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Title

Data Quality Objectives Development Guidance for Uncontrolled Hazardous Waste Site Remedial Response Activities.

Summary of Directive

Provide guidance in the development of data quality objectives (DQO's) for remedial response activities. DQOs are qualitative and quantitative statements specifying the data required to support remedial response decisions. DQOs are established prior to data collection to address site-specific requirements and are based on the intended uses of the data. The DQO guidance consists of two documents.

° DQO Development Guidance for Uncontrolled Hazardous Waste Site Remedial Response Activities - Provides general discussion on the DQO process addressing both analytical and sampling considerations.

° DQO Development Example for Uncontrolled Hazardous Waste Site Remedial Response Activities - Scenario 1 - Presents a site-specific application of the DQO process for RI/FS activities at a site with contaminated soils and ground water.

Key words: DQOs, RI/FS, RD/RA, Sampling and Analysis, QA/QC

Type of Directive (Manual, Policy Directive, Announcement, etc.)	Status
Guidance document	☒ Draft ☐ New ☐ Final ☐ Revision

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Signature of Lead Office Directives Officer

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Signature of OSWER Directives Officer

Date

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DRAFT

DATA QUALITY OBJECTIVES DEVELOPMENT GUIDANCE FOR UNCONTROLLED HAZARDOUS WASTE SITE REMEDIAL RESPONSE ACTIVITIES

Office of Emergency and Remedial Response
Office of Waste Programs Enforcement
Office of Solid Waste and Emergency Response

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October 17, 1986

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PREFACE

This document provides guidance in the development of data quality objectives (DQOs) for remedial response activities under the Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA). This document, Data Quality Objectives Development Guidance for Uncontrolled Hazardous Waste Site Remedial Response Activities, is intended to guide the user through the process of developing data quality objectives (DQOs) for site-specific remedial activities. Remedial response activities include remedial investigations (RI), feasibility studies (FS), remedial design (RD), and remedial action (RA). This guidance manual should be used in conjunction with the Data Quality Objectives Development Example for Uncontrolled Hazardous Waste Site Remedial Response Activities (Example Scenario I - RI/FS Activities at a Site With Contaminated Soils And Ground Water) which provides an outline of how the DQO process is applied to a hypothetical site situation. Additional example case studies will be developed in the future, addressing different site scenarios.

This is one of a series of guidance documents prepared in accordance with the National Oil and Hazardous Substance Pollution Contingency Plan (NCP) final rule, published in the Federal Register November 20, 1985 and effective February 18, 1986. These guidance documents have been prepared under the direction of the Office of Solid Waste And Emergency Response (OSWER). The guidance document series includes the following titles:

o   Guidance on Remedial Investigations Under CERCLA (EPA 540/G-85/002)

o   Guidance on Feasibility Studies Under CERCLA (EPA 540/G-85/003)

o   Superfund Remedial Design and Remedial Action Guidance (OSWER Directive 9355.0-4A)

o   Quality Assurance/Field Operation Methods Manual (Draft, March 1986)

o   Superfund Public Health Evaluation Manual (OSWER Directive 9285.4-1)

o   Superfund Exposure Assessment Manual (OSWER Directive 9285.5-1)

Guidance on Remedial Investigations Under CERCLA and Guidance on Feasibility Studies Under CERCLA were both issued in June 1985. These documents provide direction for the planning and execution of RI/FS projects consistent with legislation and site-specific requirements. The Superfund Remedial Design and Remedial Action Guidance provides guidance in the planning, administration, and management of remedial design and remedial action at Superfund sites. The draft Quality Assurance/Field Operations Method Manual presents detailed descriptions of the mechanics of data and information collection during the RI/FS process. The Superfund Public Health Evaluation Manual establishes a framework for analyzing public health risks associated with hazardous waste sites during the RI/FS process.

Collectively, these documents provide guidance for the development and performance of technically sound and cost-effective remedial response activities which will support the program goals of both the Office of Emergency and Remedial Response (OERR) and the Office of Waste Programs Enforcement (OWPE). These documents are also available for use by state agencies and private parties conducting remedial actions to ensure that their activities are consistent with the intent of CERCLA.

ACKNOWLEDGMENTS

This document was developed for the Office of Solid Waste and Emergency Response (OSWER) by a task force composed of the following individuals:

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Dean Neptune (QAMS)
Gene Brantly (RTI)
Daniel Michael (RTI)

LIST OF ACRONYMS

ATSDR	Agency for Toxic Substances and Disease Registry
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (Superfund)
CDC	Centers for Disease Control
CLP	Contract Laboratory Program
DQO	Data Quality Objective
EMSL-LV	Environmental Monitoring and Support Laboratory - Las Vegas
ESD	Environmental Services Division (of EPA)
FIT	Field Investigation Team
FS	Feasibility Study
HSL	Hazardous Substance List
MDL	Method Detection Limit
NBS	National Bureau of Standards
NCP	National Contingency Plan
NEIC	National Enforcement Investigation Center
NPL	National Priorities List
PARCC	Precision, Accuracy, Representativeness, Completeness, Comparability
PRP	Potentially Responsible Party
QAMS	Quality Assurance Management Staff
QAPP	Quality Assurance Program Plan
QAPjP	Quality Assurance Project Plan
RA	Remedial Action
RAS	Routine Analytical Service
RD	Remedial Design
RI	Remedial Investigation
ROD	Record of Decision
RPM	Remedial Project Manager - federal official designated by EPA or another lead agency to coordinate, monitor, or direct remedial or other response activities under the NCP (Section 300.6)
RSCC	Regional Sample Control Center
SAS	Special Analytical Service
SMO	Sample Management Office
SRM	Standard Reference Materials

Section 1.0

1.0 INTRODUCTION

Data quality objectives (DQOs) are qualitative and quantitative statements which outline the decision making process and specify the data required to support Agency decisions during remedial response activities. Remedial response activities include remedial investigations (RI), feasibility studies (FS), remedial design (RD), and remedial actions (RA). Individual site characteristics make it impossible to apply a generic set of DQOs to all CERCLA activities; therefore, site-specific DQOs must be developed based on the proposed end uses of the data from sampling and analytical activities.

In order to ensure that the data generated during remedial response activities are adequate to support decisions, a clear definition of the decisions should be established early in the planning of remedial response activities. These determinations are facilitated through the development of data quality objectives (DQOs).

It is important to realize that DQOs are an integrated set of thought processes which define data quality requirements based on the identified end use of the data base. The DQO is not a separate deliverable. The analysis of sampling and analytical options provided in this example document will not appear explicitly in either the work plan or sampling and analysis plan. However, the analysis presented in this example will occur during project scoping, and meetings and phone conversations between the RPM and data users. The rationale behind the selection of a particular sampling and analysis option will appear in meeting minutes or internal memos which will become part of the project file. The result of the DQO process will be a well thought out sampling and analysis plan which details the chosen sampling and analysis option.

DQOs are established prior to data collection and are critical in developing a sampling and analytical plan (S&A Plan) consistent with CERCLA program objectives. DQOs are developed to address the specific requirements of individual sites and are based on the intended uses of the data. Through implementation of the DQO process it is possible to

calculate the level of uncertainty associated with the data collected during remedial response activities. It is important to note that this calculation can only be done accurately with a large (i.e. approximately 20 data points) existing data base. With the limited amount of data usually available for Superfund sites (especially at the start of the RI), the calculation of the level of uncertainty can only be done at the conclusion of data analysis. The level of uncertainty can then be used in making decisions regarding site remediation.

Data quality objectives should be specified for each data collection activity associated with a remedial response. The majority of data collection activities will be undertaken during a remedial investigation (RI) but additional data needs may be identified during the feasibility study (FS), remedial design (RD), and remedial action (RA).

All investigation activities should be conducted and documented such that sufficient data of known quality are collected to make sound decisions concerning remedial action selection. This applies to fund-lead, federal or state enforcement-lead, and potentially responsible party-lead projects.

1.1 PURPOSE

The purpose of this guidance document is to identify the framework and process by which DQOs are developed and the individuals responsible for development of DQOs. The document also identifies the relationship of the DQO guidance to other guidance documents and the timeframe in which DQOs are developed.

The variable nature of remedial response activities precludes development of generic DQOs for use throughout the Superfund program. This document is intended to guide the user through the process of DQO development. Each site will have a unique history, data availability, site characteristics, public and institutional considerations, and other factors. Therefore, a unique set of DQOs must be developed for each site. Investigators are expected to take advantage of previous experiece and data collected through work on sites with similar media or contamination problems.

There are a number of factors that lead to variations among site-specific projects. Project teams are made up of individuals with varying backgrounds and levels of expertise; and each site presents a unique set of conditions. This DQO guidance acts as a supplement to the existing guidance by providing procedures for determining a quantifiable degree of certainty which can be used in making site-specific decisions.

The DQO process ensures that a plan is developed describing the level and extent of sampling and analysis required to produce data adequate for the evaluation of remedial alternatives, design of the selected alternative, and verification of remedial effectiveness. In actual practice to date, projects conducted under CERCLA have complied with the intent of the DQO process. DQOs have been incorporated as parts of sampling and analytical plans, quality assurance project plans or work plans. The purpose of this guidance is to provide a more formal approach to S&A plan development and to improve the overall quality and cost effectiveness of data collection and analysis activities.

Adherence to the guidance for DQO development presented in this document should not require additional paperwork. Rather, the guidance builds upon the already established process of development of work plans, quality assurance project plans and sampling and analysis plans.

1.2 DATA QUALITY OBJECTIVE POLICY BACKGROUND

Mr. Alvin Alm, then Deputy Administrator of the EPA, in his memorandum of May 24, 1984 to the Assistant Administrators (AAs), stated that one of the most important steps in assuring the quality of environmental data is development of DQOs. He requested active participation of the AAs in the development of DQOs during the stages in which policy and guidance is crucial, and asked for identification and scheduling of significant, ongoing environmental data collection activities. The Quality Assurance Management Staff (QAMS) issued guidance to assist the Agency in development of DQOs in October 1984. A checklist for DQO review was then issued in a memorandum from Stan Blacker on April 3, 1985. Appendix A includes a

comparison of this checklist with this DQO guidance document. Additional guidance on the development of DQOs, specifically related to Stages 1 and 2 of the process, was provided in a draft document issued by QAMS March 17, 1986.

The approach to developing and implementing DQOs for remedial response activities has been established by a DQO Task Force comprising technical personnel from EPA Headquarters (OERR and OWPE), Regions 1, 2, 3, 5, 6 and 7; and EPA remedial contractors. The methodology used by the DQO Task Force involved applying the guidance provided by QAMS to the remedial response process. The efforts of the Task Force included identifying the elements of the DQO process within existing planning documents and organizing them into a formal implementation approach. The DQO development process presented in this document is based on the best available information but may be revised as additional information becomes available.

1.3 FORMAT

The Data Quality Objective Development Guidance Document for Uncontrolled Hazardous Waste Site Remedial Response Activities includes the following sections:

1.0 Introduction

2.0 DQO Development Process - provides an overview of the process for developing DQOs and a discussion of how DQO development relates to the remedial response program.

3.0 RI/FS-DQO Stage 1 - provides a description of Stage 1 of the DQO process including identification and involvement of data users, development of a conceptual site model and defining decision types that will be made during the RI/FS process.

4.0 RI/FS-DQO Stage 2 - describes approaches for determining data needs and uses and for establishing criteria for decisions and outlines methods by which analytical and sampling options are identified and selected. The sampling and analytical requirements or goals, such as percentage recovery, are established during Stage 2.

5.0 RI/FS-DQO Stage 3 - describes the approach for assembling sampling and analytical components into an overall sampling design and identifies the documentation required for a sampling and analytical program.

6.0 Remedial Design - Reserved

7.0 Remedial Action - Reserved

8.0 Statistical Considerations - provides a description of some statistical approaches which may be applied during the course of remedial action program. Scenarios are presented to illustrate the applicability of statistical techniques. References cited provide additional details on statistical methods for interested readers.

9.0 Analytical Considerations - describes the various options that are available for use in analyzing samples obtained at uncontrolled hazardous waste sites. The discussion is directed toward identification of screening techniques and analytical approaches which will result in expediting site investigations and reduce the costs associated with analysis of samples.

10.0 Sampling Considerations - provides discussion of sampling rationale related to the DQO development process. The discussion is limited to general issues which should be considered when designing a sampling program for remedial action programs. Details on sampling mechanics and standard operating procedures are documented in cited references.

Appendices to the DQO document provide information on the QAMs DQO checklist, established criteria for RI/FS activities, and CLP performance criteria.

As discussed in Section 1.0, the DQO process is specified for each data collection activity, and therefore specific sections of this Manual are applicable to specific components of the remedial response process.

As such, Sections 1, 2, 8, 9 and 10 are applicable to all remedial response activities while Sections 3, 4 and 5 apply to the RI/FS process. Sections 6 and 7 are forthcoming and will provide guidance for the application of DQOs to Remedial Design Activities (Section 6) and to Remedial Actions (Section 7).

A companion to this guidance is the Data Quality Objectives Development Example for Uncontrolled Hazardous Waste Site Remedial Response Activities (Example Scenario I) (EPA 1986) which provides an example case study of implementation of the DQO process.

Additional example case studies will be developed in the future addressing different site scenaries.

Section 2.0

2.0 DATA QUALITY OBJECTIVE DEVELOPMENT PROCESS

Data quality objectives are identified during the course of the project scoping and during development of sampling and analysis plans. DQOs are established to ensure that the data collected are sufficient and of adequate quality for their intended uses. Data collected and analyzed in conformance with the DQO process described in this document can be used in assessing the uncertainty associated with each remedial response alternative.

2.1 DQO STAGES

Data Quality Objectives are developed through a three-stage process as illustrated in Figure 2-1. Although the three stages are identified and discussed sequentially in this guidance document, they should be undertaken in an interactive and iterative manner whereby all the elements of the DQO process are continually reviewed and applied during the remedial response program. As such, the DQO process is applied and the resultant S&A plan is developed at the onset of a remedial response project and revised or expanded as needed based upon the results of each data collection activity. This process is illustrated in the companion volume, Data Quality Objective Development Example for Uncontrolled Hazardous Waste Site Remedial Response Activities (Example Scenario I — RI/FS Activities at a Site with Contaminated Soils and Ground Water (EPA 1986). It is anticipated that several DQO Example Manuals addressing a range of different site conditions (landfills, lagoons, etc.) will be developed in the future.

2.1.1 STAGE 1 - IDENTIFY DECISION TYPES

Stage 1 of the DQO process provides the foundation for Stages 2 and 3. Stage 1 is undertaken to define the types of decisions which will be made. In Stage 1, all available information on the site is compiled and analyzed to develop a conceptual model understanding of the site. This model describes suspected sources, contaminant pathways, and potential receptors. The model facilitates identification of decisions which must be made and deficiencies in the existing information. Stage 1 activities include

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┌─────────────────────────────────────────┐
│              STAGE 1                      │
│        IDENTIFY DECISION TYPES            │
│                                           │
│      • IDENTIFY & INVOLVE DATA USERS      │
│                                           │
│      • EVALUATE AVAILABLE DATA            │
│                                           │
│      • DEVELOP CONCEPTUAL MODEL           │
│                                           │
│      • SPECIFY OBJECTIVES/DECISIONS       │
│                                           │
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                    │
                    ▼
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│              STAGE 2                      │
│        IDENTIFY DATA USES/NEEDS           │
│                                           │
│      • IDENTIFY DATA USES                 │
│                                           │
│      • IDENTIFY DATA TYPES                │
│                                           │
│      • IDENTIFY DATA QUALITY NEEDS        │
│                                           │
│      • IDENTIFY DATA QUANTITY NEEDS       │
│                                           │
│      • EVALUATE SAMPLING/ANALYSIS OPTIONS │
│                                           │
│      • REVIEW PARCC PARAMETERS            │
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│              STAGE 3                      │
│     DESIGN DATA COLLECTION PROGRAM        │
│                                           │
│   • ASSEMBLE DATA COLLECTION COMPONENTS   │
│                                           │
│   • DEVELOP DATA COLLECTION DOCUMENTATION │
│                                           │
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FIGURE 2-1
DQO THREE-STAGE PROCESS

defining program objectives and identifying and involving end-users of the data. Stage 1 results in the specification of the decision making process and forming an understanding of why new data are needed.

2.1.2 STAGE 2 - IDENTIFY DATA USES/NEEDS

Stage 2 results in the stipulation of the criteria for determining data adequacy. This stage involves specifying the level of data certainty sufficient to meet the objectives specified in Stage 1. Stage 2 includes selection of the sampling approaches and the analytical options for the site, including evaluation of multiple-option approaches to effect more timely or cost-effective data collection and evaluation.

2.1.3 STAGE 3 - DESIGN DATA COLLECTION PROGRAM

Stage 3 results in the specification of the methods by which sufficient data of acceptable quality and quantity will be obtained to make decisions. This information is provided in documents such as the S&A plan or work plan.

2.2 RI/FS PROCESS

2.2.1 GENERAL APPROACH

The overall objective of an RI/FS is to determine the nature and extent of the threat posed by the release of hazardous substances and to evaluate proposed remedies. The ultimate goal is to select a cost-effective remedial alternative which mitigates threats to and provides protection of public health, welfare, and the environment, consistent with the NCP.

RIs encompass the data gathering activities undertaken to determine the degree and extent of contamination associated with an uncontrolled hazardous waste site. The data obtained are used in the identification, screening, and evaluation of remedial alternatives. The objective of the

remedial investigation is to collect the necessary and sufficient data to determine the distribution and migration of contaminants; identify cleanup criteria; and identify and support the remedial alternative technical feasibility evaluation, public health evaluation, environmental assessment, and cost analysis.

Remedial investigations are conducted concurrently with the feasibility study (FS) in an iterative process wherein data are evaluated with respect to their application to remedial alternatives. Data collection and evaluation during the remedial investigation is performed only to the extent needed to identify and evaluate remedial alternatives. The remedial investigation must provide data to demonstrate the need for remedial action, determine the extent of remedial action required, and evaluate the feasibility of the potential remedial alternatives.

Feasibility studies entail development, screening, and evaluation of remedial alternatives in a systematic manner. The objectives of the FS are to develop and evaluate the remedial action alternatives with respect to technical, public health, environmental, institutional, and cost considerations. In order to ensure that adequate and sufficient data are collected for performance of the FS, site managers must continually coordinate the evaluation of data collected during the RI.

Although the major data collection process occurs during the RI, both the RI and FS objectives must be taken into consideration during the scoping process. The RI/FS typically addresses data collection and site characterization from the perspective of contaminant source and contaminant migration pathways. Once pathways are established and human and environmental receptors are identified, further data collection efforts can be directed toward evaluating the potential impact upon receptors, and for use in evaluating potential remedial technologies and alternatives.
The DQO process is part of the RI/FS process currently in place as outlined in EPA's Guidance on Remedial Investigations Under CERCLA (EPA 1985a) and Guidance on Feasibility Studies Under CERCLA (EPA 1985b).

Through the process of developing DQOs, a series of statements and definitions of the types, quantity and quality of data will be developed. The purpose (or use) for which the data collection activity is being undertaken will also be specified. The DQO process does not require that any deliverables beyond those currently utilized in the RI/FS program be developed. Rather, it provides guidance on the method for determining appropriate means of identifying sampling/analysis options and identification of the level of detail which should be developed to support data collection activities.

2.2.2 PHASED RI/FS APPROACH

RI/FSs are undertaken at sites which have potential contaminant problems confirmed through preliminary assessments (PA), site investigations (SI), and hazard ranking system (HRS) scoring. Although data are collected during the performance of PAs, SIs, and HRS scoring, these data are generally limited in nature and may not provide adequate information on the spatial distribution of contaminants at the site on which to base a complete RI/FS.

The amount and quality of data required to support selection of a remedial alternative will vary by site. In most situations it may not be possible to identify all data needs during the initial scoping activities. Rather, data needs will become more clearly defined as additional data are obtained and evaluated. By separating the remedial investigation into distinct phases, data can be collected and evaluated sequentially with a refinement or redefinition of data collection needs at the completion of each phase. Figure 2-2 illustrates the phased RI/FS approach.

It is seldom possible to identify fully all the data needed to complete an RI/FS at the outset of the scoping process. For complex sites the phased approach allows for added control of investigative activities when compared to a singular sampling/analysis event. Through the application of the DQO process to a phased investigation the usability of the data is improved, thereby improving the cost effectiveness of the investigation.
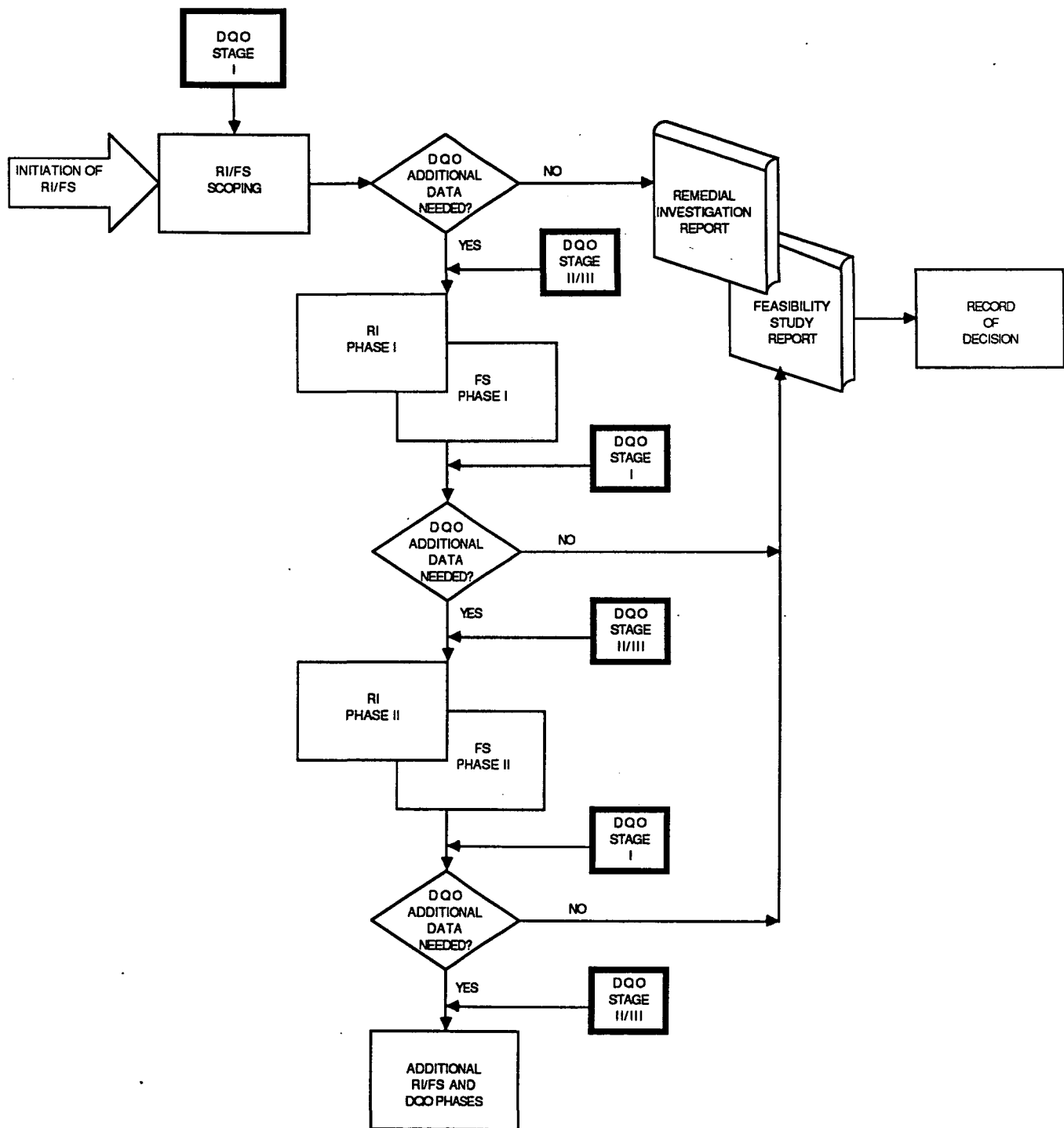
**FIGURE 2-2
PHASED RI/FS APPROACH AND THE DQO PROCESS**

2.3 REMEDIAL DESIGN

Following selection of a remedy (based on the RI/FS) and Record of Decision (ROD)/Enforcement Decision Document (EDD) approved by the designated EPA official, action must be taken to initiate design activities. The remedial design encompasses the preparation of the final construction plans and specifications to accomplish the remedial action alternative as defined in the ROD/EDD.

Remedial actions, especially those involving onsite treatment or disposal of contaminated wastes, may require additional field data collection activities during the remedial design phase to supplement the technical data available from the RI/FS, so that optimum methods and associated costs may be determined or fine tuned and refined.

Data collected during the RD should refine cost estimates to the +15/-10% range. The type of data required at this late stage of the remedial response process varies depending on the type of remedies. For soil excavation, a good estimate of contaminated soil volume is needed; for treatment options, a refined estimate of the physical/chemical waste character may be required.

The DQO process as mentioned earlier is equally applicable to data collection activities performed during the RD as during the RI/FS. The practical application of DQOs to RD activities will be described in future updates to this document.

2.4 REMEDIAL ACTION

Following completion and approval of the RD package, action must be taken to initiate remedial action (RA) activities. RA activities entail the actual implementation of the preferred alternative selected in the ROD/EDD.

As with the RD, additional data collection activities may have to be conducted during the RA, and the DQO process utilized. Data collected

during the RA is used to evaluate the progress of the RA and to verify at the end of the RA that the set performance criteria were achieved.

2.5 DATA QUALITY OBJECTIVES DOCUMENTATION

The DQO development process is initiated during the scoping process and is completed in conjunction with the development of a sampling and analysis (S&A) plan for each project phase. The various stages of the DQO development process are interactive in nature. As additional details regarding the site are discovered during the scoping process the decisions which will be made during the project are further refined. This refinement of decisions allows for further specification of data needs and for design of the data collection program.

It should be noted that as the DQO process continues, the scoping of the project will become refined. It may be determined that additional decision types are needed (Stage 1), or that data collection activities previously identified should be modified (Stage 2 and Stage 3) as a result of evaluation of data (Stage 1) collected during earlier phases of the RI.

Development of DQOs in a formal manner ensures that the appropriate data are obtained in order to meet the objectives of the RI/FS, RD or RA. Documentation of DQOs can be provided primarily in the sampling and analysis plan (which includes QAPjP elements), with summary information listed in the work plan.

2.6 REFERENCES

U.S. Environmental Protection Agency. 1985a. Guidance on Remedial Investigations Under CERCLA. Office of Emergency and Remedial Response, Office of Waste Programs Enforcement, Office of Solid Waste and Emergency Response, Washington, DC. Office of Research and Development, Cincinnati, Ohio. EPA/540/G-85/002. June.

_____. 1985b. Guidance on Feasibility Studies Under CERCLA. Office of Emergency and Remedial Response, Office of Waste Programs Enforcement, Office of Solid Waste and Emergency Response, Washington, DC. Office of Research and Development, Cincinnati, Ohio. EPA/540/G-85/003. June.

Section 3.0

3.0 RI/FS DQO STAGE 1 - IDENTIFY DECISION TYPES

Stage 1 of the DQO process is undertaken to identify the individuals
responsible for decisions, to identify and involve data users and to define
the types of decisions which will be made as part of each site specific
RI/FS. The actual decisions are made following collection and evaluation
of data at various points during the RI/FS. The general decision types are
identified early in Stage 1 to ensure that an investigative approach to
which specified degrees of certainty can be assigned is established early
in the planning process.

The major elements of Stage 1 include:

- o Identify and involve data users

- o Evaluate available information

- o Develop conceptual model

- o Specify RI/FS objectives and decisions

Stage 1 of the DQO process is an inherent part of the project scoping
process. The thought process by which a work plan is developed naturally
encompasses the Stage 1 DQO elements. Figure 3-1 provides a simplified
illustration of the Stage 1 elements. Although the elements of Stage 1 can
be thought of as distinct steps, they in fact constitute a continuous
thought process. The elements of Stage 1 are combined to identify the
types of decisions which will be made during the RI/FS process.

3.1 IDENTIFY AND INVOLVE DATA USERS

Data quality objectives are developed through a process which requires the
involvement of the data users early in the planning of the remedial
activities. Because of the interdisciplinary nature of remedial
activities, it is important that the appropriate technical expertise is
identified and involved in the DQO development process.
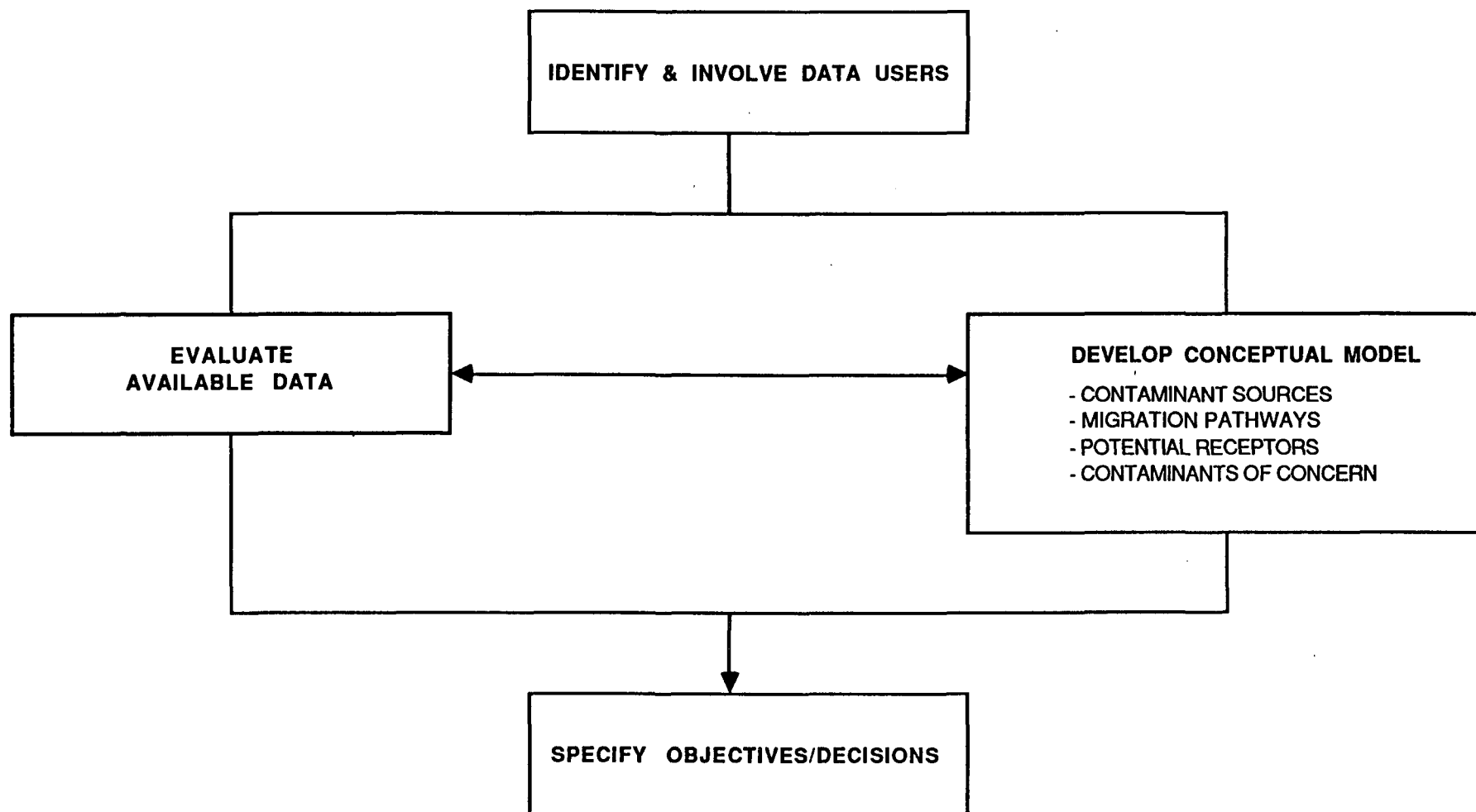
FIGURE 3-1
DQO STAGE 1 ELEMENTS

3.1.1 DECISION MAKER'S ROLE

The key RI/FS decision is remedy selection (i.e. ROD/EDD signature). For the majority of RI/FS projects, remedy selection is delegated to the Regional Administrator (RA) who is guided by the NCP and program policy. Program Management responsibilities are delegated to the Waste Management Division Director and managers, with project specific management and oversight assigned to Remedial Project Managers (RPMs).

The EPA RPM is the designated decision maker for the DQO development process. In this role, the RPM is responsible for coordinating the DQO development process, and overseeing remedial contractors, state officials, or private parties conducting the RI/FS to assure consistency with program policy/guidance with direction provided by Regional Management.

For federal lead projects, the RPM delegates a certain extent of site specific decision making to the remedial contractor's site manager performing the RI/FS. For state lead or private party lead projects, the RPM delegates a certain extent of site specific decision making to the state project manager or private party project manager, who in turn delegates some site specific decision making to their contractor's site manager. However, the RPM should be in continual communication with the federal remedial contractor, state project manager, or private party project manager, so key decisions to be made can be concurred upon.

3.1.2 DATA USERS' ROLE

The interactions of decision makers and various data users during the DQO devlopment process is illustrated in Figure 3-2 and discussed below.

Primary Data Users

Primary data users are those individuals involved in ongoing RI/FS activities. These activities include RI/FS planning and implementation, project management and oversight, site specific decision making, and DQO devopment. For federal lead projects, this includes the RPM and the

DIVISION MGMT

- PROGRAM & PROJECT
  OVERSIGHT
- ROD/SETTLEMENT
  RECOMMENDATIONS TO RA

RA/AA

- ROD/SETTLEMENT
  DECISIONS

ENFORCEMENT

- NEGOTIATIONS

STATE

- REMEDY
  CONCURRENCE

DQO
DECISION MAKER
RPM
PRIMARY DATA USERS

- RPM
- CONTRACTOR'S SITE MANAGER & STAFF
- STATE PROJECT MANAGER
  (STATE LEAD PROJECT)
- PRIVATE PARTY PROJECT MANAGER
  (PRIVATE PARTY LEAD)

ATSDR

- HEALTH
  ASSESSMENTS

CORPS

- RD/RA ACTIVITIES
  (FEDERAL LEAD PROJECT)

SECONDARY USERS

(ENF/STATE/ATSDR/CORPS)
- GENERIC DATA NEEDS
  ATSDR PAPER
  STATE STANDARDS
  CHAIN OF CUSTODY
- SITE SPECIFIC DATA NEEDS
  SPECIAL PATHWAY INFO
  PRP IDENTIFICATION
  RD/RA NEEDS

TECHNICAL SUPPORT

(ESD/OTHERS/TAC TEAM)
- UPON REQUEST BY RPM
  SAMPLING/ANALYTICAL
  SUPPORT
  REGULATORY REQUIREMENTS

PROJ REVIEW/AUDIT

(ESD/ORC/HQ)
- QA INTEGRITY
- COMPLIANCE WITH POLICY

———▶ INPUT

◀ - - - OUTPUT

FIGURE 3-2
DECISION MAKER DATA USERS INTERACTION

remedial contractor's site manager and staff. For state lead or private party lead projects, this includes the state or private party manager and their contractor's site manager/staff, along with the RPM.

The contractor's site manager has the primary responsibility for incorporating DQOs into planning and implementation activities. The contractor site manager must have a basic understanding of the site under consideration and the pertinent issues at hand. This understanding serves as the basis for identification of the appropriate contractor staff to be involved in the process. The contractor site manager must be cognizant of the range of issues pertaining to the site and be comfortable with the objectives of the RI/FS (and RD/RA as the remedial process progresses). This comfort factor can only be gained through a thorough review of available information, familiarization with the site and its environs through a site inspection, and discussion of the situation with appropriate primary data users.

The contractor site manager must identify the appropriate contractor technical staff which need to be involved in the RI/FS, based upon the overall problems posed by the site at initiation of the project. For example, if ground water contamination is of concern, geologists/ hydrogeologists and water supply or water treatment engineers may be involved at a minimum. If surface water contamination is of concern, aquatic biologists, limnologists and water resource engineers may be involved. The involvement of chemists in the RI/FS process is essential since in all RI/FS projects samples are likely to be analyzed. Analytical chemists can assist in specifying the types of analyses to be used and the limitations of the particular techniques or methods. Individuals familiar with the interactions of chemicals in the environment, such as geochemists, soil scientists, and chemists must also be involved so that the data generated can be used to assess its impact on the environment. Geostatisticians can provide assistance in evaluating spatially distributed data. Toxicologists and individuals familiar with risk assessments should also be involved early in the scoping process in order to ensure that appropriate consideration is given to potential migration pathways, receptors and contaminants of concern.

Secondary Data Users

Secondary data users include all individuals or parties that rely on RI/FS project specific outputs to support their programmatic activities. Secondary data users provide input to the decision maker and primary data users during the DQO development process through generic data needs and, on occasion, site specific data needs. Depending on project lead, secondary data users may include the State, Enforcement personnel, ATSDR, Corps of Engineers (Corps), etc.

Technical Support and Project Review/Audit

At the request of the RPM, technical specialists such as ESD personnel, other EPA personnel, etc. may provide technical support related to project specific sampling/analytical activities, regulatory requirements, etc. Project review/audit personnel such as ESD, Office of Regional Counsel, and EPA HQ help ensure QA program integrity and compliance with program policy.

3.2 EVALUATE AVAILABLE INFORMATION

A review and evaluation of the information available for a site is undertaken as an initial step in the RI/FS process. This review provides the foundation for additional on-site activities and serves as the database for RI/FS scoping (preparation of the work plan). The evaluation of available information can be summarized in a narrative report or in a file and should contain an interpretation of the site conditions based upon a review of existing information, and of the initial site inspection.

3.2.1 DESCRIBE CURRENT SITUATION

A narrative summary of the existing information on the site should be assembled as an initial step in the RI/FS scoping process. Information should be obtained from EPA technical and enforcement files, state/local regulatory agency files, USGS files, and other relevant sources. Files

from potentially responsible parties (PRPs) should also be referenced when available. A detailed list of potential data sources is contained in Section 2.0 of the Guidance for Remedial Investigations Under CERCLA (EPA 1985a).

During the initial evaluation of available information for an RI, the data are confirmed by on-site observations. The intent of evaluating and confirming the available data is to develop an objective assessment of the site conditions.

The goals of the initial site inspection are as follows:

o Utilizing field analytical procedures, obtain data on volatile chemical contaminants, radioactivity, and explosivity hazards that may be present on-site in order to determine appropriate health and safety levels to be utilized.

o Determine if any conditions pose an imminent danger to public health

o Confirm the information contained in previous documents.

o Record observable data identified as missing in previous documents.

o Update site conditions if undocumented changes have occurred.

o Perform an inventory of possible off-site sources of contamination.

o Obtain data such as location of access routes, sampling points and the site organization requirements for the field investigation.

o Determine the applicability and feasibility of proposed RI activities.

It is essential to have aerial photographs or a compiled map of the site available for the initial site inspection. Maps should provide a scaled compilation of the best available information on the site and include:

o Topography of the site

o Identification of pertinent physical site features, (e.g., buildings, water bodies, water courses, wetland areas, access points, property boundaries, wooded or vegetated areas)

o Delineation, to the extent possible, of the areas of waste
   storage or contamination, both historic and existing

The compiled map and/or aerial photographs should be developed to include a
reasonable area outside of the legal site boundaries to provide an
understanding of land use on adjacent properties and to identify
potentially sensitive off-site receptors. The compiled map and/or aerial
photographs provide an efficient tool to confirm existing site conditions;
record field notes, direct reading instrumentation, measurements, locations
of key photographs, and observations; and identify potential future
sampling locations.

Tasks such as geophysical (magnetometer, EM) surveys, limited field
screening or limited field analysis may be performed during the initial
site inspection. This type of initial sampling may help determine the
variability of the material, provide background information, assess changes
in site conditions, or determine if site conditions have changed.
Confirmatory activities which may be undertaken during the initial site
inspection include locating, numbering and labeling, photographing,
securing, and recording the condition of on-site stored waste and ground
water monitoring wells; identifying the number of occupied residences in
the vicinity of the site; and determining the adequacy and condition of the
site security system.

3.2.2   REVIEW AVAILABLE DATA

For many sites, previous studies have provided useful information upon
which further investigations can be based. For each of the major areas in
the remedial action process, all available relevant information should be
compiled and organized in a manner to fulfill the goals of the activities
to be identified. The quality of the data developed through previous
efforts should be analyzed to ensure that it is truly useful. These
evaluations determine the uncertainty associated with the conclusions drawn
from the data.

A number of factors relate to the quality of data and its adequacy for use
in the RI/FS process, including the following considerations:

Age/comparability - How long ago were the data collected? The
user must determine if the data are relevant or comparable to the
present situation. It is not unusual for 2 years to lapse between
the site investigation and initiation of the RI/FS.

Analytic Methods - Were the analytic methods used consistent with
present practices? Methods need not be identical in order to be
comparable. Higher detection limits do not necessarily imply that
the older data are inadequate.

Detection Limits - As implied above, care should be taken to
determine if the detection limits of the analytical tests were
sensitive to the standards and criteria used in evaluating data.

QA/QC - Determine the quality and usability of the existing data
by asking questions such as: Are the spike recoveries acceptable
for the intended use? Were the laboratory blanks contaminated?
Careful evaluation of QA/QC data is essential in determining the
comparability of data files. Intralaboratory bias data are
essential for this evaluation.

Methods used for sample collection are as important to consider as the
methods used for sample analysis. These considerations fall into two broad
categories: statistical and standard operating procedures (SOPs). The
statistical considerations relate to the representativeness of the data and
the level of confidence that may be placed in conclusions drawn from the
data. The SOPs identify well construction methods and other issues related
to sample collection. Following SOPs ensures sample integrity and data
comparability and reduces sampling and analytical error. Typical issues to
consider include the following:

Sample Objective - What was the purpose for collecting samples?
Were the samples collected using a random or non-random sampling
approach? Was the sampling plan adequate? (i.e., were a
sufficient number of samples collected?) Was the sampling plan
followed? Were there deviations from the sampling plan?

Sample Collection - Where and how were the samples collected?
What methods were used for sample collection? Was equipment
decontaminated appropriately prior to use? Did individuals
obtaining samples have proper training?

Chain of Custody - Were chain of custody procedures followed if
the samples were analyzed off-site? If not, this may not mean
that the information cannot be used. It merely implies that one
should discuss with legal staff the extent to which any
conclusions may depend on these data. If the data are critical in
the decision-making process, a determination should be made if the
data would be legally defensible.

Sample Preservation - Were the samples preserved properly? Poor
preservation may only mean that the results actually understate
the true extent of the contamination or if the samples were not
filtered but preserved with acids, an overestimation of metal
concentration may result.

Sample Shipment - How were the samples shipped? Were the organic
samples iced? This again relates to how the data can be
interpreted.

Holding Times - How long were the samples held before being
analyzed? As before, this could relate to the amount of
contaminant found. For example, when holding times are exceeded
for volatile organics, the likelihood of a change in concentration
increases.

If limited or no information exists on sample collection, preservation
techniques or holding times the data should be interpreted with caution.

3.2.3 ASSESS ADEQUACY OF DATA

The uncertainty associated with each data measurement activity should be
considered when data are evaluated. Although data may be validated
analytically, the level of precision of a particular data point may not
provide sufficient certainty for use in a decision.

It is important to recognize the distinction between uncertainty associated
with a measurement activity and uncertainty associated with a decision
during development of DQOs. The uncertainty associated with each
measurement activity is based upon the sampling and analytical variable.
The contractor's site manager should determine to what extent data are
valid for use prior to incorporating the data into risk assessments or
other evaluations.

Data validation activities will result in the identification of invalid
data and qualification of the usability of the remaining data. However, a
more detailed evaluation is necessary to assess whether the measurement
activity provided a true representation of the conditions as they exist at
the site. For example, data received from an analytical laboratory may
report a contaminant concentration of 35 ppm. It may be determined that

this sample is below the specified action level of 50 ppm. However, the
supporting analytical documentation may indicate that the true
concentration value may fall within a range ± 70 percent of the reported
value. The true concentration of the sample may therefore range from 10.5
to 59.5 ppm (35 ppm ± 70 percent). Therefore, it may not be possible to
state that value is above or below the action limit with any degree of
certainty when only one data point is available.

The decision made regarding the uncertainty associated with each data
differs from the uncertainty assigned to a decision regarding site
remediation. Decisions regarding site remediation are based upon a
compilation of all data points into a cohesive statement regarding, for
example, the areal extent of contamination. The data users can then
delineate areas requiring remediation based on specific action levels. The
uncertainty associated with the decision incorporates the uncertainty at
each data point as well as the entire area delineated. These types of
discussions can only be made within specific degrees of certainty if
detailed statistical evaluation of the data is undertaken. Details
regarding establishment of criteria and action levels are discussed in
(Stage 2) of this document.

3.3   DEVELOP CONCEPTUAL MODEL

Conceptual models are narrative descriptions of an uncontrolled hazardous
waste site and its environs which present hypotheses regarding the
contaminants present on site, their routes of migration, and their
potential impact on sensitive receptors. The hypotheses presented are
tested, redefined and modified during the course of the RI/FS. Figure 3-3
depicts the basic elements of a conceptual model for an uncontrolled
hazardous waste site. These elements are expanded upon to develop a
written description of the site and its environs based on available
information. Chapter 2 in Guidance on Remedial Investigations Under CERCLA
(EPA 1985a) provides additional details for development of the conceptual
model.

SOURCE

PATHWAY

RECEPTOR

| VARIABLES | CONTAMINANTS
CONCENTRATION
TIME | MEDIA
RATE OF MIGRATION
TIME | TYPE
SENSITIVITY
TIME |

HYPOTHESIS TO BE TESTED

- SOURCE EXISTS
- SOURCE CAN BE CONTAINED
- SOURCE CAN BE REMOVED AND DISPOSED
- SOURCE CAN BE TREATED

- PATHWAY EXISTS
- PATHWAY CAN BE RENOVATED
- PATHWAY CAN BE ELIMINATED

- RECEPTORS ARE NOT IMPACTED BY MIGRATION OF CONTAMINANTS
- RECEPTOR CAN BE RELOCATED
- INSTITUTIONAL CONTROLS CAN BE APPLIED
- RECEPTORS CAN BE PROTECTED

FIGURE 3-3
ELEMENTS OF A CONCEPTUAL EVALUATION MODEL

3.3.1 EVALUATION MODELS

The conceptual model should be detailed enough to address all potential or suspected sources of contaminant, types of contaminants and concentrations, affected media, rates and routes of migration, and receptors. Graphical depiction of potential routes of migration are useful for illustrating the hypothesis under investigation. Figure 3-4 presents an illustration which supports a narrative evaluation conceptual model.

