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Standard Guide for Accelerated Site Characterization for Confirmed or Suspected Petroleum Releases¹

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1. Scope

1.1 This guide covers a process to rapidly and accurately characterize a confirmed or suspected petroleum release site. This guide is intended to provide a framework for responsible parties, contractors, consultants, and regulators to streamline and accelerate the site characterization process or supplement incomplete characterization data. The accelerated site characterization (ASC) approach may be incorporated in state and local regulations as a cost-effective method of making informed corrective action decisions sooner.

1.2 This guide describes a process for collecting site characterization information in one mobilization, using rapid sampling techniques; field analytical methods; and on-site interpretation and iteration of field data to refine the conceptual model for understanding site conditions as the characterization proceeds. This information can be used to determine the need for interim remedial actions; site classification or prioritization, or both; further corrective actions; and active remediation. The process outlined in this guide can be incorporated into existing corrective action programs, and is organized to be used in conjunction with Guides E 1599 and E 1739.

1.3 For guidance concerning contractor health and safety issues, appropriate federal, state, and local regulations (for example, Occupational Safety and Health Administration) and industry standards should be consulted. For sampling quality assurance/quality control (QA/QC) practices, see references in Section 2. Considerations for field analytical method quality assurance/quality control are discussed in Section 5.

1.4 This guide is organized as follows:

1.4.1 Section 1 describes the scope,

1.4.2 Section 2 lists Referenced Documents,

1.4.3 Section 3 defines Terminology,

1.4.4 Section 4 identifies the Significance and Use,

1.4.5 Section 5 describes the Accelerated Site Characterization Process,

1.4.6 Appendix X1 identifies Additional Referenced Documents,

1.4.7 Appendix X2 provides an Example of a Data Quality Classification System,

1.4.8 Appendix X3 contains a list of physical and chemical properties and hydrogeologic characteristics applicable to site characterizations, and a list of input parameters and methodologies for ASTM RBCA Tier 1 and Tier 2 evaluations, and

1.4.9 Appendix X4 contains a case study example of the ASC process, including a RBCA Tier 1 and Tier 2 evaluation.

1.5 The values stated in inch-pound units are to be regarded as the standard. The SI units given in parentheses are for information only.

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 ASTM Standards:

D 5730 Guide to Site Characterization for Environmental Purposes With Emphasis on Soil, Rock, the Vadose Zone, and Ground Water²

E 1599 Guide for Corrective Action for Petroleum Releases³

E 1689 Guide for Developing Conceptual Site Models for Contaminated Sites⁴

E 1739 Guide for Risk-Based Corrective Action Applied at Petroleum Release Sites³

2.2 EPA Documents:

USEPA SW 846, Recommended Analytical Procedures, Test Methods for Evaluating Solid Waste-Physical/Chemical Methods⁵

USEPA, Draft Field Methods Compendium, OER 9285.2-11⁵

USEPA, Subsurface Characterization and Monitoring Techniques: A Desk Reference Guide-Vols I and II, EPA

¹ This guide is under the jurisdiction of ASTM Committee E50 on Environmental Assessment and is the direct responsibility of Subcommittee E50.04 on Performance Standards Related to Environmental Regulatory Programs.

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² Annual Book of ASTM Standards, Vol 04.09.

³ Annual Book of ASTM Standards, Vol 11.04.

⁴ Annual Book of ASTM Standards, Vol 11.05.

⁵ Available from Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.

625/R-93/003a and b⁵

USEPA, Description and Sampling of Contaminated Soils: A Field Pocket Guide, EPA 625/12-91/002⁵

USEPA, Environmental Investigations Standard Operating Procedures and Quality Assurance Manual, May 1996, USEPA Region⁵

USEPA, Expedited Site Assessment Tools for UST Sites: A Guide for Regulators, EPA 510-B-97-001⁵

3. Terminology

3.1 Definitions of Terms Specific to This Standard:

3.1.1 *accelerated site characterization (ASC)*—a process for collecting and evaluating information pertaining to site geology/hydrogeology, nature and distribution of the chemical(s) of concern, source areas, potential exposure pathways and points of exposure in one mobilization. The ASC employs rapid sampling techniques, on-site chemical analysis and hydrogeological evaluation, and field decision making to provide a comprehensive “snap-shot” of subsurface conditions.

3.1.2 *active remediation*—actions taken to reduce the concentrations of chemical(s) of concern. Active remediation could be implemented when the no further action and passive remediation courses of action are not appropriate.

3.1.3 *chemical(s) of concern*—specific constituents that are identified for evaluation in the site characterization process.

3.1.4 *conceptual model*—a summary of information that is known about a site. Available site information is compiled onto one or more simple graphics to develop an understanding of the site conditions. The conceptual model is not an analytical or numerical computer model, but may utilize these tools in developing a conceptual understanding of site conditions.

3.1.5 *corrective action*—activities performed in response to a suspected or confirmed release, which include one or more of the following: site characterization, interim remedial action, remedial action, operation and maintenance of equipment, monitoring of progress, monitoring of natural attenuation, and termination of remedial action.

3.1.6 *exposure pathway*—the course a chemical(s) of concern takes from the source area(s) to an exposed organism. An exposure pathway describes a unique mechanism by which an individual or population is exposed to a chemical(s) of concern originating from a site. Each exposure pathway includes a source or release from a source, a point of exposure, and an exposure route. If the exposure point differs from the source, a transport/exposure medium (for example, air) or media also is included.

3.1.7 *facility*—the property containing the source of the chemical(s) of concern where a release has occurred.

3.1.8 *field analytical methods*—methods or techniques that measure physical properties or chemical presence in soil, soil vapor, and ground water immediately or within a relatively short period of time to be used during a site characterization. Measurement capabilities range from qualitative (positive/negative) response to below parts per billion (sub-ppb) quantitation. Accuracy and precision of data from these methods depends on the method detection limits and QA/QC procedures.

3.1.9 *field-generated analytical data*—information generated on site soon after sample acquisition that is used to direct

the site characterization process. These data include: concentrations of chemical(s) of concern in air; soil; soil vapor or ground water, or both; and hydrogeologic conditions.

3.1.10 *indicator compounds*—compounds in ground water, soil, or air, specific to the petroleum product released, used to confirm the existence of the petroleum product, define the distribution of the chemical(s) of concern, define the target levels, monitor progress of the remedial action, and identify the termination point of the remedial action.

3.1.11 *interim remedial action*—the course of action to mitigate fire and safety hazards and to prevent further migration of hydrocarbons in their vapor, dissolved, or liquid phase.

3.1.12 *mobilization*—the movement of equipment and personnel to the site, to prepare for, collect, and evaluate site characterization data. These activities, when conducted as one continuous event (from one day to several weeks), are referred to as a single mobilization. Activities that are not conducted continuously are referred to as multiple-site mobilizations.

3.1.13 *on-site manager*—an individual who is on site and is responsible for directing field activities and decision-making during the site characterization. The on-site manager should be familiar with the purpose of the site characterization, pertinent existing data, and the data collection and analysis program. When conducting an ASC, it is necessary for the on-site manager to also be the principal investigator, developing and refining the conceptual model of site conditions. This individual must have the necessary experience and background to perform the required site characterization activities and to accurately interpret the results and direct the investigation. For the purposes of this guide, sufficient qualification criteria for the on-site manager includes knowledge and experience in the following areas:

3.1.13.1 Soil and ground water sampling and analytical methods to be used at the site;

3.1.13.2 Fate and transport of petroleum hydrocarbons in the subsurface;

3.1.13.3 Local geology/hydrogeology;

3.1.13.4 Local regulations and ordinances, including knowledge of state-specific certification requirements;

3.1.13.5 Personal health and safety requirements; and

3.1.13.6 Evaluation and interpretation of site characterization results.

3.1.14 *petroleum*—including crude oil or any fraction thereof that is liquid at standard conditions of temperature and pressure (60°F (16°C) at 14.7 psia). The term includes petroleum-based substances comprised of a complex blend of hydrocarbons derived from crude oil through processes of separation, conversion, upgrading, and finishing, such as motor fuels, jet oils, lubricants, petroleum solvents, and used oils.

3.1.15 *point(s) of exposure*—the point(s) at which an individual or population may come in contact with a chemical(s) of concern originating from a site.

3.1.16 *quality assurance/quality control (QA/QC)*—the use of standards and procedures to ensure that samples collected and data generated are reliable, reproducible, and verifiable.

3.1.17 *rapid sampling tools*—equipment and techniques that allow personnel to collect samples from different media, in

a relatively short period of time, for on-site chemical analysis and hydrogeologic evaluation within the same mobilization.

3.1.18 *receptors*—persons, structures, utilities, surface waters, and water supply wells that are or may be adversely affected by a release.

3.1.19 *regulatory agency*—any state or local program responsible for overseeing underground storage tank (or other petroleum/hazardous material source) site characterization and corrective action.

3.1.20 *release*—any spilling, leaking, emitting, discharging, escaping, leaching, or disposing of petroleum products into ground water, surface water, soils, or air.

3.1.21 *remediation/remedial action*—activities conducted to protect human health, safety, and the environment. These activities include evaluating risk, making no-further-action determinations, monitoring, institutional controls, engineering controls, and designing and operating cleanup systems.

3.1.22 *site characterization*—an evaluation of subsurface geology/hydrogeology, and surface characteristics to determine if a release has occurred, the levels of the chemical(s) of concern, and the distribution of the chemical(s) of concern. The data collected on soil, soil vapor and ground water, potential exposure pathways and location of receptors and point(s) of exposure is used to generate information to support remedial action decisions.

3.1.23 *source area(s)*—the location(s) of liquid hydrocarbons or the zone(s) of highest soil or ground water concentrations, or both, of the chemical(s) of concern.

3.1.24 *user*—an individual or group involved in the ASC process including owners, operators, regulators, petroleum fund managers, attorneys, consultants, legislators, and so forth.

4. Significance and Use

4.1 An ASC is a process for collecting and evaluating information on site geology/hydrogeology, nature and distribution of chemicals of concern, source areas, potential exposure pathways, and points of exposure. The unique goal of an ASC is to complete a site characterization in one mobilization. This can be accomplished by developing and refining a conceptual site model, utilizing rapid sampling tools and techniques, obtaining field-generated analytical data, and on-site interpretation of results. Evaluation of data concurrent with the investigation allows the on-site manager to select subsequent sampling points based on actual subsurface conditions, resulting in a more comprehensive and cost-effective “snapshot” of subsurface conditions.

4.2 The ASC process has the following advantages:

4.2.1 Immediate identification of potential risks to human or environmental receptors or potential liabilities, or both;

4.2.2 Rapid determination of the need for interim remedial actions, site classification, and prioritization;

4.2.3 Rapid sample collection and analysis, near contemporaneous analytical results, and maximum data comparability;

4.2.4 Optimization of sample point locations and analytical methods;

4.2.5 Greater number of data points for resources expended;

4.2.6 Near immediate data availability for accelerating corrective action decisions; and

4.2.7 Collection of vertical and horizontal data, allowing for three-dimensional delineation of chemical(s) of concern in soil, soil vapor, or ground water.

4.3 The ASC process described in this guide is intended for use in situations where the potential exists that petroleum has been released. The same principles may be applicable to other indicator compounds or chemical(s) of concern, and sources (for example, chlorinated solvent releases). If the ASC process is used for chemical(s) of concern, other than petroleum, the user must consider the physical and chemical characteristics of the chemical(s) of concern and the media in which they are present to ensure that the sampling tools and analytical methods are capable of measuring and detecting the chemical(s) of concern.

