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Quality Assurance Guidance for Conducting Brownfields Site Assessments

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

Notice

This guidance document describes key principles and best practices for Brownfields site assessment quality assurance and quality control based on program experience. It is intended as a reference for people involved in the Brownfields site assessment process. This guidance manual does not constitute a rulemaking by the U.S. Environmental Protection Agency (EPA). The policies set forth in this document are intended solely as guidance. They are not intended, nor can they be relied upon, to create any substantive or procedural rights enforceable by any party in litigation with the United States. EPA officials may decide to follow the guidance provided in this directive, or may take action that is at variance with the guidance, policies, and procedures in this directive, on the basis of an analysis of specific circumstances. The Agency also reserves the right to change this directive without public notice. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

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EXECUTIVE SUMMARY

Many sites across the nation once used for industrial and commercial purposes are now abandoned or under-used. Some of these sites — often referred to as "Brownfields"— are contaminated; others are perceived or suspected to be contaminated. In 1993, the Environmental Protection Agency (EPA) created the Brownfields Economic Redevelopment Initiative to empower States, Tribes, communities, and other stakeholders to work together in a timely manner to assess and safely clean up Brownfields to facilitate their reuse.

This guidance document serves to inform Brownfields site managers of important quality assurance concepts and issues, and provides a road map for identifying the type and quality of environmental data needed to present a clear picture of the site's environmental conditions.

However, because of the wide range of site-specific issues, project goals, and the degree of difficulty that the Brownfields site assessment team may encounter, this document cannot anticipate every question likely to arise during the project. Therefore, when questions arise, it is hoped that the reader will turn to the extensively referenced Internet and document resources provided in Appendix C for more detailed information.

Brownfields Site Assessments

The Brownfields site assessment requires a team approach encompassing a range of multi-disciplinary knowledge and skills. The Brownfields site assessment should provide sufficient data of adequate quality to allow officials to confidently make decisions about the potential reuse of a Brownfields site.

Brownfields Site Assessment Process

The Brownfields site assessment process routinely involves one or more of the following activities: a review of historical records; a field investigation including sample collection and analysis; the assessment of data useability; and an evaluation of cleanup options and costs.

Through careful planning, the Brownfields site assessment team develops a conceptual site model and establishes and communicates the team's goals and how the team will reach those goals using a Quality Assurance Project Plan (QAPP).

Quality Assurance/Quality Control

Brownfields team members should understand the benefits of strong quality assurance (QA) and quality control (QC) procedures.

Quality assurance is an integrated system of management activities involving planning, implementation, assessment, reporting, and quality improvement to ensure that a process, item, or service is of the type and quality needed and expected. Quality control is the overall system of technical activities (including checks on sampling and analysis) that measure the performance of a process against defined standards to verify that they meet predefined requirements. Since errors can occur in the field, laboratory, or office, QC must be part of each of these functions.

Document Control

Document control is a crucial, but an often overlooked, component of quality assurance. It is critical to completion of the last stage of a Brownfields site assessment — review of data useability.

Data useability review depends on thorough documentation of predefined data specifications and the related events that take place during implementation of the project

Data Quality Objectives (DQO) Process

Data credibility is one of the most important challenges facing municipalities, Tribes, and States managing a Brownfields site assessment. An important planning tool used to help ensure data credibility is the DQO process.

The DQO process allows the Brownfields site assessment team to determine the level of data quality needed for specific data collection activities, and to estimate the cost associated with these activities.

SUMMARY OF THE DQO PROCESS

1. State the Problem: What is the purpose of the project?

2. Identify the decision(s): What are the available options under consideration?

3. Identify Inputs in the Decision(s): What information is needed to make informed, defensible decisions?

4. Define the Boundaries of the Study: What is the geographical extent and time and budget constraints for the project.

5. Develop a Decision Rule: Formulate "if...then" statements that relate the data to the decision they support.

6. Specify Limits on Decision Errors: Estimate how much uncertainty will be tolerated in the site decision(s).

7. Optimize the Design: Identify the most cost-effective means to gather the data needed. If obstacles exist, reassess all the steps of the DQO process to refine decisions and goals until a workable roadmap or decision tree is produced.

These seven steps are used during the planning of the Brownfields site assessment process to ensure that field activities, data collection operations, and the resulting data meet the project objectives. The DQO process is iterative, and the output of one step may affect prior steps. This may lead the Brownfields site assessment team to revisit some previous steps but will ultimately lead to a more efficient data collection design.

Application of the DQO process is actually a "common sense" approach that translates broad consensus-based goals into specific tasks. In this way, the Brownfields team uses the DQO process to prepare a road map, which can guide the project, inform the public and other interested parties, and bring newcomers to the project quickly up to speed.

Quality Assurance Project Plan (QAPP)

The Environmental Protection Agency requires that all Federally funded environmental monitoring and measurement efforts participate in a centrally managed quality assurance program.

Any Brownfields site assessment team generating data under this quality assurance program has the responsibility to implement minimum procedures to ensure that the precision, accuracy, and completeness of its data are known and documented.

To ensure this responsibility is met uniformly, each Brownfields site assessment team should prepare a written QAPP. The QAPP is a formal document describing in comprehensive detail the necessary QA and QC, and other technical activities that should be implemented to ensure that the results of the work preformed will satisfy the stated performance criteria.

The QAPP documents the project planning process (i.e., the DQO process), enhances the credibility of sampling results, produces data of know quality, and saves resources by reducing errors and the time and money spent correcting them.

This guidance document includes a description of a QAPP and template forms to prepare one.

SECTION 1. INTRODUCTION

Many sites across the nation once used for industrial and commercial purposes are now abandoned or under-used. Some of these sites — often referred to as "Brownfields"— are contaminated; others are perceived or suspected to be contaminated. In 1993, the Environmental Protection Agency (EPA) created the Brownfields Economic Redevelopment Initiative to empower States, Tribes, communities, and other stakeholders to work together in a timely manner to assess, and safely clean up Brownfields to facilitate their reuse. Successful Brownfields projects can help reverse the spiral of unaddressed contamination and its related problems and help maintain deterrents to future contamination.

CONCEPTS

QA - (Quality Assurance) an integrated system of planning, quality control, assessment, improvement, and reporting.
QC - (Quality Control) a system of technical activities that measure and control quality so that data meet users' needs.
QAPP - (Quality Assurance Project Plan) a document containing detailed procedures for achieving data quality; generally prepared for all EPA environmental data collection activities and approved prior to data collection.
DQOs - (Data Quality Objectives) quantitative and qualitative statements that define the type, quantity, and quality of data needed to support the site decision and acceptable levels of uncertainty in the data that form the basis for the decision.
DQO Process - a systematic planning tool that focuses on investigative goals and resultant decisions to help decision-makers plan to collect the type and quality of data that meet the acceptable level of uncertainty.

Because concerns about future environmental risks and liability can hinder redevelopment, the Brownfields Initiative seeks to minimize the uncertainty surrounding actual or perceived contamination associated with these sites. Establishing and following comprehensive quality assurance (QA) procedures during the collection of environmental data relating to site contamination helps to minimize uncertainty.

This document provides municipalities, Tribes, and States with guidance for an overall approach to quality assurance for Brownfields site assessments. It includes a description of a Quality Assurance Project Plan (QAPP) and forms necessary to prepare one. (See Appendix A for the QAPP template.) The guidance presented here provides a road map for identifying the type and quality of environmental data needed to present a clear picture of the environmental conditions of the site. Knowing the quality of environmental measurement data will allow municipalities, Tribes, and States to make site redevelopment decisions that are both technically sound and financially feasible.

Section 2 describes the range of environmental activities expected during Brownfields site assessments. Section 3 outlines and provides examples of the data quality objectives (DQO) process. Section 4 discusses sampling design strategies and the importance of QA and quality control. Section 4 also builds on information in Section 3 by providing more specific sampling design examples and other information. Section 4 refers the reader to the QAPP template provided in Appendix A — a series of forms that can be used to develop a site-specific QAPP. Section 4 discusses the assessment of collected data including whether they meet the objectives of the Brownfields site assessment as defined during the DQO process. This document contains a glossary (Appendix B) and a list of sources of information (Appendix C). Each section introduces a set of new concepts.

This document does not present step-by-step instructions on how to conduct all aspects of a Brownfields site assessment. Instead it outlines what the various tasks are, and the expertise necessary for the tasks. For those unfamiliar with Brownfields site assessments, it will provide the background necessary to communicate effectively with other Brownfields team members, contractors, and laboratories.

SECTION 2. BROWNFIELDS SITE ASSESSMENTS

A Brownfields site assessment should provide sufficient data of adequate quality to allow officials to confidently make decisions about the potential reuse of a Brownfields site. The site assessment should minimize the uncertainties inherent in environmental investigation and focus on producing data relevant to site-specific objectives.

Beneficial reuse of Brownfields sites requires a team approach encompassing a range of multi-disciplinary knowledge and skills, including expertise in analytical chemistry, environmental engineering, geology, sample collection, statistics, public policy, and economics. Public satisfaction with the project will also depend on the Brownfields project team's (team) efforts to build a consensus and meet the interests of the public, local community, and commercial sector.

Brownfields Site Assessment Purpose

Brownfields site assessments are conducted to facilitate the reuse of properties by determining whether contamination exists onsite, and if so, the characteristics of contamination, including the threat it poses, potential solutions for cleanup, and the cost of solutions necessary to prepare the site for redevelopment.

Brownfields Site Assessment Process

A Brownfields site assessment routinely involves one or more of the following activities: a background investigation; a field investigation including sample collection and analysis; an evaluation of cleanup options and costs; and the assessment of the useability of resulting data.

Frequently, the first step is to conduct a site background or historical investigation to identify past uses of the property, including types and amounts of chemicals that may have been used onsite and waste generation and disposal activities that may have contributed to contamination. The team can obtain this information through review of historical records, and through interviews with personnel who may have knowledge of past waste generation and disposal practices at the site. A site visit is also helpful for identifying visible signs of contamination.

A sampling and analysis investigation typically follows the background investigation. Sampling and analysis focuses on those areas of concern identified during the background investigation. The field sampling activities identify the contaminants (e.g., arsenic in soil), the concentrations of those contaminants (e.g., 50 parts per million (ppm)), and the areas of contamination that should be addressed before redevelopment can begin (e.g., all areas of contamination greater than 20 ppm arsenic in soil).

CONCEPTS

Brownfields Project Team - term applied to the group of individuals essential to the success of the project; the team is collectively skilled in analytical chemistry, environmental engineering, statistics, economics, public policy, etc.

Brownfields Site Assessment - a process to determine the feasibility of site redevelopment through various activities, including background investigations, site sampling and analysis, and evaluation of cleanup options and costs.

Another activity is estimating the cost of cleanup options based on future uses and redevelopment plans. Information on cleanup options can be found on EPA's CLU-IN website located at *http://www.clu-in.com/supply1.htm*.

The next activity is assessing whether the data are sufficient for their intended purpose. For example, are they sufficiently reliable to determine that the site does not require cleanup prior to redevelopment?

This document focuses on preparing for a Brownfields site assessment (see Exhibit 1 below). Careful planning is critical to ensure collection of useful data at minimum cost.

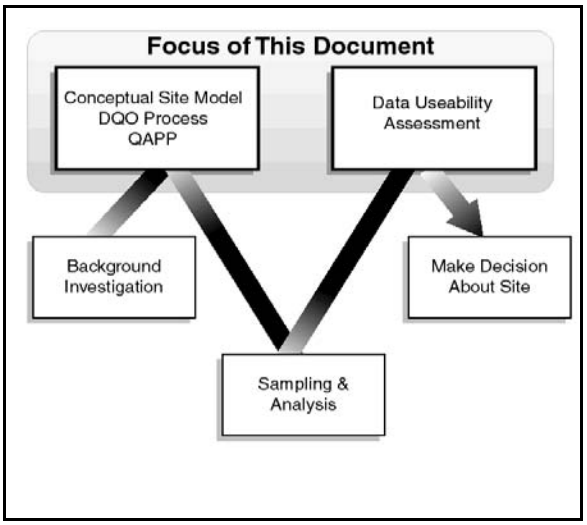
Planning tools that will help the team produce the data they need include the idea of a conceptual site model, the data quality objectives (DQO) process, and some important statistical concepts. These tools help the team complete the QAPP, which establishes and communicates the team's goals and how the Brownfields site assessment will reach those goals.

The QAPP developed for Brownfields site assessments should combine planning for the entire project — management, sampling, analysis, data review/evaluation, and reporting — under one cover. The QAPP should be shared with all members of the Brownfields project team and contractors performing sampling and analytical work. During the preparation of the QAPP, the team should rely on its contractors and the laboratory it has chosen to perform analyses to provide assistance where needed.

Planning for data review is especially important to an effective QAPP. Data review involves comparing the actual data generated during site assessment against the DQOs established during project planning.

It is expected that a Brownfields team may use Federal funding for various Brownfields site assessment activities. These activities can range from developing an inventory of potential sites to extensive sampling events at individual sites to documenting the technical feasibility of cleanup options. The following sections present systematic methods for planning a cost-effective Brownfields site assessment with appropriate quality assurance that will produce data of adequate quality to meet project goals.

