused on collecting only that information necessary to make risk-based corrective action decisions; use of dynamic work plan and on-site decision making; three-tier evaluation of risk-based screening levels (RBSL) and site-specific target levels (SSTL); remedial action; integration of risk-based criteria; resources allocated to sites that pose the greatest risk to human health and the environment	None specified

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SOURCE	APPROACH [a]	PURPOSE	APPLICABILITY [b]	MAJOR COMPONENTS	RECOMMENDED TECHNOLOGIES
ASTM C D 5730-95a (1995)	Site Characterization for Environmental Purposes [S]	Improve consistency of practice and encourage rational planning of a site characterization program by providing a checklist to assist in the design of environmental reconnaissance or investigation plans	Any type of environmental investigation that has a primary focus on the subsurface and major factors affecting the surface and subsurface environment [C]	Iterative process of continually refining a conceptual site model as new information becomes available; definition of DQOs and site boundaries; collection of available existing site information and data; development of conceptual site models; performance of reconnaissance site investigation; development of detailed site investigation and sampling plan; use of geostatistical methods for developing sampling strategies; collection of field samples and measurements; analysis of field and laboratory data to refine conceptual model	Remote sensing and geophysical surveys; CPT; various in situ testing and analytical methods
Bechtel Environmental, Inc. C VIP-47 (1995)	ESC Using the M^3 Approach [S]	Identify and classify potential areas of concern (AOC) as "clean" or contaminated, thereby allowing potentially responsible parties to save limited resources by ceasing costly investigations and undertaking removal actions expeditiously	Potentially contaminated or identified hazardous waste sites; implemented in EPA Region 9 [A & C]	Three-step approach consists of a "massive" sampling effort using a grid approach and real-time data analysis to generate field-screening data, a "moderate" sampling effort to provide on-site verification using Contract Laboratory Program (CLP) methods for field quantification data, and a "minimum" sampling effort to provide analytical verification and confirmation by an off-site laboratory; elimination of further action on those AOCs found to be clean; reduction in the large number of nondetect samples that are commonly submitted for CLP analyzes	None specified
Boulding Soil-Water Consulting C Ann Arbor Press, Inc. (1996)	EPA Environmental Assessment Sourcebook [S]	Compilation into one reference sourcebook of approximately 20 of EPA's classic, but relatively short, documents that provide up-to-date information about the current state of knowledge about environmental site assessment and remediation of contaminated soil and groundwater.	Intended for the evaluation of soil and groundwater contamination at uncontrolled hazardous waste sites, but applicable to a wide range of environmental investigations in which prevention, control, or identification of contaminants in air, soil, and groundwater are of potential concern. [A & C]	Resource documents discuss specific site characterization and monitoring techniques; environmental site assessment; sampling approaches for various contaminants in groundwater and soils; and behavior, transport processes, and modeling of contaminants.	Numerous modeling tools; sampling devices; field GC/MS, ion-mobility spectrometers, and others.

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CMECC/DoD/EPA/Cal EPA • Final Report (1996)	Field Analytical Measurement Technologies, Applications, and Selections [S]	Expedite environmental restoration and reuse of closing military bases in California by assisting military and regulatory remedial project managers and military base consultants in selection and application of field analytical measurement technologies	Targeted for use at former, active, and closing military bases, but applicable to all potentially contaminated or identified hazardous waste sites [C]	Incorporation of DQO process for field measurements; inclusion of a matrix of recently developed field analytical measurement technologies that provides detection limits, false negative/positive rates, unsuitable physical conditions, chemical interferences, and costs; matrix used to match appropriate technologies with site-specific conditions and data needs of the project	Immunoassay, immunochemical, and colorimetric tests; SCAPS; XRF; soil gas surveys and mobile laboratories recommended
DoD and EPA • USACE Waterways Experiment Station Technical Report GL-93-16 (1993) • EPA/540/R-95/520 (1995)	Site Characterization and Analysis Penetrometer System (SCAPS) [T]	Provide rapid on-site, real-time data acquisition and processing, as well as on-site three-dimensional visualization of subsurface soil stratigraphy and regions of contamination	Developed to characterize soil conditions at DoD sites undergoing installation restoration; however, in theory, the technology should be applicable to any potentially contaminated or existing hazardous waste sites consisting of nominally consolidated, fine-grained soils and sediments [A & C]	Use of 20-ton truck equipped with vertical hydraulic rams to force a cone penetrometer into the ground; relatively nonintrusive with minimal environmental effects; continuous data collection and recording with 2 cm spatial resolution; multisensor penetrometer probes determine soil stratigraphy, boundaries of layers, soil type, and presence of contaminants in each stratum; real-time data acquisition, analysis, and processing; trailer-mounted grout pumping system to facilitate backfilling holes with grout as the push rods and probe are retracted	VOC, explosives, petroleum, oil, and lubricant sensors; laser-induced breakdown spectroscopy, XRF
DoD-Navy and EPA • Draft (1997)	Field Sampling and Analysis Technologies Matrix [R]	Ensure that project managers are aware of the full range of technology options available to them to assess and characterize contamination at their sites	All persons interested in analytical and sampling technologies [A & C]	Comparative screening information on analytical and sampling technologies in poster format; when final, the matrix will list approximately 70 sample access, collection, and analytical tools; includes comparative information such as media, contaminants, applicability to various characterization phases, cost, time requirements, detection limits, and quantitative data quality	Comprehensive list of available technologies