4.4 A conventional site characterization approach most often involves several mobilizations. Each mobilization typically includes a predefined sampling and analysis plan, where analysis and interpretation of results are performed off-site after demobilization. A conventional site characterization can provide high-quality data; however, multiple mobilizations often prolong the process required to adequately characterize subsurface conditions.

4.5 The ASC process requires an on-site manager to make decisions to guide the characterization. Without an individual on site who is able to interpret data as it is generated, and is authorized to adjust sample locations or scope of the investigation, or both, an ASC has little chance of meeting its stated objective of full characterization in one mobilization. Levels of communication and authority between the on-site manager and the user should be established prior to beginning the characterization.

5. Accelerated Site Characterization Process

5.1 The unique feature of the ASC process is the collection, analysis, and evaluation of hydrogeologic and chemical data while on-site. A flowchart of the ASC process is presented in Fig. 1, and a discussion of each activity begins in 5.2. While many of the steps in an ASC are similar to those in a conventional characterization, the following activities, as illustrated in the area labeled “Field Activities” in Fig. 1, are performed on-site during an ASC:

5.1.1 Interpretation and evaluation of field-generated data as it is collected;

5.1.2 Continuous refinement of the conceptual model, and the understanding of site conditions;

5.1.3 Modification of the sampling and analysis program to address any necessary adjustments in the scope of work; and

5.1.4 Collection of additional data necessary to complete the characterization.

5.2 Step 1—Identify Site Characterization Purpose:

5.2.1 *Purpose*—The objectives of any environmental site characterization, as noted previously, are to understand the site geology/hydrogeology, the nature and distribution of the chemicals of concern, the migration pathways and location of potential receptors and point(s) of exposure. The scope of work, however, will vary depending upon the purpose of the specific characterization. Typical purposes include one or more of the following: hazard determination, initial response action,

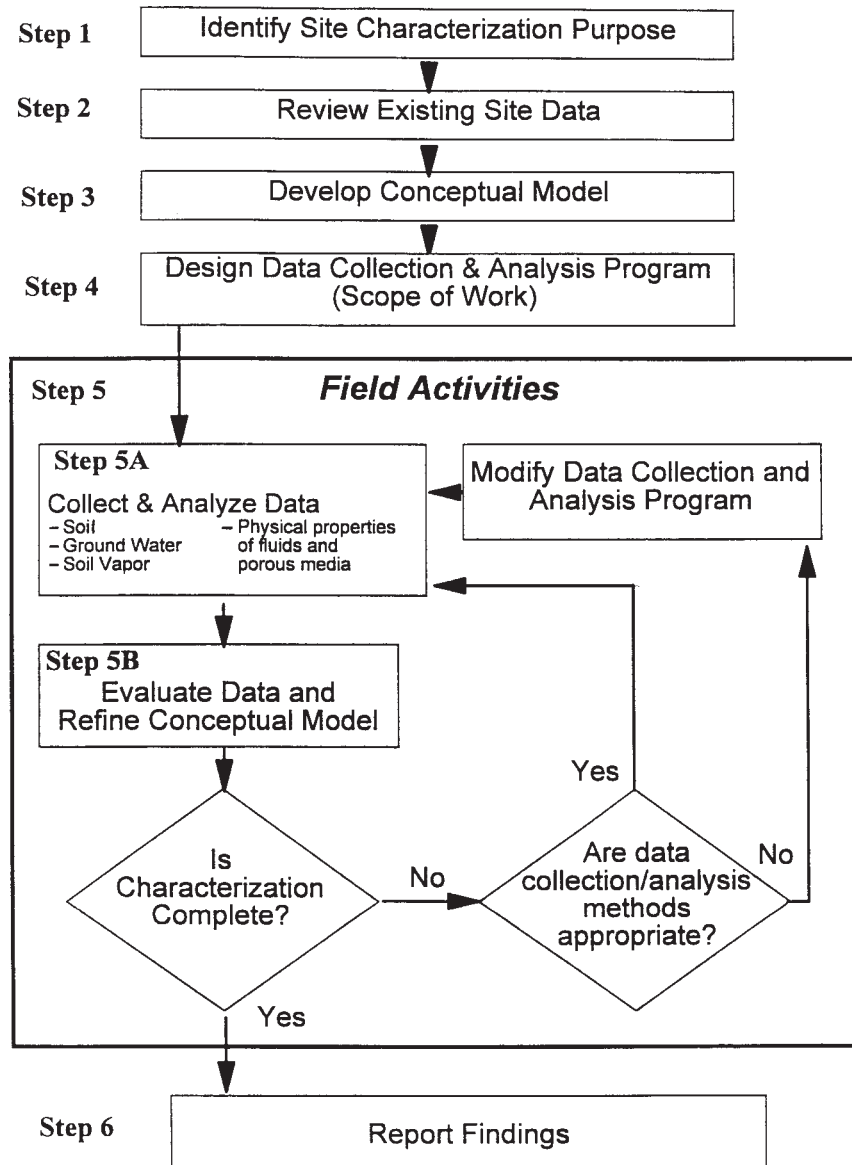


FIG. 1 ASC Process Flowchart

release confirmation, risk determination, remedial action evaluation, regulatory compliance, or real estate transaction. For example, an ASC for an initial response action might focus on defining imminent hazards, potential migration of chemical(s) of concern and the location of receptors and point(s) of exposure, while a characterization for a real estate transaction focuses on identifying the presence of chemicals of concern. A corrective action evaluation will require a higher priority be placed on understanding subsurface hydrogeologic conditions, whereas a risk determination will focus first on receptors, exposure pathways and points of exposure, in addition to levels of chemical(s) of concern.

5.2.2 The scope of the ASC is determined prior to mobilization, but will often be revised based on interpretation of the field-generated data.

5.3 Step 2—Review Existing Site Information:

5.3.1 A variety of regional and site-specific information should be obtained prior to mobilization. A review of existing

information, and a site visit, are important in the design of a data collection and analysis program, and in the development of the conceptual model. Information obtained through the site visit, interviews, and records search include the following:

5.3.1.1 Local and regional hydrogeologic maps to identify general soil types/regional depth to bedrock, rock type, depth to ground water, aquifer properties, and so forth;

5.3.1.2 Past and current land use history of the site and adjacent properties (including future land use if known);

5.3.1.3 Location of potential sources (for example, current and former storage tank systems);

5.3.1.4 Releases, spills, and overfill incidents on the site and adjacent properties;

5.3.1.5 Previous or on-going corrective action activities, or both, on-site and on nearby properties (that is, existing monitoring wells);

5.3.1.6 Potential receptors and point(s) of exposure including private and public water supply wells, surface waters,

utility conduits, basements, sensitive ecosystems, and other sensitive land uses within a given proximity of the site;

5.3.1.7 Potential migration pathways and transport mechanisms to the points of exposure (ground water flow, vapor migration through soils and utilities, and so forth);

5.3.1.8 Other potential off-site sources of chemical(s) of concern; and

5.3.1.9 Site conditions that may affect the health and safety plan.

5.3.2 If the review of existing data does not provide adequate information regarding UST or subsurface structure locations, the use of surface geophysical survey techniques may be appropriate.

5.4 Step 3—Develop Conceptual Model:

5.4.1 The initial conceptual model is the starting point of the characterization, and is used as a basis for planning field activities. The model is developed by compiling and interpreting all information obtained from the existing site information review, and may include the following:

5.4.1.1 Anticipated locations and depths of subsurface geologic units;

5.4.1.2 Anticipated ground water depth and flow direction(s) and possible interaction with surface water bodies;

5.4.1.3 Layout of the site, including areas and depths of artificial fill (tank and trench backfill), subsurface utility lines, and subsurfacing piping;

5.4.1.4 Existing soil and ground water analytical data and information regarding the location and volume of the release;

5.4.1.5 Potential releases in the vicinity of the site (especially upgradient from the site);

5.4.1.6 Location of potential receptors, point(s) of exposure, and migration pathways; and

5.4.1.7 Topographic conditions.

5.4.2 The on-site manager should summarize this information onto simple graphics such as a large-scale base map, structure contour maps, ground water elevation contour maps, isoconcentration contour maps, and geologic/hydrogeologic cross sections. These graphics can easily be hand drawn or can be generated using computerized graphics programs before actual field work begins. These documents should be used on-site and updated as the characterization progresses.

5.4.3 The initial conceptual model, developed before beginning any field work, focuses on specific features that are relevant to the characterization objectives. For example, the features of a conceptual model of a leaking underground storage tank site may include preliminary estimates of: source areas; three dimensional distribution of chemical(s) of concern; chemical(s) of concern impact to and distribution in the ground water; geologic units or structures that influence migration of chemical(s) of concern; and ground water depth, flow direction and velocity. The components of the initial conceptual model that are emphasized depends on the purpose of the characterization, and assists the investigator in focusing on the most salient site features. For more information regarding developing conceptual models, see Guide E 1689.

5.5 Step 4—Design Data Collection and Analysis Program:

5.5.1 The data collection and analysis program is developed based on the initial conceptual model, prior to mobilization.

This program does not need to be a formalized document, but should be agreed upon between the on-site manager and the responsible party prior to initiation of field activities (in some cases, the regulatory agency is involved as well). The exact number and location of data collection points are left somewhat flexible, and are determined in the field based on the actual site conditions. Levels of communication and authority between the on-site manager and the responsible party will keep all parties informed as the ASC progresses.

5.5.2 Proper implementation of the data collection program requires that the on-site manager be familiar with the capabilities and limitations of the sampling tools and field analytical methods, and that he or she interpret the field-generated data as it becomes available.

5.5.3 The design of the data collection and analysis program should consider the following:

5.5.3.1 Purpose of the ASC;

5.5.3.2 Initial conceptual model, including site historical information, hydrogeologic characteristics of the site, and physical properties of fluids and porous media;

5.5.3.3 Methods to collect and analyze data;

5.5.3.4 General location and number of initial samples and the decision process for locating additional samples;

5.5.3.5 Media to be analyzed;

5.5.3.6 Sample collection and analysis criteria (depth, interval, sampling protocol, chemical(s) of concern, data quality levels, analytical methods, and data validation);

5.5.3.7 Specific qualifications of the on-site manager(s);

5.5.3.8 Site constraints (for example, USTs, structures, canopy, limited space, utilities, property boundaries, depth to bedrock, and access constraints);

5.5.3.9 Data for fate and transport modeling, risk evaluations, or corrective action design (for example, soil properties, air permeability, natural attenuation indicators);

5.5.3.10 Level of communication between the on-site manager and the responsible party (for example, agreement on changes to the scope of work or the data collection and analysis program);

5.5.3.11 Contingencies based on reasonably anticipated deviations from expected site conditions, such as shallow bedrock, depth to ground water, disposal of investigatory wastes, change in equipment requirements, and the appearance or detection of unanticipated chemical(s) of concern; and

5.5.3.12 Determination of the possible need for off-site access.

5.5.4 *Data Collection Methods*—The selection of sampling tools should be based on the following:

5.5.4.1 Purpose and anticipated scope of the ASC;

5.5.4.2 Capabilities, limitations, and cost of each tool;

5.5.4.3 Speed by which samples can be obtained;

5.5.4.4 Advantages of using a combination of tools;

5.5.4.5 Site features and layout;

5.5.4.6 Anticipated geologic site conditions;

5.5.4.7 Anticipated chemical(s) of concern and concentrations;

5.5.4.8 Disturbance to site operations and neighboring properties; and

5.5.4.9 Anticipated next steps.

5.5.4.10 Table 1 presents several common tools and devices that can be used to obtain samples. This guide recognizes that additional tools and techniques exist and continue to be developed, and sample collection during an ASC is not limited to those tools listed in Table 1. The sample collection tools are an integral, though not an exclusive part of an accelerated site characterization in defining subsurface structures, potential migration pathways, or barriers at a site, and in selecting areas for further investigation. The case study example in Appendix X4 identifies information and data collection methods which may be necessary to complete an ASC and perform an ASTM Tier 1 or Tier 2 evaluation.