The following are assessed during development of the conceptual model to determine appropriate remedial and/or removal actions at a site:

o Population, environmental, and welfare concerns at risk

o Routes of exposure

o Spatial distribution of contaminants

o Atmospheric dispersion potential and proximity of targets (wind rose)

o Amount, concentration, hazardous properties, environmental fate (e.g., ability to bioaccumulate, persistence, volatility, solubility, mobility, etc.), and form of the substance(s) present

o Hydrogeological factors (e.g., soil permeability, depth to saturate zone, hydrologic gradients, proximity to a drinking water aquifer, floodplains and wetlands proximity)

o Climate (rainfall, seasonal variations etc.)

o Extent to which the source can be adequately identified and characterized

o Potential for reuse, recycling or treatment of substances at the site

o Likelihood of future releases if the substances remain on-site

o Extent to which natural or man-made barriers currently contain the substances and the adequacy of the barriers

o Assessment of the potential pathways of migration and a model of such
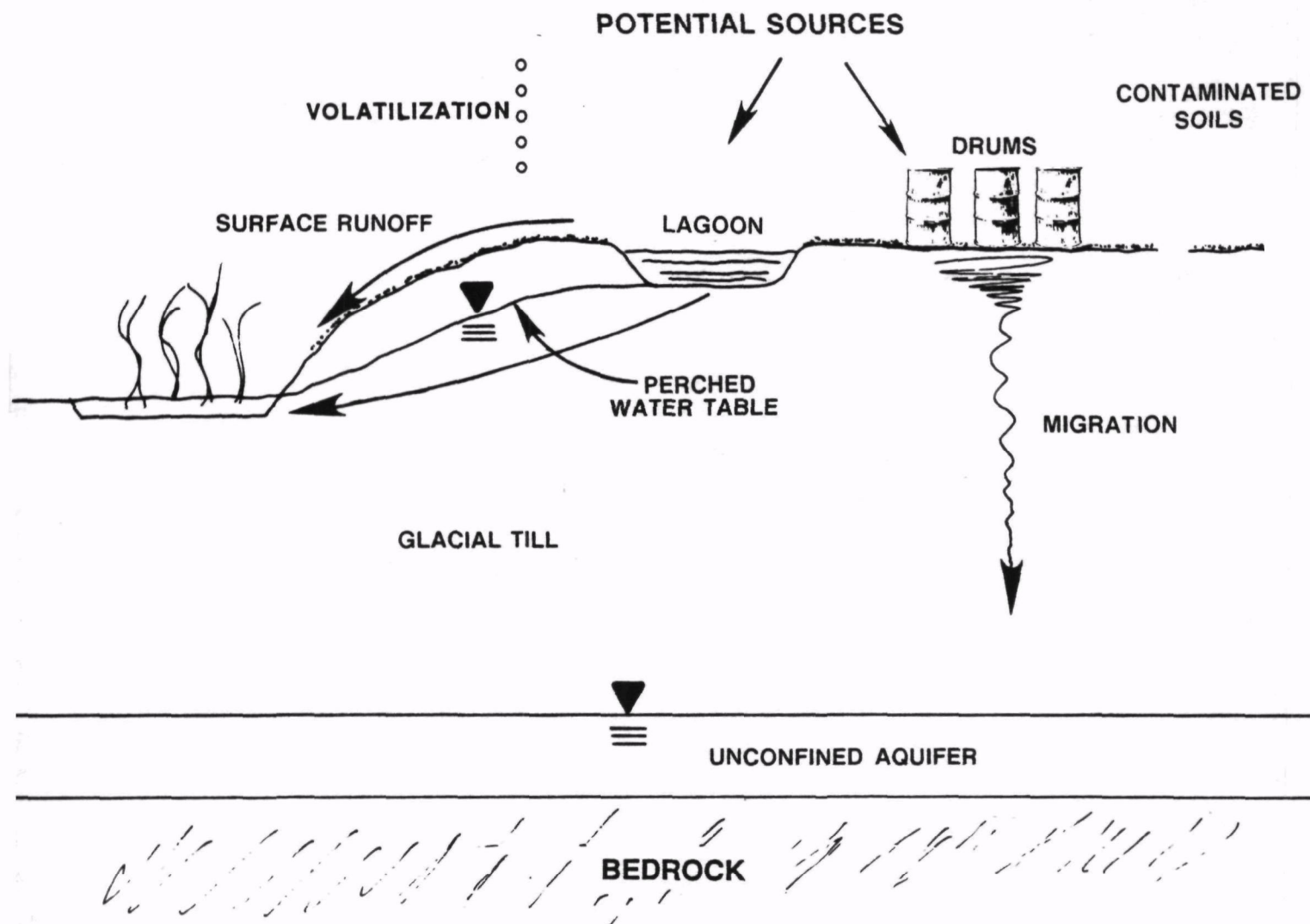
FIGURE 3-4
EXAMPLE CONCEPTUAL MODEL
ILLUSTRATION

o   Extent to which the substances have migrated or are expected to migrate from their area of origin and whether migration poses a threat to public health, welfare, or the environment

o   Extent to which contamination levels exceed applicable or relevant and appropriate federal public health or environmental standards and criteria

o   Contribution of the contamination to an air, land, or water pollution problem

o   Ability of responsible party to implement and maintain the remedy until the threat is permanently abated

Numerous techniques are available to evaluate the fate and migration of contaminants in environmental media. Soil contamination evaluation models which take into consideration soil properties (texture, pH, permeability), the characteristics of the contaminant of concern (Koc, solubility) and environmental factors (temperature, precipitation) are useful in estimating the movement of contaminants. These types of models are especially meaningful when used to relate a 10^{-6} cancer risk at a receptor, for instance, to an action level for remediation of soils on a site.

By determining the rate of migration of contaminants from a source to a receptor by use of evaluation models a better understanding of the urgency for implementation of remedial actions can be obtained.

The principal assumptions and calculation methods used to develop risk assessments can also be utilized during the early phases of an RI to assist in identifying data needs. Although it is not practical to assume that a risk assessment can be performed during the scoping process, use of an abbreviated approach which takes factors such as migration and concentration of contaminants at potential receptors into consideration can be of value in developing an evaluation model.

The process of evaluating data should be undertaken at the initiation of any remedial action program and at each point within the program that additional data are obtained. Additional data collected during the RI are used to expand the conceptual model and determine if sufficient data of

adequate quality have been obtained to address the issues of concern. As
the data base for the site expands, the level of uncertainty associated
with making a decision should decrease. For example, at the initiation of
an RI, information may be available on the general constituents present in
a lagoon on an uncontrolled hazardous waste site. These data may indicate
that the material in the lagoon contains priority pollutants. Subsequent
sampling rounds may be undertaken to define the range of variability of
constituents within the lagoon in terms of total volume and parameters
which would effect disposal options. These additional data are then used
to evaluate disposal/treatment options and develop cost estimates for
removal.

3.3.2 COMPUTER MODELS

The more difficult and more common questions to be addressed during a
remedial action program deal with defining the extent of contamination,
setting action limits and establishing total uncertainties associated with
remedial options. These types of decisions generally require that data be
evaluated utilizing tools such as ground water contaminant migration
·simulation models, air quality models, and/or geostatistical methods.
These techniques allow for further evaluation of the data and provide the
decision maker with a data base upon which an uncertainty value associated
with removal of contaminated soils can be developed.

Ground water models include several levels of analysis: simple graphical
techniques, analytical solution techniques, and numerical solution
techniques. Using this broad definition of modeling, one of these
techniques is almost always applied to examine a ground water contamination
problem. Thus, the primary question becomes not when to use modeling, but
what level of analysis is required to meet the objectives of the study.

The role of modeling must be evaluated with respect to the entire site
investigation. The evaluation of small sites with relatively uniform
geology may be accomplished by the use of simple analytical models. This

is in contrast to larger sites with complex stratigraphy involving contamination in multiple layers with variable aquifer parameters. This complexity can only be represented by a sophisticated numerical model involving a major effort by the hydrogeologist/modeler.

One of the most common misconceptions about ground water modeling and geostatistical techniques is that they are applied only during the final stages of an RI, after all the data are collected. While model application at the final stages of an investigation may provide useful information, modeling techniques could be applied throughout the RI. For example, during the early stages of an RI, the conceptual model can be used to guide the data collection program. Sensitivity analyses can help identify the types of data which need to be collected, as well as the most critical locations for data collection. As data collection proceeds during a phased RI, or when a large amount of data exist from previous investigations, models can be used to provide a consistent framework for organizing the data. The need to compare model results with field data forces a systematic categorization and review of existing data. During the latter stages of an FS, models can be applied to predict the future behavior of a ground water system under natural or artificial stresses, particularly implementation of remedial actions such as varied pumping schemes.

The role of geostatistical techniques and ground water models is to aid investigators in the formulation of appropriate questions concerning planning and design problems, and to help in obtaining quantitative answers of sufficient accuracy and detail to guide the decision maker. Models may not provide precise answers to the questions which have been posed. Rather, the model should be used to produce information needed to guide the thinking underlying the decisions to be made. For systems of even relatively low complexity, the number and nature of alternatives, interactions, and responses which are possible far exceed the capability to enumerate and evaluate completely. Use of geostatistics and ground water models allow decisions to be based on objective data, not solely on intuition or past experience.

Detailed discussions of computer modeling techniques are beyond the scope of this guidance document; however, the decision maker should be aware of these tools and determine if they should be incorporated as part of a data evaluation system for the site. Likewise, detailed discussion of possible geostatistical techniques is beyond the scope of this document. However, an overview of statistical methods is provided in Section 8.0 for reference purposes.

3.4 SPECIFY OBJECTIVES/DECISIONS

In a broad sense, the objective of remedial action program is to determine the nature and extent of the threat posed by the release or threat of release of hazardous substances and to select a cost effective remedial action which can be implemented at the site to minimize the risk of migration of or exposure to contaminants. Achieving this broad objective requires that several complicated and interrelated activities be performed, each having objectives, acceptable levels of uncertainty, and attendant data quality requirements. The expression of these objectives in clear precise decision statements is the first step toward the development of a cost-effective program for collection of sufficient data for decision making.

3.4.1 DECISION TYPES

Project objectives should address major areas of the remedial action process. These include characterizing the site with respect to the environmental setting, proximity and size of human population, and nature of the problem; identifying potential remedies; and determining specific performance levels of the potential remedies.

Data collected during the RI are used to support decisions regarding remedial actions for the site. Specifying the objectives can be thought of as identifying problems to be solved. The fact that most uncontrolled hazardous wastes sites pose numerous problems with respect to contaminant

migration will result in development of objectives geared towards separate media or sources. However, these objectives should be consistent with the ultimate objective of selecting a remedial alternative(s) to address the entire site.

Table 3-1 lists general RI/FS objectives. These objectives are somewhat simplistic but will be used in the ensuing steps in the process to refine DQOs.

Defining the types of decisions which will be made regarding remedial actions for uncontrolled hazardous waste sites requires a clear understanding of the problems posed by the site and awareness of the consequences of making a wrong decision.

3.4.2 DETERMINE NEED FOR ADDITIONAL DATA

The consequences of a wrong decision regarding site remediation will vary depending on the situation under consideration. For example, a decision may be made not to implement a remedial alternative designed to mitigate the migration of contaminants in ground water because the data indicate that dispersion and degradation of the contaminants will reduce concentrations to health-based levels within the area of attainment. If in actuality the contaminants migrated beyond the waste management levels and were encountered in the ground water system beyond the site, it may be suggested that a wrong decision was made. The consequences of this wrong decision made at a site where neighboring residents derive their water from private water supply wells tapping the contaminated aquifer would be different from the consequences of contamination of an aquifer which was not used as a source of water supply. The consequences of a wrong decision when individual water supply systems are contaminated would generally be considered more serious than those associated with contamination of an aquifer system not used as a water supply.

TABLE 3-1

General RI/FS Objectives

Objective	RI Activity	FS Activity
- Determine presence or absence of contaminants	- Establish presence/absence of contaminants at source and in all pathways.	- Evaluate applicability of no action alternative for source areas/pathways.
- Determine types of contaminants	- Establish "nature" of contaminants at source and in pathways; relate contaminants to PRP-cost recovery	- Evaluate environmental/public health threat; identify applicable remedial technologies.
- Determine quantities (concentrations) of contaminants	- Establish concentration gradients	- Evaluate costs to achieve applicable or relevant and appropriate standards
- Determine mechanism of contaminant release to pathways	- Establish mechanics of source/ pathway(s) interface	- Evaluate effectiveness of containment technologies
- Determine direction of pathway(s) transport	- Establish pathway(s)/transport route(s), Identify potential receptor(s)	- Identify most effective points in pathway to control transport of contaminants
- Determine boundaries of source(s) and pathways	- Establish horizontal/vertical boundaries of source(s) and pathway(s) of contamination	- Evaluate costs to achieve relevant/applicable standards; identify applicable remedial technologies
- Determine environmental/public health factors	- Establish routes of exposure, and environmental and public health threat	- Evaluate applicable standards or risk; identify applicable remedial technologies
- Determine source/pathway contaminant characteristics with respect to mitigation (bench studies)	- Establish range of contaminants/ concentrations	- Evaluate treatment schemes

The consequences of a wrong decision must be weighed for each major
decision to be made during the remedial action process. Where the
consequences of a wrong decision carry significant public health, safety or
environmental impacts, greater attention must be paid to obtaining the data
required to ensure that the decision is sound.

The information available for making a decision is related to the risk of
making a wrong decision and the significance of the consequences. As shown
in Figure 3-5, as the quantity and quality of data increase, the risk of
making a wrong decision based upon the information generally decreases.
This is not a true inverse relationship since at some point the collection
of additional data or improvement of data quality will not significantly
decrease the risk of making wrong decisions. This can best be expressed
graphically as shown in Figure 3-6. The risk of making a wrong decision
decreases as data quantity and quality increases, until it reaches a point
of diminishing returns, where additional data or increased quality of data
do not significantly reduce the risk of making a wrong decision.

It should also be noted that data quantity and data quality are independent
variables which must be considered jointly during assessment of the
consequences of making a wrong decision. Collecting increasing quantities
of data points which are of low quality may not add significantly to the
reduction of risk of making a wrong decision. Increasing the data quality
of a limited number of samples may not add significantly to the body of
knowledge to be used in making a decision.

As part of the development of the objectives for the RI/FS, the decision
making process should be outlined. Specific decisions that will be made,
when they will be made, and by whom they will be made are critical in the
outline development. Critical decisions need to be considered when
defining the data to be collected, the sampling and analytical methods, the
sensitivities of the methodologies, and the method detection limits. The
adequacy of the data which will be collected during the RI/FS to meet the
overall project objectives must therefore be evaluated in Stage 1 of the
DQO process.

INCREASING
RISK OF
MAKING WRONG
DECISIONS

INCREASING DATA QUALITY/QUANTITY
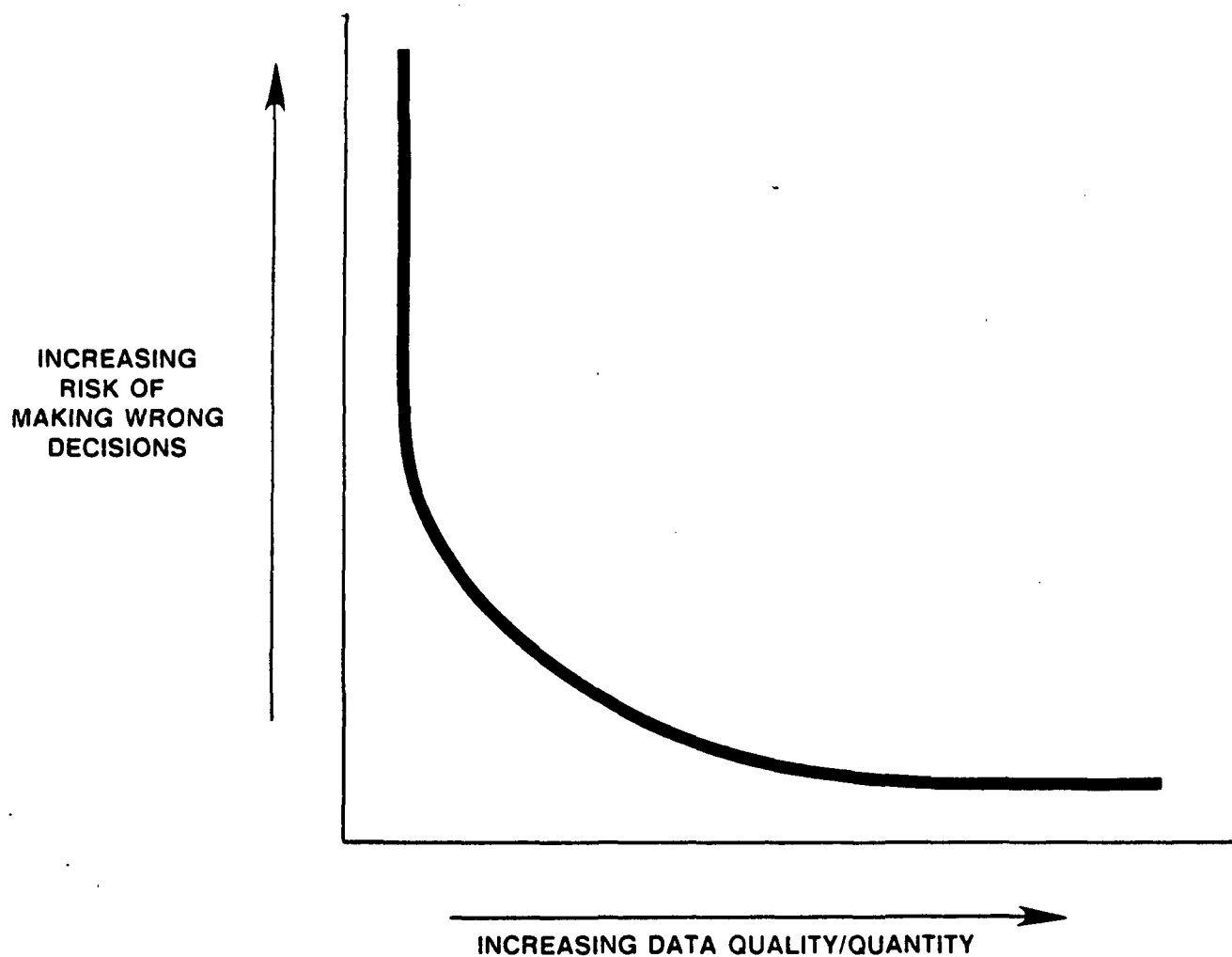
FIGURE 3-5
RELATIONSHIP OF RISK AND DATA
QUALITY/QUANTITY

INCREASING

DECREASING

DATA QUALITY AND QUANTITY

RISK OF MAKING WRONG DECISION

INCREASING

DECREASING
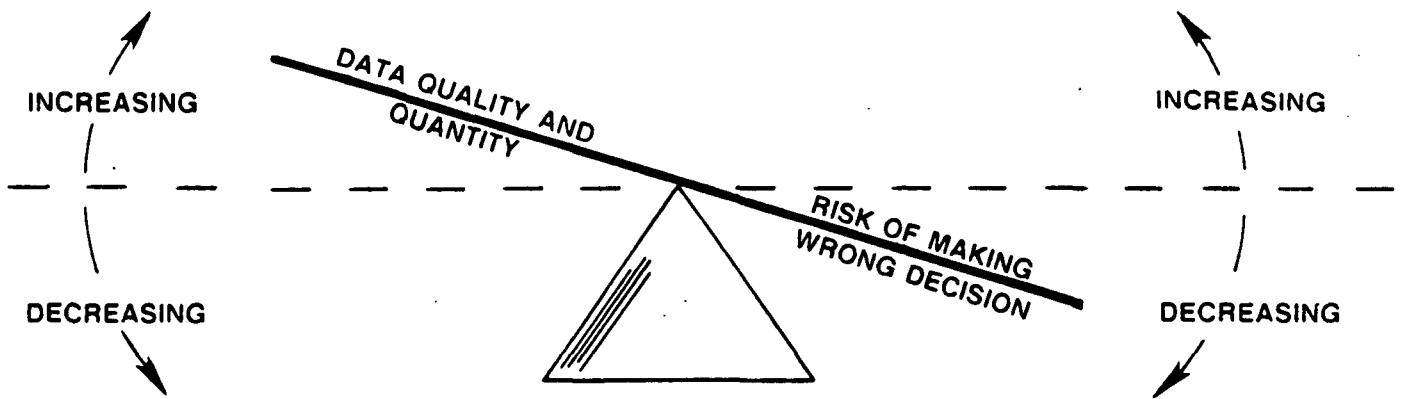
FIGURE 3-6
RELATIONSHIP OF DATA AVAILABLE TO RISK
FOR MAKING A DECISION

The following are some general questions which should be addressed when determining if additional data are required.

o   What are migration pathways?

o   What are potential receptors?

o   Are contaminants present above levels of concern at points of receptors?

o   Is background an appropriate comparison?

o   Are contaminants above levels of concern as determined from available standards or technical guidance? (e.g., What are applicable/relevant standards? How clean is clean?)

o   What are the three-dimensional (spatial) and time boundaries, of contaminant above action levels?

o   Are there migration concentration gradients that could be handled separately?

o   Are there any operable units that can be expedited in order to protect public health and the environment (e.g., source control, alternate water supply)?

o   Which alternatives are feasible and sufficient to protect public health and the environment.

o   Is treatment a viable option? Should treatment tests or pilot studies be conducted concurrent with the RI?

o   Have sufficient data been collected so that cost estimates are within the +50 percent to -30 percent range for RI/FS? Within +15 percent to -10 percent range for remedial design (RD)?

o   Which alternative should be selected in accordance with NCP? Would the remedy comply with other environmental laws?

The value of obtaining additional data or increasing data quality has traditionally been based on professional judgment for RI/FS projects. The intent of the DQO process is to provide a systematic approach for the evaluation of the risk associated with making a wrong decision and for determining levels of uncertainty associated with decisions to provide a framework for the RPM.

3.5 REFERENCES

Federal Register. 1985. National Oil and Hazardous Substances Pollution Contingency Plan. Final Rule. Vol. 50, No. 224. November 20.

U.S. Environmental Protection Agency (EPA). 1985a. Guidance on Remedial Investigations Under CERCLA. Office of Emergency and Remedial Response, Office of Waste Programs Enforcement, Office of Solid Waste and Emergency Response, Washington, D.C. Office of Research and Development, Cincinnati, Ohio. EPA/540/G-85/002. June.

_____. 1985b. Guidance on Feasibility Studies Under CERCLA. Office of Emergency and Remedial Response, Office of Waste Programs Enforcement, Office of Solid Waste and Emergency Response, Washington, D.C. Office of Research and Development, Cincinnati, Ohio. EPA/540/G-85/003. June.

Section 4.0

4.0 RI/FS STAGE 2 - IDENTIFY DATA USES/NEEDS

Stage 2 of the DQO process is undertaken to define specific data uses, and to specify the types of data needed to meet the project objectives. Although data needs are identified generally during Stage 1, it is during Stage 2 that specific data uses are defined.

The major elements of Stage 2 of the DQO process, as identified in Figure 4-1, are:

- o Identify data uses

- o Identify data types

- o Identify data quality needs

- o Identify data quantity needs

- o Evaluate sampling/analysis options

- o Review PARCC parameters

Stage 2 begins after the completion of the site specific conceptual model and the specification of the overall project objectives. The conceptual model and the general decisions that need to be made become the basis for determining data uses and data needs. The result of Stage 1 is a determination of the sufficiency or insufficiency of the existing data to meet the project objectives. If the existing data are sufficient, there is no need to collect additional data. If the data are insufficient, the types, quality, and quantity of data which must be collected will be determined in Stage 2.

The purpose or use to which the data will be applied is defined in terms of the specific purpose of the project, whether it is problem definitions, alternative analyses, identification of PRPs, or design of remedial actions. Identification of data needs occurs simultaneously with identification of data uses since these factors are inseparable.

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                    ┌─────────────────┐
                    │    IDENTIFY     │
                    │   DATA USES     │
                    └────────┬────────┘
                             │
                             ▼
                    ┌─────────────────┐
                    │  IDENTIFY DATA  │
                    │     TYPES       │
                    └────────┬────────┘
                   ╱                   ╲
                  ╱                     ╲
                 ▼                       ▼
    ┌─────────────────┐        ┌─────────────────┐
    │    IDENTIFY     │◄──────►│    IDENTIFY     │
    │  DATA QUALITY   │        │  DATA QUANTITY  │
    │     NEEDS       │        │     NEEDS       │
    └─────────────────┘        └─────────────────┘
                  ╲                   ╱
                   ╲                 ╱
                    ▼               ▼
            ┌───────────────────────────┐
            │        EVALUATE           │
            │  SAMPLING/ANALYTICAL      │
            │        OPTIONS            │
            └─────────────┬─────────────┘
                          │
                          ▼
            ┌───────────────────────────┐
            │      REVIEW PARCC         │
            │      PARAMETERS           │
            └───────────────────────────┘
```
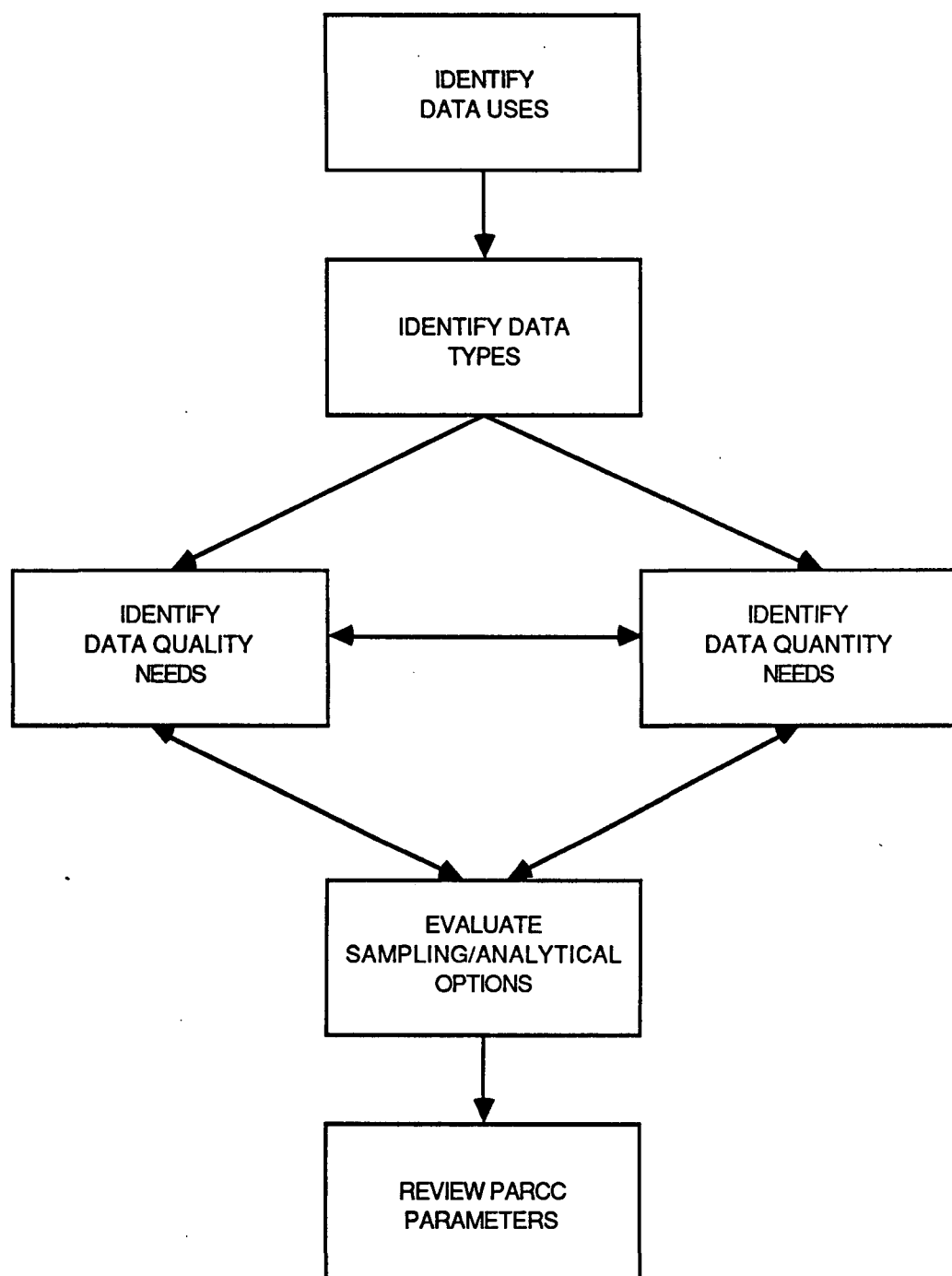
FIGURE 4-1
DQO STAGE 2 ELEMENTS

4.1 IDENTIFY DATA USES

Although the use of the data may appear to be relatively easy to define
during the scoping phase, it is important that a detailed evaluation of
data uses be undertaken to ensure that the amount of data are appropriate
for their intended uses.

For example, during the scoping process it may be determined that ground
water samples should be obtained in the vicinity of a site at which
contaminants have been encountered in the shallow ground water aquifer on
site. The homes in the largely rural area surrounding this hypothetical
site derive water from private wells which tap the bedrock aquifer. Based
upon the DQO approach, professional experience, and program guidelines
provided by the RPM, the contractor decides that ground water from the
bedrock aquifer should be sampled to determine if contaminants are present.
However, the more difficult questions to address during Stage 2 of the DQO
process include:

o How many samples are required?

o Where should samples be obtained?

o How many QA/QC samples are needed (field trip blanks, collocated
   sample, field and laboratory duplicates, spikes)

o Will data obtained be used to determine if an alternative water
   supply should be provided to affected homes?

o At what contaminant level are water supplies considered to be
   affected?

o Will decisions be based upon results of data from analysis of
   private water supply wells or from monitoring wells?

o If contaminants are not detected in private water supply wells but
   are detected in monitoring wells, how will data be used to assess
   risks to receptors?

As demonstrated, the list of questions which can be generated to evaluate a
simplistic problem in one medium can be quite extensive.

4.1.1 DATA USE CATEGORIES

To facilitate the sequential thought process required to effectively and accurately answer these questions raised in Section 4.1, and thus develop DQO Stage 2 elements, Standard Forms DQO 1.001 and 1.002 are provided as Tables 4-1 and 4-2. Whereas these forms are shown as tables in the Guidance Manual, during the development of DQOs for an actual remedial response activity, they would be completed as part of the sampling and analysis plan. Not only can these forms be used to summarize all DQO decisions, but also as a working checklist to assure that all of the required elements have been addressed.

The intended uses for data to be collected during an RI/FS can be described in general purpose categories. These categories represent generic uses but vary on a site-by-site basis. Further, specific sites may require data for purposes other than those described here. In this case, site-specific data use categories will be identified. As discussed above Table 4-1 presents a suggested format to be used in identifying data use. The categories listed represent the most common RI/FS data uses. They do not represent different data qualities, only different uses which may require data of a given quality. In other words, data collected for a site at a given level of quality may be used for different purposes. The data use categories are briefly described below:

o   Site Characterization - Data collected for site characterization
    purposes are used to determine the nature and extent of
    contamination at a site. This category is usually the one that
    requires the most data collection. Site characterization data are
    generated through the sampling and analysis of waste sources and
    environmental media.

o   Health and Safety - Data collected for health and safety purposes
    are typically used to establish the level of protection needed for
    investigators or workers at a site, and if there should be an
    immediate concern for the population living within the site
    vicinity. Standard practice is to collect baseline health and
    safety data, followed by collecting data during any site activities
    which involve disturbing baseline conditions (e.g., test-pitting,
    well drilling). Health and safety data are generally collected
    using real-time, direct-reading portable instruments such as a
    photoionization meter.

TABLE 4-1
DATA USES

S⁙E
NAME _____
LOCATION _____
NUMBER _____
PHASE _____
    RI1 RI2 RI3 ERA FS RD RA

EPA REGION

_____

DATE _____
CONTRACTOR _____
SITE MANAGER _____

DATA USE / MEDIA	SITE CHARACTERIZATION (INCLUDING HEALTH & SAFETY)	RISK ASSESSMENT	EVALUATION OF ALTERNATIVES	ENGINEERING DESIGN OF ALTERNATIVES	MONITORING DURING REMEDIAL ACTION	PRP DETERMINATION	OTHER _____
SOURCE SAMPLING TYPE _____							
SOIL SAMPLING							
GROUND WATER SAMPLING							
SURFACE WATER/SEDIMENT SAMPLING							
AIR SAMPLING							
BIOLOGICAL SAMPLING							
OTHER _____							

NOTE: CHECK APPROPRIATE BOX (ES)

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TABLE 4-2
DQO SUMMARY FORM

1. SITE

NAME _____

LOCATION _____

NUMBER _____

EPA
REGION _____

PHASE _____
RI 1 RI 2 RI 3 ERA FS RD RA
(CIRCLE ONE)

2. MEDIA *(CIRCLE ONE)*	SOIL	GW	SW/SED	AIR	BIO	OTHER _____

3. USE *(CIRCLE ALL THAT APPLY)*	SITE CHARAC. (H&S)	RISK ASSESS.	EVAL. ALTS.	ENGG DESIGN	PRP DETER.	MONITORING REMEDIAL ACTION	OTHER _____

4. OBJECTIVE _____
_____
_____
_____

5. SITE INFORMATION

AREA _____ DEPTH TO GROUND WATER _____

GROUND WATER USE _____

SOIL TYPES _____

SENSITIVE RECEPTORS _____

6. DATA TYPES *(CIRCLE APPROPRIATE DATA TYPES)*

A. ANALYTICAL DATA

pH	PESTICIDES	TOX
CONDUCTIVITY	PCB	TOC
VOA	METALS	BTX
ABN	CYANIDE	COD
TCLP	_____	_____

B. PHYSICAL DATA

PERMEABILITY	HYDRAULIC HEAD
POROSITY	PENETRATION TEST
GRAIN SIZE	HARDNESS
BULK DENSITY	_____
_____	

7. SAMPLING METHOD *(CIRCLE METHOD(S) TO BE USED)*

| ENVIRONMENTAL | BIASED | GRAB | NON- INTRUSIVE | PHASED |
| SOURCE | GRID | COMPOSITE | INTRUSIVE | _____ |

8. ANALYTICAL LEVELS *(INDICATE LEVEL(S) AND EQUIPMENT & METHODS)*

LEVEL 1 FIELD SCREENING - EQUIPMENT _____

LEVEL 2 FIELD ANALYSIS - EQUIPMENT _____

LEVEL 3 NON-CLP LABORATORY - METHODS _____

LEVEL 4 CLP/RAS - METHODS _____

LEVEL 5 NON STANDARD _____

9. SAMPLING PROCEDURES

BACKGROUND - 2 PER EVENT OR _____

CRITICAL (LIST) _____

PROCEDURES _____

10. QUALITY CONTROL SAMPLES *(CONFIRM OR SET STANDARD)*

A. FIELD
COLLOCATED - 5% OR _____
REPLICATE - 5% OR _____
FIELD BLANK - 5% OR _____
TRIP BLANK - 1 PER DAY OR _____

B. LABORATORY
REAGENT BLANK - 1 PER ANALYSIS BATCH OR _____
REPLICATE   - 1 PER ANALYSIS BATCH OR _____
MATRIX SPIKE   - 1 PER ANALYSIS BATCH OR _____
OTHER _____

11. BUDGET REQUIREMENTS

BUDGET _____ SCHEDULE _____

STAFF _____

CONTRACTOR _____ PRIME CONTRACTOR _____

SITE MANAGER _____ DATE _____

FOR DETAILS SEE SAMPLING & ANALYSIS PLAN

CDM SF DQO 1.002

o Risk Assessment - Data collected for risk assessment purposes are used to evaluate the threat posed by a site to public health and the environment. Some of the data must be qualitative so that the chemical/physical properties, toxicity, and persistence of contaminants can be factored into the risk assessment. The data must also be quantitative to the degree that they may be compared with quantitative statements of health risk criteria (e.g., 10^{-6} lifetime cancer risk level). Therefore, a high level of data certainty is necessary. Risk assessment data are generated through the sampling and analysis of environmental and biological media, particularly where the potential for human exposure is great. The level of data quality required will be related to the precision of the model. For models in which gross assumptions are made, qualitative data may be adequate whereas quantitative data may be required for use in sophisticated models.

o Evaluation of Alternatives - Data collected for engineering purposes are used to evaluate various remedial technologies. Engineering data is collected in support of remedial alternative evaluation and to develop cost estimates (+50 to -30 percent). This may involve performing bench-scale or pilot scale studies to determine if a particular process or material may be effective in mitigating site contamination.

o Engineering Design of Alternatives - Data collected during the RI/FS can be used for engineering design purposes to develop a preliminary data base in reference to the performance of various remedial technologies. Data types collected during the RI/FS which are applicable to the RD process include waste characterization and preliminary volume estimates (these estimates usually need to be refined further by additional data collection activities during the RD/RA).

o Monitoring During Remedial Action - During the implementation of the remedial action, samples can be taken to assess the effectiveness of the action. Based on the analysis of these samples, corrective measures to improve the performance of the action may be taken.

o PRP Determination - Data collected for this purpose are used to help establish the liability at multiple-party sites. For known RPs, data are used to link their wastes to those found on the site and to pollutants released to the environment, and for unknown RPs, by comparing the site wastes to pollutant profiles of known waste streams. Data collected to document the nature and extent of contamination, and to justify the Agency selection of the remedial alternative as being consistent with the NCP, are also used for injunctive actions, as well as for cost recovery.

The format presented in Table 4-1 can be used by contractor personnel involved in RI/FS scoping to identify sampling and analysis needs. The actual matrix used should be developed on a site specific basis by sampling task and intended data use category.

Once the data use categories are listed, the intended uses must be prioritized. Establishing an order of priority for the intended data uses will help identify the most demanding use of each type of data, i.e., the use requiring the highest level of confidence, and therefore the lowest level of uncertainty. The data quality required will be a function of the acceptable limits of uncertainty established by the decision maker. The limits on uncertainty will drive the selection of both the analytical and sampling approaches.

Prioritizing the intended data uses begins with examining the list of uses for each data collection task and identifying the use which is most important for meeting the RI/FS objectives. Uses having lesser importance are then arranged in order, under the first priority use. This is especially true when analytical turn-around requirements differ based on schedule constraints.

When a secondary use requires data of a much higher quality and the number of samples required is different than the primary data use, it may be more advantageous to treat the two uses as separate activities by collecting two different data sets. Consideration should be given to developing a phased approach to the data collection, in which the design of each subsequent data collection task for an intended use is built upon the results of the preceding one.

4.1.2 RI/FS USES

During the evaluation of data uses, a review of the potential remedial options which will be considered during the RI/FS must be undertaken.

To the extent that is both possible and appropriate, at least one alternative shall be developed for each of the five categories listed below, as specified in Section 300.68 of the National Contingency Plan:

o Alternatives for <u>off-site</u> treatment or disposal, as appropriate

o Alternatives that <u>attain</u> applicable or relevant and appropriate federal public health and environmental requirements

o As appropriate, alternatives that <u>exceed</u> applicable or relevant and appropriate federal public health or environmental requirements

o As appropriate, alternatives that <u>do not attain</u> applicable or relevant and appropriate federal public health and environmental requirements but will reduce the likelihood of present or future threat from the hazardous substances and that provide significant protection to public health and welfare and the environment

o <u>No action</u> alternative.

For each of the appropriate action categories, the following information or analysis should be considered during the DQO process:

o List of candidate remedial actions

o Method by which the initial alternatives will be screened, including cost criteria, acceptable engineering practice criteria, and effectiveness criteria

o Method by which the limited number of alternatives will be evaluated, including refinement and specification of alternatives; detailed cost estimation; and evaluation of engineering implementation, reliability and constructibility

o Analysis methods to assess the extent to which the alternative is expected to effectively prevent, mitigate, or minimize threats to, and provide adequate protection of, public health, welfare, and the environment

The remedial action process involves a number of data collection activities, each having specific objectives. Since the objectives require varying degrees of data quality, it is critical to identify the specific use to which each set of data will be applied.

4.2 IDENTIFY DATA TYPES

Data use categories define the general purposes for which data will be collected during the RI. By defining the intended uses for the data early in the RI scoping process, a concise statement regarding the data types which are needed can be developed. After identifying the data types and uses, data quality needs can be defined, and a systematic evaluation of sampling and analysis options can be performed.

Data types can be specified in broad groups initially, such as background samples, or media samples. For example, environmental media samples can be used to determine the extent of contamination at a specific site. The DQO process requires that data types be specified to a continually more detailed level to ensure that the data obtained are useful in meeting the objectives of the RI/FS. Figure 4-2 illustrates the process of continual refinement of data types for a hypothetical ground water contamination problem. The process should be followed for each media of interest or each source material. The result of completing the entire decision matrix is the specification of the data type needed for each intended data use.

Since environmental media and source materials are interrelated at uncontrolled hazardous waste sites, data types to be used to evaluate ground water contamination may also be used to evaluate soil contamination. By identifying data types by media, the decision maker and the data users can discuss overlapping data needs to refine the scope of the RI.

The types of analyses which will be performed on each sample must be determined while identifying data types. The analytical requirements are dictated by the use of the data, which is ultimately driven by the remedial alternative under consideration.

Evaluation of the limitations posed by various treatment/disposal options allows one to develop a listing of analytical data types required during the RI. For example, in order to adequately evaluate treatment/disposal
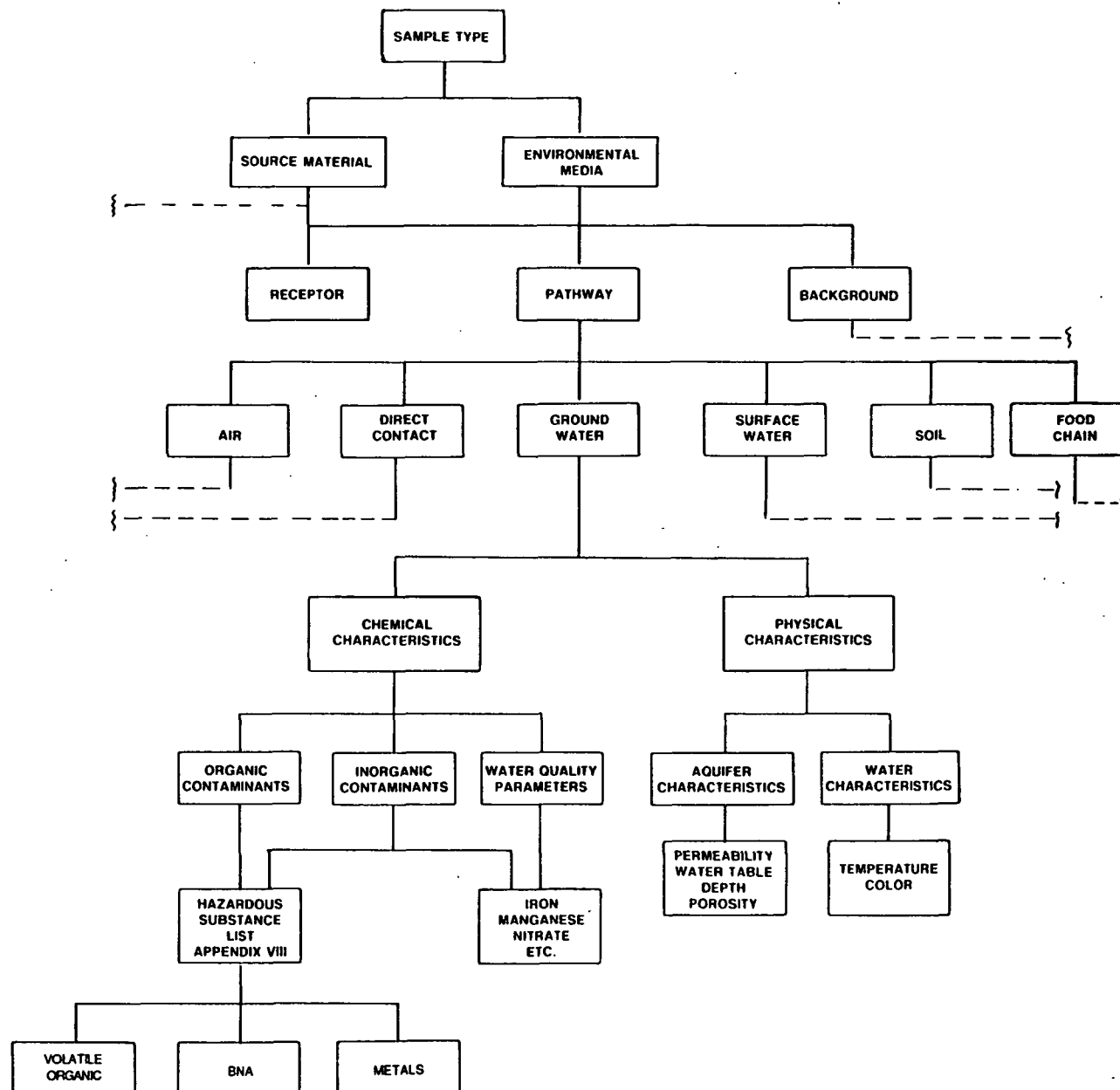
FIGURE 4-2
SAMPLE TYPE SPECIFICATION LOGIC DIAGRAM

options for materials contained in a waste impoundment, its PCB content, pH, halogen content, viscosity, as well as other parameters which would influence its treatability or acceptability for disposal must be determined during the RI.

The data types specified in Stage 2 should not be limited to chemical analytical parameters, but should also include physical parameters such as permeability and porosity, which are needed to evaluate contaminant migration. The level of detail to which data types are defined during the DQO process must be sufficient to allow for evaluation of sampling/analysis options during subsequent stages of the DQO process.

4.3   IDENTIFY DATA QUALITY NEEDS

4.3.1 DATA QUALITY FACTORS

Consideration of data quality needs should begin with the identification of data uses and data types. Important factors in defining data quality include:

    o Prioritized Data Uses

    o Appropriate Analytical Levels

    o Contaminants of Concern

    o Level of Concern

    o Required Detection Limit

    o Critical Samples

These factors should be considered to define data quality needs in a general way at the start of an RI/FS. As work proceeds and more data become available, more precise statements can be made. These factors, coupled with consideration of data quantity needs and an evaluation of sampling and anlaysis options, lead to a more quantitative statement of quality needs as Precision, Accuracy, Representativeness, Completeness, and Comparability (PARCC) parameters.

Data uses and their prioritization have been addressed in Section 4.1.1. The remaining data quality factors are discussed in this section. PARCC parameters will be reviewed in Section 4.1.6.

Appropriate Analytical Levels

The quality of measurement data needed is dependent on the end use of the data but site conditions vary so much that guidelines applicable to generic RI/FS data uses cannot readily be provided. In addition, there is little or no information on many factors which critically affect data quality such as: sample variability, sample container cleanliness, effect of different sample collection and analytical preparation techniques, etc. Most available measurement data quality information addresses only the analytical technique. To provide some guidance, this section defines analytical levels and then indicates the levels appropriate to different generic RI/FS data uses. Section 9 of this document provides a more detailed discussion of analytical considerations.

The analytical levels are arbitrarily defined as follows:

o   Level I - field screening or analysis using portable instruments. Results are often not compound specific and not quantitative but results are available in real-time. It is the least costly of the analytical options.

o   Level II - field analyses using more sophisticated portable analytical instruments; in some cases, the instruments may be set up in a mobile laboratory onsite. There is a wide range in the quality of data that can be generated. It depends on the use of suitable calibration standards, reference materials, and sample preparation equipment; and the training of the operator. Results are available in real-time or several hours.

o   Level III - all analyses performed in an offsite analytical laboratory using methods other than CLP/RAS procedures (i.e. SW846 methods). The laboratory may or may not be a CLP laboratory.

o   Level IV - CLP routine analytical services (RAS). All analyses are performed in an offsite CLP analytical laboratory following CLP protocols. Level IV is characterized by rigorous QA/QC protocols and documentation.

o   Level V – analysis by non-standard (NS) methods. All analyses are
     performed in an offsite analytical laboratory which may, or may
     not, be a CLP laboratory. Method development or method
     modification may be required for specific constituents or detection
     limits. CLP special analytical services (SAS) are level NS.

In general, offsite analytical laboratories have a large amount of
analytical equipment and instrumentation enabling them to handle complex
sample matrices. With the exception of the CLP RAS, the laboratories can
use varied sample preparation and analysis techniques to optimize the
quality of the resulting data.

Levels III, IV and NS all incorporate some time lag between submission of
samples to the laboratory and receipt of results. Table 4-3 provides more
information on these analytical levels; Table 4-4 identifies appropriate
analytical levels for generic RI/FS data uses.

It can be seen from Table 4-4 that, for each generic data use, several
analytical levels may be appropriate. The decision maker needs further
criteria to select the most appropriate. Important criteria are the
contaminants of concern and the level of concern for each contaminant.

Contaminants of Concern

At some sites it may be clear which contaminants are of concern because
they have known impacts on human health. In such cases, the appropriate
health standards can be used to set action levels. Often a large number of
contaminants are found at a site. In such cases it is not feasible or
desirable to specify action levels for each observed contaminant. Rather,
a small number of indicator chemicals are selected and action levels are
determined for these chemicals. Indicator chemicals are the most toxic,
mobile, persistent, and frequently occurring contaminants found on site.
The process of selecting indicator contaminants is described in the
Superfund Public Health Evaluation Manual
(EPA 1985).

TABLE 4-3
SUMMARY OF ANALYTICAL LEVELS APPROPRIATE TO
DATA USES

DATA USES	ANALYTICAL LEVEL	TYPE OF ANALYSIS	LIMITATIONS	DATA QUALITY
SITE CHARACTERIZATION MONITORING DURING IMPLEMENTATION	LEVEL I	- TOTAL ORGANIC/INORGANIC VAPOR DETECTION USING PORTABLE INSTRUMENTS	- INSTRUMENTS RESPOND TO NATURALLY-OCCURING COMPOUNDS	- IF INSTRUMENTS CALIBRATED AND DATA INTERPRETED CORRECTLY, CAN PROVIDE INDICATION OF CONTAMINATION
SITE CHARATERIZATION EVALUATION OF ALTERNATIVES ENGINEERING DESIGN MONITORING DURING IMPLEMENTATION	LEVEL II	- VARIETY OF ORGANICS BY GC; INORGANICS BY AA; XRF - TENTATIVE ID; ANALYTE-SPECIFIC - DETECTION LIMITS VARY FROM LOW ppm TO LOW ppb	- TENTATIVE ID - TECHNIQUES/INSTRUMENTS LIMITED MOSTLY TO VOLATILES, METALS	- DEPENDENT ON QA/QC STEPS EMPLOYED - DATA TYPICALLY REPORTED IN CONCENTRATION RANGES
RISK ASSESSMENT PRP DETERMINATION SITE CHARACTERIZATION EVALUATION OF ALTERNATIVES ENGINEERING DESIGN MONITORING DURING IMPLEMENTATION	LEVEL III	- ORGANICS/INORGANICS USING EPA PROCEDURES OTHER THAN CLP CAN BE ANALYTE-SPECIFIC - RCRA CHARACTERISTIC TESTS	- TENTATIVE ID IN SOME CASES - CAN PROVIDE DATA OF SAME QUALITY AS LEVELS IV, NS	- SIMILAR DETECTION LIMITS TO CLP - LESS RIGOROUS QA/QC
RISK ASSESSMENT PRP DETERMINATION EVALUATION OF ALTERNATIVES ENGINEERING DESIGN	LEVEL IV	- HSL ORGANICS/INORGANICS BY GC/MS; AA; ICP - LOW ppb DETECTION LIMIT	- TENTATIVE IDENTIFICATON OF NON-HSL PARAMETERS - SOME TIME MAY BE REQUIRED FOR VALIDATION OF PACKAGES	- GOAL IS DATA OF KNOWN QUALITY - RIGOROUS QA/QC
RISK ASSESSMENT PRP DETERMINATION	LEVEL V	- NON-CONVENTIAL PARAMETERS - METHOD-SPECIFIC DETECTION LIMITS - MODIFICATION OF EXISTING METHODS - APPENDIX 8 PARAMETERS	- MAY REQUIRE METHOD DEVELOPMENT/MODIFICATION - MECHANISM TO OBTAIN SERVICES REQUIRES SPECIAL LEAD TIME	- METHOD-SPECIFIC

TABLE 4-4
APPROPRIATE ANALYTICAL LEVELS - BY DATA USE

ANALYTICAL LEVEL \ DATA USE	SITE CHARACTERIZATION (INCLUDING HEALTH & SAFETY)	RISK ASSESSMENT	EVALUATION OF ALTERNATIVES	ENGINEERING DESIGN OF REMEDIAL ACTION	MONITORING DURING IMPLEMENTATION OF REMEDIAL ACTION	PRP DETERMINATION	OTHER ———
LEVEL I	✓				✓		
LEVEL II	✓		✓	✓	✓		
LEVEL III	✓	✓	✓	✓	✓	✓	
LEVEL IV		✓	✓	✓		✓	
LEVEL V		✓				✓	
OTHER							

NOTE: CHECK APPROPRIATE BOX (ES)

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In either case, the contaminants of concern should be identified to assist in determining data quality needs.

Levels of Concern

The level of concern specifies a concentration range above which some action may need to be taken. The level of concern is intimately linked with the action level.

An exact action level is not required before initiating an RI field investigation; however, a rough estimate is necessary to ensure that the chosen analytical methods are accurate at the level of concern. Also, knowledge of the level of concern can influence the number of samples required and the selection of analytical methods. For these reasons, an acceptable range of values should be specified. As work on a site progress and more data become available, the level of concern will be further refined and incorporated into the ROD as an action level.

Determination of levels of concern is a site specific activity. The decision maker and data users (toxicologists, geologists, and engineers) must meet to determine the appropriate action level range for the site. For sites with contaminated surface and ground water the following can serve as a guideline to determining levels of concern.

o Maximum Contaminant Levels (MCLs) stated for 20 chemicals in the Safe Drinking Water Act

o National Ambient Water Quality Criteria (NAWQC) developed for 95 chemicals in ambient water systems (non-drinking water) under the Clean Water Act (Note that NAWQC have the force of law in only a few states.)

o Health Advisories; Suggested No Adverse Response Levels (SNARLs) developed for 22 contaminants in drinking water under the Safe Drinking Water Act

o Critical toxicity values such as:

- EPA potency factors (10^{-6} cancer risks) developed for suspected carcinogens, and

- EPA reference doses (acceptable doses) for non-carcinogens

o State water quality standards

Regulatory guidelines and criteria are generally lacking for soil and sediment contamination. Therefore, the action level for these media must be set specifically for each site. However, criteria have been set for PCBs in TSCA and for dioxin.

Several tables are provided in Appendix B that summarize potentially applicable or relevant and appropriate requirements and toxicity values. The standards do not consider simultaneous exposure from multiple routes. Standards may also be based on levels, durations, or frequencies of exposure that differ from those at a specific site. The standards and criteria that are used, especially when conducting public health assessments, must correspond to the media for which they are developed. As a result of the various technical aspects of standards development, some concentration limits will require adjustment before being applied.

It should be noted that applicable or relevant and appropriate ambient concentration limits are not available for all media for many chemicals commonly found at Superfund sites. In addition, it is possible that there will be overlaps in the applicable or relevant and appropriate requirements, other criteria, and toxicity values developed for EPA's Health Effects Assessments (HEAs). For these reasons, it will be necessary to rank these values, when available. Often a large number of contaminants are found at a site. In such cases it is not feasible or desirable to specify action levels for each observed contaminant. Rather, a small number of indicator chemicals are selected and levels of concern are determined for these chemicals. Indicator chemicals are the most toxic, mobile, persistent, and frequently occurring contaminants found on site. The process of selecting indicator contaminants is described in the Superfund Public Health Evaluation Manual (EPA 1985).

In the listing of applicable standards which can be used for selecting action levels, few standards are available for soil contamination. Standards are not available because direct ingestion of contaminated soil is not common and routes of exposure are site specific. Generally some

type of modeling may be required to specify the level of concern for soil. The type of model selected for use will be based on the potential route of exposure. If contaminated soil is carried in the air and inhaled by receptors, air modeling may be required. If contaminants leach from soils into ground water and are transported to receptor wells, a ground water model may be required. These models are useful in assessing the potential impact resulting from migration of on-site contaminants at a specified level of concern to a receptor at a specified cancer risk level, for instance. The available models are specified in the Superfund Exposure Assessment Manual (EPA 1985).

In any numerical modeling procedures such as level of concern determination, there are some input parameters which are unknown or uncertain. Generally these parameters are determined in an iterative procedure known as calibration or history matching. When beginning model calibration, input parameters are assumed or estimated and the model is run. By using the model to predict values at known data points and computing the modeling errors, the predictive power of the model is obtained. Based on the observed modeling errors, input parameters are then refined so that the predictive power of the model increases.

When a model has several input parameters, the calibration process is time consuming because there are an extremely large number of input parameter combinations. In most modeling efforts it is impossible to test every likely combination of input parameters. In these cases, the first few calibration runs are performed to determine the input parameters which when varied, produce the largest response in the model output values. The procedure by which these parameters are determined is termed a sensitivity analysis. Once a sensitivity analysis is performed, further calibration of the model centers on varying the parameters identified in the sensitivity analysis while keeping the other parameters constant.

Model calibration is an inexact science which is best performed by experts in the theory underlying the model. Calibrated models have no unique solution; that is, there are many combinations of the input parameters which will yield similar model outputs. Finally, models generally contain

assumptions and simplifications of the underlying mathematical theory which allow them to be utilized on a computer. For these reasons models can make severe prediction errors at unsampled locations and it is impossible to predict or evaluate the effect that the accuracy and precision of the data will have on the efficiency of the model. It is believed, however, that the uncertainties associated with the choice of input parameters and the non uniqueness of the model are at least an order of magnitude larger than the precision of the data.

Detection Limit Requirements

The level of concern selected will have an immediate impact on data quality requirements. The sampling and analysis methods selected must be capable of accurate measurement at the level of concern. Since sampling accuracy is hard to evaluate or control, it is extremely important that the analytical technique chosen has a detection limit well below the level of concern. This factor must be considered in evaluating analytical options. Section 9.2.4 provides more detailed information on detection limits. Appendix E lists CLP contractually required detection limits.

Critical Samples

Critical samples are those for which valid data must be obtained to satisfy the objectives of the sampling and analysis task. The identification of critical samples should be based on careful review of these objectives. Critical data points should be identified in every completeness statement developed during the DQO. An example of a critical data point may be an upgradient well in a ground water contamination study or any other data point considered vital to the decision making process. Critical data points should be carefully considered when designing data collection activity and every effort must be made to obtain valid data for these samples. In some cases, taking critical samples in duplicate is appropriate. It should be recognized that a common problem of any sampling design is the loss of data during implementation of the design.

4.3.2 COST ANALYSIS OF ALTERNATIVES

The program goal for developing cost estimates in feasibility studies is to estimate the cost of the selected remedial alternative to within +50 percent and -30 percent of the actual cost. This statement not only puts requirements on the type and amount of data which must be collected during the field investigation, it also requires the decision maker to consider the range of potential remedial alternatives before planning the field investigation. Thus, after developing the site conceptual model, the range of potential remedial alternatives must be developed.

In situations where a possible alternative is source removal, the cost criteria may be used to determine the number of data required. If the cost of the remedial alternative is strictly proportional to the volume of material removed, sufficient data must be obtained to determine the volume of material to within +50 percent and -30 percent. Normally, however, there is some uncertainty in the capital costs and the efficiency of the treatment or removal procedure. For this reason, it may be necessary to determine the uncertainty in the volume of contaminants much more accurately.

In many cases the cost estimates developed for remedial actions have fallen outside the established +50 percent to -30 percent range. The reasons for these differences may not be solely attributed to cost estimating deficiencies but to performance deficiencies. For instance, developing a cost estimate for removal of 1000 yd^3 of contaminated soils from a site can be readily computed by utilizing unit cost estimates for excavation ($/yd^3); trucking ($/yd^3/mile); and disposal ($/yd^3). Each of the unit costs will have a certain degree of variability due to contractor competitive bidding systems and field conditions which may affect excavation or trucking. However, if all factors such as time required for excavation, miles transported to disposal, and disposal costs are constant, it would be relatively easy to develop a cost estimate within +50 percent to -30 percent of actual costs. The single most important factor in developing the cost estimate for this example is the volume of soil to be removed.

During the excavation of the soil the contractor may determine that
contaminants exist outside the limits set for excavation and it may be
necessary to increase the volume of material to be removed. Such a
situation could result in a significant increase in site remediation costs.
This demonstrates the need to establish performance criteria and determine
a level of uncertainty associated with the amount of contaminated soil to
be removed.

4.4 IDENTIFY DATA QUANTITY NEEDS

The number of samples which should be collected can be determined using a
variety of approaches. The validity of the approach utilized is dependent
on the characteristics of the media under investigation and the assumptions
used to select sample locations. Experience and professional training are
the basis for making initial determinations of where samples should be
collected and how many are required. Usually the greater the quantity of
data available for making a decision regarding sample numbers, the higher
the chances are that data will be obtained which address the project
objectives. In situations where data are not available or are limited in
nature, sampling should be undertaken in a phased approach to allow for
collection of initial samples to characterize the general conditions at the
site. These data then can be used to guide in selection of the appropriate
number of samples to be obtained in subsequent phases of the RI.

In the absence of available data, the data users and decision makers will
be required to develop a rationale for selecting sampling locations for the
initial sampling phases. Questions to be asked to guide the data users in
selecting appropriate sampling numbers and locations could include:

o Do source materials still exist on the soil surface?

o Is there evidence of soil disturbance or vegetative stress based
   upon review of aerial photographs?

o Do geologic features in the area control ground water and surface
   water flow patterns?

o Do site conditions favor surficial soil erosion or wind erosion?

o Are sensitive receptors located in the vicinity of the site?

These types of questions can be addressed in the absence of any analytical data and will assist in identifying additional data needs. Subsequent discussions may lead to the recommendation that geophysical surveys or field screening be conducted in areas of soil disturbance during the initial sampling phases. Collection of a limited number of samples from identified source materials or pathways, such as streams, may also be considered during the initial stage of the RI. Limited air sampling may also be warranted during the early stages of the RI to determine if organic vapors or particulates could pose a problem to those performing subsequent sampling phases or to nearby residents.

In situations where data are available, or as new data are added to the site's data base, statistical techniques may be utilized in determining the number of data required. A number of EPA documents provided detailed guidance for applying statistical methods to estimate data quantity requirements, including:

o <u>Soil Sampling Quality Assurance User's Guide</u> (EPA 1984)

o <u>Sediment Sampling Quality Assurance User's Guide</u> (EPA 1985)

The documents referenced in Section 8.0 provide more complete descriptions of the applicability and approach for statistical techniques.

Following evaluation of the data as discussed in Stage 1, a determination can be made as to whether the data provides adequate levels of confidence to support a decision. If a higher degree of certainty in the data is required (e.g., a more definitive statement regarding the extent of contamination), then additional data should be obtained in subsequent

sampling phases. In all cases, the actual level of confidence which can be attributed to a set of data can only be established following collection and evaluation of data. Therefore, at the completion of each data collection activity, the data should be evaluated.

Comparability in the data collection activity must take into consideration whether the events are even comparable in the first place. An example would be trying to compare data from the same aquifer in a high water and a low water situation. This criterion is most important when conclusions are being drawn from existing data. If an activity is being planned to augment existing data, field conditions must be considered as well as sampling and analytical techniques.

4.5 EVALUATE SAMPLING/ANALYSIS OPTIONS

Following the identification of data uses, data types, and data quality needs, an evaluation of sampling and analysis options can be undertaken. Numerous sampling and analysis options could be developed for any data collection activity. The options will be dictated by the data types needed. In addition, the sampling and analysis option evaluation must be undertaken in a manner which ensures that data quality needs (Section 4.3) and data quantity needs (Section 4.4) are addressed and balanced. The evaluation of sampling and analysis options is an interactive and iterative process which must not be undertaken independent from other elements in the DQO process.

The evaluation of sampling and analysis options must be undertaken considering the following factors:

o Sampling and analysis components

o Sampling and analysis approach (phasing)

o Resource constraints, schedule, seasonal and special requirements

4.5.1 SAMPLING AND ANALYSIS COMPONENTS

Evaluation of sampling and analysis options can only be undertaken after all components or subsets of the sampling and analysis options are identified. The components of a sampling and analysis plan include the individual sample collection and analysis procedures which will result in the data types specified. For example, in order to provide data on the concentration of volatile organics in a monitoring well, sampling procedures which will result in a representative sample and analytical methods which yield the desired results must be identified.

It is critical that the contractor's site manager involve technical personnel familiar with analytical techniques during this stage of the DQO process.

Analytical approaches which should be considered consist of Levels I - V (see page 4-13) which vary as to cost, time required for analysis, and the quality of the resulting analytical data:

Section 9.0 of this document contains additional details on analytical considerations and Section 10.0 provides discussion of sampling considerations which should be addressed during the evaluation of sampling and analysis components. Additional details are also contained in the publications referenced in this document including Quality Assurance/Field Operations Method Manual (EPA 1986).

All sampling activities should be conducted and documented such that sufficient data are collected to make sound decisions concerning remedial action selection. This applies to fund-lead, Federal or state enforcement-lead, and potentially responsible party lead projects. The data collection and documentation activities should be similar for all types of remedial action project phases. In other words, if enough data are collected using appropriate protocols, and the data are sufficiently valid upon which to base a remedial action decision, then the procedures and documentation should be sufficient to be admissible as evidence in litigation.

Enforcement/cost recovery actions have at least one additional requirement. This requirement is to identify viable PRPs. This may require additional sample collection and more complex analysis. Regional enforcement personnel should be consulted prior to the planning of sampling and analytical activities to assure that their data needs will be met. Distinction must also be made between civil and criminal cases, with the latter usually having more stringent requirements.

4.5.2 SAMPLING AND ANALYSIS APPROACH (PHASING)

Data collection activities for each uncontrolled hazardous waste site must be designed to ensure that the use of available and collected data is maximized. Data collection activities must therefore be undertaken in a manner which results in cost effective and usable data. Collection of data beyond that needed to meet the RI/FS objectives wastes resources. Collection of inadequate quality or insufficient data likewise results in inefficient use of resources. Developing a sampling and analysis approach which ensures that appropriate levels of data quantity and quality are obtained may be accomplished by use of a phased RI approach and by the use of field screening, field analysis or remote sensing approaches to direct the data collection activities. By subdividing the data collection program into a number of phases, the data can be obtained in a sequence which allows it to be used to direct subsequent data collection activities.

The extended periods of time required for receipt of analytical data from laboratories often results in delays in an RI program. By utilizing field techniques for assessing contaminant concentrations or media characteristics, the RI can proceed in a directed manner towards the intended goal.

Direct reading instruments which should be considered for use during the evaluation of a sampling/analysis approach include:

o   Photoionization detectors (PIDs)

o   Flame ionization detectors (FIDs)

o   Hydrogen sulfide analyzers

o   Hg vapor analyzers

o   Respirable particulate meters

o   Radiation meters

o   Oxygen/explosimeters

o   pH and conductivity meters

Other devices and field tests which allow for assessment of site conditions
without the need for laboratory support include:

o   Oil/water interface units

o   Slug tests

o   Infiltrometers

These direct reading instruments can be taken into the field to obtain data
without extensive calibration procedures. Additional levels of
quantification can be obtained by the use of transportable instruments such
as gas chromatographs (GC), X-ray fluorescence or atomic adsorption
devices. For these instruments, however, calibration using known standards
must be developed prior to use in the field.

The extent to which these mechanisms can be used depends on their ability
to identify contaminant concentrations of concern. Analytical support can
be developed by integrating aspects of individual analytical support levels
into one cohesive analytical approach. This type of approach permits a
larger number of samples to be collected and analyzed cost effectively.

Conceptually, this approach can be thought of as a large "inverted funnel"
whereby large numbers of samples can be initially analyzed quickly and cost
effectively in the field with succeedingly smaller numbers of samples
analyzed further at a higher level of sophistication. This approach
combines the advantages of each level of analytical support and offsets
disadvantages. The use of less sophisticated techniques initially allows
for large numbers of samples to be screened quickly and at low cost. Next,

a proportion of these samples are analyzed by a more sophisticated procedure to verify the results of the lower level analysis. If parameters were selected for screening purposes, full analysis should be performed on a percentage of samples to verify assumptions of chemicals present or of concern. The type and design of this analytical approach is determined by how the data will be used. By strategically selecting which samples are to be analyzed at each level, a much higher degree of certainty can be obtained for the overall data set without sacrificing either the quantity of samples to be analyzed or the quality of data collected.

For example, consider a hazardous waste site where the soil is contaminated with volatile organic compounds (VOCs). For this example, the objectives of the sampling are to determine concentration of VOCs at site boundaries and to assess the direct contact threat. It is assumed that a photoionization detector will detect contaminants at the levels of concern for this example.

Based upon review of existing data, a sampling plan was developed which calls for soil samples to be collected at locations determined using a grid pattern. To illustrate this approach in general terms, data uses and data quality are not specified in this example.

The analytical approach for this hypothetical situation is illustrated in Figure 4-3 and summarized below:

- o Sample from all locations are analyzed in real time using photoionization field headspace techniques (Level I).

- o Samples which register below the detection limits of this instrumentation are considered clean for the purposes of this study.

- o A selected number of the clean samples (for which nothing was detected) and all of the dirty (contaminated) samples are analyzed onsite using a portable gas chromatograph (Level II) to obtain semiqualitative and semiquantitative results within a few days.

- o A number of samples are selected for analysis by CLP Routine Analytical Services (RAS) (Level IV) for the Hazardous Substance List (HSL) compounds. Included in these samples are all samples identified as critical data points (CDPs). This step provides confirmation for all preceding work including verification that

DATA
QUALITY

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                              △
                            ╱   ╲
                          ╱       ╲
                        ╱           ╲
                      ╱   Level IV    ╲
                    ╱                   ╲
                  ╱     Level III[1]      ╲
                ╱                           ╲
              ╱      Level II                 ╲
            ╱                                   ╲
          ╱        Level I                        ╲
        ╱_____╲
```