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DOE • GJ0-96-3TAR (1997)	Environmental Cleanup Privatization Products and Services Directory [R]	Serve as a vendor guide to commercial remedies for environmental cleanup problems	All persons interested in environmental treatment, characterization, extraction, delivery, and material handling [A & C]	Directory and database of domestic and international commercial firms operating in the environmental cleanup market; information included about each vendor's product or service includes contact address, process type, contaminants, media, application, brief description, maturity of product or service, performance history, comments, and source of information	Examples include, but are not limited to, sensors and field analytical equipment, physical samplers, geophysical scanning systems, remote sensing devices, and decision support tools
DOE - Argonne National Laboratory • Burton, J.C. and others (1997) • Burton, J.C., and others (1995) • Burton, J.C. (1994) • Burton, J.C., and others (1993) • DOE ESC Training Course (1997) • DOE (1996a)	Expedited Site Characterization (ESC) "QuickSite[SM]" [S]	Determine whether a contaminated site requires remediation	Potentially contaminated or existing hazardous waste sites that have undergone numerous previous site characterizations without reaching closure [C]	Emphasis on good scientific investigation principles and expert judgment; requires thorough understanding of the geology and hydrology of a site before investigations on contaminant distribution and migration begin; technical team leader with a broad range of expertise in the geosciences and a multidisciplinary geoscience-based team with strong field experience conduct the program; team leader and team remain constant throughout the program and participate in all phases of the program, including field activities; use of multiple work hypotheses; flexible process that is neither site- nor contaminant-dependent; use of multiple, complementary technical methodologies, with emphasis on nonintrusive and minimally intrusive investigative methods; high-quality data required for accurate decision making; screening techniques of lower quality are not used; dynamic work plan allows adjustment of the program as indicated by on-site data analysis and decision making; regulatory guidance does not direct the program without paying heed to science	Noninvasive and minimally invasive technologies are emphasized, but not individually specified; no one technique works well at all sites; multiple technologies are employed to increase confidence in conclusions about site features
DOE and Martin Marietta Energy Systems, Inc. • VIP-47 (1995)	Field Assessment Screening Team (FAST) Technology [S]	Determine the horizontal and vertical extent of soil and groundwater contamination with one mobilization of the field investigative team	Potentially contaminated or existing hazardous waste sites that have nominally consolidated fine-grained soils and sediments [A & C]	Use of DQO process; integrated system of technological components, including intrusive sampling systems, based on push technology; field mobile laboratories; GPS systems; and data management systems ; real-time data analysis allows decision maker optimum information for real-time decisions	Examples include, but are not limited to Geoprobe, GC (IMS), XRF, ICP, GPS, CAD/GIS

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DOE • Principles of Environmental Restoration, Albuquerque Field Office (1997) • Pilot Project - Final Report (1996)	Streamlined Approach for Environmental Restoration (SAFER) [S]	Plan and conduct efficient and effective remediation to minimize uncertainty through the entire restoration process	CERCLA and RCRA operable units, waste area group, or release sites, as well as statewide [C]	Involvement of regulators, stakeholders, and project managers in an integrated process that includes all activities associated with site characterization and remediation; integration of the DQO process with the observational method, an operational framework for managing uncertainty and planning decision making; use of an effective project team; clear, concise, and accurate identification and definition of problems; early identification of likely response actions; management of uncertainty and contingency planning	None specified
EPA Region 5 • LUST Site Characterization Methods Seminar (1995)	Accelerated Site Characterization (ASC) Methods [S]	Provide an overview of methods used in an expedited approach to characterizing site conditions when petroleum releases from leaking UST systems are suspected or have been confirmed	UST sites [C]	Use of versatile, efficient, and innovative soil probing tools, subsurface mapping technologies, and on-site analytical equipment to locate, define, and quantify subsurface effects of discharges from a UST system or from other sources in one mobilization; analyzes large volume of samples during a typical three-day investigation; use of real-time data	Soil probing and CPT systems; subsurface mapping techniques that use Geoprobe, GPR, and electromagnetic surveys; on-site analyses, using TOV headspace analyzers, immunoassay test kits, and portable and transportable GC
EPA • EPA/540/R-93/071 (1993) • EPA/600/R-95/055 (1994) • EPA/600/R-96/056 (1994) (also see listing under DOE Source)	Data Quality Objectives (DQO) [S]	Ensure that data collected are appropriate, sufficient, and of adequate quality for their intended use; provide a systematic procedure for defining the criteria that a data collection design should satisfy, including when to collect samples, where to collect samples, the tolerable level of decision errors for the study, and how many samples to collect	All scientific data collection activities for site characterization [A & C]	Seven-step iterative process that is integrated with development of sampling and analysis plan and revised as needed; general approach for determining sample size, sample collection equipment, and field analytical methods; steps include: stating the problem, identifying the decision, identifying factors influencing the decision, defining the study boundaries, developing a decision rule, specifying tolerable limits on decision errors, and optimizing the design; employs statistical parameters and specifies tolerable limits on decision errors; provides for an approach to problem resolution and defensibility of data collection; forces user to identify all possible uses of data and assess whether all criteria will be satisfied; use of dynamic work plans	All methods approved by EPA are acceptable

