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Section	Page	Paragraph	Revision
4.4.2.1	4-11	First	First line, delete the word “be”
6.2.1	6-4	Last	Second line, change “Chapter 6” to “Section 6.4”
7.4	7-15	First	First bullet, change “legal” to “constructive”
7.5	7-16	Last	Last sentence, change “COCss” to “COCs”
7.9	7-23	Last	Second line, change “constituent” to “contaminant”
Appendix 1	A.1-11	Row 6, Column 8	Methyl ethyl ketone (MEK), change Migration to GW level from “12” to “11”
Appendix 1	A.1-11	Row 6, Column 10	Methyl ethyl ketone (MEK), change Default Closure Level from “12” to “11”
Appendix 1	A.1-11	Row 14, Column 8	Nitrobenzene, change Migration to GW from “0.12” to “0.028”
Appendix 1	A.1-11	Row 14, Column 10	Nitrobenzene, change Default Closure Level from “0.12” to “0.028”
Appendix 1	A.1-11	Row 14, Column 13	Nitrobenzene, change Residential from “0.018” to “0.0043”
Appendix 1	A.1-11	Row 14, Column 10	Nitrobenzene, change Default Closure Level from “0.018” to “0.0043”
Appendix 1	A.1-11	Row 26, Column 6	1,1,1,2-Tetrachloroethane, change Direct level from “42” to “37”
Appendix 1	A.1-14	Row 22, Column 6	1,1,1,2-Tetrachloroethane, change Direct level from “74” to “63”
Appendix 1	A.1-18	Row 8, Column 10	Arsenic, change MP from “817” to “818”
Appendix 1	A.1-18	Row 8, Column 11	Arsenic, change BP from “615” to “613”
Appendix 1	A.1-20	Row 3, Column 11	Cyanide, Free, change BP from “-201” to “201”
Appendix 1	A.1-21	Row 4, Column 4	Dimethylphthalate, change Koc from “3.70e+01” to “3.74e+01”
Appendix 1	A.1-21	Row 4, Column 8	Dimethylphthalate, change S from “4.30e-03” to “4.30e+03”
Appendix 1	A.1-22	Row 6	An informational note about lead was added
Appendix 1	A.1-22	Row 19, Column 4	2-nitroaniline, change Koc from “3.93e+02” to “2.66e+01”

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Section	Page	Paragraph	Revision
Appendix 1	A.1-24	Notes	Added note #2: "Lead is regulated using two different models: a media-specific ingestion and absorption model for industrial exposure, and a pharmacokinetic model for children in residential exposure. See also footnote 8 on page A-15"
Appendix 1	A.1-45	Row 2, Column 9	Nitrobenzene, change RfDi Value from "1.1e-01" to "5.7e-4"
Appendix 1	A.1-45	Row 2, Column 10	Nitrobenzene, change RfDi Source from "H" to "9 (H) "
Appendix 1	A.1-46	Table Legend	Added the following note: "A parenthesis indicates the reference cited by a source. Example: 9 (N) means the value was taken from EPA Region 9 Screening Tables, and Region 9 cited NCEA as its source."

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Chapter 1 Risk Integrated System of Closure (RISC)

Overview of Chapter 1

- Introduction
- Definitions and Terms
- Purpose and Applicability
- Exceptions to Using the RISC Default Approach
- Constituent Concentration Limits
- Exposure Pathway Evaluation
- Background Considerations
- Remedial Approaches

1.0 Introduction

This Technical Resource Guidance Document (Technical Guide) was written for use by environmental professionals seeking closure on sites through an Indiana Department of Environmental Management (IDEM) remedial program. This guidance document provides information on how to use the IDEM Risk Integrated System of Closure (RISC) within the authority of IDEM's remediation programs. The intent of the document is to provide (1) a default approach to site closure and (2) a framework for nondefault options if the default approach is not used. The primary goal of RISC is to ensure that risks to human health and the environment are reduced to a negligible level. A companion manual, the RISC User's Guide (User's Guide), offers a broader perspective on programmatic considerations as well as program-specific procedures. The User's Guide should be consulted for program-specific information on how the Technical Guide procedures may be applied.

Although RISC may be used to obtain information relevant to real estate transfers, RISC is not intended for this use, and IDEM is not a party to property transfers. Other methods and procedures, such as those specified by the American Society for Testing and Materials (ASTM), have gained broad, national acceptance in documenting environmental conditions for property transfers.

This chapter provides an overall introduction to RISC, defines key terms, discusses the purpose and applicability of RISC, and identifies exceptions to using the RISC default approach. This chapter also discusses constituent concentration limits, exposure pathways, and remedial approaches.

Non-Rule Policy

As a non-rule policy document, RISC guidance does not have the effect of law. Instead, it provides a systematic approach for consistently and rationally implementing the laws and rules that govern site investigation and closure. If a conflict exists between RISC and state or federal rules and statutes, the rules and statutes will prevail. Upon adoption of the Ground Water Quality Standards rule, IDEM will take appropriate steps to conform the ground water concepts in RISC (such as the Perimeter of Compliance) with the rule.

1.1 Definitions and Terms

The following concepts and terms are fundamental to RISC and to the development of this document: target risk levels, closure, default and nondefault approaches, site size and source area, and risk management. Each of these is discussed below.

1.1.1 Target Risk Levels

An important component of any risk assessment program is the acceptable target risk. For the RISC default approach, target risk levels have been set as follows:

- 1×10^{-5} cancer risk
- Hazard index of 1.0 by critical effect categories for noncarcinogenic effects

In a nondefault evaluation, cancer risk will be set within the range of 1×10^{-6} to 1×10^{-4}, depending on site-specific information, and the noncarcinogen hazard index will be set at 1.0 based upon critical effect categories (see Appendix 1, Table G).

1.1.2 Closure

RISC provides users with a well-defined process for reaching closure. RISC defines closure as follows:

> a. IDEM's written recognition that a party has demonstrated attainment of specific remedial or screening objectives (closure levels) for chemicals of concern at a particular area.
> b. Under the Resource Conservation and Recovery Act (RCRA), refers to a series of formal procedures required to end the operation of a permitted treatment, storage, or disposal (TSD) unit.

The *RISC User's Guide* is available as a companion document to this Technical Guide. The User's Guide provides program-specific information on how RISC may be applied. IDEM strongly recommends that users read the entire Technical Guide and any pertinent chapters of the User's Guide before applying RISC.

The regulatory and legal implications of achieving a particular closure level or levels vary depending on the remedial program involved. For example, achieving closure levels specified in an approved remediation work plan under Indiana's Voluntary Remediation Program leads to the issuance of a certificate of completion by IDEM and a covenant not to sue from the Governor. Achieving residential "clean closure" levels at a RCRA TSD unit means there are no further RCRA regulatory obligations for that unit. These different legal

implications, the form of the closure documentation, and the level of repose achieved vary by remedial program, and are described in more detail in Chapter 6 below, in the User's Guide, and, ultimately, in the governing statutes and regulations.

Closure is granted when an area is suitable for a particular use. The closure document specifies the use and any limitations. Closure may be specific to a facility, a property, a regulated unit, or a specific area within a property.

Closure does not necessarily mean that the area in closure status is free from risk to human health and the environment with regard to *any* possible contaminant. Rather, closure is limited to the specific chemicals of concern addressed during the RISC evaluation. If certain contaminants, geographical areas, or environmental media were not specifically evaluated under RISC, closure will not apply to them. Closure is provided only for areas of a site that have either negligible contamination as demonstrated by sampling, or sufficient institutional controls.

To evaluate a site for closure, representative sampling and analysis is necessary to determine constituent concentrations in environmental media at the site. Representative sampling requires a statistically valid sampling approach; however, no sampling approach will provide absolute certainty with regard to contaminant concentrations in environmental media. The goal of representative sampling is to determine the confidence interval within which the true mean of the chemical of concern (COC) concentrations lie — and to keep the confidence interval as small as possible. These representative COC concentrations are compared to RISC closure levels to determine the extent of remediation, if needed.

1.1.3 Default and Nondefault Approaches to Closure

This Technical Guide differentiates between default and nondefault approaches to closure. *The term "default" refers to the use of any model, equation, constant, strategy, or process that is prescribed for general application as a standard within this RISC Technical Guide.* For example, the "default process" refers to the use of standard procedures described within this document, such as the default process for area screening, plume stability determination, closure sampling, and other activities.