DECREASING % OF SAMPLES ANALYZED

COST
AND
TURNAROUND
TIME
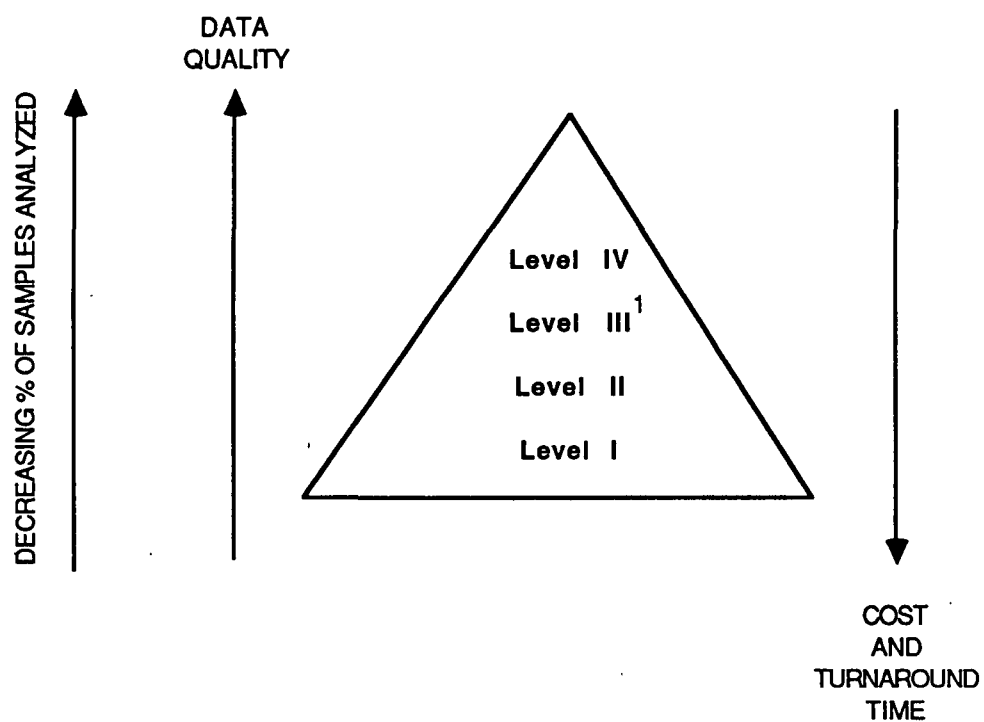
[1] Although not applicable to the example situation, level III support is shown to indicate that this is a viable option for confirmatory analyses.

FIGURE 4-3
INTEGRATION OF ANALYTICAL
SUPPORT LEVELS

indicator parameters are representative of contaminants of concern and are identified appropriately. The results of all split samples analyzed by different levels are interpreted for quality control purposes.

This approach can also be utilized in a time-phased manner, i.e., by using the results of an initial sampling round with a lower level of analysis to fine-tune the sampling approach for a subsequent sampling round using higher level(s) of analytical support. Another approach involves complete GC/MS analysis of the initial sampling round to identify the organic compounds present followed by GC analysis of specific compound of interest in later rounds. Gas chromatography with the appropriate detector can provide lower cost analyses, often with lower detection limits and higher precision and accuracy, than GC/MS. It is necessary, however, to verify by GC/MS that interfering compounds are not present.

4.5.3 RESOURCE CONSIDERATIONS

The resources available for performance of a remedial action must be evaluated during the scoping process. Within Stage 2 of DQO development, the time required for obtaining data, the personnel resources and equipment required, and the costs for data collection must be evaluated. This evaluation is most effectively performed as sampling/analysis options are identified.

The cost for analytical support varies considerably depending on the type of analysis required. Schedule requirements which dictate the need for rapid turnaround of data further escalate analytical costs. The CLP is one source that provides analytical support to the superfund program. The cost associated with CLP analysis of a single RAS sample for HSL Tasks 1 and 2 approaches $1,000.00. This significant cost must be taken into consideration when evaluating analytical options in order to balance the cost of analysis with the quality of data required. In many cases, CLP RAS analysis may not be warranted and field screening and field analysis techniques (including mobile labs) could provide the data required. In other situations a total HSL analysis may not be required and savings in analysis can be realized by use of CLP SAS services for specific compounds of interest.

The cost associated with obtaining samples must also be considered during the evaluation of sampling/analysis options. Cost savings can be achieved by performing multiple media sampling activities simultaneously (e.g., sample ground water and surface water during same sampling event). The sampling tasks which are conducted simultaneously should coincide with each other with respect to the overall phasing approach developed for the RI.

Technical staff resources must also be evaluated during the course of identification of analytical/sampling options. Special training may be required in order to undertake certain field sampling or laboratory analysis tasks.

Development of a schedule for the sampling activities requires a substantial effort in identifying critical path elements. The schedule must be linked with the other components of the remedial action project since many of these may proceed simultaneously. Critical path elements in all sampling activities include the considerations outlined below:

o Site Access – Site access for each property involved in the site investigation activities must be obtained. The site access permission may be required for each sampling round or investigation activity. Access may be denied at any time or restrictions may prohibit planned activities. Additional information on site access is contained in Chapter 6, Institutional Issues, of the Guidance on Remedial Investigations Under CERCLA (EPA 1985).

o Weather – Weather can have a great impact on the schedule for field activities. For example, geophysical studies such as seismic refraction cannot be performed when there is a substantial layer of snow or ground frost. Weather conditions may also delay or slow the rate at which activities can be performed. For example, temperatures may require the job be shut down for activities requiring personnel protective equipment.

o Health and Safety – Health and safety requirements may increase the time required to perform field activities. For example, limitations of the bottled air supply required for Level B activities can increase time required for field investigations by a factor of four.

o Subcontractor and Equipment Procurement – Procurement of subcontractors and equipment can severely impact schedules. Preparation of subcontractor technical specifications, evaluation of bids, award of subcontract, and mobilization of the subcontractor require significant time commitments. For example, the request for

bids may not yield an acceptable number of bids or a reasonable bid may not be received, requiring the request for bid process to be repeated. Equipment procurement may also delay project schedules since much of the special equipment required for RIs is built to order and is not available "off-the-shelf."

o   Sample Analysis and Data Validation - Sample analysis and data validation must be completed before analysis of the data can be performed. Adequate time must be provided in the schedule for data analysis and data validation. Turnaround time for CLP analysis, for example, ranges from 4 to 6 weeks excluding data validation. Data validation generally requires 2-3 hours per sample for complete RAS packages.

4.6   REVIEW PARCC PARAMETER INFORMATION

The PARCC (Precision, Accuracy, Representativeness, Completeness, and Comparability) parameters are indicators of data quality. Ideally, the end use of the measurement data should define the PARCC parameters that are necessary to satisfy that end use. In the ideal situation, numerical precision, accuracy, and completeness goals would be established and these goals would aid in selecting the measurement methods to be used.

As noted earlier, RI/FS work does not fit this ideal situation. RI/FS sites are so different from each other and information on overall measurements (sampling plus analysis) is so limited that it is not practical to set PARCC goals at this time. Rather, the historical precision and accuracy achieved by different analytical techniques should be reviewed to aid in selection of the most appropriate technique.

To correlate with earlier information on analytical levels several tables in Appendix C present precision and accuracy information for analytical techniques classified by level. EPA will continue to make information of this type available to data users so that, gradually, a data base of numerical precision and accuracy requirements appropriate to different data uses will develop.

4.6.1 PRECISION

Precision is a measure of the reproducibility of measurements under a given set of conditions. Specifically, it is a quantitative measure of the variability of a group of measurements compared to their average value. Precision is usually stated in terms of standard deviation but other estimates such as the coefficient of variation (relative standard deviation), the range (maximum value minus minimum value), and the relative range are common.

The overall precision of measurement data is a mixture of sampling and analytical factors. Analytical precision is much easier to control and quantify than sampling precision. There are more historical data related to individual method performance and the "universe" is limited to the samples received in the laboratory. In contrast, sampling precision is unique to each site.

Sampling precision may be determined by collecting and analyzing collocated or field replicate samples and then creating and analyzing laboratory replicates from one or more of the field samples. The analysis results from the collocated or field replicate samples provide data on overall measurement precision; analysis results from the laboratory replicates provide data on analytical precision. Subtracting the analytical precision from the measurement precision defines the sampling precision.

4.6.2 ACCURACY

Accuracy is a measure of the bias in a measurement system; it is difficult to measure for the entire data collection activity. Sources of error are the sampling process, field contamination, preservation, handling, sample matrix, sample preparation and analysis techniques. Sampling accuracy may be assessed by evaluating the results of field/trip blanks, analytical accuracy may be assessed through use of known and unknown QC samples and matrix spikes.

As an example of how the sampling process can impact accuracy, consider the collection of ground water samples for volatile organic analysis. In the actual sampling, some portion of the volatile components may be lost. There is no way to measure this loss easily. The sample could also be subjected to contamination from a wide range of sources in the field and laboratory. To check the system for contamination, trip and field blanks can be used.

4.6.3 REPRESENTATIVENESS

Representativeness expresses the degree to which sample data accurately and precisely represent a characteristic of a population, parameter variations at a sampling point, or an environmental condition. Representativeness is a qualitative parameter which is most concerned with the proper design of the sampling program. The representativeness criterion is best satisfied by making certain that sampling locations are selected properly and a sufficient number of samples are collected.

Representativeness is addressed by describing sampling techniques and the rationale used to select sampling locations. Sampling locations can be biased (based on existing data, instrument surveys, observations, etc.) or unbiased (completely random or stratified-random approaches). Either way, the rationale used to determine sampling locations must be explicitly explained. If a sampling grid is being utilized, it should be shown on a map of the site. The type of sample, such as a grab or composite sample, as well as the relevant standard operating procedure (SOP) for sample collection, should be specified.

An example of the way representativeness is ensured in a sampling program is the use of proper ground water sampling techniques. The SOPs for ground water sampling require that a well be purged a certain number of well volumes prior to sampling, to be certain that the sample is representative of the underlying aquifer at a point in time.

Representativeness can be assessed by the use of collocated samples. By definition, collocated samples are collected so that they are equally representative of a given point in space and time. In this way, they provide both precision and representativeness information.

4.6.4 COMPLETENESS

Completeness is defined as the percentage of measurements made which are judged to be valid measurements. The completeness goal is essentially the same for all data uses: that a sufficient amount of valid data be generated. It is important that critical samples are identified and plans made to achieve valid data for them.

Almost no historical data on the completeness achieved by individual methods exists. However, the CLP data has been found to be 80-85% complete on a nationwide basis. This fact can be extrapolated to indicate that level III, IV and V analytical techniques will generate data that is approximately 80% complete. Hence, ignoring other factors, 1.25 times more data may be necessary. Levels I and II would be expected to have lower completeness levels. However, since they are onsite measurement techniques providing results in real-time or after minimal delay, invalid measurements can be repeated easily. Thus, a high degree of completeness can be achieved with these analytical levels.

4.6.5 COMPARABILITY

Comparability is a qualitative parameter expressing the confidence with which one data set can be compared with another. The goal for all data uses is the sample data are comparable with other measurement data for comparable samples and sample conditions. This goal is achieved through the use of standard, well-recognized techniques to collect and analyze representative samples and report analytical results in appropriate units.

4.7 UTILIZING PARCC PARAMETER INFORMATION

In Stage 2 of the DQO process, the PARCC parameters should be considered in evaluating sampling and analysis options. To the extent possible, they should be defined as goals in the Stage 3 Data Collection Program. It must be recognized, however, that data quality objectives can be developed for RI/FS work without strictly defined PARCC goals.

Whenever measurement data are reviewed (in Stage 1 of the DQO process), the PARCC parameters which were achieved should be included in the review. The analytical laboratory should provide numerical precision and accuracy data; Level 2 field analyses may also generate precison and accuracy data. The data user should request this information if it is not provided. Precision and accuracy data may be expressed in several ways and are best evaluated by an analytical chemist or a statistician. Since the precision data are quantifying the scatter of results about a mean value, a lower precison value means less scatter. Accuracy is most frequently reported as percent recovery, or percent bias. A 100 percent recovery indicates a completely accurate measurement; the closer the recovery is to 100%, the more accurate the measurement. Percent bias reports the difference of the result from the true value. A completely accurate measurement would have zero percent bias; the lower the percent bias, the more accurate the measurement.

The data user must keep the level of concern and the end use of the data in mind when reviewing precision and accuracy information. In some cases, even data of poor precision and/or accuracy may be useful. For example, if all the results are far above the level of concern, the precision and accuracy are much less important. However, close to the level of concern, precision and accuracy are quite important and should be carefully reviewed. If results have very good precision but poor accuracy, it may be acceptable to correct the reported results using the percent recovery or percent bias data. This judgment should be made by a data user with appropriate technical expertise.

4.8 REFERENCES

U.S. Environmental Protection Agency (EPA). 1986. Quality Assurance/Field Operations Method Manual (draft) March.

_____. 1983. Characterization of Hazardous Waste Sites - A Methods Manual. Volume 1 - Site Investigations. NTIS PB84-126929. EPA/600/4-84/075

_____. 1985. Guidance on Remedial Investigations Under CERCLA. Office of Emergency and Remedial Response, Office of Waste Programs Enforcement, Office of Solid Waste and Emergency Response, Washington, D.C. Office of Research and Development, Cincinnati, Ohio. EPA/540/G85/002. June.

_____. 1985. Guidance on Feasibilility Studies Under CERCLA. Office of Emergency and Remedial Response, Office of Waste Programs Enforcement, Office of Solid Waste and Emergency Response, Washington, D.C. Office of Research and Development, Cincinnati, Ohio. EPA/540/G85/003. June.

_____. 1985. Superfund Exposure Assessment Manual. Office of Solid Waste and Emergency Response. OSWER Directive 9285.5-1

_____. 1985. Sediment Sampling Quality Assurance User's Guide. EPA 600/4-85-048

_____. 1984. Superfund Public Health Evaluation Manual. Office of Solid Waste and Emergency Response, OSWER Directive 9285.4-1

_____. 1984. Soil Sampling Quality Assurance User's Guide. EPA 600/4-84-043

5.0 RI/FS STAGE 3 DESIGN DATA COLLECTION PROGRAM

Stage 3 of the DQO process is undertaken to develop and assemble the detailed data collection program for the remedial action project. Through the process of addressing the elements identified in Stages 1 and 2, all the components required for completion of Stage 3 should be available for compilation.

Stage 3 of the DQO development process is undertaken to specify the complete sampling and analysis approach required to meet the project objectives as outlined in Figure 5-1.

5.1 ASSEMBLE DATA COLLECTION COMPONENTS

The data collection program should be assembled by the contractor's site manager and staff in a coordinated manner in Stage 3. During Stage 2, specific DQOs have been developed by media or sampling activity. These DQOs should have been developed by contractor staff which have specialized expertise in appropriate disciplines. The intent of Stage 3 is to compile the information and DQOs developed for specific tasks into a comprehensive data collection program.

The data collection program should be developed to account for all sampling tasks and phases. During this process a detailed list of all samples to be obtained should be assembled in a format which includes phase, media, sample type, number of samples, sample location, analytical methods, and QA/QC samples (type and number). In addition, a schedule for all sampling activities should be developed in bar chart or critical path method format.

5.2 DEVELOP DATA COLLECTION DOCUMENTATION

The output of the DQO process is a well defined sampling and analysis (S&A) plan with summary information provided in the work plan.

