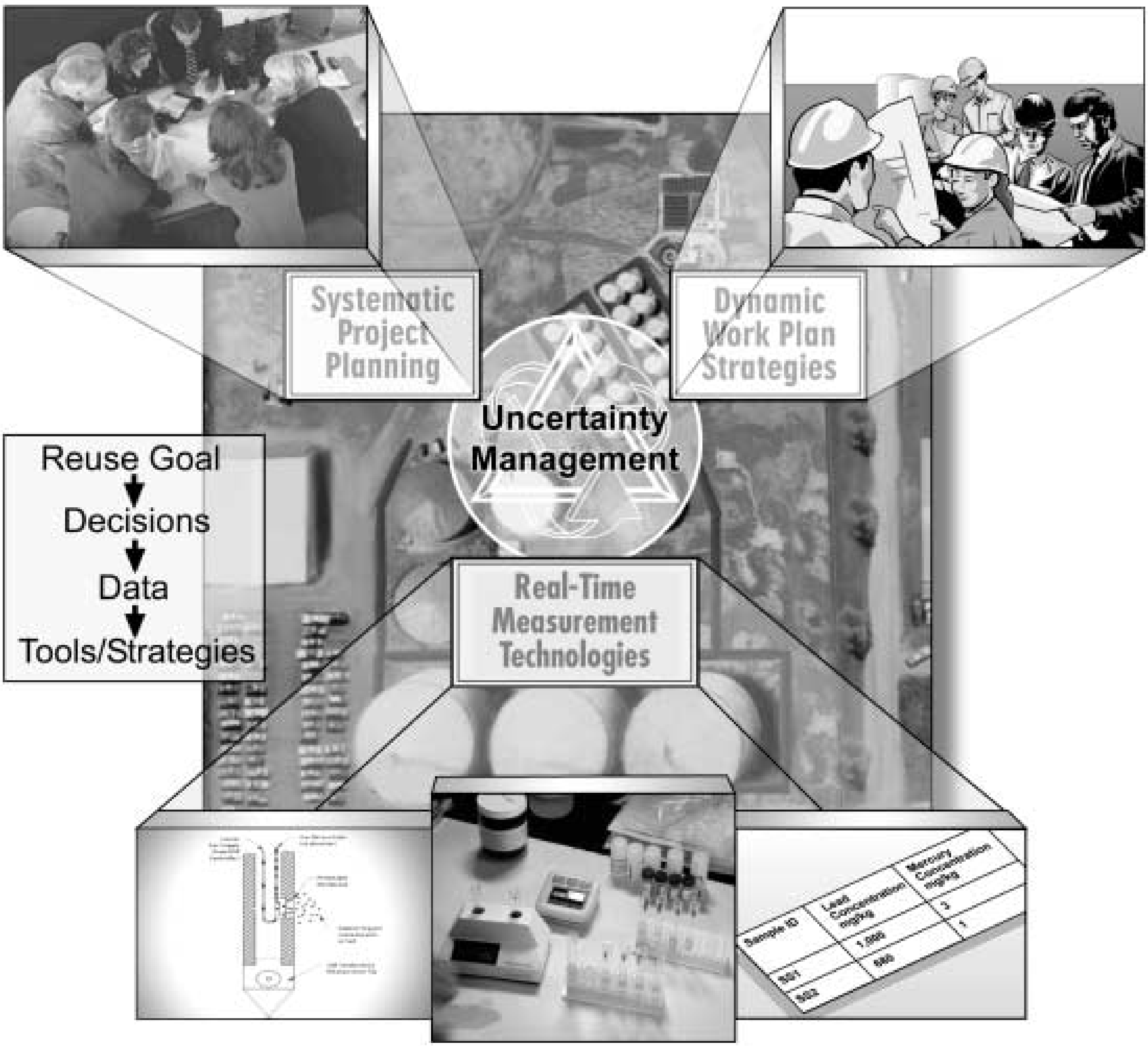
Using the Triad Approach to Streamline Brownfields Site Assessment and Cleanup



Brownfields Technology Primer Series

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Using the Triad Approach to Streamline Brownfields Site Assessment and Cleanup – Brownfields Technology Primer Series

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

NOTICE AND DISCLAIMER

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1.0 INTRODUCTION

1.1 PURPOSE

The U.S. Environmental Protection Agency (EPA) Brownfields Technology Support Center (BTSC) has prepared this document to provide an educational tool for site owners, project managers, and regulators to help streamline assessment and cleanup activities at brownfields sites. Strategies that reduce costs, decrease time frames, and positively affect regulatory and community acceptance also can improve the economics of redevelopment at brownfields sites. Increased attention to brownfields sites and the manner in which they are redeveloped places greater importance on the approach to site cleanup. This primer is one in a series that will address specific cleanup issues.

Brownfields Technology Support Center

EPA established the Brownfields Technology Support Center (BTSC) to ensure that brownfields decision-makers are aware of the full range of technologies available for conducting site assessments and cleanup, and can make informed decisions about their sites. The center can help decision makers evaluate strategies to streamline the site assessment and cleanup process, identify and review information about complex technology options, evaluate contractor capabilities and recommendations, explain complex technologies to communities, and plan technology demonstrations. The center is coordinated through EPA's Technology Innovation Office (TIO) and offers access to experts from EPA's Office of Research and Development (ORD) and other Federal agencies such as the Department of Defense (DoD) and the Department of Energy (DOE). Localities can submit requests for assistance directly through their EPA Regional Brownfields Coordinators; online at *brownfieldstsc.org*; or by calling toll free 1-877-838-7220. For more information about the program, contact Dan Powell of EPA TIO at 703-603-7196 or *powell.dan@epa.gov*. Contact information for Regional Brownfields Coordinators can be found at *www.epa.gov/brownfields/contacts.htm*.

Other publications developed through the BTSC:

- Brownfields Technology Primer: Selecting and Using Phytoremediation for Site Cleanup
- Brownfields Technology Primer: Requesting and Evaluating Proposals That Encourage Innovative Technologies for Investigation and Cleanup
- Road Map to Understanding Innovative Technology Options for Brownfields Investigation and Cleanup, Third Edition
- Assessing Contractor Capabilities for Streamlined Site Investigations
- Directory of Technology Support Services to Brownfields Localities

Primers currently under development:

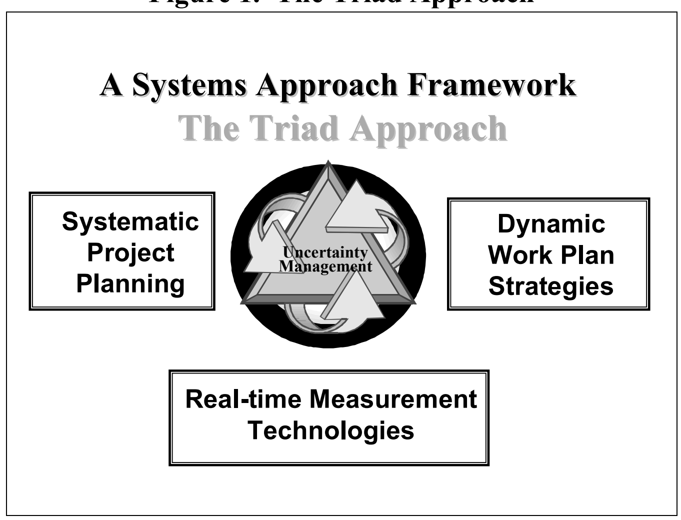
- Brownfields Technology Primer: Perspectives on Technology Selection and Use
- Directory of Technical Assistance for Land Revitalization
- Understanding Procurement for Innovative Sampling and Analytical Services for Waste Site Cleanup

1.2 BACKGROUND

> ***The Brownfields Revitalization and Environmental Restoration Act of 2001*** defines a "brownfield site" as real property, the expansion, redevelopment, or reuse of which may be complicated by the presence or potential presence of a hazardous substance, pollutant, or contaminant.

Since its inception in 1995, EPA's Brownfields Initiative has grown into a major national program that has changed the way contaminated property is perceived, addressed, and managed in the United States. In addition, over time, there has been a shift within EPA and other environmental organizations in the way that hazardous waste sites are cleaned up. Historically, sites have largely been cleaned up using a relatively standard approach to "command and control" the cleanup process . This approach was developed for dealing with the most heavily contaminated and hazardous sites and often did not (or could not due to specific long-term issues) consider the ultimate end use of a property, and could be both costly and lengthy. More recently, regulators and site managers are increasingly recognizing the value of implementing a more dynamic approach to site cleanup that is flexible and recognizes site-specific decisions and data needs and can reduce costs, improve decision certainty, and expedite site closeout. As shown in Figure 1, this new approach relies on a three-pronged or Triad approach that focuses on the management of decision uncertainty by incorporating: (1) systematic project planning, (2) dynamic work plan strategies, and (3) the use of real-time measurement technologies to accelerate and improve the cleanup process.

Figure 1. The Triad Approach



EPA has shown its support for the adoption of streamlined approaches to sampling, analysis, data reviews, and evaluations conducted during site assessment, characterization, and cleanup through a number of activities, including technical and guidance documents. As part of these activities, EPA has been coordinating with many Federal and state agencies to educate regulators, practitioners, site owners, and others involved in site cleanup decisions about the benefits of a streamlined approach.

Brownfields sites are well suited to using the Triad approach, where limited funding and intended reuse strongly influence cleanup. Inherent in the Triad approach is the need for cooperation and collaboration among the many stakeholders in the process. A goal of the Brownfields Initiative is to enable states and communities to work together to assess, safely cleanup, and sustainably reuse brownfields sites, consistent with EPA's emphasis on future use, including engineering and land use controls.

Both the Triad approach and the Brownfields Initiative mutually reinforce each other through a common sense approach where barriers are removed and dollars are leveraged to provide the most cost-effective and streamlined approach to monitoring and measurement activities. Use of real-time measurements, including real-time measurement technologies, combined with a rigorous planning process to understand and control sources of uncertainty, is inherent to the Triad approach and helps stakeholders improve the reliability of risk-related decisions.

1.3 ORGANIZATION

The primer is organized into three sections, including this introduction. Section 2 describes the three elements of the Triad approach, and provides examples of using each element. Section 3 discusses the role of the technical team in managing a project, procurement considerations when planning a project, and decision-support software and other tools that are available to help brownfields site managers.

In addition, this primer includes the following appendices:

- Appendix A – Frequently asked questions (FAQ)
- Appendix B – List of acronyms
- Appendix C – List of resources
- Appendix D – Descriptions of commonly used field-based sampling and analytical technologies

2.0 THE TRIAD APPROACH

The keystone concept of the Triad approach is the identification and management of those unknowns (i.e., uncertainties) that could cause excessive or intolerable errors in decision-making. An example of such a decision error would be to declare a site "clean" for redevelopment to proceed because contamination that would have been treated or removed prior to redevelopment was missed during sampling. The Triad minimizes the likelihood of mistakes by cost-effectively supporting the development of an accurate conceptual site model (CSM). CSMs are discussed in detail in Section 2.1. Briefly, a CSM is any graphical or written representation (or "conceptualization") of site contamination concerns: how it got there, whether or not it is migrating or degrading, how variable concentrations are across the site, what receptors might be exposed, and what risk-reduction strategies are most feasible. An accurate CSM is a primary work product of the Triad approach that is refined and matured over the course of an investigation. To develop an accurate CSM, the Triad approach incorporates the elements of systematic project planning, dynamic work plan strategies, and real-time measurement technologies into a decision support matrix designed to manage uncertainties associated with environmental restoration projects. Selected Triad resources are identified below.

Selected Triad Resources

Listed below are useful resource materials about the Triad approach. For more information on these resources and references to additional material, please see Appendix C.