EXHIBIT 1
THE BROWNFIELDS
SITE ASSESSMENT PROCESS



SECTION 3. DATA QUALITY OBJECTIVES

Data credibility is one of the most important challenges facing municipalities, Tribes, and States managing Brownfields assessments. In accepting a Brownfields grant, the recipient has agreed to comply with the quality assurance (QA) provisions set forth in 40 CFR 31.45 (see box).

40 CFR 31.45 Quality Assurance

If the grantee's project involves environmentally related measurements or data generation, the grantee shall develop and implement quality assurance practices consisting of policies, procedures, specifications, standards, and documentation sufficient to produce data of quality adequate to meet project objectives and to minimize loss of data due to out-of-control conditions or malfunctions. [53 FR 8076, Mar. 11, 1988]

Members of the Brownfields team who are involved in project planning, sample collection, laboratory analysis, data review, and data assessment should understand the benefits of QA and quality control (QC) procedures. These procedures will be used during the planning of the Brownfields site assessment to ensure that field activities and data collection operations, and the data they generate, meet the objectives of the project. The DQO process allows the team to determine the level of data quality needed for specific data collection activities, and to estimate the costs associated with these activities.

The DQO process is actually a "common sense" approach to translate broad consensus-based goals into specific tasks. Only after defining the overall goals of the project can the team identify the tasks that will produce the data needed to support decision-making at the end of the project. In this way, the team uses the DQO process to prepare a road map, which can guide the project, inform the public and other interested parties, and bring newcomers to the project up to speed.

It is not possible to provide a common set of DQOs applicable to Brownfields site assessments because site characteristics, decisions, and data quality needs vary from site to site. However, the following is an overview of the DQO framework and examples of its application to a hypothetical Brownfields site assessment.

An overview of the DQO process is summarized in Exhibit 2 below, and a more thorough discussion will follow. The DQO process is iterative, and the output of one step may affect prior steps. This may lead the team to revisit some previous steps but ultimately will lead to a more efficient data collection design.

EXHIBIT 2
SUMMARY OF THE DQO PROCESS

1. State the Problem: What is the purpose of the project?

2. Identify the Decision(s): What are the available options under consideration?

3. Identify Inputs in the Decision(s): What information is needed to make informed, defensible decisions?

4. Define the Boundaries of the Study: What is the geographical extent, time, and budget constraints for the project?

5. Develop a Decision Rule: Formulate "if...then" statements that relate the data to the decision they support.

6. Specify Limits on Decision Errors: Estimate how much uncertainty will be tolerated in the site decision(s).

7. Optimize the Design: Identify the most cost-effective means to gather the data needed. If obstacles exist, reassess all the steps of the DQO process to refine decisions and goals until a workable road map or decision tree is produced.

The first step in the DQO process is to develop a conceptual site model. A conceptual site model provides an understanding of the site based on currently available data prior to the site assessment. It identifies historical uses of the site, potential exposure pathways, cleanup concerns, and future land use. As data from the Brownfields site assessment become available, they are used to refine the model and give the

team a clearer picture of the site. A well-defined, detailed conceptual site model will help the team identify data necessary to support decisions about the property.

To determine the kinds of data to be collected, the DQO process translates the goals of the Brownfields site assessment into qualitative and quantitative statements that define the type of data needed to support decisions and that specify the amount of uncertainty (i.e., the chance of drawing an incorrect conclusion) the decision-maker is willing to accept. For example, different future uses may require that different environmental standards be met. Excessive sampling to detect contamination below the levels required for the planned future use can waste resources.

Keeping these goals in mind, the DQO process guides the team to define items such as the number and types of samples to be collected, analytical detection limits, and certainty. After these parameters (the DQOs) are established, analytical methods and instrumentation can be selected to develop the most cost-effective sampling design that will meet these objectives.

Uncertainty — the chance of drawing an incorrect conclusion — is addressed in Step 6 of the DQO process. For critical decisions, such as whether a Brownfields site can be safely reused as a public recreation area, the degree of certainty that the site will not pose a threat to human health must be quite high in order to gain public acceptance. Because the term "quite high" is indefinite, the level of safety at the site may be in question. Quantifying the amount of uncertainty present in a decision clarifies how confident the team can be that it is correct. For example, some decision-makers may require certainty of 90% to 95% before they feel comfortable making the decision to allow reuse of a site for public recreation. The only way to make such a definitive statement about certainty is by using a statistical sampling design. This type of design is discussed in Section 4 of this document.

Some stakeholders may demand a statistical expression of certainty in cases where the planned reuse will allow the public unrestricted access to potentially contaminated media at a site (e.g., residential or recreational reuse). For less critical decisions, for example, industrial reuse where much of the property is used for buildings and parking lots, less certainty may be acceptable or a qualitative statement may be sufficient.

The DQO process controls the potential for making decision errors due to uncertainty in the data by helping the team set limits on the probability of making a decision error (i.e., decision error rate). A hypothesis about the condition of the site is the basis for this determination. The hypothesis, referred to as the null hypothesis, should be designed to guard against making the decision error that has the most undesirable consequences. The null

CONCEPTS

Conceptual Site Model - the conceptual site model is dynamic in nature. It is initially based on the best-available information and is updated as additional data becomes available during the site assessment.

Uncertainty - the probability of making an erroneous decision based on available data.

Null Hypothesis - an assumption that is tested by a scientific investigation (e.g., environmental investigation); the baseline condition assumed to be true in the absence of contrary evidence or an alternative hypothesis (e.g., the earth is flat unless proven round, the site is dirty unless proven clean); generally based on the case with the least desirable consequences.

Decision Error - an incorrect conclusion about a site (e.g., deciding site cleanup is not needed when it really is) caused by using data that are not representative of site conditions due to sampling or analytical error.

False Negative Decision Error - accepting the null hypothesis when it is actually false. Implications of the false negative decision error depend on the structure of the null hypothesis.

False Positive Decision Error - rejecting the null hypothesis when it is actually true. Implications of the false positive decision error depend on the structure of the null hypothesis.

Screening Assessments - short site inspections that may have already been conducted, or that the team may need to conduct, to gather sufficient data for an effective sampling and analysis plan. The data gathered will be useful in the initial conceptual site model.

hypothesis is derived from information in the Statement of the Problem (Step 1 of the DQO process), including what is known about the site, the projected site reuse scenario, and the resources available for study and cleanup. Typical null hypotheses are the following: "the site is clean enough" or "the site is too dirty for the reuse scenario." The team will identify an alternative hypothesis contrary to the null hypothesis and the sampling and analysis plan is then designed to test the null hypothesis by providing strong evidence to the contrary.

Generally, the more severe consequences of making the wrong decision at a Brownfields site occur when the site is actually contaminated above established health limits, but the decision-maker acts on data that erroneously indicate that the site is clean. In this situation, human health could be endangered if reuse occurs without cleanup. Therefore, the null hypothesis at a Brownfields site is likely to be "the site is too dirty for the reuse scenario," and the site assessment is then designed to show that the site is clean, which is the alternative hypothesis. Additional explanation is provided under Step 6 of the DQO process.

Because of the limited funding for Brownfields site assessments, it may not be possible to collect data sufficient to achieve a desired level of certainty in site decisions. Because increasing certainty usually requires the collection of more samples, it can be costly. If the team can afford to collect and analyze only a limited number of samples, decision-makers must take care to communicate only what they know about the environmental conditions at a site and how confident they are in that knowledge.

Limited funding highlights the need for a well-planned investigation that capitalizes on time- and cost-saving technologies. By following a systematic planning process, such as the DQO process, decision-makers will be able to strike the best balance between what they want to know about a property and what they can afford to know about a property given the realities of their budget.

The DQO process offers several benefits. By using the DQO process, the team can establish criteria for determining when data are sufficient for site decisions. This provides a "stopping rule" — a way for the team to determine when they have collected enough data of sufficient quality to achieve the desired objectives. In addition, the DQO process helps the team establish an adequate level of data review and documentation. Data review is a process of assessing data quality based on written performance-based acceptance criteria (e.g., samples must be analyzed by the laboratory within a specific period of time referred to as the holding time). Data review also determines whether the data satisfy the predefined DQOs.

Another benefit of the DQO process is that it focuses studies by clarifying vague objectives and identifying the decisions that should be made prior to the selection of sampling and analysis parameters. This gives the team confidence that the data collected will support the decisions concerning redevelopment of the site.

The DQO Process

The outputs of the DQO process include the information the team will need to complete most of the Quality Assurance Project Plan (QAPP). Forms D through N of the QAPP template provide space for describing the sampling and analysis plan (SAP). (See Appendix A.) The pre-defined objectives and decision statements that are a product of the DQO process form the basis for the SAP. Section 4 of this document discusses elements of the QAPP and SAP in more detail with reference to the corresponding forms in Appendix A.

Step 1: Stating the Problem

The first step of any decision-making process is to define the problem that has prompted the study. The team will develop a concise and complete description of the problem, which can be documented on form C of the QAPP template. This description provides the basis for DQO development and is built on information collected during the background investigation.

Project planning is perhaps the most critical component of the Brownfields assessment process, as it allows team members to determine fully the goals and scope of sampling events and the resources necessary to accurately characterize the site. Therefore, it is important that all interested parties (including project managers, engineers, chemists, field sampling personnel, statisticians, local government officials, and the public) be involved in the project from the conceptual design stage. Roles and responsibilities can be documented on forms A and B of the QAPP template.

The conceptual site model is an important part of Step 1, *Stating the Problem*. The conceptual site model should be updated as additional information becomes available, but should initially illustrate the following:

- Potential chemicals of concern;
- Media in which these chemicals may be present and to which they may migrate (surface and subsurface soil, surface water, groundwater, and onsite structures);
- Whether human or environmental receptors (i.e., targets) at or near the site may be exposed to contamination; and
- Current and anticipated land use.

The conceptual site model should include maps and site diagrams that illustrate structures and areas of potential contamination including locations of chemical handling, storage, and disposal. If facility records are unavailable, the team may find information through State, Resource Conservation and Recovery Act (RCRA), and National Pollutant Discharge Elimination System (NPDES) programs, and local records offices.

Some information may be available from current and past owners, lending institutions, and/or environmental regulatory and real estate agencies. Some States have laws that require property owners to disclose the available reports to prospective purchasers. These reports may answer some of the team's questions about a site.

Two common examples of "screening" assessments are EPA's Preliminary Assessment (PA) and ASTM's Phase I Assessment (Phase I), which are briefly described in Exhibit 3 below. Because the scope of these assessments varies, they may not answer all of the questions the team wants to address. For example, to find a discussion about offsite receptors, the team will want to look at a PA rather than a Phase I.

EXHIBIT 3
COMPARISON OF PRELIMINARY ASSESSMENTS AND DUE DILIGENCE SITE ASSESSMENTS

Preliminary Assessment (PA)	Due Diligence - ASTM Phase I
A site may consist of the legal property boundaries and other areas where contaminants have come to be located.	A site within the context of a Due Diligence study is limited to the legal boundaries of the subject property.
Level of effort is approximately 120 hours.	Level of effort is approximately 40 hours.
Examines all available site-related documents during file searches of Federal, State, and local agencies.	Examines all "practically reviewable" and "reasonably ascertainable" site-related documents.
Surveys on- and offsite pathway potential targets.	Surveys onsite targets within property boundaries.
Considers hazardous substance migration to offsite human and environmental targets.	Considers only onsite targets and impacts to the site from on- and offsite sources.
Identifies sources and estimates extent of contamination on- and offsite.	Identifies sources and estimates extent of contamination only within property boundaries.
Does not evaluate sources within secure buildings.	Evaluates sources within all buildings (e.g., asbestos).
Petroleum products are not considered.	Petroleum products are considered.

Source: Site Assessment: A Comparison of Federal Program Methods and Commercial Due Diligence. *Journal of Environmental Law & Practice*. p.15-25 March/April 1997

Previously collected analytical data are particularly important to the conceptual site model. This information may identify some of the chemicals onsite and their locations. It also can indicate the variability of contamination onsite. The sampling and analytical methods that were used previously may also prove helpful to the Brownfields sampling and analysis plan.

Especially when using previously collected analytical data, the team needs to review the information for accuracy and completeness. If the data are several years old, reported analytical data and site features may not represent current site conditions.

Aerial photos are often helpful in reconstructing the history of a site with multiple prior owners. Aerial photos are available through *http://mapping.usgs.gov*.

The team should also ensure that the conceptual site model illustrates site conditions that may lead to an unacceptable threat or that are based on current and projected future land uses. For example, if local groundwater is used in households and businesses, the physical characteristics of the soil and local hydrogeology should be understood to better assess the threat to groundwater resources.

Finally, the team should document the available resources and relevant deadlines for the study in the problem statement. This description should specify the anticipated budget, available personnel, and contractual vehicles, where applicable.