Conversely, the term *"nondefault" refers to the use of any model, equation, constant, strategy, or process that is not prescribed for general application as a standard within this RISC Technical Guide*.

The nondefault process is not, by definition, superior or inferior to the default process. Nondefault procedures may be more applicable or advantageous for use at a particular site, and closure may be granted for nondefault approaches, when appropriate. Chapter 7 describes how nondefault procedures may be used as options within RISC. IDEM technical staff may require more time to review nondefault closure procedures and approaches, and more interaction with regulatory staff should be expected. In all cases, the validity of any nondefault approach must be adequately demonstrated before IDEM can approve such a submittal.

1.1.4 Site and Source Area

Some applications within RISC limit the source area to 0.5 acre or less. *"Source area (source)" is defined as the horizontal and vertical geographical area that exceeds default residential soil closure levels.*

The terms "source" or "source area" should not be confused with *"Site" is defined as a geographical area where environmental chemical of concern evaluation is desired.* This is usually the potential impact area of source area contamination. This may consist of a permitted unit, a facility, an entire property (depending upon program limitations), or adjacent property. Generally speaking, a source area is a specific area within a site. The only time these terms are synonymous is when the entire site, facility, or property is a suspected source area. A site may contain several separate source areas that may be evaluated individually under RISC.

1.1.5 Risk Management Policy

"Risk management" is defined in the RISC Technical Guide as the process of collecting, interpreting, and applying scientific data to ensure that risks to human health and the environment are reduced to a negligible level. To accomplish the RISC goal of negligible risk, the scientific data used to determine risk management decisions must be properly collected and interpreted. The primary goal of reducing risk involves preventing pollution from adversely impacting human health and the environment. A secondary risk management goal is to avoid unnecessary costs and burdens and to move sites through the RISC process to closure in a reasonable period of time

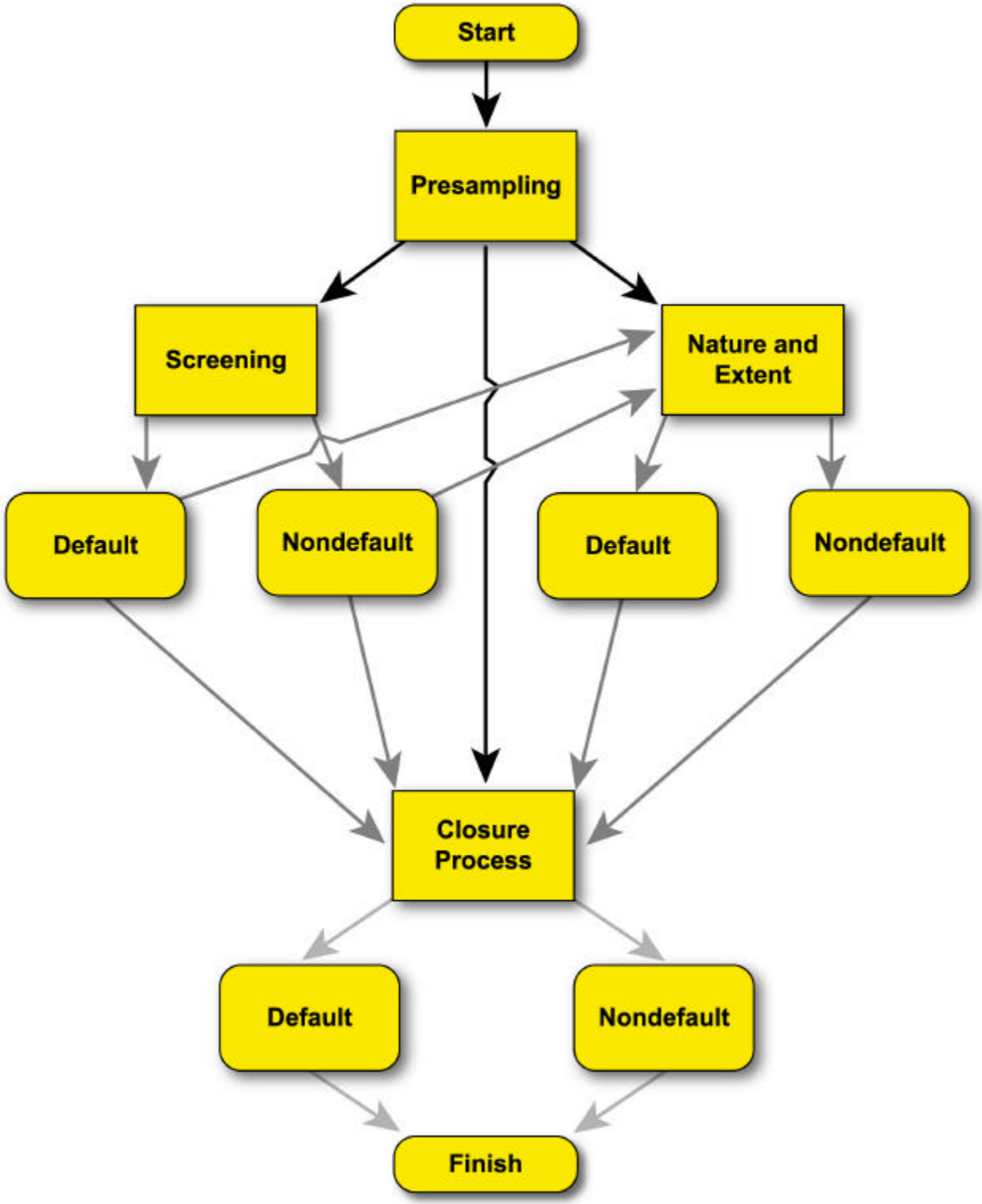
1.2 Purpose and Applicability

RISC is designed to serve as a flexible framework for achieving closure within the following existing IDEM programs:

- Leaking Underground Storage Tank Program (LUST)
- Voluntary Remediation Program (VRP)
- RCRA (Subtitle C) Permitting and Corrective Action Programs
- State Cleanup Program (SCP)

Figure 1-1 provides a flowchart that depicts the specific steps involved in the RISC process. As the figure shows, there are many acceptable approaches and many possible routes from beginning to end. Site-specific goals and time schedules should be evaluated to determine the best way to proceed. The advantage of RISC is its flexibility in the options available for closure.

Figure 1-1. The RISC Process



IDEM may require a post-closure response if new information indicates that site conditions could ultimately present a threat to human health or the environment.

Regardless of the specific program regulating a particular closure, the process involves the same basic steps. First, presampling is an essential activity at any site (see Chapter 2). These activities are conducted to gather available information on current and historic uses of the site. After presampling activities are complete, three courses of action are possible: (1) screening, (2) characterization of the nature and extent of contamination, and (3) closure. For each of these it is possible to use either default or nondefault procedures. Because IDEM has preapproved the default procedures, default submittals will likely move through the review and approval process more quickly than nondefault submittals.

Federal regulations under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and RCRA Subtitle C specify the required parameters for site assessment and cleanup. For these sites, RISC provides supplemental guidance to be considered within the larger context of the federal regulations. In addition, RISC policies supplement existing rules by filling program gaps, particularly in the area of closure standards.

1.3 Exceptions to Using the RISC Default Approach

Because a risk assessment requires significant time for completion, RISC, (default or nondefault), is not suitable for situations that require immediate action or that otherwise present a potential acute or imminent risk. The following are examples of situations that must be remedied before it is appropriate to consider using a risk assessment:

- Releases covered under the Spill Rule (327 IAC 2-6.1)
- Potential acute exposures
- Presence of corrosive, flammable or toxic vapors
- Potential or actual contamination of a drinking water supply well

In some situations, RISC default procedures may not be appropriate because situations at the site are not consistent with RISC default assumptions. In these cases, a nondefault risk assessment is required. Examples of conditions and types of sites that require a nondefault approach include the following:

- Sites with COC source areas greater than 0.5 acre.

- Contaminated areas where bedrock is less than 10 vertical feet from the COC source. In this case, application of the soil-to-ground water partitioning model will require greater IDEM scrutiny and may be subject to additional requirements.

- Sites where vapors are present or intruding. As discussed above, acute, hazardous situations should be addressed immediately.

- Sites that contain or may be connected by a significant migration pathway to any geologically susceptible areas including karst terrains, mined areas, and other fractured rock geology where conduit ground-water flow occurs.