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SOURCE	APPROACH [a]	PURPOSE	APPLICABILITY [b]	MAJOR COMPONENTS	RECOMMENDED TECHNOLOGIES
EPA • Draft (1997) • EPA Region 1 and Tufts University Center for Field Analytical Studies and Technologies	Dynamic Work Plans and Field Analytics Guideline [S]	Illustrate the factors that should be considered in incorporating field analytical instruments and methods into an adaptive sampling and analysis program for expediting site investigations	Potentially contaminated or existing hazardous waste sites [A & C]	Emphasis on good scientific investigation principles; core technical team with expertise in analytical chemistry, geology, geochemistry, geophysics, hydrogeology, and risk analysis; at least one expert on site at all times; use of site-specific, six-step dynamic work plan; that specifies the decision-making logic to be used in the field to determine which chemical compounds require analysis, where to collect the samples, and when to stop sampling; incorporation of DQOs; implementation of SOPs and use of field analytical instruments; use of adaptive sampling and analysis strategies; real-time data analysis; development of conceptual models; integration of risk-based criteria	GC/MS; GC with PID or EC detector; strategic diagnostic enzyme kits
EPA • 510-B-97-001 (1997)	Expedited Site Assessment (ESA) [S]	Rapid characterization of UST sites to support corrective action decisions	UST sites [C]	Single mobilization phase of investigation; emphasis on good scientific investigation principles; senior scientists as field managers with experienced staff; use of multiple complementary and innovative technologies; sampling locations depend on existing data, allowing on-site iterative process; minimal well installation; location of most significant contaminant mass in three dimensions; flexible work plan; hourly and daily interpretation of data; optional integration of risk-based criteria, using RBCA process	Surface geophysical methods, including GPR, electromagnetic surveys, electrical resistivity, metal detection, seismic methods, and magnetometry; active and passive soil gas surveying methods; direct-push technologies; and petroleum hydrocarbon analytical equipment, including detector tubes, fiber-optic chemical sensors, colorimetric test kits, FIDs, PIDs, turbidimetric test kits, immunoassay test kits, portable IR detectors, and field GCs
EPA Workshop C Draft (1997) C CERCLA Education Center/TIO	Field-Based Site Characterization Technologies [R]	Present approaches and tools for field-based site characterization, why those approaches or tools are used, how they can be applied, and factors that affect the quality of field-based site characterization	All scientific data collection activities for site characterization [A & C]	Comprehensive compilation of site characterization and monitoring technologies; emphasis on proper use of applicable technologies to address site-specific hazardous waste problems, data interpretation, and quality	Numerous technologies grouped under geophysical, organic chemical, and inorganic chemical characterization categories

a = Category contains mostly approaches that involve strategies, but also includes major resources and technology dominated methods with emphasis on approach. The letters within the brackets inform the reader if a listing involves strategy [S], is a major resource [R], or is dominated by a technology [T].

b = The letters within the brackets inform the reader if a listing focuses predominantly on characterization [C], assessment [A], or a combination of both.