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┌─────────────────────────┐
│        ASSEMBLE          │
│    DATA COLLECTION       │
│      COMPONENTS          │
│                          │
└─────────────┬───────────┘
              │
              ▼
┌──────────────────────────────────────┐
│                                        │
│  DEVELOP DATA COLLECTION DOCUMENTATION │
│                                        │
│    •   SAMPLING & ANALYSIS PLAN        │
│          Include QAPjP Elements        │
│    •  WORK PLAN                        │
│                                        │
└──────────────────────────────────────┘
```
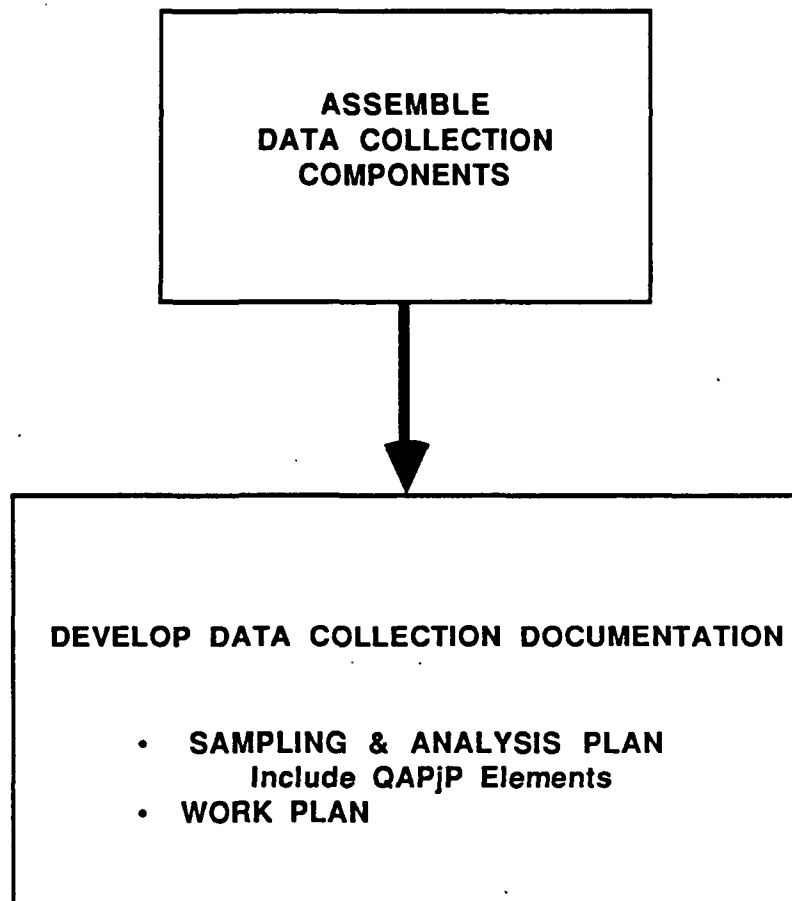
FIGURE 5-1
STAGE 3 ELEMENTS
DESIGN DATA COLLECTION PROGRAM

Data collection documentation requirements vary on a regional basis within the EPA. Region specific requirements for development of S&A plans and work plans should be followed during the course of development of data collection documentation. The DQO guidance provided in this document does not require the submittal of deliverables in addition to those already established in the regions. Rather, the DQO process provides a framework to ensure that all the pertinent issues related to the collection of data with known quality are addressed.

5.2.1 SAMPLING AND ANALYSIS PLANS

Section 300.68 of the NCP specifies that a written quality assurance/site sampling plan must be prepared for all remedial investigation activities which involve sampling. These plans should include the following:

o Description of the objectives of the sampling efforts with regard to both the phase of the sampling and ultimate use of the data

o Sufficient specification of sampling protocol and procedures

o Sufficient sampling to adequately characterize the source of the release, likely transport pathways, and/or potential receptor exposure

o Specification of the types, locations, and frequency of samples taken, taking into account the unique properties of the site, including the appropriate hydrological, geological, hyrogeological, physiographical and meteorological properties of the site

The S&A plan identifies the individuals responsible and the procedures for field activities and sample analyses associated with remedial investigations. Quality Assurance Project Plan (QAPjP) elements should be addressed in the S&A plan. The standard elements of a QAPjP are listed in Table 5-1. Details on preparation of QAPjPs are contained in Interim Guidelines and Specification for Preparing Quality Assurance Project Plans (EPA 1980).

The 16 points required to be addressed for each site in a QAPjP should not be repeated in an S&A plan if the information has been documented elsewhere. For example, if a project description (Section 3) is available

TABLE 5-1

QUALITY ASSURANCE PROJECT PLAN ELEMENTS

1	Title Page Introduction
2	Table of Contents
3	Project Description
4	Project Organization
5	Quality Assurance Objectives for Data Measurement
6	Sampling Procedure
7	Sample and Document Custody Procedures
8	Calibration Procedures and Frequency
9	Analytical Procedures
10	Data Reduction, Validation and Reporting
11	Internal Quality Control Checks
12	Performance and System Audits
13	Preventive Maintenance
14	Data Measurement Assessment Procedures
15	Corrective Action
16	Quality Assurance Reports to Management

in the work plan it is acceptable to refer to this document rather than repeat the information in the S&A plan. Sample and document custody procedures (Section 7) of the QAPjP and calibration procedures and frequency (Section 8) may be provided in standard operating procedures which need not be repeated in the S&A plan but should be included by reference. Other quality assurance issues which are program wide in nature, such as internal quality control checks (Section 11), performance and system audits (Section 12), corrective action (Section 15) and quality assurance reports to management (Section 16), are generally specified in the quality assurance program plan (QAPP).

Field investigation activities are generally undertaken in a phased approach in which each phase reflects a further refinement of knowledge. Therefore, separate sampling/analysis plans may be prepared for the separate phases of a remedial investigation. For example, geophysical investigations may be performed to select locations for installation of monitoring wells. In such a case, a sampling plan should be prepared for the geophysical investigations and, following evaluation of the data, a separate plan should be developed for installation of monitoring wells. Additional plans for the subsequent phases of a remedial investigation may be prepared at any time during the course of the project as the need for additional field investigation is identified.

5.2.2 WORK PLANS

Work plans define the scope of services, level-of-effort, costs, and schedule for performing the RI/FS. The scope of the sampling effort depends on the quality of existing data, an understanding of the site problems, an identification/ evaluation of the feasible remedial actions and data necessary to support them, and enforcement needs.

Sampling should be undertaken only to the extent it is necessary and sufficient to fulfill the requirements of subsequent remedial action implementation and/or legal enforcement proceedings. Sampling efforts may begin at different levels depending on (1) the understanding of the scope of the problem at the site, and (2) whether or not there are enforcement

considerations. For example, surveying all areas of large and complex sites in great detail might be an inefficient use of resources if initial screening indicates the problem is confined to small sub-areas.

The work plan provides the general description of the activities to be performed as part of the RI/FS. However, it does not contain the detailed description of how a sample is obtained or an analysis performed. This type of information is presented in the S&A plan. The level of detail to be included in the work plan for the RI phase is outlined below:

o How site mapping will be performed including survey limits identified on map included in the draft work plan, the scale of the plan to be produced, the horizontal and vertical control and identification of significant site features

o Number of individuals to be involved in each field sampling task and estimated duration in days

o Identification of geophysical survey areas or transects, soil boring and test pit locations on the map provided in the draft work plan

o Number of samples to be obtained in the field including blanks and duplicates and the location from which the samples will be obtained illustrated on a map included in the draft work plan

o List of analyses to be performed

o Identification of pilot or bench-scale studies that will be performed

This information is required as part of the work plan in order to establish a basis for the schedule and cost estimate. Work plans prepared for a phased RI approach should be specific for the initial phase, and general for subsequent phases, with subsequent phases well defined when the previous phase is completed.

5.2.3 ENFORCEMENT CONCERNS

All RI/FS activities should be conducted and documented such that sufficient data are collected to make sound decisions concerning remedial action selection. This applies to fund-lead, and potentially responsible party lead projects. The data collection and documentation activities should be similar for all types of RI/FSs. In other words, if enough data

are collected using appropriate protocols, and the data are sufficiently valid upon which to base a remedial action decision, then the procedures and documentation should be sufficient to be admissible as evidence in litigation.

The guidelines outlined below should be followed to assure that data quality objectives are met:

o Appropriate plans (i.e., work plans, sampling and analysis plans, QAPjP) should be developed to document intentions.

o Field notebooks should include information on field conditions, sample location, sample number, collection time, sample description (chain of custody forms or other mechanism can be used to record this information).

o Personnel throughout the process from planning, sample collection, analysis and decision making should have experience or be sufficiently trained.

o Chain of custody must be documented with a chain of custody form for samples taken offsite for analysis. This assures the decision maker that the analysis given is actually for the sample collected and that the sample has not been tampered with. If analysis is performed onsite, documentation of the process for custody of samples in field logs or other media is sufficient. The chain of custody form is, however, not necessary.

o Methods used for sampling and analysis should be generally considered valid from an engineering/scientific standpoint and be consistent with standard analytical procedures. Methods utilized should be referenced in the RI/FS report or other documents and a statement given that protocols were followed. Any deviation from the referenced method should be documented and explained.

o Documentation should be sufficient to allow the persons involved in the site studies to reconstruct the work years later when the matter is litigated. If the documentation is adequate, the defendents may be convinced by the strength of the government's case not to contest those particular points, and hence testimony by the government or contractor employees may not be necessary.

o EPA's or the state's responsibility from a QA/QC standpoint is to audit randomly some RI/FS field sampling, analysis (QA/QC) and data validation to confirm that procedures utilized were sufficient.

o Actual samples, sample tags and sample bottles are not required to be kept to prove that samples were taken and maintained. This is the purpose of the chain of custody sheet, field notebook, or other similar mechanisms.

The above requirements pertain to civil cases only. Criminal cases will require additional documentation and/or materials.

5.3 REFERENCES

American Chemical Society. 1983. Principles of Environmental Analyses. Analytical Chemistry 55:2210-2218.

ASTM. 1985. Quality Assurance for Environmental Measurements. ASTM Special Tech Pub 867. J.K. Taylor and T.W. Stanley eds.

Camp Dresser & McKee Inc. 1985. Performance of Remedial Response Activities at Uncontrolled Hazardous Waste Sites, Technical Operations Manual. April.

Taylor, J.U. 1981. Quality Assurance of Chemical Measurements Analytical Chemistry. Volume 53, No. 14. December.

U.S. EPA. 1980. Standard Operating Procedures and Quality Assurance Manual-Draft. Region IV Surveillance and Analysis Division. -Water Surveillance Branch. Athens, Georgia.

_____. 1980. Interim Guidelines and Specifications for Preparing Quality Assurance project Plans. QAMS. EPA-600/4-83-004. NTIS PB83-170514.

_____. 1981. Work Plan Development Technical Methods for Investigating Sites Containing Hazardous Substances. Technical Monograph No. 6.

_____. 1982. Draft Guidance For Preparation of Combined Work/Quality Assurance Project Plans for Water Monitoring. November 15.

_____. 1984. Soil Sampling Quality Assurance User's Guide. EPA 600/4-84-043.

_____. 1984. Memorandum from Stanley Blacker, about QAMS Checklist for DQO Review.

_____. 1984. Quality Assurance Management and Special Studies Staff, Calculation of Precision, Bias, and Method Detection Limit for Chemical and Physical Measurements. March 30.

_____. 1984. Soil Sampling Quality Assurance User's Guide. EMSL-LV 600/4-84-043. May.

_____. 1985. Guidance on Remedial Investigations Under CERCLA Hazardous Waste Engineering Research Laboratory Office of Emergency and Remedial Response and Office of Waste Programs Enforcement.

_____. 1985. Sediment Sampling Quality Assurance User's Guide. Environmental Research Center Cooperative Agreement CR 810550.01

_____. 1985. Construction Quality Assurance for Hazardous Waste Land Disposal Facilities Public Comment Draft. EPA/530-SW-85-021

_____. 1985. Draft DQO Report for SI Superfund Process. March.

_____. 1985. Protection of Public Water Supplies from Groundwater Contamination. EPA/625/4-85/016.

_____. 1985. RCRA. Groundwater Monitoring Technical Enforcement Guidance Document. Office of Waste Programs Enforcement, Office of Solid Waste and Emergency Response.

_____. 1985. Draft Superfund Public Health Evaluation Manual. OSWER Directive 9285.4-1. December.

6.0 REMEDIAL DESIGN

RESERVED

Section 7.0
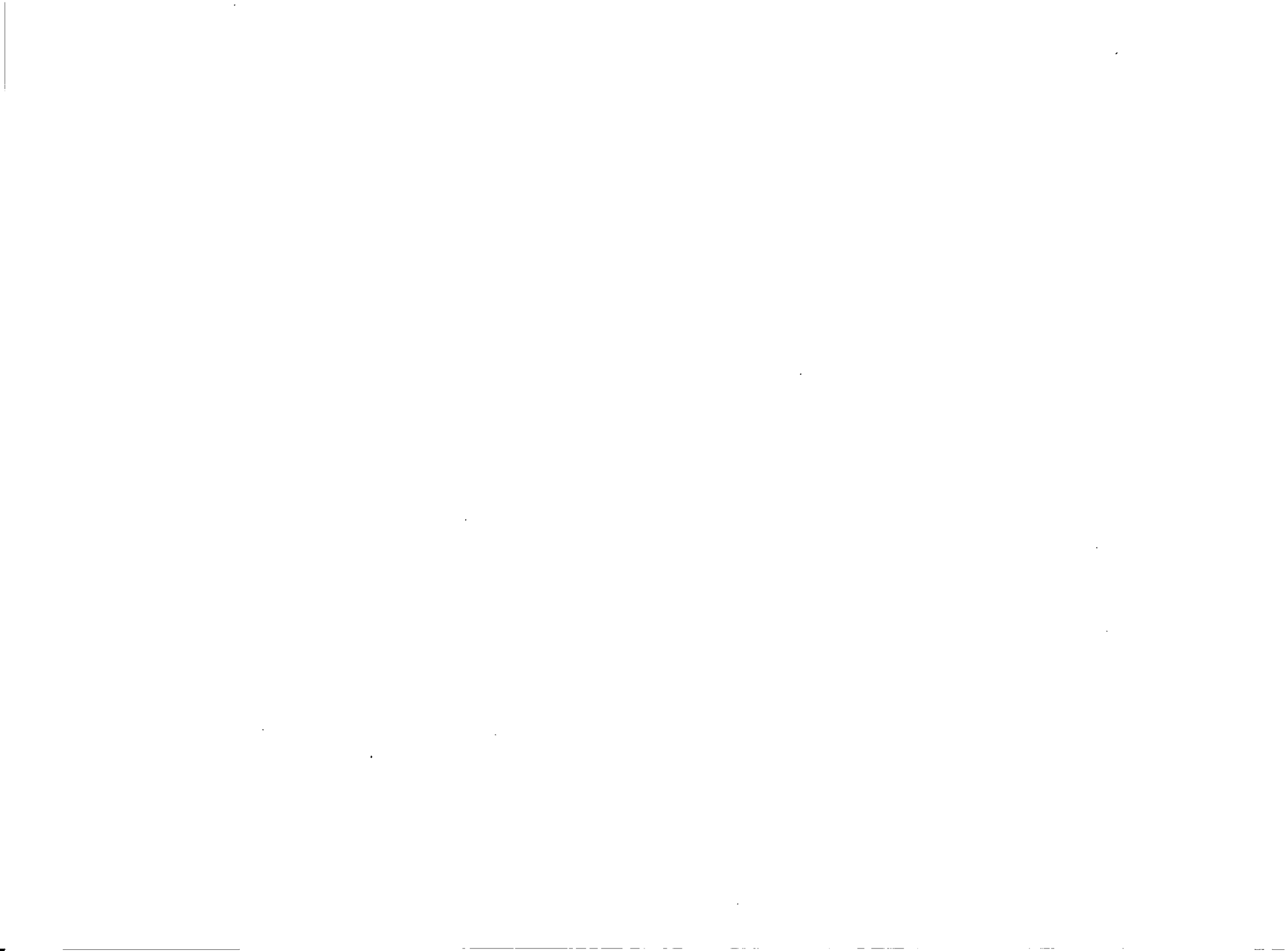
7.0   REMEDIAL ACTION

RESERVED

Section 8.0

8.0 STATISTICAL CONSIDERATIONS

Statistical techniques can be utilized to evaluate environmental data and to assist in designing appropriate sampling plans based on the data. Statistical techniques may be applied during RI/FS, RD, and RA activities, and become more meaningful as additional data are obtained.

Statistical considerations come into play in Stages 1, 2, and 3 of the DQO process. In Stage 1 the existing data are compiled and evaluated and statistical techniques can be used to evaluate the comparability of different sets of existing data and to evaluate the need to obtain additional data. In Stage 2 data quality and quantity needs can be stated in terms of confidence limits or within other statistical framework. After Stage 3, statistics can be used to evaluate newly acquired data and to assess uncertainty in various decisions.

This section provides discussions of various statistical approaches which may be appropriate for remedial action programs. The discussions are based upon hypothetical scenarios which have or might occur at hazardous waste sites and links available statistical methods to potential applications. The scenarios presented are not the only situations in which statistics can be applied, but they provide an indication of the information that can be obtained from statistical methods. Additional discussion of statistical techniques are provided in the references cited at the end of this section.

8.1 DETERMINATION OF NUMBER OF SAMPLES

The technical objectives, budget, and schedule of the program must be considered when determining the number of samples to be obtained. Numerous factors must be considered in the evaluation in an iterative manner with the types of analyses as well as the constituents to be evaluated being of primary importance.

Statistical approaches can be used to determine the number of samples which are required in order to generate data which have specified limits of confidence. However, application of statistical formulas to determine the number of samples requires that previously obtained information on the environmental media under consideration be available for evaluation.

Basic t-test methods for determining the number of samples required to achieve a specified precision and confidence level have been utilized with varying degrees of success in the development of data quantity requirements. These techniques provide an estimate of the number of samples required to achieve a specified level of precision and confidence. However, in order to apply these equations, the mean of the population and the standard deviation of the population must be known. Therefore, these equations cannot be applied unless data are available for calculating means and standard deviations. Furthermore, t statistics are based on assumptions that the data are normally distributed and independent.

The number of data points required to characterize a population to a specified confidence level within a specified confidence interval is related to the variability of the population. The number of samples required to characterize populations which have relatively low variability (e.g., waste streams resulting from a treatment process) that would, in most cases, be expected to be less than those required to characterize a population in which the variability is higher (e.g., contaminants present in the soil) for the same level of confidence and similar confidence intervals.

The number of data required to characterize the population is further influenced by the distribution frequency of the data. The analysis of samples which are normally distributed would be expected to fall under a bell shaped curve as shown in Figure 8-1. The majority of measurements would be expected to fall near the average measurements for normally distributed populations. Measurement of environmental media at uncontrolled hazardous waste sites do not generally fall within the category of normally distributed data. However, if a ground water sample obtained from a hazardous waste site was divided into a number of

ACCEPTANCE REGION

20.2   μ = 30.0   39.8
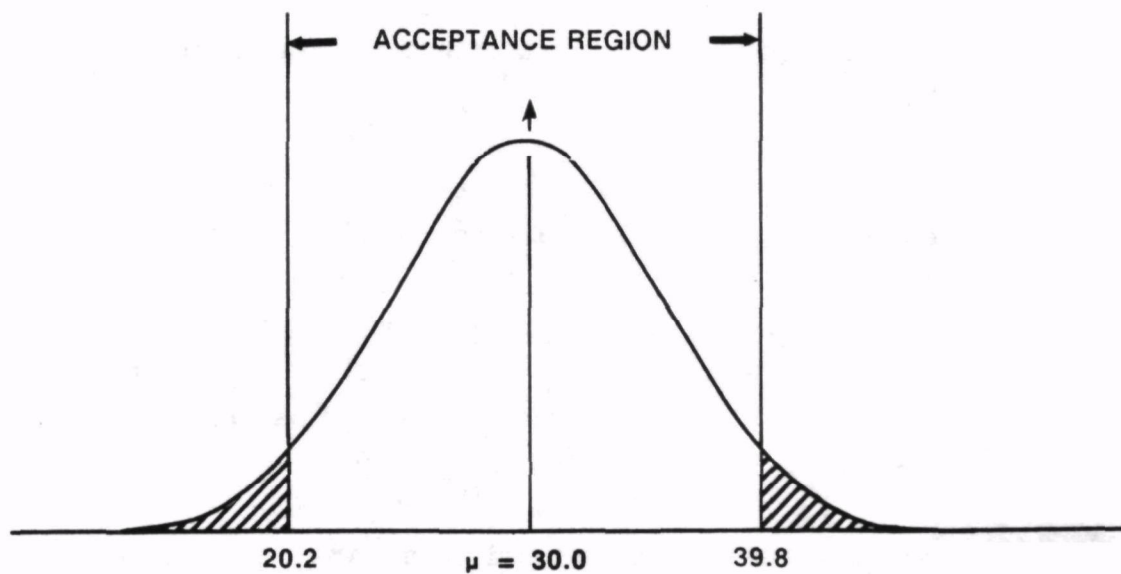
(a) Acceptance region for H: μ = 30.0

FIGURE 8-1
NORMALLY DISTRIBUTED DATA

subsamples and these subsamples were each handled and analyzed in a controlled laboratory setting, then the resulting data would be expected to be normally distributed about an average value.

Environmental media populations in some cases may be log-normally distributed. In these situations, repetitive measurements of the media would fall under a skewed curve. The repetitive measurement of the permeability of soil samples would result in a log-normal distribution of data, for example.

Comparison of ground water quality analytical results or soil permeability values obtained at any one location with the results of other samples obtained at separate locations may not, however, be represented as normal or log-normal populations. More frequently, the measurements are dependent on one another and may vary over space due to factors such as those which would influence migration of contaminants in ground water, or natural soil forming processes which would affect permeability.

In a simplistic sense, as contaminants migrate from a source, the concentration of the contaminants would be expected to decrease as the distance from the source increases. Figure 8-2 illustrates this concept in two dimensions. The concentration of the contaminants at any point in this system is related to other (dependent) factors such as flow gradient, dispersion coefficients and attenuation/biodegradation rates. As stated, this is a simplistic model, and caution should be used when applying it to actual site conditions.

The analytical values obtained from samples over the area of contamination would range from the maximum level encountered at the source to lowest level at the furthest distance from the source. The plotting of these data would not yield a normal distribution or log-normal distribution. Therefore, statistical techniques which require data which are normally distributed and independent would not be valid for estimating the number of samples to be obtained. Geostatistical techniques which take into consideration the spatial dependence of these data are, therefore, more appropriate for use in these situations.

GROUND WATER
FLOW

SOURCE 1000 ppm

50 ppm

10 ppm

1 ppm
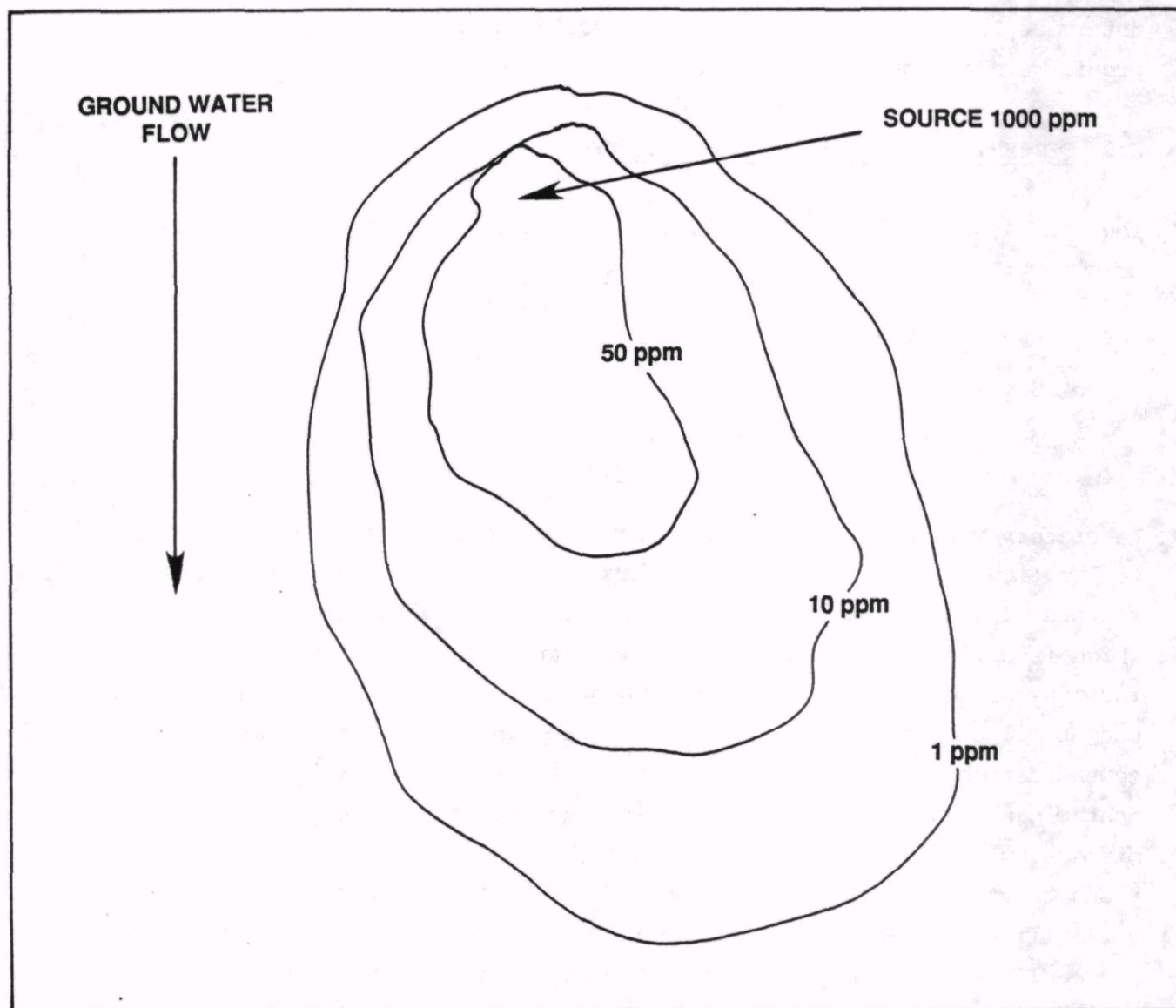
**FIGURE 8-2
CONTAMINANT CONCENTRATION/
DISTANCE RELATIONSHIP**

The information available for review during project scoping of an RI may not be adequate for purposes of applying statistical formulas. In these types of situations it may be necessary to gather preliminary data in order to determine the appropriate number of samples to be obtained during the RI. This additional information may be obtained using a phased RI approach wherein the initial investigative phase provides the data necessary to determine the number of samples which would be required during the RI to provide statistically valid results.

8.2 DETERMINATION OF TOTAL UNCERTAINTY

The sources of variability influencing the total uncertainty can be broken down into:

o Laboratory variability

o Sampling variability

o Variability of the contaminant plume

Laboratory variability is the most commonly discussed source of variability. For this discussion, laboratory variability will include all factors which cause a laboratory to report a contaminant concentration which is different from the actual concentration. Sampling variability includes all errors introduced by random infrequent events which can affect one or all of the samples. Sources of sampling error include cross contamination and incorrect sampling procedures. Variability of the contaminant plume is caused by physical and chemical processes, such as dispersion and adsorption, which cause the chemical concentration within a plume to vary as a function of location in space. Because of this variability, contaminant concentrations of water samples taken from the same well over time may be different even if laboratory and sampling variability are zero.

8.2.1 UNCERTAINTY ASSOCIATED WITH ONE SAMPLE ANALYSIS

Total uncertainty is a function of the actual contaminant concentration, the analytical method, the sample matrix, the sampling procedures, and contaminant variability in space and time. Ideally, information should be gathered concerning all variables contributing to the total uncertainty; however, in most instances, data will not be gathered in sufficient amounts to perform such an analysis. The following discussion will address examples for which total uncertainty might be of interest. The information required and the techniques used to obtain total uncertainty will be discussed for each case.

In this example a single water sample from a potentially contaminated well is sent to a laboratory for analysis. The laboratory reports a contaminant concentration for the sample. Of concern is the uncertainty associated with the reported value since the uncertainty will indicate the risk associated with the decision to shut down the well.

If only one sample is submitted to the laboratory, it will be impossible to specify the sampling or contaminant plume variability since these values are site specific. It will also be impossible to determine the site specific laboratory uncertainty due to matrix effects; however, if sufficient historical information concerning laboratory methods is available, an estimate of the laboratory uncertainty is possible. Assuming that no large errors are made during the sampling of the well, the laboratory uncertainty will accurately describe the uncertainty associated with the particular sample.

The uncertainty associated with a reported concentration value can be determined if historical information necessary to develop the bivariate distribution of actual and reported values is available. A bivariate distribution specifies the probability that a pair of random variables will take on a particular pair of realizations. In this application, the

bivariate distribution of interest is the distribution of actual and reported values. The bivariate distribution of actual and reported values will specify, for example, the probability that the lab will report 5 ppm when the actual concentration is 6 ppm.

Given the bivariate distribution of actual and reported values, the conditional distribution of actual values for a given reported value can be determined. As an example of a conditional distribution, consider a case where a spiked sample of known concentration is submitted to a lab several times; the lab is likely to report a different concentration value for each spike. In this case, the distribution of the reported values is the conditional distribution of reported values for the particular actual value. Any conditional distribution of interest can easily be determined once the bivariate distribution is known. Specifically, the conditional distribution of actual values for any reported value can be determined. The mean of the conditional distribution is related to accuracy and the variance is related to precision. By determining the conditional distribution for a large number of possible reported values, the regression of actual or reported values can be obtained. Once the regression function is available, the information contained in the curve can be summarized in a table. The table will identify, for a specific method, the best estimate of the actual value for any reported value. A second table can be developed which specifies the confidence limits for any particular reported value. These confidence limits will vary as a function of the reported value.

If only the accuracy and precision of the statistical method are known, an estimate of the confidence limits can be obtained. This method will not be as accurate at the previously described method but the results will give a rough idea of the uncertainties. To apply this method the accuracy and precision of the statistical method must be known and it must be assumed (incorrectly) that accuracy and precision are independent of concentration. Finally the distribution of analytical errors must be assumed to be normal. Given these assumptions, confidence statements can be made concerning the value observed at a particular location.

The DQO with regard to each sample is to obtain data of known quality. This concept is encompassed in the total uncertainty, U, associated in a single lab measurement. Any single measurement varies as a function of the accuracy and precision of the analytic test. Both of these measures vary as a function of the true concentration in the sample and sample matrix, as well as the other contaminants which make up the sample.

Even with these variations, chemists use two measures to describe the performance of an analytic test, P, percentage recovery, and relative standard deviation (RSD). A rough measure of U for a single sample is:

$$U = (P \pm 2 \times RSD)$$

It is important to note that this uncertainty is a function of the analytic test and no additional sampling will reduce the uncertainty values for single samples below this level. However, through the careful choice of QA/QC samples, adequate estimates of P and RSD can be obtained. P is the most significant variable to determine whether a sample is below an action level.

Consider the following example: A site has a true concentration of 120 ppm and the recovery is 70 percent, well within the CLP acceptable window of recoveries. Historically, the RSD for for this hypothetical compound has been 10 percent.

$$U = (.7 \pm 2 \times .1)$$

$$U = 0.5 \text{ to } 0.9$$

The action level is 110 ppm for this hypothetical compound. U describes the likely range of reoported values on a percentage basis. Given U, the 95 percent confidence level interval for the reported values is

$$0.5 \times 120 \text{ to } 0.9 \times 120$$

$$60 \text{ to } 108$$

Thus, the confidence region misses the action level and misses the true concentration.

The only way to solve this problem is to correct samples by percentage recovery as follows:

$$U = [1 \pm (2 \times 0.1)]/0.7)$$

$$= (1 \pm 0.286)$$

$$U = 0.714 \text{ to } 1.286$$

In making confidence statements concerning a particular reported value, the accuracy of the method must be considered. Figure 8-3 demonstrates the effects of not accounting for accuracy as measured by percent recovery. The curves in this figure give the probability that a sample which in actuality contains contaminant concentrations in excess of the action level will have reported concentrations above the action level if percent recovery is not considered. Percent recovery is a numerical representation of the inaccuracy of an analytical procedure. Percent recovery is generally determined by adding a known quantity of an analyte (spike) to an environmental sample. The concentration value reported by the laboratory divided by the known concentration of the sample expressed in percent is known as percent recovery.

Percent recovery is not a constant. Not only is percent recovery a function of concentration, it is also a non-repeatable measurement. That is, if several replicates of a sample are spiked and analyzed, several different percent recovery values will be obtained. These percent recovery values may vary considerably. Based on the uncertainty in the percent recovery, it is not recommended that analytical results be systematically corrected for percent recovery. Correction for percent recovery can introduce signficant errors if performed indiscriminantly. Hence, correction for percent recovery should only be performed after detailed discussions with an analytical chemist. The chemist will determine if the recovery problem is due to a chemical change or a failure to recover the total pollutant present.
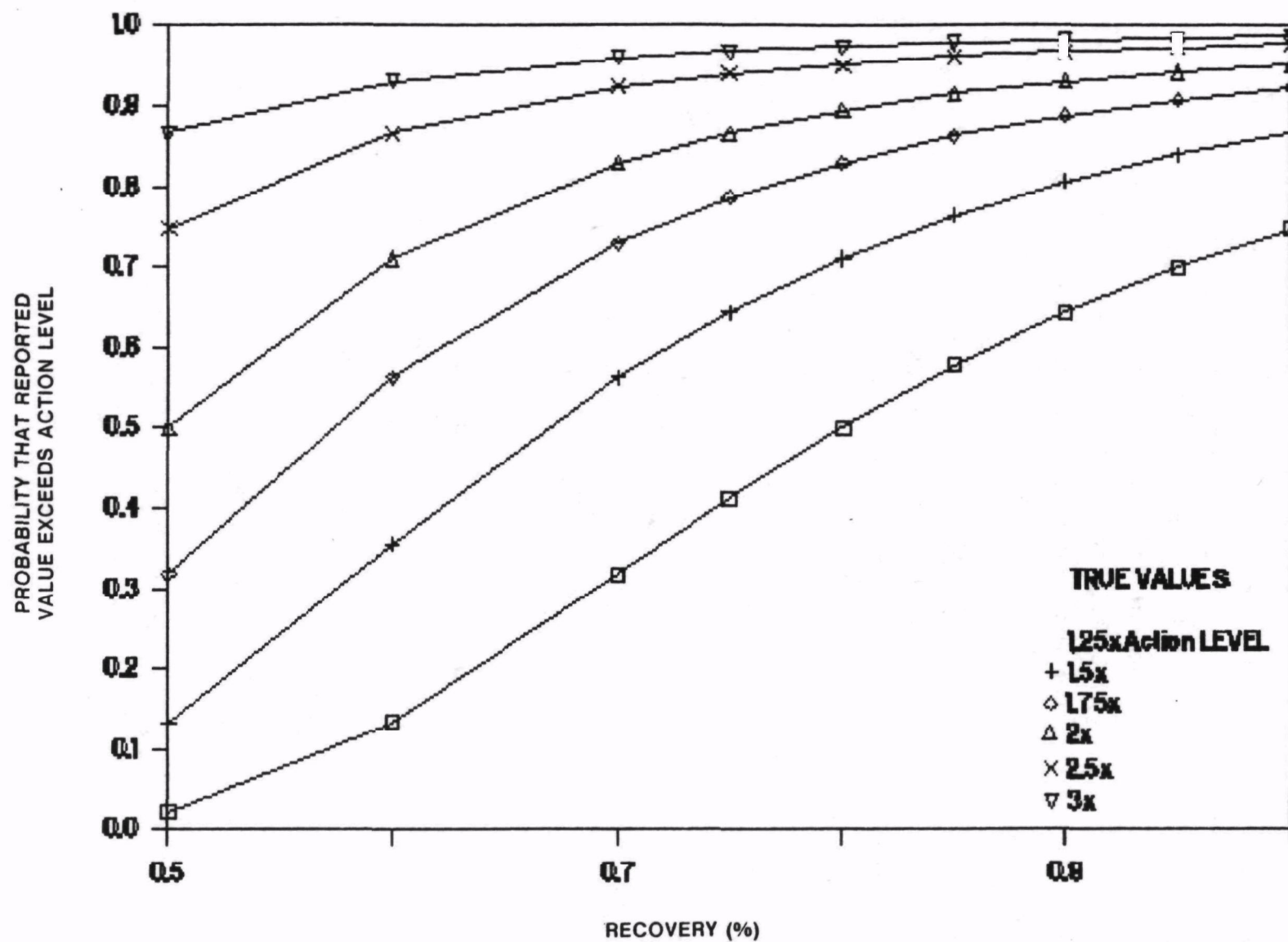
FIGURE 8-3
EXAMPLE PROBABILITY THAT REPORTED
VALUE EXCEEDS ACTION LEVEL VERSUS PERCENTAGE
RECOVERY PLOT (RSD = 30%)

8.2.2 TOTAL UNCERTAINTY ESTIMATES WHEN MANY DATA ARE AVAILABLE

For sample matrices other than water, development of laboratory correction tables may be impossible due to matrix effects. However, if a sufficient number of samples are obtained, statistics can be used to directly determine total uncertainty. Statistics examine the variability within a set of data. If there are no systematic errors, the variation observed in a set of data is the sum of laboratory, sampling, and contaminant plume variation. Thus, any statistical determinations of uncertainty will be measures of total uncertainty. If statistics will be used to measure total uncertainty, the sampling plan must include at least 10 split samples to measure laboratory and sampling uncertainty. At least 20 additional samples are required to measure the spatial variability of the contamination.

8.2.3 TOTAL UNCERTAINTY WHEN MANY DATA ARE AVAILABLE AND LABORATORY UNCERTAINTY IS KNOWN

When laboratory uncertainty has been determined and many data are available total uncertainty can be made. In this case, the estimate of total uncertainty can be estimated by evaluating laboratory uncertainty and other types of uncertainty. The laboratory uncertainty can be used to replace each reported concentration by the conditional distribution of actual values. Thus, each reported value can be transformed into a distribution of values. Statistics can be applied to then utilize the distribution of values at each sample location to estimate total uncertainty at any particular unsampled point or over any region of the site. This type of conditional estimate of total uncertainty can be used when the uncertainty at a specific point is required.

8.3 PROBABILITY OF LOCATING A CONTAMINATED ZONE

At sites or portions of sites where soil contamination is suspected but no definite sources have been identified, an objective of the remedial investigation might be to determine if soil contamination is present.

Important decisions facing the site manager are how many samples must be taken to investigate the potentially contaminated area and where the samples will be located.

In certain given situations geophysical surveys can be utilized in determining the location of contaminated zones. Geophysics can effectively be used to determine the locations of certain ground water plumes (such as hydrocarbon plumes) and concentrations of buried metalic objects (drums and tanks).

The following discussion concerning the probability of locating a contaminated zone is applicable to geophysical methods as wells as to standard sampling technologies.

The decision maker must determine, in Stages 1 and 2 of the DQO process, the acceptable probability of not finding an existing contaminated zone in the suspected area. For instance, it might be determined that a 20 percent chance of missing a 100 ft by 100 ft contaminated zone is acceptable but only a 5 percent chance of missing a 200 ft by 200 ft zone is acceptable. This probability value provides the basis for using statistics to determine how many samples are required. Statistics will be used to determine the number and location of data required to lower the probability of missing an existing contaminated zone to a value less than the acceptable predefined value.

The acceptable probability of missing a contaminated zone must be established by the decision maker working in concert with the data users. Individuals involved in developing risk assessments may provide meaningful inputs into determination of the appropriate probability values to be utilized.

The statistical method applied in this instance involves geometric probabilities. That is, the probability of not identifying a contaminated zone is related to the area or volume of the contaminated zone and the spatial location of the samples. To apply this method, the following assumptions are required:

AW3E-4   8-13

o The shape and size of the contaminated zone must be known at least approximately. This known shape will be termed the target.

o Any sample located within the contaminated zone will identify the contamination.

These assumptions are not severe and should be met in practice.

If in addition to the above assumptions, data are located on a perfectly regular grid and the target is circular, the probability of hitting the target for a given grid size is shown by the following: (Gilbert, 1982).

Probability of a Hit	G/ A_1
0.8	1.13
0.9	1.01
0.95	0.94
0.99	0.86

Where A_1 is the diameter of the target and G is the linear grid spacing.

If data are not regularly located or the target is not circular, a simulation procedure is used.

The procedure used for the hit and miss analysis includes the following steps:

o Simulate a contaminated zone or target.

o Randomly locate the target within the site.

o Determine if any sample locations fall within the boundaries of the target. If so score a hit.

o The simulation is repeated several hundred times using a computer program and the number of hits and misses are recorded.

The probability of locating the contaminated zone is equal to the total number of hits divided by the total number of simulations.

Figure 8-4 illustrates a hit and miss approach for two simulated contaminated zones. The method is flexible so various different sample numbers and locations and various different target sizes can be quickly examined. By varying the number of samples for a fixed target, the number of samples required to lower the risk of missing the contamination to an acceptable level can be determined. Thus, this method allows determination of both the number and location of samples necessary to satisfy DQOs.

8.4 CONFIDENCE LIMITS ON ESTIMATES OF MEAN CONTAMINATION

At sites where contamination is known to exist, a parameter of interest is the mean contaminant concentration over the contaminated area. Mean contaminant concentrations are important when evaluating contaminants contained within a confined area such as a lagoon. In this case, the mean contaminant concentration determines the total amount of contaminants contained in the lagoon. To assess various remedial alternatives it is important to know the maximum quantity of contaminants present in the lagoon. Confidence limits can be used to state the probable range of total contaminants contained in the lagoon.

Confidence limits are a means of placing uncertainty limits on the data. Confidence limits can be used to replace qualitative statements such as "the data at site A are more precise than the data at site B" and ambiguous quantitative statements such as "the data are accurate to within ± 20 percent" by precise probabilistic statements of uncertainty such as "The chance the 10 to 15 ppm interval includes the unknown mean is 95 percent." In the previous statement, the values 10 and 15 ppm are the confidence limits for the 95 percent confidence interval. As the number of data increases, the confidence interval narrows and the confidence in any value derived from the data increases. Thus, if the desired degree of certainty is known at the beginning of the project, confidence limits can be used to determine the number of data required.

The number of available data points will determine the method which can be used to calculate confidence limits. If there are less than eight existing data, confidence limits cannot be reliably determined. If there are

A
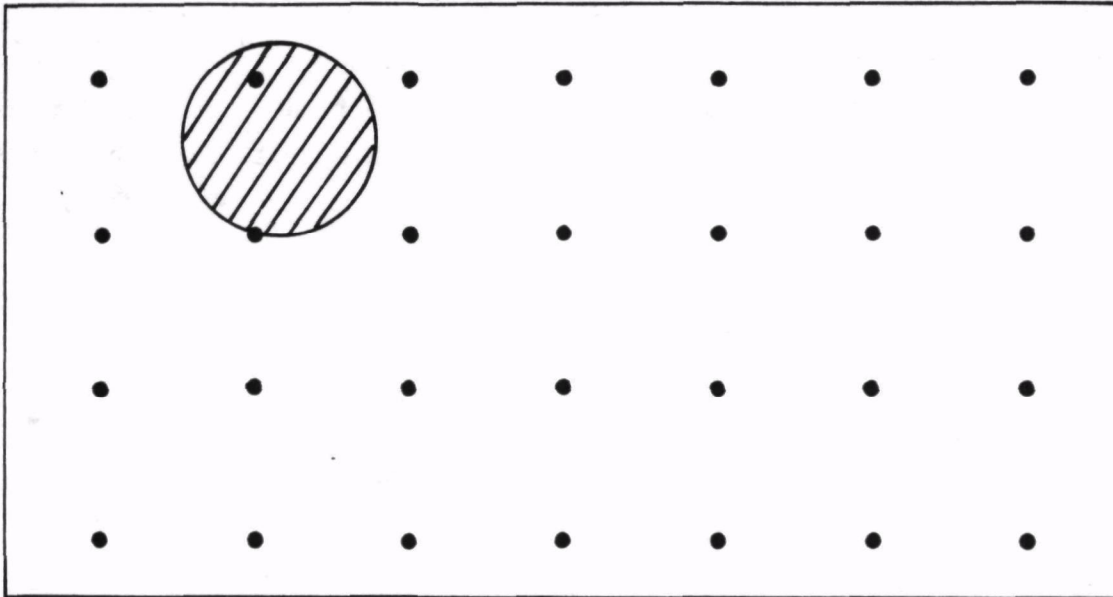
B
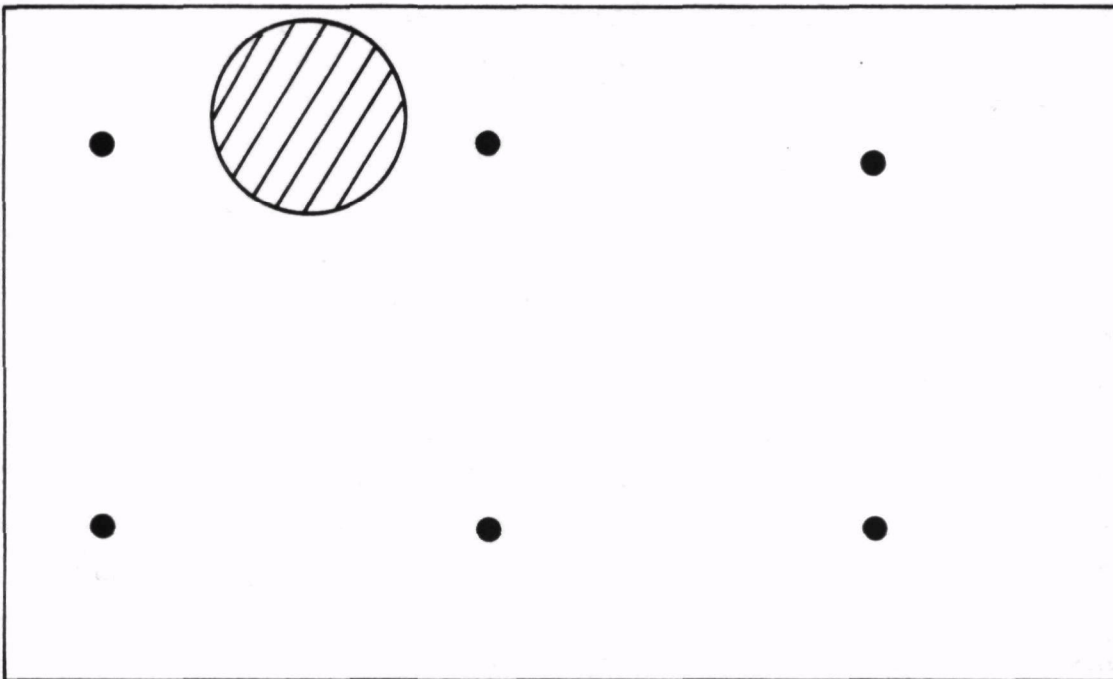
NOTE: This figure illustrates two possible simulations of a circular target for a fixed
set of data locations. The upper figure (a) illustrates a hit while the lower
figure (b) illustrates a miss

FIGURE 8-4
HIT & MISS EXAMPLE

between 8 and 30 existing data, confidence limits can be determined using a simple non-parametric technique. If more than 30 data are available, more sophisticated methods can be used.

The problem of estimating confidence limits about the true mean is commonly encountered. It can be shown that when very specific conditions hold, a simple function of the sampling parameters follows a Student's t distribution. When the t distribution is valid, the mean and variance of the data are calculated and the t statistic for the confidence interval of interest is obtained from a table. A formula which directly determines the number of data is then applied.

Because of the simplicity of this formula, the t statistic is widely used. The t statistic appears in several documents discussing the determination of data requirements at hazardous waste sites (EPA, 1984; EPA, 1985). It is extremely important to realize that the conditions necessary to apply the t statistic are generally not met at hazardous waste sites. The conditions which must be met to apply the t statistic are:

o The sample mean must follow a normal distribution.

o The sample variance must follow a Chi squared distribution.

o The sample mean and variance must be independent.

o The data must be independent.

o The data must be identically distributed.

These conditions do not hold at the great majority of hazardous waste sites, so any confidence limits calculated based on the t distribution will be very inaccurate. For this reason, the t distribution should not be used to evaluate hazardous waste sites unless the aforementioned conditions are met.

For small data sets, the distribution of the sample mean is unknown and site dependent. Because the shape of the distribution is unknown, estimation of confidence limits on the population mean require the

application of non-parametric or distribution free statistical methods.

Non-parametric techniques can be applied regardless of the shape of underlying distribution. One well known non-parametric technique is Chebyshev's inequality which states:

$$P[\ \overline{X} - u \leq k\sigma/\sqrt{n}] \geq (1-1/k^2)$$

Where: X is, in this case, the sample mean
u is the population mean
σ is the population variance
k is some value >1
n is the number of data

This inequality states that, regardless of the distribution of $\overline{X}$, the total probability lying in the tails of the distribution does not exceed $1/k^2$. This method can be used to determine confidence limits on the population mean or to determine the number of data required to reduce the confidence interval to an acceptable value.

Chebyshev's inequality can be used to solve for the number of samples which should be collected provided the variance of the data. If it is assumed that the data are independent and a 95 percent confidence limit the equation can be solved as follows:

$$P[\ \overline{X} - u \leq Z\ /\sqrt{n}] \geq 0.95$$

For normally distributed data a Z value of 1.96 is obtained from statistical tables for the 95 percent confidence limit. The normally distributed data can be related to number of samples needed (n_2) when no distributional assumptions are made by equating the two inequalities as follows:

$$(1-1/K^2) = 0.95$$

$$K = 4.472$$

For normal distribution:

$$P[\ \bar{X}-u \leq 1.96\ /\ n] \geq 0.95$$

For unknown distribution:

$$P[\ \bar{X}-u \leq 4.472\ /\ n_2] \geq 0.95$$

Solving these inequalities yields:

$$n_2 = 5.206\ n_1$$

Therefore, approximately five times as many samples would be required if an assumption of normally distributed data cannot be made.

Chebyshev's inequality can be applied in all cases, regardless of the particular distributional properties of an individual site; however, it is a conservative method which will often predict that very large numbers of data are required to reach a predefined level of precision. If more than 30 data are available, a more exact technique, based on geostatistics, can be applied.

8.5 GEOSTATISTICS

Geostatistics, or more formally, the theory of regionalized variables, is similar to classical statistics in many ways. However, it differs with respect to basic assumptions regarding mutual independence of data. Classical statistics assumes that data are mutually independent, that is, that one data point is not related to another. Geostatistics recognizes that data are related by spatial proximity as governed by physical processes; thus, geostatistics can be used to estimate mean values at unsampled points. Information at one particular point in space can be used to impart information concerning the contaminant level at a location 5 or 10 ft away from the sampled point. Because knowledge of the contaminant level at one point in space provides information concerning the contaminant level at a second point in space, the data are spatially correlated. Geostatistical tools measure and exploit the correlation between data to estimate contaminant concentrations and determine the uncertainty associated with the estimate.

The geostatistical estimate of a mean value is optimally obtained using a method known as kriging. Associated with this estimate is the kriging variance, which is a measure of the uncertainty of the estimate. Geostatistics can be used to determine the variance of errors associated with any estimate. In particular, geostatistics can be used to determine the variance of errors associated with estimating the true mean contaminant concentration by the mean of the available data. The detailed derivation of the error variance is given in Journal and Huijbregts (1978). An intuitive discussion of the method is provided here.

An estimate of the true mean site contamination can be determined from an average of the available data. The estimate is not, in general, equal to the true mean so an error is made. The error of estimation is defined as the estimated mean less the true mean. The particular error observed is one realization of the error random variable. The distribution of the error variable is unknown, but it is known that the mean of the error distribution is zero since only unbiased estimators will be used. The variance of the error distribution can be determined using geostatistics.

The variance estimate requires knowledge of the average correlation between the data and the average correlation between the data and the volume defining the site. Determination of these quantities requires a model of correlation at the site. This correlation model is provided by the experimental variogram determined from the data. The experimental variogram is defined as follows:

$$g(h) = \frac{1}{n(h)} \Sigma (z(x_i + h) - z(x_i))^2$$

Where: $n(h)$ is the number of data separated by distance h

$z(x_i)$ is the contamination observed at location x_i

$z(x_i+h)$ is the contamination observed at location x_i+h

$g(h)$ is the experimental variogram for distance h

By varying h, a model of the variogram versus h can be developed and
applied to determine the variance of errors.

To this point, the mean and variance of the distribution of errors have
been discussed. The remaining parameter of interest is the shape of the
distribution of errors. As the number of data used to estimate the true
mean increases, the distribution of errors becomes more and more like a
normal distribution. This is not a theoretical result but a practical
observation from applications in the mining industry. Given that the
errors follow an approximately normal distribution, the confidence limits
can be determined by the following procedure.

- o Define the level of confidence required.

- o Find the standard normal variate corresponding to this probability
  in a normal table.

- o Apply the following formula:

  $Z - ys < u < Z + ys$

  Where: y is the standard normal variate
  corresponding to the confidence interval

           Z is the sample mean

           s^2 is the variance of errors determined by geostatistics

           u is the true mean

The number of data used does not appear explicitly in this formula. How-
ever, as the number of data used increases, the variance decreases and the
confidence limits narrow. Geostatistics can be used to determine the
number of data required to lower the confidence limits to any required
values and furthermore can be used to determine the exact data locations
which will cause the greatest reductions in the variance of errors. In
this way, geostatistics can be used to determine optimal locations for
additional data.

8.5.1 LOCAL ESTIMATION OF CONTAMINATION

In many instances, the contamination at a particular point within the site
is of interest. For example, consider a site with a known source of
contamination. Available information indicates that contaminants are
migrating toward the western edge of the site. An objective of the RI
might be to determine the western extent of contaminant migration.
Geostatistics can be used to determine the likely extent of contamination.
This information will greatly aid in choosing data locations.

A second example where local estimation is important is in determining
optimal contours for a variable. For instance, in many enforcement cases
an accurate determination of the ground water gradient is required to
correctly identify potentially responsible parties. Water levels are
measured in wells which are separated by varying distances. The heads
between wells are unknown. To create a contour map of head, estimates of
heads between wells must be obtained. To ensure that the estimated heads
and associated contour lines are as accurate as possible the heads at
unsampled points should be estimated optimally using geostatistics.

Geostatistics can be used to address problems presented in the previous
scenarios. The geostatistical technique which will be applied is known as
kriging. Kriging, which is similar to multiple regression, determines an
optimal estimate of a variable at any particular location in space.
Associated with this estimate is an associated qualitative measure of