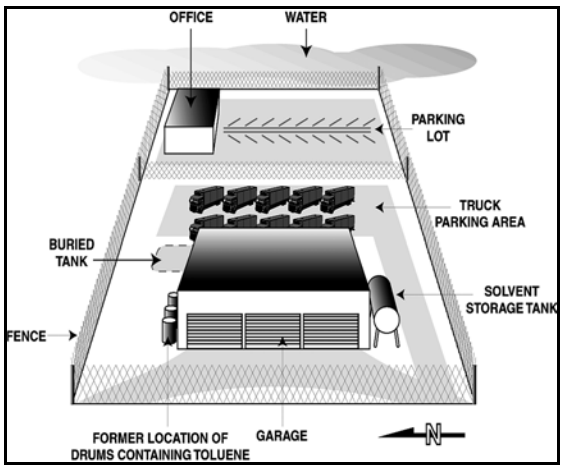
An example problem statement follows:

The Springfield team is considering Brownfields redevelopment of a site comprised of 10 acres of waterfront property historically used for truck repair. The site, depicted in Exhibit 4, is currently fenced and abandoned. Aerial photos indicate a repair garage located on the western portion of the property, an office and employee parking on the east end near the water, and truck storage between these two areas. A central fence separates the garage and truck storage area from the office section of the property.

Facility records indicate that an underground fuel storage tank is located behind the northeast corner of the garage. A previous site assessment mentions the removal of four barrels of toluene by the County health department in 1983 and the presence of a second storage tank for spent solvent disposal south of the garage. Analytical results from the previous site assessment indicate that total petroleum hydrocarbons (TPH — constituents of fuel) and volatile organic compounds (VOCs — constituents of solvents) are present in soils near the areas of former storage of toluene and the spent solvent tank. Interviews with past employees indicate that trucks were washed on occasion in the truck parking area of the site.

The site appears to present a threat via exposure to soils; groundwater and surface water may also be contaminated. The site is located in a commercial/residential zone. The city wants to redevelop the site for commercial and public use.

EXHIBIT 4
THE SPRINGFIELD SITE



Step 2: Identifying the Decision

While environmental field investigations are designed to satisfy a broad array of objectives, the goal of a Brownfields site assessment is to collect adequate environmental data for decision-makers to determine if the site is suitable for a specific reuse. This determination may require several separate but related decisions.

The "decision statements" usually take the form of questions that the study will attempt to answer. Form C of the QAPP template (Appendix A) provides space to document these decisions. The decision statements are important because they indicate alternative actions and decision performance criteria in later steps of the DQO process.

Decision Statements for the Springfield site might include the following:

Historical information indicates that the eastern portion of the property has not been used for chemical management activities; the waterfront section may be reused as a park or other publicly accessible facility. To assess the feasibility of this option, the team will make the following decisions: Will the site need to be cleaned up before it can be reused as a park? If cleanup is too expensive, can the site be redeveloped for another use?

Because historical information indicates that the western portion of the site is at least partially contaminated, this area is being considered for commercial reuse. The team will make the following decisions to facilitate commercial financing: Is the site clean enough to attract a private sector developer? Have issues of concern to lenders been addressed? What level of cleanup or other actions is necessary to answer the questions of developers and lenders?

For the Springfield site, the team will make two distinct decisions based on different projected reuse options for different portions of the site.

Step 3: Identifying Inputs to the Decision

The team should identify the information needed to resolve the decision statement(s) and determine how this information will be obtained. For example, if groundwater use is a consideration in the site reuse scenario, the team should identify how samples of groundwater will be used to support the reuse decision. The team should review the conceptual site model to learn whether existing groundwater data provide the information needed for the study and identify data gaps in the model.

The team will identify the characteristics of the site that need to be measured based on a threshold value (i.e., a drinking water action level) that provides the criterion for choosing among alternative actions. Regulatory standards, such as State drinking water standards, usually form the basis for action levels. If no regulatory threshold or standard can be identified during this step, the team should identify information needed to develop a realistic concentration goal. This information will be critical to the final sampling design.

Later, in Step 7 of the DQO process, *Optimizing the Design*, the input identified during this step is reviewed and refined. The team should be aware that the decisions made during this step are "draft" and may be changed during optimization. The team will make the final decision on which analytical methods to use in Step 7.

The products of this step include a list of informational input needed to make the decision and a list of environmental characteristics that will be measured. In essence, the output of this step are actually the input to the decision.

Some input that might be identified for the Springfield site include the following:

All soil samples in the waterfront area slated for public access reuse will be collected to depths specified in State regulations. The samples will be analyzed for chemicals likely to be present using a State, EPA, or other analytical method that meets the objectives of the Brownfields assessment. To rule out the possibility of other contaminants of concern, one representative sample will be analyzed for a broad spectrum of compounds, including those whose presence is considered unlikely.

Because previous analytical data from the western portion of the site indicate contamination with TPH and VOCs in the former toluene storage and spent solvent storage areas, field techniques will be used to confirm contamination in these areas. Data gaps for this portion of the site include the following: whether the underground storage tank has leaked and if so, whether contamination has reached groundwater; whether contamination exists in the truck washing area; and remaining areas of

the site for which no previously collected data exist. Soils in these areas will be analyzed for a combination of TPH and VOCs using a State, EPA, or other analytical method that meets the objectives of the Brownfields assessment. To rule out the possibility of other contaminants of concern, at least one representative sample will be analyzed for a spectrum of compounds including those whose presence is considered unlikely. Groundwater at the site will be collected and analyzed for TPH and VOCs using a State, EPA, or other analytical method that meets the objectives of the Brownfields site assessment.

Step 4: Defining the Boundaries of the Study

The boundaries of the study refer to both spatial and temporal boundaries. To define the boundary of the decision, the team should identify the geographic area within which all decisions apply. A spatial boundary could be the property boundary, a portion of the property, potential exposure areas, or an area with a specific reuse projection. For example, a soil-sampling boundary may include the top 12 inches of soil where truck washing reportedly took place.

The scale of decision-making is the smallest area, volume, or time frame of the media for which the team wishes to make a decision. For example, to decide whether to clean up the top 2 feet of surface soil, the scale of decision-making might be related to the method of cleanup; if contaminated soil will be hauled in a 5-ton capacity truck, the boundary of decision-making might be a 2-foot deep, 65-square foot area. This example is based on the practicalities of cleanup rather than exposure scenarios.

The team should also define the temporal boundaries of the decision. The team may find it impossible to collect data over the full time period to which the decision will apply. The team will have to determine the most appropriate part of that period for gathering data that reflect the conditions of interest.

Practical boundaries that could also affect sampling are identified in this step. For example, seasonal conditions or the unavailability of personnel, time, or equipment may make sampling impossible. Form D of the QAPP template contains space for the team to document the boundaries of the investigation, including a project timeline.

Boundaries for the Springfield studies might include the following:

The park reuse decision applies to the area of the site east of the fence that divides the garage and truck parking area from the office area. This portion of the property is not further subdivided.

The commercial reuse decision applies to the areas west of the fence. This portion of the property is further subdivided into the groundwater and soil boundaries. The soil is further subdivided into the subsurface soil around the underground storage tank, the surface soils in the truck washing area, and the soils in the remaining portion of the site.

Temporal boundaries are addressed by performing studies when personnel are available, during the dry season, following notification of the local community and receipt of authorization from site owners.

Step 5: Developing a Decision Rule

The purpose of developing a decision rule is to integrate the output from the previous steps of the DQO process into a statement that estimates the parameter(s) of interest, delineates the scale of decision-making, specifies the action level, and describes the logical basis for choosing among alternative actions.

A decision rule is usually a comparison of a statistical parameter of interest (such as the average level of arsenic in soil, or the maximum level of toluene in groundwater) to a specific action level. The action level is the contaminant threshold that defines the conditions around which the team should select among the alternative actions and/or take different directions to solve the problems. For example, if the action level is exceeded, the team may choose to clean up the site.

The output for this step is an "if...then" statement that defines the conditions that would cause the

team to choose among alternative courses of action. Form D of the QAPP template provides space to record these decision rules.

Decision rules for the Springfield site include the following:

If the average levels of TPH and VOCs in soil samples are less than selected action levels, then the redevelopment project can proceed.

If the average levels of TPH and VOCs soil samples are higher than selected action levels, then cleanup to the action level is required prior to reuse.

If the site assessment indicates that groundwater has become contaminated from site activities, the team should contact the State to discuss the impact on redevelopment scenarios for the western portion of the site.

Step 6: Specifying Limits on Decision Errors

Because of the limitations of environmental sampling and analysis, the team runs the risk of making the wrong decision because of incomplete information. Sampling may not capture all of the variations in concentrations, and analyses can only *estimate* the "true" value. The team must therefore develop means to limit or control the impact of errors in estimations on the likelihood of making a decision error. These limits should be incorporated into the sampling and analysis plan during Step 7 of the DQO process.

Decision-makers are interested in knowing the true state of some feature of the environment (e.g., the average concentration of arsenic in the top twelve inches of soil). The measurement data that describe this feature can be in error. Sampling "error" occurs when the sampling scheme (which determines the sampling locations) does not adequately detect the variability in the amount of contaminant in the environmental matrix from point to point across the site. Measurement errors can occur during sample collection, handling, preparation, and analysis when standard procedures as described in the SAP are not followed. Report preparation is another source of error. The sum of the sampling and measurement errors is called the total study error.

As mentioned earlier, sampling and measurement errors can lead to errors in data thereby causing the decision-maker to select the wrong course of action. The DQO process helps the team control these errors through development and testing of the null hypothesis and selection of limits for erroneously accepting or rejecting the null hypothesis.

Although some Brownfields sites are only perceived to be contaminated, many may be contaminated at levels exceeding health-based action levels. In selecting the null hypothesis for a Brownfields site, the team should choose the circumstances that can have the most severe consequences. The null hypothesis in Step 6 will usually be "the site is contaminated" and needs some level of cleanup (i.e., the site is contaminated above certain action levels). To test this hypothesis, the team must provide ample evidence to the contrary or prove that the site is clean (i.e., any contamination present is below certain action levels). Erroneously accepting the null hypothesis as true (false negative decision error) may unnecessarily increase the cost of site cleanup because decision-makers may believe that action is warranted when it is not. Erroneously rejecting the null hypothesis (false positive decision error) can increase the risk of exposure at a property because a decision-maker may believe that no action is warranted when it is.

In contrast to the situation above, if the null hypothesis were "the site is clean enough," the team would need to show the presence of contamination above certain action levels. In this case, erroneously accepting the null hypothesis (false negative decision error) can increase the risk of exposure at a property because a decision-maker may believe that no action is warranted when it is; whereas, erroneously rejecting the null hypothesis (false positive decision error) may increase the cost of site cleanup. The amount and quality of data collected will depend on how the team plans to control decision error rates.

In the Springfield site example, because the projected reuse of the eastern portion of the property involves its unrestricted public use, the null hypothesis is that the eastern portion of the property is dirty. The team will need to show it is clean. This hypothesis reflects what most of the public will probably assume before any environmental studies occur at the site. The team already has data showing that the western portion of the site is contaminated.

To completely avoid any decision errors (100% certainty), the team would have to sample all surface soil related to the decision whether to clean up the surface soil at the site. Because this is financially infeasible, the team must collect a number of representative samples from the area in a manner that reduces the decision error rate. The analytical results from these samples will be translated into an estimation of contamination on part of or the entire site. The more samples collected, the greater the certainty the team will have in its decision; however, the more samples collected, the more costly the investigation. The team needs to balance the level of certainty desired with the cost of that certainty (the cost of additional sample collection and analysis). Form D of the QAPP template can be used to document limits on decision errors.

Limits on the decision errors for the Springfield site may include the following:

Because of public access reuse projections, reuse of the eastern portion of the property may result in children coming into contact with site soils; therefore, the null hypothesis is that the site is contaminated. The probability of false positive decision errors (erroneously rejecting the null hypothesis or deciding that the site is clean when it is not) should therefore be minimized as much as possible. Errors that increase the probability of leaving soils in place when they contain substances at levels greater than the action level — false positive decision errors — will be considered acceptable no more than 10% of the time.

Errors that increase the probability of cleaning up soils when that action is not required — false negative decision errors — will be considered acceptable only 10% of the time.

Limits on the probability of errors in decision-making for the western portion of the site are not needed because the sample design is intended to simply define the boundaries of known contamination.

Step 7: Optimizing the Design

The team should evaluate the cost of sampling design options that meet the DQO constraints and select the most resource-effective option. The chosen alternative that meets the DQOs may be the lowest cost alternative, or it may be a relatively low-cost design that still performs well when design assumptions change. Because the role of statistics is very important when developing a sampling design that achieves specified decision error rates, the team member with statistical expertise should be consulted at this stage. (See Section 4 for a more thorough discussion of sampling strategies.)

The team should review the output of the previous steps to determine exactly how the selected limits on decision errors will define the required number and location of samples and the types of analyses. This step frequently involves refinement of initial design parameters.

Many different strategies could be employed to optimize the investigation at the Springfield site; only a few are presented here. Section 4 describes more options available to the team to reduce the project's sampling and analysis costs while meeting DQOs.

Optimizing the SAP for the Springfield site:

The waterfront portion of the property is not likely to be significantly contaminated because waste-related activities were neither documented nor likely conducted there. It should therefore be possible to reject the null hypothesis — reject the assumption that the site is dirty by showing that the site is clean — by collecting 40 to 50 samples using a statistical design that maintains a 10% false positive decision error rate. This allows a 10% chance that the decision-maker will consider the site clean when it is not.