Table 1
Approaches to Improving Methods for the Study of Contaminated and Potentially Contaminated Sites
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SOURCE	APPROACH [a]	PURPOSE	APPLICABILITY [b]	MAJOR COMPONENTS	RECOMMENDED TECHNOLOGIES
EPA • 540/R-95/141 (1995)	Representative Soil Sampling [S]	Ensure that a sample or a group of samples accurately characterizes site conditions	Intended for use throughout the Superfund program; focuses on early action activities and emergency response [C]	Emphasis on good scientific investigation principles; development of conceptual site models, sampling approaches, and statistical sampling designs; use of appropriate geophysical, analytical screening, and sampling equipment; proper sample preparation techniques; suitable types and numbers of QA/QC samples; determination of probability and confidence levels of sampling results; interpretation and presentation of analytical and geophysical data; integration of risk-based criteria	Analytical screening equipment, including portable XRF, FID, PID, field test kits, radiation detectors; geophysical equipment, including GPR, magnetometry, electromagnetic conductivity, and resistivity meters; soil sampling equipment, including trier, scoops or trowels, tulip bulb planters, soil coring devices, thin-wall tube, split spoon and shelby tube samplers, bucket and power augers
EPA • 540/F-95/041 (1996) • 540/R-95/128 (1996) • 540/R-96/018 (1996)	Soil Screening Levels (SSL) [S]	Standardize and accelerate the evaluation and cleanup of contaminated soils at sites on the NPL at which future land use is anticipated to be residential	Simple and complex sites at which there are contaminated soils or potentially contaminated sites [C]	Part of a larger framework that includes both generic and more detailed approaches to calculation of screening levels; environmental science and engineering professionals calculate site specific SSLs for contaminants in soil, using a seven-step process; if concentrations of contaminants fall below SSLs, no further action or study is required under CERCLA; if concentrations of contaminants are equal to or exceed SSLs, further study or investigation, but not necessarily cleanup, is warranted	None specified
EPA • OSWER Directive 9203.1-03 (1992) • EH-231-025/1294 (1994) • EH-413-067/0196 (1996)	Superfund Accelerated Cleanup Model (SACM) [S]	Streamline the measures that traditionally have been taken to achieve cleanup of releases and that have required redundant site evaluations, sampling, and public participation steps	Initially intended for use at Superfund sites, but also applied to cleanups under RCRA [C]	Integration of traditional site assessment functions to allow continuous assessment for high-priority sites that proceeds until all necessary data are collected to screen sites or to support necessary response actions; directed by nonscientific management to coordinate activities that support both removal and remedial assessments; initiation of response action decisions as soon as evidence indicates that early action is warranted; considers use of "presumptive remedies" without regard for geologic variability among sites; streamlined risk evaluation (SRE) and the site conceptual exposure model (SCEM) may be used to address those sites that pose the greatest threat	None specified

a = Category contains mostly approaches that involve strategies, but also includes major resources and technology dominated methods with emphasis on approach. The letters within the brackets inform the reader if a listing involves strategy [S], is a major resource [R], or is dominated by a technology [T].

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Table 1
Approaches to Improving Methods for the Study of Contaminated and Potentially Contaminated Sites
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SOURCE	APPROACH [a]	PURPOSE	APPLICABILITY [b]	MAJOR COMPONENTS	RECOMMENDED TECHNOLOGIES
EPA • 542-N-97-007 (1997)	Vendor FACTS [R]	Promote use of innovative technologies for streamlining field analysis, as well as site characterization and assessments	All scientific data collection activities for site characterization [A & C]	Database lists vendors of more than 120 innovative geophysical, sampling, extraction, and analytical technologies; includes cost and performance data on portable or transportable technologies for on-site screening, characterization, monitoring, and analysis of hazardous substances; specific technology application and performance information can be searched by media, contaminants, technologies, or vendors to determine applicability for a specific site need; includes stand-alone software used in the field to facilitate site characterization process	Examples include air measurement devices, analytical detectors, GC, chemical reaction-based indicators, immunoassays, soil gas analyzers, CPT, down-hole sensors, XRF, GPR, and IR monitors
Florida Department of Environmental Protection	Considerations for Assessment of Dry Cleaning Solvent Contaminated Sites [S]	Provide a methodology for rapid screening of sites contaminated with wastes from dry cleaning operations	All persons conducting studies at sites contaminated with wastes from dry cleaning operations [A]	Describes industry practices, primary target waste constituents, use of conceptual models and generic work plans that are modified in the field	Mobile laboratory with GC/MS capabilities, surface geophysics, passive and active soil gas surveys, and direct-push equipment for subsurface sampling
Illinois EPA • Title 35 part 742 (1997)	Tiered Approach to Corrective Action Objectives [S]	Provide a methodology for making risk-based decisions about corrective action	Contaminated sites under Region 5's LUST program and site remediation program, and sites having RCRA Part B permits and closure plans [C]	Three-tiered approach for the development of remediation objectives; integration of risk assessment, risk management, site assessment, and selection of monitoring and corrective action approaches; includes an option for exclusion of pathways from further consideration; use of background concentrations as remediation objectives; specifies criteria for compliance with remediation objectives	None specified

a = Category contains mostly approaches that involve strategies, but also includes major resources and technology dominated methods with emphasis on approach. The letters within the brackets inform the reader if a listing involves strategy [S], is a major resource [R], or is dominated by a technology [T].