5.5.4.11 In addition to the tools listed in Table 1 to obtain samples, surface and downhole geophysical techniques (for example, ground penetrating radar, electromagnetic induction, electrical resistivity) may assist in obtaining information regarding subsurface features such as undocumented USTs, utility lines or other unknown features. This information can assist the on-site manager in determining locations of intrusive sampling points.

5.5.5 Sample Analysis:

5.5.5.1 *Hydrogeologic Conditions and Physical Properties*—Information on the geology/hydrogeology and physical characteristics of the subsurface is essential to refine

the conceptual model, evaluate potential migration pathways and transport mechanisms, and to develop an appropriate corrective action plan. A list of characterization properties and parameters, including physical properties, chemical properties, hydrogeologic characteristics and input parameters/methodologies for an ASTM RBCA Tier 1 and Tier 2 evaluations are located in Appendix X3.

5.5.5.2 *Chemical Analysis*—Field analytical methods are used in an ASC to analyze soil, soil vapor, ground water or air, or a combination thereof. On-site analysis for indicator compounds/chemicals of concern allows the on-site manager to determine the location of, or need for additional samples. Field analytical methods can typically provide more data at lower cost with minimal sample disturbance than sending samples to an off-site laboratory. Key considerations in selecting field analytical methods are as follows:

5.5.5.3 *Analyte*—The analytical method(s) selected will depend on the chemical(s) of concern or indicator compound(s) of interest. For example, when gasoline is the suspected release, the indicator compound may be total volatile organics. Therefore, a method that measures total organic vapors may be used. In many cases, specific chemicals of concern, such as benzene, may need to be measured. Depending on the chemical(s) of concern, it may be necessary to use either field

TABLE 1 Example Sample Collection Tools^A

Method	Access ^C	Suitable Media			Sample Depth (m) ^B	Comments
		Soil	Soil Vapor	Ground Water		
Grab samplers (trowels, scoops, shovel, post-hole digger)	M, B	X			< 1	Low cost. Loss of volatiles. Ease of use.
Hand augers	M	X			< 3	Slow. Labor intensive. Shallow depth. Can be used near located utility/product lines.
Slam Bar & Tubing						
Split spoon	DP, DR	X			< 100	Minimal sample disturbance. Difficult to use below water table w/o auger.
Sample sleeve	DP	X			< 100	Difficult in cobbles or hardpan. Visual obs of sample. Can be used below water table. Minimal sample dist.
Other core samplers ^D	M	X			< 2	Equipment-specific capabilities and limitations.
	DP	X			< 100	
	DR	X			< 100	
Active gas samplers (vacuum pumps & tubing)	OH, DP, DR		X		< 100	Larger sample volume. Loss of volatiles. Low \$
Passive gas samplers	M		X		< 1	Time intensive.
Pneumatic depth-specific samplers	OH		X	X	< 100	
Check valve and tubing	OH			X	< 100	Limited sample volume. Low cost.
Exposed-screen sampler	DP			X	< 100	
Bailer	OH			X	< 100	Labor-intensive.
Sheathed Wellpoint	DP, DR			X	< 100	
Peristaltic pump	OH			X	< 10	
Gas-drive/displacement pump	OH			X	< 100	
Gas-drive/piston pump	OH			X	< 100	
Bladder pump	OH			X	< 100	
Helical rotor pump	OH			X	< 100	

^A Some commonly-used tools for shallow and intermediate depth investigations (generally < 50 meters) are listed. Many other tools are available. Refer to "Subsurface Characterization Monitoring Techniques: A Desk Reference Guide, Vols. I and II," (EPA/625/R-93/003a&b), USEPA, May 1993, for additional information about these and other methods.

^B Sample depth refers to practical depth limitation range, depending upon the sampling device used and the lithologic conditions.

^C Access to the sample for collection or installation of sample tool via the listed approaches.

M = manual (hand-operated equipment).

B = backhoe (mechanical excavating equipment).

OH = open hole (unobstructed access to the sample medium via a pit or cavity, a cased well, or narrow-diameter sampling point).

DR = drill rig (mechanical boring equipment, such as hollow-stem auger, mud/air rotary).

DP = direct-push (mechanical, hydraulic, pneumatic or vibratory devices which push or drive narrow diameter sampling points into the subsurface).

^D Numerous types and sizes available for different soil conditions. Drill rig is the only sample access equipment listed in this table which can be used readily to sample consolidated material.

analytical method capable of providing chemical-specific results, or a combination of methods capable of analyzing a broader suite of compounds. Table 2 is a summary of commonly used field screening and analytical techniques. For a discussion of the level of data quality produced by each method, see the data quality level discussion below.

5.5.5.4 Media—Consideration must be given to the targeted sample media (soil, soil vapor, ground water, air) and the method’s capability of measuring concentrations in that medium. The performance of field analytical methods will vary depending on the sample preparation required for the media being analyzed (especially for soil analyses).

5.5.5.5 Data Quality Level—The reliability of results is related to the data quality level of the method used. An example of a data quality classification system for commonly used analytical methods is presented in Appendix X2. As shown in the example, several of the field analytical methods are capable of measuring chemical(s) of concern and/or indicator compounds at differing data quality levels. Selection of field analytical methods should be based in part on the chemical of concern or indicator compounds of interest, the intended use of the data, and the capability of the method. For example, lower quality methods (often called field screening methods) may be used for source identification, while higher data quality methods should be used to delineate chemicals of concern at lower detection limits. Both quantitative and qualitative field analytical methods should be used to acquire data necessary to perform a risk evaluation, or to develop future action plans. When determining what level of data quality is most appropriate, the following is considered:

5.5.5.6 The quality level selected should be consistent with the purpose and scope of the ASC and the intended use of the data.

5.5.5.7 Many points containing lower quality level data can provide a better understanding of site conditions than fewer data points at a higher data quality level.

5.5.5.8 Regulatory requirements should be considered with respect to the detection limit of the selected field analytical method.

5.5.5.9 Limitations—All analytical methods and instruments have limitations that may affect results. These include affects of temperature or humidity, cross-sensitivity issues, and masking of certain constituents. In addition, the operational expertise of the person performing the analysis may also effect results. These limitations should be considered when selecting analytical methods or instruments.

5.5.5.10 Regulatory Acceptance—Field analytical methods are changing rapidly and the appropriate regulatory authority should be consulted in advance of collecting and analyzing data for accepted methods and procedures when an ASC is performed for regulatory purposes.

5.5.5.11 Method Protocol and QA/QC Considerations—Each analytical method has a standard protocol established either by the United States Environmental Protection Agency (USEPA), a state regulatory agency, an industry consensus group or manufacturer, or has a protocol specifically developed for use on-site. Prior to performing the analysis, method protocol and quality control procedures should be developed and documented in a quality control plan. A method quality

TABLE 2 Example Sample Field Screening and Analytical Techniques^A

Method	Analyte	Media			Detection Range			Limitations	Result Time
		Soil Vapor	Soil	Ground Water	Soil Vapor	Soil	Ground Water		
PID- or FID- headspace	TOV ^B	X	X	X	ppmv	ppmv	ppmv	Temperature. Humidity. Instrument flowrate. Cross Sensitivity Issues.	Immediate.
Indicator tube	Specified compound	X	X		ppmv	ppmv			
O ₂	Oxygen	X			%				
CO ₂	Carbon dioxide	X			ppmv				
pH meter	pH			X			1-14	None. Temperature. Active fouling by materials that react, coat, or clog.	
DO meter	Dissolved oxygen			X			mg/l		
REDOX meter	REDOX potential			X					
Conductivity meter	Electrical conductivity			X					
Ion-specific meter	Indicator compounds			X			mg/l		
Infrared (IR) spectrometer	Indicator compounds		X	X		mg/kg	mg/l	Low bias for aromatics. Organic rich soils may cause bias.	Minutes.
Turbidimetric test kit	Indicator compounds		X			mg/kg			
Colorimetric methods	Indicator compounds		X	X		mg/kg	mg/l		
Immunoassay kits	Indicator and specific compounds		X	X		mg/kg	ug/l	Cross-reactivity.	
Portable GC	Specific compounds	X	X	X	ppbv	ug/kg	ug/l	Moderate peak resolution.	
Laboratory grade GC (on-site)	Specific compounds	X	X	X	ppbv	ug/kg	ug/l	Negligible.	Minutes to hours.
Laboratory grade mass spectrometer (on-site)	Specific compounds	X	X	X	ppbv	ug/kg	ug/l	Negligible.	
Laboratory grade GC (off-site)	Specific compounds	X	X	X	ppbv	ug/kg	ug/l	Negligible.	Days to weeks.
Laboratory grade mass spectrometer (off-site)	Specific compounds	X	X	X	ppbv	ug/kg	ug/l	Negligible.	

^A Some commonly-used techniques for analyzing environmental media are listed. Many other techniques are available. This list was generated using “Field Analysis Manual,” New Jersey Department of Environmental Protection and Energy, May 1994, and “Subsurface Characterization and Monitoring Techniques: A Desk Reference Guide, Vols. I and II,” (EPA/625/R-93/003a&b), USEPA, May 1993.

^B TOV refers to Total Organic Vapors.

control plan should specify the following: instrument calibration procedures; generation of calibration curves; preparation and analysis of field standards; analysis of matrix spikes, matrix spike duplicates, blanks and control samples; frequency for instrument calibration and quality control sample analysis; and acceptable criteria for results of instrument calibration and quality control samples.

5.5.5.12 The on-site manager must be familiar with the quality control plan and must ensure that the methods are being performed and the samples are being analyzed in accordance with the plan. The results of the quality control sample analysis should be recorded and reviewed as the data is being generated as well as during data evaluation and refining of the conceptual model. Quality control procedures and analytical results should be included in the final site characterization report.

5.5.5.13 Table 2 presents several analytical methods that can be used to analyze soil vapor, soil and ground water samples. The methods are listed in the order of increasing capabilities and time required for analysis. Both field analytical and off-site laboratory methods are listed. This guide recognizes that additional methods continue to be developed and sample analysis during an ASC is not limited to those methods listed in Table 2. The case study in Appendix X4 demonstrates the use of on-site analytical methods which may be used in completing an ASC and in performing an ASTM RBCA Tier 1 and Tier 2 evaluation.

5.6 Step 5—Field Activities:

5.6.1 Step 5A—Collect and Analyze Data—The established data collection and analysis program is implemented to perform an intensive, short-term field investigation. As samples are acquired, it is important to observe physical appearance and conditions such as lithology, structure, soil staining, color and moisture content (see Appendix X3). Flexibility is a key component for a successful ASC, therefore, the data collection and analysis program should be used to guide the site characterization to completion. As data is collected and analyzed, it may be necessary to adjust the data collection and analysis program to refine the conceptual model and satisfy the purpose of the site characterization.

5.7 Step 5B—Evaluate Data and Refine Conceptual Model:

5.7.1 Hydrogeologic, and analytical data collected during the field investigation are periodically interpreted on-site by the field manager. As shown in the flowchart in Fig. 1, the conceptual model is refined in an iterative process of data collection and evaluation. Compilation of the data onto simple graphics is essential for on-site data interpretation. This is best done by updating the maps and cross sections prepared to develop the initial conceptual model. As the investigation proceeds, the maps and cross sections are continually revised (geologic contacts are erased and moved, borehole lithologic data are plotted on cross sections, new isoconcentration contour lines are drawn, and so forth), by incorporating the new data. Using the field-generated graphics, the on-site manager directs the investigation to fill in data gaps or resolve differences between anticipated and actual results, or both. As new data are collected and the investigation proceeds, variances between the initial conceptual model and the data obtained during the characterization are used to adjust the sampling and

analysis program in an iterative, scientific manner, until the site geology/hydrogeology, and nature and distribution of the chemical(s) of concern in soil and ground water are accurately defined.