For the western portion of the site, the team will use field techniques to confirm previously detected levels of VOCs in the former toluene

storage and spent solvent storage areas. The same techniques will be used in areas suspected to be contaminated with VOCs and TPH — the areas around the underground storage tank and truck washing area.

This example assumes the variability in site contamination is approximately 25%. The effect of this factor on the sampling design is explained in Section 4. Errors may also result from mishandling of samples or improper field procedures. Section 4 of this document discusses the effect of variability, cross-contamination and other problems on decision errors and how quality control samples can be used to identify and control the impact of some of these effects.

Estimating Costs

The cost of conducting a Brownfields site assessment is driven by the adequacy of available historical data, the type and level of contamination, the site assessment technologies used, and the property's projected site reuse. Estimating costs for Brownfields site assessments creates unique challenges. Although the tendency may be to expedite the planning period, care must be exercised to ensure that the interest of site owners, investors, purchasers, and lenders is maintained. The cost estimates should therefore be developed quickly while preserving the highest level of accuracy possible. As stated earlier in this section, increasing the quality of environmental measurements will likely increase the cost of a Brownfields site assessment.

Developing Brownfields site assessment cost estimates is hindered by a lack of detailed cost estimating literature that applies to typical Brownfields sites. The majority of available information is based on large Federal government and private sector sites such as abandoned rail yards and steel mills, not the smaller former industrial sites such as automotive repair shops or metal finishing facilities. Some guides that may assist in the development of cost estimates are listed in Appendix C.

Once the team has selected the final sampling design based on all considerations, including cost, it should properly document the design. This will protect the efficiency and effectiveness of predefined field sampling procedures, quality control procedures, and statistical procedures for data analysis. Forms D through N of the QAPP template provide space for the final sampling design. All drafts of the sampling and analysis design generated during the DQO process should be discarded once the final sampling design is selected and documented.

A complete discussion of DQOs and their use in developing the SAP can be found in the following documents available through EPA's Quality Assurance Division (QAD) website (*http://es.epa.gov/ncerqa/qa/qa_docs.html*):

Guidance for the Data Quality Objectives Process, September 1994. EPA QA/G-4: EPA 600-R-96-055.

Guidance for Quality Assurance Project Plans, February 1998. EPA QA/G-5 EPA 600-R-98-018.

EPA Requirements for Quality Assurance Project Plans, Draft Final, October 1997. EPA QA/R-5 (final publication pending).

SECTION 4. QUALITY ASSURANCE PROGRAMS & SAMPLING DESIGN STRATEGIES

This section describes basic sampling design strategies that can be used to optimize Brownfields sampling and analysis plans (SAP); introduces the QA and QC concepts; and discusses terminology used during implementation of Brownfields site assessment and the assessment of the resulting data. The concepts discussed in this section, related to preparation for collection, analysis, and review of site assessment data, will be helpful in the development and preparation of the QAPP for a Brownfields site assessment.

The last part of Section 4 discusses how the QAPP integrates all technical and quality aspects for the life cycle of the project — including planning, implementation, and assessment — to produce a project-specific road map for obtaining the type and quality of environmental data needed for a specific decision. Appendix A of this document contains forms that the team can use directly or as a guide for writing the QAPP. Some of the forms may not be necessary depending on site conditions and sampling design. The following elements related to sampling should be included in the QAPP:

- Sampling design (form E of the QAPP template);
- Sampling methods (form F-1);
- Sample handling and custody (form K);
- Analytical methods (forms F-1 and F-2);
- Quality control (form M);
- Instrument/equipment testing, inspection, and maintenance (forms G and I);
- Instrument calibration frequency (form J); and
- Data management (form N).

The design and extent of a Brownfields site assessment will be dictated largely by the conceptual site model, the availability of resources, and the required data quality and level of quality control exercised. The DQO development process should define all aspects of the sampling design and these details should be documented in the QAPP.

CONCEPTS

Sampling Design - scheme for sample collection that specifies the number of samples collected in a biased and/or unbiased pattern, as grabs or composites, etc.
Biased Sampling - collection of samples at locations based on the judgment of the designer.
Statistical Sampling - collection of samples in a systematic or random manner.
Multi-phase Sampling - sample collection in multiple stages; data are used to plan subsequent rounds.
Adaptive Sampling - when multi-phase sampling is performed in a single mobilization using field analytical methods which provide results in 24 hours or less.
Low Bias Analytical Error - when analytical data indicate that a substance is not present above a specified concentration, when in fact it is. Low bias errors can increase the risk of exposure because a decision-maker may be led to conclude that no action is warranted when it is.
High Bias Analytical Error - when analytical data indicate that a substance is present above a specified concentration, when in fact it is not. High bias errors can increase the cost of cleanup because a decision-maker may be led to conclude that action is warranted when it is not.
Grab Sample - sample from a single location useful for identifying and quantifying chemicals in an area where contamination is suspected.
Composite Sample - composed of more than one discrete sample taken at different locations, useful to quantify average contamination across a site.
Analytical Method - procedures used to identify and/or quantify chemicals in a sample.
Measurement Error - the difference between the true sample value and the measured analytical result.
Broad Spectrum Analysis - analytical procedure capable of identifying and quantifying a wide range of chemicals.
Field Analysis - measurement taken in the field; results are quick and quantitative or qualitative.
Data Useability - adequacy of data for decisions; determined by comparing resulting data quality with predefined quality needs documented in QAPP (defined during the DQO process).

Quality Assurance

QA is an integrated system of management activities that are part of a project's planning, implementation, assessment, reporting, and quality improvement. These activities ensure that products are of the type and quality expected.

QA will be an integral part of a Brownfields site assessment because it provides the road map to all activities necessary to collect data of known and adequate quality. Data of adequate quality will give the team a sufficient level of confidence in the data to make informed decisions about the redevelopment of the site including the following: the threat posed by the contamination, potential site remediation alternatives, and additional projects needed to prepare a site for redevelopment.

The QAPP provides the framework for the Brownfields project's QA program by outlining activities that promote the collection of data with the accuracy and precision required for the project. Some elements of the QA program include the following:

- Staff organization and responsibility (form B of the QAPP template);
- Standard Operating Procedures (SOPs) for sampling and analytical methods (form F-1);
- Field and laboratory calibration procedures (forms H and J);
- Routine and periodic quality control activities (form M);
- Data assessment procedures (form O); and
- Data reduction, validation, and reporting procedures (forms P, Q-1, Q-2, and R).

Quality Control

Quality control (QC) is integral to the success of a QA program. It is the overall system of technical activities that measure the performance of a process against defined standards to verify that they meet predefined requirements. Since errors can occur in the field, the laboratory, or the office, it is necessary for QC to be part of each of these functions.

An example of a QC activity is collection of a rinsate blank sample. When equipment is cleaned and reused in the field, the sampling team will collect a sample of the spent rinse water. Analysis of this sample will show whether the equipment was sufficiently cleaned or if hazardous substances have remained on the equipment that will contaminate the next sample. The data from the rinsate blank measure the performance of decontamination procedures in the field. If contaminants are found in the rinsate blank, other samples collected with the same equipment may also be contaminated and may not meet the stated requirements established by the DQOs. QA and QC procedures are discussed below in the context of expected environmental measurement activities for Brownfields site assessments.

QA and QC parameters apply to the two primary types of data — definitive and nondefinitive data — and whether the data collection activity is associated with field measurements or laboratory measurements. The following boxes provide definitions of these terms.

Definitive Data

Definitive data are documented to be appropriate for rigorous uses that require both hazardous substance identification and concentration and are generated using methods that produce data suitable for scrutiny of the data validation and useability criteria described later in this section. Definitive data are analyte-specific, with confirmation of analyte identity and concentration. Methods produce tangible raw data (e.g., chromatograms, spectra, numerical values) as paper printouts or computer-generated electronic files. Definitive data may be generated at the site or at an offsite location, as long as the QA/QC requirements of the method are satisfied.

For data to be definitive, either analytical or total measurement error should be determined. For further guidance on definitive data, refer to *Guidance for Performing Site Inspections Under CERCLA, Interim Final*, and *Guidance for Data Useability in Risk Assessment.* These documents are available through NTIS at http://*www.ntis.gov/envirn/envirn.htm.*

Nondefinitive Data

Nondefinitive data are frequently collected during the first stage of a multi-phase screening assessment using rapid, less precise methods of analysis with less rigorous sample preparation. Nondefinitive data can provide analyte identification and quantification, although both may be relatively imprecise. Typically, 10% of nondefinitive samples or all critical samples are confirmed using analytical methods and QA/QC procedures and criteria associated with definitive data. Nondefinitive data without associated confirmation data are of unknown quality.

Qualitative, nondefinitive data identify the presence of contaminants and classes of contaminants and can help focus the collection of definitive data, which is generally the more expensive of the two.

Each site assessment should be guided by a detailed description of the work to be performed in the SAP. The SAP takes the conceptual site model developed in the DQO process and translates it into a sampling and analysis design that identifies where, how, how many, and what types of samples will be collected; how the samples will be stored and transported; how, when, and by what method the samples will be analyzed; and what procedures and records will be used to track the samples through the process. Depending on the complexity of the Brownfields site, multiple SAPs may be needed. QA and QC parameters should be described in detail for each of these steps, and include specific corrective actions to be taken if difficulties are encountered in the field. Guidance documents on sampling methods are listed in Appendix C.

Sampling Design Strategies

Sampling design strategies should factor in the conditions unique to the site being considered for redevelopment, including data gaps in the conceptual site model, exposure potential, projected site reuse, and available resources.

Step 7 of the DQO process should identify several possible sampling design strategies. Some of the variables that may be used in these strategies to bring down the cost of the project are described below. The details of the selected sampling design can be documented on forms E through N of the QAPP template. The overall sampling design is described on form E.

Unique site conditions that may call for a certain strategy include a site with buildings slated for reuse. In this situation, non-routine sampling and analysis may be required for unusual sample matrices, such as building materials.

The main sampling design decision is whether a statistical (probability based) or judgmental (nonrandom or biased) sampling design should be employed. Judgmental sampling is a useful design when the team wants to characterize areas of suspected contamination. Statistical sampling designs are suited for evaluating trends and estimating the distribution of contaminants. Sometimes both judgmental and statistical sampling is required on a single site. An important distinction of statistical sampling designs is that they are usually required when the level of confidence needs to be quantified.

For surface soil sampling in residential reuse scenarios, a statistical sampling design is likely to be chosen because a quantitative statement of the decision error will be needed to show that the level of any contamination at the site is safe. Industrial reuse may not require as rigorous a result or may be possible with a qualitative statement at sites where exposure is not possible.

When historical data are unavailable to indicate discrete areas of contamination, i.e., hot spots, a useful strategy is to collect samples along a grid. Grid sampling is designed to cover the entire site with samples collected at regularly spaced intervals. The goal of grid sampling is to reduce the probability of making a decision error. It allows the calculation of the probability of remaining undetected hot spots. This technique could be particularly useful on the previously unsampled western portion of the Springfield site where industrial activities are known to have been carried out. Different types of grids are available and are generally selected based on the difficulty of layout in the field, sufficient detection capability, and cost.

Factors affecting the success of grid sampling include the size and shape of the grid and the size and shape of the hot spot. If the hot spot is small relative to grid spacing, the probability of missing a hot spot will be relatively high. The cost of grid sampling is determined by the number of samples, which is determined by the grid shape and spacing. Closer spacing yields a higher probability of detecting a hot spot.

If data are needed to determine if groundwater onsite is contaminated, a statistical sampling design would be unnecessary and impractical because of the cost of installation of groundwater wells. Judgmental groundwater samples might be collected from nearby wells, or if the budget can bear it, one or more wells may be located where the contamination is most likely to be present. Appendix C identifies several groundwater sampling and monitoring guidance documents.

Errors in judgmental sampling may come from cross-contamination of samples in the field or improper calibration, maintenance, and use of field equipment (these issues are discussed later in this document). To ensure useable data if these problems arise, the field team should have previously defined alternative options, such as routing samples to a fixed laboratory. QC samples (discussed later in the section) will also be helpful.

Because of the need for quantification of the decision error in the public park reuse scenario — a sampling design that translates the results from a limited number of samples to an estimate of the contamination on part of the site — a statistically based sampling design will be required.

While this document does provide some description of how statistics are used to assist in the decision process, statistical expertise and support should be enlisted throughout the project to ensure a defensible environmental decision is possible at the end of the project. For more information, refer to EPA Quality Assurance Division's (QAD) *Guidance for the Data Quality Objectives Process* and other documents listed in Appendix C. To quantitatively demonstrate that a specific level of certainty has been achieved for site decisions, individual data sets must be of sufficient quality, and overall statistical analysis (which integrates information from the individual data sets into a site decision) must be able to support the site decision.

Section 3 introduced the concept of testing the null hypothesis and its relation to decision errors. A false positive decision error is the erroneous rejection of the null hypothesis; a false negative decision error is the erroneous acceptance of the null hypothesis. At the Springfield site, the null hypothesis is that the site is dirty. The false positive decision is that the site is clean when it is dirty; the false negative decision is that the site is dirty when it is clean.