- Sites that contain, or may be connected by a migration pathway to any ecologically susceptible area.

- Sites where contamination may affect a wellhead protection area.

- Sites with an exposure pathway that differs from the default exposure pathway. Default exposure pathways are presented in Table 2-1 (see also Chapter 7, Tables 7-2 and 7-3).

Nondefault Exposure Pathways

Some examples of pathways not considered in the default process include recreational exposure from swimming in contaminated waters, consuming fish from contaminated waters, and inhaling vapors from contaminated industrial process water. If these pathways are present, they must be considered.

1.4 Constituent Concentration Limits

Risk-based closure levels are constituent concentrations calculated to be protective of human health. Limits have been established for risk-based closure concentrations, and some are listed in Appendix 1. A comprehensive list of constituent concentration limits is included on the following page.

1.5 Exposure Pathway Evaluation

Chemicals reach humans through soil, water, and air. These media serve as vehicles that carry chemicals to potential receptors. Such "exposure pathways" provide a means for contaminants to move through environmental media, ultimately creating an exposure. "Exposure route" refers to the ways that chemical contaminants transfer from environmental media into the body. RISC provides guidance for a default evaluation of contamination present in soil and ground water. The default evaluation is based on certain assumptions regarding exposure pathways and routes. These assumptions are necessary to calculate closure levels. Because closure levels identify constituent concentrations that are acceptable for human exposure, it is imperative that potentially contaminated areas be evaluated in a manner consistent with the assumptions of the calculations.

The subsections below discuss the evaluation of three default exposure pathways: soil exposure, ground water exposure, and construction worker occupational exposure.

1.5.1 Evaluating Soil Exposure Pathways

Exposure to soil contamination may occur by three main pathways: direct contact, migration to ground water, and other types, such as ingestion. It is necessary to evaluate each pathway when considering the actual and potential effect of soil COCs to human health.

- Direct contact with soil contamination may occur through any of the following exposure routes:
  - Direct contact with skin (dermal absorption route)
  - Inhalation of COC on soil particulates and dust (ingestion and inhalation routes)
  - Volatilization from soil into the air (inhalation route)
  - Soil consumption (ingestion and dermal absorption routes)
  - COC migration from soil to ground water, which could result in ground water ingestion, inhalation of volatile substances in ground water, and dermal absorption (such as showering or washing).

Additional Limits for Constituent Concentration

1. For each discrete sample, the sum of the concentrations of all organic constituents must not exceed the attenuation capacity of the soil, to be determined as follows:

   The sum of concentrations of residual organic constituents at each discrete sampling point must be less than the natural organic carbon fraction of the soil. If there is any information regarding the concentration of other organic constituents (in addition to chemicals of concern) such information should be included in the sum. The natural organic carbon fraction (f_{oc}) may be established by one of the following criteria:

   - A default value of 6,000 milligrams per kilogram (mg/kg) for soils within the top 2 feet of surface soils and a value of 2,000 mg/kg for soils more than 2 feet below ground surface

   - A site-specific value as measured by ASTM D2974-87, Nelson and Sommers, 1990, or by SW-846 Method 9060 for total organic carbon

   - Another method, approved by IDEM, which shows that the soil attenuation capacity is not exceeded

2. For each discrete sample, the concentration of any organic constituents remaining in the soil must not exceed the soil saturation limit (see Chapter 6).

3. For each discrete sample, no soil containing constituents shall exhibit a pH of less than or equal to 2.0 or greater than or equal to 12.5, as determined by (1) SW-846 Method 9040B: pH Electrometric for soils with 20 percent or greater aqueous (moisture) content, or (2) SW-846 Method 9045C: Soil pH for soils with less than 20 percent aqueous (moisture) content. These test methods are incorporated by reference in 329 IAC 3.1-1-7 (referencing 40 CFR 260.11).

4. For each discrete sample, no soil containing constituents shall exhibit any of the characteristics of reactivity for hazardous waste, as determined by 329 IAC 3.1-6 (referencing 40 CFR 261.23).

5. For each discrete sample, no soil shall contain a metal listed in the Default Closure Table at concentrations that exceed 10,000 mg/kg.

6. Free product must be removed from ground water to the maximum extent practicable. A constituent may not be present in ground water at concentrations that exceed the constituent's solubility concentration in the ground water.

(Cont. from 1-9)

– Other exposure pathways for metals in soils include ingestion, such as the consumption of produce grown in contaminated soil.

Direct contact routes (skin contact, dust inhalation, volatilization, and soil consumption) are associated with direct exposure to contaminated soil. Because the four direct contact routes often exist simultaneously for any potential receptor, their evaluation is often performed as one operation. Potential health effects from direct contact are considered by calculating one target remedial objective or closure level.

The exposure pathway that considers the migration of soil COCs to ground water assumes no direct soil exposure. Rather, COCs are assumed to leach from soil into ground water, where they become available for ingestion. Because the mechanisms differ for exposure from direct contact and migration to ground water, two separate soil assessments must be made to evaluate these pathways. The separate assessments usually result in two different closure levels for soil: one for direct contact and one for migration to ground water.

When evaluating potential health impacts to humans from direct contact, the evaluation will depend on the depth of potential activities relative to the exposure pathways. For example, if gardening is evaluated, the top 12 to 15 inches of surface soil (spade depth) should be considered. If construction of, or addition to, a building is anticipated, the top 15 feet of soil should be considered. Soil is often excavated to this depth to install building footers, and excavated soil may be used as fill in a low area. As a result, the new "surface soil" may not be safe for direct contact. Because of the uncertainty associated with identifying the potential for such activities, the default procedure for evaluating soil contamination requires the *lesser* of the direct contact and migration to ground water closure levels.

It may be possible to demonstrate that one or more pathways can be eliminated, and closure criteria may be based on direct contact or migration to ground water only. For example, if no building construction activity can be reasonably anticipated, there may be no need to consider the direct contact pathway to a depth of 15 feet - a shallower depth may be more appropriate (*e.g.* 0 - 8 feet). Pathways that have been eliminated from consideration are generally noted on the Environmental Notice (see Appendix 5); however, there may be cases where that is not necessary.

Consumption of produce grown in contaminated soil is a type of food web transfer from the plant-uptake pathway. The lack of empirical data for plant uptake of other chemical types limits the default evaluation of this pathway to metals only.

1.5.2 Evaluating Ground Water Exposure Pathways

Exposure to COCs in ground water can occur by three pathways and associated routes of exposure:

- Volatilization from water to air (inhalation route)
- Direct contact with skin (dermal absorption route)
- Water consumption (ingestion route)

Each of these pathways must be evaluated when considering the overall effect of ground water COCs and potential risks to human health. The default residential closure levels in RISC were calculated assuming (1) water consumption and (2) inhalation of volatiles during showering. Direct contact with skin was not considered in the calculation of default residential closure levels. Inhalation and ingestion routes are believed to be the predominant routes of exposure, and dermal contact was considered relatively insignificant. The RISC default commercial/industrial closure levels were calculated assuming reduced consumption, no showering, and a well ventilated workplace. These pathways should be reevaluated when calculating nondefault closure levels.

1.5.3 Evaluating Construction Worker Occupational Exposure

The preceding discussion of soil and ground water exposure pathways focuses on the protection of human health, assuming that exposure is related to either residential or commercial/industrial land use exposure criteria. Another category of soil exposure that is unrelated to land use is construction worker exposure. RISC assumes construction worker exposure activity within an excavation or trench.

Closure levels considered protective for construction workers are listed in the Default Closure Table (see Appendix 1, Table A). The construction worker closure levels must be compared with applicable soil closure levels to determine if the construction worker will be protected.

1.6 Background Considerations

Background sampling should be conducted any time that it is suspected that naturally occurring chemicals of concern are causing exceedences of closure levels at any site, or if it is suspected that off-site sources may be contributing to chemicals of concern detected at the site. Naturally occurring background contaminants are usually heavy metals. Very few organic chemicals are produced naturally at levels exceeding the analytical method's estimated quantitation limits.

In cases where it is needed, the background concentration should be established for each naturally occurring constituent that can be associated with activities at the site in question. Background concentrations should be determined for each soil horizon or appropriate interval, consistent with the source area investigative results. Background concentrations in soils can then be statistically compared with the source area concentrations.