5.7.2 The degree of detail and accuracy of the graphical representation of site conditions varies according to the purpose of the characterization, complexity of the site geology/hydrogeology, and the type and volume of the chemical(s) of concern. As multiple measurements are made and the amount of information that describes more complex subsurface conditions increases, the site data can be compiled on graphical software that is commercially available for laptop computers.

5.7.3 *Data Validation*—To ensure that it is useful, field-generated data must be validated. Considerations for data validation include the following:

5.7.3.1 Quality assurance/quality control (QA/QC) results (for example, duplicates, multi-point calibration curves, calibration checks, blanks, and so forth);

5.7.3.2 Comparison of higher quality level data to check lower quality level data;

5.7.3.3 Consistency of results among analytical methods and sampling techniques;

5.7.3.4 Comparison with results from other media;

5.7.3.5 Comparison with other chemical(s) of concern or indicator compounds;

5.7.3.6 Comparison against previous data, if available; and

5.7.3.7 The data should make sense in the context of the site conditions and previously generated data.

5.7.4 Once the validity of the data has been assessed, it can be used to determine whether data quality requirements have been satisfied.

5.8 Termination of Data Collection:

5.8.1 The data collection and evaluation should continue until the on-site manager has determined that the purpose of the site characterization has been met or that constraints prevent complete characterization. Typically, the ASC is complete and no further data collection is required when the following have been satisfied:

5.8.1.1 The conceptual model of the site geology/hydrogeology, the nature and distribution of chemicals of concern, and indicator compounds fit the regional hydrogeologic setting; and

5.8.1.2 The conceptual model of the site generally incorporates/fits all of the site data; and

5.8.1.3 The conceptual model can be used to make accurate predictions of subsurface conditions, and

5.8.1.4 Sufficient detail and delineation of the chemicals of concern have been achieved to fulfill the requirements of the user; or

5.8.1.5 Constraints prevent collection of any additional data.

5.9 Step 6—Report Findings:

5.9.1 Upon completion of the field work, a report of findings is provided to the user. The report should contain at a minimum: the purpose of the characterization, a statement of objectives, the background data, a description of the data collection and analysis program, a presentation or summary of the data, and quality assurance/quality control measures. The

report may be used to identify the appropriate course of action, which may include the following:

5.9.1.1 No further action;

5.9.1.2 Compliance monitoring;

5.9.1.3 Further risk evaluation under the RBCA process Tier 2 or Tier 3 analysis (data collection during the ASC should be sufficient to meet the requirements of a Tier 1 and Tier 2 analysis); or

5.9.1.4 Evaluation of remedial action alternatives, and subsequent selection of technologies, or combination thereof.

5.9.2 For further information on these courses of action, please refer to Guides E 1599 and E 1739.

5.9.3 The steps of an ASC process presented in 5.1 to 5.8 are illustrated in the example in Appendix X4. In addition, the example uses the results of the ASC to perform a RBCA Tier 1 and Tier 2 evaluation.

6. Keywords

6.1 accelerated; analytical methods; borings; characterization; chemicals of concern; corrective action; data quality; exposure pathways; field methods; ground water; LUST; mobilization; parameters; petroleum; risk based approach; sampling tools

APPENDIXES

(Nonmandatory Information)

X1. OTHER REFERENCES

X1.1 *ASTM Standards*:

D 1452 Practice for Soil Investigation and Sampling by Auger Borings⁶

D 1586 Test Method for Penetration Test and Split-Barrel Sampling of Soils⁶

D 1587 Practice for Thin-Walled Tube Geotechnical Sampling of Soils⁶

D 2488 Practice for Description and Identification of Soils (Visual-Manual Procedure)⁶

D 3550 Practice for Ring-Lined Barrel Sampling of Soils⁶

D 4447 Guide for Disposal of Laboratory Chemicals and Samples³

D 4448 Guide for Sampling Ground Water Monitoring Wells³

D 4700 Guide for Soil Sampling from the Vadose Zone⁶

D 4750 Test Method for Determining Subsurface Liquid Levels in a Borehole or Monitoring Well (Observation Well)⁶

D 4823 Guide for Core-Sampling Submerged, Unconsolidated Sediments⁷

D 5092 Practice for Design and Installation of Ground Water Monitoring Wells in Aquifers²

D 5299 Guide for the Decommissioning of Ground Water Wells, Vadose Zone Monitoring Devices, Boreholes and Other Devices for Environmental Activities²

D 5314 Guide for Soil Gas Monitoring in the Vadose Zone²

⁶ *Annual Book of ASTM Standards*, Vol 04.08.

⁷ *Annual Book of ASTM Standards*, Vol 11.02.

X2. AN EXAMPLE OF A DATA QUALITY CLASSIFICATION SYSTEM

X2.1 *Introduction*:

X2.1.1 This appendix describes an example of a four tiered data quality hierarchy modified from *New Jersey Department of Environmental Protection Field Analysis Manual*.⁸ Two significant modifications to the New Jersey Department of Environmental Protection and Energy (NJDEPE) Manual⁹ have been incorporated into the example data quality level hierarchy. First, the applications are for petroleum products only. The second modification designates Level 1 as screening levels, either qualitative or semiquantitative, that may require confirmatory analyses with higher data quality methods. Levels 2, 3, and 4 are considered to be essentially quantitative, with

Level 2 being less quantitative than Levels 3 or 4. These levels can produce data of sufficient quality that does not necessarily need laboratory confirmation on a routine basis. An overview of these data quality levels are presented in this appendix.

X2.1.2 The USEPA utilizes a two-tiered approach to data quality. The first category “Screening Data With Definitive Confirmation” would include data quality Levels 1 and 2. The second category “Definitive Data” would include data quality Levels 3 and 4.

X2.1.3 State regulatory programs may develop their own definitions for data quality for the methods listed in this appendix, and may have specific reporting requirements when using these methods. Details on data quality levels, use of field analytical methods, and specific reporting requirements can be obtained by contacting the appropriate state environmental regulatory agency, fire marshal, or other local jurisdictions.

⁸ New Jersey Department of Environmental Protection and Energy, *Field Analysis Manual*, July 1994.

⁹ New Jersey Department of Environmental Protection and Energy, *Alternative Groundwater Sampling Techniques Guide*.

X2.2 Data Quality Level 1:

X2.2.1 Level 1A methods are intended to be used for health and safety evaluations, initial screening of soil and ground water for chemical(s) of concern. The measurements made with these methods (1A) are qualitative and only provide an indication of the presence of contamination above a specified value (for example, pass or fail, positive or negative). Because measurements made with these methods may not always be consistent, the data shall only be used as an initial screening for sample locations for analysis using higher level methods. Clean samples cannot be determined from these methods at this level.

X2.2.1.1 Instruments used for data quality Level 1 include: photoionization detector (PID) survey instruments, flameionization detector (FID) survey instruments, colorimetric analysis, and headspace analysis.

X2.2.1.2 Quality control procedures are limited primarily to instrument calibration, consistency in method procedure, and background level checks. Since relatively few quality control procedures are employed compared to higher-level field methods, data quality is very much a function of sample handling techniques and analyst skill.

X2.2.2 Level 1B methods can be used for qualitative and semiquantitative screening and defining the location of known types of contamination (that is, orders of magnitude or ranges). Level 1B data can be generated when PIDs and FIDs are used with controlled sample preparation and analysis procedures that include additional QA/QC such as that used with polyethylene bag headspace.

X2.2.2.1 Quality Assurance (QA) procedures include multipoint calibration curves using matrix-spiked field standards, a calibration check using matrix spike duplicates, and a field blank/background sample.

X2.2.2.2 Depending on regulatory requirements, laboratory confirmation may be needed for establishing laboratory-field correlation over the concentration ranges measured for confirming the achievable lower detection limit.

X2.3 Data Quality Level 2:

X2.3.1 Level 2 methods are intended to be used for delimitation of chemical(s) of concern. These methods can achieve a high degree of reproducibility when required QA/QC procedures are employed.

X2.3.2 Level 2 methods are typically laboratory methods that have been adapted for field use (that is, field gas chromatograph (GC), portable infrared (IR)) or are EPA-derived methods (for example, immunoassay). These methods may not be as rigorous because field extraction's are not directly comparable to laboratory extraction methods.

X2.3.3 Quality assurance (QA) requirements include initial multi-point calibration curves, continuing calibration checks, matrix spike duplicates, background/blank samples, laboratory confirmation of clean samples, and possibly contaminated samples depending on the objective. A matrix spike recovery should be performed on a site-specific basis.

X2.3.4 Level 2 methods that provide a direct numerical value for the indicator measured but do not definitively identify the chemical(s) of concern present (for example, immunoassay, portable IR) are considered semiquantitative. Level 2 methods that measure specific constituents (for example, transportable GC's) are considered quantitative.

X2.3.5 Depending on regulatory requirements, laboratory confirmation of a portion of the samples may be needed for establishing laboratory-field correlation over the concentration ranges measured for confirming the achievable lower detection limit.

X2.3.6 Level 2 methods also include EPA field screening and laboratory methods. The laboratory methods considered to be Level 2 have limited QA information documented. The quality of the data generated using Level 2 laboratory methods depends on the sample handling, storage, and preservation procedures, and analytical procedure and QC used.

X2.4 *Data Quality Level 3*—Level 3 methods are approved laboratory methods with complete QA/QC (for example, EPA Laboratory Methods [see USEPA SW846], third or more recent edition). Level 3 analyses can be performed at off-site laboratories or at on-site mobile laboratories that perform EPA methods. Certain regulatory agencies may require these laboratories to be certified.

X2.5 Data Quality Level 4:

X2.5.1 Level 4 methods are generally “state of the art” methods developed specifically for a particular site or chemical(s) of concern. Level 4 methods are used when standard laboratory methods are either unavailable or impractical.

X2.5.2 Generation of Level 4 data may necessitate the use of a laboratory that specializes in methods development.

X3. CHARACTERIZATION PROPERTIES AND PARAMETERS

X3.1 Two sets of parameters are presented in this Appendix. See Table X3.1 for a list of physical and chemical properties and hydrogeologic characteristics and Table X3.2 for a list of input parameters and methodologies for ASTM RBCA Tier 1 and Tier 2 evaluation. These lists are provided as an example of parameters that may be collected and evaluated during an ASC.

X3.2 List of Physical and Chemical Properties and Hydrogeologic Characteristics:

X3.2.1 This list is intended to provide an example of a broad range of information that may be collected during a site characterization. It is not comprehensive nor does it imply that all of this information should be collected for every site characterization. A user applying the ASC approach would consider this list, when determining the benefits of collecting information before and during the mobilization.