If a goal of the project is to document whether onsite contaminant concentrations are higher than background concentrations, previous data may help estimate the relative difference between the background concentrations and the onsite concentrations. By using that estimation and the predefined degree of statistical certainty, the team can calculate the number of samples required. The greater the difference between background and site contaminant levels, the easier it is to document and quantify that difference; therefore, fewer samples are needed.

The amount of contaminant variability onsite also directly impacts the planning and implementation of sampling design. The higher the variability, the greater the number of samples that have to be collected to adequately document that variability. If previous data can help estimate the amount of variability, sampling protocols can be optimized during project planning.

Exhibit 5 can be used in some cases to optimize the sampling design by keeping samples to a minimum while maintaining a known level of confidence. It illustrates the number of samples required for selected decision error rates given a statistical sampling design, the requirement to differentiate the site levels from background levels (minimum detectable relative difference (MDRD)), and a 25% variability in contaminant levels onsite. It also assumes normally distributed data; for lognormally distributed data, the data should be transformed to a normal distribution before the methods described here can be applied.

EXHIBIT 5
NUMBER OF SAMPLES REQUIRED TO ACHIEVE GIVEN RATES OF FALSE POSITIVE AND NEGATIVE, AND MDRD*

False Positive	False Negative	MDRD	Number Samples
10%	10%	10%	42
10%	10%	20%	12
20%	10%	20%	8
30%	20%	10%	19
20%	20%	20%	5
20%	10%	40%	3

***Number of Samples** is based on known variability in contaminant levels represented by a coefficient of variation (CV) of 25%, random sampling design, and normal distribution.
Minimum detectable relative difference (MDRD) is used when discriminating site levels from background levels. It is the percent difference between the two detected levels.
Source: EPA. *Guidance for Data Useability in Risk Assessment*. April 1992.

These parameters, the MDRD and the variability in contaminant concentrations (coefficient of variation (CV)), can be estimated based on previously collected data at the site being assessed or by using data from sites with similar uses and substances. If the CV is low — the concentrations on the site do not vary greatly — fewer samples are needed to achieve the same decision error rates. The MDRD represents the difference between concentrations of substances on the site and substances in the background. The greater the difference, the easier it is to distinguish between background and site levels and therefore, fewer samples are needed for the same decision error rate.

An underestimation of the actual variability in existing contamination is the most likely reason the results would fall short of the desired confidence level. The team should prepare to perform the necessary calculation as soon as the data results become available to determine if the desired confidence level is being met. If not, costly resampling or reanalysis of critical samples may be necessary.

Exhibit 5 also provides an overview of the interplay of site characteristics and decision error rates in the sampling design by illustrating the number of samples needed to meet specified decision error rates in given circumstances. In general, the number of samples increases as the desired error rate decreases. The exhibit shows, for example, that to achieve a false positive decision error rate of 20% requires 4 fewer samples than to achieve a rate of 10%, other factors being equal. For a given decision error rate, the number of samples also tends to increase with decreasing MDRD. For example, to achieve the same decision error rate, 42 samples are required if background and onsite contaminant levels differ by only 10%. If background and onsite levels differ by 20%, only 12 samples are required to reach the same decision error rate.

A change in the coefficient of variation, the factor held constant in Exhibit 5, also can affect the number of samples required for a given decision error rate. In general, as the variability in the concentration of a chemical of concern increases, more samples are needed to adequately represent the onsite concentrations of that chemical.

For the public park reuse portion of the property in the Springfield example in Section 3, 40 to 50 samples collected in a statistical design

(assuming no need to compare to background (MDRD) and a variability factor of 25%) will produce a statistical confidence of 10% false negative and positive decision error rates (assuming normally distributed data).

If the Springfield team had not optimized the sampling and analysis design through the DQO planning process, either too many or too few samples may have been collected.

- If too many samples were collected and unnecessary analyses were conducted, money that could have been spent on other projects would have been wasted.

- If too few samples were collected, the data may be insufficient to confidently allow safe reuse of the property.

Multi-phase Investigations

A single sampling event may not provide an adequate characterization of the contamination onsite, especially when the conceptual site model contains significant data gaps. In these situations multi-phase sampling may be helpful. The need for this sort of investigation should be identified during the DQO process.

Based on a review of existing site assessment reports, the team should determine if the previous data are of sufficient quality and quantity to guide the sampling design or if some preliminary information must be obtained to properly plan for collection of the predefined samples. The team should base the assessment of existing data on a review of the documented quality of the data, and the decision rule criteria established as part of the DQO process.

If a multi-phase assessment is selected, preliminary activities should be developed using guidelines found in ASTM E1527 (*Standard Practice for Environmental Site Assessment: Phase I Environmental Site Assessment Process*) or a similar, accepted protocol. When historical information is scarce, preliminary sampling designs may include measurement of contamination in soils, groundwater, and surface water. To develop this information relatively inexpensively, field technologies may be used, including real-time detection instruments such as a photoionization detector or organic vapor analyzer. These tools provide ranges of concentrations of classes of substances. More definitive results can be obtained with immunoassays and x-ray fluorescence instruments, which are discussed later in the document. Results of the preliminary study should enable the team to plan a more focused and cost-effective sampling design.

When no previous data are available to estimate the variability of the contamination at the site, a multi-phase investigation may be useful. A preliminary investigation may be used to calculate an estimate of variability in site contaminant concentrations; this estimate can then be used to determine the number of samples required to achieve the specified confidence level or decision error rate. Not knowing the actual variability in existing contamination is the most likely reason for the results to fall short of the desired confidence level.

Because of the expense of multiple field mobilizations, a dynamic work plan that combines two phases of sampling into a single mobilization would be helpful in keeping down costs. A dynamic work plan combines field technologies that quickly provide the data needed for planning the next phase of data acquisition with adaptive sampling designs that are flexible enough to respond to data generated in the field. For example, field data could be collected to demonstrate the variability of chemical concentrations, which influences the number of samples required to reach a specific decision error rate.

Types of Sample*s*

The types of samples to be collected and analyzed are determined during the DQO process. Like other variables of the sampling design, the type of sample collected is dependent on the team's predefined decision error rate, required degree of accuracy, the spatial and temporal variability of the media, and the cost.

The paragraphs below discuss grab and composite samples and how they can be used in the sampling design.

A sample can be collected discretely or as a composite sample. Discrete samples, called grab samples, are taken at a single location and are useful for identifying and quantifying chemicals in areas of a site where contamination is suspected. For example, grab samples collected around tanks and drums can answer the questions of whether and what substances may have leaked from the tanks and drums.

To identify average contamination across a site, composite samples may be more appropriate. Composite samples are composed of more than one discrete sample taken at different locations. The discrete samples are mixed to obtain a homogeneous single composite sample and analyzed. Composite sampling allows sampling of a larger area while controlling laboratory analytical costs because several discrete samples are physically mixed and one or more samples are drawn from the mixture for analysis. The drawbacks of composite samples are related to the averaging of the contamination levels in discrete samples. Compositing minimizes the significance of low levels of contamination and may mask locations where contamination is above the action level. The number of composite samples and the number of individual samples within a composite sample should be based on the decision error rate goals established during the DQO process.

Collection of composite samples was not recommended at the Springfield site described in Section 3 because the samples were to be analyzed for compounds that may volatilize during mixing. If the contaminant of concern was a metal, then compositing samples to reduce the number of samples and analyses would have been cost-effective.

The Brownfields team should request standard operating procedures (SOPs) for sampling activities from its contractor. (SOPs are discussed in more detail later in this section.) The SOPs should describe all aspects of sample collection, including how to determine if the sample is representative, handling and custody requirements, and the sample volume that must be collected to provide enough material for all necessary analyses. The laboratory chosen to perform analyses should be able to provide volume requirements for selected analytical methods.

Sometimes SOPs will call for the collection of extra volumes of a sample. For example, when sampling for VOCs, loss of the analytes through breakage of a sample container or through volatilization (loss of the container's headspace) can render the sample or analysis useless.

Background Samples

Some action levels are derived from naturally occurring or background concentrations. In these cases, teams should collect background or upgradient samples from nearby areas that are not impacted by site contamination.

Background samples are analyzed for the same parameters as the site samples to establish background concentrations of target analytes and compounds. They are collected in areas unaffected by the site, and therefore, indicate whether the concentration of a particular analyte in a sample is related to site activities.

When it is necessary to compare site contamination levels to background levels, it is helpful to collect and analyze background samples prior to the final determination of the sampling design since the number of samples necessary for a specific decision error will be reduced if background concentrations are low.

Analytical Methods

The samples called for in the SAP will be analyzed either onsite or in a laboratory according to analytical methods selected during the DQO process. Analytical methods can be classified based on the medium (e.g., soil, water) from which the sample was taken, the sample preparation method, the chemicals for which the analysis is requested (analytes), the expected

levels of the analytes (detection limits or ranges), the level of confidence in the results, and cost. Due to the variety of analytical methods available, the team should work closely with the laboratory to select appropriate methods that meet the predefined DQOs.

The team should pay particular attention to the action levels for the site decision when selecting analytical methods. Different methods have different detection limits, the lowest concentration of a contaminant that can be detected by a particular test method or analytical instrument. When contaminant concentrations in a sample decrease, that is, as they approach the detection limit, they become increasingly difficult to quantify, and the instrument readings or test results become less reliable. Measurements that fall below the detection limits are not reliable, and are usually reported as less than or equal to the detection limit. The team will want to select a method with a detection limit appropriate for the intended use of the data. For the decision of whether to clean up the site for public park use, the team will want to use a method that can accurately quantify concentrations below the action level.

Analytical methods can be varied during optimization of the sampling design to produce more cost-effective results. For example, if a sampling design option calls for a multi-phase investigation, the preliminary study may collect data using a broad spectrum analytical method to identify classes of compounds. Subsequent analyses can focus on compounds for which analyte- and class-specific methods are available, thereby producing less expensive and more accurate data than full spectrum methods. The combination of a multi-phase strategy and varied analytical methods allows for the collection of more samples without a loss of confidence or increase in cost. Also, an early broad spectrum analysis increases the probability of identifying all contaminants of concern. This sampling design strategy would have been useful for the park reuse portion of the Springfield site for which no previous sampling data exist if the site history indicated a high likelihood of contamination.

Forms F-1 and F-2 of the QAPP template provide space for documentation of analytical methods to be used in the sampling design. SOPs should be attached to the QAPP for all analytical methods: standard, non-modified publicly available methods and nonstandard or modified methods that accommodate site-specific conditions. An example of a nonroutine method is analysis of samples from building materials that may have become contaminated. All field methods or mobile laboratory methods should also have clearly written SOPs.

An alternative approach to selecting analytical methods is included in the Performance Based Measurement System (PBMS). This approach is a partnership-style relationship with the laboratory that facilitates cost-effective, method adaptations that best serve site-specific project needs. Instead of prescribing how to accomplish a task, PBMS statements of work describe in objective terms what performance standards must be met. If the team chooses this approach, it should work closely with the laboratory to document site-specific performance of the method and how this performance supports the predefined data quality needs. More data on PBMS can be found on the following webpage: *http://www.epa.gov/epaoswer/hazwaste/test/pbms.htm*.

If the team decides to analyze samples in the field, they should be aware of any limitations of the field methods under consideration and ensure that the DQOs will be met. Two common types of field analytical methods are immunoassays and x-ray fluorescence (XRF). These methods can produce rapid results at relatively little cost but they may have limited ability to identify certain contaminants and reach very low detection limits. Ongoing technological advances are rapidly expanding the capabilities and usefulness of field analytical technologies. Information on performance of field analytical technologies can be obtained from the Cleanup Information website at *http://www.clu-in.com/supply1.htm*. See Appendix C for additional references.

Matrix interferences are common obstacles to successful sample analysis. For example, a clayey matrix may not release analytes of concern during sample preparation causing the resulting levels to be biased low. The team should explore and document contingency plans to guide field work in the event that site-specific interferences hinder the reliability of a particular method. Contingency plans, which can be documented on form O of the QAPP template, can save considerable time and money by averting the downtime of expensive field teams and limiting the costs of producing non-informative data and of subsequent resampling.

Quality Control in the Field

Field quality control requirements and documentation of all field sampling and observations is critical to provide a historical record for future reviews and analysis of the useability of the data produced. The official field log book will contain documentation of field activities that involve the collection and measurement of environmental data. Additional forms may be used in the field to record related activities as explained below.

SOPs delineate the step-by-step approach that field personnel will follow in collecting samples, taking field measurements, calibrating instruments, etc. Sampling and field analytical SOPs that may be used during a Brownfields site assessment include the following:

- Sampling of surface and/or subsurface soil;
- Wipe sampling;
- Sampling of concrete and debris;
- Sampling of groundwater and surface water;
- Use of field analytical instrumentation, such as onsite GC, GC/MS, XRF, or other field measurement methods;
- Monitoring well installation and development; and
- Direct push sampling.