Each document listed below can be found at the CLU-IN Internet Site at *http://cluin.org/triad/*:

- Innovations in Site Characterization Case Study: Site Cleanup of the Wenatchee Tree Fruit Test Pilot Site Using a Dynamic Work Plan
- Using the Triad Approach to Improve the Cost-Effectiveness of Hazardous Waste Site Cleanups
- Improving Sampling, Analysis, and Data Management for Site Investigation and Cleanup Sheet (Fact Sheet) (EPA 542-F-01-030a)
- Resources for Strategic Site Investigation and Monitoring (Fact Sheet) (EPA 542-F-01-030b)
- A Dynamic Site Investigation: Adaptive Sampling and Analysis Program for Operable Unit 1 at Hanscom Air Force Base, Bedford, Massachusetts

Related Internet sites include:

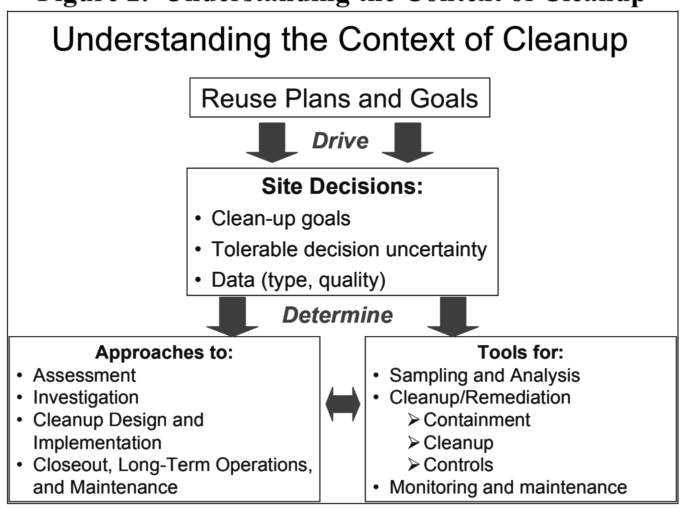
EPA's Dynamic Field Activities Internet Site: *http://www.epa.gov/superfund/programs/dfa/index.htm*
EPA's Field Analytical Technologies Encyclopedia: *http://fate.cluin.org*

Note: Web addresses are current through 6/16/03

The Triad approach is applicable to many elements of monitoring and measurement activities that occur on site - from early investigations aimed at risk estimation, through designing, implementing, and monitoring the implementation of a remedy. The key to the Triad approach and its benefits to brownfields sites is that decisions are not made in a vacuum, but with the full consideration of existing information developed during past site use and cleanup activities, and with a thorough understanding of how the site might be reused. Using this approach, activities are performed that target the principal sources of uncertainty that can affect the confidence of site decisions. Use of the Triad approach at brownfields sites allows decision-makers to economically collect the volume and quality of data necessary to reassure regulators and communities that a property is safe for reuse.

Figure 2 summarizes the interaction between reuse plans and goals, site decisions, and sampling and analysis approaches and tools. As shown, these approaches are inter-dependent. Unlike the Triad approach, a traditional one-size-fits-all approach leads to predetermined strategies and cleanup tools and does not generally consider the inter-dependence of reuse plans and goals with a cleanup approach.

Figure 2. Understanding the Context of Cleanup



The three elements of the Triad approach are discussed in more detail below.

2.1 SYSTEMATIC PROJECT PLANNING

In the context of contaminated site cleanup, systematic project planning is a transparent, deliberate, and coordinated effort to identify and manage factors and issues that contribute to decision uncertainty (those unknowns that could contribute to decision errors).

During systematic project planning, factors and variables that may impact the design and execution of project activities should be identified so that cost-effective strategies to manage those factors (or manage around them) can be developed. Drawing on previous personal experience and institutional knowledge, a project manager should try to anticipate issues that may adversely impact the project. Factors that may be important to systematic planning (depending on the particulars of the site and the project) include budget (including contracting mechanisms), schedule (time frames) and other resources (including the availability of staff and support personnel, the state of scientific and technical knowledge, and the availability of technology/equipment), as well as regulatory and programmatic requirements. For some sites, political and media interest, local community health and economic concerns, and broader health and economic considerations can have a large impact on the design and flow of site activities.

Of the three elements of the Triad approach, the systematic planning component is the most important and the most universally applicable. Regardless of the type of site and strategy chosen for data collection, decision-makers should engage in systematic planning to tie the data collection to site decisions. It is the basis for creating a defensible approach and a scientifically sound data set. A thorough and systematic planning effort will help determine if and where field technologies can be used. Systematic planning helps determine if and how a dynamic implementation approach makes sense at a site and it establishes the framework to ensure that the data collected are sufficient for site needs. The emphasis on a thorough planning process is essential to achieving the savings (time and cost) that are possible with the Triad approach and achieving the defensibility and confidence in site decisions. Some examples of the types of data gaps and the tools used to manage uncertainty in the systematic planning process are shown in Table 1.

Table 1. Data Gaps and Tools to Manage Uncertainty

Portion of the Cleanup Process	Types of Data and/or Information Gaps Typically Identified	Tools to Address Filling Data Gaps and Managing Uncertainty
Early on and throughout the project as more is learned and decisions change	• What are the potential environmental issues at the site? • What are the potentially impacted media and potential receptors? • What are the planned reuse and political status? • What is the economic viability of cleanup? • Who are the responsible party and regulating authority?	• Historical records, depositions, and visual inspections • Site location, historical photos, geological information • Public and other stakeholders • Cost benefit analyses • Record searches • Depositions • Operational history
Investigations	• What is the nature and extent of regulated chemical contaminants?	• Analytical chemistry methods • Sampling designs • Sample collection equipment • Classical statistical models to estimate contaminant concentrations • Geostatistical models to define contaminant populations • Contaminant distribution maps
	• What is the estimated fate and transport of contaminants?	Geological measurements • Hydrogeological measurements • Geophysical measurements • Modeling

Table 1. Data Gaps and Tools to Manage Uncertainty (continued)

Portion of the Cleanup Process	Types of Data and/or Information Gaps Typically Identified	Tools to Address Filling Data Gaps and Managing Uncertainty
Investigations (continued)	• Are exposure pathways complete?	• Analytical chemistry methods • Sampling designs • Geological measurements • Hydrogeological measurements • Geophysical measurements • Air release measurements • Sampling and analysis data
	• What are the appropriate cleanup levels for the site?	• Toxicological information • Existing regulations • Exposure scenarios • Future use
	• Are reporting limits above the potential action levels?	• Analytical chemistry methods • Method modifications • Risk data
Investigations and cleanup actions	• Is there sufficient data to support site closure?	• Statistical data • Modeling • Existing data
Remedy designs and cleanups	• What data are needed to support implementation of potential remedies at the site	• Information concerning available remedies • Nature and extent data • Engineering considerations • Land use controls
Remedy design	• Do viable treatment or containment technologies or other alternatives exist?	• Vendor cost and performance information • Case studies
Remedy implementation	• What is the preferred alternative? • What data are needed to evaluate remedy effectiveness, including need for source removal? • How can closure be documented?	• Pilot studies • Engineering designs • Statistical evaluations • Operational data • Confirmation sampling results • Engineering/land use controls
Operations and maintenance	• How can system performance be optimized and operating costs reduced?	• Chemical and engineering data • Cost-effectiveness evaluation

To Learn More about Systematic Project Planning

The Marino Scrap Yard site in the Borough of Rochester, Pennsylvania, is using the Triad approach for streamlining site assessment and cleanup. The city is considering reuse of this site. However, there are concerns about contamination of shallow soils with lead, mercury, and polychlorinated biphenyls (PCBs). The BTSC has provided support to the city for this site, including: (1) tools and methods used to develop a conceptual site model for contamination at the site; (2) pathway analysis and risk estimation; (3) development of a dynamic work plan strategy; (4) requirements for the use and control of field-based technologies to limit decision uncertainty; (5) procurement approaches and costing methods in support of Triad type projects; and (6) the key elements of systematic planning for reuse at the site. The conceptual site model developed by the BTSC, the dynamic work plan strategy, and statement of work can be found at *brownfieldstsc.org*.

Under the Triad approach, decision-makers may need to expend a greater amount of time and energy on up-front planning than is commonly needed under a more traditional approach, including adequate time to plan for project schedules and resources. However, this up-front planning effort will reduce the uncertainty and increase the efficiency of activities while crews are in the field. Conversely, insufficient planning often can lead to cost overruns, extended project time frames, and confusion over data. In addition, users of the Triad approach need to devote adequate time for procuring and conducting site work.

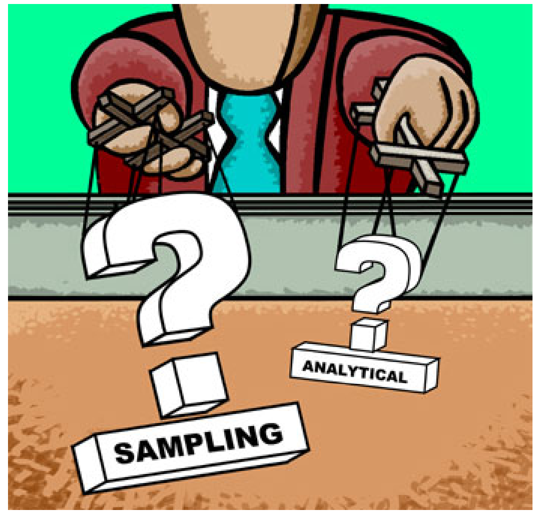
What is meant by systematic planning? Systematic planning is a common-sense approach to help ensure that the level of information gathered will facilitate the decision-making process required to reach site redevelopment objectives. An important component of systematic planning is to identify decision end-points and estimate acceptable levels of uncertainty for the decisions that need to be made at a site (see box on decision quality). The rigor of the techniques used to collect and analyze data should match the intended use. For example, data used for waste segregation prior to final characterization often can be of lesser analytical rigor. Money saved on analytical costs can be used to manage other critical aspects of data quality, such as improving sampling representativeness and the accuracy of the CSM by taking greater numbers of samples. Confirmation of the presence or absence of specific contaminants on a few samples of <u>known</u> representativeness may require highly accurate, analyte-specific analytical techniques.

Decision Quality

The term “decision quality,” in its broadest sense, implies that decisions are defensible. Ideally, decision quality would be equivalent to the correctness of a decision. However, in the environmental field, decision correctness is often unknown (and perhaps unknowable) at the time of decision-making. "Correct" decisions are those that would be made if project decision-makers possessed complete and accurate knowledge about site contamination. When knowledge is limited, decision quality hinges on whether the decision can be defended against reasonable challenge in whatever venue it is contested, be it scientific, legal, or otherwise. Scientific defensibility requires that conclusions drawn from scientific data do not extrapolate beyond the available evidence. If scientific evidence is insufficient or conflicting, decision defensibility may rest properly on other considerations. No matter what those considerations are, “defensibility” implies there is honest and open acknowledgment of the full range of uncertainties impacting the decision-making process. Systematic planning may identify a number of ways to manage decision uncertainty. For regulatory programs seeking to use sound science as the basis for defensible decision-making, then the uncertainty involved in generating and interpreting scientific data will have to be addressed and managed. The Triad approach makes it cost-effective to do so. [EPA’s Office of Solid Waste and Emergency Response (OSWER) policy states that sound science must underscore all OSWER regulatory, policy, and programmatic decisions.]

While the use of real-time measurement is a key component of maximizing information value while minimizing costs, decision-makers should ultimately focus on the <u>best</u> analytical and sampling strategy for conducting an investigation. This will often involve "mixing and matching" various sampling and analytical techniques. Detailed systematic planning encourages project managers to consider the use of field-based technologies or quick turnaround fixed laboratory analyses to support timely decision-making. Decisions made on a timely basis (daily or weekly) help ensure that project decision points are reached in as few mobilizations as possible, and that project technical staff optimize the efficiency of a sampling or cleanup design, which is one of the biggest advantages of using the Triad approach.

Managing Sources of Uncertainty...



Systematic planning is undertaken to chart a course for the project that is both cost-effective and technically sound and defensible, attaining the appropriate decision quality based on "sound science." A primary goal of the Triad approach is a CSM that can be used to support correct decisions.

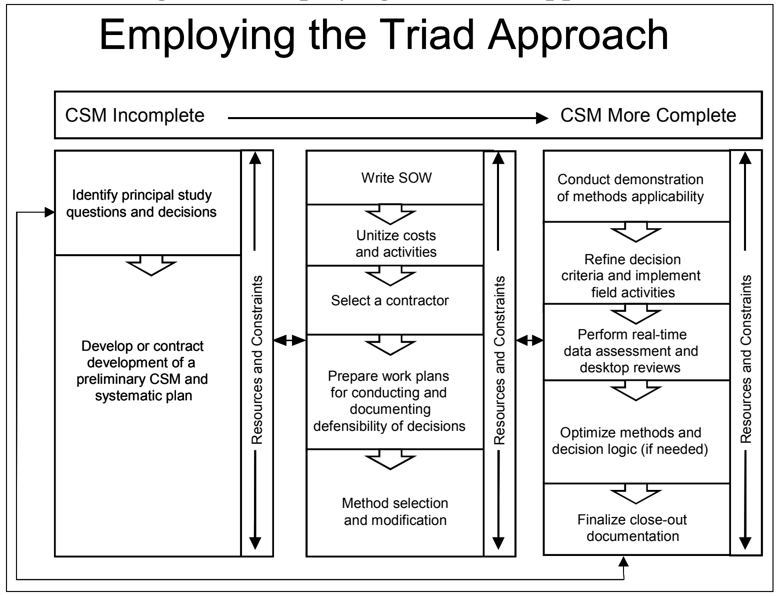
The Conceptual Site Model

The CSM is the one of the primary planning tools used in systematic project planning. The CSM organizes the information known about a site and helps the team identify additional information that needs to be obtained. The systematic planning process ties project goals to those individual activities necessary to reach these goals by identifying data gaps. The project team uses the CSM to direct the gathering of needed information; the CSM is revised and decision goals refined as more is learned about the site. As the CSM matures and as contaminant characteristics become better defined, the project team may need to revisit measurement quality objectives and decision criteria.