uncertainty known as the kriging variance.

To apply kriging, a model of the correlation between data is required.
This model is obtained by modeling the experimental variogram of the data.
An adequate correlation model cannot be developed if less than 30 data are
available so the use of kriging should be restricted to sites where more
than 30 data are available or will be obtained.

An example of the use of kriging to optimally estimate the concentration of
lead in soil surrounding a smelter is shown in Figure 8-5.
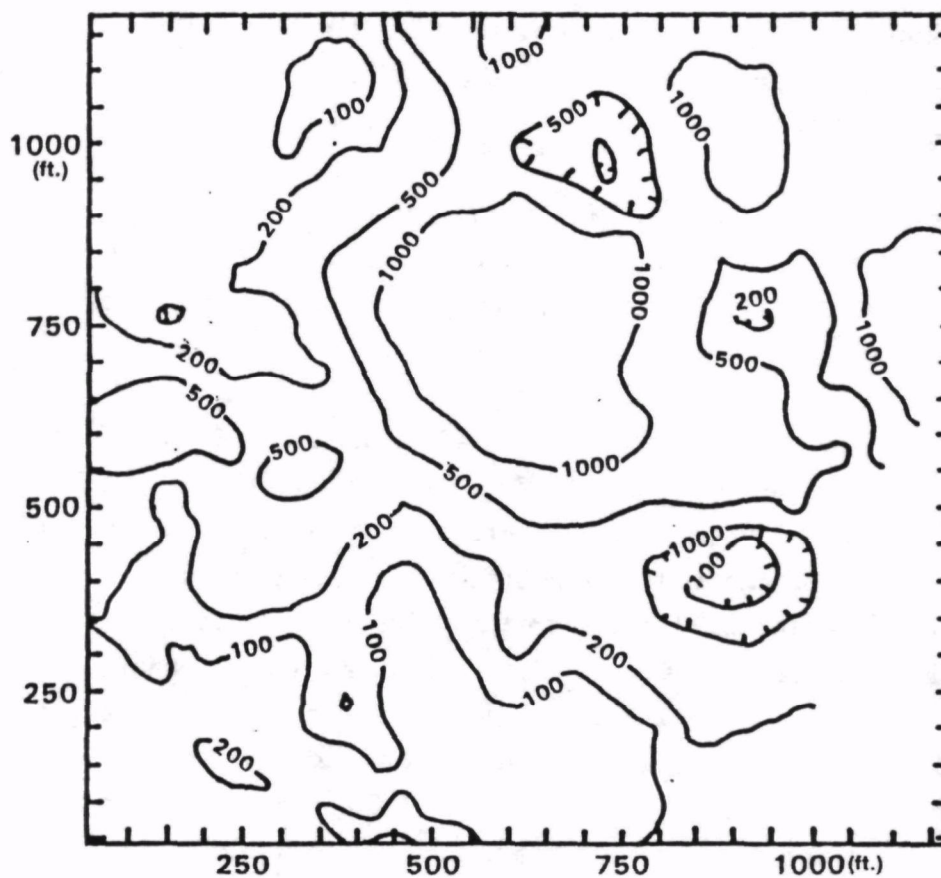
Note: Contour map of lead concentration in soil surrounding a smelter. Contours are based on estimates of soil lead concentration (in ppm) determined by kriging.

**FIGURE 8-5
EXAMPLE OF KRIGING**

8.5.2 LOCAL ESTIMATION OF PROBABILITY

At soil contamination sites where a fixed cleanup criterion has been set, geostatistics can be used to estimate the risk associated with not removing any particular quantity of soil. Geostatistics can be used to quantify the probability of exceeding this criteria and to develop probability contour maps. This map can be used in conjunction with the acceptable uncertainty determined during Stages 1 and 2 of the DQO process to define what volume of soil must be removed.

To determine the probability of exceeding a given value at an unsampled point it is necessary to estimate the entire contaminant distribution at that point. Given this distribution, the probability that the contaminant concentration exceeds any value of interest can be determined.

An example of a probability map is provided in Figure 8-6. In this example, lead contamination has been found in soil surrounding a lead smelter. It has been determined that all soil in excess of 1000 ppm will be removed as part of the remedial action. The probability map gives the likelihood of exceeding 1000 ppm, at each point in the site. If through the DQO process 30 percent had been determined, as an acceptable probability of exceeding 1000 ppm then all soil within the 30 percent contour would be removed. The remaining soil would have, at most, a 30 percent chance of exceeding 1000 ppm. If a different acceptable probability was defined, the volume of soil removed would be defined by the particular contour. This method provides an objective method for determining the volume of soil to be removed.

Techniques for estimating local probability distributions include indicator kriging, probability kriging, and multivariate gaussian kriging. (Journal 1983; CDM 1986; Verly 1983; and Isaakes 1983). These techniques are known as non-linear estimators and are related to but are more complex than kriging. Application of these techniques requires approximately 50 data. This number of data is required because non-linear estimators require an accurate and detailed model of the correlation structure of the data.
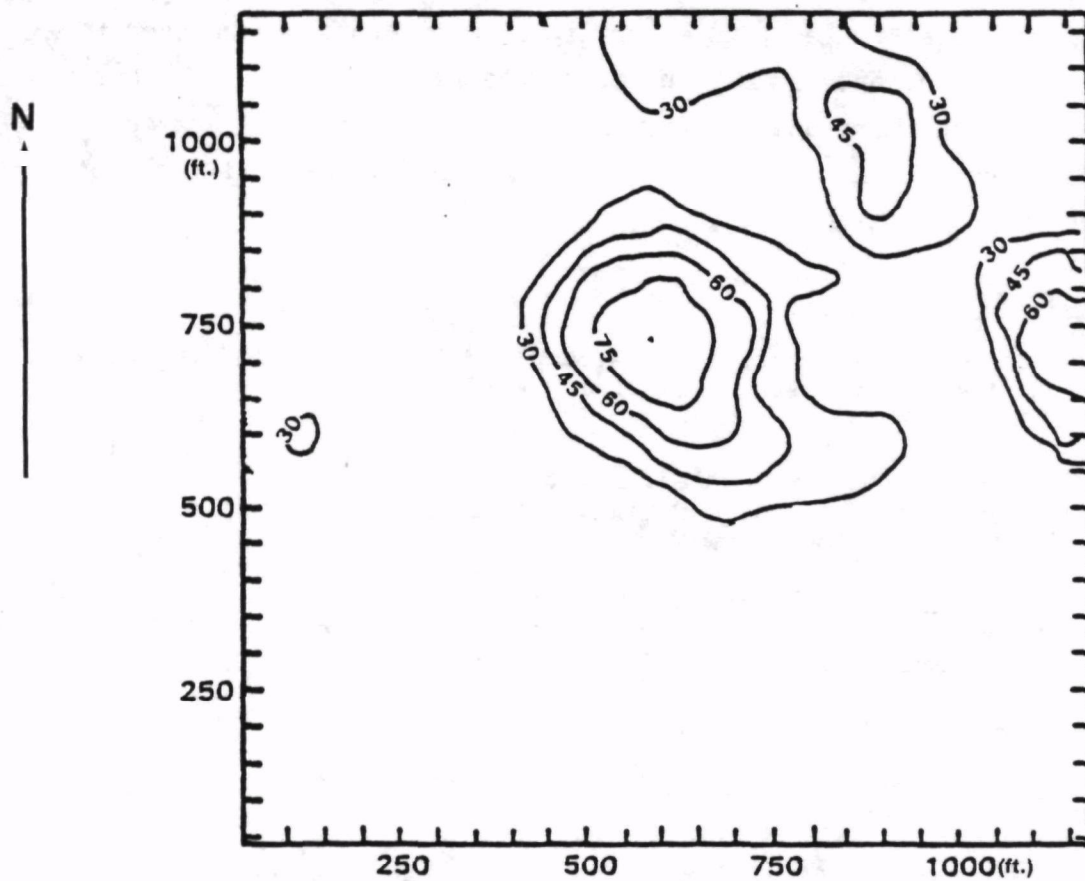
NOTE: Probabilities of exceeding 1000 ppm soil lead concentration near a smelter.
Material with probabilities exceeding the acceptable risk defined in the DQO
process will be removed as part of the remedial action.

FIGURE 8-6
PROBABILITY MAP

An important feature of non-linear estimators is that any uncertainty in the data values, stemming from laboratory or sampling errors can easily be incorporated into the estimate. Since non-linear estimators can be used to estimate the mean or variance at a point or over a region, these techniques provide a means of including uncertainty in any regional or local estimate of the mean. The uncertainty associated with these estimates will include the uncertainty present in the data.

8.6 REFERENCES

Addiscott, T.M., and R.J. Wagenet. 1985. A Simple Method for Combining Soil Properties that Show Variability. Soil Science Society of America Journal. 49: 1365-1369.

Box, G.E.P., W. Hunter, and J.S. Hunter. 1978. Statistics for Experimenters: An Introduction to Design, Data Analysis, and Model Building. John Wiley and Sons. New York.

Camp Dresser & McKee Inc. (CDM). 1986. Probability of Locating Contaminated Zones at the North Cavalcade Site, CDM Internal Correspondence, J. Sullivan.

EPA. 1984. A Soil Sampling Quality Assurance User's Guide EPA 600/4-84-043

EPA. 1985. Sediment Sampling Quality Assurance User's Guide EPA 600/4-85-048

Flatman, G.T. 1985 Design of Soil Sampling Program: Statistical Considerations Draft.

Flatman, G.T. and A.A. Yfantis. 1984. Geostatistical Strategy for Soil Sampling: The Survey and the Census. Environmental Monitoring and Assessment 4:335-349.

Gilbert, 1982. Some Statistical Aspects of Finding Hot Spots and Buried Radioactivity. TRAN-STAT Statistics for Environmental Studies, Batelle Institute, Richland Washington, No. 19.

Isaaks, E., 1984. Risk Qualified Mappings for Hazardous Waste Sites: A case study in distribution free geostatistics, unpublished master's thesis, Stanford University.

Journel, A.G., 1983. Non Parametric Estimation of Spatial Distributions, Jurnal of Mathematical Geology, Vol. 15, No. 3, pp. 445-468.

Journel, A.G. and Ch.J. Huijbregts.1978. Mining Geostatistics. Academic Press, London.

Klusman, R.W. 1985. Sample Design and Analysis for Regional Geochemical Studies. Journal of Environmental Quality. 14:369-375

Ripley, B. 1982. Spatial Statistics. John Wiley & Sons, New York.

Russo, D. 1984. Design of an Optimal Sampling Network for Estimating the Variogram. Soil Science Society of America Journal 48 (4): 708-716

Sullivan, J. 1984. Conditional Recovery Estimation through Probability Kriging - Theory and Practice, in Geostatistics for Natural Resource Characterization, Reidel, Dordrecht, Holland.

Verly, G. 1983. The Multigaussian Approach and its Application to the Estimation of Local Reserves, Journal of Mathematical Geology, Vol. 15, No. 2, pp. 263-290.

Yost, R.S., G. Uehara and R.L. Fox. 1982. Geostatistical Analysis of Soil Chemical Properties of Large Land Areas. I. Semi-variograms. Soil Science Society of America Journal 46(5):1028-1032

Yost, R.S., G. Uehara and R.L. Fox. 1982. Geostatistical Analysis of Soil Chemical Properties of Large Land Areas. II. Kriging. Soil Science Society of America Journal 46(5):1033-1037

Zirschky, J., Deary, G.P., Gilbert, R.O., Middlebrooks, E.J. 1985 Spatial Estimation of Hazardous Waste Site Data. In: Journal of Environmental Engineering. Vol.111, No.6 pp.777-787.

Section 9.0

9.0 ANALYTICAL CONSIDERATIONS

Analytical methods must be evaluated during the development of site specific data quality objectives. The specific parameters for which the analytical method is valid, its limitations, and any special considerations (such as sample preparation) which will affect the resulting data quality must be understood in order to select appropriate analytical methods for specific uses.

This section provides an overview of the analytical considerations which should be taken into account during DQO development. Analytical considerations must be evaluated concurrently with statistical and sampling considerations in order to ensure that a consistent approach is proposed and that the data quality objective ultimately established can be attained.

9.1 ANALYTICAL SUPPORT LEVELS

The analytical options available to support remedial investigation/ feasibility study activities are presented in five general levels. These levels are distinguished by the types of technology and documentation used, and their degree of sophistication as follows:

o LEVEL V – Non-standard methods. Analyses which may require method modification and/or development.

o LEVEL IV – CLP Routine Analytical Services (RAS). This level is characterized by rigorous QA/QC protocols and documentation and provides qualitative and quantitative analytical data. Some regions have obtained similar support via their own regional laboratories, university laboratories, or other commercial laboratories.

o LEVEL III – Laboratory analysis using methods other than the CLP RAS. This level is used primarily in support of engineering studies using standard EPA approved procedures.

o LEVEL II – Field analysis. This level is characterized by the use of portable analytical instruments which can be used on-site, or in mobile laboratories stationed near a site (close-support labs). Depending upon the types of contaminants, sample matrix, and personnel skills, qualitative and quantitative data can be obtained.

o <u>LEVEL I</u> - Field screening. This level is characterized by the use of portable instruments which can provide real-time data to assist in the optimization of sampling point locations and for health and safety support. Data can be generated regarding the presence or absence of certain contaminants (especially volatiles) at sampling locations. Essentially nonqualitative; quantitative only for total organics.

Table 9-1 provides a summary of the analytical levels, their applicability, and limitations. Within each level, different procedures may be used to produce different quality data to some extent. For example, Level II encompasses both mobile laboratory procedures and less sophisticated "tailgate" operations which may produce data of different quality.

9.1.1 LEVEL V ANALYTICAL SUPPORT - NON-STANDARD METHODS

The objective of non-standard analytical support is to provide the RI/FS process with data that cannot be obtained through standard avenues of analytical support. Analytical support of this type may involve the research, development and documentation of a method, or more typically, the modification of an existing method. EMSL, Las Vegas can be consulted for protocol availability, modification, or development. Level NS methods are available through CLP Special Analytical Services (SAS), university laboratories, commercial laboratories, National Enforcement Investigation Center, and Environmental Services Division. The types of analyses available through Level NS support may ultimately be technology-limited.

Level V includes the modification of existing methods for lower detection limits or for verification of tentatively identified compounds (TIC). TICs are defined as the 30 non-HSL peaks of greatest apparent concentration under the CLP RAS procedures. A more detailed discussion of TICs is presented in Section 9.2.6. Level V support is used when "off the shelf" procedures listed in other levels will not provide the needed data, when analytical standard operating procedures (SOPs) are not available, or non-standard techniques are required.

TABLE 9-1 SUMMARY OF ANALYTICAL LEVELS FOR RI/FS

Option	Type of Analysis	Uses	Limitations	Data Quality	Cost	Time
Level V	- Non-conventlal parameters - Method-specific detection llmits - Modification of existing methods - Appendix 8 parameters - TIC	- Confirmational - Toxicology - Site-specific conditions/parameters - RCRA compliance	- Requires method development/modifica-tion - Mechanism to obtain services requires special leadtime - Calibration standards may not be readily available	- Method-specific	- Initially high, if method development is required.	- Entries refer to all types of analysis listed. No specific time/cost requirements can be specified. In general the time frame can range from a few weeks to signifi-cantly longer if method development is needed.
Level IV	- HSL Organics/inorganics by GC/MS; AA; ICP.	- Confirmational - Toxicology - All other program Activities	- Tentative identifica-tion of non-HSL parameters - Some time is Required for Validation of packages	- Rigorous QA/QC - Standard Methods	- $1,000/Sample for organics - $200/Sample for metals	-Contractually, 30-40 days -Shorter turnaround time possible through SAS request
Level III	- Organics/Inorganics using EPA procedures other than RAS can be analyte-specific - RCRA characteristic tests	- Confirmational but with less documentation - Presence or absence of contaminants - Engineering uses - Screening	- Methods may vary	- Similar detection limits to CLP - Less rigorous QA/QC	- $960/Sample for organics - $200/Sample for metals	- 14 days
Level II	- Variety of organics by GC; inorganics by AA; XRF - Tentative ID; analyte-specific - Detection limits vary from low ppm to low ppb - Portable/mobile instrumentation	- Presence or absence of contaminants - Relative concentrations - Engineering - Screening	- Tentative ID - Techniques/instruments limited	- Dependent on QA/QC steps employed - Data typically reported in concentration ranges	- $15-40/Sample	- Real-time to several hours
Level I	- Total organic vapor detection using portable instruments - pH, conductivity, salinity, DO	- Assist in identifying sample locations - Field screening - Health and safety	- Instruments respond to naturally-occurring compounds	- If instruments cali-brated and data interpreted correctly, can provide indication of contamination	- Negligible, if capital costs excluded	- Real-time

The analysis of samples for the RCRA modified Appendix VIII list of contaminants could currently be considered a Level NS application. The modified Appendix VIII list contains 92 organic compounds that are not a part of the Hazardous Substances List (HSL) and therefore are not normally tested for, samples obtained from CERCLA sites. Appendix D of this document contains a preliminary feasibility study performed to address the applicability of using or modifying existing analytical procedures for Appendix VIII analysis.

Level V poses limitations to implementation because the amount of lead-time for start-up may be significant, and the analyses may be "one-of-a-kind" applications of the method, resulting in a lack of comparability of the data. The unit costs for Level V sample analysis are dependent on the analysis requested. Generally, initial unit costs will be high, reflecting the costs of becoming familiar with the method. If the method is used for other projects or sites, unit costs may decrease with the demand, and the method may become standard. The amount of documentation available for Level V analytical support will vary depending on the sophistication of the technology used. If method development is required, this information should be requested and reviewed by the user.

Accuracy and precision information is generally not available for Level NS due to the type of analytical support it provides. Specific data quality information can best be obtained on a case-by-case basis by reviewing the laboratory's method development work prior to submitting samples. If the specific support required represents a modification of an existing procedure or protocol, data quality information can be extrapolated from the existing procedure.

9.1.2   LEVEL IV ANALYTICAL SUPPORT - CONTRACT LABORATORY PROGRAM (CLP)
        ROUTINE ANALYTICAL SERVICES (RAS)

A high level of quality assurance and documentation has been incorporated in all aspects of program activities. The CLP RAS provides for analyses of all types of media for Hazardous Substance List (HSL) organic compounds and priority pollutant inorganic compounds. These services are available

through CLP RAS and regional EPA ESD laboratories. Level IV analyses are currently used for most RI/FS activities. However, the use of Level IV data may not be required for many RI/FS purposes. Level IV analyses are typically used for confirmation of lower level data, risk assessment, and to obtain highly documented data.

CLP RAS generated data have the following properties:

o Confirmed identification and quantitation of compounds (for HSL parameters only unless otherwise specified) to the detection specified in the IFB.

o Tentative identification of a contractually-specified number (30) of non-HSL parameters.

o Sufficient documentation to allow qualified personnel to review and evaluate data quality.

o Uniform methods of analysis activities.

o Detection limits may not be sufficient for toxicological evaluations

o CLP support is one of the most expensive routine analytical services available to the Superfund program, (e.g., RAS for organics is about $1,000/sample. RAS for inorganic is about $200/sample).

o RAS is contractually operating on a 30-40 day turnaround although delays can occur. Since demands fluctuate, space may be limited at times for the Superfund program. In addition, data validation usually takes 3-4 weeks after data is received.

The CLP RAS is very specific concerning the amount of laboratory documentation that is supplied with every data package. The RAS deliverables package contains information on initial and continuing calibration, GC/MS tuning, surrogate percent recovery, and matrix spike duplicates. In addition, hard copies are provided of reconstruction ion chromatograms, GC chromatograms, and spectra for every sample and every blank, standard, or spike run with a particular set of samples. Documentation is also provided for blank analyses, internal chain of custody and holding times.

The bias and precision of CLP analytical procedures can be assessed by examining the performance of the laboratory in analyzing matrix spikes. However, an indication of the performance of the laboratory is also provided by the results of quarterly laboratory performance evaluation samples. These evaluation samples are submitted blind so the laboratory has no indication of the actual contaminant value. In contrast, the laboratory knows the exact concentration of a matrix spike.

Historical CLP precision and accuracy data classified by media is presented in Appendix C as Level IV. Each table is footnoted to show the source of the precision and accuracy data and, to the extent possible, the type of QC samples used, the numbers of data points, etc. Contract required detection limits are presented in Appendix E.

9.1.3 LEVEL III ANALYTICAL SUPPORT - LABORATORY ANALYSIS

Level III analytical support is designed to provide laboratory analysis using standard EPA approved procedures other than current CLP RAS. This level is used to obtain similar analysis with less documentation.

Generally the analyses performed using Level III techniques are designed to provide confirmed identification and quantification of organic and inorganic compounds in water, sediment, and soil samples. These analyses are available through commercial laboratories, ESD, CLP SAS, and the CLP screening service (in development).

Level III provides data for site characterizations, environmental monitoring, confirmation of field data and to support engineering studies (e.g., design, modeling, and pilot/bench studies).

Level III laboratory analysis provides the following:

   o Data to support engineering design parameters

   o Data for use in evaluating the site for further action, e.g., to
      determine extent of environmental contamination

   o Data for use in risk assessments

o   Rapid turnaround of data may be available

o   Detection limits for presence or absence of compounds comparable to Level IV

o   Costs range from about $200/sample for inorganics to $960/samples, for organics analysis. Turnaround time for Level III laboratory analysis for organics is expected to be about 14-21 days.

Level III protocols all have built-in QA/QC, including calibration runs, surrogate standards, etc. External QA, which is also used for the CLP, is employed in the form of trip blanks, replicate and duplicate samples, and blind spikes submitted with the samples.

The CLP screening service, which is currently under development, may be more appropriate for hazardous waste analysis than the SW-846 methods, Test Methods for Evaluating Solid Waste Physical/Chemical Methods, Second Edition, (EPA 1982). This service would utilize CLP RAS methods with the exception of the extensive documentation currently provided.

The type of laboratory support available under Level III ranges in sophistication from GC/MS instrumentation to the measurement of water quality parameters. The type and amount of documentation available depends on the type of analysis requested. Data users should review a sample report issued by the laboratory for the analysis requested to determine if the degree of documentation supplied is adequate or whether additional information must be requested. If the documentation is sufficient, Level III could save time and cost.

Accuracy, precision and MDL information that is considered representative of this level of analytical support was compiled from SW-846. This information is provided in Appendix C. These procedures are applicable for all sample matrices; however, the SW 846 information presented in Table C-1-C was derived from the analysis of water and wastewater samples and performance evaluation standards. Therefore, the criteria specified in this table should be considered as "best case" information when non-aqueous media samples are analyzed. Also, these data are presented irrespective of the sample pretreatment or preconcentration techniques used. These

techniques may include liquid-liquid extraction (3520), acid/base-neutral clean-up extraction (3530), soxhlet extraction (3540), sonication extraction (3550), headspace (5020), and purge and trap (5030). They are used in conjunction with the analytical procedures presented in SW 846.

9.1.4 LEVEL II ANALYTICAL SUPPORT - FIELD ANALYSIS

Level II analytical support is designed to provide real-time data for ongoing field activities or when initial data will provide the basis for seeking laboratory analytical support. There have also been a significant number of instances where data derived from field analytical techniques have been the sole basis for making decisions about site disposition or health and safety. Level II analysis can also be utilized effectively when a phased approach is used for field sampling. In a phased sampling effort, the results of the first phase guide the development of subsequent phases, and thus, real-time data are important.

Field analysis involves the use of portable or transportable instruments which are based at or near a sampling site. Field analysis should not be confused with the process of obtaining total organic readings using portable meters.

Field analysis can provide data from the analysis of air, soil and water samples for many Hazardous Substance List (HSL) organic compounds, including volatiles, base neutral acid (BNA) extractable organics, and pesticides/PCBs. Inorganic analysis can also be conducted using portable atomic adsorption (AA) or other instruments.

The simplest type of field analysis is for volatile organic compounds. Since the headspace analytical technique is used, the sample preparation is minimal. Extractable organic and inorganic analyses require additional time and equipment.

Level II analysis is used for onsite, real-time screening, baseline data development, extent of contamination and onsite remedial activities.

Field analytical techniques provide the following:

o Rapidly available data for a variety of activities, including
hydrogeologic investigations (establish depth/concentration profiles
as wells are installed); cleanup operations (determine extent of
contaminated soil excavation); and health and safety (determine
nature and extent of release to ambient air).

o Detection limits for volatiles range from 0.5 ppb in air, 2-3 ppb in
water, and 10 ppb for soil. Detection limits for PCBs in soil are
about 1.0 ppm. Detection limits for extractable organic compounds
analyzed in mobile labs are in the vicinity of 10 ppb.

o Special applications – e.g., vadose zone monitoring.

o Volatile organic data can be used as early indicators or tracers of
off-site contaminant migration. Volatiles are the most mobile of
contaminants in all media, and are typically found at some
concentration at virtually all sites.

The ability to assess data quality for field activities is dependent upon
the QA/QC steps taken in the process (e.g., documentation of blank
injections, calibration standard runs, runs of qualitative standards
between samples, etc.).

If capital expenditures are excluded, the costs of field analysis are in
terms of personnel time in performing analyses, preparation/maintenance of
equipment, etc. Per sample costs for mobilizing and staffing a field
laboratory will decrease as the number of samples increases. Based on
limited data from Region I FIT experience, per-sample costs for volatile
and inorganic analyses are approximately $15. Per-sample costs for mobile
laboratory analyses may approach $100. Depending on the type of analysis,
time requirements per analysis range from 10 minutes to 1-2 hours.

Since Level II analyses are performed in the field, the amount and type of
documentation available will vary with the type of analysis and the
standard operating procedures used. Typically, a gas chromatograph
operated in the field provides the bulk of the analytical support at this

level. The documentation available utilizing this level of analytical support would consist of the output of the strip chart recorder for all samples, standards, and blanks analyzed. Field and analysis log books would also be a source of additional documentation.

Data generated by Level II analysis are typically confirmed by submitting some duplicate samples to CLP and/or a local laboratory. No statistical methods are available to determine the exact number of samples to submit for confirmation. Some guidance can however be provided.

Numerous factors have to be considered in choosing the number (or subset) of samples to be submitted for confirmational purposes including:

o   Total number of samples taken (i.e., when only a few samples are taken, 100% confirmational analyses may be appropriate)

o   Objective of sampling

o   Data uses

o   Method of analyses used

In general confirmational samples should include a subset (or all) of designated critical samples, a subset of samples covering the entire range of identified concentrations, and a subset of samples near the (preliminary) action level and near the "0" concentration or not detectable range.

An additional factor to consider is the measured precision of the field instrument in use. When high precisions are measured less samples need to be confirmed; if however a low precision is calculated, it is recommended that analysis be suspended until the reason for the low precision is determined. A qualified chemist should be contacted for input on instrument calibration, and the utility of the analysis method with the specific field conditions.

The data base for documenting accuracy, precision and MDL information for Level II analyses is sparse. A number of factors have recently stimulated an interest in the development of Level II methods. This activity is centered primarily in various EPA Environmental Service Divisions (ESD) and remedial contractors. There are two ongoing projects expected to contribute significantly to the Level II data quality criteria data base. These projects are an EPA Headquarters-directed compilation of all Level II analytical methods currently used by Field Investigation Teams (FITs) and the operation of a mobile field analytical laboratory being directed by EPA/ESD in Region IV. The Region IV project, in particular, holds the promise of a significant contribution, since virtually all organic Hazardous Substance List (HSL) parameters are being analyzed for. As these data become available they will be incorporated into this document. Examples of the performance Level II types of analysis are summarized below.

Analysis of Polychlorinated Biphenyls (PCBs) in Soils and Sediments - The EPA Region I Laboratory has developed a rapid method for the determination of PCBs in soils and sediments that can be used in the field or in a close-support laboratory setup. The procedure makes use of a simple micro-extraction technique, with subsequent analysis by gas chromatography using an electron capture detector (GC-ECD). Samples can be extracted in less than 10 minutes and the GC analysis takes approximately 15 minutes. By extracting the next samples to be analyzed while the previous sample is being run on the GC, appoximately 25 samples can be run in a single 8-hour day.

Percentage recovery of PCB Aroclor 1242 using this procedure ranges from 80-150 percent according to Region I estimates. It is theorized, but not documented, that the extraction efficiency of this method decreases for the heavier molecular weight aroclors. It is estimated that the recovery of PCB Aroclor 1260 is approximately 50 percent. As such, the resulting data has to be reviewed keeping these varying accuracies in mind.

Table 9-2 shows the results obtained by Region I using this procedure to analyze a sediment reference material prepared by the Environmental Monitoring Support Laboratory (EMSL) in Cincinnati, Ohio (Spittler 1986).

This procedure is referenced at the end of this section and should be consulted for specific information regarding its use. It should be noted that this procedure may be applicable to the analysis of other halogenated compounds, such as chlorinated pesticides and pentachlorophenol. As is the case with all Level II analyses, the procedure must be developed for individual applications (sample matrix and analytes of interest) prior to the actual analysis of investigative samples.

Lead Analysis of Soil Samples Using a Portable X-Ray Fluorescence Analyzer
Preliminary data have been obtained regarding the use of a portable X-ray Fluorescence Analyzer (XRF) to analyze approximately 200 soil samples for lead (CDM 1986).

Two calibration curves were required for this analysis due to the wide range of lead values encountered in the samples. A low curve covering the 0-1000 mg/kg range, and a high curve covering the 1,000 to 17,900 mg/kg range were prepared. Sample preparation consisted of grinding the dried sample with a mortar and pestle to less than approximately 100 mesh. Sample preparation averaged between 10 and 15 minutes per sample.

Initial indications are that sample preparation is critical in the use of this procedure. On samples that had been ground to a homogeneous mixture, acceptable precision and accuracy was obtained around a central value of 1000 mg/kg. However, the accuracy decreased near the detection limit and at high concentrations.

Table 9-3 displays data obtained by the analysis of split samples by the XRF procedure and CLP analysis.

TABLE 9-2

COMPARISON OF PCB SCREENING RESULTS
FOR AROCLOR 1242 WITH SRM
TRUE VALUE

	Cincinnati True Value(ug/gm)	Screening Results (ug/gm)
Average Concentration	24.6	22
95% Confidence Interval[1]	MDL – 51.6	14–35
Standard Deviation	11.1	8.4

Data were generated by three alternate methodologies

Source: EPA, 1984. Internal Memorandum from M. Lataille (Region I).

[1] Provided by EMSL – Cincinnati. The acceptable range of values for this QC sample is from the detection limit to 51.6 ug/gm

TABLE 9-3

X-RAY FLOURESCENCE ANALYZER
RAW SAMPLE SPLIT DATA

Lead Concentration (mg/kg)

Location	CLP RAS	XRF	RPD (%)
1	492	517	5.0
2	5,600	9,450	51.2
3	94	347	114.7
4	18,200	21,694	17.5
5	3,770	7,890	70.7
6	718	879	20.2
7	90	208	79.2
8	9	298	188.3
9	1,800	5,540	101.9

9.1.5 LEVEL I ANALYTICAL SUPPORT - FIELD SCREENING

The objective of Level I analysis is to generate data which are generally used in refining sampling plans and determining the extent of contamination. This information supplements background data and visual evidence of contamination pathways. A second objective is to conserve other analytical support resources. This type of support also provides real time data for health and safety purposes. Additional data which can effectively be obtained by Level I analyses include, pH, conductivity, temperature, salinity, and dissolved oxygen.

Level I analyses are generally effective for total vapor readings using portable photoionization or flame ionization meters which respond to a variety of volatile inorganic and organic compounds. Detection is limited to volatiles which have characteristics enabling them to be measured by the respective instruments. These analyses are available through ESD or remedial contractors.

Level I analysis provides data for onsite, real-time total vapor measurement, evaluation of existing conditions, samples location optimization, extent of contamination, and health and safety evaluations. Data generated from Level I support are considered qualitative in nature. Data generated from this type of analysis provide the following:

o Identification of soil, water, air and waste locations which have a high likelihood of showing contamination through subsequent analysis.

o Real-time data to be used for health and safety consideration during site reconnaissance and subsequent intrusive activities.

o Quantitative data relative to a primary calibration standard if the contaminant(s) being measured are unknown.

o Quantitative data if a contaminant is known and the instrument is calibrated to that substance.

o Presence or absence of contamination.

Some instruments show a response to naturally occurring, non-hazardous substances (methane) or other possible interferences. Data from instruments may also be affected by weather and operator skill and interpretive ability.

A hardcopy strip chart recorder output can be obtained for instrumentation operated in the general total vapor survey mode but it is not common practice. The most available form of documentation for this support level is the field operator log book. Sample identification, location, instrument reading, calibration and blank information is usually contained in the field log book.

There are no data quality criteria specified for Level I, Field Screening Support, because this level is characterized by the use of non-qualitative, hand-held instrumentation (PID, FID). This instrumentation measures total organic vapor concentrations only, and as such, is not conducive to the generation of quantitative data. Specific information regarding individual compound sensitivities and response factors can be obtained in the manufacturer's owner's manual for specific instruments.

9.2 ANALYTICAL FACTORS

Other factors which may affect development of DQOs include the following:

- o Analytical quality control

- o Instrumentation options

- o Media variability

- o Method detection limit

- o Matrix effects

- o Tentatively identified organic compounds

- o Data qualifiers

9.2.1 ANALYTICAL QUALITY CONTROL

The classification of analytical support into broad levels takes into account internal laboratory quality assurance/quality control (QA/QC) in a general manner only. Internal QA/QC refers to the surrogate and matrix spikes, method blanks, and duplicate/replicate runs, among other laboratory or field operation quality control. Within a given level of analytical support, there may be differences in the way individual laboratories or field operations approach internal QA/QC. For CLP Invitation for Bid (IFB) RAS analytical support, the procedures are standardized and contract-specified.

The methods and QA/QC for laboratories or field operations should be based on the types of data needed for decision making. Documentation requirements and appropriate QC requirements should also be required. Performance of laboratories should be considered before selecting a lab.

Laboratory operation QA/QC plans should include calibration procedures, frequency of laboratory blank and duplicate analysis, the use of surrogate standards and spikes, and standard operating procedures. The laboratory/field operation report format should also be evaluated in terms of what information is reported along with the sample data (method blanks, duplicates, spikes, etc.). At a minimum, method blank, internal duplicate/replicate and matrix spike information should be reported along with the sample data. Surrogate spike information should also be reported for all GC/MS data.

When evaluating laboratory QA/QC, it is important for the reviewer to keep the level of analytical support in perspective. These levels produce data of different quality and documentation and should be reviewed with this in mind. For example, it would be inappropriate to hold a screening laboratory to CLP RAS standards, or expect a field screening operation to have as rigorous QA/QC as a laboratory. Expectations such as these would be inconsistent with the concept of classifying analytical support by the quality of the data needed.

Once the required data quality for a given activity is established, the data user must select the appropriate level of analytical support that will supply data of the required quality. For example, an analytical level can be flexible by specifying more or less QA/QC. The cost and turnaround time can be increased or decreased within a given level by adjusting the amount of QA/QC. This reasoning results in a continuum of analytical support services available to cover a wide spectrum of data quality requirements.

9.2.2 INSTRUMENTATION OPTIONS

In some cases, the decision maker may have the option of choosing between similar analytical procedures for the analysis of a given parameter. Although each procedure is an EPA approved method, the reason for the equivalent procedures is that different analytical instrumentation is used for each method. Although the results obtained are equivalent, there can be subtle differences in the types of data produced by different instrumentation. When choosing analytical procedures, consideration should always be given to the instrumentation used in order to select the method that will best satisfy the stated analytical requirements.
The most common example of equivalent procedures using different instrumentation for the analysis of the same parameters is the gas chromatography (GC) and gas chromatography/mass spectrometry (GC/MS) procedures used for the analysis of organic compounds. For example, consider the analysis of a water sample for volatile organics using each type of instrumentation. Both GC and GC/MS analysis will yield qualitative and quantitative results but there are trade-offs associated with each technique. In deciding which analytical technique to use in the above example, the major issues to consider are the confirmation of compound identification, the detection limits achievable, and the cost of analysis. In general, GC/MS analysis is superior to GC analysis in the area of compound identification. This is because individual compounds are identified by their mass spectra, which are plotted from a compound's ion fragmentation pattern. These fragmentation patterns are specific (at least

for target compounds) and can be thought of as a compound's fingerprint.
This identification is further confirmed by the chromatographic retention
time. By use of the GC/MS system's spectral library, the tentative
identification of non-target compounds found in a sample can also be made
by running a library search.

Compound identification is determined by chromatographic retention time
alone in GC analysis. A second analytical column can be used to confirm an
identification (the confirmation column) but the primary method of
identification is still the retention time. Gas chromatographs are set up
with different detectors that are sensitive to different classes of
compounds which do provide some qualitative information. The presence of
non-target compounds can also be detected by GC, but the identification of
unknown chromatographic peaks is limited to trial and error. There is
nothing analogous to a GC/MS library search.

The GC has advantages over GC/MS analysis when the lowest possible
detection limits are the deciding factor. For volatile organic compounds
in water, the difference in detection limits can be as much as a factor of
100. Typically, GC methods report detection limits ranging from 0.1 to 1.0
ug/l; GC/MS detection limits typically range from 5.0 to 10.0 ug/l for this
type of analysis. The GC/MS detection limits for specific compounds can be
improved by using the selective ion monitoring (SIM) technique.

GC analysis is usually less costly than GC/MS. The relative costs for each
type of analysis will vary from laboratory to laboratory, however,
depending on which type of instrumentation is more commonly used for a
given application by that laboratory. Also, the manner in which a gas
chromatograph is set up for analysis will influence cost. (GC analysis of
volatiles requires two separate detectors. If the two detectors are placed
in series, only one analysis is required versus two separate analyses if
the detectors are used individually.)

In deciding which type of instrumentation to use for volatile organic
analysis, the central issue is whether the increased confirmation of GC/MS
identification is worth the trade-off in detection limits. Often, the

identity of the contaminants is already known. In this case, GC/MS analysis is not providing any additional information other than confirming what is already known. However, the increased sensitivity provided by GC analysis can provide much usable information such as insight as to how "clean" a water supply really is, a better indication of where the leading edge of a ground water contaminant plume is, and the low analysis of drinking water. As a rule of thumb, samples taken from unknown sites or sources should always be analyzed by GC/MS, at least initially, to confirm compound identification. Also, GC/MS is the method of choice when non-target or a wide variety of different compounds are suspected. When the application is more of a monitoring function, or whenever low level analysis is required, GC procedures are the method of choice. It should be noted that once non-target compounds are identified, they too can be analyzed by GC.

Regarding the choice between GC versus GC/MS analysis for acid/base-neutral extractable compounds (ABNs), pesticides, and PCBs, the choice is more clear cut. There is no reason to opt for GC analysis of the ABN fraction unless specific compound analysis is all that is desired. Pesticides and PCBs are usually analyzed by GC procedures because of the greatly improved detection limits. However, if positive values are detected and are above GC/MS detection limits, the analysis is usually confirmed by GC/MS.

9.2.3 MEDIA VARIABILITY

Decision makers and data users should be aware that a great deal of variability exists in regard to how a given analytical technique or method responds to a given sample medium. Most of the analytical methods utilized in support of RI/FS activities were developed, at least originally, for aqueous samples and modified for use with other media with varying results. Also, the quality control data published for most analytical methods (concerning accuracy and precision information) were developed using aqueous samples. The performance criteria published may not totally apply to the use of the method with other sample media. When considering the analysis of source materials, leachate or other complex matrices, qualified analytical support personnel should be consulted to determine the most appropriate analytical approach.

9.2.4 METHOD DETECTION LIMIT

Regardless of the specified method detection limit, the actual detection
limit reported may be sample specific. This is especially true of samples
having complex sample matrices. Also, if the concentration of a particular
sample constituent is so high that it requires dilution prior to analysis,
the resulting detection limit for that sample will be raised by the
dilution factor. For example, consider a sample being analyzed by GC/MS
for volatile organics. If the laboratory's normal detection limit for this
method is 5.0 ug/l, and the sample contains 20.0 mg/l of benzene, the
sample will have to be diluted (say by at least a 1:10 ratio) and the
resulting detection limit will be 50.0 ug/l. In some cases, the laboratory
can analyze the same sample twice to obtain the specified detection limit
but this is not always possible, is not considered standard practice, and
would have to be specified prior to sample submittal. If several compounds
are present with an order of magnitude difference in concentrations, then
all the compounds may not be reported.

Another factor regarding detection limits is that data quality parameters
are usually concentration dependent. The standard error of the analytical
method being used increases as the concentration of the analyte of interest
decreases. The surest way for predicting what the accuracy and precision
will be for analyses at the detection limit is by generating QC data using
the detection limit concentration. In light of this decrease in the level
of certainty as the concentration decreases, the relationship between
action levels and detection limits should be considered carefully.

It is important to recognize that quantitative results reported at the
detection limit may not be reliable. If the action level of a contaminant
is 5.0 ug/l, an analytical method with a detection limit of 5.0 ug/l may
not provide suitable data to meet the criteria. For example, the action
level for trichloroethene (TCE) as defined by the Safe Drinking Water Act
as a proposed Maximum Contaminant Level (MCL) is 5 ug/l. Analytical method
624 for volatile organics by GC/MS has a detection limit of 5 ug/l.

However as analytical techniques have an inherent inaccuracy, especially near their detection limits, based on the objectives of the analysis, method 624 may not be applicable.

When levels of interest are at or approaching MDL, caution must be used in specifying precision in terms of a percentage. The use of percentages distorts accuracy and precision information when relatively small numbers are being compared. Accuracy and precision in terms of absolute values or ranges may be more appropriate. For example, consider a precision objective specifying that blind replicate samples must be within 50 percent of each other. If the two replicate concentrations are 50 and 75 ug/l, the use of this objective is reasonable. If the two replicate concentrations are both in the 1-10 ug/l range, the 50 percent objective would classify these results as being outside of criteria, whereas in all probability the replicate analyses show excellent precision. Caution must be used when applying objectives expressed in percentages to numbers less than fifty. If the precision objective is specified using a percentage, the working range of the objective should also be specified.

9.2.5 MATRIX EFFECTS