Background soil borings and monitoring wells should be located in areas unaffected by past or present operations at the site and unaffected by other localized sources. Background soil samples must be collected from areas of similar soil type and land form as those found in the source areas. If more than one soil type or land form is present in the source area, an appropriate number of background samples should be collected to account for the variability. When possible, background soil samples should be collected in natural, undisturbed soil from the same soil horizon and depth as the source areas.

Background soil sampling may be accomplished in one of two ways depending upon the site conditions:

- a minimum of four background soil borings are performed, and samples are collected at intervals suitable for comparison with source area, or
- a minimum of four background soil borings are performed, and samples are collected from each distinct soil horizon.

Analytical results are averaged for each interval or horizon as appropriate. The mean plus one standard deviation should be compared to individual source area concentrations for each soil interval or horizon. If the coefficient of variation (CV, see Equation 7-7 on next page) for the background samples exceeds 1.2, additional sampling or other measures may be necessary.

Soil horizons and soil types will need to be evaluated and documented within the background and source areas. If specific soil horizons are

not present due to such things as anthropogenic alternation, it is advisable to consult IDEM staff for an alternate approach.

In the case of naturally occurring chemicals of concern, the appropriate standard for closure is the greater of either the background level or the risk based closure level. Source areas which exceed risk based closure levels due to background chemicals of concern that are attributed to anthropogenic sources require a method to control potential human exposure.

To establish background concentrations for ground water, it is necessary to determine the number and kinds of samples that are appropriate for the statistical test employed, which is generally the 95% upper confidence limit of the mean of quarterly samples from each well. The sample size should be as large as necessary to ensure that the background samples are representative of the flow zone. Background ground water samples must be obtained from appropriate flow zones and locations to ensure that the samples represent ground water unaffected by on-site contamination sources. The distinct geological and hydrological characteristics of the saturated material must be described and correlated for each appropriate flow zone in the source and background areas.

Coefficient of Variation

Equation 7-7. $$CV = \frac{s}{m_1}$$

Where:

s	=	Population standard deviation
m	=	Population mean

1.7 Remedial Approaches

Remedial approaches to site closure may or may not include institutional controls. Both types of approaches are discussed below.

1.7.1 Remedial Approaches Without Institutional Controls

Remedial approaches for achieving closure that do not involve institutional controls include (1) removal of the contaminated media to residential closure levels and (2) treatment through physical, chemical, or biological methods.

Removal is the excavation and shipment of contaminated media to an appropriate location for processing or deposition. The most common example of removal is the excavation of contaminated soil. Any soil excavated as part of a removal action where COC concentrations exceed residential default closure levels must be managed in accordance with applicable solid or hazardous waste rules.

Treatment permanently reduces contaminant concentrations to levels equal to or less than the designated closure levels. Examples of decontamination technologies that qualify as treatment methods include bioremediation, soil washing, thermal destruction, thermal desorption, and ground water recovery and treatment.

Removal and treatment are both permanent processes. When contaminant reduction or elimination control measures are used, institutional controls are not necessary.

1.7.2 Remedial Approaches With Institutional Controls

An institutional control is a legal mechanism for maintaining a land use restriction, either through activity restrictions or engineering controls When any land use restriction is employed, an institutional control must be in place (see Appendix 5 and Chapter 6 for a more detailed discussion). For site closure that relies on engineering controls and activity restrictions, a closure plan must be developed that details how engineering controls and reporting will be implemented and maintained. The remainder of this section discusses activity restrictions and engineering controls.

Activity Restrictions

If a remedy does not eliminate all potential exposures associated with the contaminated media, then an activity restriction may be used to prevent such exposures. Activity restrictions prohibit operations that could result in exposure to COCs. For example, an activity restriction could require that no drinking water wells be constructed within a certain area or screened above a certain depth. These restrictions may be accomplished through an environmental notice, a ground water ordinance or nondefault procedures. See Appendix 5 for information on environmental notice and ground water ordinances, and Chapter 7 for information on nondefault criteria.

When areas are remediated to commercial/industrial closure levels, a commercial/industrial land use designation must be recorded on the property deed. This designation is one type of institutional control

used to notify all future landowners that the property meets industrial/commercial closure levels, but that it may not be suitable for residential use.

Engineering Controls

Engineering controls are physical controls that prevent exposure to contaminated media or prevent COCs from migrating further. Any physical treatment method that provides an appropriate barrier but does not permanently and irreversibly decrease COC concentrations to closure levels throughout the contaminated media is considered an engineering control. For example, construction of a watertight cap to prevent infiltration into a source area is an engineering control that will limit COC migration from soil to ground water. Concrete and asphalt surfaces are not considered impervious materials, and they will not prevent infiltration; nevertheless, they may prevent direct contact with soil.

Some engineering controls that eliminate exposure pathways include protective caps or covers, slurry walls, extraction wells, or fencing. Some controls, such as an asphalt parking lot, may already exist at a site. Obligations for ongoing repair and maintenance of these existing structures may be necessary if they are to serve as engineering controls for the site.

Public Notice and Comment

Conscientious efforts to involve the community in the decision-making process will be considered essential for the acceptance of the remedy. It is the responsibility of the party seeking closure to inform the neighbors and other potentially affected parties of all relevant details regarding the proposed closure. The RISC User's Guide provides additional information regarding programmatic considerations.

Overview of Chapter 2

- Introduction
- Applicability and Scope
- Gathering and Reviewing Existing Site Information
- Identifying Acute Hazards
- Identifying Preliminary Chemicals of Concern
- Identifying Potentially Affected Media
- Identifying Potential Exposure Pathways
- Identifying Potential Susceptible Areas
- Determining Present and Future Land Use
- Classifying Areas of the Site
- Developing a Conceptual Site Model

2.0 Introduction

The principal objective of presampling is to evaluate available information to determine the presence of contamination at a site and its potential to result in increased risks to human health and the environment. Presampling activities also can focus resources in an effective and efficient manner to achieve the desired closure objective. Presampling is the identification, collection and review of available site information. The assessment of this information will direct the use of default or nondefault applications of RISC.

2.1 Applicability and Scope

If presampling identifies potential or actual increased risks from site contamination, the information obtained during the presampling phase may help determine what further action is necessary at the site. As the first stage of a RISC investigation, presampling is a relatively quick and low cost approach to obtaining information about the site and its surrounding area. Presampling activities should emphasize the comprehensive identification of chemical releases and relevant information on potential human and environment exposure pathways. Such information can usually be obtained by reviewing and compiling existing site-related information.

The following activities are typically included as part of the presampling effort:

- Gathering and reviewing existing site information
- Identifying acute hazards
- Identifying preliminary chemicals of concern
- Identifying potentially affected media
- Identifying potential exposure pathways
- Identifying potential susceptible areas
- Determining present and future land use
- Classifying areas of the site
- Developing a conceptual site model

Information obtained during presampling can then be compared to the RISC default exceptions (see Section 1.3). This comparison of site attributes and conditions with RISC default exceptions will help determine the steps necessary to achieve closure.

2.2 Gathering and Reviewing Existing Site Information

Gathering and reviewing site information typically involves an extensive record review, a site visit (sometimes referred to as a preliminary visual site inspection), and a summary and tabulation of all existing data related to site contamination. Gathering comprehensive site information before collecting any samples usually saves time and money by producing better initial site sampling plans.

Site information may be available from a variety of sources, including the remedial investigation and assessment reports associated with operations at the site (see the appropriate chapter of the User's Guide), regulatory agency files, operating records, or other documents. If the information available from these resources is not sufficient, a Phase I Environmental Site Assessment (ESA) in accordance with American Society of Testing and Materials (ASTM) guidelines (E1527-94 and E1528-93) may need to be performed. .