Figure 3 summarizes how the planning components and in-field activities typically interact in a step-wise fashion during the life cycle of a CSM under the Triad approach. Figure 4 provides a more detailed overview of the life cycle of a CSM, as a project moves through increasing levels of complexity.

In guiding the site characterization process, the CSM provides:

Figure 3. Employing the Triad Approach

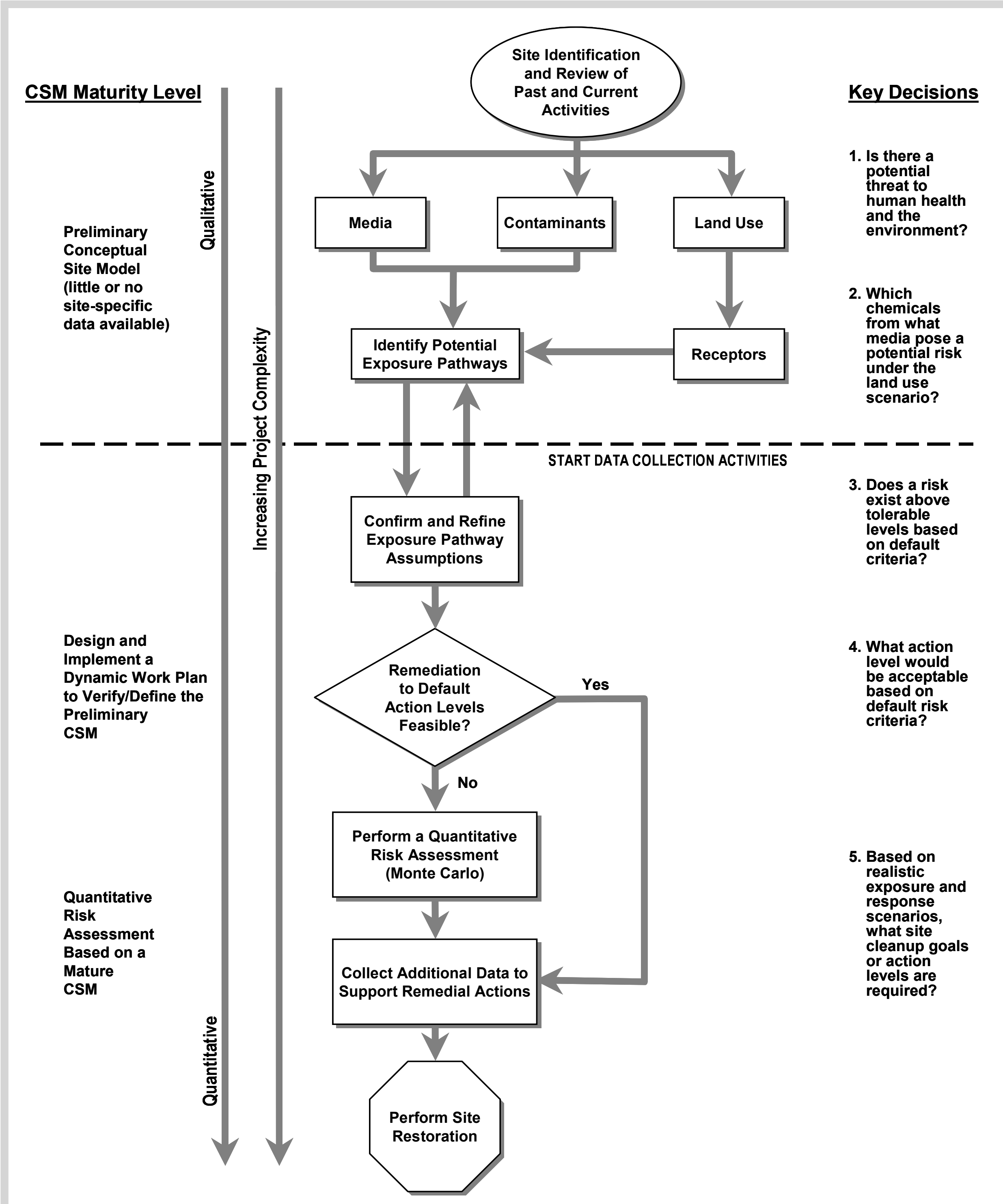


- The framework for conducting and scoping a site investigation or cleanup action that takes into account the future use of the site
- A detailed description of the site and its setting that is used to form hypotheses about the release and ultimate fate of contamination at the site
- Sources of contamination at the site, potential chemicals of concern, and the media (soil, groundwater, surface water, structures) affected
- How contaminants may be migrating from the sources, and the media and pathways through which migration and exposure of potential human or environmental receptors could occur (including possible air releases)
- An evaluation of potential or preferred cleanup options
- A basis for developing site-specific sampling designs and procedures for sample collection and analysis
- A reliable estimate of site conditions that may lead to unacceptable risks and warrant further study

As shown in Figure 3, as a CSM is made more complete, it is typical to conduct a methods applicability study. This study is performed to evaluate specific analytical methods in the context of site-specific project needs.

The initial or preliminary CSM should be refined using information collected during measurement, analysis, and integration of data activities to assist in the decision-making process. It is used as a planning tool to provide a basis for determining when data collection is sufficient to meet project needs (creating a tangible end point for sampling and analysis).

Figure 4. Life Cycle of a Conceptual Site Model



To Learn More about Demonstrations of Methods Applicability

The Town of Bluffton, South Carolina, is using the Triad approach to develop a cost-efficient strategy for assessing the extent of lead contamination in a soil berm at a shooting range (Small Arms Firing Range) used by the town police force. A first step in developing the strategy was designing a demonstration of methods applicability study, consistent with EPA SW-846 method development guidelines. The BTSC has provided the state with a white paper discussing potential options for evaluating how XRF samples should be collected, what sample preparation should be considered, and how these options can be driven by proposed reuse and remedial alternatives. Results from the BTSC effort are described in Analysis of Considerations for Developing a Methods Applicability Study at a Small Arms Firing Range in Bluffton, South Carolina. Two documents that were used as supplemental material for the applicability study that provide useful information on the remediation of small arms firing ranges are:

- Technical/Regulatory Guidelines Characteristics and Remediation of Soils at Closed Small Arms Firing Ranges; Prepared by the Interstate Technology Regulatory Council.
- Technical Protocol for Determining the Remedial Requirements for Soils at Small-Arms Firing Ranges; Prepared for Air Force Center for Environmental Excellence Technology Transfer Division, Brooks Air Force Base, Texas.

The white paper along with the supplemental materials can be found at *brownfieldstsc.org.*

Examples of the types and sources of background information that can be important when developing a preliminary CSM and refining a CSM are described below. Study areas are rarely exactly alike and the construction of a CSM for an individual site will require site-specific background information sources. Some types of background information will frequently be relevant to a CSM while others will have little or no significance to the site. It is the project planning team's job to identify and research the relevant types of background information to aid in the construction of a preliminary CSM.

Archeological/Historical Use

The archeological and historical use of a site can reveal a variety of important data for the construction of a CSM. For example, if a region had been historically used as a mining district, the impacts from the historical mining could contribute to the CSM in numerous ways. Such mining influences can significantly alter all aspects of a site's surface and groundwater geochemistry, fauna, flora, and geomorphology, and should be considered in the construction of a CSM. The impacts of future land use and other effects on archeological sensitive sites should also be considered. A starting point for gathering archeological information on a specific site can be found at the National Archeological Data Base at *http://web.cast.uark.edu/other/nps/nadb*. This site provides information on archeological activities and sites nationwide.

Physiographic

Identifying the physiographic province in which a site is located can be important to a CSM. A physiographic province is a region with similar geologic structures and climate, and whose pattern of topographic relief differs significantly from that of adjacent regions, indicating a unified geomorphic history. With the identification of the site's physiographic province, key climatic, geologic, and hydrologic components to the CSM may be identified. A good starting point for gathering general physiographic information for sites in the United States can be found at *http://www.blm.gov/wildlife/pifplans.htm*. More detailed information available in U.S. Geological Survey (USGS) topographic maps illustrating physiographic features can be found at *http://rmmcweb.cr.usgs.gov/public/outreach/featureindex.html*.

Climatic

Climatic conditions can play a major role in a CSM. Climatic conditions have significant influences on several key components of a CSM, including hydrologic budget, fauna, flora, and land use. For example, precipitation rates can impact aquifer recharge and land use. Basic climatic properties, such as air temperature, precipitation, and prevailing wind speed and direction can be important properties of a CSM. With a basic understanding of a few climatic indicators, an understanding of the climate's impact on the study area can be incorporated into a CSM. Climatic information from worldwide weather stations can be found at *http://www.worldclimate.com/worldclimate*.

Geologic

A fundamental understanding of the geology of a study area is essential in the construction of a sound CSM. Among the basic geologic components that need to be incorporated into a CSM are the types of geologic materials that make up the study area, structural geologic features, depositional environments, and geomorphology. For example, a CSM would indicate what the study area consists of, such as unconsolidated alluvial deposits underlain by bedrock. A starting point to gather geologic information is USGS geologic research activities, which are grouped by geographic locations and can be found at *http://geode.usgs.gov/*. For topographic, photoimage, geologic, and hydrologic maps, go to *http://mac.usgs.gov/mac/isb/pubs/booklets/usgsmaps/ usgsmaps.html*. Additionally, the site *http://geosurvey.state.co.us/GeoLinks.htm#state* will provide links to each state's geologic survey.

Hydrogeologic

When a CSM is constructed as a result of environmental concerns, the hydrogeologic component typically receives the most attention because of the importance placed on groundwater and surface water quantity and quality. An understanding of the site hydrogeology is required to provide an adequate representation of the hydrogeologic component of a CSM. A site's hydrogeology may be broken into three main categories: aquifer characteristics, hydrologic budget, and groundwater flow.

Examples of the types of hydrogeologic information included in a CSM are provided below.

1. Aquifer characteristics
   a. Type (Examples: unconfined, confined, or semi-confined)
   b. Characteristics (Examples: hydraulic conductivity, transmissivity, storitivity)
   c. Geology (materials and structure)

2. Hydrologic budget
   a. Recharge rates (Examples: precipitation, artificial recharge)
   b. Discharge rates (Examples: evaporation, transpiration, groundwater pumping)

3. Groundwater flow
   a. Hydraulic gradient (Examples: groundwater elevations, flow direction)
   b. Flow velocity (travel time)
   c. Boundary conditions (Examples: Dirichlet, Neumann)

To characterize a site's hydrogeology, many different sources of hydrogeologic data may be used. The availability of hydrogeology data for a particular study is simply a matter of what work has been performed—and if it is publicly available. A good source of publicly available hydrogeologic data and reports is the USGS. The USGS produces open file reports and maintains a database of hydraulic information for sites throughout the United States and its territories.

A good starting place to develop the hydrogeologic portion of a CSM is to identify the hydrologic setting of the study area from the Army Corps of Engineers Cycle II National Water-Quality Assessment (NAWQA) Study Units (*http://water.usgs.gov/nawqa/studyu.html*). Additional sources for hydrogeologic information on U.S. water resources can be found at *http://water.usgs.gov/nwis*.

In addition, the hydrogeological portion of a CSM also might address environmentally sensitive areas (e.g., wetlands, watersheds, and breeding areas). These areas should be considered within an overall CSM, including the potential impact of contamination on human or environmental endpoints.

Other Data Sources Used to Build a Preliminary CSM

Additional sources of data used to build a CSM include database reviews, usually conducted for a fee by professional data resource companies such as Environmental Data Resources *http://www.edrnet.com/* and Vista Info *http://www.vistainfo.com/*. ASTM Standard E1527 (see box below) requires a review of the physical setting of the property being investigated. A current USGS 7.5 Minute Topographic Map (or equivalent) showing the area where the property is located should be reviewed. Maps can be obtained through the USGS at *http://mapping.usgs.gov/* or through professional data resource companies such as Environmental Data Resources and Vista Info. The 7.5 Minute Topographic Maps can be used in describing the physical setting of the property and adjoining properties, determining prior land uses, and in estimating local groundwater flow direction. Groundwater flow direction is important in determining if nearby sites identified in the database searches have the potential to impact the property.

ASTM Standard E1527 - Phase 1 Site Assessments

The American Society for Testing and Materials (ASTM) (*www.astm.org*), has developed Standard E1527-00 "Standard Practice for Environmental Site Assessments: Phase 1 Environmental Site Assessment Process." This standard, along with its predecessor E1527-97, is intended to define good commercial and customary practice in the U.S. for conducting an environmental site assessment of a parcel of commercial real estate with respect to the range of contaminants within the scope of CERCLA or for petroleum products. Under 40 CFR Section 312, EPA recently finalized a rule (68 FR 24888; 5/9/03) that identifies these standards as satifying the requirements for conducting "all appropriate inquiry" under The Brownfields Revitalization and Environmental Restoration Act of 2001.