A matrix effect is a phenomenon that occurs when the sample composition interferes with the analysis of the analyte(s) of interest. This can bias the sample result either in a positive or in a negative way, with the negative bias being the most common.

The magnitude of a matrix effect is best assessed by the use of matrix spikes. Matrix spikes supply percentage recovery information which addresses the amount of bias present in the measurement system. This information can be used to adjust reported concentrations by the application of a correction factor based on percentage recovery. It is not recommended that sample values actually be adjusted for percent recovery unless a worst-case scenario is being developed. For non-aqueous matrices (soils, sediments, leachate, solid wastes, etc.), this type of data should be collected over the life of a project so that certain expectations about the quality of data being produced can be developed.

9.2.6 TENTATIVELY IDENTIFIED ORGANIC COMPOUND (TIC)

Under the CLP RAS procedures, 30 non-HSL peaks present in the reconstructed ion chromatogram are identified as tentatively identified compounds (TICs). Other laboratories may not address TICs or have different reporting criteria. If compounds of interest are tentatively identified by GC/MS and are high in spectra matching criteria (above 90 percent match) and above action levels, samples may be re-run against a standard in order to verify the compound's identity. Chromatographic retention time consideration is an important factor in assessing the probability of tentative identification reliability. Approaches for providing more reliable tentative identifications are under development.

9.2.7 DATA QUALIFIERS

When analytical data are validated, the analytical results and the associated QA/QC information are reviewed using criteria specific to the analysis performed. This review can range from superficial to very rigorous, depending on the level of analytical support utilized and the type of technical review requested by the data user.

Data qualifiers are commonly used during the data validation process to classify sample data as to its conformance to QC requirements. The most common qualifiers are listed below:

o A – Acceptable

o J – Estimate, qualitatively correct but quantitatively suspect

o R – Reject, data not suitable for any purpose

o U – Not detected at a specified detection limit (e.g., 10U)

Sample data can be qualified with a "J" or "R" for many different reasons. Poor surrogate recovery, blank contamination, or calibration problems, among other things, can cause sample data to be qualified. Whenever sample data are qualified, the reasons for the qualification are stated in the data validation report.   Data users are reminded that data validation is

generally performed using strict analytical criteria which do not take the sampling activity's DQOs into account. Data users should request that the technical staff interpret the validation report according to the sampling activity's objectives and data uses. For example, data qualified with a "J" may be perfectly suitable for some data uses.

9.3 ANALYTICAL UNCERTAINTY

Analytical uncertainty can be estimated for each compound or element of interest by method. Analytical uncertainty should be calculated for non-standard (Level V) or field (Level I) methods when possible.

In order to determine total analytical uncertainty, the accuracy and precision of the method must be known. Calculation of total uncertainty is based on the generally accepted assumption that there is a direct relationship between the accuracy and precision of environmental analyses and the analyte concentration and matrix of the environmental sample. The information required to develop meaningful calculations of analytical uncertainty would include interlaboratory information for matrix spikes, surrogate recoveries, duplicated and blind performance evaluation standards for each compound analyzed for each analytical procedures as follows:

o Statistical Information - N, bias, RSD of percent recovery, concentration of spike, and concentration of analyte

o Matrix - Air, aqueous, soil/sediment, leachate or source material

o Concentration Range - Liquids: 0-10 mg/l; 10-100 mg/l; 100-1000 mg/l or >1000 mg/l. Solids: <1 mg/kg; 10-1000 mg/kg; or >1000 mg/kg

If the above listed information is available, analytical uncertainty could be predicted for the majority of analyses conducted in support of remedial actions.

For example; based on N number of interlaboratory spike recoveries of benzene from ground water matrices, in the 0 to 10 ug/l concentration range using Method 624, the confidence interval at the 95 percent confidence

level can be stated. This statement would be further qualified based on the number and types of laboratories, other types of performance evaluation criteria, matrix strength, and other pertinent analytical information.

In the absence of the required information, uncertainty statements could still be made using available information, but would be somewhat more qualified. The confidence level associated with the analytical data will be directly related to how closely the QA/QC data base used to develop the uncertainty statement reflects the actual analytical conditions. In some cases, a significant deviation between the analytical conditions associated with the uncertainty statement and the actual analytical conditions could produce significant distortions.

Given that the statistical data described above are not presently available for all analytical support levels, the following represents an estimate of the type of uncertainty statements that can be produced for analytical support levels II, III, and IV, using available information.

9.3.1 LEVEL IV

Precision and bias data provided by the CLP RAS to be used in the estimation of analytical confidence limits include:

o Interlaboratory volatile organic matrix spike duplicate data for water and soil samples (N, percent RSD, percent RSD at 85th Percentile)

o "Interlaboratory" surrogate recovery data of generated volatile compounds from water and soil material (N, bias percent, percent RSD)

o Interlaboratory performance evaluation standard data for volatile and semi-volatile organic compounds in water and soil (N, bias percent, percent RSD).

In all cases, the data base has been sanitized, i.e., outliers have been removed. In the case of "interlaboratory" surrogate recoveries the data base should be considered interlaboratory in the classic sense - same sample submitted to a number of laboratories - but it is actually a close approximation. The same chemical surrogates are added to samples in

individual laboratories but the laboratories are not recovering the surrogate from the same matrix. In addition, recovery data should be provided for the air, leachate and source material.

All of this information can still be used individually or in concert to develop uncertainty statements but with some inherent limitations.

o   The interlaboratory matrix spike data as provided do not stratify the data with respect to concentration. Using this data would require the implicit assumptions that matrix recovery is independent of concentration and the laboratory in which the analysis was conducted.

o   The "interlaboratory" surrogate recovery data are generally for one concentration range and as a result do not account for variability of accuracy as a function of concentration, assume that all analytes act as surrogate during the analytical process, and do not account for interlaboratory variations associated with different matrices.

o   Interlaboratory performance evaluation standard data can probably be considered a "best case" for the development of uncertainty statements (actual samples would have a greater degree of uncertainty). The uncertainty associated with these data do not account for true sample matrix effects, or a wide range of analyte concentrations and as a result, the actual analytical uncertainty could only be worse than that estimated using this data set. It does have the advantage of being truly interlaboratory and blind (sample concentrations not known by participating laboratories) and should be a true measure of analytical uncertainty for the concentration range and matrix analyzed.

The best estimate of analytical uncertainty would be a composite of the uncertainty associated with matrix spike with the uncertainty associated with performance evaluation standards (interlaboratory performance only).

9.3.2 LEVEL III

The available information to estimate uncertainty for Level III is the accuracy and precision statements included with the individual EPA approved procedures in SW-846. While this information is rarely stratified as to matrix and concentration, it could serve as a starting point (best case) from which the uncertainty associated with the actual analytical conditions could be estimated.

9.3.3 LEVEL II

The most important factor that influences the uncertainty associated with Level II analyses is the skill of the analyst doing the work. Because the procedures used are not formalized, a great deal of improvization usually takes place. The inherent variability of the procedures themselves would make the development of a centralized quality assurance data base tenuous. The same reasoning would apply to making uncertainty predictions based on a centralized data base.

9.3.4 LEVEL I

Level I analyses are qualitative, and therefore it is not possible to quantify the uncertainty in these methods.

9.4 REFERENCES

Aleckson, K.A., J.W. Fowler and Y.T. Lee. 1986. Inorganic Analytical Methods Performance and Quality Control Considerations. In: Quality Control in Remedial Site Investigation: Hazardous Industrial Solid Waste Testing Fifth Volume ASTM STP 925.

American Public Health Association, American Water Works Association, Water Pollution Control Federation. 1975. Standard Methods for Examination of Water and Wastewater, 14th Ed.

American Society for Testing Materials. 1976. Annual Book of ASTM Standards, Part 31, "Water", Standard D3223-73, p. 343

Anderson, D.C., K.W. Brown and J. Green. 1981. Organic Leachate Effects on the permeability of clay liners. National Conference on Management of Uncontrolled Hazardous Waste Sites. pp 223-229. October 28-30, 1981 Washington, DC.

Bishop, J.N. 1971. Mercury in Sediments, Ontario Water Resources Comm., Toronto, Ontario, Canada.

Boston Society of Civil Engineers. 1985. Controlling Hazardous Wastes. Lecture Series.

Brandenberger, H. and H. Bader, 1967. The Determination of Nanogram Levels of Mercury in Solution by a Flameless Atomic Absorption Technique, Atomic Absorption Newsletter (6), 101

CDM. 1986 Draft Memorandum re: XRF Field Analysis of Smuggler Mountain Soil Samples from R. Chappel, R. Olsen to J. Hillman January 13, 1986 EPA Contract No. 68-01-6939 Document No. 149-WP1-EP-CCCU-1.

Federal Register, Organochlorine Pesticides and PCBs, Method 608; 2,3,7,8-TCDD, Method 613; Purgeables (Volatiles), Method 6224; Base/Neutrals, Acids and Pesticides, Method 625; Vol. 44, No. 233, Monday, December 3, 1979, pp. 69501, 69526, 69532 and 69540.

Flotard, R.D., M.T. Homshen, J.S. Wolff and J.M. Moore. 1986. Volatile Organic Analytical Methods Performance and Quality Control Considerations. In: Quality Control in Remedial Site Investigation: Hazardous and Industrial Solid Waste Testing, Fifth Volume ASTM STP 925.

Garbarino, J.R. and H.E. Taylor, 1979. An Inductively-Coupled Plasma Atomic Emission Spectrometric Method for Routine Water Quality Testing. Applied Spectroscopy 33, (3)

Garner, F.C., M.T. Homsher and J.G. Pearson. 1986. Performance of USEPA Method of Analysis of 2, 3, 7, 8 – Tetrachlorodibenzo-P Dioxin in Soils and Sediments by Contractor Laboratories. In: Quality Control in Remedial Site Investigation: Hazardous and Industrial Solid Waste Testing Fifth Volume TSTM STP 925.

Goulden, P.D. and B.K. Aighan, 1970. An Automated Method for Determining Mercury in Water. Technicon, Adv. in Auto. Analy. 2 317

Government Institutes. 1982. Superfund Comprehensive Environmental Response, Compensation, and Liability Act of 1980. Third Edition.

Hatch, W.R. and W.L. Ott, 1968. Determination of Sub-Microgram Quantities of Mercury by Atomic Absorption Spectrophotometry Analytical Chemistry 40: 2085.

Kopp, J.F., Longbottom, M.C. and Lobring, L.B. 1972. Cold Vapor Method for Determining Mercury. AWWA, 64:20.

Martin, T.D. (EMSL/Cincinnati). Inductively Coupled Plasma – Atomic Emission Spectrometric Method of Trace Elements Analysis of Water and Waste, Method 200.7, Modified by CLP Inorganic Data/Protocol Review Committee.

Martin, T.D., J.F. Kopp, and R.D. Ediger, 1975. Determining Selenium in Water, Wastewater, Sediment and Sludge by Flameless Atomic Absorption Spectroscopy. Atomic Absorption Newsletter 14: 109

Owerbach, D. 19__ The Use of Cyanogen Iodide (CNI) as a Stabilizing Agent for Silver in Photographic Processing Effluent Sample. Photographic Technology Division, Eastman Kodak Company, Rochester, New York, 14650.

Shackelford, W.M., D.M. Cline, L. Faas, and G. Kurth, 1983. An Evaluation of Automated Spectrum Matching for Survey Identification of Wastewater Components by Gas Chromatography – Mass Spectrometry. Analytica Chimica Acta.

Technicon Industrial Systems. 1980. Operation Manual for Technicon Auto Analyzer 11C System. Technical Pub. #TA9-0460-00, Tarrytown, New York.

U.S. EPA. 197_ Handbook for Analytical Quality Control in Water and Wastewater Laboratories, USEPA-600/4-79-019.

_____. 1973. Handbook for Monitoring Industrial Wastewater, USEPA Technology Transfer.

_____. 1974. Methods for Chemical Analysis of Water and Wastewater, USEPA Technology Transfer.

_____. 1979. Methods for Chemical Analysis of Water and Wastes. 600/4-79-20.

_____. 1981. EMSL, Users Guide for the Continuous Flow Analyzer Automation System. Cincinnati, Ohio.

_____. 1982. Test Method for Evaluating Solid Waste. Physical/Chemical Methods. SW-846. 2nd Edition.

_____. 1982. Office of Solid Waste and Emergency Response, Modification (By Committee) of Method 3050. SW9846, 2nd Ed., Test Methods for Evaluating Solid Waste. July.

_____. 1984. Soil Properties, Classification, and Hydraulic Conductivity Testing. Draft-Technical Resource Document for Public Comment. SW-925.

_____. 1984. Solid Waste Leading Procedure. Draft-Technical Resource Document for Public Comment. SW-924.

_____. 1984. Toxicity Characteristic Leaching Procedure (TCLP) - Draft Method 13XX. TK0703.

_____. 1984. OERR. User's Guide to the Contract Laboratory Program.

_____. 1984. Test Methods for Evaluating Solid Waste, Physical/Chemical Methods. SW-846.

_____. 1984. Calculation of Precision, Bias and Method Detection Limit for Chemical and Physical Measurements. (QAMS Chapter 5.)

_____. 1986. Demonstration of a Technique for Estimating Detection Limits with Specified Assurance Probabilities. Contract No. 68-01-6939.

Winefordner, J. D., Trace Analysis: Spectroscopic Methods for Elements. Chemical Analysis, Vol. 46: 41-42.

Winge, R.K., V.J. Peterson, and V.A. Fassel, 1970 Inductively Coupled Plasma - Atomic Emission Spectroscopy Prominent Lines. EPA-600/4-79-017.

Wise, R.H., D.F. Bishop, R.T. Williams, and B.M. Austern, 19__ Gel Permeation Chromatography in the GC/MS Analysis of Organics in Sludges. USEPA, Municipal Environmental Research Laboratory; Cincinnati, Ohio 45268.

Wolff, J.S., M.T. Homsher, R.D. Flotard and J.G. Pearson. 1986.
  Semi-volatile Organic Analytical Considerations. In: Quality Control in
  Remedial Site Investigation. Hazardous and Industrial Solid Waste
  Testing, Fifth Volume, ASTM STP 925.

10.0 SAMPLING CONSIDERATIONS

The uncertainty introduced by sampling procedures must be considered during the development of DQOs. Factors which affect sampling uncertainty include sampling/handling variability and the variability of contaminants as a function of location and time. The magnitude of each of these factors is largely site specific. The site specific nature of sampling uncertainty distinguishes sampling from analytical uncertainty, which is largely site independent.

In this section, factors associated with sampling uncertainty are discussed. Discussion of specific sampling methods is not provided. Rather, the discussion centers on how and why each factor influences sampling uncertainty and provides general guidance on sampling considerations to be evaluated during DQO development. Rigid guidelines for sampling design are not provided because of the site specific nature of the sampling uncertainty.

10.1 SAMPLING STRATEGY

In designing a sampling plan there are a large number of factors which must be considered. Some of these factors such as the physical characteristics of the site (geology, hydrogeology, physiography) are unique to each site. However, there also are several general factors which must be considered for all sites. The general factors include decisions addressed during the DQO process such as:

   o Will a phased approach be used?

   o Will samples be collected for site characterization?

   o Will samples be collected for confirmation purposes?

   o Will grab or composite samples be collected?

   o Will a grid system be used?

The importance of each of these factors varies from site to site, and therefore must be analyzed individually.

Remedial investigations are undertaken to collect the data needed to evaluate and select appropriate remedial actions to be implemented at a site. The type of data collected will vary depending on the media of interest. Although most RIs require that multi-media sampling be performed, in some cases the sampling may be limited to one medium. The level of detail to which an investigation is undertaken is influenced by the amount of existing data and by the remedial actions which could potentially be implemented at the site.

For sites at which a significant amount of data have been generated as a result of preliminary assessments and site investigations a focused approach to the RI can be developed. For sites for which little or no data are available or data are inconclusive, a broader approach to site investigations must be implemented.

In all cases, the RI should be directed towards providing the information required to select and implement a remedial action. It may be quite obvious at the outset of an RI/FS that the major source of contaminants at a site is a lagoon, for instance. The RI should therefore be geared towards identification of the characteristics of the wastes in the lagoon which would govern the manner in which it could be disposed of (i.e., PCB content, RCRA parameters etc.). The RI must also provide information relative to the quantity of waste material which must be disposed of or treated in order to allow for development of cost estimates during the feasibility study.

10.2 SAMPLING PROGRESSION

Samples obtained at uncontrolled hazardous waste sites during a remedial investigation are obtained in a progressive manner to allow for expansion of the data base in a controlled manner. Due to the heterogeneity of materials present and the variability of environmental conditions at sites, it is difficult in most cases to develop a work plan which will encompass all environmental measurement activities which may be undertaken in order to satisfy the RI/FS and RD. Because of the variable nature of sites, RIs must be designed in a manner which allows for flexibility and adjustment of

sampling approaches based on data which are continually obtained during field investigations. This type of progressive sampling approach can be accommodated by implementation of a phased RI/FS.

In the DQO process it may be necessary to identify a sampling approach before sufficient information has been gathered to use statistical methods as discussed in Section 8.0. In these cases, it may be beneficial to use a phased data collection approach. In a phased approach, samples are collected in a series of independent sampling events. The first phase may be undertaken for site characterization purposes while subsequent phases use the information generated by earlier phases to fill in data gaps. If a mobile lab is utilized, phases may be continuous as results are analyzed and data gaps are identified and filled. The DQO process applies to each phase of an RI and for each sampling task. Initial sampling undertaken during the first phase may not yield specific information since little or no site specific data may be available. However, in subsequent phases of the RI more data will be available for decision making.

A phased approach to sampling is, in most cases, a cost effective method since areas of concern are identified in the early phases and are then targeted for additional sampling. When sampling is performed in only one phase, every conceivable target must be completely sampled. If one or several of the targets prove to be uncontaminated, a large number of unnecessary samples will have been taken.

Phased approaches must be developed on a site specific basis but generally will follow sequentially from less intensive to progressively more sophisticated field sampling and analysis programs as follows:

o Review of existing information/data

o Remote sensing

o Field screening

o Intrusive sampling

o Pilot studies

10.2.1 REVIEW OF EXISTING INFORMATION/DATA

All sources of available information should be obtained and reviewed during the initial stages of the RI/FS work plan preparation process. It is especially important to obtain and review data from any previous investigations gathered in the National Priorities List (NPL) ranking process, FIT and/or TAT team investigations, and other data gathering activities conducted by the state or other parties. Detailed discussions of the various data sources which should be accessed during review of existing information are contained in the Remedial Investigation Guidance Document (EPA, 1985).

10.2.2 REMOTE SENSING

Remote sensing is a term applied to methods used for the detection, recognition, or evaluation of objects or conditions by means of distant sensing or recording devices including aerial photography or satellite imagery. Geophysical techniques are in fact remote sensing methods which allow for the characterization of subsurface conditions without excavation. For the purposes of this document, remote sensing will be used to denote airborne data collection techniques and geophysical methods are those applied at the earth's surface.

Remote sensing/geophysical techniques are used in RIs to obtain data on site conditions while minimizing disruption of the site environs. These techniques are used extensively for selection of sampling points and siting for installation of in-situ monitoring devices such as ground water monitoring wells.

Remote sensing and geophysical techniques can be applied as a tool in the overall remedial investigation of a hazardous waste site. However, in no instance should remote sensing or geophysical techniques be utilized in the place of disruptive techniques for the confirmation of data obtained. Remote sensing and geophysical techniques should be used in conjunction with disruptive techniques to adequately characterize a site. Remote sensing/geophysical techniques can be used to:

o Map geohydrologic features — both natural and those changed by man

o Map conductive and nonconductive contaminant plumes in both the
   saturated and unsaturated zones

o Locate and define the horizontal and vertical extent of buried
   materials

o Locate and define buried objects such as drums, tanks, pipes,
   conduits, etc.

o Locate and define sources of contamination

Remote sensing/geophysical techniques provide data that are useful in the
performance of RIs. The information can be useful in development of DQOs
when generated early in the RI process. Remote sensing/geophysical
investigations should be used in the initial stages of RIs in order to gain
an overall sense of the site environs (aerial photographs) and subsurface
conditions. These techniques may also be utilized in the latter phase of
the RI to provide a means for extrapolation of data obtained from
disruptive techniques. For example, soil borings installed at a site may
reveal the presence of a clay lens over a portion of a site which could
affect ground water migration. Geophysical techniques could be used to
provide information on subsurface conditions between the soil borings and
allow for a determination of the nature of subsurface conditions. In the
absence of this information, an extrapolation of the soil strata between
the borings may result in an erroneous interpretation of subsurface
conditions.

When geophysical techniques will be utilized, the RI/FS process should be
phased to allow for interpretation of the remote sensing/geophysical data
and application of this information in the process for subsequent RI
phases.

Data obtained upon completion of each successive phase should be evaluated
in order to determine if the subsequent phase should be modified.
The results of geophysical investigation may provide information on the
suspected areal extent of a contaminant plume. This information can be
used in the DQO process for guiding selection of sampling points or

monitoring well installation locations. Rather than establishing a grid system over the entire site, the results of the geophysical investigation could be used to guide in the establishment of a targeted sampling grid. Although this may introduce bias into the sampling approach from a statistical perspective, the value of taking a completely unbiased approach must be weighed against the cost, schedule and overall objectives of the RI/FS. Likewise, selection of sampling locations at random for a site may not take into account accessibility of areas to drilling rigs, for instance. Modification of the sampling locations are necessitated by safety considerations as well as practical considerations.

In establishing a grid system for sampling, remotely sensed information such as aerial photographs are required at a minimum. This information is useful in determining which areas may not be accessible for drill rigs or not practical to sample because of other restrictions (e.g., rock outcrops, water bodies). Final sampling locations are also modified in the field based on the information available to the investigator. For example, magnetometry or radar may indicate that buried drums are present in a localized area. The investigator may therefore choose to relocate the soil boring location based on safety considerations. Relocation of the sampling point should be justified and should not be construed as diminishing the quality of the data, since the investigator is relocating the sampling point through a logical, thorough process.

Remote sensing and geophysical techniques can be considered as survey methods to define areas in which investigations should be undertaken. The limits of these areas (i.e., lateral and vertical extent) and the characteristics of these areas (i.e., degree of contamination) must be determined based on detailed sampling plans. Remote sensing/geophysical investigation methods provide information necessary to develop a systematic approach for sampling.

Remote sensing or geophysical techniques are generally not applied to sites in a random manner. These techniques are generally used to characterize a specific area of interest (i.e., historical aerial photographs of site to identify areas used for waste disposal or aerial photos to define limits of

a watershed). Geophysical techniques may be used to confirm areas with suspected buried wastes. Those survey techniques are therefore applied to areas based on an investigator's knowledge or bias regarding the site.

10.2.3 FIELD SCREENING

Field screening is primarily used to provide indications of contamination (e.g., Level I & II - Field Screening). Thus, the decisions that will be based on the results of this type of sampling are in many cases yes/no type decisions. For instance, on the basis of soil gas sampling it may be determined that contamination of a particular unconfined aquifer is indicated and further direct sampling is warranted.

10.2.4 INTRUSIVE SAMPLING

Intrusive sampling includes all methods in which a physical sample from the media of concern is obtained. Intrusively obtained samples are used to obtain a numerical value for a physical or chemical measurement at a particular point. Intrusive sampling provides much more exact information concerning the concentration of contaminants or physical features than non-intrusive remote sensing or field screening techniques.

All intrusive sampling methods are used to obtain physical samples of material from the media of interest. Samples may be highly variable for some sampling methods. For instance, when sampling a stream at a particular location, the source of any contaminants found is uncertain. Since the stream is a dynamic system, the concentration of contaminants is expected to vary substantially over time and therefore a higher level of variance is associated with this sample. Other examples of direct samples with high variance are:

o Storm water runoff samples

o Cuttings sampled from a solid stem auger

o Ground water samples from wells with very large screened intervals

For each of these types of samples it is difficult to specify the exact position from which any contamination originated. All of these sample types will have large variability associated with them. These types of direct samples are often used to investigate suspected contamination pathways or to obtain background site information.

The highest level of confidence is associated with data obtained from samples taken at precise locations in relatively stable media such as soil. Such data are not expected to have high temporal variability. Examples of data which would be expected to have low temporal variability include:

o Soil samples obtained from a split spoon

o Ground water samples from a monitoring well

o Surface water samples from a lined lagoon

o Sediment samples

This type of data is required if decisions requiring precise point estimates of contamination will be made.

It should be noted, however, that over time contaminant concentration may increase in any media as the source materials are subject to leaching. Contaminant migration may in some cases approximate the behavior of a wetting front, where a high concentration of contaminants analogous to the advancement of a wetting front in soil. The concentration of contaminants may be very low ahead of the wetting front and significantly greater at the wetting front. In other cases, dispersion may be a major factor to consider. In these cases, the contaminants may disperse through an aquifer system at low levels. Soil contaminant evaluation models should be utilized in evaluating these situations.

Intrusive samples are obtained to determine the contamination within the site. These samples can be obtained to investigate suspected contaminant pathways, identify contaminants present in the waste material, measure contaminant concentrations for health and safety purposes, or examine the contamination present in a municipal well. Intrusive sampling generally

entails different levels of data quality. For example, samples taken to determine if a municipal well is contaminated require much higher data quality than samples used to determine the range of contaminants present at a site. Thus, careful analysis of the uses and purposes of intrusive samples must be undertaken during the DQO process.

10.2.5 PILOT STUDIES

Pilot studies are undertaken to obtain data to assess the applicability of various proposed alternatives for site remediation in a controlled manner. In general, pilot studies can be designed to allow for control of variables and thereby generate high quality data. Pilot studies include soil column tests in which a known quantity of waste is applied to a known mass of soil over a fixed period of time to evaluate the attenuation capacity of the soil. Pilot testing could also entail isotherm testing to evaluate the adsorption capacity of carbon for a specific compound present in ground water associated with a site. In this type of approach, known quantities of adsorbant are mixed with ground water containing various concentrations of the contaminant of concern to construct isotherms.

Pilot studies can also be undertaken to evaluate the effectiveness of various unit processes for treatment of a contaminant source at a site or for developing data needed to optimize system design and operation.

Pilot treatability studies are undertaken to evaluate the technical performance of a unit process or system. Optimization testing of the system is generally undertaken to determine the most effective set of operating parameters for the system. During optimization testing the sensitivity of overall system performance for each parameter is evaluated. The results of pilot treatability studies are used to develop design criteria; develop cost estimates; and to identify any special management or operational constraints which must be implemented in order to utilize the system.

The approximate range of applicability of treatability procedures for various contaminants is given in Figure 10-1. Water quality parameters which should be determined to evaluate the potential effectiveness of treatability schemes are given in Table 10-1.

10.3 SOURCES OF VARIABILITY

To determine the uncertainty associated with a decision, all sources of variability must be identified and either measured or inferred. Other important sources of variability are sampling/handling variability and the variability of contaminants as a function of location and time. Of these three sources of variability, the variability of the contaminants as a function of location is expected to be the largest.

10.3.1 SAMPLING/HANDLING VARIABILITY

Sampling/handling variability is defined as any variability introduced by the sampling and/or handling procedures, resulting in a contaminant concentration in the sample that is different than the concentration in the original media. Causes of sampling variability include incorrect sampling procedures and cross contamination. Since most of the causes of sampling/handling variability are related to errors in procedures, measurement of sampling variability is difficult. The magnitude of sampling variability can range from small to very large; however, if correct sampling and handling procedures are followed, sampling variability should be small compared to laboratory variability.

Sampling/handling variability can effectively be reduced by thoroughly training sampling personnel and ensuring that all sampling is performed in accordance with standard operating procedures (SOPs). SOPs are developed to ensure that any samples collected are representative of the undisturbed media of interest. By adhering to the SOPs, intra- and intersite variability for a given sampling method are greatly reduced or eliminated.
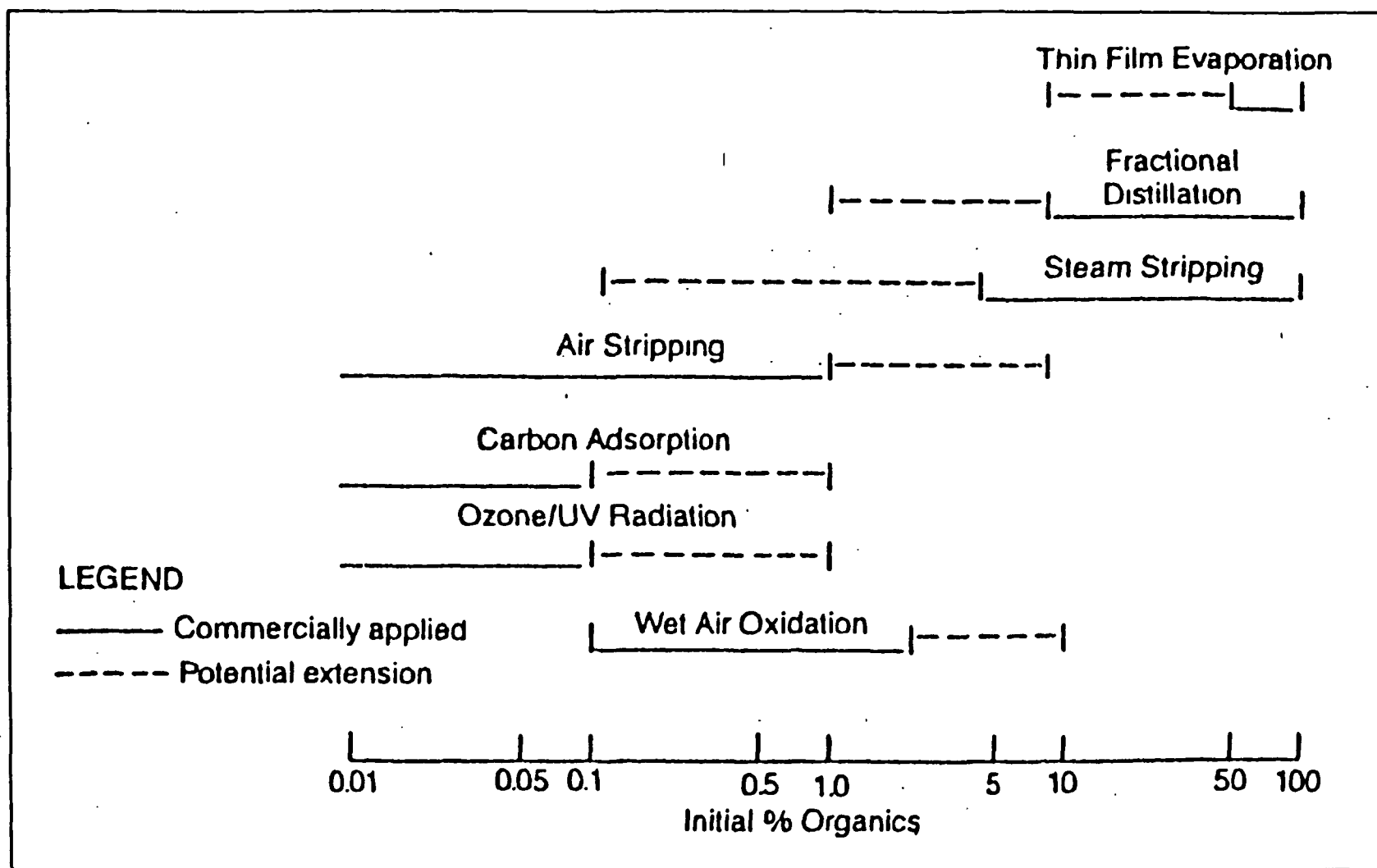
SOURCE: Allen, C.C. & B.C. Brancy, 1985. "Techniques for Treating Hazardous Wastes to Remove Volatile Organic Constituents," JAPCA, Vol. 35 No. 8, August 1985.

FIGURE 10-1

**APPROXIMATE RANGES OF APPLICABILITY OF VOC
REMOVAL TECHNIQUES AS A FUNCTION OF
ORGANIC CONCENTRATION IN LIQUID WASTE STREAMS**

TABLE 10-1

CONVENTIONAL WATER QUALITY PARAMETERS
FOR TREATABILITY STUDIES

o Iron (mg/l)

o Manganese

o pH

o Total dissolved solids

o Total suspended solids

o Total organic carbon

o Total organic halides

o Hardness

o Alkalinity

o Organic color

o Chemical oxygen demand

o Filtered and unfiltered metals

Sampling/handling variability is expected to be largest for volatile organic compounds. During sampling, care must be exercised to avoid volatilizing these compounds. Samples must be kept cool and separated from organic fumes during shipping and handling to avoid migration of organic compounds out of or into the sample vial. Measurement of any migration of organic compounds into the sample can be performed by shipping trip blanks along with the samples.

Another important component of sampling/handling variability is cross contamination. Cross contamination can be caused by improper decontamination of sampling or downhole instruments. Cross contamination can be greatly reduced or eliminated by following proper procedures. Cross contamination can be identified through the use of field blanks.

10.3.2 TEMPORAL VARIABILITY

Many observed contaminant concentrations are dependent on time related variables such as the time of day or season of the year. The important variable linking concentration and time is often climatological (i.e., temperature or rainfall). Since the linking variables (temperature, for instance) follow cyclical patterns over a day or year, time dependent contaminant levels are also expected to follow cyclical patterns. To obtain representative samples of time related variables, it is important to identify the cyclical nature of the contaminant concentrations and to sample at various phases of the cycle to obtain a representative sample. Some general considerations related to influences of seasonality on data for the following media are contained herein: air, surface water, ground water and soil. Discussion of other environmental media such as biota are not included.

Air – Assessment of atmospheric contamination at uncontrolled hazardous waste sites is accomplished by use of real time monitoring devices or collection of air samples in bags, of particulates on filters, or of volatiles on sorbents to be analyzed in the laboratory. Seasonal variations in climate as well as weather conditions at the time of sampling may affect all of these sample types.

Volatile organic levels in the atmosphere would generally be expected to rise as temperatures increase, provided the volatilization from the source is not limited by some other factor. Temperature changes associated with the seasons may have a pronounced impact on volatile organic levels emanating from a source. Daily fluctuations in temperatures within any season would also be expected to significantly affect volatilization rates. In order to obtain meaningful data, it is necessary to establish what the data will be used for. If the intent is to determine the risk associated with volatile emissions to on-site workers, an evaluation of the conditions over the work day within the season of interest may be adequate. If, however, the potential risks to sensitive receptors are required, an assessment which takes into consideration variations of conditions over the night as well as diurnal fluctuations would be required.

Monitoring of air quality should be geared to provide information of use in assessing site conditions. Air monitoring on clear, calm days may provide data necessary to establish baseline conditions, however, it may not provide accurate information relative to particulate contaminant dispersion associated with windy conditions. Likewise, sampling for particulates when a snow cover exists would not likely provide information useful to assess offsite migration as a result of wind erosion.

Sampling during precipitation events can significantly affect data not only because of its impact on air quality but also because of the impact moisture has on most air sampling devices and real time monitors. Precipitation washes particulates as well as volatiles from the air; therefore, risks associated with particulates and volatiles would be less during rain events. Precipitation adversely affects electronics of some real time monitors, resulting in false readings. Rain also hinders the collection efficiencies of sorbent tubes such as tenax and charcoal as well as personal sampling pumps. Therefore, sampling of air during rain events may not provide data of value in undertaking an RI.

Surface Water/Ground Water – Surface water and ground water quality vary seasonally as influenced by the hydrologic cycle. Inputs to the cycle which are associated with precipitation or snow melt output include evapotranspiration and evaporation. Interconnections between surface waters and ground waters also affect quality of these media. Contaminated ground waters discharging to surface waters may adversely affect the quality of the surface waters and vice versa. The degree to which surface waters and ground water are related is dependent in part upon geologic conditions. Where these media are intimately related, a change in the quality of one may be manifest in the other in a very short time.

Where surface waters and ground water are in close communication, seasonal changes in water quality may be closely correlated. In areas where ground water is separated from surficial waters (i.e., confined aquifer), seasonal changes may not be as significant.

Sampling of surface waters and ground waters must be undertaken in a manner which will provide data representative of the media. Sampling of a stream during low flow, for instance, may not provide a representative depiction of the quality of the stream if an assessment of the impact of the flow on downgradient receptors is required. In order to obtain data which can be used in evaluating the potential impacts of a stream containing contaminants on downstream receptors such as wetlands or a water supply, data quality and quantity determinations over the range of seasonal conditions should be obtained.

During high flow conditions, the concentration of contaminants in a stream may be decreased as a result of dilution, or in some cases may be elevated if contaminants are flushed from a source or erosion of contaminants associated with soil results. Therefore, surface water conditions should be monitored over a period of time adequate to account for seasonal variations. Monitoring of meteorological conditions during the sampling period is necessary in order to provide a means to interpret the data.

Surface water temperatures also vary seasonally and as such can influence the chemical data obtained. In stagnant surface water systems, evaporation can have a concentrating effect on chemicals. In addition, elevated temperatures, within a certain range, can accelerate the rate of biodegradation or volatilization. Therefore, organic levels may decrease in some instances, only to rebound once biodegradation rates decline, provided the contaminant source continues to discharge to the surface water at a constant rate.

Variations in ground water quality as a result of seasonal changes may not be as pronounced as those observed in surface water. For instance, ground water temperatures encountered at depth do not vary significantly with seasons or on a daily basis. Perched ground waters encountered near the soil surface, however, do experience diurnal fluctuations in characteristics, as well as being subject to seasonal influences. The degree to which these variations are manifest is related in part to topographic position. Figure 10-2 illustrates the relative rise in a perched ground water table in response to a rainfall event. The perched water table in the lower elevations will show a more pronounced response to the rainfall event than those at upper elevations due to the contribution of water from upslope areas. The confined aquifer underlying this area does not respond to the event in the short term. The lag period during which the changes in ground water elevations result is related to the characteristics of the media in which the ground water occurs as well as the intensity of the event.

Although ground water quality is subject to change over time, these changes usually occur at a slower rate than observed in surface waters. The quality of ground water is more closely associated with the characteristics of its host rock or formation than with seasonal influences. Therefore, ground water sampling programs generally do not include components to evaluate seasonal variations. Nonetheless, time series analyses are required in order to evaluate change as a result of contaminant introduction to the system.
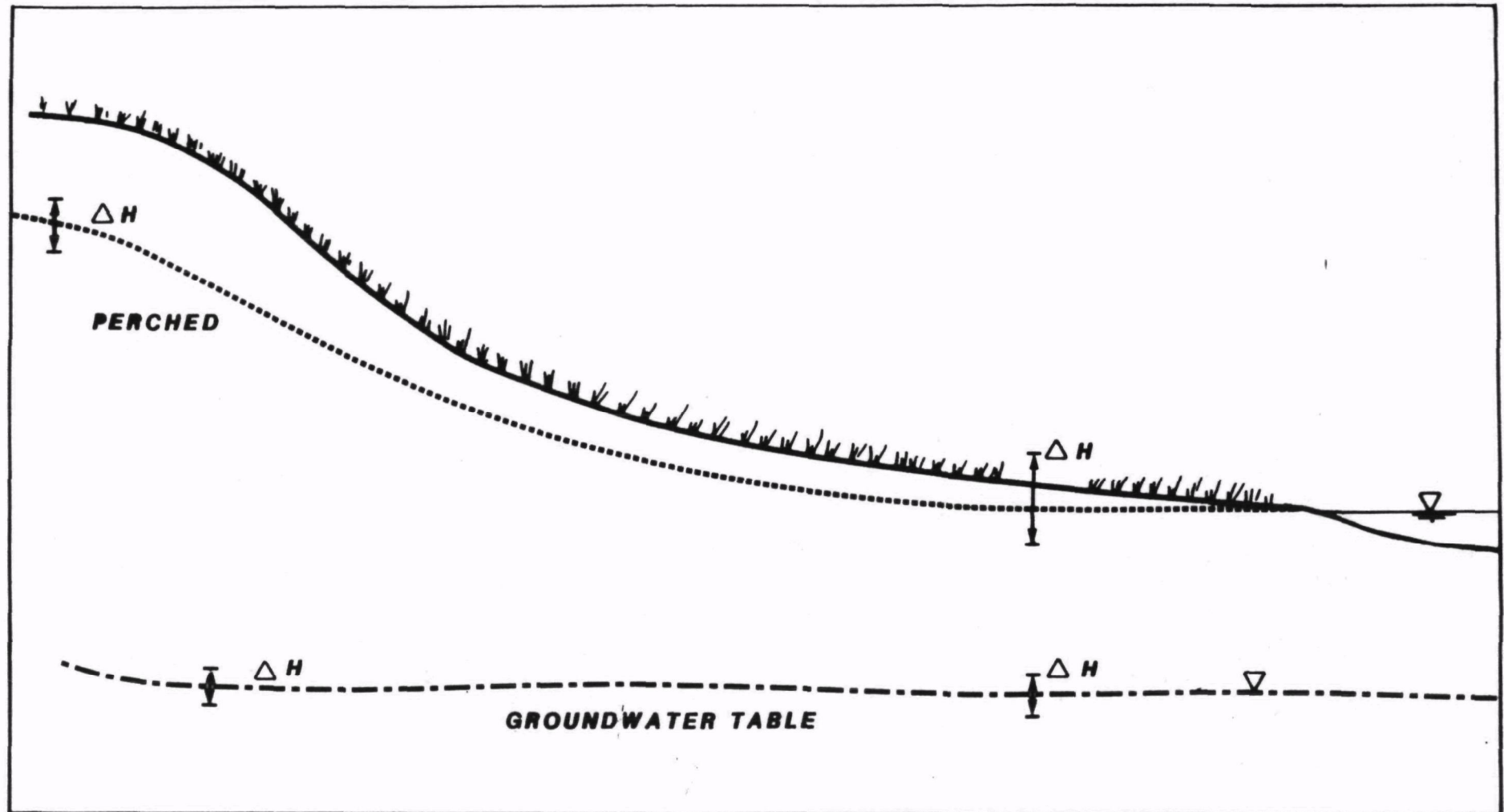
FIGURE 10-2
RELATIVE RISE IN PERCHED WATER TABLE
AND GROUND WATER TABLE IN RESPONSE TO RAINFALL
EVENT

Soil - The influences of climate and weather on soil conditions are most pronounced at the surface and become less apparent with increasing depth, becoming negligible at depths greater than 20 feet. The rates at which chemical compounds undergo biodegradation or volatilization will be influenced by temperature and by the water content of the soil. Increases in the water content of soil will result in decreases in the rate of diffusion of gases to the soil surface and thus reduced volatilization rates. Soil which becomes saturated may not be conducive to aerobic degradation of compounds although anaerobic decomposition may take place. These types of variations in soil conditions brought on by seasonal changes are important with respect to remedial investigations. In developing data quality objectives, efforts should be taken to ensure that the data obtained are of value in evaluating alternatives. Volatilization of organics from a soil sample obtained to assess the impacts of organics on workers during excavation should be undertaken in a manner which would simulate conditions expected during the period of planned excavation. Samples taken during the winter should be allowed to equilibrate to a temperature anticipated to be encountered during a summer excavation program for instance.

In many of the examples of temporal variability which have been discussed, contaminant concentrations vary over a yearly cycle. To measure the total change in concentration over the period of the cycle, samples must be taken over the course of a year. Such sampling does not fit conveniently into the normal framework of an RI/FS. Schedule and budget constraints can preclude the use of seasonal samples. In such cases, the occurrence of seasonal variation should be noted and an estimate of the effects of the seasonal variation should be made if possible.

10.3.3 SPATIAL VARIABILITY

Spatial variability describes the manner in which contaminants vary as a function of location. Although this source of variability is normally not considered explicitly, it is implicitly expected. It is intuitive that soil samples taken at locations separated by 10 ft will have different levels of contamination. The magnitude of the difference in contaminant