2.2.1 Record Review

This investigative procedure involves collecting and reviewing readily available information regarding the site and its surroundings. The following sources of information should be reviewed as applicable:

- Site records pertaining to operational processes and chemical and waste storage and disposal practices
- Site information available in regulatory agency databases, including information from the U.S. Environmental Protection Agency (EPA) Region 5, the Indiana Department of Environmental Management (IDEM), city and county health departments
- Historic aerial photographs, satellite imagery, and geographic information system (GIS) maps
- Geological site information presented on the U.S. Soil Conservation Service surface soil maps, U.S. Geological Service (USGS) subsoil bedrock maps, USGS topographical maps, and state soil surveys

- Current and historic demographic and land use information, such as that provided by Sanborn fire insurance maps
- Information on site utilities, storm and sanitary sewers, wastewater treatment plants and disposal/discharge areas, and electrical transformers
- Regional ground water and surface water records
- Interviews with current or past employees, local fire and police departments, county health officials, and site neighbors

The record review should include information on local and regional conditions relevant to COC migration and potential receptors, such as the following:

- Regional geology and hydrogeology
- Location of designated Wellhead Protection Areas for public water supplies
- Location of residential, municipal, and commercial drinking water wells
- Surface water systems near the site
- Background soil types
- Types of vegetation on site and in nearby areas
- Rare, threatened or endangered species, sensitive environmental areas, or critical habitats at the site vicinity

2.2.2 Site Visit

The purpose of a site visit is to obtain information based on visual observations of the site. Particular attention should be paid to the physical features of the site (such as the dimensions and locations of buildings, potential contamination sources, and former or current operational or disposal areas). The site visit should focus on identifying potential environmental impacts on the surrounding area and collecting any additional information to assist in the presampling evaluation of the site. Observations from the site visit should be recorded in a logbook for later compilation with any investigative field data collected.

The site visit should include observations that will help answer the following questions:

- Are oils, chemicals or wastes currently stored on the property?
- Is there visible evidence of spills or leaks?
- What conditions exist in areas and pathways where materials were treated, stored, transported, or disposed?
- What conditions exist at or near facility doors, bay exits, shipping docks, and pumping station areas?
- What underground piping and USTs are on the site?
- What is the surrounding land use – residential, recreational, agricultural, commercial, or industrial?
- Are ecological or surface water impacts from site releases evident or possible?
- What vegetation and habitat types are present or near the site?
- Is there evidence of unexplained stressed or dead vegetation or wildlife?

2.3 Identifying Acute Hazards

The preliminary site inspection should identify any acute hazards that may pose an immediate or imminent threat to human health or the environment. *If any acute hazards are identified, the risk of the hazard must be mitigated before resuming the RISC evaluation.* Examples of acute hazards include the following (see Figure 2-1):

- Presence of free product
- Recent or ongoing spills (regulated by Indiana spill rule 327 IAC 2-6.1)
- Corrosive, toxic or flammable vapors
- Acutely harmful human health exposures

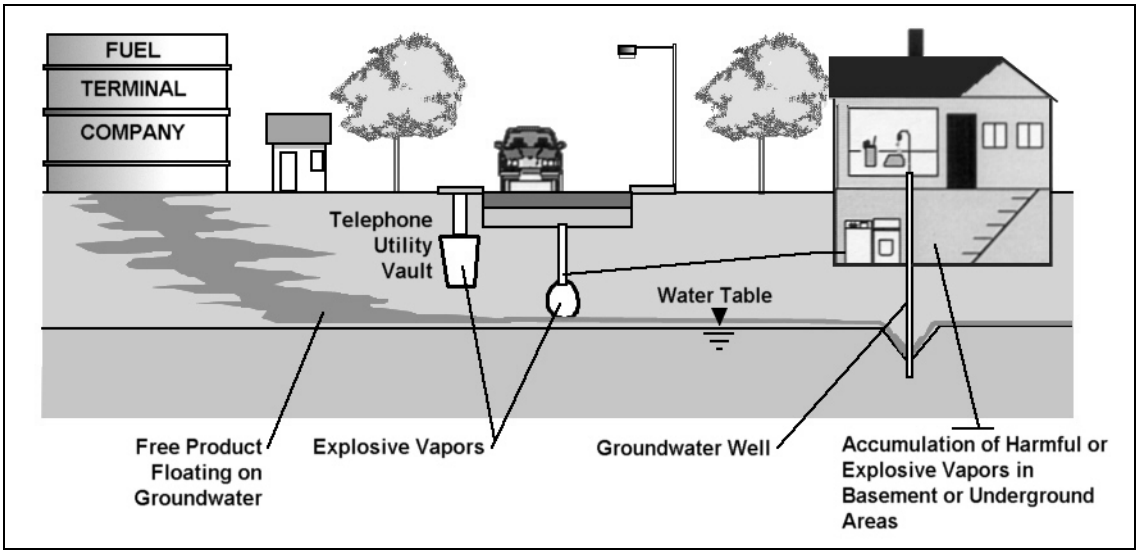


Figure 2-1. Acute Hazards

2.4 Identifying Preliminary Chemicals of Concern

Identifying chemicals of concern (COCs) at a site begins during the presampling investigation and continues throughout the site evaluation process. This COC list includes any regulated compound that has been used, treated, stored, or disposed of on site or any compound that may result from fate and transport mechanisms acting on the regulated compounds. An IDEM program may require a specific "COC scan" if site-specific operating information is incomplete or unreliable. In such cases, the COC list is developed based on the comprehensive program list. For Subtitle C sites, this comprehensive list may include the analyte list from Appendix VIII (Code of Federal Regulations [CFR], Title 40, Part 261) and Appendix IX (CFR, Title 40, Part 264).

A less comprehensive list, such as CERCLA's Target Compound List (TCL) or Target Analyte List (TAL) may be appropriate for sites if:

- the potential COCs for the site are included within the list, and
- the detection limits are appropriate.

EPA Contract Laboratory Program (CLP) analytical methods may utilize detection limits that are too high to quantify COC concentrations at the RISC closure levels.

As the investigation proceeds from presampling to screening and/or a determination of the nature and extent of contamination, the list of COCs may be modified. It may be necessary to reduce or expand the list of COCs as additional site information is acquired. Nevertheless, the list should be re-evaluated at each stage in the process.

The User Guide identifies COCs and their applicability under various programs, as summarized in the box below.

Program	**User's Guide**
RCRA Closure and Corrective Action, Subtitle C	Chapter 2
Leaking Underground Storage Tank (LUST) Program	Chapter 3
Voluntary Remediation Program (VRP)	Chapter 4
State Clean-Up Program (SCP)	Chapter 5

2.5 Identifying Potentially Affected Media

Figure 2-2 shows the six types of environmental media and how they may be affected by contamination: (1) air, (2) surface soil, (3) subsurface soil, (4) ground water, (5) surface water, and (6) sediment.

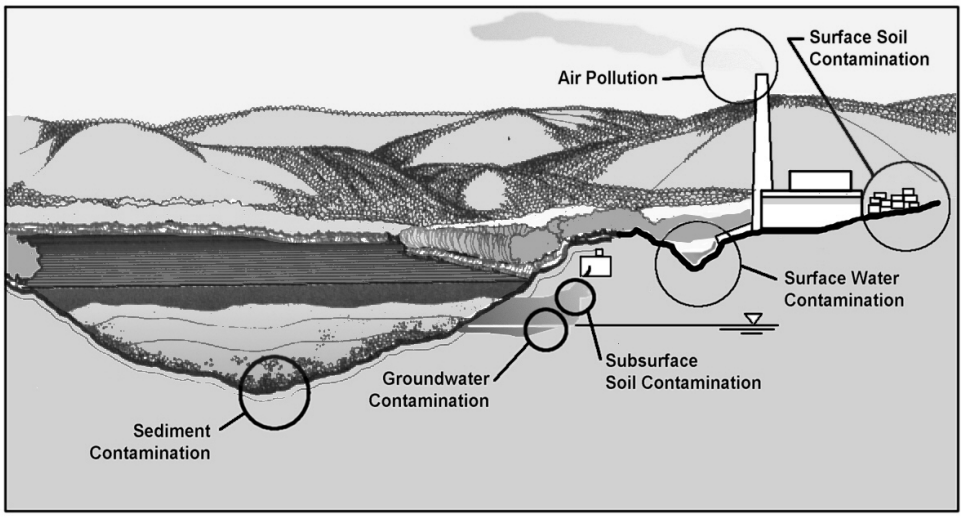


Figure 2-2. Potentially Affected Environmental Media

An IDEM program may require that all potential human or ecological exposures associated with each of the six media must be identified and assessed. RISC establishes default closure levels for surface soil, subsurface soil, and ground water. A nondefault closure process and a risk assessment are required if air, surface water, or sediments are contaminated.