X3.2.2 The footnoted parameters (see Table X3.1) are listed in Guide D 5730. There are additional ASTM standards and references for methods that may apply but have not been listed

TABLE X3.1 List of Physical and Chemical Properties and Hydrogeologic Characteristics

Fluid Properties (Liquid, Dissolved and Vapor-Phase Contaminants):

Density^A
 Viscosity
 Interfacial tension^A
 Solubility
 Sorptive properties^A
 Vapor transport properties^A
 Chemical composition

Fluid-Media Properties:

Wettability^A
 Capillary pressure-saturation relations
 Moisture content^A
 Relative permeabilities (includes air permeability)^A

Porous Media Properties:

Intrinsic permeabilities
 Porosities (total and effective)
 Bulk density^A
 Pore volume^A
 Hydraulic conductivity^A
 Grain size distribution^A
 Organic carbon content^A
 Clay content (soil classification)^A
 Infiltration rate^A
 Oxygen and carbon dioxide content
 Soil pH^A
 Storativity^A

Local Geology/Hydrogeology:

Heterogeneities
 Stratigraphy/lithology/soil type
 Presence, type, and relative abundance of consolidated media
 Preferential migration pathways (for example, utilities, fractures, and so forth)
 Depth to ground water^A
 Depth to bedrock
 Aquifer thickness
 Hydraulic gradient^A
 Ground water flow direction^A
 Dissolved oxygen^A
 REDOX potential^A
 Dissolved metals
 Total dissolved solids^A
 Ground water pH^A

Distribution of Chemical(s) of Concern:

Presence of nonaqueous phase liquid.
 Depth to impacted soil in the unsaturated or saturated zones.
 Spatial distribution of chemical(s) of concern in soils.
 Spatial distribution of chemical(s) of concern in ground water.

^A The parameters listed are in Guide D 5730.

in this guide.

TABLE X3.2 Input Parameters and Methodologies for ASTM RBCA Tier 1 and Tier 2 Evaluations

NOTE 1—Collection of data should not be limited to a specific tier and should be collected based on site specific conditions and potential impacts to receptors.

RBCA Input Parameters	Methodology/Source	Tier
Physical and Chemical Characteristics of the Chemicals of Concern (COC)		
Identify Potential Source, Nature of Release and COC: time, location of potential release, substance released (gasoline, diesel, etc.)	Evaluate historical data, release reports, site specific information	1
Identify Characteristic of COC: most prevalent, mobile, toxic constituents	Review literature to evaluate chemical/toxicological properties of COC	1
Maximum COC Concentrations: maximum concentrations in affected media (source areas)	Obtain samples, conduct chemical analysis of soil, ground water, and/or vapor samples, identify presence/absence of NAPLs	1
Extent of COC in affected media: lateral and vertical extent of COC affected media	Collect soil/ground water/vapor samples, perform chemical analysis to determine concentration and migration pathways of COC	1,2
Representative COC Concentrations: representative COC concentrations in source area	Perform statistical evaluation of sampling analytical results	1,2
Regional and Site Specific Hydrogeologic Conditions		
Regional Surface and Subsurface Geology/Hydrogeology: ground water recharge areas, ground water to surface water discharge rates, topography, location of surface waters, local drainage. General/published soil and aquifer properties (for example, permeability, porosity, hydraulic conductivity)	Review published information: topographic maps, local geologic mapping information. Based on site specific sampling observations, determine general soil and aquifer properties from published literature	1
Site Specific Soil Characteristics: stratigraphy, soil heterogeneity, presence, type, and abundance of consolidated media, permeability, moisture content, bulk density	Collect and observe soil samples in both impacted and non-impacted areas	1,2
Site Specific Aquifer Properties: depth to capillary fringe, depth to ground water, gradient and direction, effective porosity, hydraulic conductivity.	Collect site specific measurements in both impacted or non-impacted areas	1,2
Site Specific Ground water Attenuation Factors: soil fraction organic carbon (f_{oc}), determination of COC decay rate	Collect and analyze samples for f_{oc} , COC, and ground water natural attenuation parameters. Calculate site specific COC decay rate	1,2
Potential Receptors, Current and Future Land Use		
Receptor Survey: private and public potable and non-potable water supply wells, surface waters, public water supply points of intake, wetlands, basements, residential properties	Review state and local health department water supply maps and records. Perform a site specific well canvas to locate unrecorded private wells. Identify nearby subsurface structures. Determine existing or potential receptors	1
Current and Reasonably Potential Future Land Use Survey: residential, commercial and industrial land use, zoning ordinances and restrictions, long term city land use plans	Perform site specific survey to identify land use including residential, commercial and industrial areas, locations of schools and day care facilities. Review local zoning ordinances, city land use plans, determine reasonably potential future land use	1,2
Exposure Assessment		
Transport Media	Identify potential transport media through which COC will migrate. Media based on site specific data	1
Transport Mechanism	Based on transport media, determine the soil to ground water leaching potential, volatilization, dispersion and ground water migration	1,2
Exposure Pathways	Review site specific information, transport media and mechanisms to determine possible exposure pathways such as ingestion of soil and/or ground water, vapor inhalation, dermal contact with soils and/or ground water. (Evaluate preferential migration pathways.)	1,2
Points of Exposure	Review receptor survey and site specific information, identify points of exposure such as drinking water, surface waters, surface soils and basements	1,2

X4. EXAMPLE OF THE USE OF AN ACCELERATED SITE CHARACTERIZATION PROCESS IN A RBCA TIER 1 AND TIER 2 EVALUATION

X4.1 Introduction

X4.1.1 The following example illustrates the ASC process presented in Fig. 1 at a petroleum release site. A hypothetical site with relatively complex geologic conditions is presented in this example to show that the ASC process works for complex sites as well as simple ones. For complex sites, the ASC

process can be used to quickly identify gaps in the subsurface data and then fill those gaps while the subsurface sampling tools are still on site.

X4.1.2 In this example, the site is being characterized to provide data necessary to make corrective action decisions following a method similar to Guide E 1739. An ASC can be

used at any UST (or other petroleum source) site for accurate and rapid site characterization.

X4.2 Release Scenario

X4.2.1 Discovery and Notification—In 1995, a release of petroleum hydrocarbons at a closed service station was suspected after a contractor noticed a strong gasoline odor in the sanitary sewer adjacent to the station (see Fig. X4.1(a)). The contractor contacted the local fire department who determined that the gas vapors did not constitute an immediate explosion hazard. The fire department filed an inspection report with the State Environmental Department (SED). The SED subsequently sent a letter to the current property owners and owners of nearby gas stations, requesting an investigation of the source of the gasoline release.

X4.3 Step 1—Identify Site Characterization Purpose

X4.3.1 The site was investigated because of the letter from the SED to investigate the suspected release. The property owner was also interested in selling the property and needed to define the residual hydrocarbons identified during the tank closure. The site owner retained a consultant who proposed conducting an accelerated site characterization in order to

collect the information necessary to perform an ASTM Risk-Based Corrective Action (RBCA) evaluation and determine the appropriate corrective action, an approach that is supported by the SED. The guidelines for risk-based corrective action are outlined in a new state UST corrective action manual, which closely follows the ASTM three-tiered Guide E 1739.

X4.4 Step 2—Review Existing Information

X4.4.1 Before the field activities were defined, available information about the site geology, history, ground water conditions, and nature and distribution of chemical(s) of concern was collected and reviewed. A summary of the review included the following information.

X4.4.2 Site History—The former station began dispensing gasoline in the mid-1950's. Gasoline was stored in two 10 000-gal tanks in the southern portion of the property. Two pump islands were located adjacent to the UST area. The station was closed in the early 1980s, and, according to a note in the fire department's file, the tanks and associated piping were removed and the excavation was filled with clean soil. The dispensing pumps were removed, and the site is now operated as a tune up shop and auto repair garage. No records are available regarding the construction of the tanks, the tank

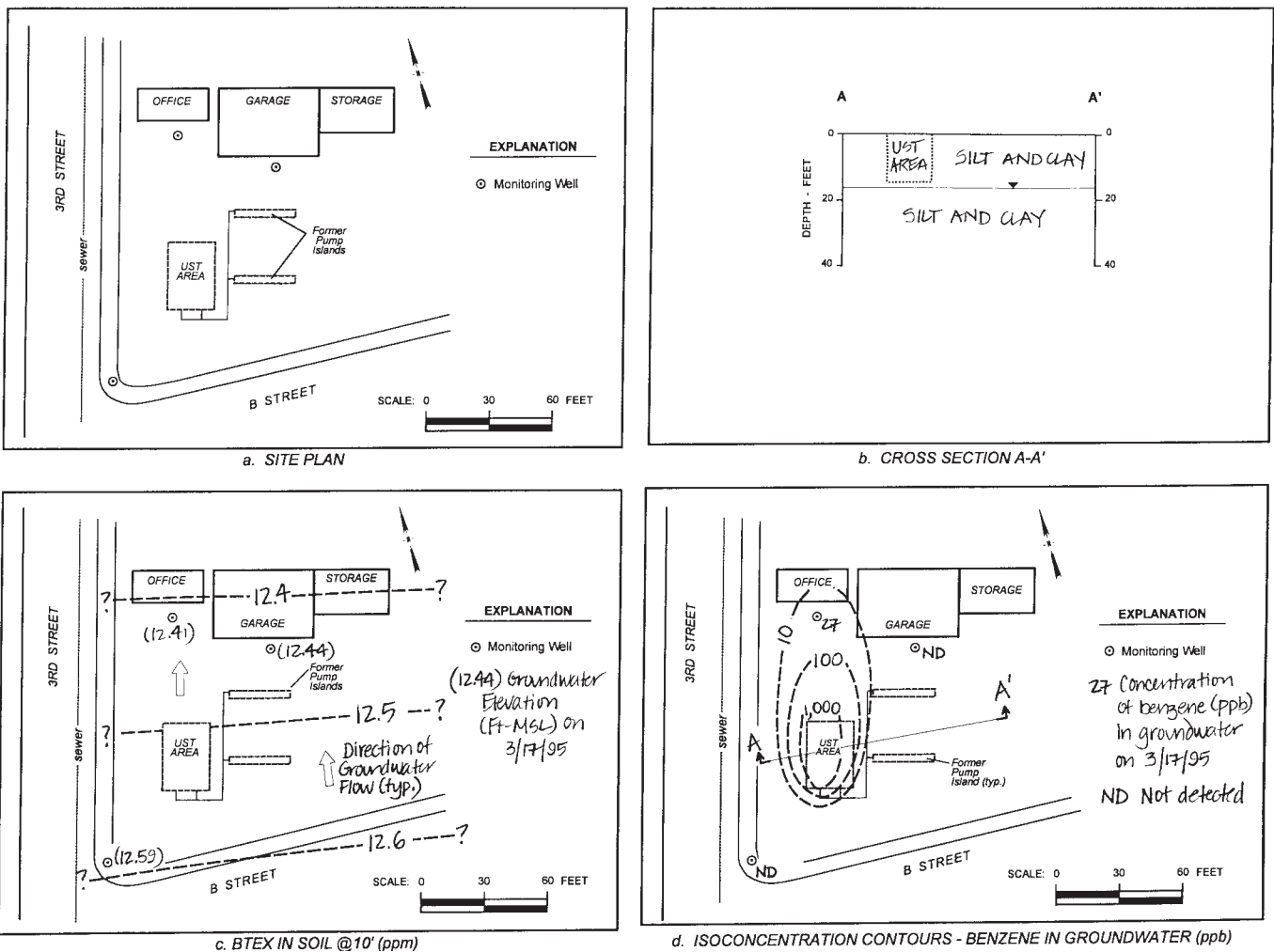


FIG. X4.1 Initial Conceptual Model (Prior to Beginning Field Work)

removal, or the location of underground piping. No inventory records were found that might have helped define the type and magnitude of the subsurface petroleum hydrocarbon release. From the 1984 source investigation report, the site well installation report, boring logs, and previous analytical results were carefully reviewed. Geologic data shown on the boring logs was compared to published data from USGS and Soil Conservation Service maps.

X4.4.3 Regional and Local Hydrogeologic Reports—Reports published by the United States Geological Survey (USGS), State Geologic Survey, Soil Conservation Service, and the local water service provided valuable information regarding the subsurface geology and ground water conditions (for example, water table elevation, hydraulic properties, general flow direction) near the site. Regional information was also obtained from subsurface investigation reports of nearby sites.