Other relevant ASTM Standards include D6235-98a Standard Practice for Expedited Site Characterization of Vadose Zone and Ground Water Contamination at Hazardous Waste Contaminated Sites and E1912-98 Standard Guide for Accelerated Site Characterization for Confirmed or Suspected Petroleum Releases.

Figure 5 is a simplified CSM that identifies examples of pathway receptor networks. Typical questions asked during the planning process and in building a CSM include:

1. What is the proposed reuse or current use of the site?
2. Is the proposed reuse of the site politically, economically, and socially viable?
3. What media are impacted and by what type of contamination?

4. Are there any potentially complete receptor pathway networks present at the site?

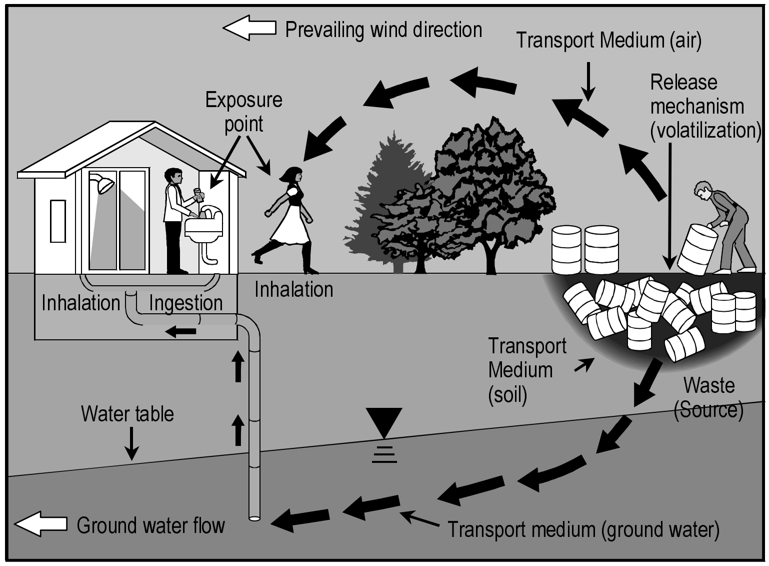
5. What exposure point concentration might represent a potential risk?

6. Do the exposure assumptions used in the risk assessment match the reuse scenario?

7. What method reporting limits are needed to assure the delineation of potential hot spots?

8. What are some of the available remedies for the site?

Figure 5. CSM of Example Pathway Receptor Networks



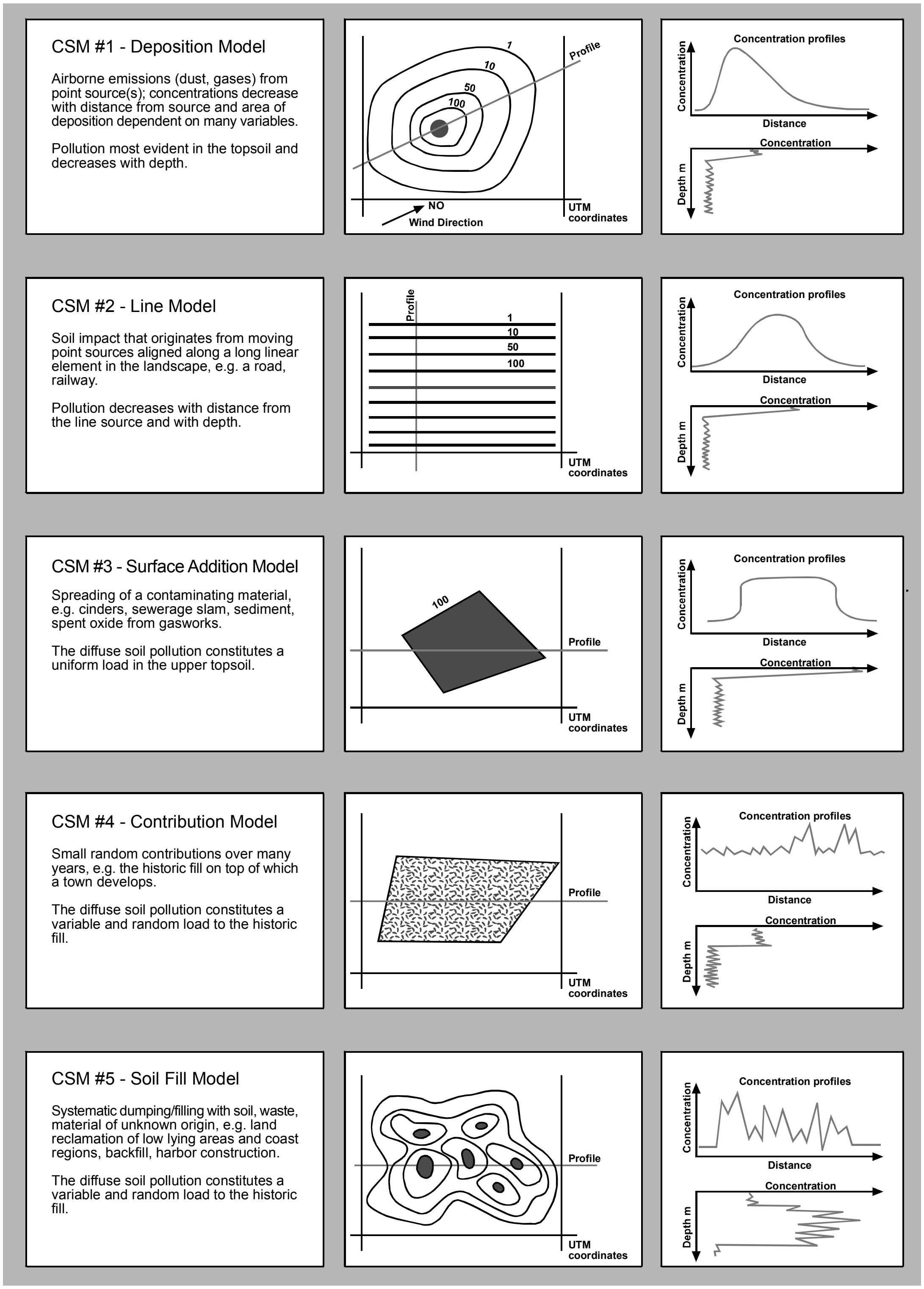
9. What are the potential human exposure pathways? (EPA's 1996 Soil Screening Guidance (SSG) provides site managers with a tiered framework for developing risk-based, site-specific soil screening levels for the protection of human health. The SSG, specifically the User's Guide and Appendix A, provides additional guidance on developing a CSM. More information on the guidance can be found at *http://www.epa.gov/superfund/resources/soil/#fact*).

A CSM should not be limited to soil and groundwater contamination; rather, it should consider all potential exposures and receptors. For example, air exposure pathways (e.g., inhalation) are particularly important to consider in those situations where contamination will be left in-place, such as when a building will be located above an area with residual waste.

Figure 6 shows additional examples of CSMs that are relevant to brownfields sampling and cleanups that represent varieties of urban soil contamination. As this figure shows, identifying the model for contaminant deposition is an important consideration in the development of a representative sampling and analysis plan for urban soil contamination.

Under dynamic work plan strategies (described in the next section), the CSM is continuously updated (usually daily or weekly) as additional information is produced from the investigation. As the knowledge about site conditions increases, there is an increase in the level of certainty about whether the objectives of the investigation can be achieved with the available resources. Decision-makers need to recognize that it is virtually impossible to achieve 100 percent certainty about site conditions – no matter how much money is spent on the investigation. In using a CSM, decision-makers identify the data quantity and quality that will maximize the weight of evidence upon which decisions will be made.

Figure 6. Example of CSMs for Urban Soil Contamination



Source: Project on diffuse soil pollution funded by the Danish EPA. Paper by Jacqueline Falkenberg, NIRAS; Ulla Højsholt, the Danish EPA; Arne Rokkjaer, Information Center of Contaminated Sites; Mariam Wahid, the Agency of Environmental Protection in Copenhagen. Consoil 2003. (Used with permission)

At brownfields sites, systematic planning and development of the CSM need to closely tie into the reuse plans for the site. A balance must be achieved between the costs required to purchase and redevelop the site and the potential benefits (revenues, resale/asset value, social/political) once the site is ready for reuse. CSMs will identify the environmental, financial, and social factors that will likely determine the potential reuse scenarios possible at a site.

2.2 DYNAMIC WORK PLAN STRATEGIES

What is a dynamic work plan strategy? Dynamic work plan strategies are the second element of the Triad approach. These types of strategies use real-time decision-making in the field to limit the number of mobilizations back to the field to fill data gaps or take remedial actions. This approach significantly reduces project costs and the schedule to reach project closeout. Use of a dynamic work plan strategy and related project management strategies can improve the economics that drive the reuse potential for brownfields properties.

A dynamic work plan strategy is one where decisions are made and the work plans guiding sampling and analysis are adjusted <u>in response to data generated while the field crew is still on site</u> (i.e., while still in the field). Proper application of a dynamic strategy allows field teams to efficiently collect the data needed for decision-making and to fill data gaps (described in the preceding section) with as few mobilizations as possible. Dynamic work planning is the element of the Triad approach that can have the greatest impact on cost and time savings.

A dynamic work plan strategy relies on real-time data to reach decision points and quickly identify the need for alternative action. Real-time data is defined in terms of the timing required to satisfy decision-making needs. Decisions are often of several different types – small scale decisions may need to be made daily, while larger scale decisions may need to be made weekly to keep the project moving. A key element is the development of decision logic to guide the teams while in the field. This logic should be reviewed and approved by the regulator and others who will use the data and determine the appropriateness and validity of specific site decisions. The logic for decision-making is identified and responsibilities, authority, and lines of communication clearly established in the plan. Implementation of all field work is driven by the critical project decisions needed to reach closure. These decision points and potential scenarios are carefully mapped during the planning process.

To Learn More about Dynamic Work Plan Strategies

The Cos Cob Power Plant site in Greenwich, Connecticut, was formerly a coal-fired power generation station. The city was examining a reuse plan for the site consisting of multiple use recreation areas, however concerns existed about PCB- and petroleum-contaminated soils at the site. Polycyclic aromatic hydrocarbons (PAHs), metals, and asbestos were suspected to be present at the site. The BTSC has provided support to the city for using the Triad approach, including participation in the development of a dynamic work plan strategy to implement a field-based measurement program. These activities have been documented in a project profile/case study available at *brownfieldstsc.org*.

The Wenatchee Tree Fruit Fruit Research and Extension Center site is an agricultural research facility located in Wenatchee, Washington. The test plot area of the site contained soils contaminated with organochlorine pesticides, organophosphorus pesticides, and other pesticides. Site investigation and cleanup was performed using the Triad approach, including use of a dynamic work plan strategy and immunoassay field test kits. In addition, a pilot test was performed that demonstrated the applicability of immunoassay test methods for pesticides such as DDT and cyclodiene and that was used to guide on-site decision-making. The U.S. Army Corps of Engineers (USACE) prepared several documents about this effort, including a Remedial Action Management Plan and a Sampling and Analysis Plan. These documents provide background on the site, as well as discuss project scope and objectives, and field activities, including soil characterization by immunoassay and traditional techniques. These documents can be found at *brownfieldstsc.org*.

Once the strategy and logic are established, an approved decision tree can then be used by the field team to guide their dynamic decision-making during field activities. The decision tree provides the basis for decisions made in the field and results in a defensible paper trail for the field work and resulting data. Deviations from the approved decision tree require thorough documentation, and may require real-time approval of regulators and stakeholders. Dynamic work plans are designed to use decision trees and real-time uncertainty management practices to reach critical decision points in as few mobilizations as possible. Sequencing of activities is used to minimize crew sizes and allow for data collection and processing time, while not slowing overall project progress. For example, members of a field crew can be split into groups to perform concurrent activities. One group can be staking locations while another is sampling and analyzing samples, and another is determining and managing excavation activities.

The likelihood of success for a dynamic approach is enhanced when experienced staff, at least initially, go to the field to review operations and trouble-shoot decision logic during project startup. Having some level of senior staff review during project startup helps to ensure that the appropriate staff are empowered to make decisions, that decision logic is sound, and that foreseeable problems are anticipated before they arise. Field staff in a dynamic field program are responsible for involving core technical team members who, in turn, usually are responsible for communicating results to regulators or others overseeing the project. After completion of a project, summary reports should clearly discuss the decisions that were made, the uncertainties that impacted project decision-making, and the strategies used to manage these uncertainties.