2.6 Identifying Potential Exposure Pathways

RISC provides guidance for the default evaluation of contamination present in soil and ground water and the exposure pathways and routes by which an organism may be affected. To calculate closure levels, some assumptions must be made regarding exposure pathways and COC migration routes. Contaminated areas must be evaluated in a manner consistent with closure levels because the closure levels identify contaminant concentrations acceptable for human exposure.

Table 2-1 lists default exposure pathways by media and land use (see Figure 2-3).

Table 2-1. Default Exposure Pathways Listed by Media and Land Use

Exposure Pathway	Residential Land Use	Commercial or Industrial Land Use	Construction Worker Exposure
Direct Soil Contact	• Skin contact • Ingestion of soil • Inhalation of soil vapors and particulates		
Soil Leaching to Ground Water	• Ingestion of ground water contaminated by soil leachate		• Not evaluated
Ground Water	• Ingestion of ground water • Inhalation of vapors released from ground water	• Ingestion of ground water	• Not evaluated

Exposure pathways potentially associated with the particular COCs, media, and property uses at a site should be considered from the earliest stages of the RISC process.

Eliminating an **exposure pathway** from consideration requires professional judgment and a sound rational approach. All information describing COCs, known concentrations, migration pathways, and potential human and environmental receptors should be clearly understood before deciding to eliminate an exposure pathway. Such information should accompany the rationale for eliminating the pathway.

If exposure to a particular pathway is considered possible, but one or more of the **exposure routes** associated with that pathway is considered inapplicable, a nondefault assessment would be used to

eliminate that route from the exposure calculations (see Chapter 7).

2.7 Identifying Potential Susceptible Areas

RISC defines "susceptible areas" as areas where humans or ecologically sensitive species are more likely to be affected by contamination. RISC establishes three types of susceptible areas:

- Geologically susceptible areas
- Ecologically susceptible areas
- Wellhead Protection Areas

Each of these is discussed and defined in Chapter 5. Persons performing a site inspection and records review should be familiar with these classifications and should identify whether contamination at the site could potentially affect any of these types of areas.

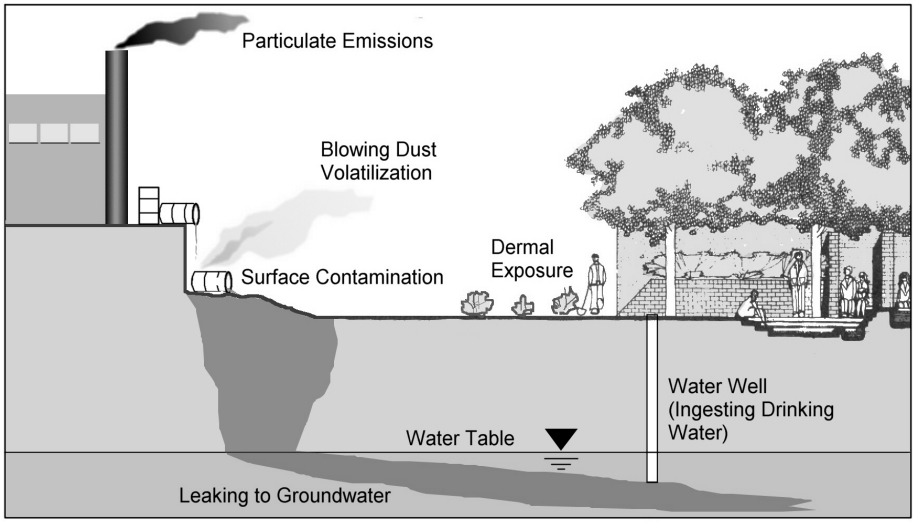


Figure 2-3. Examples of Exposure Pathways

2.8 Determining Present and Future Land Use

Present and future land use of the site must be determined because exposure assumptions are different for residential and commercial or industrial land uses. Current or future construction activities should also be determined for the site because the site-specific default closure levels apply to construction worker exposure scenarios.

The current land use should be apparent during the site inspection. The definitions in the box below should help determine whether the current land use is classified as commercial, industrial, or residential.

Commercial or Industrial Land Use	Residential Land Use
■ Defined as property where activities are being conducted that have the following primary Standard Industrial Classification (SIC) major group codes (SIC codes are defined and listed in Appendix 4): - 07 to 67 (except 4941) - 72 to 97 (except 8051, 8059, 8062, 8063, 8069, 8211, 8221, 8222, 8351, 8361, 8661,8811, and 9223) ■ Commercial or industrial land use includes all of the adjacent blocks and lots controlled by the same owner or operator that are used in conjunction with the business or that are vacant land not intended for future human habitation. For leased properties, commercial or industrial property includes the leasehold and any external tank, surface impoundment, septic system, or any other structure, vessel, contrivance, or unit that provides or is used to manage contaminants to or from the leasehold.	■ Includes any property used as a place of residence. Property defined as commercial or industrial may include residential activities or areas. For example, a day care center (SIC 8351) meets the definition of residential property because typical residential activities occur there. At a minimum, residential closure criteria must be applied to the residential portion of the property. ■ Includes land used for agriculture

Probable future uses of the site and adjacent property may influence the type of risk assessment and the remedy ultimately selected for the site. EPA guidance on how to consider future land use in the remedy selection process is provided in the memorandum, *Land Use in the CERCLA Remedy Selection Process* (OSWER Directive No. 9355.7-04). The memorandum (see Appendix 7) identifies the following activities as valuable in determining future land use:

- Communicating with site owners, local planners, officials, developers, and members of the community to evaluate the possible future uses of a given site. If no definite plan exists for future use, the most likely future use must be determined.

- Developing or modifying remedial objectives to reflect likely or known future land uses

- Evaluating the cost-effectiveness and practicability of remedial objectives based on site data and modifying potential future land uses, if necessary

The key step in determining future land use is to develop accurate assumptions about the long-term future of a site. If accurate assumptions can be made, remedial objectives can establish criteria that are only as restrictive as required for the intended land use. This approach allows site characterization and remedy selection to focus on practical and cost-effective remedial alternatives, rather than requiring cleanup to residential closure levels at all sites.

An essential relationship exists between identifying remedial objectives, characterizing the site, and selecting the appropriate remedy. Data from site studies may indicate that remediating a site to a certain concentration is neither practical nor cost-effective. This situation may require that the proposed land use and remedial objectives be reevaluated based on revised land use assumptions. As a result of this process, the future land use of all or part of a site may be more restricted than originally intended. When land use is restricted or when other activity or exposure restrictions are put in place, RISC requires that an Institutional Control be recorded on the property deed (see Section 6.2 and Appendix 5).

2.9 Classifying Areas of the Site

Based on the information gathered during the presampling investigation, the site may be subdivided into any of the following three classifications:

- Areas unlikely to be contaminated
- Areas known to be contaminated
- Areas that may be contaminated

Areas unlikely to be contaminated are portions of a site where there is no reason to suspect contamination. Available historical site data is used to make this determination. Closure documentation cannot include any portion of a site that has been classified in this category unless analytical information is available to verify that each area is unaffected by the targeted COCs.

Areas known to be contaminated are areas where COC releases are known to have occurred. Previous sampling data, records that document site contamination, visibly stained soils, soil odors, and other investigative data that indicate contamination can be used as a basis for this classification.

Areas that may be contaminated are areas that cannot be classified in either of the other two categories. Significant data gaps or ambiguous or inconclusive information exists for these areas.

Table 2-2 summarizes the information used to classify surface soils.