Most qualified sampling contractors and State and Federally certified laboratories develop SOPs and analytical methods as part of their overall QA program. These SOPs and analytical methods can be used to evaluate a potential contractor's competence to perform field activities or as a standard for conducting a field audit (described later in this section). SOPs are especially important for field activities where significant error can be introduced into data measurements. Data review and acceptance depends on the documentation that SOP protocols were followed. Any modifications to the SOPs during field work should be thoroughly documented. All SOPs used for a Brownfields site assessment should be included as appendices to the QAPP (see form F-1 of QAPP template). For further reference, see *Guidance for the Preparation of Standard Operating Procedures for Quality-Related Operations* (see Appendix C).

SOPs are necessary for field activities including calibration, decontamination, and preventive maintenance and should be a part of the SAP. The field team should document what SOP they are using in the field and any deviations from the SOP.

Decontamination protocols describe methods, tools, and products used to clean reusable sampling equipment after sample collection to prevent contaminating the next collected sample. These protocols are sometimes dictated by the specific sampling SOPs. A field preventive maintenance protocol involves ensuring that all field equipment has been properly calibrated, charged, and inspected prior to and at the end of each working day and that replacement parts are available.

Field Instrument/Equipment Inspection and Calibration

Sampling and analysis generally requires the use of varied equipment and tools in the gathering of environmental data. All field equipment needs to be inspected to determine if it is adequate for the media, parameters to be sampled, and the tests to be performed.

Data may be generated onsite through the use of real-time equipment, such as a photoionization detectors, an organic vapor analyzer, or a pH

meter. A more detailed analysis may call for mobile lab-generated data.

The field-testing and mobile laboratory equipment should be examined to ensure that it is in working condition and properly calibrated. The calibration of field instruments should be performed according to the method and schedule of an SOP — usually based on the manufacturer's operating manual. Calibration should be performed more often as field conditions dictate.

Field Documentation

Generally, the Brownfields team records field activities in ink, in a bound notebook with prenumbered pages or on a preprinted form. For each sampling event, the field team provides the site name and location, date, sampling start and finish times, names of field personnel, level of protection, documentation of any deviation from protocol, and signatures of field personnel.

For individual samples, field teams should document the exact location and time the sample was taken, any measurement made (with real-time equipment), physical description of the sample, sample number, depth, volume, type of sample, and equipment used to collect the sample. This information can be critical to later evaluations of the resulting data's useability.

Individual samples should be labeled in the field. Labels should include sample location, sample number, date and time of collection, sample type, sampler's name, and method used to preserve the sample, if applicable. (Sample preservation involves the treatment of a sample usually through the addition of a compound that adjusts pH to retain the sample properties, including concentration of substances, until it can be analyzed.) The field team should follow a sample summary table similar to form F-2 of the QAPP template for each sampling event. The table should include a listing of the total number of samples, types of sample matrices, all analyses planned for each sample differentiating critical measurements, and other information that may be relevant to later assessments of the data's useability.

The team should track the transfer of samples from the field to the laboratory with chain-of-custody forms. Information on the chain-of-custody forms should include name of laboratory, persons relinquishing and receiving samples, quantity of sample material, preservation solutions, test methods requested, unit of measurements, and signatures of laboratory personnel. Custody procedures should be discussed in QAPP template form K: Sample Handling and Custody Requirements.

Field System Audits

During the initial stages of field activities, a QA representative from the Brownfields team should determine whether the field activities are following the protocols delineated in the QAPP. If, during the audit, the QA representative identifies deviations from the prescribed procedures, the field team manager should take on-the-spot actions to ensure that field activities are conducted in accordance with the QAPP. The QA representative should document any deficiencies encountered and the corrections made. Results of the audit should be maintained at the site assessment office as part of the document control program. Document control is discussed later in this section.

Quality Control in the Laboratory

The team should select laboratories that have defined QA protocols. All laboratories used to analyze samples should have an overall Quality Assurance Plan available for review, including SOPs and analytical methods, internal QA/QC procedures and logs, and data review procedures. The team may decide to conduct a laboratory system audit to ensure that these plans and procedures are in place and in use.

The team may also decide to audit its laboratory by submitting performance evaluation (PE) samples to the laboratory with the other environmental samples collected at the Brownfields site. A PE sample is a sample of

known composition provided for laboratory analysis to monitor laboratory and method performance. A PE sample can be used to rate the laboratory's ability to produce analytical results within the pre-set limits documented in the QAPP. PE samples may be the simplest and most cost-effective way to audit a laboratory.

Laboratories that participate in EPA's Contract Laboratory Program (CLP) and State programs typically analyze PE samples on a routine basis. The team should request a copy of the laboratory's PE results as part of its audit program. The team should rely on existing audit information, if available and relevant, to determine the reliability of a laboratory.

Quality Control Samples

QC samples are collected and analyzed to determine whether sample concentrations have changed between the time of sample collection and sample analysis, and if so, when and how. For example, cross-contamination may occur during sampling, and degradation may occur during storage. A field QC sample is a sample that is collected and produced in the field. The laboratory QC sample is prepared by the person conducting the first step of the sample analysis. The number of field and laboratory QC samples used during the project depends on the analytical method and requirements of the QAPP. The general rule is that 10% of samples should be QC samples. This means that if 20 samples are collected, at least two additional samples should be submitted as QC samples. Exhibit 6 lists typical QC samples and the data they provide.

Three basic types of QC samples that are prepared in the field and laboratory include blanks, spikes, and replicates. A blank sample is a clean sample that has not been exposed to the sample medium being analyzed but is subjected to the same procedures used in the preparation and analysis of the sample from the medium being analyzed. The blanks may be exposed to the same decontamination, transport, storage, or analytical process as the regular samples to obtain a baseline value that may be used later to evaluate other data.

EXHIBIT 6
TYPES OF QC SAMPLES

QC Sample	Information Provided
Blanks field blanks rinsate blanks reagent blanks method blank	**Bias introduced during sampling and analysis** field handling or transport contaminated equipment contaminated reagent any aspect of laboratory analytical system
Spikes matrix spike matrix spike duplicate analysis matrix spike surrogate spike	**Bias introduced in laboratory** preparation and analysis preparation and analysis precision instrumentation analysis
Duplicates, Splits, etc. co-located samples field duplicates field splits laboratory duplicates laboratory splits analysis duplicates	**Precision** sampling and analysis precision precision of all steps after sample collection shipping and interlaboratory precision analytical precision interlaboratory precision instrument precision

Source: *Guidance for Quality Assurance Project Plans*. February 1998, EPA QA/G-5 EPA 600-R-98-018.

A spike sample is a sample to which a known amount of a chemical has been added for the purpose of determining the efficiency of recovery of the analytes. These QC samples are particularly helpful during analysis of complex matrices (e.g., sediment or sludge). A duplicate sample is a second sample taken from the same source at the same time and analyzed under identical conditions. A split is a duplicate that is sent to a different laboratory for analysis. When more than one duplicate is collected it is called a replicate.

For the portion of the Springfield site slated for reuse as a public park, the team planned for 40 to 50 samples. Following the 10% rule of thumb stated above, the team will need four to five QC samples. Considering the importance of the accuracy of the data, the team will be particularly interested in knowing if any bias is present in the data. Because historical data did not identify hazardous waste activities on this portion of the property the team will not be as concerned about cross contamination. One field QC sample will be collected to detect any contamination introduced by field procedures. Two laboratory QC samples, a matrix spike and a matrix spike duplicate will be collected to check bias and precision. The fourth sample, a co-located sample, might be collected to test the precision of field collection procedures. Many of the QC samples are defined in the *Glossary of Terms* in Appendix B of this document.

Document Control

Document control is a crucial component of QA. Although it is critical to completion of the last stage of a Brownfields site assessment (review of data useability), it is sometimes overlooked. Data useability review depends on thorough documentation of predefined data specifications and the events that take place during implementation of the project which may cause the data to fall short of the predefined specifications.

The team should identify those documents that will be necessary to check for compliance with all field and laboratory procedures. As explained under the next heading of this document, expertise in analytical chemistry and statistics are necessary for the last stages of the assessment of data useability. Therefore, during planning for the Brownfields site assessment, these team members should be consulted to identify the types of documentation they will need. Critical types of documentation include the following:

Field Logbook
- Site sketch or map with location of each sample collection point
- Full descriptions of all deviations from analytical SOPs, SAP, and the QAPP
- Description of field sampling conditions and physical parameter data as appropriate for the media involved

QAPP
- Site description, including surrounding structures and terrain features, nearby populations, flow directions of relevant media, and a description of active industrial processes
- Description and rationale for sampling design and procedures and references to all SOPs

Field SOPs
- Sampling, decontamination, and calibration procedures

Analytical SOPs
- Analytical methods used, sample tracking and log-in procedures

Laboratory Deliverables
- Narrative explanation of level of analytical data review used by the laboratory and resulting data qualifiers, indicating direction of bias based on the assessment of QC samples (e.g., blanks, field and laboratory spikes)
- Results for each analyte and sample qualified for analytical limitations
- Sample quantitation limits (SQLs) and detection limits for undetected analytes, with an explanation of the detection limits reported and any qualifications

- Instrument printouts and logbooks, spectra, and raw data

Laboratory Notebook
- Full descriptions of all deviations from analytical SOPs, SAP, and the QAPP

Custody Records
- Chain-of-custody forms
- Laboratory custody records

Additionally, project specific documentation may include status reports, teleconference records, and other correspondence.

The documents and records that should be tracked and secured should be listed on form P of the QAPP template. The list should identify the party responsible for producing these reports and provide directions for where they should be stored or sent.

Documentation permits the reviewer to trace a sample from collection to analysis and reporting of results. The goal of the document control program is to account for all necessary project documents produced during planning, implementation, or analysis.

Grantees under EPA's Brownfields program should adhere to program requirements for record retention found in 40 CFR Subpart O. Requirements include a numerical document control system, document inventory procedure, and a central filing system with a designated person(s) responsible for its maintenance.

Deliverables for Data Useability Review

Review of the useability of data culminates in the determination of whether actual data meet the data objectives. This determination is impossible without the development, implementation, and documentation of procedures used for sample collection, shipment, analysis, and data reporting. This information will allow QA reviewers to determine, with reasonable certainty, whether data collected during the Brownfields site assessment meet the DQO criteria documented in the QAPP. As in all aspects of a Brownfields site assessment, the activities that occur during this stage of the project should be planned and documented in the QAPP. Forms Q-1, Q-2, and R provide space for the team to describe what procedures will be performed during data useability review.

Through data useability review, the team determines whether the project has performed within the specifications in the planning objectives. The decision to accept data, reject data, or accept only a portion of the data, should be made after consideration and analysis of all parameters described in the QAPP. The team should have an analytical chemist and a statistician for portions of this assessment but some items do not require special expertise. The data useability review begins with an analysis of the data for their own merit and ends with a statistical reconciliation of the data with site-specific data quality objectives.

The stages of data useability review generally begin with an evaluation of the effectiveness of the sampling operations, their conformance to the SAP and SOPs, and whether any unusual circumstances are documented in the field logs. The five data quality indicators that should be assessed during the review of field procedures include completeness, comparability, representativeness, precision, and bias (accuracy). These terms are described in Appendix B of this document.

Some activities that should be carried out include identifying all samples (including locations and analytes) called for in the QAPP and comparing those to sample locations documented in the field log and on a field map. These samples are also compared to the sample results submitted by the laboratory to see if the predefined number of samples was actually analyzed. This review should also check if the predefined analytical methods and detection limits were used. These reviews should give an indication of the completeness of the data. Any discrepancies that cannot be resolved may affect the level of certainty in the final decision about site reuse.

The next step is to verify the analytical data. This activity is often guided by the analytical method used, and several guidance documents are available that provide a framework for data verification based on the analytical method. QAPP form Q-2 provides space to describe the process to be used during data verification.

During data verification (some EPA Guidance documents use the terms verification and validation interchangeably), an analytical chemist reviews the results of QC samples to identify sources of error in the data overall, on a sample basis and analyte by analyte. The reviewer will look at sample holding times that may affect the data from a single sample, and calibration and analyte recoveries that may affect the quantification of individual analytes. After the data verification is complete, the team should have a better idea of what chemicals are present at what levels and what threats the site poses.

The five data quality indicators listed above should also be applied when verifying the analytical data. The QAPP should describe the level of verification that will be required.

The last stage of data useability review is validation, which should be carried out by the statistician to determine whether the data can support their intended use. The QAPP should explain on form R how the results will be reconciled with the predefined data requirements. Methods for determining possible deviations from planning assumptions should be described. The QAPP should also specify how the limitations on data use will be reported. EPA's *Guidance for Data Quality Assessment* provides some information on this determination (see Appendix C for full reference).

Improving Data Useability

The team should plan for corrective actions to improve data useability when performance fails to meet objectives for data that is critical to the Brownfields site assessment. Corrective actions can be costly (resampling) or relatively inexpensive (requesting additional information from the laboratory). Much of this information is determined by the team as part of Step 6 of the DQO process*: Specifying Limits on Decision Errors*. Corrective actions are intended to improve data quality and reduce uncertainty, and may eliminate the need to qualify or reject data. Some corrective actions include the following:

- Retrieving missing information;
- Resolving technical or procedural problems by requesting additional explanation or clarification from the technical team;
- Requesting reanalysis of sample(s) from the extract stored at the laboratory;
- Requesting construction and re-interpretation of analytical results from the laboratory or team chemist;
- Requesting additional sample collection and analysis for site or background characterization; modeling potential impacts on uncertainty using sensitivity analysis to determine range of effect;
- Adjusting or questioning data based on approved default options and routines; and
- Qualifying or rejecting data for use in the site assessment.