Recent advances in communications technologies and communications plans support modern dynamic strategies. Conference calls, mobile telephones, wireless email and Internet access, decision support software, videostreaming, and faxes are among the tools that can be applied to facilitate communication among team members. These tools can support the daily and weekly decision meetings that are needed without necessarily requiring that all the key decision-makers (for example, regulators, risk assessors, senior managers, and so forth) be physically on site during field work. It is essential, however, that the field team include a senior authority who has the confidence of the project team to effectively transmit information and to execute project decisions in the field.

2.3 REAL-TIME MEASUREMENT TECHNOLOGIES

What is real-time measurement? Real-time measurements are those that are produced within a rapid time frame so that real-time decision-making and maturation of the CSM can occur in real-time (i.e., while the team is in the field). The term "real-time measurement technologies" encompasses much more than just on-site analytical tools such as test kits and field instrumentation such as field-portable gas chromatography (GC) or x-ray fluorescence (XRF). It also includes rapid sampling platforms, *in situ* detection technologies, and the software programs used to manage, interpret, display, and map data in real-time to make dynamic work plan strategies possible. In addition, the term includes rapid turnaround of results from a fixed laboratory that may use either definitive or screening methods. Although screening methods traditionally have been associated with field use, running "field" methods in a traditional laboratory should be considered since under certain circumstances it is the most efficient option both logistically and economically.

Using field analytical tools and non-traditional analytical strategies are key to saving time and money while limiting decision uncertainty, but requires thinking "outside of the box." The tools include a broad category of analytical methods and equipment that can be applied either at the sample collection site or at a nearby laboratory capable of generating results on a quick or slightly accelerated rate. They include methods that can be used outdoors with hand-held, portable equipment, as well as more rigorous methods that require the controlled environments of a mobile (transportable) or fixed laboratory. During the planning process, the project team identifies the type, quality, and quantity of data needed to answer the questions requiring resolution to reach project closeout. Use of decision support software can also save project managers time and money and is discussed further in Section 3.3.

When using innovative field-based technologies to better characterize a site, it is often desirable to combine information collaboratively for the purpose of obtaining a clearer image of the problem present at a site. Collaborative data sets are two or more distinct data sets that are used together to manage different sources of uncertainty for a particular decision. For example, cheaper analytical methods can be used to increase sampling density (i.e., the number of samples per matrix volume, area, or decision) and to improve the accuracy of the CSM (i.e., manage sampling uncertainty). After sampling representativeness has been established, residual analytical uncertainty is then managed by carefully selecting informative samples to be sent for more rigorous analyses to provide lower detection limits, analyte-specific results as needed to meet risk assessment or regulatory requirements. The use of collaborative data sets can take several forms including the following:

1. Comparison of results from fixed lab methods to those from proposed field-based methods to evaluate anticipated performance. Depending on results, this might involve selecting alternative conservative action levels for use with field-based methods. For example, use of a field-based method with less analytical precision or accuracy might be coupled with a lower action level to provide for greater certainty in identifying contaminated soil.

2. Using data collaboratively to arrive at a particular conclusion. For example, laser induced fluorescence measurements, cone penetrometer geotechnical data, and field-based gas chromatography information to guide design of a treatment system.

3. Using field-based immunoassay results to decide when and where confirmation samples should be collected for fixed laboratory gas chromatography mass spectrometry results.

4. Upfront demonstrations of methods (sampling and analytical) applicability developed using field-based and modeling methods can be used to understand the inherent variability of contamination expected in the field prior to the commencement of site characterization activities. The EPA on-line calculators (*www.epa.gov/athens/onsite*) were developed to provide modelers and model reviewers with prepackaged tools for performing site assessment calculations (i.e., inherent variability of contamination expected in the field prior to the commencement of site characterization activities).

An example of using data collaboratively to arrive at a solution in the most expeditious and economically efficient manner is provided on the next page.

Real-time measurements can support successful redevelopment at brownfields sites by providing a clearer view of the problems and potential action alternatives. Screening analyses provide vital input to developing the CSM by estimating the variability in contaminated matrices and indicating when one of more distinct populations (such as "clean" areas vs. hotspots) are present. The role of more rigorous, traditional fixed laboratory methods is to provide analyte-specific data with low detection limits, low bias, and better precision for samples of known representativeness (i.e., the sample representativeness is already established on the basis of the maturing CSM) when higher analytical rigor is needed for risk assessment or establishing regulatory compliance. The collaborative use of screening and definitive data collection methods for monitoring and measurement is changing standard assumptions of what is possible in terms of cost, time required to reach closure, and viability of remedial alternatives. Owners can more reliably predict what it will cost to obtain a "clean" value (purchase price plus redevelopment costs). Achieving a "clean" value at a lower cost can have a significant affect on properties for redevelopment.

EXAMPLE: Use of Collaborative Data Sets

If disposal costs vary widely based on a specific land disposal restriction (LDR) at a site, it may be desirable to obtain more accurate results when concentrations are close to the LDR value. For example, when screening analysis accompanied by appropriate quality control (whether performed in a fixed or field laboratory) indicates total PCB concentrations for a given volume of waste material is either far above or far below the regulatory threshold (that can trigger costly treatment such as incineration), then there would be little doubt about whether treatment is required or not based on the screening method results. However, if the screening analysis results indicates that PCB concentrations are close to the regulatory threshold (i.e., closer than the resolution of the screening method can distinguish), then follow-on analysis using a more definitive method could be warranted. It would be important however, to first use the results of the screening method to estimate the variability within the waste volume, so that the proper strategy to collect representative samples (e.g., by compositing or calculating a statistically valid number of samples) for more expensive, definitive PCB analysis can be determined. Both sets of data are then used to justify the final decision about disposal: the much larger data set composed of screening analyses collaborates with the smaller set of definitive analyses so that definitive analysis of one or a few samples can be confidently extrapolated to represent the entire matrix volume in question. While this approach could result in an additional, upfront expense, it may result in saving more at a later date when it is time to dispose of material and to justify to stakeholders that the correct decision was made.

When matrix heterogeneity is greater than analytical variability and the cost of making a wrong decision (i.e., about disposal of potentially contaminated materials) is high, collecting more samples for less expensive (i.e., less rigorous) analytical quality is usually desirable to permit management of the data uncertainties caused by sampling variability. Dynamic work plans that provide for reactions to the observed variability in results help project teams make "on the fly" decisions to increase sampling density as appropriate to target the volume of contaminated soil that would need to be disposed.

Further information about the legal defensibility of using field methods can be found in "Using Field Methods - Experiences and Lessons: Defensibility of Field Data"; Barton P. Simmons, California Department of Toxic Substances Control; available at *www.cluin.org/char1*.

3.0 PROJECT MANAGEMENT AND PROCUREMENT CONSIDERATIONS

This section discusses project management and procurement considerations important for use at brownfields sites, including management tools that can be used to assist project managers in decision-making.

3.1 PROJECT MANAGEMENT

During the development of a systematic plan for a site, a project manager should assemble a core technical team. This project team should include multi-disciplinary members and area experts as necessary. A typical project team consists of a geologist, chemist, hydrogeologist, risk assessor, field manager, engineer, and a procurement specialist. Activities should be rolled into logically related groups and unitized rates developed when possible. Using unit rates and activities will assist project managers in scoping out and managing project growth or costs as more is learned about a site. For example, surface soil sample collection, analyses, data management, data interpretation, and communication of daily results could be rolled into a unit cost with associated sample processing minimums (for example, 30 samples per day). By using a dynamic work plan strategy approach, decisions about whether additional samples are required can be made in the field. Project managers should estimate the maximum number of samples required based on existing information but still plan for the unknown potential for project growth or shrinkage. By obtaining unit costs from service providers, project managers have the information needed to decide about the impact of authorizing additional work or reallocating project resources as necessary.

The approach used for project management will vary based on the nature and complexity of the site activities. Relatively large, complex sites or groups of sites in an area-wide approach tend to involve a more complex project management team, while relatively smaller, straightforward sites will have a less complex team. However, in all cases that use the Triad approach, the project manager can use unitized rates and draw on expertise as needed to manage the uncertainty and plan and execute a cost-effective site assessment or cleanup. Use of experienced staff can help to more quickly identify potential problems as they develop in the field and determine solutions that would more quickly get the project moving toward completion.

When applying the Triad approach, it may be beneficial to use internal or separate contractors to assist during planning, rather than those who actually implement or perform the work. This practice helps to ensure the unbiased development of a plan to limit costs during project implementation. A higher level of expertise may be required during planning. However, detailed instructions that are clear and a well defined scope can encourage less expensive, less experienced contractors to bid on more complex jobs. Once the systematic plan and statement of work are developed by the core technical team, it should be communicated to stakeholders and other project personnel and feedback solicited. Senior core technical team members, stakeholders, and project team members need to have clear lines for communication so that the approach and associated documents can be revised as more is learned about a site. Once a course of action and appropriate triggers for corrective action are identified, an organized trail of documentation, electronic and hard copy, needs to be put in place. Daily and weekly decision-making requires the use of innovative communication tools such as those discussed in Section 3.3. Having a well thought out communication strategy helps to ensure that finalizing results and obtaining a closeout letter on a site is streamlined. Cost savings realized in streamlineg the investigation, cleanup, and closeout cycle are where the true benefits of the Triad approach can be realized.

Insurance also is becoming a critical component to the success of Brownfields programs. Insurance companies are experts at identifying a monetary value for “managing uncertainty.” By using the Triad approach, the level of uncertainty at a site can be decreased and a more accurate CSM can be developed, resulting in the potential for a lower premium for an insurance policy to cover the cleanup and redevelopment of a site. If insurance is anticipated to be a component of a Brownfield redevelopment, an insurance company should be consulted during the systematic planning process to identify their information needs. Case studies on these approaches and other publications indicate that upfront management and planning costs can be higher with the use of the Triad approach than for other more traditional programs. However, use of the Triad approach can result in back-end savings for implementation and cleanup of 50 percent or more than the original estimation of project costs.

EPA’s Dynamic Field Activities guidance provides site project managers with an overview of the information needed to oversee the effective implementation of dynamic field activities, which include systematic planning, dynamic work plans, and rapid analytical results, at their sites. More information on this new guidance can be found at *www.epa.gov/superfund/programs/dfa/*.

Achieving State Regulatory Acceptance of the Triad

A major part of implementing the Triad approach is developing a framework that works within state regulations, for example addressing variations in terminology and standards. Several efforts with state regulators currently are underway to broaden the understanding of the requirements related to using the Triad approach.

Northeast Waste Management Officials' Association (NEWMOA)

NEWMOA's waste site cleanup program focuses on issues of interests to state programs that have responsibility for the investigation and remediation of contaminated sites. Currently, the waste site cleanup program is working on issues surrounding the use of innovative site characterization and remediation technologies within state programs. More information on NEWMOA's efforts can be found at *http://www.newmoa.org/Newmoa/htdocs/cleanup/*.

Interstate Technology Regulatory Council (ITRC)

ITRC is a state-led coalition working together with industry and stakeholders to achieve regulatory acceptance of environmental technologies. ITRC consists of 40 states, the District of Columbia, multiple federal partners, industry participants, and other stakeholders, cooperating to break down barriers and reduce compliance costs, making it easier to use new technologies, and helping states maximize resources. ITRC teams have developed guidance on accelerated site characterization including documents such as the ITRC/ASTM Partnership for Accelerated Site Characterization Summary Report. In addition, ITRC has formed a Sampling, Characterization, and Monitoring Team. The team is examining not only innovative sampling and monitoring technologies, but also innovative approaches like the Triad approach and helping them gain acceptance from state agencies. For more information on the ITRC, please visit *www.itrcweb.org*.

3.2 PROCUREMENT ISSUES

Procurement of innovative sampling and analytical technologies and services is an important part of planning for streamlined site investigations and use of the Triad approach. Innovative procurement strategies can help with implementing a Triad approach, including use of fixed unit costs for sampling and analytical activities. The following information is further discussed in EPA's Understanding Procurement for Innovative Sampling and Analytical Services for Waste Site Cleanup (currently in draft form) and in Assessing Contractor Capabilities for Streamlined Site Investigations (EPA 542-R-00-001, January 2000, *brownfieldstsc.org/publications_index.htm*).

Among the essential procurement issues related to use of the Triad approach are:

- The need to ensure that solicitations and requests for proposals (RFP) allow flexibility necessary to use field methods and rapid sampling and to allow for use of technologies and approaches that can support dynamic decision-making about a range of measurements during implementation of the project.
- The need to require and budget for adequate systematic planning in the RFP and the project work plan.

- The need to match the expertise of available contractors (for example, those likely to bid on the job) and their ability to employ field tools with the required level of knowledge and understanding.