Table 2-2. Classifying Areas of the Site Prior to Surface Soil Sampling

Category	Definition	Basis for Classification
Unlikely to be Contaminated	An area where there is no reason to suspect contamination	Historical site data that is reasonably complete and accurate
Known to be Contaminated	An area where releases are known to have occurred	Previous sampling data, records that document contamination, visibly stained soils, soil odors, or other investigation data that indicate contamination is present
May be Contaminated	An area that cannot be classified in either of the other two categories	Ambiguous or incomplete information or a lack of data

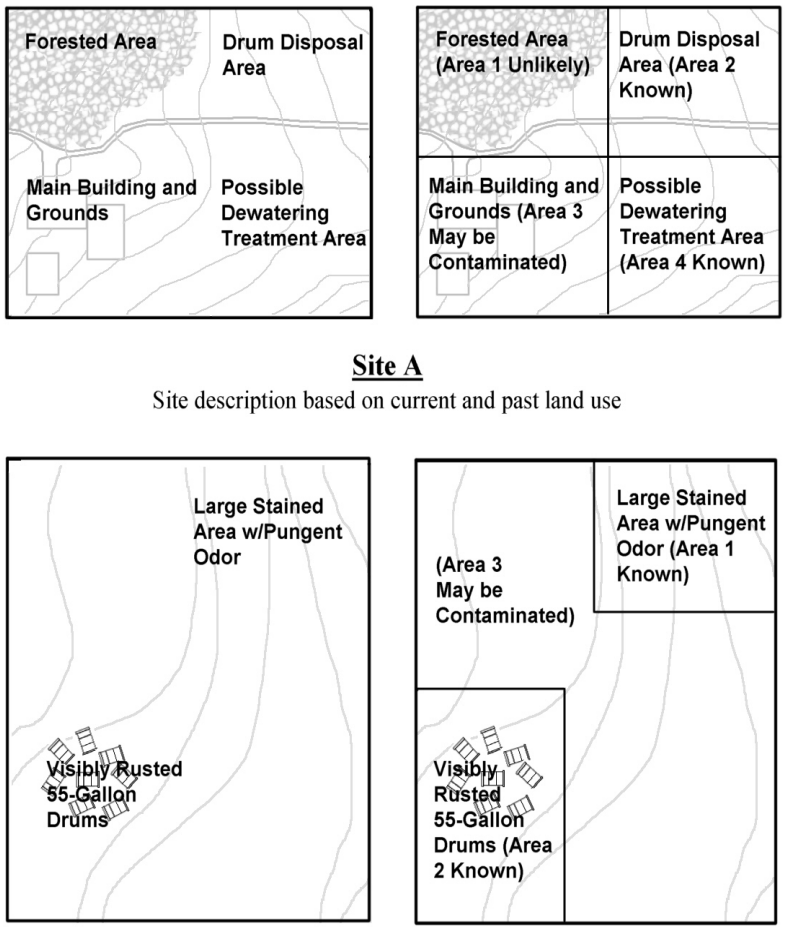
The classification of a site typically begins with surface soil classification because surface soil contamination may indicate contamination in subsurface soil and ground water. However, surface soil contamination is not the only indicator of subsurface contamination; all relevant information should be used to appropriately evaluate potential subsurface soil and ground water contamination.

The Default Closure Table assumes a source area of no more than ½ acre to ensure the statistical integrity of sampling results. If an area of surface soil contamination is larger than ½ acre, it may be characterized using different methodology, such as the "large site" methods detailed in Section 7.5.1.

2.10 Developing a Conceptual Site Model

Figure 2-4 (see 2-12) presents an example of a preliminary conceptual site model (CSM). The CSM is a map or diagram of the site that summarizes all of the information currently available concerning contaminated areas, contaminated media, types of contamination, and potential exposure pathways and receptors at the site. It combines written information and a map or diagram of the site. It may be depicted as a top-view site plan showing how source areas and potential human and ecological receptors are positioned relative to existing site features. Cross-sectional drawings may also be included

Figure 2-4. Conceptual Site Model Diagram



to show site geology and hydrology, as well as any available data on COC concentrations below the surface.

To the extent possible, the CSM should incorporate all the relevant information gathered during presampling activities. The CSM should include preliminary boundaries showing areas that are not likely to be contaminated, known to be contaminated, and may be contaminated (see Table 2-2). This exercise presents available information in a format that can be used for the rest of the RISC process, from the site screening evaluation through the determination of the extent of contamination and a possible nondefault assessment. The CSM begins to organize information in terms of the type and degree of risk that

may be posed to human health or the environment. The development of the CSM is an iterative and interactive process that can incorporate new information as it is available. The framework for developing a CSM is part of the RISC software available on the IDEM website: www.state.in.us/dem/olq/risc.

Overview of Chapter 3

- Introduction
- Applicability and Scope
- Developing a QAPP
- Performing Field Activities
- Sampling Procedures for Area Screening

3.0 Introduction

This chapter presents default methods available to screen source areas at a site. IDEM recognizes that these default methods may not be appropriate or feasible at some sites. However, use of the default methods will facilitate regulatory interchange and approvals. IDEM will consider other (nondefault) screening methods that better address site-specific conditions (see Chapter 7).

The purpose of screening by chemical sampling and analysis is to determine if additional investigation is warranted for a particular media. If a site is known to be contaminated, area screening may provide preliminary information needed to focus the site investigation. The most appropriate approach to screening will ultimately depend on site-specific factors and conditions. One default procedure for screening surface soil requires composited random samples from the entire potential source area. Another default method for surface soil identifies contaminated areas based upon judgement and site knowledge. The default procedure for subsurface soil focuses on finding the most severely contaminated areas to determine if further investigation is necessary.

The process for screening ground water at a site differs somewhat from soil screening requirements. Because ground water is mobile, it is difficult to determine if an individual sample was collected from a highly contaminated part of the ground water plume or from areas of lesser contamination. Because of ground water's mobility, if chemicals of concern are detected at any concentration, the nature and extent of the constituent plume must be characterized. Plume characterization may be completed using any appropriate technology; it does not necessarily require the installation of permanent monitoring wells. In addition, not all activities listed in Chapter 4 may be necessary for ground water plumes.

3.1 Applicability and Scope

Area screening is an optional activity. Screening is appropriate when contamination levels are unknown at a particular area. Screening should be conducted to determine which areas do or do not contain Contaminants Of Concern (COC) at concentrations that exceed default closure levels (see Appendix 1). If site media contain COCs at concentrations that exceed default closure levels, the user may forego area screening and instead proceed either to a determination of the nature and extent, or to remediation, of site contamination.

The default area screening approach is designed for soil COC source areas no larger than ½ acre. For individual soil COC source areas larger than ½ acre, the user may wish to consider employing nondefault screening methods (see Chapter 6). Using default methods to screen soil COC source areas that are larger than ½ acre may be inappropriate (see US EPA Soil Screening Guidance for limiting factors).

RISC includes a unique two-step procedure for combining screening and nature and extent of contamination steps in subsurface soils at a petroleum release site. The RISC User's Guide provides more details of the procedure.

In many cases area screening may be the first site investigation that includes the collection and analysis of waste and environmental samples. Sample locations should be selected strategically to best identify any COCs present at the site and to determine if COCs are affecting specific media (such as surface soil, subsurface soil, and ground water). Sample locations should also be selected strategically to determine if susceptible areas (such as geological, ecological, or wellhead protection areas) are likely to be affected.

Area screening requires three activities:

- Developing a Quality Assurance Project Plan (QAPP) that includes data quality objectives (DQO), a health and safety plan (HASP), a sampling and analysis plan (SAP), and a data quality assessment (DQA) (see Section 3.2)

- Performing field activities and sampling procedures for surface soil, subsurface soil, and ground water (see Section 3.3)

- Evaluating potential exposure concentration (PEC) screening data (see Section 3.4.4)

Area screening should not be conducted if it will impede the responsible mitigation of acute environmental hazards. If an acute hazard is identified, it must be addressed immediately (see Section 2.2). Protection of human health and the environment is paramount. Addressing acute hazards expeditiously also typically reduces subsequent remediation costs. For example, in the case of a recent release or spill, expeditious remediation is often the most cost-effective and lowest-risk response strategy. The immediate excavation of soil affected by a chemical spill may prevent subsequent ground water contamination and degradation of resources. Nevertheless, a quick response to an acute hazard is only one step in

site closure. The user must still demonstrate that all remaining contamination was delineated and addressed within programmatic requirements.

A QAPP is a complete and detailed description of the location, collection method, type, and number of samples required for the field investigation. As such, a QAPP must include all information needed to collect data and samples at the site. It should also provide a defensible and detailed description of all activities, quality specifications, and precautions associated with sample collection, handling, and analysis. A complete, well developed QAPP minimizes the health risks, liability, and costs associated with sampling errors.

At a minimum, a QAPP must contain the four components listed in Table 3-1.

Table 3-1. Elements of a QAPP

Element	Description
DQO	DQOs establish the type, quality, and quantity of data required to make and defend a particular decision. They are developed using a seven-step planning process (see Table 3-2).
HASP	The HASP advises workers of site-specific health and safety concerns and outlines procedures to prevent or minimize injuries and illnesses.
SAP	The SAP specifies elements of the required field work and associated laboratory analysis. The SAP describes the media to be sampled as well as sampling locations and methods. It must also specify the quantity, depth, and quality control requirements for samples (such as matrix spike and duplicate sample requirements). In addition, the SAP identifies the quality assurance/quality control (QA/QC) measures of site sampling-related activities.
DQA	A DQA must be conducted to ensure that the QAPP is implemented as prescribed. DQA involves assessing the effectiveness of sampling implementation and QA/QC measures.