X4.4.4 Previous Investigations—An initial source investigation was performed at the site in 1984 by the contractor who removed the tanks. The investigation consisted of installing two ground water monitoring wells along the northern boundary of the site, that was presumed to be downgradient of the UST area and the pump islands. A third well was installed upgradient from the UST area near the sewer line.

X4.4.5 Ground Water Analysis—Analyses of ground water samples collected soon after the wells were installed detected 80 mg/L (ppm) of benzene in the well downgradient from the UST area. No benzene was detected in the well located downgradient of the pump islands. No chemical analyses of soil samples from the borings was performed. Additional ground water samples were collected infrequently from the wells after the initial sampling event. Benzene concentrations in subsequent samples collected from the well downgradient from the UST area were erratic, ranging from non-detect (ND) to 150 ppb. The erratic range of analytical results was attributed to several factors including laboratory error, sampling bias, or seasonal ground water level fluctuations. Samples from the well downgradient from the pump islands consistently yielded ND results.

X4.4.6 Adjacent Property—The site is located in an urban area. Several other gas stations and industrial facilities are located within ½ mile of the site. Consequently, the possibility of upgradient sources of petroleum hydrocarbons (and other chemical(s) of concern) certainly exists. Moreover, several environmental investigations have been performed at nearby sites, providing valuable information about the geologic and ground water conditions beneath the site.

X4.4.7 Receptor Survey/Identification of Point(s) of Exposure—Further review of published reports and project files at the USEPA, SED, and the County indicated the presence of a municipal water supply well within 1500 ft (457 m) of the site. The on-site manager contacted the SED case manager and a representative from the local water department to determine the current status of the well. According to the water department, the well is no longer being used in the water supply system due to low yield. The well was recently abandoned. No other private or public water supply wells were located within a one mile radius of the site. No surface water

bodies were identified within 1500 ft (457 m) of the site. As-built plans of the utility lines adjacent to the site were reviewed at the County Public Works Department in order to identify potential pathways of vapor or ground water migration from the site to the sanitary sewer line where the hydrocarbon vapors were initially detected. Additionally, according to the tenants, the on-site tune-up/repair facility has a small basement.

X4.4.8 Nearby Releases—Review of USEPA, SED and County files indicated several petroleum release sites and one Superfund site upgradient from the subject property.

X4.4.9 Interview—A former employee who worked at the site during its operation was interviewed by the on-site manager. The former employee provided valuable anecdotal information regarding the location of the USTs and piping systems, unreported inventory losses, tank and piping upgrades, and the removal of the underground tanks. Information provided by the former employee was summarized on a scaled base map of the site (see Fig. X4.1(a)).

X4.5 Step 3—Develop Conceptual Model

X4.5.1 Based on the review of existing regional and site data, the on-site manager began to formulate an initial conceptual model of the site geology/hydrogeology, and nature and distribution of chemical(s) of concern.

X4.5.2 Developing Site Maps—A large amount of data was compiled from various sources. To keep the data organized and accessible, the on-site manager summarized and compiled the information (representing the conceptual model) onto some simple, hand-drawn graphics (see Fig. X4.1). These graphics included a large-scale base map, hydrogeologic cross sections, ground water elevation contour maps, and isoconcentration contour maps. The graphics depicted in the figures are simplified and reduced in size for the purpose of this guide. The actual graphics were larger working drawings that could easily be revised in the field as new data were collected.

X4.5.3 Developing Working Hypotheses—Regional hydrogeologic data were compiled on the site base map. The site boring logs and water level data were then reviewed to see if they were consistent with the regional information. Available data regarding the nature and distribution of chemical(s) of concern were compared with the anecdotal information obtained from the former employee and the as-built utility map obtained from the County Public Works Department. The on-site manager synthesized all of the available data and developed working hypotheses about the subsurface distribution of geologic materials, ground water flow direction, source areas, release volumes, and distribution of hydrocarbons in soil and ground water.

X4.5.4 Key Site Features—Site features that were not apparent in the previous investigation but were described in the geologic reports were incorporated into the initial conceptual model. The model emphasizes the following key features to assist the investigator in focusing the characterization.

X4.5.4.1 Fluvial Deposits—Regional geologic data indicate that the shallow subsurface materials near the site are a mixture of fluvial and estuarine sediments. Granitic bedrock occurs at a depth of approximately 500 ft (152 m) below ground surface (bgs). The fluvial deposits in the area are typically 2 to 15-ft

(0.6 to 4.6 m) thick, elongated silty sand beds (that is, buried stream channels) encapsulated within finer-grained silt and clay estuarine sediments. The buried stream channels regionally are oriented N40W. Boring logs from the three site monitoring wells do not show a silty sand unit beneath the site. However, a boring drilled across the street to the west during a previous investigation encountered a 12-ft (3.7 m) thick silty sand bed.

X4.5.4.2 Aquifer Characteristics—Unconfined ground water occurs regionally within the unconsolidated sediments at depths ranging from 25 to 30 ft (7.6 to 9.1 m) bgs. This is consistent with water levels measured in the site ground water monitoring wells. Ground water flows regionally to the north, but localized ground water flow patterns exist due to preferential ground water flow within the more permeable buried stream channels. The inferred direction of ground water flow beneath the site is toward the north.

X4.5.4.3 Source Area and Distribution of Chemical(s) of Concern—Locations of the former tanks, subsurface piping, on-site utility lines, and areas of artificial fill were compiled onto the site map by the on-site manager. A former employee indicated that strong petroleum odors and discolored soil were evident beneath the supply lines leading to the southern pump island. Several scenarios were developed to estimate the distribution and relative magnitude (volume and concentration) of residual petroleum hydrocarbons resulting from the presumed piping release. Based on the conceptual model of the site geology/hydrogeology, the likely extent of a dissolved hydrocarbon plume was estimated.

X4.6 Step 4—Design Data Collection and Analysis Program

X4.6.1 Before beginning the field investigation, the consultant prepared a “Data Collection and Analysis Program” for the field work. The program included a short discussion of the following:

- X4.6.1.1** Methods that would be used to collect subsurface samples,
- X4.6.1.2** The media to be analyzed,
- X4.6.1.3** The field analytical program,
- X4.6.1.4** Protocol for communicating project status to client and SED,
- X4.6.1.5** Contingency plans, including plans to procure off-site access, and
- X4.6.1.6** Safety program.

X4.6.2 On most projects, a data collection and analysis program is prepared as an internal guide for the use of the project team members. Highlights of the data collection and analysis program for the subject investigation were as follows:

X4.6.3 Geophysical Survey—Before a sampling strategy was fully developed, a magnetometer survey was used to confirm the location of the utilities and other potentially buried metallic objects or structures. This information was compared with the other existing information from the previous investigation, as-built plans, and anecdotal information provided by the former employee.

X4.6.4 Methods to Collect Subsurface Samples—Because of the unconsolidated nature of the subsurface materials, the relatively shallow depth of the investigation, and the need to

sample multiple media (that is, soil, vapor, and ground water) a direct-push (DP) method of sample collection was selected. The DP sampling tools are small-diameter steel probes that are pushed, pounded, or both, into the ground. These sampling tools can be used to collect soil, ground water, and soil vapor samples. The DP sampling tools collect a greater number of depth-discrete samples per day than conventional drilling methods. In addition, small-diameter monitoring wells (monitoring points or microwells) can be installed with most DP rigs, which do not generate drill cuttings, eliminating the cost of soil disposal.

X4.6.5 Alternative Sampling Methods—If the site was underlain by consolidated sediments or if the sampling depths were much greater, another method of collecting samples, such as conventional hollow stem auger or rotary drilling, would have been necessary. Accelerated site characterization (ASC) is an approach (not a set of sampling tools) that is fully compatible with conventional sampling methods.

X4.6.6 The Field Analytical Program—After discussions with the SED, a mobile laboratory was contracted to perform the analytical testing. The mobile laboratory performs the analyses of soil and ground water on site, providing real-time analytical data to the on-site manager. The mobile laboratory selected was able to process up to 35 samples per day, and was certified by the state to perform analyses for petroleum hydrocarbons. Soil and ground water samples are analyzed for the constituent of concern or indicator compound. Physical properties of the porous media and chemical(s) of concern are observed, measured, or estimated.

X4.6.6.1 Soil Screening—All soil samples were to be screened in the field with a portable flame ionization detector (FID). An FID was used because of the high sensitivity to gasoline vapors (ppmv) and especially to alkanes present in weathered gasoline. The FID has a linear response throughout its operating range and can be used to detect a wide range of hydrocarbon concentrations.

X4.6.6.2 Soil and Ground Water Analyses—Soil samples between depths of 10 and 30 ft (3.1 and 9.1 m) were to be analyzed by the mobile laboratory every 5 ft (1.5 m), and at intervals where significant hydrocarbon concentrations were indicated by the portable FID. Soil samples were to be analyzed for benzene, toluene, ethylbenzene, and xylenes (BTEX) by EPA Method 8020 and total petroleum hydrocarbons as gasoline (TPH-G) by Modified EPA Method 8015 in accordance with SED requirements. Ground water samples were to be analyzed for BTEX by EPA Method 8020, and for pH, Eh, and dissolved oxygen, using portable field instruments.

X4.6.6.3 Physical Properties—In addition to chemical analyses, physical properties of the porous media, ground water, and hydrocarbons present were observed, measured, or estimated as part of the data collection and analysis program. The vadose zone thickness, soil type and porosity, structure, stratigraphy, heterogeneities, moisture content, and location of chemical(s) of concern were documented on soil logs. In addition, soil samples were collected for measuring total organic carbon (TOC), bulk density, porosity and moisture content to make more accurate predictions of the fate and transport of chemical(s) of concern. The aquifer thickness, flow

direction, and gradient were determined from water level measurements, and hydraulic conductivity will be determined from slug tests. Ground water quality indicators (for example, p11, total dissolved solids) were measured using portable meters. Dissolved oxygen levels were also measured using portable meters to gain an understanding on whether natural biodegradation is occurring.

X4.6.6.4 Protocol for Communicating Project Status—The consultant agreed to update the client and SED with the status of the ASC at the end of each field day. The on-site manager had a pager and portable telephone to communicate with all project participants whenever necessary.

X4.6.6.5 Permits—Before beginning the field program, the on-site manager obtained permits for drilling borings (DP probes are considered to be borings by the SED) and installing monitoring wells at the site. One permit was sufficient for any number of borings and wells. Based on the data review, it seemed likely that off-site exploration beneath Third Street would be necessary. Therefore, the on-site manager obtained an encroachment permit from the city and filed a traffic plan with the county public works department. As part of this permit, the on-site manager also included B Street in the permit and plan.

X4.6.6.6 Utility Clearance—A private underground utility locating company was hired to locate subsurface utility lines beneath the property and Third and B Streets. This was done in order to avoid penetrating the utility lines with the DP sampling equipment. The utility locating was directly supervised by the on-site manager, because information regarding the location of subsurface utility lines gave the on-site manager valuable information about the location of potential migration pathways for chemical(s) of concern.

X4.7 Step 5—Field Activities

X4.7.1 The field investigation was conducted in three days. The on-site iterative process of collecting information, refining the conceptual model, and guiding the investigation is represented in this example.