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Table 1
Approaches to Improving Methods for the Study of Contaminated and Potentially Contaminated Sites
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SOURCE	APPROACH [a]	PURPOSE	APPLICABILITY [b]	MAJOR COMPONENTS	RECOMMENDED TECHNOLOGIES
TNRCC C RG-175 (1995)	Guidance for Risk-Based Assessments at LPST Sites in Texas [S]	Develop rules and define the site assessment protocol to implement risk-based corrective action for leaking petroleum storage tank (LPST) sites in Texas; collect sufficient data to determine priority among sites and to support risk evaluation	Newly confirmed and existing LPST sites [A & C]	Identification of all potential receptors, exposure pathways, and immediate and long-term hazards, as well as contaminant areas and maximum contaminant concentrations of all affected media; delineation of the vertical extent of affected media that exceeds health-protective and cross-media protective concentrations; evaluation of data concurrent with the field investigation, allowing the number of sampling points to be based on actual subsurface conditions	Push-tool and field analytical techniques are recommended when appropriate
Westinghouse Savannah River Company • Draft (1997)	Evolving Conceptual Model Approach [S]	Integration of characterization, monitoring, and remediation tool kits to define and clean up contaminant plumes	Potentially contaminated or existing hazardous waste sites [A & C]	Review of existing site history, geologic, and demographic data; development of initial conceptual model, including extent of contamination, risk factors, and probable characterization and cleanup strategies; investigation and remedial actions proceed from less invasive to more invasive strategies to refine the conceptual model and narrow the scope of cleanup; site-specific requirements demand familiarity with and proper application of environmental technologies; continued reevaluation of conceptual model; integration of risk-based criteria	Examples include, but are not limited to, surface geophysical techniques and shallow soil gas surveys; CPT; borehole logging techniques; analytical groundwater flow and transport models; soil core and water samplers; FID, PID, IR or UV-VIS spectroscopy, field GC, field GC-MS; and three-dimensional visualization computer software

a = Category contains mostly approaches that involve strategies, but also includes major resources and technology dominated methods with emphasis on approach. The letters within the brackets inform the reader if a listing involves strategy [S], is a major resource [R], or is dominated by a technology [T].

b = The letters within the brackets inform the reader if a listing focuses predominantly on characterization [C], assessment [A], or a combination of both.

(CA, FL, IL, TX), and five private organizations are the sources of the information about the study of contaminated and potentially contaminated sites.

A preliminary analysis of the information in Table 1 reveals that 13 of the 30 approaches address site characterization exclusively, another 15 address both site characterization and assessment, and only 2 address site assessment exclusively. This white paper defines site assessment as use of all information available before sampling, typically through file reviews, to perform a preliminary evaluation of a site. Site characterization refers to obtaining information about a site from scientific data collected in the field. The following subsections provide separate discussions of the assessment-oriented and characterization-oriented approaches that were identified in this study.

2.2.2.1 Assessment-Oriented Approaches

Assessment-driven approaches are analogous to the conventional phased PA/SI and RFA methodologies. Among them, listed with the organization that developed them, are:

- Phase I - Environmental Site Assessment (ESA), ASTM
- Considerations for Assessment of Dry Cleaning Solvent Contaminated Sites (Florida DEP)

Although they are analogous to older site assessment methods, these two approaches provide users with a more streamlined list of information sources that are needed to make decisions on how to manage sites. The ASTM approach is less detailed than the Florida DEP approach because it does not address sampling and it is aimed at a wider audience. The ASTM approach can be used to assess any site, whereas the Florida DEP approach is aimed exclusively at sites contaminated with wastes from dry cleaning operations. In addition, its outputs are specifically used by the state to prioritize these sites for further actions. Consequently, this approach can and does include specific information on target constituents, sampling equipment, analytical equipment, and a generic site assessment work plan. In addition, this approach specifies a number of the most advanced field sampling equipment, and recommends completion of site sampling in one mobilization.

2.2.2.2 Characterization-Oriented Approaches

The characterization-driven approaches have been grouped further into categories that emphasize conceptual-based approaches, those that are technology-based approaches, and those that are criteria-based approaches as discussed below.

Conceptual-Based Approaches

Common aspects of the conceptual-based approaches are the use of dynamic, or flexible, work plans; the development of site hydrogeologic models that are refined on site as real-time data become available; and reduction in the number of phases and mobilizations required, compared with conventional site investigations. Several of the approaches require that one or more senior-level scientists be present in the field at all times during the investigation. Although the need is not always specified, the conceptual-based approaches imply the use of field screening and analytical technologies. In general, these approaches are based on good scientific principles as recommended by Chamberlin, 1897 and reprinted in 1965; Platt, 1964; and Ferguson, 1993. The conceptual-based approaches to improving the methods of studying contaminated and potentially contaminated sites, listed with the organization that developed them, include:

- Accelerated Site Characterization (ASC), ASTM
- Expedited Site Characterization (ESC), ASTM
- Phase II, Environmental Site Assessment (ESA), ASTM
- Site Characterization for Environmental Purposes, ASTM
- Data Quality Objectives (DQO), EPA
- Dynamic Work Plan and Field Analytics, Draft, EPA Region 1 and Tufts University Center for Field Analytical Studies and Technologies
- Expedited Site Assessment (ESA), EPA
- Representative Soil Sampling, EPA
- Superfund Accelerated Cleanup Model (SACM), EPA
- ESC "QuickSite," DOE
- Streamlined Approach for Environmental Restoration (SAFER), DOE
- ESC Using the M^3 Approach, Bechtel Environmental, Inc.