concentration of samples separated by a fixed distance is a measure of spatial variability. The level of spatial variability is site and contaminant specific. When spatial variability is high, a single sample is likely to be unrepresentative of the average contaminant concentration in the media surrounding the sample. Thus, although it is important to recognize the nature of spatial variability at all times, it is crucial when the properties observed in a single sample will be extrapolated to the surrounding volume (i.e., when estimating mean site contamination).

The variability of contaminants in space tends to be a combination of two components termed the trend component and the random component. The variability seen in samples separated by large distances is due primarily to the trend component. Trend describes the large scale changes in the value of a variable over space so that a contour map is essentially a map of trend. Superimposed on the trend is the random component of variability. As the distance between a pair of sample locations decreases, the importance of random variability increases.

As an example of why spatial variability contains both trend and random components, consider the movement of contaminants in ground water. The migration of ground water contaminants is driven primarily by the hydraulic gradient present in the aquifer. The gradient causes the contaminants to spread in one primary direction, thus causing a trend or gradient in contaminant concentration. However, as individual contaminant particles move, the possible pathways in the direction of the hydraulic gradient are controlled by the configuration of the pore space in the aquifer. Thus, individual particles tend to follow different complex flow paths which lead to dispersion of the contaminant plume. Because of particle dispersion, the contaminant concentration within the plume is much more variable than the hydraulic gradient, which is the driving force behind the migration of the particles. This variability introduced by particle dispersion is one source of the random component of variability.

Spatial variability is a large portion of the total variability of contaminants, so measurement of spatial variability is important in determining DQOs. Measurement is possible through the use of geostatistical tools such as the semi-variogram (see Section 8.0).

10.4 SAMPLE TYPES

During the DQO development process the decision maker and data users must determine which types of samples should be obtained during the RI. The types of samples required to characterize a site may differ from those required to perform a pilot study. An evaluation of the intended use of the data must be undertaken in order to ensure that the type of sample obtained provides the necessary information to address the issues of concern. In determining the types of samples which should be obtained the following issues should be considered:

- o Media vs. waste samples

- o Grab vs. composite samples

- o Filtered vs. unfiltered samples

- o Random vs. non-random sampling

- o Biased vs. unbiased sampling

10.4.1 MEDIA VS. WASTE SAMPLES

Media or environmental samples refer to sampling of air, water, soils, and other environmental media to determine the extent of contamination. Waste samples refer to the sampling of the actual wastes. Typically this will mean drum, impoundment, tanks, or other areas where waste has been suspected of accumulating.

Whether considering a site investigation (SI), remedial investigation (RI), feasibility study (FS), or a removal activity, sampling will involve both investigation of general environmental media and specific waste accumulation areas. General questions regarding environmental media include:

o Which media are contaminated? (air, water, soil, ground water, biota)

o What is the average contamination?

o What is the total contamination? (mass, volume)

o What is the maximum contamination? (concentration)

o What area of the site is contaminated?

o What is the vertical and horizontal extent of contamination?

Each of these questions requires different sampling considerations. Clearly, the techniques and specific data collection factors pertaining to air will not be the same as those for ground water or any other media. However, in general, in order to answer these or related questions the collection information must be used on a sampling plan capable of being used to draw conclusions regarding the general state of the environment at the site.

Waste samples are those collected from drums, tanks, lagoons, pits, waste piles, fresh spills, and other areas of waste accumulation. The specific area or container being sampled differs from the media samples in two ways: (1) the questions asked of the data and (2) the general characteristics of the materials being sampled. The most common questions are concerned with waste characterization:

o What contaminants are present?

o Do these contaminants exceed any criteria or standards?

The areas sampled differ from environmental samples in three ways: the bounds of the contaminated area are better defined, the factors which might affect the analysis are better understood than media testing, and waste data tend to have greater variations than media samples.

With regard to the first point, tanks, drums, and even impoundments are clearly defined by their boundaries. In environmental sampling this is not the case. Always at issue in media sampling is how to define the area of interest.

Furthermore, the analyst is better prepared for the variability in the data. When sampling a lagoon, one knows to look for vertical and horizontal variations in the waste. In fact, the vertical variations are more likely. RCRA guidance for sampling impoundments and lagoons should be carefully reviewed since these guidance documents imply that compositing vertically within the waste area is an acceptable procedure.
Finally, waste areas can show dramatic variations when compared to environmental sampling. In many instances, because of the high concentrations and the large variations that are possible, composite sampling may offer the best opportunity for characterizing the waste.

10.4.2 COMPOSITE VS. GRAB SAMPLES

Grab samples are discrete aliquots which are representative of a specific location at a specific point in time. Composite samples represent the mixing of a number of grab samples and typically represent an average value. In the most common case, two or more grabs are actually added to the same container, mixed, and then a single aliquot is taken from the mixture. However, other forms of composite sampling might be from radiation badges or body samples for lead readings. In both these cases, the measurements would be over a number of hours and would not represent a single sampling location or time.

When developing or reviewing a sampling plan, it is important to consider the uses of grab and composite samples. Grab samples offer the most information regarding variation of the contaminants. Grabs can be used to

analyze time, area, sample collection errors and any other factors which relate to time and point of collection. However, composite sampling offers better estimators of average and total contamination at a site when comparing the same number of grab samples analyzed as composite samples. This occurs because in order to collect each composite, at least two grabs were collected. Thus, the actual number of samples collected is at least twice as many as a grab sample design.

In the previous discussion of waste samples, composite sampling was recommended because this method tends to average data. The large variations present in waste data are dampened by composite sampling, and thus, better estimates of the amount of contaminants present can be calculated.

10.4.3 RANDOM vs. NON-RANDOM SAMPLING

Random sampling is any method of choosing sampling locations which is based on random chance probabilities when the probability of choosing a single location is known. Non-random sampling is any other form of choosing sampling locations. The purpose of random sampling is to collect information which can be used to extrapolate or make inferences about the general population being sampled. Non-random sampling may be chosen when information regarding specific points is more important than general inferences about the population at large.

There are many sampling schemes which might not appear random at first reading, but as long as the above rules are followed, random sampling will be achieved.

Three types of sampling typically used in analysis are:

o Simple random sampling

o Systematic sampling

o Stratified random sampling

How well one method reduces variation versus its cost becomes the basis of preference. Sampling methods are always evaluated relative to their performance versus cost.

Simple Random Sampling - This form of sampling is used when there is not information available on the area or media being sampled which might help the designer of the sampling protocol account for variation in the population being sampled. Since information on the population being sampled is necessary for calculating the sample size and for more intricate sampling procedures, it is not uncommon for a pre-sample to be collected. Often this is done using simple random sampling to collect a small amount of information to make decisions regarding the type of data collection program and the amount of data.

Systematic Sampling - Systematic sampling involves the collection of samples at predetermined, regular intervals. A good example is soil sampling where a grid is designed so that each point sampled is equi-distant from its neighboring points.

Though this is a commonly employed sampling scheme, care must be taken to avoid bias; this is no easy task. The nature of systematic sampling offers the impression that all data are equally likely to be sampled and thus, the possibility of introducing bias is small. Yet, this assumption is false. For example, if there is a periodic variation in the material to be sampled, systematic sampling may produce erroneous results.

Non-random sampling or judgment sampling can also, in some cases, be systematic sampling. Consider the example of a treatment system which is being tested for its efficiency. The design engineer might require that the system be sampled at specific loadings which are based on design performance relative to the material being treated. This type of sampling is common when the engineer intends to model the results.

Stratified Random Sampling - Stratified sampling essentially involves the division of the sample population into groups based on knowledge of sample characteristics at these divisions. Stratified sampling requires more

planning than other types of data collection. The designer of the sample must analyze data and background information made available from the preliminary site survey, prior investigations conducted on site, and/or experience with similar situations.

If applied correctly, stratified sampling can give sample designs which have greater precision than simple random sampling for the same number of samples. This is accomplished by selected divisions which maximize the variation between divisions while at the same time reducing the variation within each division. For example, if drums to be sampled at a site were first grouped by the production line that produced the waste, then the variation within each group might be smaller than between the production line groups.

However, in many instances, precision may not be the only reason for including specific sectors of the sampled media or waste area. As long as the probability of picking any single division or strata is known, valid estimators can be calculated from the design. The following example points out the importance of knowing the probability of drawing a strata and the breadth of the definition of random sampling.

A common situation is to sample a lagoon for its contents. In this example we will assume that a visual inspection of the lagoon shows that one small portion of the lagoon is black while the rest of the lagoon is green. An acceptable random sample might be to divide the lagoon into equal grids the size of the black area and randomly sample a group of grids with the exception of the black one. The black grid is sampled with certainty, sometimes called a judgment sample.

10.4.4 BIASED VS. UNBIASED SAMPLING

Biased sampling refers to a sampling scheme whose resulting data places more undue emphasis on a single characteristic or factor of the problem. Unbiased sampling refers to sampling methods which, though they may overemphasize a particular characteristic, allow for estimates to be drawn from the data which are representative of the population at large. These

terms usually can be considered to be synonymous with random and non-random sampling. However, any sampling program can create data which have an inherent bias because of poor planning.

A statistician defines bias as the difference between expectation of an estimator or procedure and the actual population characteristic being estimated. An unbiased estimator is one whose expectation is the same as the population characteristic being estimated; its bias is zero. In the example above, the question which one might ask is whether the resulting estimates will be unbiased. If the purpose of the sampling is to estimate the total amount of a particular contaminant, then the sample is unbiased. The analysis of the data will correct for the bias introduced by sampling the black grid with certainty. The results of any chemical analysis are averaged by weighting the randomly chosen samples by the total area of the possible grids which could have been chosen, while the black grid is weighted by its area. This process removes any bias in the estimate.

Biased sampling is undertaken when it is not possible to calculate estimators which reflect the overall characteristics of the population. Probably the most commonly used form of biased sampling is conducted during the site investigation (SI) process. The purpose of the SI is to find out whether any contamination is present. Thus, these studies are typically conducted in ways that maximize the chance of analyzing samples which have contamination above a particular criteria.

The use of direct reading instruments to screen samples is a good example of such biased sampling. The samples which are finally analyzed using, for example, GC/MS will represent higher contamination than might exist overall at the site.

However, this type of sampling is correct for the SI. In the RI/FS, this type of sampling might still be acceptable in cases where design of a treatment system might be dependent on the maximum treated load.

10.5 SAMPLING PATTERNS

Determining the number of data points required to address issues associated with a hazardous waste site requires a multidisciplinary approach. Data are acquired to address a range of concerns and answer a diverse set of questions. Before attempting to determine how many data are required, the purposes for collecting data must be clearly defined. For instance, at a single site, soil samples may be taken to examine the characteristics of the source, to identify and evaluate potential contaminant pathways, to examine the magnitude and spatial extent of contamination, and to investigate unsampled areas where contamination is suspected. The number of data required to accomplish each of the above will vary. To characterize the source, one or two composite samples may be required and detailed statistical applications may not be appropriate in such cases. However, when data are collected to describe the distribution of contamination throughout the site or to investigate the possibility of unsampled areas, statistics should be used to determine the number of data required. Thus, in a well designed sampling plan the total number of data collected will be the sum of data collected to investigate small, precisely defined portions of the site, and the statistically determined number of data required to fully characterize the site and its environs.

When acquiring data which will be used to make general inferences concerning site characteristics, it is important that samples provide complete coverage of the area of interest and that sample locations do not introduce bias. Complete coverage is necessary to ensure that no areas of contamination are missed. Bias in a data set causes the mean of the data to be systematically different from the true mean. Bias is caused by any systematic error in data location, such as clustering of data. When data are clustered (located close together) some small portions of the site are sampled more densely than the remainder of the site. The particular contaminant value observed in the densely sampled area will be over represented in the estimate of the sample mean. If, as is often the case, samples are clustered in highly contaminated areas, the mean site contaminant concentration will be overestimated.

Sampling patterns should be designed to minimize bias and provide complete site coverage. The best sampling pattern for accomplishing both of these goals is a regular grid. It can be shown theoretically (Ripley 1982), that data taken on a regular grid will yield a more precise estimate of the mean site contamination than data located according to any other procedure. This fact combined with the superior coverage and non-biased property of regular sampling make it the preferred sampling pattern when statistics will be applied.

The use of an unbiased approach during the initial sampling phases is recommended in order to ensure that no area of the site is overlooked in sampling. Subsequent sampling phases should incorporate the information resulting from the unbiased sampling which occurred during the initial phases. The data should be used to identify areas in which additional samples should be obtained and areas where no additional samples are required. Introduction of bias during subsequent phases is justified in these instances.

10.5.1 GRID SYSTEMS

Sampling grids consist of a network of crossing parallel lines which can be used to identify locations at which samples will be obtained. Grids can be superimposed on topographic maps, aerial photographs, site plans or other graphical representations of the site to identify potential sampling locations. These mapped points can then be accurately located in the field using standard surveying techniques. Grids can also be generated in the field from some arbitrary starting point and later tied down using surveying techniques and transferred to a reference map.

Grid systems are used in developing systematic sampling plans in which samples are located at consistent distances from one another. The most elementary grid system is a straight line between two points on which regularly spaced sampling locations are noted. This type of one-dimensional sampling grid may be useful for sampling along a straight

drainage ditch or other man-made feature. The majority of environmental sampling, however, requires a two-dimensional approach to sample location identification.

Figure 10-3 presents a two dimensional square grid system for locating sampling points. The grid is comprised of equidistant parallel lines at right angles to each other. Figure 10-4 presents a two dimensional triangular grid system comprised of equidistant parallel lines intersected by lines drawn at 60° from vertical in both directions. Sampling generally is undertaken at the intersection of the parallel lines which compose a grid, although other approaches such as sampling in the center of each grid box or obtaining a composite of samples within a grid box are also acceptable. It may be appropriate to modify the grid system to account for variations in concentration gradients as illustrated in Figure 8-5.

Grid systems can be applied in sampling most environmental media provided the areal limits of the sampling media are established. The limits in which the grid is applied are generally based upon previously obtained knowledge of the site conditions, physical limitations, or property lines. In the initial stages of developing a sampling plan, the grid is generally superimposed on the site map or aerial photograph by some arbitrary means. In order to ensure that the grid is placed on the site in an unbiased manner, one grid point could be placed at a predetermined location (i.e, on an existing bench mark) with grid lines oriented parallel to a north-south line or some other predetermined orientation. Following placement of the grid the sampling locations can be surveyed and "staked" (located) in the field. In all cases the grid system established on a map must be field verified. In most cases field verification may require that some of the sampling locations be abandoned. For example, a grid system may be used to identify surficial soil sampling locations. When field verified, some sampling locations occur on bedrock outcrop where no soil exists. In these cases alternate locations may be selected or the sample point eliminated.

SITE BOUNDARY

A
B
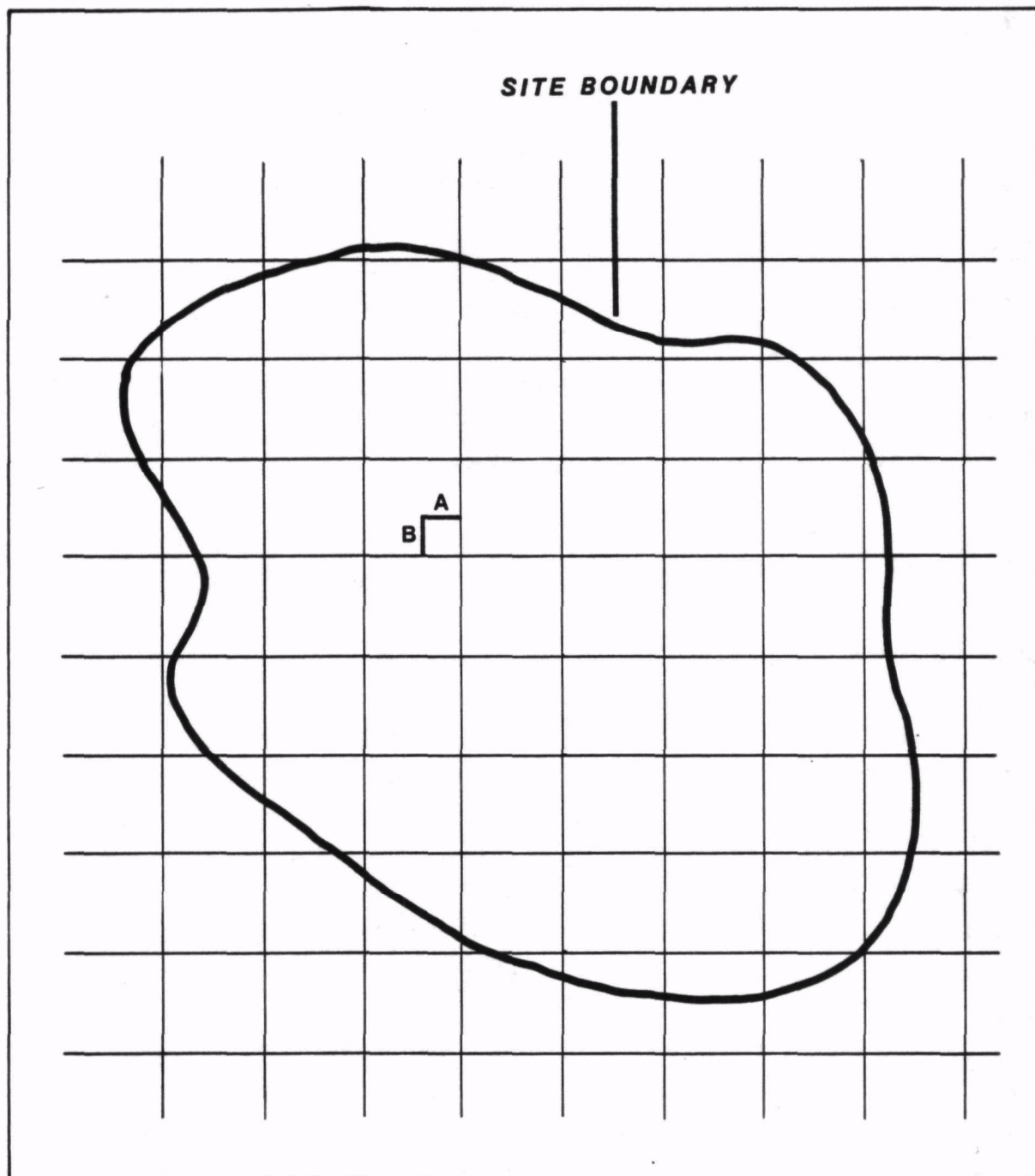
FIGURE 10-3
SQUARE GRID SYSTEM
[A = B]
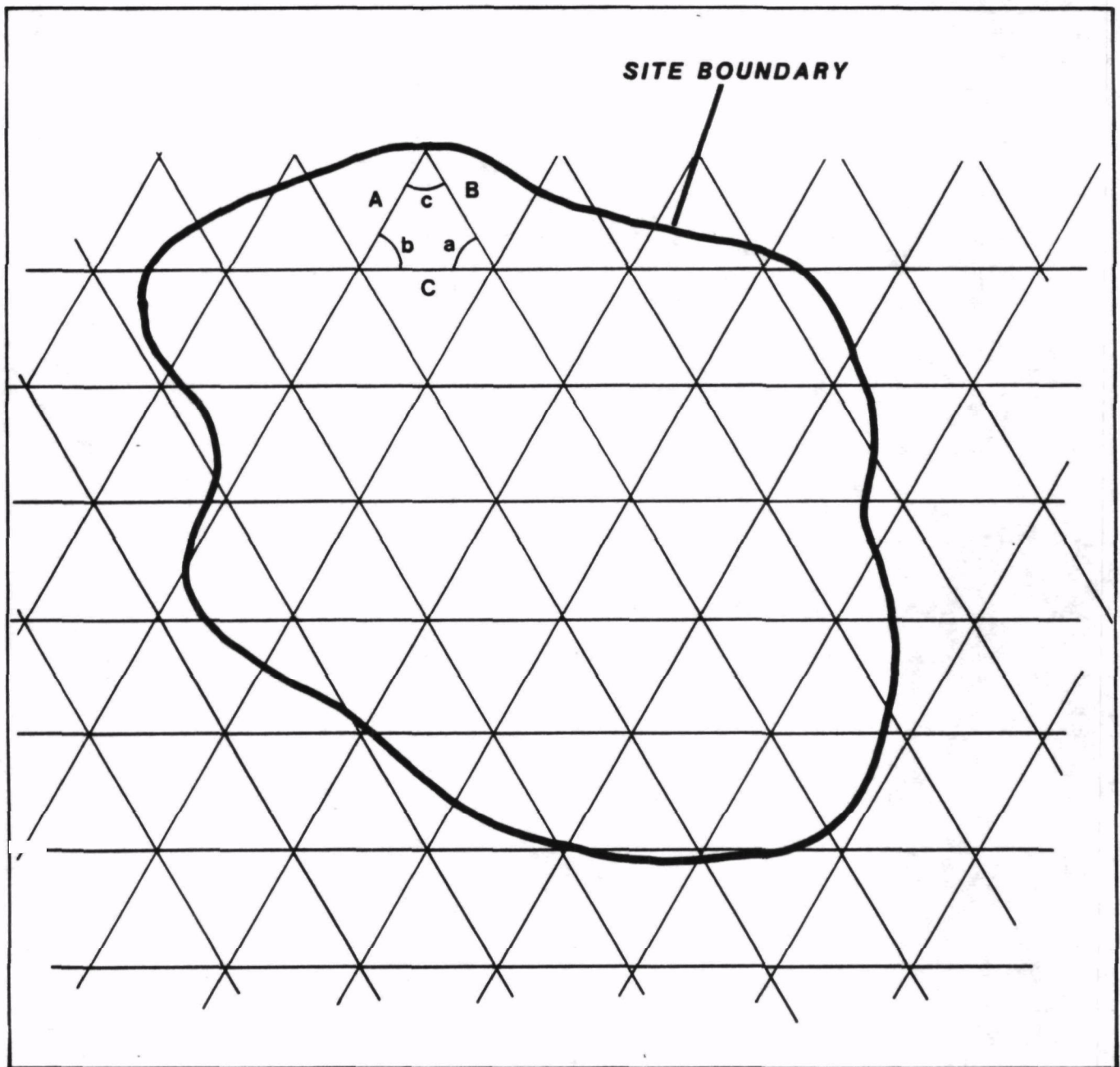
FIGURE 10-4
TRIANGULAR GRID SYSTEM
$[A = B = C < a = b = c = 60o]$
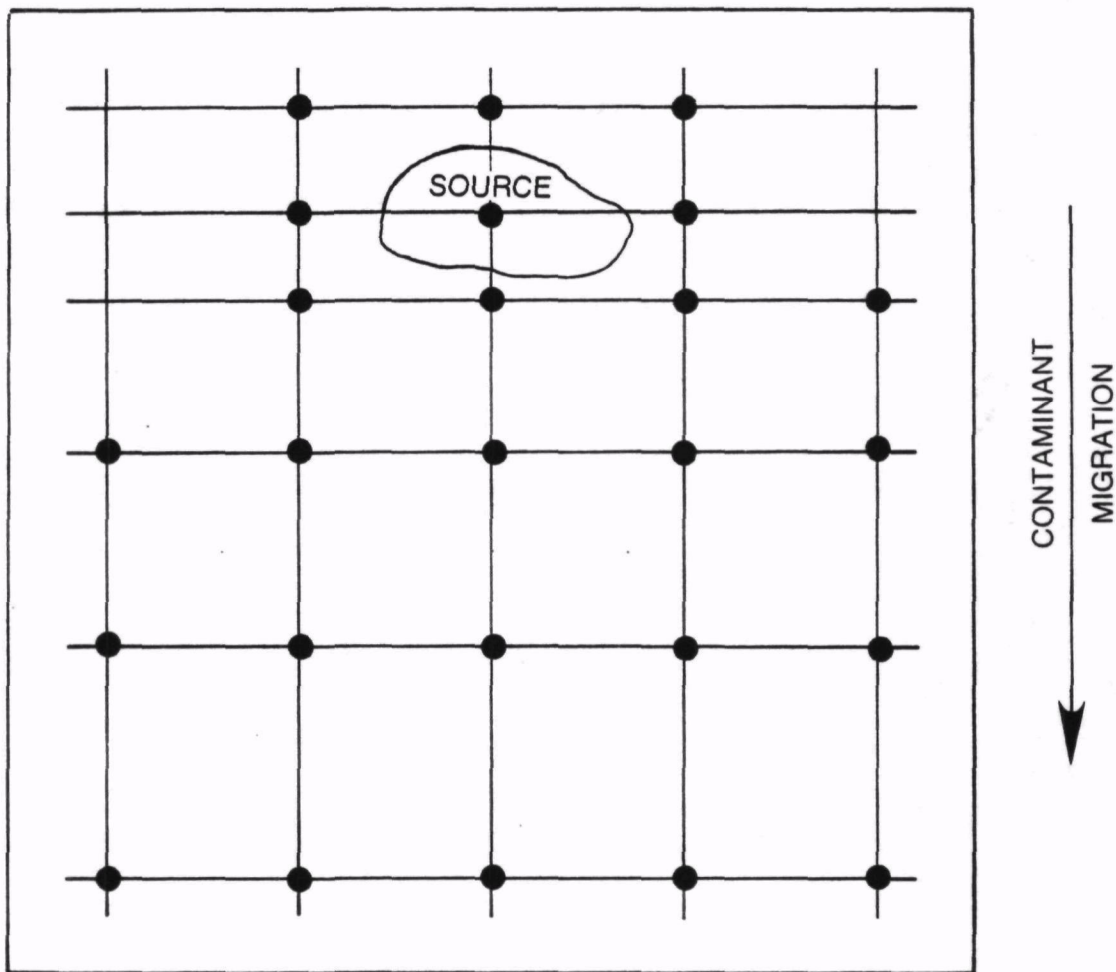
FIGURE 10-5
MODIFIED GRID SYSTEM TO
ACCOUNT FOR DIRECTIONAL CORRELATION

10.5.2 STRATIFICATION

Stratification refers to the process of locating samples within distinct populations or strata. Commonly occurring strata are geological formations, soil horizons, and visually different areas of contamination. An example of visually different contamination is a lagoon containing a zone of green liquid and a zone of black liquid. Typically the number of samples taken within strata varies. For instance, more samples should be taken from a visibly contaminated soil horizon than from an uncontaminated soil horizon. By varying the number of samples in each strata based on existing information or information obtained in the field, the sampling program can concentrate on the most important aspects of the site. Stratification is thus a valuable method for conserving resources. Grid systems are generally applied to a site in the horizontal plane such that sampling points can be identified using an X, Y; latitude, longitude; or other coordinate system. The Z or elevation coordinate of each sample must also be identified in sampling plans in order to fix the spatial location of the sample. The Z component may be designated as a depth below ground surface or relative elevation.

In situations where a determination of the areal extent of surficial soil contamination exists at a site, it may be appropriate to obtain samples at the surface of the soil. However, in most cases the extent of contamination in the vertical component (i.e., depth below the soil surface) must also be determined. Therefore, samples are generally obtained at various depths at each X,Y location. Selection of the depth at which samples are obtained should be based upon knowledge of the characteristics of the environmental media under investigation. Outlined below are a number of different situations in which the method used to select the Z component may vary:

   o Sediment samples obtained at the bottom of a lake or pond are
      generally obtained at the X,Y coordinate designated on the grid
      system. The Z component of the sample location is generally
      determined in the field as a depth below the surface of the water.
      These depths are later used to develop a bathymetric depiction of
      the pond/lake bottom.

o Soil samples obtained over an area in which liquid contaminants have
   been disposed of on the surface may be obtained at predetermined
   depths to evaluate the extent of contamination. For example, at the
   surface and at 2-ft or other specified intervals extending to
   bedrock or some other established depth.

o Soil samples may also be obtained at predetermined elevations where
   the Z coordinate will be crucial in cleanup operations. For
   instance, it may be appropriate to obtain samples at specified
   elevation increments (i.e., at 2-ft increments from 100 ft msl
   extending downward to 50 ft msl). This would provide consistency in
   the Z coordinate plane and allow for correlation of data regardless
   of changes in the surficial topography.

o Where physical conditions of the environmental media vary
   significantly, the Z sampling coordinates may best be selected to
   allow for characterization of the media. This is generally the most
   appropriate approach for characterizing geologic deposits. In these
   situations the Z location is selected to provide information on each
   horizon, or strata of instance. This type of approach would allow
   for selection of appropriate numbers of unconsolidated glacial till
   samples as well as samples of the underlying bedrock regardless of
   its orientation, for example.

The appropriate approach for stratification of samples is dependent in
large part on the objectives of the sampling program and characteristics of
the environmental media under investigation. The degree of stratification
(e.g., the vertical spacing of Z sample locations) is dependent on the
total number of samples that will be required to characterize the media and
more specifically each horizon or strata within the media under
investigation.

10.5.3 GRID SPACING

Spacings of grids are usually established to allow for sampling at each
grid intersection. These alternative sampling approaches can be used when
a low intensity investigation is used preliminary to more intensive
sampling to be performed following review of the data. For example, a grid
system may be placed over a site with grid lines spaced at 10-ft intervals.
During the preliminary investigation samples may be obtained at every tenth
intersection on every tenth grid line, thereby resulting in samples being

obtained at 100-ft spacings. Following review of the preliminary data, intensive sampling may be warranted in a number of discrete locations on the site. This intensive sampling may then be performed at the previously established 10-ft grid intersections.

The distance between the grid lines will determine the number of intersections and hence the number of potential sampling points within a specified area. As the grid line spacings increase, the number of potential sampling points will decrease for any given sampling area.

10.6 QUALITY CONTROL SAMPLES

Various types of samples may be obtained during a remedial investigation in order to provide quality control information for interpretation of data including:

   o Background samples
   o Critical samples
   o Collocated and replicate samples
   o Split samples
   o Field and trip blanks
   o Matrix spikes

In all cases QC samples must be submitted to the laboratory as blind samples.

10.6.1 BACKGROUND SAMPLES

Inclusion of background samples in an RI sampling task must be taken into consideration during the DQO process. Monitoring data as well as available literature on natural background concentrations of chemicals in the area should be collected, reviewed and/or verified to determine background conditions. Background data should be defined as either natural or anthropogenic chemical contamination resulting from a source or sources other than the site undergoing assessment.

A background sample is one taken from media characteristic of the site but outside the zone of contamination. At least two background samples should be collected for each sampling event. A sampling event is a specific media event over a specified period of time. For example, each quarterly ground water sampling round would be considered a sampling event.

10.6.2 CRITICAL SAMPLES

Critical data points are sample locations for which valid data must be obtained in order for the sampling event to be considered complete. An example of a critical data point may be an upgradient well in a ground water contamination study or any other data point considered vital to the decision making process. Critical data points should be carefully considered in the sampling plan design of a data collection activity and every effort must be made to obtain valid data for these samples. In some cases, taking critical data point samples in duplicate is appropriate. A common problem of any sample design is the loss of data during implementation of the design. Care must be taken to determine the set of points for which data must be collected in order to analyze the results accurately. The set of points which must be collected are called the "critical points." Critical points may be defined in terms of the minimum number of data points which must be collected and analyzed.

The identification of critical points can be based on statistical theory or it may be based on careful review of the issues which the analysis will address. In the lagoon sampling example, the single sample from the black grid might be considered a critical point. The assumption in the sampling plan was that this grid was different from the others. Therefore, while the sampling plan might be able to yield acceptable results if a number of the, assumed similar, green grid samples were lost, it seems unlikely that the design would be acceptable without the black grid.

Critical data points should be identified in every completeness statement developed during the DQO process.

10.6.3 COLLOCATED AND REPLICATE SAMPLES

Collocated samples are independent samples collected in such a manner that they are equally representative of the parameter(s) of interest at a given point in space and time. Examples of collocated samples include: samples from two air quality analyzers sampling from a common sample manifold, two water samples collected at essentially the same time and from the same point in a lake, or in some cases side-by-side soil core samples.

Collocated samples, when collected, processed, and analyzed by the same organization, provide intralaboratory precision information for the entire measurement system including sample acquisition, homogeneity, handling, shipping, storage, preparation and analysis. Collocated samples, when collected, processed and analyzed by different organizations, provide interlaboratory precision information for the entire measurement system.

Replicate samples are samples that have been divided into two or more portions at some step in the measurement process. Each portion is then carried through the remaining steps in the measurement process. A sample may be replicated in the field or at different points in the analytical process. For field replicated samples, precision information would be gained on homogeneity (to a lesser extent than for collocated samples), handling, shipping, storage, preparation, and analysis. For analytical replicates, precision information would be gained on preparation and analysis. Examples of field replicated samples include a soil core sample that has been collected and poured into a common container for mixing before being split and placed in individual sample containers.
Collocated samples can be used to estimate the overall precision of a data collection activity. Sampling error can be estimated by the inclusion of collocated and replicated versions of the same sample. If a significant difference in precision between the two subsets is found, it may be attributed to sampling error. As a data base on field sampling error is accumulated, the magnitude of sampling error can be determined.

The use of both collocated and replicated samples in soil sampling is an attempt to quantify the degree of error that can be attributed to the sampling process. This approach is valid when the homogeneity of the sample matrix is in question. Swiftly flowing streams or discharge pipes would also fall into this category. The use of these two types of duplicate samples and the frequency for their inclusion in an RI is dependent on the sample matrix and the intended use of the data as discussed in Stage 2 of the DQO process. More replicate samples are generally taken when nonhomogeneity is expected. The inclusion of collocated samples into a sampling program also depends on the sampling method utilized. It may not be appropriate to collocate deep soil boring samples, for example. In this case example, a field replicate would be more appropriate than drilling two separate, side-by-side boreholes.

In summary, the following are suggested guidelines for the inclusion of collocated and replicated samples in field programs:

o Ground and surface water – one out of every 20 investigative samples should be collocated. Replicated samples could be substituted where appropriate. These samples should be spread out over the sampling event, preferably at least one for each day of sampling.

o Soil, sediments and solids – one out of every 20 investigative samples should be field replicated or collocated. To estimate sampling error, collocated and field replicated samples should be of the same investigative sample. These samples should be spread out over the sampling event, preferably one per each day of sampling.

10.6.4 SPLIT SAMPLES

Split samples are replicate samples divided into two portions, sent to different laboratories, and subjected to the same environmental conditions and steps in the measurement process. They serve as an oversight function in assessing the analytical portion of the measurement system.

10.6.5 TRIP AND FIELD BLANKS

Trip blanks generally pertain to volatile organic samples only. Trip
blanks are prepared prior to the sampling event in the actual sample
containers and are kept with the investigative samples throughout the
sampling event. They are then packaged for shipment with the other samples
and sent for analysis. At no time after their preparation are the sample
containers opened before they reach the laboratory.

Field blanks are defined as samples which are obtained by running
analyte-free deionized water through sample collection equipment (bailer,
pump, auger, etc.) after decontamination, and placing it in the appropriate
sample containers for analysis. These samples will be used to determine if
decontamination procedures have been sufficient. Using the above
definition, soil field blanks could be called rinsate samples. These
should be included in a sampling program as appropriate.

The following guidelines for including blanks in sampling programs are
suggested.

  o Ground and surface water - Field blanks should be submitted at the
     rate of one field blank/matrix/per day or one for every 20
     investigation samples, whichever results in fewer samples. Trip
     blanks should be included at a frequency of one per day of sampling
     or as appropriate.

  o Soil sediments and solids - Rinsate samples should be submitted at
     the rate of one for every 20 investigative samples for each matrix
     being sampled or as appropriate. EMSL-LV is currently evaluating a
     material which can be used as a soil field blank.

Guidelines for blank, duplicate, and background samples are provided in
Table 10-2. These guidelines serve as a starting point from which to
develop site-specific sampling plan QC sample numbers. In certain
instances, it may be appropriate to utilize known reference materials when
available for QC checking. The numbers and sources of reference materials

TABLE 10-2

GUIDELINES FOR MINIMUM QA/QC SAMPLES
FOR FIELD SAMPLING PROGRAMS

MEDIA	DUPLICATES			FIELD BLANK	TRIP BLANK	BACKGROUND SAMPLE	INTER-LAB SPLIT SAMPLE[1]
	COLLOCATED	OR	FIELD REPLICATE				
Aqueous	one in twenty			one in twenty	one per day of sampling	min. of two per sampling event-media	when required to meet objectives
Soil, sediment	one in twenty			one in twenty		min. of two per sampling event-media	when required to meet objectives
Air	one in twenty			not available	one per day of sampling	min. of two per sampling event-media	when required to meet objectives
Source material	one in twenty			not usually required			when required to meet objectives

NOTE: This table is provided to serve as a guideline only; QA/QC sample requirements must be developed on a site-specific basis. Laboratory blanks and spikes are method specific and are not included in this table.

which would provide meaningful comparison and checks for media obtained from hazardous waste sites are limited. It is advisable to consult with analytical chemists regarding the appropriateness of use of reference materials as a QC check.

10.6.6 MATRIX SPIKES

Many samples exhibit matrix effects, in which other sample components interfere with the analysis of contaminants of interest. Matrix spikes provide the best measurement of this effect. When done in the field, immediately after collection, they also provide a measurement of sampling, handling and preservation error. The field matrix spike does provide the best overall assessment of accuracy for the entire measurement system, as collocated samples do for precision assessment. However, there are some serious issues regarding the field spiking of environmental samples that must be considered. Field matrix spikes are generally not recommended because of the high level of technical expertise required for proper use and their sensitivity to environmental variables.

The major problems associated with field matrix spikes are due to the fact that all spike recovery data must be interpreted very carefully. Spike recoveries are subject to many competing factors, such as analyte stability, holding time, and the sample matrix. Because of the inherent variability associated with spike recoveries, the additional variability introduced by spiking samples in the field can increase the overall uncertainty associated with a data set rather than decrease it.

The two most important issues to address when considering field spiking as an option are the source of the spiking material and the technical capability of the person doing the spiking. Spiking materials that can be used are Standard Reference Materials (SRMs), EPA quality control ampules, or laboratory-prepared solutions made from pure compounds. SRMs are stand-alone standards prepared by NBS that can be placed in the appropriate sample containers and sent to the laboratory to be analyzed. The use of certified standards such as SRMs solves the "traceability" issue concerning the integrity of the blind standard and also does not require a skilled

technician to prepare the standard. However, because the SRM is a stand-alone sample, it provides no information on the impact of the sample matrix on the measurement system. An aliquot of an SRM can be used to spike an environmental sample, but it would no longer be traceable and would require a person skilled in the appropriate analytical techniques, just as the use of quality control ampoules or laboratory-prepared spikes do. The competence of the person doing the spiking is critical. The exact amount of spiking material must be recorded for future use in assessing recoveries. Errors in measurement of the spike or use of the wrong spiking material will cause serious problems in interpreting the usability of the data.

In summary, field matrix spikes are not recommended unless the appropriate technical support is available. Absolute attention to all details is required to obtain useful information from the procedure. If field matrix spikes are used, the results should be compared with laboratory matrix spike results.

10.7 REFERENCES

American Society of Agronomy. 1965. Methods of Soil Analyses Part 1 - Physical and Mineralogical Properties Including Statistics of Measurement and Sampling. C.A. Blacked. Agronomy Monograph No. 9. Madison, Wisconsin.

Camp Dresser & McKee Inc. 1985. Site Investigation Procedures Manual - Performance of Remedial Response Activities at Uncontrolled Hazardous Waste Sites. Volumes I, II, III, IV.

Charlie, W.A., R.E. Wardwell, and O.B. Andersland. 1979. Leachate Generation from sludge disposal area. ASCE Journal of Environmental Engineering Division Vol. 10S EES:947-960.

Claassen, H.C. 1982. Guidelines and Techniques for Obtaining Water Samples that Accurately Represent the Water Chemistry of an Aquifer. USGS Open File Report 82-1024. Lakewood, CO.

Clay, P.F. and T.M. Spittler, 1982. The Use of Portable Instruments in Hazardous Waste Site Characterizations, Proceedings of the Third National Conference on Management of Uncontrolled Hazardous Waste Sites, Washington, D.C.

Ecology and Environment, Inc. 1982. FIT Operations and Field Manual, HNu Systems PI 101 Photoionization Detector and Century Systems Model OVA-128 Organic Vapor Analyzer, prepared for U.S. EPA, Washington, D.C.

Elans, R.B. 1986. Groundwater Monitoring Data Quality Objectives for Remedial Site Investigations. In: Quality Control in Remedial Site Investigations: Hazardous and Industrial Solid Waste Testing Fifth Volume ASTM STP 925.

Fuller, W.H., A. Amoozeyar-Fard, E.F. Niebla, as M. Boyle. 1980. Influence of Leachate Quality on Soil Attenuation of Metals. In: Disposal of Hazardous Wastes pp 108-117. EPA-600-9-80-010.

IT Corporation. 1984. A Sampling Strategy for Remedial Action at Hazardous Waste Sites: Cleanup of Soil Contaminated by Tetrachlorodibenzo-p-dioxin. Draft No.2. August 20, 1984

Jacot, Brian. 1983. OVA Field Screening at a Hazardous Waste Site. Proceedings of the Fourth National Conference on Management of Uncontrolled Hazardous Waste Sites. Washington, D.C.

Lockheed Engineering and Management Series Co., Inc. 1984. Characterization of Hazardous Waste Sites, A Methods Manual. Volume 3 - Available Laboratory Analytical Methods. May.

Mehran, M. et al. 1983. Delineation of Underground Hydrocarbon Leaks by Organic Vapor Detection. Proceedings of the Fourth National Conference on Management of Uncontrolled Hazardous Waste Sites. Washington, D.C.

Panaro, J.M. 1984. Air Monitoring and Data Interpretation During Remedial Action at a Hazardous Waste Site. Proceedings of the Hazardous Waste and Environmental Emergencies Conference. Houston, Texas.

Quimby, J.M. et al. 1982 Evaluation and Use of a Portable Gas Chromatograph for Monitoring Hazardous Waste Sites. Proceedings of the Third National Conference on Management of Uncontrolled Hazardous Waste Sites. Washington, D.C.

Raveh, A. and Y. Avnimelech. 1979. Leaching of pollutants from sanitary landfill models. Journal WPCF 51(11):2705-2716.

Spittler, T.M. 1980. Use of Portable Organic Vapor Detectors for Hazardous Waste Site Investigations. Second Oil and Hazardous Materials Spill Conference and Exhibition. Philadelphia, Pennsylvania.

Spittler, T.M. et al. 1981. Ambient Monitoring for Specific Volatile Organics Using a Sensitive Portable PID GC. Proceedings of the Second National Conference on Management of Uncontrolled Hazardous Waste Sites. Washington, D.C.

Spittler, T.M. 1983. Field Measurement of PCBs in Soil and Sediment Using a Portable Gas Chromatograph. Proceedings of the Fourth National Conference on Management of Uncontrolled Hazardous Waste Sites. Washington, D.C.

U.S. EPA. 1977. Procedures Manual for Groundwater Monitoring at Solid Waste Disposal Facilities. EPA 530/SW-611.

U.S. EPA. 1980. Environmental Monitoring and Support Laboratory, Cincinnati, Ohio, Interim Methods for the Sampling and Analysis of Priority Pollutants in Sediments and Fish Tissue. October.

_____. 1981. EPA/DOT: Hazardous Waste Transportation Interface.

_____. 1981. Soil and Sediment Sampling Methods. Technical Methods for Investigating Sites Containing Hazardous Substances. Technical Monograph No. 17.

_____. Handbook for Sampling and Sample Preservation of Water and Wastewater. EPA 600/4-82-029.

_____. 1983. Characterization of Hazardous Waste Sites—A Methods Manual, Volume II, Available Sampling Methods. NTIS PB84-126929.

_____. 1983. Preparation of Soil Sampling Protocol: Techniques and Strategies NTIS PB83-20-6979 EPA 600/4-83-020.

_____. 1984. Soil Sampling Quality Assurance User's Guide. EPA 600/4-84-043

_____. 1984. Vegetation Sampling: Techniques and Strategies LIP 83-159.

_____. 1984. Quality Assurance Handbook for Air Pollution Measurement Systems. Volumes 1 and 2, EPA - 600/9-76-005. January 19.

_____. 1984. Standard Operating Safety Guides. Office of Emergency and Remedial Response.

_____. 1985. Sediment Sampling Quality Assurance User's Guide.

_____. 1985. Characterization of Hazardous Waste Sites - A Methods Manual. Volume 1 - Site Investigation. EPA/600/4-84/075.

_____. 1985. Field Standard Operating Procedures No.4: Site Entry. Office of Emergency and Remedial Response.

_____. 1985. Field Standard Operating Procedures No.6: Work Zones, Office of Emergency and Remedial Reponse.

_____. 1985. Field Standard Operating Procedures No.8: Air Surveillance. Office of Emergency and Remedial Response.

_____. 1985. Field Standard Operating Procedures No.9: Preparation of a Site Safety Plan. Office of Emergency and Remedial Response.

_____. 1985. Technical Background Document to Support Rulemaking Pursuant to CERCLA Section 102. Volume 1 Contract No. 68-03-3182.

_____. 1986. Groundwater Monitoring Quality Assurance for RCRA April 1986 Second Draft.

Appendix A

APPENDIX A

REVIEW OF QAMS DQO CHECKLIST

APPENDIX A

REVIEW OF QAMS DQO CHECKLIST

In a memorandum dated April 3, 1983, Mr. Stanley Blacker, Director of the Quality Assurance Management Staff (QAMS) issued a checklist to be used by QAMS staff during their review of DQOs. The purpose of this appendix is to review the QAMS checklist with respect to this RI/FS DQO guidance.

The QAMS checklist is designed for use in reviewing specific DQOs rather than an approach to DQO development for a complex process such as an RI/FS. This appendix presents a review of the checklist items, along with a reference to the section where the item is addressed and/or a comment regarding the applicability of the item to the RI/FS DQO process.