X4.7.2 Day 1: Initial Investigation—On the first day of the field investigation, samples were collected at the locations shown in Fig. X4.2(a). Soil samples were collected at a minimum of every 5 ft (1.5 m). The assistant geologist logged the soil samples in detail. Soil and ground water samples were screened with a portable FID. Select samples were submitted to the on-site mobile laboratory for chemical analysis. Several soil samples were collected and preserved for later analysis of

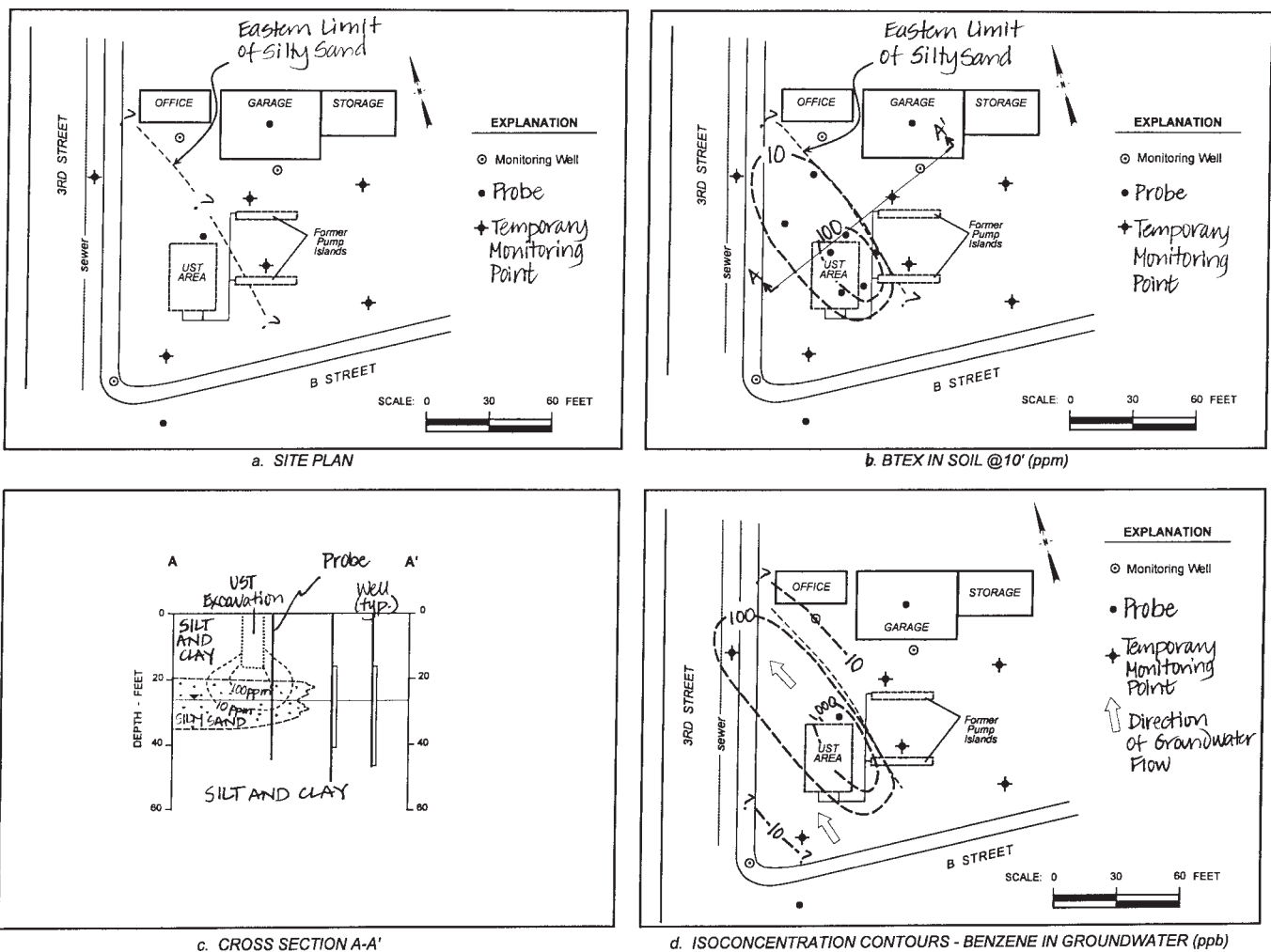


FIG. X4.2 Conceptual Model (After Day 1)

total organic carbon (TOC), bulk density, and moisture content. Site-specific values of those parameters would be necessary for making more accurate estimates of fate and transport of chemical(s) of concern during the RBCA evaluation (see X4.9). Geologic information, depth to ground water, and soil and ground water analytical results were compiled throughout the day onto the field drawings shown in Fig. X4.2.

X4.7.2.1 Source Area—To investigate the suspected source area, soil and ground water samples were collected from locations immediately north of the former UST area and former tank islands. Soil and ground water immediately north of the UST area contained high concentrations of chemical(s) of concern as anticipated from the initial conceptual model, however, the samples adjacent to the pump islands contained little or no concentrations of chemical(s) of concern. Dissolved oxygen levels were also significantly lower than levels measured in the upgradient location. The UST area, therefore, seemed to be the likely source of the release. This is consistent with the initial conceptual model.

X4.7.2.2 Site Geology/Hydrogeology—The boring drilled near the former UST area penetrated a native silty sand bed between the depths of 20 and 33 ft (6.1 and 10.1 m) bgs, that was thought to extend beneath the neighboring property to the west (a northwest orientation of this sand bed was consistent with the regional geologic setting). This finding indicated a revision to the initial conceptual model. Soil and ground water samples were then collected from other portions of the site to identify significant geologic units or obvious zones of contamination. Because the subsurface geology was more heterogeneous than initially thought, continuous soil cores were collected below a depth of 15 ft (4.6 m) bgs. (Continuous soil cores are necessary to accurately identify geologic contacts and thin beds.) During the course of the day, the silty sand bed was penetrated in three additional locations, confirming its northwest-southeast orientation. Unconfined ground water was encountered within the silty sand bed at a depth of approximately 26 ft (7.9 m) bgs.

X4.7.2.3 Distribution of Chemical(s) of Concern in Ground Water—Once the presence of the buried stream channel was identified, the on-site manager suspected that it may control the movement of ground water, and hence migration of chemical(s) of concern, beneath the site. Indeed, isoconcentration contours of benzene in the ground water samples clearly indicated a northwest alignment of dissolved chemical(s) of concern within the unit (see Fig. X4.2(d)). Benzene concentrations in ground water in the southwest portion of the site upgradient from the former UST area, however, were anomalously high (see Fig. X4.3(b)). Chromatograms of water samples collected in the southwestern area had a different “fingerprint” than chromatograms of water samples in the UST area, leading the on-site manager to speculate about the likelihood of an upgradient source(s) of dissolved petroleum hydrocarbons. Also, background dissolved oxygen levels were significantly higher than those encountered in the plume.

X4.7.2.4 Temporary Monitoring Points—Six small-diameter temporary monitoring points, consisting of 3/4-in. (19.05 mm) diameter slotted PVC, were installed in the DP probe holes shown in Fig. X4.2(a). The temporary monitoring

points were installed to provide a way to measure the ground water elevation at many locations beneath the site. Installing numerous temporary monitoring points allowed complete definition of ground water flow direction and hydraulic gradient beneath the site. Holes that were not converted to temporary monitoring points were filled with bentonite grout.

X4.7.3 Day 2—Refining Conceptual Model—Characterization of the site continued on Day 2, with the on-site manager collecting additional subsurface data to refine the conceptual model of the site geology/hydrogeology, and nature and distribution of chemical(s) of concern. The elevation of the tops of the temporary monitoring points were surveyed relative to the site datum (mean sea level) in order to convert depth-to-water measurements to ground water elevations.

X4.7.3.1 Defining Buried Stream Channel—The eastern and western limits of the buried stream channel were refined by collecting additional soil samples from locations in between DP probe holes advanced during Day 1. The western limit of the buried stream channel was found to coincide with the southwestern corner of the site (see Fig. X4.3(a) and (b)). Additional DP probes were advanced to confirm that the eastern and northern portion of the site was underlain entirely by silt and clay, and that ground water there was not impacted by the petroleum hydrocarbon release.

X4.7.3.2 Distribution of Chemical(s) of Concern in Soil—The areal and vertical distribution of chemical(s) of concern in soil began to be clearly defined. Contours of BTEX in soil showed that the highest levels of concentrations of chemical(s) of concern were directly beneath the former UST excavation (see Fig. X4.3(a)), and lower levels occurring downgradient from the UST excavation area. Also, analyses of additional ground water samples showed that the dissolved plume of benzene extended off site, beneath Third Street (see Fig. X4.3(b)).

X4.7.4 Day 3—Filling Gaps—On the third and last day of the investigation, the remaining gaps in the site characterization were filled.

X4.7.4.1 Migration Pathways for Chemical(s) of Concern—Soil samples were collected in and around the former UST excavation to further define the source of the release. The material used to fill the excavation was found to be permeable, medium-grained sand. In addition, original tank backfill material (also medium-grained sand) underlay the excavation fill and extended several feet deeper than was originally thought, into the buried stream channel (see Fig. X4.3(c)), thus providing a direct pathway from the UST backfill to the silty sand bed.

X4.7.4.2 Source Confirmation—Several soil samples were collected adjacent to the location of the former supply lines where the former employee recalled seeing discolored soil. Analyses of soil samples from these locations indicated that the distribution of chemical(s) of concern was limited to shallow depths. This confirmed that the former supply lines were not a significant source of the petroleum release. The true location of the hydrocarbon release was identified using geologic data from two DP probes that penetrated the tank excavation. The floor of the original tank excavation slopes towards the north,

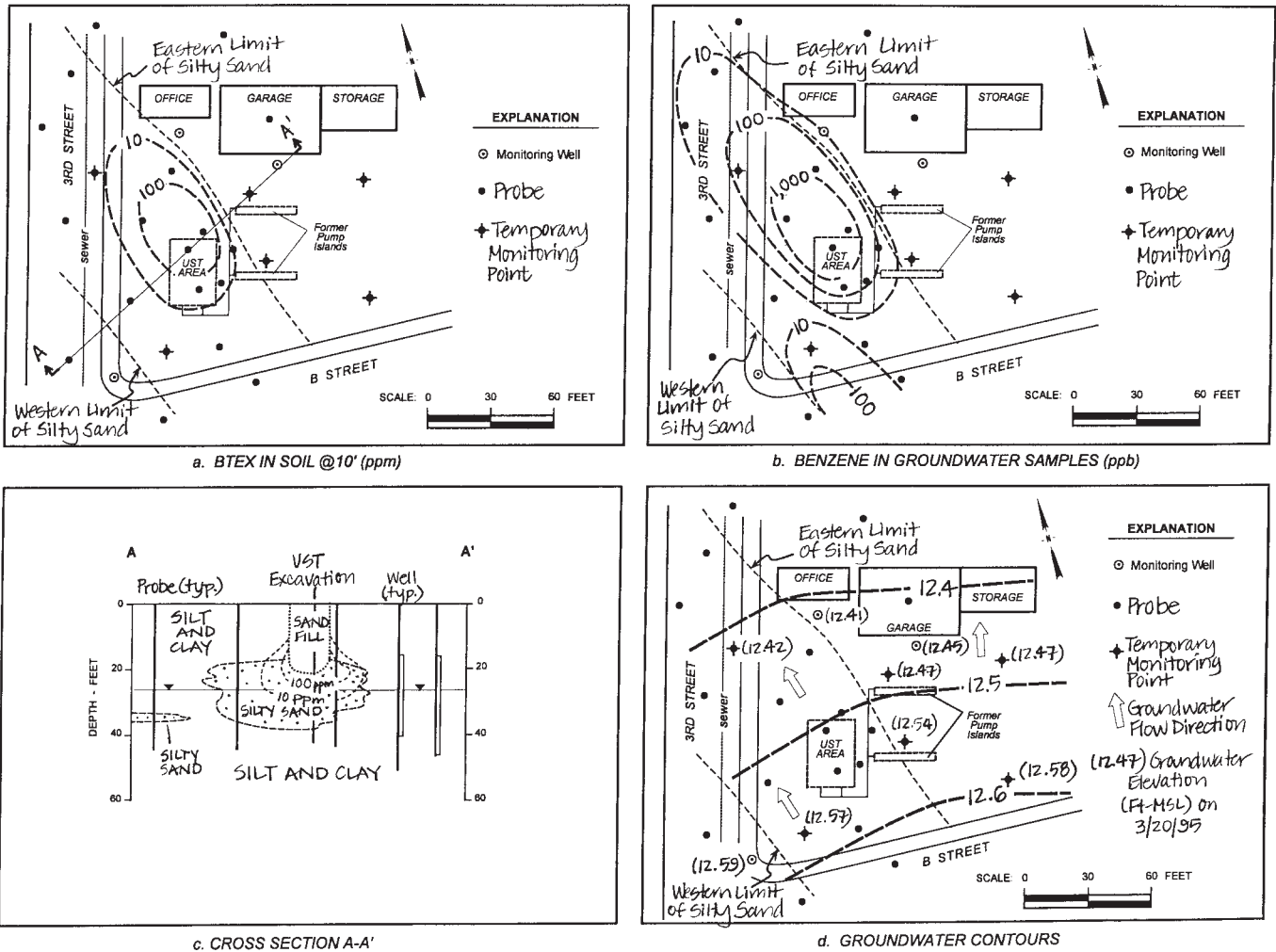


FIG. X4.3 Final Conceptual Model (After Day 3)