- Environmental Site Investigation (ESI) Guidance Manual, American Society of Civil Engineers (ASCE)
- Evolving Conceptual Model, Draft, Westinghouse Savannah River Company

Technology-Based Approaches

Technology-based approaches are organized into two subgroups: 1) those approaches that include guidelines for integrating and employing the various applicable technologies to site-specific conditions, and 2) those that are resources that predominantly provide information on the various field technologies and services for locating, sampling, screening, and analyzing contaminants that are currently available. The first subgroup includes:

- ASC Methods, EPA Region 5
- Field-Based Site Characterization Workshop, EPA
- Field Assessment Screening Team (FAST) Technology, DOE
- SCAPS, DoD, U.S. Army Corps of Engineers Waterways Experiment Station
- Field Analytical Measurement Technologies, Applications, and Selections, California Military Environmental Coordination Committee (CMECC), DoD, EPA, and the California Environmental Protection Agency (Cal EPA)
- Field Screening Methods Symposium Proceedings, Air and Waste Management Association (AWMA) and EPA
- EPA Environmental Assessment Sourcebook, Boulding Soil-Water Consulting

The second subgroup, which, although dominated by technologies, also includes investigational services, such as DOE's Quicksite, is:

- Vendor FACTS, EPA
- Environmental Cleanup Privatization Products and Services Directory, DOE
- Field Sampling and Analysis Technologies Matrix - Draft, DoD

Criteria-Oriented Approaches

Criteria-based approaches may incorporate some aspects of the two approaches discussed above, but they also provide for specific criteria that allow the user to stop gathering field data or remove a site from further investigation or corrective action. These approaches include:

- Risk Based Corrective Action (RBCA), ASTM
- Soil Screening Levels (SSL), EPA
- Tiered Approach to Corrective Action Objectives, Illinois Environmental Protection Agency
- Guidance for Risk-Based Assessments at Leaking Petroleum Storage Tank (LPST) Sites in Texas, Texas Natural Resources Conservation Commission (TNRCC)

In addition to developing risk-based contaminant threshold levels, the state of Illinois's tiered approach to risk-based cleanup objectives includes specific criteria for site characterization sampling for determining compliance with remediation objectives.

3.0 ANALYSIS OF RESULTS

The purpose of this section is to present analyses focused on three objectives that will have significant effects on the content and format of the template and the technology bulletins discussed in the introduction to this paper. The objectives are:

- Identification and comparison of the major components of approaches that were identified in Table 1 that are candidates for use in the template
- Definition and documentation of how the observed wide differences in the scopes of various new approaches for studies of contaminated or potentially contaminated sites may affect the preparation of a template for such studies
- Determination of how information about studies of sites in the four target industries can be used to prepare technical bulletins

Analyses performed to meet the objectives are discussed separately below.

3.1 IDENTIFICATION AND COMPARISON OF THE MAJOR COMPONENTS

The analysis performed to meet this objective was conducted by carefully reviewing the major components identified in Table 1 and composing a list of those components that appeared to be new and innovative. The list then was used to create Table 2, which demonstrates the prevalence of various major components among the literature that was reviewed in this study. Table 2 also reveals that no single document addresses all of the new information that can be used to improve the study of contaminated or potentially contaminated sites. Therefore, the analysis used to create Table 2 should be expanded to allow the further consolidation of new approaches for use in the template for studying contaminated and potentially contaminated sites.

3.2 DEFINITION AND DOCUMENTATION OF DIFFERENCES IN SCOPE

A preliminary analysis of the literature reviews, the information in Table 1, and transcripts of discussions with points of contact has indicated that any template for conducting studies of contaminated or potentially contaminated sites would need to be defined in terms of the scope of the study a user of the template was considering. Such a user would consult a menu of items that would allow the user to chose a scope, which would lead to a number of strategies, resources, and technologies that are tailored to the study of concern. The following paragraph provides the results of this preliminary analysis.

The scopes of various site assessments can differ considerably. They are used by buyers of property to determine the existence of contamination; prospective buyers often will decline to buy property on which there is known contamination. A site assessment for this purpose does not require collection of any information about pathways or receptors, because the decision about purchase is predicated on the existence of contamination. A more sophisticated decision may be based on a site study that provides a complete model of the areal and vertical extent of contamination at a site, combined with thumbnail sketches of the pathways and receptors. If the contamination in such a case is not extensive, more buyers may be willing to purchase the site and clean it up.