The RI/FS process involves multiple levels of data and data uses, and culminates in a decision regarding the degree of remedial response to be implemented for a site. Decisions are based on analytical and other measurement data which are often integrated to interpret various aspects of a site's characteristics. Thus, many different sets of DQOs may be required for a given RI/FS.

APPENDIX A

SUMMARY OF DQO CHECKLIST ITEMS WITH RESPECT TO
RI/FS DQO APPLICABILITY

DQO CHECKLIST ITEM	COMMENT RE: RI/FS DQO APPLICABILITY
A-1. The decision maker and associated users are clearly identified.	The key RI/FS decision is remedy selection (i.e., ROD/EDD signature). For the majority of RI/FS projects, remedy selection is delegated to the Regional Administrator (RA). Program Management responsibilities are delegated to the Waste Management Division Director and Managers, with project specific management and oversight assigned to Remedial Project Managers (RPM). In this role the regional EPA RPM, is responsible for coordinating the DQO development process, and overseeing remedial contractors, state officials, or private parties conducting the RI/FS. Associated data users include primary, secondary and technical support and project review/audit personnel.
A-2. The decision maker and associated data users have been involved in the development of DQOs.	See Section 2.0, Stage 1 - Identify & Involve Data Users.
B-1a. A statement of the decision(s) that depend(s) on the results of this data collection activity.	The decision(s) that result from the RI/FS process involve multiple levels of data for multiple purposes. See Section 3.0, Stage 1 - Specify RI/FS Objectives.
B-1b. If the data collection activity is of an exploratory nature and not formally linked with a regulatory decision, then the document should include a clear explanation of the purpose for which the environmental data are intended.	- See Section 4.0, Stage 2 Identify Data Uses/Needs.

AW3F-10

APPENDIX A

SUMMARY OF DQO CHECKLIST ITEMS WITH RESPECT TO
RI/FS DQO APPLICABILITY (continued)

DQO CHECKLIST ITEM	COMMENT RE: RI/FS DQO APPLICABILITY
B-2. Statements of each specific question that will be addressed in the data collection activity and the type of conclusion that is anticipated as an appropriate answer to each question. The conclusions should depend only on measurement data.	See Section 4.0, Stage 2
B-3. A clear statement of the way in which each conclusion of the study will be represented, in terms of the results of statistical calculations made with the data.	See Section 4.0, Stage 2 - The conclusions of an RI/FS study are highly interdependent. The format for data presentation will vary, based upon data quantity. A statistical approach may not be feasible.
B-4. Statements of the acceptable levels of precision and accuracy associated with each of the conclusions depend on measurement data.	See Section 4.0, Stage 2.
B-5. A definition of the population to which each of the conclusions apply, including definitions of all subpopulations or strata.	See Section 4.0, Stage 2.
B-6. Definitions of the variables that will be measured.	See Section 4.0, Stage 2.
B-7. The acceptable levels of precision and accuracy for the measurements to be made.	See Section 4.0, Stage 2.
B-8. A flow chart or spread sheet illustrating the relationship between the measurement data and each conclusion that will be made with the data.	See Section 4.0, Stage 2.

Appendix B

APPENDIX B

POTENTIALLY APPLICABLE OR
RELEVANT AND APPROPRIATE REQUIREMENTS

excerpt from National Contingency Plan final rule

Federal Register, Vol. 50, No. 224
November 20, 1985

Potentially Applicable or Relevant and Appropriate Requirements

1. EPA's Office of Solid Waste administers, inter alia, the Resource Conservation and Recovery Act of 1976, as amended (Pub. L 94–580, 90 Stat 95, 42 U.S.C. 6901 et seq.). Potentially applicable or relevant requirements pursuant to that Act are:

a. Open Dump Criteria—Pursuant to RCRA Subtitle D criteria for classification of solid waste disposal facilities (40 CFR Part 257).

Note.—Only relevant to nonhazardous wastes.

b. In most situations Superfund wastes will be handled in accordance with RCRA Subtitle C requirements governing standards for owners and operators of hazardous waste treatment, storage, and disposal facilities: 40 CFR Part 264, for permitted facilities, and 40 CFR Part 265, for interim status facilities.

• Ground Water Protection (40 CFR 264.90–264.109).
• Ground Water Monitoring (40 CFR 265.90–265.94).
• Closure and Post Closure (40 CFR 110–264.120, 265.110–265.112).
• Containers (40 CFR 264.170–264.178, 265.170–265.177).
• Tanks (40 CFR 264.190–264.200, 265.190–265.199).
• Surface Impoundments (40 CFR 220–264.249, 265.220–265.230).
• Waste Piles (40 CFR 264.250–264.269, 265.250–265.258).
• Land Treatment (40 CFR 264.270–299, 265.270–255.282).
• Landfills (40 CFR 264.300–264.339, 265.300–265.316).
• Incinerators (40 CFR 264.340–264.999, 265.340–265.369).
• Dioxin-containing Wastes (50 FR 1978). Includes the final rule for the listing of dioxin containing waste.

2. EPA's Office of Water administers several potentially applicable or relevant and appropriate statutes and regulations issued thereunder:

a. Section 14.2 of the Public Health Service Act as amended by the Safe Drinking Water Act as amended (Pub. L 23. 88 Stat 1880. 42 U.S.C. 300f et. seq.)

• Maximum Contaminant Levels (for all sources of drinking water exposure). CFR 141.11–141.16).
• Underground Injection Control Regulations. (40 CFR Parts 144. 145. 146. and 147).

b. Clean Water Act as amended (Pub. L 92–500. 86 Stat 816. 33 U.S.C. 1251 et. seq.)

• Requirements established pursuant to sections 301. 302. 303 (including State water quality standards). 306. 307. (including Federal pretreatment requirements for discharge into a publicly owned treatment works). and 403 of the Clean Water Act. (40 CFR Parts 131. 400–469).

c. Marine Protection. Research. and Sanctuaries Act (33 U.S.C. 1401).

• Incineration at sea requirements. (40 CFR Parts 220–225. 227. 228. See also 40 CFR 125.120–125.124).

3. EPA's Office of Pesticides and Toxic Substances

Toxic Substances Control Act (15 U.S.C. 2601).

• PCB Requirements Generally: 40 CFR Part 761: Manufacturing Processing. Distribution in Commerce. and Use of PCBs and PCB Items (40 CFR 761.20–761.30); Markings of PCBs and PCB Items (40 CFR 761.40–761.45); Storage and Disposal (40 CFR 761.60–761.79). Records and Reports (40 CFR 761.180–761.185). See also 40 CFR 129.105. 750.

• Disposal of Waste Material Containing TCDD. (40 CFR Parts 775.180–775.197).

4. EPA's Office of External Affairs

• Section 404(b)(1) Guidelines for Specification of Disposal Sites for Dredged or Fill Material (40 CFR Part 230).

• Procedures for denial or Restriction of Disposal Sites for Dredged Material (§ 404(c) Procedures. 40 CFR Part 231).

5. EPA's Office of Air and Radiation administers several potentially applicable or relevant and appropriate statutes and regulations issued thereunder:

a. The Uranium Mill Tailings Radiation Control Act of 1978 (42 U.S.C. 2022).

• Uranium mill tailing rules—Health and Environmental Protection Standards for Uranium and Thorium Mill Tailings (40 CFR Part 192).

b. Clean Air Act (42 U.S.C. 7401).

• National Ambient Air Quality Standards for total suspended particulates (40 CFR Parts 50.6–50.7).
• National Ambient Air Quality Standards for ozone (40 CFR 50.9).
• Standards for Protection Against Radiation—high and low level radioactive waste rule. (10 CFR Part 20). See also 10 CFR Parts 10, 40, 60, 61, 72, 960, 961.
• National Emission Standard for Hazardous Air Pollutants for Asbestos. (40 CFR 61.140–61.156). See also 40 CFR 427.110–427.116, 763.
• National Emission Standard for Hazardous Air Pollutants for

Radionuclides (40 CFR Part 61. 10 CFR 20.101–20.106).

6. Other Federal Requirements.

a. OSHA requirements for workers engaged in response activities are codified under the Occupational Safety and Health Act of 1970 (29 U.S.C. 651). The relevant regulatory requirements are included under:
• Occupational Safety and Health Standards (General Industry Standards) (29 CFR Part 1910).
• The Safety and Health Standards for Federal Service Contracts (29 CFR Part 1926).
• The Shipyard and Longshore Standards (29 CFR Parts 1915. 1918).
• Recordkeeping. reporting. and related regulations (29 CFR Part 1904).

b. Historic Sites. Buildings. and Antiquities Act (16 U.S.C. 461).

c. National Historic Preservation Act. 16 U.S.C. 470. Compliance with NEPA required pursuant to 7 CFR Part 650. Protection of Archaeological Resources: Uniform Regulations—Department of Defense (32 CFR Part 229, 229.4), Department of the Interior (43 CFR Part 7, 7.4).

d. D.O.T. Rules for the Transportation of Hazardous Materials. 49 CFR Parts 107, 171.1–171.500. Regulation of activities in or affecting waters of the United States pursuant to 33 CFR Parts 320–329. The following requirements are also triggered by Fund-financed actions:
• Endangered Species Act of 1973. 16 U.S.C. 1531. (Generally, 50 CFR Parts 81. 225. 402). Wild and Scenic Rivers Act. 16 U.S.C. 1271.
• Fish and Wildlife Coordination Act. 16 U.S.C. 661 note.
• Fish and Wildlife Improvement Act of 1978. and Fish and Wildlife Act of 1956. 16 U.S.C. 742a note.
• Fish and Wildlife Conservation Act of 1980. 16 U.S.C. 2901. (Generally, 50 CFR Part 83).
• Coastal Zone Management Act of 1972. 16 U.S.C. 1451. (Generally. 15 CFR Part: 930 and 15 CFR 923.15 for Air and Water Pollution Control Requirements).

Other Federal Criteria. Advisories. Guidance. and State Standards To Be Considered

1. Federal Criteria. Advisories and Procedures

• Health Effects Assessments (HEAs).

• Recommended Maximum Concentration Limits (RMCLs).

• Federal Water Quality Criteria (1976, 1980, 1984). Note: Federal Water Quality Criteria are not legally enforceable. State water quality standards are legally enforceable. and are developed using appropriate aspects

of Federal Water Quality Criteria. In many cases, State water quality standards do not include specific numerical limitations on a large number of priority pollutants. When neither State standards nor MCLs exist for a given pollutant. Federal Water Quality Criteria are pertinent and therefore are to be considered.

• Pesticide registrations.
• Pesticide and food additive tolerances and action levels. Note: Germane portions of tolerances and action levels may be pertinent and therefore are to be considered in certain situations.
• Waste load allocation procedures. EPA Office of Water.
• Federal sole source aquifer requirements.
• Public health basis for the decision to list pollutants as hazardous under section 112 of the Clean Air Act.
• EPA's Ground-water Protection Strategy.
• New Source Performance Standards for Storage Vessels for Petroleum Liquids.
• TSCA health data.
• Pesticide registration data.
• TSCA chemical advisories (2 or 3 issued to date).
• Advisories issued by FWS and NWFS under the Fish and Wildlife Coordination Act.
• Executive Orders related to Floodplains (11988) and Wetlands (11990) as implemented by EPA's August 6. 1985. Policy on Floodplains and Wetlands Assessments for CERCLA Actions.
• TSCA Compliance Program Policy.
• OSHA health and safety standards that may be used to protect public health (non-workplace).
• Health Advisories. EPA Office of Water.

2. *State Standards*

• State Requirements on Disposal and Transport of Radioactive wastes.
• State Approval of Water Supply System Additions or Developments.
• State Ground Water Withdrawal Approvals. .
• Requirements of authorized (Subtitle C of RCRA) State hazardous waste programs.
• State Implementation Plans and Delegated Programs Under Clean Air Act.
• All other State requirements. not delegated through EPA authority.
• Approved State NPDES programs under the Clean Water Act.

• Approved State UIC programs under the Safe Drinking Water Act. Note: Many other State and local requirements could be pertinent. Forthcoming guidance will include a more comprehensive list.

3. *USEPA RCRA Guidance Documents*

• Draft Alternate Concentration Limits (ACL) Guidance.

A. EPA's RCRA Design Guidelines

1. Surface Impoundments. Liners Systems. Final Cover and Freeboard Control.
2. Waste Pile Design—Liner Systems.
3. Land Treatment Units.
4. Landfill Design—Liner Systems and Final Cover.

B. Permitting Guidance Manuals

1. Permit Applicant's Guidance Manual for Hazardous Waste Land Treatment. Storage. and Disposal Facilities.
2. Permit Writer's Guidance Manual for Hazardous Waste Land Treatment. Storage. and Disposal Facilities.
3. Permit Writer's Guidance Manual for Subpart F.
4. Permit Applicant's Guidance Manual for the General Facility Standards.
5. Waste Analysis Plan Guidance Manual.
6. Permit Writer's Guidance Manual for Hazardous Waste Tanks.
7. Model Permit Application for Existing Incinerators.
8. Guidance Manual for Evaluating Permit Applications for the Operation of Hazardous Waste Incinerator Units.
9. A guide for Preparing RCRA Permit Applications for Existing Storage Facilities.
10. Guidance Manual on Closure and Post-Closure Interim Status Standards.

C. Technical Resource Documents (TRDs)

(1) Evaluating Cover Systems for Solid and Hazardous Waste.
(2) Hydrologic Simulation of Solid Waste Disposal Sites.
(3) Landfill and Surface Impoundment Performance Evaluation.
(4) Lining of Water Impoundment and Disposal Facilities.
(5) Management of Hazardous Waste Leachate.
(6) Guide to the Disposal of Chemically Stabilized and Solidified Waste.
(7) Closure of Hazardous Waste Surface Impoundments.
(8) Hazardous Waste Land Treatment.
(9) Soil Properties. Classification. and Hydraulic Conductivity Testing.

D. Test Methods for Evaluating Solid Waste

(1) Solid Waste Leaching Procedure Manual.
(2) Methods for the Prediction of Leachate Plume Migration and Mixing.
(3) Hydrologic Evaluation of Landfill Performance (HELP) Model Hydrologic Simulation on Solid Waste Disposal Sites.
(4) Procedures for Modeling Flow Through Clay Liners to Determine Required Liner Thickness.
(5) Test Methods for Evaluating Solid Wastes.
(6) A Method for Determining the Compatibility of Hazardous Wastes.
(7) Guidance Manual on Hazardous Waste Compatibility.

4. *USEPA Office of Water Guidance Documents*

A. Pretreatment Guidance Documents

(1) 304(g) Guidance Document Revised Pretreatment Guidelines (3 Volumes)

B. Water Quality Guidance Documents

(1) Ecological Evaluation of Proposed Discharge of Dredged Material into Ocean Waters (1977)
(2) Technical Support Manual: Waterbody Surveys and Assessment for Conducting Use Attainability Analyses (1983)
(3) Water-Related Environmental Fate of 129 Priority Pollutants (1979)
(4) Water Quality Standards Handbook (1983)
(5) Technical Support Document for Water Quality-based Toxics Control.

C. NPDES Guidance Documents

(1) NPDES Best Management Practices Guidance Manual (June 1981)
(2) Case studies on toxicity reduction evaluation (May 1983).

D. Ground Water/UIC Guidance Document

(1) Designation of a USDW
(2) Elements of Aquifer Identification
(3) Interim guidance for public participation
(4) Definition of major facilities
(5) Corrective action requirements
(6) Requirements applicable to wells injecting into. through or above an aquifer which has been exempted pursuant to §146.104(b)(4).
(7) Guidance for UIC implementation on Indian lands.

5. *USEPA Manuals from the Office of Research and Development*

(1) EW 846 methods—laboratory analytic methods.
(2) Lab protocols developed pursuant to Clean Water Act § 304(h).

Appendix C

APPENDIX C

HISTORICAL PRECISION AND ACCURACY DATA
CLASSIFIED BY MEDIA AND BY ANALYTICAL LEVELS

APPENDIX C CONTENTS

HISTORICAL PRECISION AND ACCURACY TABLES

Introduction

INTRODUCTION

The data in this Appendix have been compiled to assist the reader in selecting an analytical method appropriate for each data use. The methods are classified by media and by analtyical levels defined as follows:

o Level I - field screening or analysis using portable instruments.
   Results are often not compound specific and not quantitative but
   results are available in real-time.

o Level II - field analysis using more sophisticated portable
   analytical instruments; in some cases, the instruments may be set up
   in a mobile or onsite laboratory. There is a wide range in the
   quality of data that can be generated. Quality depends on the use
   of suitable calibration standards, reference materials, and sample
   preparation equipment; and the training of the operator. Results
   are available in real-time or several hours.

o Level III - all analyses performed in an offsite analytical
   laboratory using standard, documented procedures. The laboratory
   may or may not be a CLP laboratory.

o Level IV - CLP routine analytical services (RAS). All analyses are
   performed in an offsite CLP analytical laboratory following CLP
   protocols.

Precision and accuracy data are presented in tabular fashion. Footnotes to each table cite the sources of the data and the concentration or concentration range at which the precision and accuracy were determined. When no concentration is cited no concentration information was available in the source material.

Precision is a measure of the variability in repeated measurements of the same sample compared to the average value. Precision is reported as % Relative Standard Deviation (RSD). The lower the % RSD, the more precise the data.

RSD is calculated for a pair of replicates using the following formula:

$$\%RSD = [2|X_1-X_2|/(X_1+X_2)] \, (100/\sqrt{2})$$

where X_1 is measurement #1 of a replicate

X_2 is measurement #2 of a replicate

Accuracy is reported as % Bias; as % Bias approaches zero, accuracy increases. Bias is calculated by the following formula:

$$\% \text{ Bias} = \frac{X-Y}{Y} \, (100)$$

where Y is the known concentration or true value
X is the reported concentration

Bias measures the systematic error within an analytical technique.

TABLE C-1-C: HISTORICAL PRECISION AND ACCURACY DATA/WATER [a]

LEVEL III ANALYTICAL TECHNIQUES - METHODS OTHER THAN CLP RAS METHODS

ANALYTES	METHOD (TECHNIQUE)	CONCENTRATION RANGE	PRECISION % RSD	ACCURACY % BIAS
BENZENE	624 (GC/MS)	11 ug/l 480 ug/l	16 21	0 -16
	8240 (GC/MS)	5-100 ug/l	21	12
BROMODICHLOROMETHANE	624 (GC/MS)	8 ug/l 480 ug/l	28 18	-8.8 -6.7
	501.1 (PURGE & TRAP GC/MS)	0.9 ug/l 550 ug/l	66 34	0 -3.8
	501.2 (EXTRACTION GC/MS)	1.8 ug/l 170 ug/l	61 23	33 -19
BROMOFORM	624 (GC/MS)	9 ug/l 400 ug/l	32 30	-23 10
	501.1 (PURGE & TRAP GC/MS)	4.8 ug/l 550 ug/l	44 41	-27 7.5
	501.2 (EXTRACTION GC/MS)	6 ug/l 170 ug/l	14 15	-23 1.8

TABLE C-1-C: HISTORICAL PRECISION AND ACCURACY DATA/WATER [a]
(continued)

LEVEL III ANALYTICAL TECHNIQUES - METHODS OTHER THAN CLP RAS METHODS

ANALYTES	METHOD (TECHNIQUE)	CONCENTRATION RANGE	PRECISION % RSD	ACCURACY % BIAS
CHLOROFORM	624 (GC/MS)	4.5 ug/l	31	2.2
		300 ug/l	14	-0.6
	501.1 (PURGE & TRAP GC/MS)	0.9 ug/l	64	44
		550 ug/l	14	-0.02
	501.2 (EXTRACTION GC/MS)	1.8 ug/l	68	-39
		170 ug/l	26	-1.2
DIBROMOCHLOROMETHANE	624 (GC/MS)	8.1 ug/l	13	-3.1
		360 ug/l	19	10
	501.1 (PURGE & TRAP GC/MS)	0.8 ug/l	35	-12.5
		550 ug/l	36	4.7
	501.2 (EXTRACTION GC/MS)	1.8 ug/l	37	0
		170 ug/l	13	0.02
DIOXIN	613 (GC/MS)	21 ng/l	25	N.A.
		202 ng/l	21	N.A.

LEVEL III ANALYTICAL TECHNIQUES - METHODS OTHER THAN CLP RAS METHODS

ANALYTES	METHOD (TECHNIQUE)	CONCENTRATION RANGE	PRECISION % RSD	ACCURACY % BIAS
METHYLENE CHLORIDE	624 (GC/MS)	7.2 ug/l 480 ug/l	78 52	-17 -25
TOLUENE	624 (GC/MS)	13.5 ug/l 600 ug/l	19 31	15 -14
	8240 (GC/MS)	25 ug/l 75 ug/l	19	-10
TRICHLOROETHENE	624 (GC/MS)	5.4 ug/l 360 ug/l	48 39	44 -2.3
	8240 (GC/MS)	25 ug/l 75 ug/l	24	5
LEAD	200.7 (ICP)	42 ug/l 47.7 ug/l	34 5	31 4.4
	239.1 (FLAME AA)	12 ug/l 105 ug/l	5.9 6.7	17 -1.9
	239.2 (FURNACE AA)	10 ug/l 234 ug/l	53 19	-22 -3.1

a. Source: Draft Compendium of Information and Performance Data on Routinely Used Measurement Methods (RUMM) - Pilot Phase, RTI/3087/03, prepared for EPA Quality Assurance Management Staff, January 1986. This document should be consulted for more information on individual analytes.

TABLE C-1-C: HISTORICAL PRECISION AND ACCURACY DATA/WATER
(Continued)

LEVEL III ANALYTICAL TECHNIQUES - SW-846 METHODS

Method Number	Method Name	Data Source	Range of Recovery (%)	Precision (%)	MDL (mg/l)
ORGANICS:					
8010	Halogenated Volatile Organics	SW 846	75.1 - 106.1	2.0 - 25.1	0.03 - 0.52
8020	Aromatic Volatile Oranics	SW 846	77.0 - 120	9.4 - 27.7	0.2 - 0.4
8030	Acrolein, Acrylonitrile, Acetonitrile	SW 846	96 - 107	5.6 - 11.6	0.5 - 0.6
8040	Phenols	SW 846	41 - 86	7.9 - 16.5	058 - 2.2
8060	Esters	EPA 606	82 - 94	1.3 - 6.5	0.29 - 3.0
8080	Organochlorine Pesticides and PCBs	SW 846	86 - 97	1.3 - 6.5	0.29 - 3.0
8090	Nitroaromatics and Cyclic Ketones	SW 846	63 - 71	3.1 - 5.9	0.06/ND
8100	Polynuclear Aromatic Hydrocarbons		NA[b]	NA	NA
8120	Chlorinated Hydrocarbons	SW 846	76 - 99	10 - 25	0.03 - 1.34
8140	Organophosphorous Pesticides	SW 846	56.5 - 120.7	5.3 - 19.9	0.1 - 5.0
8150	Chlorinated Herbicides	SW 846	NA	NA	0.1 - 200
8240	Volatile Organics	SW 846	95 - 107	9 - 28	1.6 - 6.9
8250	GC/MS Semivolatiles (Packed Column)		41 - 143	20 -145	0.9 - 44
8040	GC/MS Semivolatiles (Capillary)		NA	NA	NA

TABLE C-1-C: HISTORICAL PRECISION AND ACCURACY DATA/WATER
(Continued)

LEVEL III ANALYTICAL TECHNIQUES - SW-846 METHODS

Method Number	Method Name	Data Source	Range of Recovery (%)	Precision (%)	MDL (mg/l)
8310	Polynuclear Aromalic Hydrocarbons (HPLC) (Capillary)	SW 846	78 - 116	7.3 - 12.9	0.03 - 2.3
INORGANICS:	Metals (ICAP)	EPA 200.7	NA	3 - 21.9 (RSD)	1.3 - 75 Mg/l
	Metals (FLAME) 7000 Series	EPA 200	NA	NA	0.01 - 5
7000 Series	Metals (FLAME LESS/GF)	EPA 200	NA	NA	0.001 - 0.2 Mg/l
7470	Metals (MERCURY)	EPA 245.2	87 - 125	0.9 - 4.0	0.0002
9010	Cyanides	EPA 335.2	85 - 102	0.2 - 15.2	0.02 Mg/l
9030	Sulfides	EPA 376.1	NA	NA	1 Mg/l

a. For water only

b. NA Not Available

NOTES: Method Detection Limit (MDL) as listed on this table is the minimum concentration of a substance that can be measured and reported with 99% confidence that the value is above zero.

Accuracy, presented as an average percent recovery, was determined from replicate (10-25) analyses of water and wastewater samples fortified with known concentrations of the analyte of interest at or near the detection limit. In most cases this was less than 10 times the MDL.

Precision data are used to measure the variability of these repetitive analyses reported as a single standard deviation or, as a percentage of the recovery measurements. For presentation purposes accuracy, precision and MDL information is presented as an average range of individual values for every analyte covered by the procedure. If specific information on a particular compound is required, the specific analytical method cited should be consulted.

TABLE C-1-D: HISTORICAL PRECISION AND ACCURACY DATA/WATER[a]

LEVEL IV   ANALYTICAL TECHNIQUES - CLP RAS METHODS

ANALYTES	TECHNIQUE	CONCENTRATION RANGE	PRECISION % RSD	ACCURACY % Bias
Volatiles[b]	Purge & Trap GC/MS	N.A.[c]		
Methylene chloride			56	+36.6
1,1-Dichloroethene			20	-26.3
1,1-Dichloroethane			13	-46.4
Trans-1,2-Dichloroethene			31	-21.7
Chloroform			12	-21.1
1,2-Dichloroethane			13	+2.4
1,1,1-Trichloroethane			19	-41.0
Carbon Tetrachloride			12	-32.1
1,1,2,2-Tetrachloroethane			11	-5.8
Bromodichloromethane			19	-13.0
1,2-Dichloropropane			18	-12.9
Trans-1,3-Dichloropropene			31	-41.2
Trichloroethene			17	-22.8
Dibromochloromethane			14	-3.3
1,1,2-Trichloroethane			11	-7.0
Benzene			12	-3.3
Cis-1,3-Dichloropropene			22	-35.5
Bromoform			16	+6.5
Tetrachloroethene			13	-42.5
Toluene			14	-23.3
Chlorobenzene			14	-15.9
Ethyl Benzene			4	-31.9
Semivolatiles[d]	GC/MS	N.A.[c]		
bis(2-Chloroethyl)ether			24	-16
2-Chlorophenol			29	-21
1,3-Dichlorobenzene			24	-48
1,4-Dichlorobenzene			21	-25
1,2-Dichlorobenzene			29	-28
2-Methylphenol			29	-30
bis(2-Chloroisopropyl)ether			25	-22

TABLE C-1-D: HISTORICAL PRECISION AND ACCURACY DATA/WATER

LEVEL IV ANALYTICAL TECHNIQUES - CLP RAS METHODS

ANALYTES	TECHNIQUE	CONCENTRATION RANGE	PRECISION % RSD	ACCURACY % Bias
Semivolatiles[d]	GC/MS	N.A.[c]		
4-Methylphenol			33	-36
N-Nitroso-di-n-propylamine			31	+0.3
Nitrobenzene			32	-23
Isophorone			23	-8
2-Nitrophenol			30	-21
bis(2-Chloroethoxy)methane			34	-2.6
2,4-Dichlorophenol			29	-20
1,2,4-Trichlorobenzene			30	-47
Naphthalene			44	-38
4-Chloro-3-methylphenol			26	-32
2,4,6-Trichlorophenol			25	-17
2-Chloronapthalene			24	+3.4
Acenapthene			28	-12
2,4-Dinitrophenol			24	-23
2,4-Dinitrotoluene			34	-33
2,6-Dinitrotoluene			25	-48
4-Chlorophenyl-phenylether			34	+12
Fluorene			25	-24
4,6-Dinitro-2-methylphenol			30	-13
4-Bromophenyl-phenylether			32	-0.1
Hexachlorobenzene			36	-42
Pentachlorophenol			31	-24
Phenanthrene			21	-28
Fluoranthene			42	-15
Benzo(b)fluoranthene			39	-10
Benzo(a)pyrene			42	-29

TABLE C-1-D: HISTORICAL PRECISION AND ACCURACY DATA/WATER
(continued)

LEVEL IV ANALYTICAL TECHNIQUES - CLP RAS METHODS

ANALYTES	TECHNIQUE	CONCENTRATION RANGE	PRECISION % RSD	ACCURACY % Bias
Metals[e]				
Aluminum	ICP	1000-3000 ug/l	9.1	-4.3
Antimony	ICP	180-600 ug/l	11	-9.2
Arsenic	Furnace AA	50-150	9.4	-8.3
Barium	ICP	800-1500	6.8	-3.9
Beryllium	ICP	30-45	15	+3.7
Cadmium	ICP	25-50	12	-3.3
Calcium	ICP	1000-30000	6.0	-1.6
Chromium	ICP	50-150	9.8	-2.6
Cobalt	ICP	200-1000	6.7	-2.9
Copper	ICP	125-250	6.7	-1.1
Iron	ICP	200-800	10.4	+6.5
Lead	Furnace AA	30	32	-0.7
Magnesium	ICP	10000-40000	6.6	-2.5
Manganese	ICP	30-150	6.2	-1.0
Mercury	Cold Vapor	5-20	18.8	-14.4
Nickel	ICP	160	9.0	-2.5
Potassium	ICP	10000-20000	16.2	-12.1
Selenium	Furnace AA	50	8.7	-5.7
Sodium	ICP	10000-45000	8.7	-2.8
Thallium	Furnace AA	80-100	17.7	-4.2
Tin	ICP	160	N.A.[c]	-2.5
Vanadium	ICP	60-200	7.6	-0.46
Zinc	ICP	50-800	9.1	+3.0

a. Source: Quality Control in Remedial Site Investigation: Hazardous and Industrial Solid Waste Testing, Fifth Volume, ASTM STP 925, C.L. Perket, Ed., American Society for Testing Materials, Philadelphia, 1986.

b. Volatile precision and accuracy data from 26-34 laboratories' results on quarterly blind performance evaluation samples; 29-152 data points for each compound.

c. N.A. = Not Available.

d. Semivolatile precision and accuracy data from 1935 preaward program data; 22-227 data points for each compound.

e. Metals precision and accuracy data is based on performance evaluation sample results from 18 laborator es; number of data points is not given.

TABLE C-2-A: HISTORICAL PRECISION AND ACCURACY DATA/SOILS

LEVEL I FIELD SCREENING TECHNIQUES

MEASUREMENT	INSTRUMENT (TECHNIQUE)	INSTRUMENT RANGE	INSTRUMENT PRECISION [b]	INSTRUMENT ACCURACY [c]
RESISTIVITY	Bison 2390 T/R (Resistivity meter)	0-1999 millivolts	at 1% range setting, 0-5% of full scale	2% of measured value
TERRAIN CONDUCTANCE	EM 31 (conductivity)	0-1000 millimhos/meter	2% of full scale	5% at 20 millimhos/meter
TERRAIN CONDUCTANCE	EM 34-3 (conductivity)	0-300 millimhos/meter	2% of full scale	5% at 20 millimhos/meter
Magnetic Field Intensity	EDA – Omni IV (Magnetometer)	18000-110000 gammas	0.02 gamma	1 gamma at 50000 gammas at 23oC
Subsurface Lithology Changes	SIR-8 (Ground Penetrating Radar)	1-81 dielectric constant	N/A[d]	N/A[d]
Subsurface Lithology Changes	EG+G 1225 (Seismograph)	0-2000 milliseconds	N/A[d]	0.01%

TABLE C-2-A: HISTORICAL PRECISION AND ACCURACY DATA/SOIL[a]
(continued)

LEVEL I FIELD SCREENING TECHNIQUES

MEASUREMENT	INSTRUMENT (TECHNIQUE)	FIELD SCREENING RESULTS in ppm (X)	CLP RESULTS in ppm (Y)	ACCURACY[e] (% Bias)
TOTAL	PHOTO VAC	11.4	26.9	-57.6
VOLATILE	(GC/Photoionization)	22.0	32.8	-32.9
ORGANICS		56.0	129.7	-56.8
		139	228.0 & 258.0	-42.8
		70.0	126.7	-44.8
		24.9	2823.0	+99.1
		60.0	53.3	+12.6
		6.6	0.056	+116.9
		12.1	0.032	+377.1
		8.7	0.024	+361.5

a. Source: Manufacturers' manuals unless otherwise cited. Mention of specific models does not constitute and endorsement of these instrument.

b. Precision refers to reproducibility of meter or instrument reading as cited in instrument specifications.

c. Accuracy refers to instrument specifications unless otherwise cited.

d. N.A. = not available.

e. Accuracy of PhotoVac field screening results calculated by assuming that CLP results on the same samples were completely accurate.   % Bias = $100 \frac{(X-Y)}{Y}$. Source of these data is CDM project files.

TABLE C-2-B: HISTORICAL PRECISION AND ACCURACY DATA/SOIL[a]

<u>LEVEL II FIELD TECHNIQUES</u>

<u>ANALYTES</u>	INSTRUMENT (TECHNIQUE)	FIELD RESULTS IN ppm (x)	CLP RESULTS IN ppm (y)	ACCURACY [b] % BIAS
<u>PCBs</u>	HNu 301 (GC/ELECTRON CAPTURE)	6.0	22.0	-72.7
		6.0	6.1	-1.6
		6.0	510.0	-98.8
		9.0	3.9	+56.7
		13.0	3.0	+333.3
		14.0	3.1	+351.6
		14.0	23.5	-40.4
		21.0	8.1	+159.3
		35.0	7.7	354.5
		41.0	2.1	+1,852
		48.0	11.0	+336.3
		50.0	460.0	-89.1
		65.0	23.1	+181.4
		67.0	18.7	+258.3
		92.0	75.0	22.7
		95.0	30.0	+216.7
		11	12.3	-10.6
		202	99.0	+104.0
		269	370.0	-27.3
		286	80.5	+255.3
		1215	640.0	+90.0
		1647	1040.0	+58.4
		3054	9,300	-67.2.

a. Source: CDM Project files.

b. Source: Accuracy calculated by assuming that CLP results on the same samples were completely accurate. % Bias = $100 \dfrac{(x-y)}{y}$

TABLE C-2-C: HISTORICAL PRECISION AND ACCURACY DATA/SOIL[a]

LEVEL III ANALYTICAL TECHNIQUES - METHODS OTHER THAN CLP RAS METHODS

ANALYTE	METHOD (TECHNIQUE)	CONCENTRATION RANGE	PRECISION % RSD	ACCURACY % BIAS
DIOXINS	8280 (HPLC/LRMS)	5 ppb 125 ppb	6-30 3-10	N.A. N.A.
	JAR EXTRACTION GC/MS	1 ppb 10 ppb	20 10	0 -18

a. Source: Draft Compendium of Information and Performance Data on Routinely Used Measurement Methods (RUMM) - Pilot Phase, RTI/3087/03, prepared for EPA Quality Assurance Management Staff, January 1986. This document should be consulted for more information on individual analytes.

TABLE C-2-D: HISTORICAL PRECISION AND ACCURACY DATA/SOILS[a]

LEVEL IV ANALYTICAL TECHNIQUES - CLP RAS METHODS

ANALYTES	TECHNIQUE	CONCENTRATION RANGE	PRECISION % RSD	ACCURACY % Bias
Volatiles[b]	Purge & Trap GC/MS	N.A.[c]		
Chloroform			8.0	-0.1
1,2-Dichloroethane			13.1	+11.1
Dibromochloromethane			35.0	-12.0
Benzene			32.1	-10.3
Bromoform			16.6	-12.1
2-Hexanone			16.6	-45.5
Toluene			13.8	+13.7
Chlorobenzene			21.2	+13.2
Semivolatiles[d]	GC/MS	N.A.[c]		
1,4-Dichlorobenzene			27	-51
Nitrobenzene			21	-48
Isophorone			24	-47
2-Nitrophenol			35	-36
2,4-Dichlorophenol			31	-59
1,2,4-Trichlorobenzene			28	-43
Penta Chlorophenol			17	-48
Pyrene			25	-15
2-Methylnaphthalene			26	-42
bis-(2-Ethylhexyl)phthalate			33	-2
Phenol			38	-27
Acenaphthylene			26	-27
Diethyphthalate			16	-20
Dioxin[e]				
2,3,7,8-TCCD		1-10 ug/kg	15	-11.5

TABLE C-2-D: HISTORICAL PRECISION AND ACCURACY DATA/SOILS[a]
(continued)

LEVEL IV ANALYTICAL TECHNIQUES - CLP RAS METHODS

ANALYTES	TECHNIQUE	CONCENTRATION RANGE	PRECISION % RSD	ACCURACY % Bias
Metals[b]				
Aluminum	ICP	2-22600 ug/kg	14.4	-78.8
Cadmium	ICP	5.5-20	33.3	+2.9
Calcium	ICP	2664-29000	N.A.[c]	-4.2
Chromium	ICP	8.5-29600	7.8	-6.1
Copper	ICP	33-109	11.2	-2.5
Iron	ICP	5028-113000	10.7	-27.0
Lead	Furnace AA	11.5-714	9.2	-2.2
Magnesium	ICP	2428-7799	7.5	-10.6
Manganese	ICP	73.5-785	9.4	-15.1
Mercury	Cold Vapor	1.1-26.5	25.0	-9.1
Nickel	ICP	44-67	15.0	-17.0[c]
Tin	ICP	N.A.[c]	44.1	N.A.[c]
Zinc	ICP	19-1720	5.8	-6.2

a. Source: Quality Control in Remedial Site Investigation: Hazardous and Industrial Solid Waste Testing, Fifth Volume, ASTM STP 925, C.L. Perket, Ed., American Society for Testing Materials, Philadelphia, 1986.

b. Volatiles precision and accuracy data is based on 1985 preaward analysis results from laboratories awarded contracts; 6-14 data points for each compound.

c. N.A. = Not Available.

d. Semivolatiles precision and accuracy data is based on 1985 preaward analysis results; 9-20 data points for each compound.

e. Dioxin precision and accuracy data is based on results of four performance evaluation samples including 120 data points.

f. Metals precision and accuracy data is based on performance evaluation sample results from 18 laboratories; number of data points is not given.

TABLE C-3-A: HISTORICAL PRECISION AND ACCURACY DATA/AIR[a]

LEVEL I FIELD SCREENING TECHNIQUES[b]

ANALYTES	INSTRUMENT (TECHNIQUE)	INSTRUMENT RANGE	INSTRUMENT SENSITIVITY[c]	INSTRUMENT PRECISION[c]
Organics	Century OVA-128 (Flame Ionization)	0.1 - 1000 ppm Methane	0.1 ppm Methane	N.A.[d]
Organics	HNu PI-101 (Photoionization)	0.1 - 2000 ppm Benzene	0.1 ppm Benzene	± 1% of full scale deflection
Organics	AID - 710 (Flame Ionization)	0.1 - 2000 ppm Methane	0.1 ppm Methane	N.A.[d]
Organics	PhotoVac (GC-Photoion-ization)	N.A.	0.001 ppm Benzene	N.A.[d]

a. Source: Manufacturers' manuals unless otherwise cited. Mention of specific models does not constitute an endorsement of these instruments.

b. It is difficult to differentiate between Level I and Level II techniques and instrumentation. Several instruments may be used at both levels.

c. Sensitivity and precision refer to instrument specifications.

d. N.A. = Not Available.

TABLE C-3-B: HISTORICAL PRECISION AND ACCURACY DATA/AIR[a]

LEVEL II FIELD TECHNIQUES[b]

ANALYTES	INSTRUMENT (TECHNIQUE)	INSTRUMENT RANGE	INSTRUMENT SENSITIVITY[c]	INSTRUMENT PRECISION[c]
Organics Compound-Specific	Miran IB (Infrared)	Compound Dependent, 0-2000 ppm	N.A.[d]	N.A.[d]
Organics, Compound-Specific	Century OVA-128 (GC/Flame Ionization)	1-1000 ppm Methane	N.A.	N.A.
Organics, Compound-Specific	PhotoVac (GC-Photo-ionization)	N.A.	0.001 ppm Benzene	N.A.
Organics, Compound-Specific	SCENTOR (Argon Ionization or Electron Capture)	N.A.	0.001 ppm Benzene	N.A.
Mercury	Gold film Mercury Analyzer	N.A.	less than 0.01 ppm	N.A.

a. Source: Manufacturers' manuals. Mention of specific models does not constitute an endorsement of these instruments.

b. It is difficult to differentiate between Level I and Level II techniques and instrumentation. Several instruments may be used at both levels.

c. Sensitivity and precision refer to instrument specifications.

d. N.A. = Not Available.

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TABLE C-3-C: HISTORICAL PRECISION AND ACCURACY DATA/AIR[a]

LEVEL III ANALYTICAL TECHNIQUES - METHODS OTHER THAN CLP RAS METHODS

ANALYTES	METHOD (TECHNIQUE)	CONCENTRATION RANGE	PRECISION % RSD	ACCURACY % BIAS
BENZENE	CRYOGENIC TRAP/GC	3.9 ppb	4.0	N.A.
		93 ppb	5.1	N.A.
	TENAX GC/MS	7.8 ug/m3	11	N.A.
		4.5 ug/m3	21	N.A.
TOLUENE		10.8 ppb	5.11	N.A.
TRICHLOROETHENE		3.5 ppb	4.1	N.A.
		84 ppb	3.7	N.A.
VINYL CHLORIDE		7.8 ppb	6.37	N.A.
LEAD	40 CFR 50, APP G (FLAME AA)	0.6 ug/m3	8.6	0
		8.01 ug/m3	3.9	-3.6

a. Source: Draft Compendium of Information and Performance Data on Routinely Used Measurement Methods (RUMM) - Pilot Phase, RTI/3087/03, prepared for EPA Quality Assurance Management Staff, January 1986. This document should be consulted for more information on individual analytes.

TABLE C-4-C: HISTORICAL PRECISION AND ACCURACY DATA/OTHER MEDIA[a]

LEVEL III ANALYTICAL TECHNIQUES - METHODS OTHER THAN CLP RAS METHODS

ANALYTE	METHOD (TECHNIQUE)	MEDIUM	CONCENTRATION RANGE	PRECISION % RSD	ACCURACY % BIAS
LEAD	6010 (ICP)	OIL WASTE	1.0 mg/kg -2.5 mg/kg	3.1 22	-10 -20
		SOLID WASTE	50 mg/kg 75 mg/kg	10 3.7	3.4 -0.8
	SOLID	SLUDGE	5 mg/kg 20 mg/kg	2 11	0 55

a. Source: Draft Compendium of Information and Performance Data on Routinely Used Measurement Methods (RUMM) - Pilot Phase, RTI/3087/03, prepared for EPA Quality Assurance Management Staff, January 1986. This document should be consulted for more information on individual analytes.

Appendix D

APPENDIX D

MODIFIED RCRA APPENDIX VIII

TABLE D-1

ORGANIC COMPOUNDS ON CLP/HSL
BUT NOT INCLUDED ON MODIFIED APPENDIX VIII

Common Name	CAS RN
Acetone	67.64.1
Vinyl Acetate	108.05.4
2-Hexanone	591.78.6
Ethylbenzene	100.41.4
Styrene	100.42.5
Xylenes (Total)	1330-20-7
Benzyl Alcohol	100.51.6
Isophorone	78.59.1
2-Nitrophenol	88.75.5
Benzoic Acid	65.85.0
2-Methylnaphthalene	91.57.6
2-Nitroaniline	88.74.4
3-Nitroaniline	99.09.2
Dibenzofuran	132.64.9
4,Chlorophenyl-phenylether	7005.72.3
Endrin Ketone	53494.70.5
Endosulfan Sulfate	1031.07.8

TABLE D-2

ORGANIC COMPOUNDS ON MODIFIED APPENDIX VIII LIST
BUT NOT INCLUDED ON CLP/HSL

Common Name	CAS RN	Class[a]
Acetonitrile	75.05.8	CLP/VOA
Acetophenone	98.86.2	CLP/BNA
2-Acetylaminofluorine	53.96.3	CLP/BNA
Acrolein	107.02.8	CLP/VOA
Acrylonitrile	107.13.1	CLP/VOA
Allyl Alcohol	107.18.6	NRA
4-Aminobiphenyl	92.67.1	CLP/BNA
Aramite	140.57.8	CLP/BNA
Benzenethiol	108.98.5	CLP/BNA
p-Benzoquinone	106.51.4	CLP/BNA
Bromoacetone	598.31.2	NRA
2-sec-butyl-4,6-dinitrophenol	88.85.7	CLP/BNA
Chlorobenzilate	510.15.6	CLP/BNA
2-chloro-1,3-butadiene	126.99.8	CLP/BNA
3-chloropropene	107.05.1	CLP/VOA
3-chloropropionitrile	542.76.7	CLP/BNA
Diallate	2303.16.4	CLP/BNA
Dibenzo [a,e] pyrene	192.65.4	CLP/BNA
Dibenzo [a,h] pyrene	189.64.0	CLP/BNA
Dibenzo [a,i] pyrene	189.55.9	CLP/BNA
1,2-dibromo-3-chloropropane	96.12.8	CLP/VOA
1,2-dibromoethane	106.93.4	CLP/VOA
Dibromomethane	74.95.3	CLP/VOA
1,4-dichloro-2-butene	764.41.0	CLP/VOA
Dichlorodifluoromethane	75.71.8	CLP/VOA
2,6 Dichlorophenol	87.65.0	CLP/BNA
1,3-Dichloropronene	542.75.6	CLP/VOA
0,0-Diethyl 0-2-pyrazinyl phosphorothioate	297.97.2	NRA
3,3-Dimethoxybenzidine	119.90.4	CLP/BNA
p-Dimethylaminozobenzene	60.11.7	CLP/BNA
7,12-Dimethylbenz[a]anthracene	57.97.6	CLP/BNA
3,3'-Dimethylbenzidine	119.93.7	CLP/BNA
alpha-Dimethylphenethylamine	122.09.8	CLP/BNA
1,4-Dioxane	123.91.1	NRA
Diphenylamine	122.39.4	CLP/BNA
1,2-Diphenylhydrazine	122.66.7	CLP/BNA
Di-n-propylnitrosamine	621.64.7	CLP/BNA
Disulfoton	298.04.4	CLP/VOA
Ethyl Cyanide	107.12.0	CLP/VOA
Ethylene Oxide	75.21.8	NRA
meta-dinitrobenzene	100.25.4	CLP/BNA
Silvex	93.72.1	NRA
1,2,3-trichloropronene	96.18.4	CLP/VOA
Tris (2,3-dibromopropyl) phosphate	126.72.7	CLP/BNA

TABLE D-2 (CONT'D)

Common Name	CAS RN	Class[a]
Phenacetin	62.44.2	CLP/BNA
N-Phenylthiourea	103.85.5	CLP/BNA
Phorate	298.02.2	NRA
Famphur	52.85.7	NRA
2-Picoline	109.06.8	CLP/BNA
Propanamide	23950.58.5	CLP/BNA
2-Propyn-1-ol	107.19.7	NRA
Pyridine	110.86.1	CLP/BNA
Resorcinol	108.46.3	CLP/BNA
Safrole	44.59.7	CLP/BNA
1,2,4,5-Tetrachlorobenzene	95.94.3	CLP/BNA
1,1,1,2-Tetrachloroethane	630.20.6	CLP/VOA
2-Naphthylamine	91.59.8	CLP/BNA
N-Nitrosodi-n-butylamine	924.16.3	CLP/BNA
N-Nitrosodiethylamine	55.18.5	CLP/BNA
N-Nitrosomethylethylamine	10595.95.6	CLP/BNA
N-Nitrosomorpholine	59.89.2	CLP/BNA
N-Nitrosopiperdine	100.75.4	CLP/BNA
5-Nitro-o-toluidine	99.44.8	CLP/BNA
Parathion	56.38.2	NRA
Pentachlorobenzene	608.93.5	CLP/BNA
Pentachloroethane	76.01.7	CLP/BNA
Pentachloronitrobenzene	82.68.8	CLP/BNA
Kepone	143.50.0	CLP/PCB-Pest
Malonitrile	109.77.3	CLP/BNA
Methyacrylonitrile	126.98.7	CLP/VOA
Methapyrilene	91.80.5	CLP/BNA
3-Methylchloranthrene	56.49.5	CLP/BNA
4,4-Methylene-bis (2-chloroaniline)	101.14.4	CLP/BNA
Methylmethacrylate	80.62.6	CLP/BNA
Methylmethanesulfonate	66.27.3	CLP/BNA
Aldicarb	116.06.3	CLP/BNA
Methyl parathion	298.00.0	NRA
1,4 Naphthoquinone	130.15.4	CLP/BNA
1-Naphthylamine	134.32.7	CLP/BNA
2,3,4,6-Tetrachlorophenol	58.90.2	CLP/BNA
Tetraethyldithiopyrophosphate	3689.24.5	NRA
Trichloromethanethal	75.70.7	CLP/BNA
Trichloromonofluoromethane	75.69.4	CLP/VOA
2,4,5-T	93.76.5	NRA
Ethyl Methacrylate	97.63.2	CLP/BNA
Isodrin	465.73.6	CLP/PCB-Pest
Hexachlorophene	70.30.4	CLP/BNA
Hexachloropropene	1888.71.7	CLP/VOA
Iodomethane	74.88.4	CLP/VOA
Isobutylalcohol	78.33.1	CLP/VOA
Isosafrole	120.58.1	NRA

TABLE D-2 (CONT'D)

NOTES

[a]Class Abbreviations

NRA - Not readily analyzable using current CLP Procedures

CLP/VOA - Potentially analyzable using current CLP/HSL GC/MS Volatile Organics Procedure

CLP/BNA - Potentially analyzable using current CLP/HSL Base/Neutral Acid Extractable GC/MS Procedure

CLP/PCB-Pest - Potentially analyzable using current CLP/HSL PCB/Pesticide GC Procedure

TABLE D-3

ORGANIC COMPOUNDS ON MODIFIED
APPENDIX VIII
LIST THAT ARE NOT READILY ANALYZABLE BY CURRENT
CLP/HSL PROCEDURES

Common Name	CAS RN	Class[a]
Allyl alcohol	107.18.6	WS/NV
Bromoacetone	598.31.2	WR
O,O-Diethyl-O-2-Pyrazinyl phosphorothioate	297.97.2	OP
1,4 Dioxane	123.91.1	WS/NV
Ethylene Oxide	75.21.8	NR (VOA)
Silvex	93.72.1	CH
Phorate	298.02.2	OP
Famphur	52.85.7	OP
2-Propyn-1-ol	107.19.7	WS/NV
Parathion	56.38.2	OP
Methyl Parathion	298.00.0	OP
Tetraethyldithiopyrophosphate	3689.24.5	WR
2,4,5-T	93.76.5	CH
Isosafrole	120.58.1	D/H

NOTES

[a]Class Abbreviations

WS/NV - Water soluble, nonvolatile compound probability not amenable to
purge and trap or liquid/liquid extraction pretreatment.

WR - Water reactive, unanalyzable in aqueous matrix.

OP - Organophosphorous pesticide best analyzed by a modified SW-846,
Method 8140.

NR (VOA) - Not recoverable at 200 PPB using standard HSL/CLP volatile
organics procedures. May be more ameneable to head space analysis.

CH - Chlorinate herbicide, must be derivatized prior to analysis. Best
analyzed using modified SW-846 Method 8150.

D/H - Decomposes at conventional GC temperatures HLPC procedure may be
applicable.

APPENDIX E

CONTRACT – REQUIRED DETECTION LIMITS
FOR HSL ANALYSIS
USING CLP IFB PROCEDURES

TABLE E-1

CLP VOLATILE ORGANIC CRDL

Target compound name	SPCC[b] CCC[c]	Low soil CRDL, µg/kg	Low water CRDL, µg/L	CAS number
Chloromethane	SPCC	10	10	74-87-3
Bromomethane		10	10	74-83-9
Vinyl Chloride	CCC	10	10	75-01-4
Chloroethane		10	10	75-00-3
Methylene Chloride		5	5	75-09-2
Acetone		10	10	67-64-1
Carbon Disulfide		5	5	75-15-0
1,1-Dichloroethene	CCC	5	5	75-35-4
1,1-Dichloroethane	SPCC	5	5	75-35-3
Trans-1,2-Dichloroethene		5	5	156-60-5
Chloroform	CCC	5	5	67-66-3
1,2-Dichloroethane		5	5	107-06-2
2-Butanone		10	10	78-93-3
1,1,1-Trichloroethane		5	5	71-55-6
Carbon Tetrachloride		5	5	56-23-5
Vinyl Acetate		10	10	108-05-4
Bromodichloromethane		5	5	75-27-4
1,1,2,2-Tetrachloroethane	SPCC	5	5	79-34-5
1,2-Dichloropropane	CCC	5	5	78-87-5
Trans-1,3-Dichloropropene		5	5	10061-02-6
Trichloroethene		5	5	79-01-6
Dibromochloromethane		5	5	124-48-1
1,1,2-Trichloroethane		5	5	79-00-5
Benzene		5	5	71-43-2
Cis-1,3-Dichloropropene		5	5	10061-01-5
2-Chloroethyl Vinyl Ether		10	10	110-75-8
Bromoform	SPCC	5	5	75-25-2
4-Methyl-2-pentanone		10	10	108-10-1
2-Hexanone		10	10	591-78-6
Tetrachloroethene		5	5	127-18-4
Toluene	CCC	5	5	108-88-3
Chlorobenzene	SPCC	5	5	108-90-7
Ethyl Benzene	CCC	5	5	100-41-4
Styrene		5	5	100-42-5
Total Xylenes		5	5	N.A.

[a]CRDL values obtained from the IFB WA85-J664 [7].
[b]System Performance Check Compounds (SPCC) are used to check compound instability and degradation in the GC/MS and to insure minimum average response factors are met prior to the use of the calibration curve.
[c]Column Check Compounds (CCC) are used to check the validity of the initial calibration.
Note: Medium soil and water CRDLs are 100 times the low level CRDLs.

SOURCE: Flotard, R.D. et al 1986

TABLE E-2

CLP INORGANIC COMPOUND CRDL,
INSTRUMENT DETECTION LEVEL AND WAVELENGTH

Element	CRDL	Method	N	IDL Mean	IDL Std Dev	Wave-Length (nm)
Al	200	ICP	7	70.7	59.3	309.3
Sb	60	ICP	5	42.3	11.3	217.6
As	10	FAA	18	4.6	2.3	198.7
Ba	200	ICP	5	22.1	31.7	493.4
Be	5	ICP	10	2.3	1.7	312.0
Cd	5	ICP	5	4.0	1.1	228.8
Ca	5000	ICP	7	529	472	317.9
Cr	10	ICP	9	5.8	2.9	267.7
Co	50	ICP	11	11.4	8.5	228.6
Cu	25	ICP	11	9.7	6.5	324.5
Fe	100	ICP	10	27.4	20.9	259.9
Pb	5	ICP	12	2.3	1.2	283.3
Mg	5000	ICP	11	385	449	279.6
Mn	15	ICP	10	5.2	4.6	257.6
Hg	0.2	CV	12	0.2	0.1	253.7
Ni	40	ICP	9	17.8	10.1	232.0
K	5000	ICP	8	668	444	766.5
Se	5	FAA	18	2.8	1.3	196.0
Ag	10	ICP	10	5.4	2.7	328.1
Na	5000	ICP	9	756	864	589.0
Tl	10	ICP	18	4.3	2.4	276.8
Sn	40	ICP	7	23.8	8.4	190.0
V	50	ICP	10	13.1	10.0	292.5
Zn	20	ICP	0	8.3	6.3	213.9

IDL - Instrument Detection Limit (μg/L).
N - Number of laboratories using the most common wavelength.
CRDL - Contract Required Detection Limit (μg/L).

SOURCE: Aleckson, K.A. et al 1986.

TABLE E-3

CLP SEMI-VOLATILE HSL COMPOUNDS AND CRDL

Compound name	SPCC[d] or CCC[b]	Low Soil CRDL, µg/kg	Low Water CRDL, µg/L	CAS Number
Phenol	CCC	330	10	108-95-2
bis(2-Chloroethyl)ether		330	10	111-44-4
2-Chlorophenol		330	10	95-57-8
1,3-Dichlorobenzene		330	10	541-73-1
1,4-Dichlorobenzene	CCC	330	10	106-46-7
Benzyl alcohol		330	10	100-51-6
1,2-Dichlorobenzene		330	10	95-50-1
2-Methylphenol		330	10	95-48-7
bis(2-Chloroisopropyl)ether		330	10	39638-32-9
4-Methylphenol		330	10	105-44-5
N-Nitroso-di-n-propylamine	SPCC	330	10	621-64-7
Hexachloroethane		330	10	67-72-1
Nitrobenzene		330	10	98-95-3
Isophorone		330	10	78-59-1
2-Nitrophenol	CCC	330	10	88-75-5
2,4-Dimethylphenol		330	10	105-67-9
Benzoic acid		1,600	50	65-85-0
bis(2-Chloroethoxy)methane		330	10	111-91-1
2,4-Dichlorophenol		330	10	120-83-2
1,2,4-Trichlorobenzene		330	10	120-82-1
Naphthalene		330	10	91-20-3
4-Chloroaniline		330	10	106-47-8
Hexachlorobutadiene	CCC	330	10	87-68-3
4-Chloro-3-methylphenol	CCC	330	10	59-50-7
2-Methylnaphthalene		330	10	91-57-6
Hexachlorocyclopentadiene	SPCC	330	10	77-47-4
2,4,6-Trichlorophenol	CCC	330	10	88-06-2
2,4,5-Trichlorophenol		1,600	50	95-95-4
2-Chloronaphthalene		330	10	91-58-7
2-Nitroaniline		1,600	50	88-74-4
Dimethylphthalate		330	10	131-11-3
Acenaphthylene		330	10	208-96-8
3-Nitroaniline		1,600	50	99-09-2
Acenaphthene	CCC	330	10	83-32-9
2,4-Dinitrophenol	SPCC	1,600	50	51-28-5
4-Nitrophenol	SPCC	1,600	50	100-02-7
Dibenzofuran		330	10	132-64-9
2,4-Dinitrotoluene		330	10	121-14-2
2,6-Dinitrotoluene		330	10	606-20-2
Diethylphthalate		330	10	84-66-2
4-Chlorophenyl-phenylether		330	10	7005-72-3
Fluorene		330	10	86-73-7
4-Nitroaniline		1,600	50	100-01-6
4,6-Dinitro-2-methylphenol		1,600	50	534-52-1

TABLE E-3

CLP SEMI-VOLATILE HSL COMPOUNDS AND CRDL
(continued)

Compound name	SPCC[a] or CCC[b]	Low Soil CRDL, ug/kg	Low Water CRDL, ug/L	CAS Number
N-Nitrosodiphenylamine	CCC	330	10	86-30-6
4-Bromophenyl-phenylether		330	10	101-55-3
Hexachlorobenzene		330	10	118-74-1
Pentachlorophenol	CCC	1,600	50	87-86-5
Phenanthrene		330	10	85-01-8
Anthracene		330	10	120-12-7
Di-n-butylphthalate		330	10	84-74-2
Fluoranthene	CCC	330	10	206-44-0
Pyrene		330	10	129-00-0
Butylbenzylphthalate		330	10	85-68-7
3,3'-Dichlorobenzidine		660	20	91-94-1
Benzo(a)anthracene		330	10	56-55-3
bis(2-Ethylhexyl)phthalate		330	10	117-81-7
Chrysene		330	10	218-01-9
Di-n-octylphthalate	CCC	330	10	117-84-0
Benzo(b)fluoranthene		330	10	205-99-2
Benzo(k)fluoranthene		330	10	207-08-9
Benzo(a)pyrene	CCC	330	10	50-32-8
Indeno(1,2,3-cd)pyrene		330	10	193-39-5
Dibenz(a,h)anthracene		330	10	53-70-3
Benzo(g,h,i)perylene		330	10	191-24-2

[a]CCC-Calibration Check Compound
[b]SPCC-System Performance Check Compound
Note: Medium soil/sediment contract required detection limits are 60
       times the individual low soil/sediment CRDL and medium water
       contract required detection limits are 100 times the individual
       low water CRDL.

SOURCE: Wolf, J.S. et al 1986.