- The need to seek expertise in reviewing proposals and interviewing service providers to determine if the proposed approach will yield data required for specific tasks. This consideration becomes particularly important when an RFP allows flexibility in approach, numbers of samples, analytical strategies, and so forth. Simple comparisons of costs and schedules may not be sufficient. Hiring someone to conduct the planning and to review a technical approach separately from and prior to hiring a contractor to do the field work may be a way to simplify the review process.

To Learn More about Innovative Procurement Strategies

The former Reitz #4 property in Central City, Pennsylvania was used to support coal mining operations in the surrounding area and includes a motor/car repair shop, a powerhouse, and a machine shop. Potential concerns at the site included the presence of transformers, which may contain PCBs, drums and containers of inks and thinners, and basements full of potentially-contaminated water. The BTSC helped the city with using the Triad approach through the development of a statement of work based on a dynamic work plan strategy for conducting a Phase II investigation. The city incorporated some elements of the Triad into a RFP. The RFP and proposed statement of work can be found at *brownfieldstsc.org*.

The City of Trenton, along with multiple partners including New Jersey Institute of Technology, EPA Region 2, EPA's BTSC, New Jersey DEP, and USACE, acquired services to perform a site investigation/remedial investigation at 60-acre site that formerly had been used for industrial purposes. The property consists of multiple brownfields sites contaminated with numerous substances including heavy metals, PAHs, and PCBs. The entire area will be incorporated into the planned Assunpink Creek Park and Greenway. The objective of the project was to use the concepts of the Triad approach including use of field analytical technologies to achieve the goals of the investigation and define the level of remediation necessary to implement the planned reuse. This project involved coordination between Federal and state partners regarding a variety of technology-related items including use of field analytical technologies. More information on this site, including the RFP, can be found at *brownfieldstsc.org*.

3.3 MANAGEMENT TOOLS

Use of innovative technologies and approaches can save time and money, and project managers can use decision support software packages to help implement these approaches. Many good decision-support software packages are available to support the determination of attainment, preparation of sampling plan design, and estimation and tracking of remediation costs and progress. However, it should be noted that every statistical tool is based on certain assumptions about contaminant distribution. If the assumptions of a statistical tool are violated, the statistical results may not be reliable. Users of these tools need to understand what drives the statistical models and the assumptions they rely on. As more information becomes known, the user should continually re-assess whether the assumptions of the chosen statistical model are still valid. In addition, there must be a clear understanding of what decisions are going to be made and what role statistics will play in those decisions (i.e., what data are needed to guide those decisions and what variability and distinct contaminant populations the CSM predicts). Several publicly-available EPA-sponsored software packages currently are available that can help in managing projects that use the Triad. Additional information is also provided in Appendix C. Examples of software packages include:

- **Spatial Analysis Decision Assistance (SADA)** – The University of Tennessee, Knoxville, with support from EPA and DOE, and in collaboration with Oak Ridge National Laboratory, has developed a software program that integrates visualization, geospatial analysis, statistical analysis, human health risk assessment, cost-effective analysis, sampling design, and decision analysis *(www.tiem.utk.edu/~sada/)*. SADA is free software that incorporates tools from environmental assessment fields into an effective problem solving environment. These tools include integrated modules for visualization, geospatial analysis, statistical analysis, human health risk assessment, ecological risk assessment, cost/benefit analysis, sampling design, and decision analysis. The capabilities of SADA can be used independently or collectively to address site-specific concerns when characterizing a contaminated site, assessing risk, determining the location of future samples, and when designing remedial action. For information on training sessions, email *sada@tiem.utk.dcu*. Question and user support can be obtained by sending a blank email to *sadusers-subcribe@yahoogroups.com*.

- **U.S. EPA FIeld EnvironmentaL Decision Support (FIELDS)** – EPA Region 5 developed the FIELDS system which combines geographic information systems (GIS), global positioning systems (GPS), database analysis, and imaging technologies to identify, assess, communicate, and help solve environmental problems *(www.epa.gov/region5fields/)*. The FIELDS system is a set of software modules designed to simplify sophisticated site and contamination analysis. Each module is a self-contained unit that can be applied to a variety of scenarios. When used together, either working through the FIELDS process, or being applied according to a different schedule, the modules offer unprecedented power and efficiency in the characterization, analysis, and cleanup of environmental contamination. FIELDS has been used at many brownfields sites supported by the BTSC in an effort to facilitate the planning process. Information about training sessions on FIELDS can be found at the website referenced above.

- **U.S. DOE Pacific Northwest National Laboratory Visual Sampling Plan (VSP) –** VSP provides statistical solutions to sampling design to help users decide where samples should be collected and how many are needed *(http://dqo.pnl.gov/vsp/)*. The purpose of VSP is to provide simple, defensible tools for defining an optimal, technically defensible sampling scheme for characterization. VSP is applicable for any two-dimensional sampling plan including surface soil, building surfaces, water bodies, or other similar applications. VSP development has been partially supported by the DOE's National Analytical Management Program (NAMP) and is presently a joint effort between Pacific Northwest National Laboratory (PNNL) *(www.pnl.gov)* and Advanced Infrastructure Management Technologies (AIMTech) - Grand Junction, Colorado.

- **U.S. EPA Removal Cost Management System (RCMS) 2000, Version 1.2 –** RCMS is a cost accounting and reporting system used on removal sites to track costs and usage of personnel, equipment, subcontractors, and purchases. Modules include: cost tracking, cost projection, and EPA invoicing. To order RCMS, please visit *www.ert.org*.

- **U.S. EPA Scribe (Environmental Field Data Capture), V2.2 –** A Windows software that can be used to assist in the management of environmental sampling data for soil, water, groundwater, air, and biota. Outputs include sample labels, assorted field data sheets and reports, and chain of custody generation. This software currently is being updated by EPA's Environmental Response Team (ERT). For more information, please call ERT's Software Support at (800) 999-6990.

- **Center for Subsurface Modeling Support (CSMoS) –** CSMoS provides public domain ground-water and vadose zone modeling software and services to public agencies and private companies throughout the nation. CSMoS is located in Ada, Oklahoma at the National Risk Management Research Laboratory (NRMRL), EPA's Center for Ground-Water Research. The primary aims of CSMoS are to provide direct technical support to EPA and state decision-makers in subsurface model applications and to manage and support the ground-water models and databases resulting from the research at NRMRL. For more information on CSMoS, please visit *http://www.epa.gov/ahaazvuc/csmos.html*.

- **Center for Exposure Assessment Modeling (CEAM) –** CEAM was established to meet the scientific and technical exposure assessment needs of EPA as well as state environmental and resource management agencies. CEAM provides proven predictive exposure assessment techniques for aquatic, terrestrial, and multimedia pathways for organic chemicals and metals. More information can be found at *http://www.epa.gov/ceampubl/*.

4.0 SUMMARY

The concepts of the Triad approach are not new. From the early 1980s on, DOE articulated many of the core concepts of the Triad approach as Expedited Site Characterization (ESC). In addition, DOE linked the use of a dynamic work plan strategy with systematic planning with the intent of speeding up Superfund site investigations and feasibility studies at DOE sites in an approach called SAFER (Streamlined Approach for Environmental Restoration). The USACE began institutionalizing an integrated approach to systematic planning under the name "Technical Project Planning (TPP) Process". For more information on the TPP Process, please visit http://hq.environmental.usace.army.mil/tools/tpp/brochure/pdf). Although it does not address dynamic work plan strategies and the use of real-time measurements directly, the TPP engineering manual stresses the importance of a multi-disciplinary team that performs "comprehensive and systematic planning that will accelerate progress to site closeout within all project constraints." In 1996-1997, EPA Region 1 and Tufts University coordinated with the U.S. Air Force to conduct a demonstration of a dynamic site investigation using real-time results generated by a mobile laboratory to delineate residential soil contamination at Hanscom Air Force Base (*Innovations in Site Characterization Case Study: Hanscom Air Force Base, Operable Unit 1*, September 1998, EPA 542-R-98-006, http://www.epa.gov/swertio1/download/char/hafbcs2.pdf). The project showed that innovative technologies combined with an adaptive sampling and analysis program could drastically reduce the time and cost, while increasing the confidence of site decisions. Argonne National Laboratory's Environmental Assessment Division (EAD) refers to the same basic concepts as Adaptive Sampling and Analysis Programs (ASAP) to expedite data collection in support of hazardous waste site characterization and remediation. ASAPs emphasize "real-time" data collection and field-based decision-making, using dynamic work plan strategies. The Triad approach takes these same concepts further by explicitly making the management of decision uncertainty the linchpin for systematic planning, while relying on innovative technologies and dynamic/adaptive work planning as the only mechanisms to cost-effectively manage data uncertainty and build accurate CSMs.

The Triad approach is a common sense approach that has been successfully applied by other Federal, state, local, and private organizations. Similarly, the dynamic nature of the Triad approach allows decision-makers to focus on the best strategy for conducting environmental measurements that is flexible and meets site needs. Use of systematic planning has continually resulted in lower overall project costs. Use of dynamic work plan strategies can reduce or eliminate the need for multiple mobilizations on a site to reach closeout. For brownfields sites, where decision-making is so closely tied to economic constraints and public acceptance, increased information value obtained using real-time measurement technologies collaboratively with definitive fixed laboratory methods for data collection will provide stakeholders with the confidence they need at a reduced cost. Reducing project costs and schedules to obtain closure means that more dormant or abandoned sites may become economically viable for redevelopment.

The Triad approach can be implemented at sites by taking advantage of the key elements and steps outlined in this primer. In addition, the documents referenced throughout this primer and the resources identified in Appendix C provide valuable information on the application of the Triad approach at various sites and describe various technologies that can be used to characterize or remediate a site. By using these approaches and technologies at brownfields and other redevelopment sites, site owners and environmental professionals can streamline the effort involved with bringing a contaminated site back into productive use.

APPENDIX A
FREQUENTLY ASKED QUESTIONS (FAQ) WHEN DESIGNING A PROGRAM USING THE TRIAD APPROACH

Question 1: ***What is the Triad approach?***

Answer 1: The Triad approach consists of using systematic project planning, dynamic work plan strategies, and real-time measurement technologies, and is applicable to contaminated site investigations and cleanup. It is a work strategy framework for economically managing project decision uncertainties by drawing on the technical knowledge and experience gained over the past 20 to 30 years of hazardous site cleanup. The Triad approach proactively exploits new characterization and treatment tools, using work strategies developed by innovative and successful site professionals. An important product of the Triad approach is a conceptual site model (CSM) accurate enough to support correct project decisions.

Question 2: ***Who should use the Triad approach?***

Answer 2: Project managers and their technical staff responsible for cleanups at hazardous waste sites should consider using the Triad approach.

Question 3: ***What is systematic project planning?***

Answer 3: Systematic project planning is the most important and often used element of the Triad approach. Systematic planning is a common sense approach to identifying the decisions that need to be made to reach project goals. Once it is clear what decisions are driving the project, systematic planning identifies the inputs needed to feed those decisions and project constraints (budgetary, regulatory, legal, scientific, etc.). Inputs to decisions about contaminated sites usually involve some kind of environmental data, so systematic planning also involves developing the technical strategies used to generate and interpret the data feeding the decision-making process. Up-front systematic planning should involve all parties, including stakeholders, and a multi-disciplinary technical team.

Question 4: ***What is a dynamic work plan?***

Answer 4: A dynamic work plan is a work plan that is written to be flexible so that the course of site work can adapt to new information as it is being acquired in real-time. Dynamic work plan strategies are the second element of the Triad approach. These types of strategies use real-time decision-making in the field to limit the number of mobilizations back to the field to fill data gaps or take remedial actions. This approach can reduce project costs and the time needed to reach project closeout. Use of a dynamic work plan strategy and related management strategies can drastically improve the economics that drive the reuse potential for brownfields properties.

Question 5: ***What are field-based measurement technologies?***

Answer 5: Field-based measurement technologies provide analytical results on site, and they are a primary means of providing measurements in real-time, although by no means are they the only way. Note that "real-time measurement technologies" (NOT "field-based measurements") constitutes the third leg of the Triad. Field-based technologies are but one option to provide real-time turnaround of results. Field-based measurement technologies include mobile laboratories equipped with instrumentation ranging from state-of-the-art sophisticated instrumentation to "simple" test kits. Field-based measurement technologies also include using a test kit under a tent, taking XRF measurements on the ground or through a plastic bag, performing fence-line monitoring with "high tech" ultraviolet (UV) or infrared (IR) spectroscopy instrumentation, and taking a pH or turbidity measurement in a well. Modern field-based measurement technologies now run the gamut from highly accurate analytical instrumentation to "low-tech" screening analyses. The quality of data generated in the field cannot be judged based on the location where the results were generated, but according to the data's ability to support the intended decisions, which includes sufficient quality control documentation to ensure that data are of known quality.