EPA uses site assessments, in the form of RFAs and PA/SIs, to determine the order in which sites will be characterized and cleaned up. Those sites that have little or no contamination or few pathways and receptors are not addressed, while those that score high in the NCAPS or HRS approach to establishing cleanup priorities receive the most attention from EPA. In general, there appears to be less interest currently in site assessments with the exception of the ASTM and Florida DEP approaches which were

Table 2
Prevalence of Major Components Among Selected Approaches
(Page 1 of 3)

Major Components of Approaches	AWMA/EPA	ASCE/ESI	ASTM/ASC	ASTM/ESC	ASTM/PHASE I	ASTM/PHASE II	ASTM/RBCA	ASTM/SCEP	BECHTEL/ESC-M^3	BOULDING/EEAS	DOD/FLD. ANAL. MEASMNT.	DOD/FLD. SAMP. ANAL.	DOD/SCAPS	DOE/ENV. CLNUP. PRIV.	DOE/ESC	DOE/FAST	DOE/SAFER	EPA/ASC	EPA/DQOs	EPA/DYN. WPLANS	EPA/ESA	EPA/FBSC	EPA/REP. SOIL SAM.	EPA/SACM	EPA/SSLs	EPA/VENDOR FACTS	FLORIDA DEP	ILLINOIS EPA/TACAO	TNRCC/GRBA	WESTINGHOUSE
Thorough review of records		!	!	!	!	!		!			!				!		!	!	!	!	!			!			!	!		!
Emphasis on complete site evaluation in one mobilization			!															!			!						!			
Dynamic work plans			!	!		!		!										!			!			!			!	!	!	!
Emphasis on definition of all data quality objectives		!		!						!	!				!	!	!		!	!				!					!	!
Provides process for determining where and how many samples to collect at a given site																			!	!								!		
Use of statistical sampling design techniques				!			!	!							!		!		!					!	!			!		
Risk-based decision making that directs collection of characterization data			!	!			!								!					!	!		!		!			!	!	!
Emphasis on stopping site characterization process when objectives have been met				!	!	!	!		!										!	!					!			!		

Table 2 (continued)
Prevalence of Major Components Among Selected Approaches
(Page 2 of 3)

Major Components of Approaches	AWMA/EPA	ASCE/ESI	ASTM/ASC	ASTM/ESC	ASTM/PHASE I	ASTM/PHASE II	ASTM/RBCA	ASTM/SCEP	BECHTEL/ESC-M^3	BOULDING/EEAS	DOD/FLD. ANAL. MEASMNT.	DOD/FLD. SAMP. ANAL.	DOD/SCAPS	DOE/ENV. CLNUP. PRIV.	DOE/ESC	DOE/FAST	DOE/SAFER	EPA/ASC	EPA/DQOs	EPA/DYN. WPLANS	EPA/ESA	EPA/FBSC	EPA/REP. SOIL SAM.	EPA/SACM	EPA/SSLs	EPA/VENDOR FACTS	FLORIDA DEP	ILLINOIS EPA/TACAO	TNRCC/GRBA	WESTINGHOUSE
Use of multiple working hypotheses				!																	!									
Use of the "observational method"				!													!													
Development and refining of conceptual site geologic models			!	!				!		!					!			!		!	!		!	!					!	!
On-site decision making			!	!					!				!		!	!		!		!	!						!			!
Emphasis on presence of senior-level scientists in the field				!											!		!		!	!	!				!					
Emphasis on involvement of regulators, stakeholders, and senior project managers		!		!	!	!					!				!	!	!		!	!				!						
Preference for noninvasive sampling			!	!		!		!	!	!		!	!	!	!	!		!		!	!	!	!	!		!	!		!	!
Preference for rapid sampling tools			!	!		!			!	!	!	!	!	!	!	!		!		!	!	!	!	!		!	!		!	!
Preference for field analytical tools and methods			!	!				!	!	!	!	!		!	!	!		!		!	!	!	!			!	!		!	!

Table 2 (continued)
Prevalence of Major Components Among Selected Approaches
(Page 3 of 3)

Major Components of Approaches	AWMA/EPA	ASCE/ESI	ASTM/ASC	ASTM/ESC	ASTM/PHASE I	ASTM/PHASE II	ASTM/RBCA	ASTM/SCEP	BECHTEL/ESC-M^3	BOULDING/EEAS	DOD/FLD. ANAL. MEASMNT.	DOD/FLD. SAMP. ANAL.	DOD/SCAPS	DOE/ENV. CLNUP. PRIV.	DOE/ESC	DOE/FAST	DOE/SAFER	EPA/ASC	EPA/DQOs	EPA/DYN. WPLANS	EPA/ESA	EPA/FBSC	EPA/REP. SOIL SAM.	EPA/SACM	EPA/SSLs	EPA/VENDOR FACTS	FLORIDA DEP	ILLINOIS EPA/TACAO	TNRCC/GRBA	WESTINGHOUSE
Real-time data analysis			!	!					!	!			!		!	!		!		!	!						!			
Emphasis on on-site data management, evaluation, and interpretation			!	!									!		!	!	!			!	!		!				!		!	!
Emphasis on on-site calculation of SSLs and/or SSTLs							!												!				!		!					
Emphasis on evaluation of RBSLs							!																!					!	!	
Resource for selecting innovative field-based technologies	!									!	!	!		!								!				!				
Highlighting of numerous SCAPS applications											!		!			!										!	!			
Consideration of use of presumptive remedies																								!						