Summary

This document has presented the DQO process as a systematic planning tool for cost-effective site assessments. It has introduced elements of a QAPP, which helps the team maintain control of the project and achieve its objectives through use of QA and QC measurements. It also discussed elements of sampling strategies and how to determine whether resulting data meet project objectives. These tools will help municipalities, Tribes, and States reduce the environmental uncertainty associated with Brownfields sites by producing environmental measurement data of known and adequate quality. This will, in turn, support defensible decision-making and stakeholder satisfaction. The QAPP template that follows in Appendix A can be used to guide the design of a QAPP or the forms can simply be reproduced and completed as the QAPP.

Appendix A - Model Quality Assurance Project Plan

INTRODUCTION

The EPA requires that all environmental monitoring and measurement efforts participate in a centrally managed quality assurance (QA) program.

Any Brownfields team generating data under this quality assurance program has the responsibility to implement minimum procedures to ensure that the precision, accuracy, completeness, and representativeness of its data are known and documented. To ensure the responsibility is met uniformly, each party should prepare a written QA Project Plan (QAPP) covering each project it is to perform.

The QAPP documents the project planning process, enhances the credibility of sampling results, produces data of known quality, and saves resources by reducing errors and the time and money spent correcting them. The QAPP is a formal document describing in comprehensive detail the necessary QA, quality control (QC), and other technical activities that should be implemented to ensure that the results of the work performed will satisfy the stated performance criteria.

All QA/QC procedures should be in accordance with applicable professional technical standards, EPA requirements, government regulations and guidelines, and specific project goals and requirements.

The tables and figures contained in the Appendices to this document can be used to compile the Brownfields Site QAPP. These forms can be reproduced or downloaded from EPA's Brownfields web page located at *http://www.epa.gov/swerosps/bf/*, or similar forms with the same requirements can be created. Standard Operating Procedures (SOPs) and standard analytical methods should be referenced in the text and included as appendices to the Brownfields Site QAPP. SOPs should be referenced in the QAPP by title, date, revision number and the originator's name.

Brownfields
Quality Assurance Project Plan

TABLE OF CONTENTS

FORMS

Form A

Title and Approval Page

_____

Document Title

_____

Prepared by: (Preparer's Name and Organizational Affiliation)

_____

Address and Telephone Number

_____

Day/Month/Year

Project Manager: _____

Signature

_____

Printed Name/Date

Project QA Officer: _____

Signature

_____

Printed Name/Date

U.S. EPA Project Manager Approval: _____

Signature

_____

Printed Name/Date

U.S. EPA QA Officer Approval: _____

Signature

_____

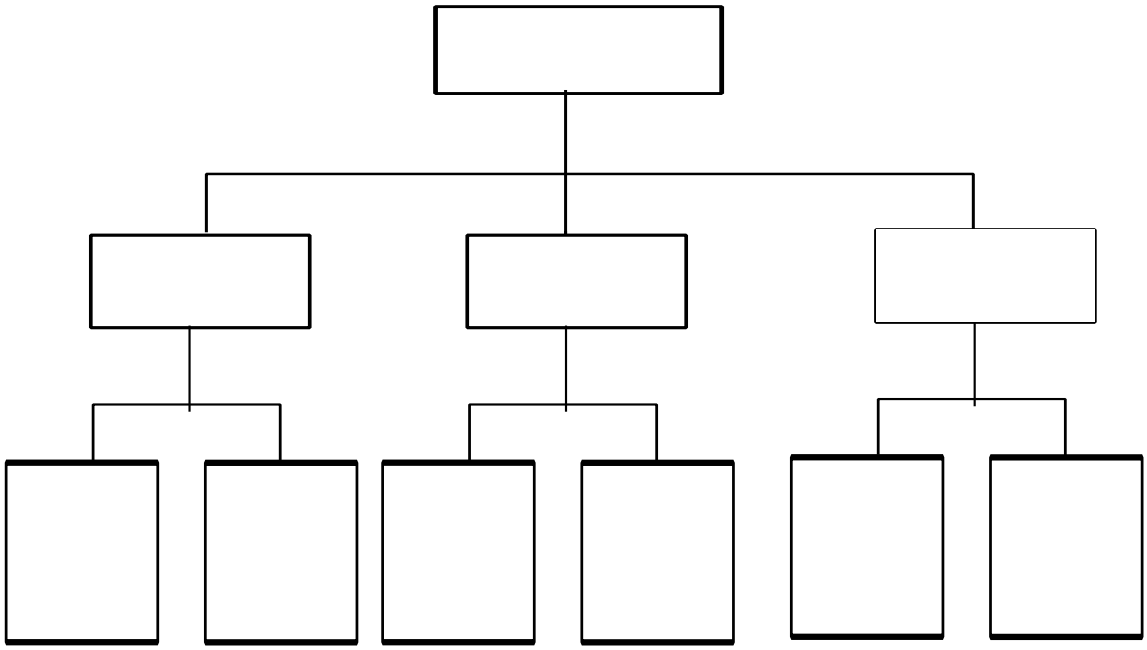
Printed Name/Date

Form B

Project Organization and Responsibility

(Fill-in the blanks, if applicable, otherwise insert another project-specific chart.)

Develop an organizational chart that identifies the chain of command of key personnel, including the QA representative. Include titles, responsibilities, and organizational affiliation of all project participants.



Title: **Revision Number:**
Site Name: **Revision Date:**
Site Location: **Page: ___ of ___**

Form C

Problem Definition (use multiple pages if needed)

Briefly state the specific problem that the data collection project is designed to solve or the decisions to be made (i.e., the project objectives). Include relevant characteristics of the site, such as site use history, suspected locations and identification of contaminants, range of contaminant concentrations, media that may be affected, and likely migration routes. Cite previous studies that indicate why the project is needed.

Title: **Revision Number:**
Site Name: **Revision Date:**
Site Location: **Page: ___ of ___**

Form D

Project Description (use multiple pages if necessary):

Provide a detailed description of the work to be performed, e.g., identify media to be sampled, whether field or fixed laboratories will be used, if field analytical methods will be used**,** likely action levels, work schedules, required reports, etc.

Form D (Cont.)

Project Timeline

Prepare an overall project timetable that outlines beginning and ending dates for the entire project as well as specific activities and products within the project.

Activities (list products)	Activity Start Dates (MM/DD/YY) Activity End

Form E

Sampling Design (use multiple pages if needed)

Discuss project sampling design and provide a rationale for the choice of sampling locations for each parameter/matrix to be sampled during this project, e.g., a judgmental sampling strategy with broad spectrum analysis using methods from SW-846. Identify action levels. Attach a detailed site map with anticipated sampling locations. State whether and how field analytical techniques will be used and identify the number of field analyzed samples that will be sent for confirmation by a permanent laboratory.

Form F - 1

Method and SOP Reference Table (use multiple pages if needed)

Use this form to create an SOP Reference Table. The appropriate number/letter reference from this table will be used to complete Forms F-2 through J, and Form L. Attach all referenced Project Analytical and Sampling SOPs to the QAPP.

Analytical Method Reference: Include document title, method name/number, revision number, date	**Project Analytical SOPs: Include document title, date, revision number, and originator's name**
1a.	1b.
2a.	2b.
3a.	3b.
4a.	4b.

Project Sampling SOPs:* Include document title, date, revision number, and originator's name
1c.
2c.
3c.
4c.

* Project Sampling SOPs include sample collection, sample preservation, equipment decontamination, preventive maintenance, etc.

Form F-2

Sampling and Analytical Methods Requirements (use multiple pages if needed)

Describe the details of the data collection and analysis design for the project. Insert the appropriate SOP number/letter reference in the table. Form F-1 contains the Method and SOP Reference Table. Attach analytical SOPs for sample collection and analysis for each parameter/matrix. The following is example data.

Parameter	Matrix	Number of Samples (include field QC)	Analytical Method*	Sampling SOP*	Containers per Sample (number, size and type)	Preservation Requirements (temperature, light, chemical)	Maximum Holding Time at Lab (preparation/ analysis)
benzo(a) pyrene	soil	23	CLP Organic SOW OLM 03.2	1c	2x 4oz, flint glass jar, polyprop cap, teflon liner	stored in dark at 4°C	extract in 7 days

* Insert the appropriate SOP number/letter reference in the above table. Form F-1 contains the Method and SOP Reference Table.

Form G

Preventive Maintenance - Field Equipment

Identify the equipment and/or systems requiring periodic preventive maintenance. Cite references on how periodic preventive and corrective maintenance of measurement or test equipment shall be performed to ensure availability and satisfactory performance of the systems. Cite descriptions of how to resolve deficiencies and when re-inspection will be performed. Describe the availability of spare parts identified in the manufacturer's operating instructions and how SOPs will be maintained.

Instrument	Activity	Frequency	SOP Ref. *

* Insert the appropriate reference number/letter from Form F-1, Method and SOP Reference Table.

Form H

Calibration and Corrective Action - Field Equipment

Identify all tools, gauges, instruments, and other equipment used for data collection activities that must be calibrated to maintain performance within specified limits. Reference calibration procedures to be conducted using certified equipment and standards with known relationships to recognized performance standards. Reference procedures on the maintenance of records of calibration.

Instrument	Activity	Frequency	Acceptance Criteria	Corrective Action	SOP Ref. *

* Insert the appropriate reference number/letter from Form F-1, Method and SOP Reference Table.

Form I

Preventive Maintenance - Laboratory Equipment

Identify the equipment and/or systems requiring periodic preventive maintenance. Cite references on how periodic preventive and corrective maintenance of equipment shall be performed to ensure availability and satisfactory performance. Cite discussions of how the availability of critical spare parts, identified in the manufacturer's operation instructions and/or SOPs, will be assured and maintained. Cite corrective actions for calibration check samples that exceed the control limits, drift in the calibration curve, or if a reagent blank indicates contamination.

Instrument	Activity	Frequency	SOP Ref. *

* Insert the appropriate reference number/letter from Form F-1, Method and SOP Reference Table.

Form J

Calibration and Corrective Action - Laboratory Equipment

Identify all tools, gauges, instruments and other equipment used for data collection activities that must be calibrated to maintain performance within specified limits. Reference calibration procedures to be conducted using certified equipment and/or standards with known relationships to recognized performance standards. Reference procedures on the maintenance of records of calibration.

Instrument	Activity	Frequency	Acceptance Criteria	Corrective Action	SOP Ref. *

* Insert the appropriate reference number/letter from Form F-1, Method and SOP Reference Table.

Form K

Sample Handling and Custody Requirements (use multiple pages if needed)

Describe the procedures for sample handling and custody. Include chain-of-custody forms; identify the sampling tags and custody seals the field teams should use. Refer to SOPs for collecting, transferring, storing, analyzing, and disposing of samples.

Form L

Analytical Precision and Accuracy (use multiple pages if needed)

Identify the analytical methods and equipment required, including sub-sampling or extraction methods, laboratory decontamination procedures and materials, waste disposal requirements (if any), and specific performance requirements (i.e., quantitation limits, precision, and accuracy) for each method.

Analyte	Analytical Method*	Detection Limit (water/soil) (units)	Quantitation Limit (water/soil) (units)	Precision (water/soil)	Accuracy (water/soil)

* Insert the appropriate reference number/letter from Form F-1, Method and SOP Reference Table.

Form M

Field Quality Control Requirements

The procedures and requirements contained in *EPA Requirements for Quality Assurance Project Plans,* October, 1997. EPA QA/R-5 (Draft Final), or latest revision, should be followed and referenced below.

QC Sample	Frequency *	Acceptance Criteria	Corrective Action
Duplicate	**5% per parameter per matrix** **or _____**		
Equipment Blank	**5% per parameter per matrix** **or _____**		
VOA Trip Blank	**1 per Cooler** **or _____**		
Cooler Temperature Blank	**1 per Cooler** **or _____**		
Bottle Blank	**1 per Lot #** **or _____**		
Other (specify)			

* Circle criteria listed or indicate alternative criteria

Form M (Cont.)

Laboratory Quality Control Requirements

QC Sample	Frequency *	Acceptance Criteria	Corrective Action
VOA Reagent/Method Blank	**Daily** **or _____**		
Reagent/Method Blank	**5% per parameter per matrix** **or _____**		
Duplicate	**5% per parameter per matrix** **or _____**		
Matrix Spike	**5% per parameter per matrix** **or _____**		
Performance Evaluation (PE) Sample	**5% per parameter per matrix per concentration level** **or _____**		
Other			
Other			

* Circle criteria listed or indicate alternative criteria.

Form N

Data Management and Documentation (use multiple pages if needed)

Briefly discuss data documentation and management from field collection and laboratory analysis to data storage and use. Analytical data packages should include all relevant documents (for example, a laboratory narrative, tabulated summary forms for laboratory standards, quality control, and field sample results in order of analysis, raw data for laboratory standards, quality control, and laboratory log book sheets). Describe procedures for detecting and correcting errors during data reporting and data entry. Provide examples of any forms or checklists, such as chain-of-custody or field calibration forms.