Questions 6: ***What are real-time measurement technologies?***

Answer 6: "Real-time measurement technologies" compose the third leg of the Triad approach. The term includes any mechanism that supports turning around data results within the time frame needed to support real-time decision-making. ("Real-time decision-making" refers to updating the CSM with new information and adapting subsequent site work to that updated knowledge while the field crew remains in the field.) The mechanisms used to provide real-time measurements include rapid turnaround from a fixed laboratory; on-site measurement in a mobile lab, or in the back of a truck, or *in situ*; and the hardware and software used to rapidly process instrument signals, store and retrieve analytical results, evaluate quality control, perform statistical analysis, display or map data, and share data with colleagues, regulators, and stakeholders back in the office or across the country.

Question 7: ***What are the benefits of using non-traditional measurement technologies?***

Answer 7: Frequently, the most cost-effective option for generating real-time data is to use field-based measurement technologies. Another advantage of using screening methods in fixed laboratories and field analytical methods is that they can provide the higher numbers of samples needed to manage the uncertainties associated with sample representativeness. Whatever measurement techniques are used, data of known quality must be produced using a technically sound quality control program. "Mixing-and-matching" several analytical methods (i.e., fixed and field methods) according to their various strengths is usually the most economical way to generate data sets that are effective for making project decisions because sampling and analytical uncertainties have been managed commensurate with the desired or negotiated project outcome. For brownfields sites, increased information content to support decision-making is essential. Making sound decisions will ensure long-term liability is reduced within the context of the reuse scenario, including residential, industrial, or recreational scenarios.

Question 8: ***When should the Triad be applied?***

Answer 8: Systematic project planning should always be applied when tackling problems at hazardous waste sites. Developing a CSM accurate enough to support correct decisions should be a goal for every project. Dynamic work plan strategies are best used early and throughout the investigative portions of a project when physical and chemical conditions at a site are being defined. They are particularly useful during cleanup actions when the scale of decision-making is being redefined and economic constraints are of paramount concern. Real-time measurements can reap benefits throughout all portions of the cleanup process from investigation through long-term monitoring and verification of the effectiveness of risk management cleanup strategies.

Question 9: ***How do I identify contractors or forms of support to assist in implementing the Triad?***

Answer 9: EPA's Technology Innovation Office (TIO), Superfund, and many other organizations are partnering to promote the use of the Triad approach. Planning, technological, and vendor resources can be identified through the TIO web site at *http://cluin.org*. The BTSC also provides related information at *brownfieldstsc.org*.

Question 10: ***Can the Triad approach assist in improving lender confidence or reducing the cost of environmental insurance?***

Answer 10: The Triad approach can be used to alleviate the need for deed restrictions or conditions-on-closure letters in some cases. Lending and insurance requirements are generally driven by policy. The Triad approach can be used to reduce the perception of risk because more direct, objective evidence and hard data can be developed during early site evaluations. The Triad approach can improve the confidence with which environmental decisions are made by targeting the primary sources of uncertainty that increase the perception of risk.

Question 11: ***What is a dynamic work plan strategy and what planning documents describe the approach to be used?***

Answer 11: A dynamic work plan strategy is a flexible, adaptive work strategy that rapidly reaches project objectives by allowing real-time feedback (i.e., data) to guide selection of the alternative options of a pre-approved decision tree. A common theme is that the number and placement of samples is not fixed before field work begins, but is decided in the field (according to pre-established decision logic) based on site conditions. During systematic planning, the core technical team works with stakeholders to agree upon a plan of action. The flow of activities is designed to work through as many branch points of the decision tree as possible during a single field mobilization. The necessary details for implementation are then translated into concisely worded, streamlined planning documents such as a work plan, field sampling and analysis plan, or quality assurance project plan.

Question 12: ***Is a dynamic work plan strategy appropriate for every site?***

Answer 12: Dynamic work plan strategies are not always appropriate. They involve development of decision logic about appropriatenss and validity of site-specific decisions. Programs that do not provide clearly-identified responsibilities or authority to implement decision logic may lead to relatively slower progress on implementing a dynamic work plan. In addition, site conditions or level of maturity (i.e., long-term monitoring or background type of evaluations) may not warrant the need for a dynamic approach. However, many projects from the initial investigation through cleanup can benefit from the use of a dynamic work plan strategy for some or all of the site activities.

Question 13: ***What contingencies are necessary to assure that project progress is not hampered?***

Answer 13: Practical and analytical contingencies should be anticipated and addressed during project planning. For example, if direct-push rig refusal is expected at a specific depth, then a rig with an auger attachment might be considered. If analytical results for a particular soil management area are unclear, then perhaps more samples should be budgeted for in case they are required to verify if the area should be considered clean. A practical approach using the expertise from the project team and pool of stakeholders should be used to identify potential contingencies.

Question 14: ***At what frequency should senior staff review field and laboratory activities?***

Answer 14: Early in an investigation, senior staff should go to the field to trouble-shoot problems encountered and assure that documentation is being adequately prepared. Similarly, senior staff should also visit the fixed laboratory (if one is being used) before samples are sent. Closeout audits by senior staff also are recommended; adequately prepared electronic and hardcopy records will allow a project to seamlessly reach closeout.

Question 15: ***How can primary decision-makers assure the quality of decisions made in the field and justify changes made in initial sampling plans?***

Answer 15: Through the development of well designed decision trees and standard operating procedures for identifying the need for changes in decision logic, a project manager and technical lead can identify and incorporate changes easily. Addendum development protocols and triggers designed into QA review procedures help ensure that decisions are based on sound science and that problems are identified and addressed early in the process. Decision trees should be communicated along with the proposed approach to stakeholders before a project is implemented. Options should be identified and public comment addressed as appropriate before project startup. Periodic review of field activities before and during implementation should be conducted as another type of safety check.

Question 16: ***Should field-based or fixed laboratory analysis be used?***

Answer 16: The answer to this question should not be seen as “either-or." It will depend heavily on the nature of the contaminants of concern (COC), the type of decision(s) being made, and the sampling and analytical uncertainties that need to be managed in order to make the decision(s). For example, some XRF units are capable of analyzing for the presence of a wide variety of metals in the field. However, XRF reporting limits are typically in the parts per million (ppm) range. Therefore, if decisions will be based on metals concentrations in the parts per billion (ppb) range, fixed-laboratory analysis using inductively coupled plasma spectrometry (ICP-OES) may be the preferred option to produce ppb concentration data and manage analytical uncertainty. However, the cheaper, faster XRF technique may be useful to characterize the variability of contaminant concentrations, and detect “hotspots” or other spatial patterns of distinct populations that could compromise the representativeness of the data set. The XRF can be used to manage sampling uncertainty, while samples established to be representative of the decision are sent for ICP analysis. The selectivity required to meet project needs also drives instrument selection. For example, if a decision can be based on total polychlorinated biphenyls (PCB) concentrations, immunoassay results may be sufficient. Decisions requiring homolog or congener-specific PCB analyses will require much more rigorous methods than field kits can provide. However, as with the XRF example, the high sampling density provided by the immunoassay method may be critical to establishing the representativeness of data provided by expensive fixed laboratory methods.

It is prudent to perform a cost-benefit analysis prior to deciding what mix of field- and/or fixed-laboratory analyses should be used. While instrument rental costs can be low relative to fixed-laboratory unit costs, additional personnel are also required in the field to conduct the analyses. In general, as the number of analyses required to support a dynamic work plan and manage sampling uncertainty increases, field-based analysis becomes generally more appealing. As mentioned previously, development of collaborative data sets to optimize a sampling and analytical strategy will improve the efficiency of the characterization approach.

The project may also consider running a non-standard method in a fixed laboratory setting as opposed to running the method in the field. Sometimes logistically and financially this approach makes more sense and still provides the project team with timely data at a lower cost.

Question 17: ***How can analytical costs be managed when using field-based technologies?***

Answer 17: When using field-based or real-time measurement strategies, project technical leads should combine data collection, analysis, review and reporting into unit costs that can be managed on a daily basis. In this way, as a project grows or shrinks costs can be managed. Identifying and funding contingencies early in a project can help project managers avoid unnecessary delays.

Question 18: ***How can available technologies be identified for use?***

Answer 18: EPA identifies several site characterization and monitoring technologies through web sites for Field-based Analytical Technology Encyclopedia (FATE) (*http://fate.cluin.org/*), EPA Environmental Technology Verification (ETV) (*http://www.epa.gov/etv/*), EPA Superfund Innovative Technology Evaluation (SITE) Program (*http://www.epa.gov/ORD/SITE*), and the Interstate Technology Regulatory Council (*http://www.itrcweb.org*). It is also important for the project team to seek out vendor assistance, but only with the assistance of the team's own technical experts. Hazardous Substances Technical Liaisons (*http://www.epa.gov/osp/features/factsheets.htm*) also are available for technical support.

Question 19: ***What documentation will assure that the results obtained are legally and technically defensible?***

Answer 19: Documentation must be sufficient to reproduce a result and to assure stakeholders that "good scientific practices" were adhered to during the project. The method used should have been peer reviewed or be sufficiently convincing that the results can stand on their own merit. There must be evidence that the samples were representative of the matrix population for the decision being defended. For environmental matrices which tend to be highly heterogeneous with great variability in contaminant concentration from place to place, demonstrating data representativeness has been difficult because of the relatively higher cost for analysis of a larger number of samples. With the wider availability of field analytical methods and screening methods for use in fixed-based laboratories (such as dioxin screening methods), it is now possible to analyze enough samples to ensure data representativeness. (Also refer to paper by Barton Simmons "Using Field Methods - Defensibility of Field Data" available at *www.cluin.org/*.

APPENDIX B
LIST OF ACRONYMS

AIMTech	Advanced Infrastructure Management Technologies
ASAP	Adaptive Sampling and Analysis Program
BTSC	Brownfields Technology Support Center
COC	Contaminants of concern
CSM	Conceptual site model
DOE	U.S. Department of Energy
EAD	Argonne National Laboratory Environmental Assessment Division
EPA	U.S. Environmental Protection Agency
ESC	Expedited site characterization
FAQ	Frequently asked questions
FIELDS	FIeld EnvironmentaL Decision Support
GC	Gas chromatography
GIS	Geographic information systems
GPS	Global positioning systems
ICP	Inductively coupled plasma
IR	Infrared
LDR	Land disposal restriction
NAMP	National Analytical Management Program
NAWQA	National Water-Quality Assessment
ORD	EPA Office of Research and Development
OSWER	EPA Office of Solid Waste and Emergency Response
PAH	Polycyclic aromatic hydrocarbon
PCB	Polychlorinated biphenyls

PNNL	Pacific Northwest National Laboratory
RCMS	Removal Cost Management System
RFP	Request for proposal
RI	Remedial investigation
SADA	Spatial Analysis Decision Assistance
SAFER	Streamlined Approach for Environmental Restoration
SITE	Superfund Innovative Technology Evaluation
SOW	Statement of work
TCLP	Toxicity Characteristic Leaching Procedures
TIO	EPA Technology Innovation Office
TPH	Total petroleum hydrocarbons
TPP	Technical project planning
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey
UV	Ultraviolet
VOC	Volatile organic compound
VSP	Visual Sampling Plan
XRF	X-ray fluorescence

APPENDIX C
LIST OF RESOURCES

Brownfields Technology Support Center *(http://brownfieldstsc.org)* – EPA established the Brownfields Technology Support Center (BTSC) to ensure that brownfields decision-makers are aware of the full range of technologies available for conducting site assessments and cleanup, and can make informed decisions about their sites. The center can help decision-makers evaluate strategies to streamline the site assessment and cleanup process, identify and review information about complex technology options, evaluate contractor capabilities and recommendations, explain complex technologies to communities, and plan technology demonstrations. The center is coordinated through EPA's Technology Innovation Office (TIO) and EPA's Office of Research and Development. Localities can submit requests for assistance directly through their EPA Regional Brownfields Coordinators; online at *brownfieldstsc.org*; or by calling toll free 1-877-838-7220. For more information about the program, contact Dan Powell of EPA TIO at 703-603-7196 or *powell.dan@epa.gov*.

Hazardous Waste Cleanup Information (CLU-IN) Internet site *(http://cluin.org)* – The CLU-IN site provides information about innovative treatment technologies and site characterization technologies to the hazardous waste remediation community. It describes programs, organizations, publications, and other tools for Federal and state personnel, consulting engineers, technology developers and vendors, remediation contractors, researchers, community groups, and individual citizens.

CLU-IN Case Studies *(http://cluin.org/char1.cfm)* – As part of a section on Site Characterization, the CLU-IN web site provides selected case studies which involved use of field analytical technologies. These include projects at the Wenatchee Tree Fruit, Oak Ridge Drum Disposal, and Hanscom Air Force Base sites.