therefore, petroleum hydrocarbons that leaked from the USTs accumulated and seeped from the northern end of the original tank excavation. This hypothesis is supported by the distribution of residual petroleum hydrocarbons in soil (see Fig. X4.3(b)).

X4.7.4.3 Potential Off-Site Source—Several soil and ground water samples were collected in the southwestern portion of the site and beneath B Street to investigate the anomalous analytical data collected during Day 1. The presence of relatively high benzene concentrations in ground water beneath B Street, different chromatographic fingerprint of samples collected in that area, and pattern of decreasing benzene concentrations in ground water samples collected closer to the former UST area indicates that a plume of dissolved petroleum hydrocarbons has migrated onto the subject property from an upgradient source.

X4.7.4.4 Ground Water Flow Direction/Slug Test—Water elevations measured in the temporary monitoring points and the existing monitoring wells indicate that ground water within the silt and clay flows toward the north, consistent with the regional ground water flow direction. Not surprisingly, within the buried stream channel, ground water flow toward the

northwest is indicated. A slug test was conducted to estimate the hydraulic conductivity of the silty sand in the buried stream channel. Results from the slug tests indicated that the silty sand has a hydraulic conductivity of approximately 2×10^{-3} cm/s, a low to moderate hydraulic conductivity.

X4.7.4.5 Finalizing Conceptual Model—By the afternoon of the third day, the conceptual model had been developed in sufficient detail to meet the purpose of the project. No anomalies remained, and new DP probes yielded expected geologic information and analytical results. Moreover, the site data, including the geologic units, ground water depth and flow direction, and upgradient impacts, were consistent with the regional setting. The final conceptual model of the site is depicted in Fig. X4.3.

X4.7.4.6 Site Decommissioning—Before demobilizing from the site, two of the temporary monitoring points were removed and the resulting holes were filled with bentonite grout. The remaining four temporary monitoring points were left in place for an extended period (to provide additional ground water elevation and analytical data to help determine the stability of

the plume for remediation by natural attenuation purposes) before they were removed.

X4.8 Step 6—Report Findings

X4.8.1 Through the use of the ASC process, site characterization was completed in a fraction of the time needed for a conventional investigation. The use of a geophysical survey, DP sampling technology and on-site analysis allowed the on-site manager to direct the investigation, filling in gaps in the subsurface data, until the characterization was complete. The marked reduction in dissolved BTEX concentrations in ground water downgradient from the UST excavation area, coupled with low dissolved oxygen levels in the core of the plume, indicates that remediation by natural attenuation of BTEX components may be occurring.

X4.8.2 A key to the success of the investigation was the up-front, pre-field review of available data and development of the initial conceptual model. Because of this work, the presence of the buried stream channel and upgradient petroleum release was not unexpected, and the investigation was not delayed when these anomalies were encountered. The significance of these discoveries should not be minimized. The presence of an upgradient source of dissolved hydrocarbons would certainly complicate efforts to remediate the subject property (if required). The results of this investigation would be more than sufficient for the SED to request an environmental investigation by the owner of the upgradient property.

X4.8.3 The primary migration pathway for chemical(s) of concern beneath the site is certainly different than what was initially thought. The ground water velocity and adsorptive properties of the buried stream channel are significantly different than the values from previous investigations. Moreover, because of the localized northwest ground water flow direction, the probable receptors and point(s) of exposure for chemical(s) of concern in ground water are altogether different than those identified in the previous investigations.

X4.8.4 In this example, the ASC provided accurate data to perform a RBCA Tier 1 and Tier 2 evaluation. Section X4.9 summarizes the details of this RBCA evaluation. If active remediation was deemed necessary, the thorough understanding of the site conditions ensures that effective remedial measures will be undertaken. Ongoing ground water monitoring will likely be required at the example site. The location of permanent monitoring wells can be selected based on the clear understanding of the site ground water flow patterns. In the report which was submitted to the SED within two weeks of the mobilization, the on-site manager summarized the major findings from the accelerated site characterization as follows:

X4.8.4.1 The USTs were the primary source of chemical(s) of concern. Chemical(s) of concern around associated piping was not continuous to ground water;

X4.8.4.2 The areal and vertical distribution and concentrations of chemical(s) of concern in soil and ground water had been defined;

X4.8.4.3 A buried stream channel was the primary migration pathway for the petroleum release;

X4.8.4.4 A potential upgradient source of dissolved hydrocarbons was identified; and

X4.8.4.5 Remediation by Natural Attenuation of petroleum hydrocarbons may be occurring beneath the site.

X4.9 RBCA Tier 1 and Tier 2 Evaluation Example

X4.9.1 *Initial Site Assessment, Site Classification and Initial Response*—Based upon the results from the review of existing information and the data collected during the site characterization, the on-site manager classified the site per specified scenarios (Table 3 of Guide E 1739). The site was classified as 3 - Ground water is impacted and non-potable water supply wells producing from the impacted interval are located > 2 years ground water travel time from the dissolved plume. The initial response action was to identify water usage of wells, assess the effect of potential impact, monitor the dissolved plume, and evaluate whether natural attenuation or hydraulic control are appropriate control measures.

X4.9.2 *Tier 1 Evaluation*—The site characterization information provided in the ASC example was used to perform a RBCA Tier 1 evaluation. Data collected during the site characterization defined the distribution of chemical(s) of concern in soil and ground water, location of potential receptors and point(s) of exposure, migration pathways and potentially complete exposure pathways.

X4.9.2.1 *Exposure Pathway Analysis*—Based upon the results of the receptor survey (see X4.4.7), the following exposure pathways were selected for a Tier 1 Evaluation:

X4.9.2.2 Soil-vapor intrusion from soil to enclosed spaces, and

X4.9.2.3 Ground water - vapor intrusion from ground water to enclosed spaces.

X4.9.2.4 *RBSL Comparison*—The on-site manager then compared the maximum site specific concentrations of chemical(s) of concern to the appropriate Tier 1 risk-based screening levels (RBSL's) from the Guide E 1739 example Tier 1 Look-Up Table (see tables for both soil and ground water below). The following criteria were used in the selecting the appropriate RBSL:

X4.9.2.5 Commercial/Industrial receptor,

X4.9.2.6 Target cancer risk of 10^{-4} , and

X4.9.2.7 Chronic hazard quotient = 1.

X4.9.2.8 The RBSL concentrations were selected from the table for the pathways listed above. A comparison of RBSL's to maximum concentrations of chemical(s) of concern detected during the ASC are listed below:

Soil RBSL's			
Chemical of Concern	RBSL Concentration (mg/kg)	Maximum Concentration (mg/kg)	Maximum > RBSL?
Benzene	1.09	13.23	Yes
Toluene	54.50	66.15	Yes
Ethylbenzene	1100.00	19.84	No
Xylenes	> RES ^A	112.45	No

Ground Water RBSL's			
Chemical of Concern	RBSL Concentration (mg/l)	Maximum Concentration (mg/l)	Maximum > RBSL?
Benzene	7.39	1.13	No
Toluene	85.00	0.08	No
Ethylbenzene	> S ^B	1.81	No

Xylenes	> S ^B	1.93	No
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^A RES - Selected risk level is not exceeded for pure compound present at any concentration.

^B > S - Selected risk level is not exceeded for all possible dissolved levels.

X4.9.2.9 The Tier 1 analysis indicated that the maximum benzene and toluene concentrations in soil exceeded the RBSL's. The investigator therefore performed a Tier 2 analysis.

X4.9.3 *Tier 2 Evaluation*—Before Tier 2 Site Specific Target Levels (SSTL's) were calculated, the on-site manager performed a statistical analysis of the soil analytical data to establish representative soil concentrations at the site. The analysis determined the 95th upper confidence limit (UCL) of the mean of the soil concentrations. The on-site manager compared the 95th UCL concentrations for benzene and toluene in soil to the Tier 1 soil RBSL's to determine if the SSTL's calculation was still necessary. The comparison showed that the 95th UCL concentration for toluene was below the Tier 1 RBSL, however the 95th UCL concentration for benzene exceeded the Tier 1 RBSL. In order to perform the SSTL calculation, the on-site manager summarized the site specific/physical properties data (for example, TOC, bulk density, porosity) for use in the SSTL equations.

X4.9.3.1 *Exposure Pathway Analysis*—The SSTL for benzene was calculated for the following exposure pathway: soil-vapor intrusion from soil to enclosed spaces.

X4.9.3.2 *SSTL Calculation*—The SSTL equations for the remaining pathway were developed using the examples outlined in Appendix X2 of Guide E 1739. The SSTL was calculated using the following criteria: commercial/industrial

receptor scenario, target cancer risk of 10⁻⁴, chronic hazard quotient = 1, and site specific data collected during the ASC.

X4.9.3.3 *SSTL Comparison*—The on-site manager compared the SSTL concentration to the 95th UCL:

Chemical of Concern	Soil SSTL's		
	SSTL Conc. (mg/kg)	95 th UCL Conc. (mg/kg)	95 th UCL > SSTL
Benzene	12.60	3.30	No

X4.9.4 *Corrective Action Evaluation*—The results of the Tier 1 evaluation indicated that the maximum concentrations of benzene and toluene in soil and ground water were above the Tier 1 RBSL's for the soil-vapor and ground water-vapor intrusion to enclosed space pathways. Further analysis in the Tier 2 evaluation determined that the 95th UCL concentration for toluene was below the Tier 1 RBSL and the 95th UCL concentration for benzene was below the Tier 2 SSTL. Because the 95th UCL concentrations for toluene and benzene did not exceed the RBSL's or SSTL's, active remediation was not warranted. In order to achieve the final corrective action goals, the on-site manager recommended that a ground water monitoring program be implemented. The monitoring program included collecting and analyzing ground water samples from on-site monitoring points for both concentrations of chemical(s) of concern and natural attenuation indicator parameters (for example, dissolved oxygen, nitrate, sulfate). Although not all natural attenuation parameters were analyzed during the ASC, the on-site manager believed that including natural attenuation parameters in the monitoring program would provide additional evidence that natural attenuation of the chemical(s) of concern was occurring and that the final corrective action goals would be achieved.

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