Types of information to request from the laboratory:

a) Data Results Sheets (include any performance evaluation sample results)
b) Method Blank Results
c) Surrogate Recoveries and Acceptance Limits
d) Matrix Spike/Matrix Spike Duplicate Results and Acceptance Limits
e) Spike/Duplicate Results and Acceptance Limits
f) Laboratory Control Sample Results and Acceptance Limits
g) ICP Serial Dilution Results
h) ICP Interference Check Sample Results
I) Project Narrative which contains all observations and deviations

Form O

Assessment and Response Actions (use multiple pages if needed)

Describe procedures for identifying and correcting any problems encountered during specific project operations.

Form P

Project Reports (use multiple pages if needed)

Identify the frequency, content, and distribution of project reports that detail project status, results of internal assessments, corrective actions implemented, and project results. For example, the field team may be required to submit daily status reports comprised of field log sheets describing any field measurements taken, number of samples collected and their status (shipped, at lab, or awaiting shipment), deviations from SOPs, etc.

Form Q - 1

Verification of Sampling Procedures (use multiple pages if needed)

Describe the process to be used to review the sampling procedures to verify that they conform to requirements in the sampling and analysis plan.

Form Q - 2

Data Verification and Validation (use multiple pages if needed)

Describe the process to be used to verify conformance of the analytical data with predefined requirements. Describe the process to be used to validate conformance of the analytical data to the predefined needs of the Brownfields site assessment.

Form R

Data Useability (use multiple pages if needed)

Describe the process for determining whether the data successfully meet the requirements for their intended use. Outline methods to be used to identify anomalies and departures from assumptions in the sampling and analysis design. Discuss how limitations of the data will be reported.

Appendix B - Glossary of Terms

Accuracy	A measure of the closeness of an individual measurement or the average of a number of measurements to the true value. Accuracy is influenced by a combination of random error (precision) and systematic error (bias) components which are due to sampling and analytical operations. EPA recommends that this term not be used and that precision and bias be used to convey the information usually associated with accuracy.
Analyte	The chemical for which a sample is analyzed.
ASTM	American Society for Testing and Materials — An organization which develops and publishes standard methods of analysis and standards for materials and procedures.
Background	A level of hazardous substances that approximates the level that would be present in the medium of concern if the source of contamination under analysis did not exist.
Bias	The systematic or persistent distortion of a measurement process which causes errors in one direction (i.e., the expected sample measurement is different from the sample's true value). Bias can result from improper data collection, poorly calibrated analytical or sampling equipment, or limitations or errors in analytical methods and techniques.
Bioaccumulation	The tendency of a hazardous substance to be taken up and accumulated in the tissue of organisms, either directly or through consumption of food containing the hazardous substance. Bioaccumulation typically results in increasing concentrations of hazardous substances in tissues of organisms higher up the food chain.
Blank	A sample that has not been exposed to the analyzed sample stream in order to monitor contamination during sampling, transport, storage, or analysis. The blank is subjected to the same analytical or measurement process as other samples to establish a zero baseline value and is sometimes used to adjust or correct routine analytical results.
Brownfields Site Manager	Person appointed by the cooperative agreement recipient or lead agency to oversee cleanups at specific sites.
Calibration	Comparison of a measurement standard, instrument, or item with a standard or instrument of higher accuracy to detect and quantify inaccuracies and to report or eliminate those inaccuracies by adjustments.
Calibration standard	Standards prepared by successive dilution of a standard solution covering the full concentration range required and expected to be seen in the samples, for the organic or inorganic analytical method. The calibration standard must be prepared using the same type of acid or solvent used to prepare samples for analysis.

CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980, as amended.
Chain-of-Custody	An unbroken trail of accountability that ensures the physical security of samples, data, and records.
CLP	U.S. EPA's Contract Laboratory Program. Refers to laboratory specifications, analytical methods, and QA/QC protocols required for Superfund and related activities.
Comparability	The confidence with which one data set can be compared to another.
Completeness	A measure of the amount of valid data obtained from a measurement system compared to the amount that was expected to be obtained under correct, normal conditions.
Composite sample	Non-discrete samples composed of one or more individual samples taken at different locations at a site. Composite samples are representative of the average concentrations of contaminants across a large area.
Control Sample	A QC sample introduced into a data collection process to monitor the performance of the system.
Cooperative Agreement	A form of assistance provided by a Federal agency in which substantial interaction is anticipated between the Federal agency and the assistance recipient (e.g., State, Tribal, or local government or other) during the performance of the contemplated activity.
Data Validation	Confirmation through examination and provision of objective evidence that requirements for a specific intended use have been met. The process of examining the analytical data to determine conformance to user needs.
Data Verification	Confirmation through examination and provision of objective evidence that predefined requirements for a specific intended use have been met. The process of examining the result of a given activity to verify conformance to stated requirements for that activity.
Definitive Data	Data that are documented as appropriate for rigorous uses that require both hazardous substance identification and concentration. Definitive data are often used to quantify the types and extent of releases of hazardous substances. *Guidance for Performing Site Inspections Under CERCLA, Interim Final, p. 99; Guidance for Data Useability in Site Assessment, Draft, pp. 13 and 14.*
DL	Detection Limit — the lowest concentration or amount of the target analyte that can be determined to be different from zero by a single measurement at a stated level of probability.
Duplicate Sample	A second sample taken from and representative of the same population and carried through all steps of the sampling and/or analytical procedures

	in an identical manner. See Field Duplicate, Matrix Duplicate, and Matrix Spike Duplicate.
DQOs	Data Quality Objectives — Qualitative and quantitative statements (derived from the DQO Process) that clarify the objectives of studies, technical processes and quality assurance programs, define the appropriate type of data, and specify tolerable levels of potential decision errors that will be used as the basis for establishing the quality and quantity of data needed to support decisions.
Equipment Blank	Also called the Equipment Rinsate. A sample of analyte-free reagent taken after completion of decontamination and prior to sampling at the next sample location. It is used to check field decontamination procedures to ensure that analytes from one sample location have not contaminated a sample from the next location.
False Positive Decision Error	The erroneous decision that the null hypothesis is correct.
False Negative Decision Error	The erroneous decision that the null hypothesis is incorrect.
Field Blank	A blank used to provide information about contaminants that may be introduced during sample collection, storage, and transport. A clean sample, carried to the sampling site, exposed to sampling conditions, and returned to the laboratory and treated as an environmental sample.
Field Duplicate	An independent sample collected from the same location or source, as close as possible to the same point in space and time. Duplicates are stored in separate containers and analyzed separately for the purpose of documenting the precision of the sampling process. (Laboratory variability will also be introduced into the samples' results.)
GC	Gas Chromatography — An analytical technique used to analyze environmental matrices for contaminants.
GC/MS	Gas Chromatography/Mass Spectrometry — This is a gas chromatography analyzer combined with a mass spectrometer detector. The mass spectrometer uses the difference in mass-to-charge ratio (m/e) of ionized atoms or molecules to separate them from each other and to quantify their concentrations.
Grab Samples	Discrete samples that are representative of a specific area and a specific time. Useful in identifying "hot spots" of contamination at a site.
Hazardous Substances	CERCLA hazardous substances, pollutants, and contaminants, as defined in CERCLA Sections 101(14) and 101(33).
Holding Time	The period a sample may be stored prior to its required analysis. Although exceeding the holding time does not necessarily negate the veracity of analytical results, it causes the qualifying or "flagging" of the data for not meeting all of the specified acceptance criteria.

Human Exposure	Any exposure of humans to a release of one or more hazardous substances via inhalation, ingestion, or dermal contact. *Amdur, Mary O., John Doull, and Curtis D. Klaassen, Toxicology, The Basic Science of Poisons, Fourth Edition, 1991, p. 14; Hazard Ranking System Guidance Manual, Interim Final, pp. 153, 259, 293, 317, 363, and 411.*
Interference	An element, compound, or other matrix effect present in a sample which interferes with detection of a target analyte leading to inaccurate concentration results for the target analyte.
Matrix	The substrate containing the analyte of interest — examples are soil, water, sediments, and air. Also called medium or media.
Matrix Duplicate	A duplicate field sample used to document the precision of sampling and homogeneity of a given sample matrix. (Same as field duplicate.)
Matrix Spike (MS)	A sample prepared by adding a known mass of target analyte to a specified amount of matrix sample for which an independent estimate of target analyte concentration is available. Spiked samples are used, for example, to determine the effect of the matrix on a method's recovery efficiency.
Matrix Spike Duplicate (MSD)	A split sample, both portions of which are spiked with identical concentrations of target analytes, for the purpose of determining the bias and precision of a method in a particular sample matrix.
Maximum Contaminant Level (MCL)	Maximum concentration of a contaminant allowed in drinking water systems by the National Primary Drinking Water regulations: 40 CFR 141.11 (inorganic chemicals) and 141.12 (organic chemicals).
Method Blank	A clean sample processed simultaneously with and under the same conditions as samples containing an analyte of interest through all steps of the analytical procedure.
Method Detection Limit (MDL)	The minimum concentration of an analyte that can be measured and reported with 99% confidence. It is determined by analysis of samples with known concentrations at various dilutions. This limit is matrix-specific (e.g., soils vs. waters).
Null Hypothesis	Presumed or baseline condition. In the case of environmental investigations, generally either that the site is contaminated or that the site is clean.
ppb	Parts per billion; μg/kg (micrograms per kilogram); μg/l (micrograms per liter).
ppm	Parts per million; mg/kg (milligrams per kilogram); mg/l (milligrams per liter).

Precision	A measure of mutual agreement among individual measurements of the same property, usually under prescribed similar conditions, expressed generally in terms of the standard deviation.
Priority Pollutants	List of inorganic and organic analytes commonly tested for in the National Pollution Discharge Elimination System (NPDES) program.
QA	Quality Assurance — An integrated system of management activities involving planning, implementation, assessment, reporting, and quality improvement to ensure that a process, item, or service is of the type and quality needed and expected.
QAPP	Quality Assurance Project Plan — A formal document describing in comprehensive detail the necessary QA, QC, and other technical activities that must be implemented to ensure that the results of the work performed will satisfy the stated performance criteria.
QC	Quality Control — The overall system of technical activities that measures the attributes and performance of a process, item, or service against defined standards to verify that they meet the stated requirements established by the customer; operational techniques and activities that are used to fulfill requirements for quality.
QL	Quantitation Limit — The level above which quantitative results may be obtained with a specified degree of confidence.
RCRA	The Resource Conservation and Recovery Act of 1976, as amended.
Release	Any spilling, leaking, pumping, pouring, emitting, emptying, discharging, injecting, escaping, leaching, dumping or disposing into the environment (including the abandonment or discharging of barrels, containers, and other closed receptacles containing any hazardous substance or pollutant or contaminant). *CERCLA § 101(22)*
Representativeness	A measure of the degree to which the measured results accurately reflect the medium being sampled. It is a qualitative parameter that is addressed through the design of the sampling program in terms of sample location, number of samples, and actual material collected as a “sample” of the whole.
SAP	Sampling and Analysis Plan — Site- and event- specific plan detailing sampling rationale, protocols, and analyses planned per sample type. A part of the QAPP.
Screening Data	Data that are appropriate for applications that only require determination of gross contamination areas and/or for site characterization decisions that do not require quantitative data. Screening data are often used to specify which areas to sample to collect definitive data. *Guidance for Performing Site Inspections Under CERCLA, Interim Final, pp. 99 and 100; Guidance for Data Useability in Site Assessment, Draft, p. 15.*

SOP	Standard Operating Procedure — A written document that details the method for an operation, analysis, or action with thoroughly prescribed techniques and steps, and that is officially approved as the method for performing certain routine or repetitive tasks.
Source Area	An area of contamination from which substances may have migrated to other media. Several source areas can be located within a site.
Spike	A known quantity of a chemical that is added to a sample for the purpose of determining (1) the concentration of an analyte by the method of standard additions, or (2) analytical recovery efficiency, based on sample matrix effects and analytical methodology. Also called analytical spike.
Split Samples	Two or more representative portions taken from one sample in the field or in the laboratory and analyzed by different analysts or laboratories. Split samples are used to replicate the measurement of the variable(s) of interest.
Standard Addition	The practice of adding a known amount of an analyte to a sample immediately prior to analysis used to evaluate interferences.
Standard Curve	A plot of concentrations of known analyte standards versus the instrument response to the analyte.
Surrogate	A pure substance with properties that mimic the analyte of interest. It is unlikely to be found in environmental samples and is added to them to establish that the analytical method has been performed properly.
SVOA	Semi-Volatile Organic Analysis or Analyte.
SVOC	Semi-Volatile Organic Compound. BNA; extractable organic compound.
SW-846	U.S. EPA "Test Methods for Evaluating Solid Waste," 1986 (Third Edition), plus Updates, a publication describing standard methods of analysis, sampling techniques, and QA/QC procedures.
Trip Blank	A clean sample of matrix that is carried to the sampling site and transported to the laboratory for analysis without having been exposed to sampling procedures.
VOA	Volatile Organic Analysis or Analyte.
VOC	Volatile Organic Compound.

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