Specific resources available through CLU-IN that provide useful information about the Triad approach include:

> **Innovations in Site Characterization Case Study: Site Cleanup of the Wenatchee Tree Fruit Test Pilot Site Using a Dynamic Work Plan –** This case study is designed to provide cost and performance information for innovative tools that support less costly and more representative site characterization.
>
> **Using the Triad Approach to Improve the Cost-Effectiveness of Hazardous Waste Site Cleanups –** This paper describes the overall strategy of using systematic project planning, dynamic work plans and real-time measurement technologies to speed cost-effective investigations and cleanups, while maintaining or improving the defensibility of site decision-making.
>
> **Improving Sampling, Analysis, and Data Management for Site Investigation and Cleanup Fact Sheet (EPA 542-F-01-030a) –** This fact sheet discusses the streamlined approaches to sampling, analysis, and data management activities conducted during site assessment, characterization, and cleanup. This position reflects the growing trend towards using smarter, faster, and better technologies and work strategies.
>
> **Resources for Strategic Site Investigation and Monitoring (EPA 542-F-01-030b) –** This document discusses EPA efforts, in concert with other federal agencies and state organizations, in accelerating the development of policies and information to support Strategic Investigation and Monitoring activities at hazardous waste sites. The educational, training, and guidance resources described in this fact sheet either already exist or are under development to support project managers seeking to apply these approaches.

EPA Field Analytical Technologies Encyclopedia ***(http://fate.cluin.org)*** – FATE is an online encyclopedia of information about technologies that can be used in the field to characterize contaminated soil and groundwater, monitor the progress of remedial efforts, and in some cases, for confirmation sampling and analysis for site closeout.

EPA Remediation And Characterization Innovative Technologies (REACHIT) ***(http://www.epareachit.org/)*** – EPA REACHIT is a system that lets environmental professionals search, view, download, and print information about innovative remediation and characterization technologies. The site uses information submitted by technology service providers about remediation and characterization technologies and information from EPA, Department of Defense (DoD), Department of Energy (DOE), and state project managers about sites at which innovative technologies are being deployed. These sources together provide up-to-date information about technologies that can be used to characterize or remediate a site, sites at which those technologies are being used, and the service providers that offer them.

EPA Dynamic Field Activities Internet Site ***(http://www.epa.gov/superfund/programs/dfa/index.htm)*** – This internet site provides information on the draft guidance for dynamic field activities and DFA case studies. For example, one case study provides cost and performance information for a soil and groundwater characterization at Hanscom Air Force Base. The site also provides additional information on systematic planning and dynamic work plans.

EPA ORD's Office of Science Policy Hazardous Substances Technical Liaison Program ***(http://www.epa.gov/osp/features/factsheets.htm)*** – The program was created jointly by EPA ORD, EPA OSWER, and the regional offices to expand the technical support available to regional staff.

Road Map to Understanding Innovative Technology Options for Brownfields Investigation and Cleanup, Third Edition ***(http://brownfieldstsc.org/publications_index.htm)*** – The Road Map identifies potential technology options available at each of the basic phases involved in the characterization and cleanup of brownfields sites and connects those steps with available resources. The third edition of the Road Map has been expanded significantly to include new and updated resources, one-page "spotlights," and an index of more than 150 resources. Appendices in the Road Map include a list of common contaminants found at typical brownfields sites, a detailed guide to common environmental terms and acronyms, and a list of state and EPA points of contact.

EPA's Environmental Technology Verification Program ***(www.epa.gov/etv/)*** – EPA's ETV Program develops testing protocols and verifies the performance of innovative technologies that have the potential to improve protection of human health and the environment. ETV was created to accelerate the entrance of new technologies into the domestic and international marketplace.

Case Studies

Case studies are provided in several of the resources described above, as well as on related web sites such as FRTR, SCRD, ITRC, and RTDF.

Federal Remediation Technologies Roundtable ***(http://www.frtr.gov)*** – The Federal Remediation Technologies Roundtable (FRTR) provides more than 300 case studies concerning use of remedial technologies in site cleanup, as well as more than 100 case studies about site characterization and monitoring technologies, and 7 reports about optimization of long-term monitoring. The FRTR reports focus on the cost and performance for use of these technologies, and cover a wide range of technology types and contaminants. Recent additions to the FRTR collection include reports addressing cleanup of groundwater using in situ technologies such as bioremediation, surfactant flushing, chemical oxidation, thermal treatment, permeable reactive barriers, phytoremediation, air sparging, and in-well air stripping.

State Coalition for Remediation of Dry Cleaners ***(http://www.drycleancoalition.org)*** – The State Coalition for Remediation of Drycleaners (SCRD) consists of representatives of states with established drycleaner remediation programs, including Alabama, Florida, Illinois, Kansas, Minnesota, Missouri, North Carolina, Oregon, South Carolina, Tennessee, and Wisconsin. The SCRD provides more than 60 case studies covering a diverse set of innovative treatment technologies used at dry cleaner sites.

Interstate Technology Regulatory Council ***(http://www.itrcweb.org)*** – The Interstate Technology Regulatory Council (ITRC) is a state-led coalition working together with industry and stakeholders to achieve regulatory acceptance of environmental technologies, and consists of more than 35 states, the District of Columbia, multiple federal partners, industry participants, and other stakeholders. The ITRC has prepared more than 15 guidance documents on technical topics, many of which include selected case studies.

Remediation Technology Development Forum ***(http://www.rtdf.org)*** – The Remediation Technology Development Forum (RTDF) is a public-private partnership to undertake research, development, demonstration, and evaluation efforts focused on finding innovative solutions to high priority problems. It consists of six action teams, covering subjects such as bioremediation, NAPLs, permeable reactive barriers, phytoremediation, and sediments. These action teams publish materials including information about specific sites where technologies have been applied.

EPA Superfund Innovative Technology Evaluation (SITE) Program ***(http://www.epa.gov/ORD/SITE)*** – The SITE Program was established by EPA's OSWER and the ORD in response to the 1986 Superfund Amendments and Reauthorization Act, which recognized a need for an "Alternative or Innovative Treatment Technology Research and Demonstration Program." The SITE Demonstration Program encourages the development and implementation of innovative treatment technologies for hazardous waste site remediation, monitoring, and measurement. In the SITE Demonstration Program, technologies are field-tested on hazardous waste materials. Engineering and cost data are gathered on the innovative technology so that potential users can assess the technology's applicability to a particular site.

U.S. EPA Hazardous Substance Research Centers ***(www.jhu.edu/hsrc, www.mhsrc.org, http://www.toscprogram.org/, www.toscprogram.org, http://wrhsrc.orst.edu/)*** – In 2001, EPA established five new university-based HSRCs affiliated with 22 universities. The Centers address concerns about hazardous substances in the environment by conducting basic and applied research, and providing technology transfer and community outreach. The Centers work on the remediation and redevelopment of brownfields and Superfund sites.

Training

Classroom ***(http://trainex.org)*** – In partnership with the ITRC, TIO provides a range of training information to EPA, other federal agency, state, tribal, and local staff involved in hazardous waste management and remediation. ***Trainex.org*** includes training schedules for deliveries of many courses, both classroom and Internet-based. Training Coordinators, On-Scene Coordinators (OSC), Remedial Project Managers (RPM), Permit Writers, Corrective Action Managers, Site Assessment Managers (SAM), enforcement staff, Community Involvement Coordinators (CIC), state program managers, and others will find training courses and information directly targeted to their needs.

Internet seminars ***(http://cluin.org/studio)*** – CLU-IN's ongoing series of Internet Seminars are web-based slide presentations with a companion audio portion. TIO provides two options for accessing the audio portion of the seminar, by phone line or streaming audio simulcast. More information and registration for all Internet Seminars is available by selecting the individual seminar listed on the site.

APPENDIX D
DESCRIPTIONS OF COMMONLY USED FIELD-BASED SAMPLING AND ANALYTICAL TECHNOLOGIES

Direct-Push Sampling – Direct-push sampling platforms have gained widespread acceptance in the environmental industry over the past decade because of their versatility, relatively low cost, and mobility. As opposed to drilling techniques in which soil is removed and a borehole is produced, direct-push units use hydraulic pressure to advance sampling devices and geotechnical and analytical sensors into the subsurface. The weight of the truck in combination with a hydraulic ram or hammer is used to "push" the tool string into the ground. With this, no soil is removed, and only a very small borehole is created. The two major classes of direct-push platforms are cone penetrometer (CPT) and rotary hammer systems. While "CPT" technically refers only to the geotechnical cone penetrometer instruments advanced by these large vehicles, the vehicles themselves have come to be known by this designation. The distinction between these units is that CPT advance the tool string by applying a hydraulic ram against the weight or mass of the vehicle alone, while rotary hammer units add a hydraulic hammer to the hydraulic ram to compensate for their lower mass. These platforms share the same principle of operation, similar tools, and a number of advantages and limitations. They differ in scale, application, and to some extent the types of instruments and tools that have been developed for each. For these reasons, CPT and rotary hammer platforms fill different niches in the environmental field.

Gas Chromatography – Gas chromatography (GC) analysis is a widely used technique for field-based analysis. Analysis of organic compounds is possible for a variety of matrices such as water, soil, soil gas, and ambient air. Typical settings include: (1) site characterization, (2) stationary source testing and monitoring, (3) hazardous waste sites for determining personal protective equipment (PPE) level, (4) fence line monitoring during removal or remediation activities, and (5) emergency response testing. GC analysis with photoionization detection has been used extensively to characterize and remediate sites contaminated with VOCs. Likewise, gas chromatographs coupled with an electron capture detector are used for analysis on sites contaminated with chlorinated pesticides. The recent development of truly field portable quadrupole mass spectrometers now permits GC-mass spectrometry analysis which provides definitive identification. This instrument and technique is being implemented during emergency response and counter-terrorism situations that require definitive identification of contaminants in near real-time.

Geophysics – Geophysical surveys are useful for characterization of the geology or hydrogeology of a site, detection and mapping of contamination, detection of geological conditions favorable for contaminant migration, and evaluation of past site uses. There are three primary geophysical methods: *in situ*, surface, and borehole. *In situ* geophysical measurements typically are made by placing a probe or sensor into the media of interest in such a way that causes minimal disturbance of the media. Surface geophysical techniques usually result in no significant disturbance of the subsurface media – surface sensors may be in contact with the ground surface or held above the ground surface. Borehole geophysical measurements are made only after a boring has been made into the media of interest. The sensor itself may not actually contact the walls of the borehole.

Immunoassay – Immunoassay is a widely-accepted field analytical technology for many organic contaminants and classes of contaminants (and at least one inorganic contaminant). Various immunoassay kits and methods are tailored to specific classes of environmental contaminants. Immunoassay uses antibodies that have been developed to bind with a target compound or class of compounds. The technology has been used widely in the environmental field because the antibodies can be highly specific to the target compound or group of compounds and because the kits are relatively quick and simple to use. Concentrations of analytes are identified through the use of a sensitive colorimetric reaction. The determination of the target analyte's presence is made by comparing the color developed by a sample of unknown concentration with the color formed by the standard containing the analyte at a known concentration. The concentration of the analyte is determined by the intensity of color in the sample. The concentration can be estimated roughly by the naked eye or can be determined more accurately with a photometer or spectrophotometer.

Laser-Induced Fluorescence – Laser-induced fluorescence (LIF) is a method for real-time, in-situ, field screening of hydrocarbons in undisturbed subsurface soils and groundwater. The technology is intended to provide highly detailed, qualitative to semiquantitative information about the distribution of subsurface petroleum contamination. LIF sensors are deployed as part of integrated mobile CPT systems that are operated by trained technicians. There are currently two major LIF systems available, the Site Characterization and Analysis Penetrometer System (SCAPS) and Rapid Optical Screening Tool (ROST™) systems. The SCAPS LIF system is one of several CPT-mounted sensors developed through a collaborative effort of the Army, Navy, and Air Force under the Tri-Services Program. The ROST™ system was developed by Loral Corporation and Dakota Technologies, Inc. The SCAPS LIF is available only through the U.S. Army Corps of Engineers and the U.S. Navy. ROST™ is available commercially through Fugro, Inc.

Mass Spectrometry – In the environmental field, mass spectrometers (MS) are typically used as detectors for GCs. Because of the increased durability of modern instruments, field gas chromatographs/mass spectrometers (GC/MS) are capable of the same analyses as fixed laboratory instruments.

X-Ray Fluorescence – Energy dispersive X-ray fluorescence (XRF) is a method of detecting metals and other elements, such as arsenic and selenium, in soil, sediment, and water. Some of the primary elements of environmental concern that XRF can identify are arsenic, barium, cadmium, chromium, copper, lead, mercury, selenium, silver, and zinc. Field-portable XRF units that run on battery power and use a radioactive source were developed for use in analysis for lead-based paint and now are accepted as a stand-alone technique for lead analysis. In response to the growing need for field analysis of metals at hazardous waste sites, many of these field-portable XRF units have been adapted for use in the environmental field. They provide data in the field that can be used to identify and characterize contaminated sites and guide remedial work, among other applications.