described in Section 2.2.2.1. One possible explanation for the lower attention toward assessments may be that most of such assessments are being conducted in relation to the NCAPS and HRS scoring systems, which are somewhat inflexible regarding the types of site assessment data they use as input data. However, requirements of the Government Performance and Results Act (GPRA) could spur renewed interest in the structure and content of site assessment scoring systems. The GPRA requires that government units, such as EPA, revise their methods for measuring selected aspects of their respective programs. If EPA selects the NCAPs and HRS scoring systems for revisions, the revisions would be likely to address better methods to more accurately measure risks at each site, and take advantage of the new equipment and approaches for collection of site-specific data on risks.

The recent new developments in the areas of Brownsfields and state voluntary cleanup programs also could increase interest in improving the site assessment process. States or municipalities that wish to establish their spending priorities for Brownsfields sites may find it necessary to develop specialized assessment methods that first eliminate heavily contaminated sites and then allow thorough characterizations of the remaining sites to estimate cleanup costs. The estimates would be valuable for a state or city for use in negotiations with site developers. In addition, states would need new assessment strategies for Brownsfields sites through which some sites could be declared "clean," thereby removing future liability from the developer. The ASTM Phase I and II processes provide a basic structure for that approach, but they do not provide any specific guidance for making defensible decisions at Brownsfields sites. For example, a new assessment approach for Brownsfields may incorporate practical guidelines for determining the numbers, locations, and maximum concentrations of contaminants that can form the basis for declaring certain types of sites clean. States also may need new site assessment methods tailored to their voluntary cleanup programs.

It may be necessary to rank sites that are destined for voluntary cleanup actions by priority so that state inspectors can be present when key activities (such as excavation of contaminated soil) take place at sites that pose the greatest risks to human health and the environment.

Site characterizations also vary widely in scope; however, Tetra Tech's preliminary conclusions about such variation is that much of it is caused by lack of foresight in the design of site characterization studies. Such lack of foresight involves the failure to identify all the elements that control the quality and quantity of data collected during a site characterization, including:

- Calculate present risks to human health
- Calculate present ecological risks
- Determine compliance with regulatory limits on levels of contaminants (ARARs), which are sometimes unrelated to risks
- Address site-specific community concerns
- Identify uncontaminated areas and eliminate them from further consideration
- Establish cleanup levels
- Select and design cleanup technologies.

One reason that many site characterization designs fail to consider all of the above elements may be the inability of the designer of the site characterization study to obtain complete information about how the collection of data will be affected by specific elements. For example, to make informed decisions about the number of samples needed to identify uncontaminated areas, the designer of a site characterization study must have statistically-based guidelines on the density and distribution of samples to be taken in a given media. Such guidelines, however, do not exist. Instead, decisions on the density and distribution of samples to be taken are made on an ad hoc basis, usually after considerable discussion. Such guidelines could be developed in the form of acceptable confidence limits that predict the probability that a specified volume of contaminated medium will not be found. The science for making such determinations is described in the literature encountered in this study. However, policies must allow qualified scientists to make informed value judgments at the site level.

Another example of the need for additional decision-making policies involves the identification of the highest concentrations of contaminants allowable at sites considered clean. EPA has made significant progress in this area with the development of soil screening levels; however, delays in completing site characterizations will continue to occur until there is a clearly delineated, statistically-based standard for comparing the data collected at a given site with the soil screening standards. Additional guidance for decision making also is needed for validating and verifying exposure concentrations and equations used in risk models and for selecting sample sizes for the parameters used in those models.

3.3 DETERMINATION OF HOW TO PREPARE TECHNICAL BULLETINS

Review of the information collected during this study indicates that there is little guidance on the assessment or characterization of sites in the four target industries. However, there is considerable information about the types and amounts of wastes that typically are generated by facilities in those industries. In addition, there is considerable information about typical sizes of plants and types of waste-generating operations in the industries. Therefore, it may be possible to prepare technical bulletins on these industries that can assist designers of site characterization studies in identifying appropriate sampling locations, contaminants of concern, and ARARs and selecting field analytical devices.

4.0 STRATEGY FOR PREPARATION OF THE TEMPLATE

The analyses of results obtained in this study led to the development of the following strategy for preparation of the template:

- Continue to identify major components of the approaches presented in tables 1 and 2
- Provide further analysis of the major components to determine how they could be applied to meet the various purposes and scopes of site characterization studies of sites
- Prepare an outline of the template that includes an introductory chapter in which the user is guided through a process that helps the user state clearly the scope of the study to be performed, followed by specific descriptions of strategies, equipment, and resources tied to the selected scope of the study

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