3.2 Developing a QAPP

Minimum Elements of a QAPP

- DQOs
- HASP
- SAP
- Sampling methods and requirements
- Sample custody requirements
- Analytical methods and requirements
- QA/QC and requirements
- Instrument and equipment testing, inspection, and maintenance requirements
- Instrument calibration and frequency
- DQA

The amount of detail required for each of the QAPP elements will vary by site and project. Projects of a limited scope or small aspects of larger projects may require only minimal information in the QAPP. Projects of significant duration or effort are likely to require more information. In such cases, an expanded QAPP may be required to ensure that the field investigation and laboratory analyses are well planned and properly conducted to achieve the project goals.

QAPP development is an ongoing procedure throughout the investigative and sampling process. Each time new sampling needs are identified, the appropriate elements of the QAPP (such as DQOs) should be modified to address the needs and concerns associated with the next sampling event and assessment. For area screening, the QAPP may be simple and brief. For a complicated, multiple COC, nondefault site assessment, the QAPP may be quite complex.

Many requirements for sampling and analysis are incorporated into the RISC guidance for area screening and characterization of the nature and extent of contamination. Relevant RISC guidance should be incorporated into the appropriate elements of the QAPP. The following subsections briefly discuss each element of the QAPP highlighted above (see Table 3-1). Additional discussion regarding characterizing the nature and extent of site contamination is included in Chapter 4.

3.2.1 Data Quality Objectives (DQO)

IDEM prefers that users apply the EPA-established DQO process for all sampling performed in support of RISC. IDEM used the DQO process to develop the RISC screening procedures. By following these procedures, the DQO process will be satisfied for the screening evaluations.

Table 3-2 on the following page presents an overview of the DQO process applied to surface soil screening under RISC.

Contaminant characterization involves assessing and determining qualitative and quantitative aspects of the site. Qualitative aspects typically involve determining where contamination exists, with advanced planning to locate areas of potential contamination. Quantitative aspects involve determining COC concentrations and any associated risks.

Table 3-2. DQO Process Applied to Surface Soil Screening

Step	Description
1. State the Problem	Identify areas of the site where contaminated surface soils may pose a risk to human health.*
2. Identify the Decision	The decision is to determine if the mean surface soil concentration exceeds closure levels for specific chemicals of concern within potential source areas. If contaminant concentrations exceed closure levels, further investigation is required (see Chapter 4).*
3. Identify Inputs to the Decision	■ Exposure inputs, such as ingestion, dermal contact, and fugitive dust inhalation rates* ■ COC concentrations* ■ Analytical methods (which should also be addressed in the SAP) ■ Default closure levels and applicability* ■ Quality assurance concerns (which should also be addressed in the QAPP)
4. Define the Boundaries	■ Define the potential source area ■ Identify potential surface soil COCs ■ Classify the site as follows (see Section 2.9): ▪ Areas unlikely to be contaminated ▪ Areas known to be contaminated ▪ Areas that may be contaminated Define potential source areas and pathways
5. Develop a Decision Rule	The following decision rule applies for screening tests: If the mean constituent concentration within the potential source area exceeds the screening level, further investigation is required.*
6. Specify Limits on Decision Errors	Specify the limits on decision errors, which are used to establish performance goals for limiting uncertainty in the data. IDEM provides default error limits in the Max and Chen tests (see Section 3.4).
7. Optimize the Design for Obtaining Data	■ Identify the most resource-effective sampling and analysis design for generating data that will satisfy DQOs ■ Finalize the SAP, including statistical sampling design, sampling methods, and analytical methods* ■ Finalize the QAPP and provide sufficient detail on each QAPP element

* These aspects have been incorporated into the default screening procedures

Quantitative aspects also involve estimating the level of uncertainty, which helps the user understand and control the probability of making an incorrect decision based on the data. An incorrect decision within the DQO process may mean deciding not to collect more data, when in fact more data is needed. Alternately, an incorrect decision may involve deciding to collect more data, when source area constituent concentrations are actually less than default closure levels.

DQOs must be designed to address a wide array of questions regarding the site, the COCs, and the nature and extent of contamination. Typical questions DQOs are designed to answer include the following:

- Does contamination exist at a site?
- Does the mean constituent concentration in a particular potential source area exceed screening levels?
- What is the horizontal and vertical extent of contamination?
- What volume and type of media contains COC concentrations that exceed closure levels?
- Does the contamination pose risks to human health or the environment?
- Did remediation reduce constituent concentrations in affected media to less than the closure levels?
- What are the soil characteristics in the potential source area?

The DQO process is recommended for additional site characterization and data collection for nondefault closure scenarios. The DQO process may be applied separately for each media and potential source pathway. Developing DQOs for multiple pathways, media, or COCs may require working through the process several times for each source area.

Site characterization under RISC is based on the identification and assessment of DQOs. EPA recommends the use of DQOs and has published extensive guidance on this topic. Certain programs, such as Superfund, have specifically adopted the DQO process as a requirement. For additional EPA guidance on DQOs, consult Appendix 6 and the following:

- EPA. September 1993. *Data Quality Objectives Process for Superfund, Interim Final Guidance*. EPA/540/R-93/071, PB96-963203.

- EPA. December 1994. *Soil Screening Guidance: Technical Background Document, Review Draft*. EPA/540/R-94/106, PB96-963532.

3.2.2 Health and Safety Plan (HASP)

The HASP is a written document included as part of the QAPP (in RISC). The HASP details field activities conducted in compliance with IDEM and OSHA requirements. The HASP should be completed by a competent professional with appropriate training and experience. The plan must comply with the requirements of 29 CFR 1910.120.

3.2.3 Sampling and Analysis Plan (SAP)

After DQOs are established for each type of required sampling, the user should prepare a SAP. The SAP should be designed to ensure that sample collection activities produce samples and analytical data that meet the needs established in the DQOs.

The SAP identifies where samples will be collected, usually by locating them on the conceptual site model or detailed site map. The SAP should provide details of the specific methods and equipment used to collect and handle samples in the field, and it should identify the appropriate field or laboratory methods to be used to analyze each sample.

Procedures for sampling environmental media are well documented. *The Compendium of Superfund Field Operations Manual* (EPA 1987) and other relevant documents identify demonstrated field sampling methods and techniques.

Analytical methods (see Appendix 2) should be carefully selected and should consider the advantages and disadvantages of field versus laboratory analysis for the data quality needs of the decision. Methods listed in SW 846, the EPA Contract Laboratory Program (CLP), and the *Methods for the Determination of Organic Compounds in Drinking Water* are used most commonly. Superfund sites are required to use CLP procedures.

3.2.4 Quality Assurance/Quality Control (QA/QC)

The SAP in the QAPP must include a QA/QC program. The QA/QC portion describes the policy, organization, functional activities, and protocols necessary to achieve DQOs dictated by the intended use of the data. These elements are defined in the preceding references.

Agency-wide QA/QC requirements are listed in Table 3-3.

For additional details on analytical requirements, see the discussion of estimated quantitation limits (EQL) in Appendix 2. For program-specific QA/QC requirements, the IDEM document, *Guidance to the Performance and Presentation of Analytical Chemistry Data* references the appropriate analytical determinations and requirements (IDEM 1998).

3.2.5 Data Quality Assessment (DQA)

DQA involves assessing the effectiveness of the sample design, sampling procedure, and laboratory analysis. DQA is used to ensure that the sampling and analytical quality are adequate to meet the precision, accuracy, representativeness, comparability, and completeness (PARCC) requirements established in the DQOs. DQA identifies the review process needed to support project requirements and confirms that the field sampling QA/QC event, the field documentation, and the QA/QC samples provide useable data. DQA also evaluates the final results of the site investigation and compares them to the closure levels. Figure 3-1 describes the DQA process.

3.3 Performing Field Activities

Before performing any field activities, it is essential to determine the type of environmental media requiring investigation as well as the most appropriate classification for the site. This section defines the types of environmental media and site classifications available under the RISC default closure scenario.

3.3.1 Types of Environmental Media

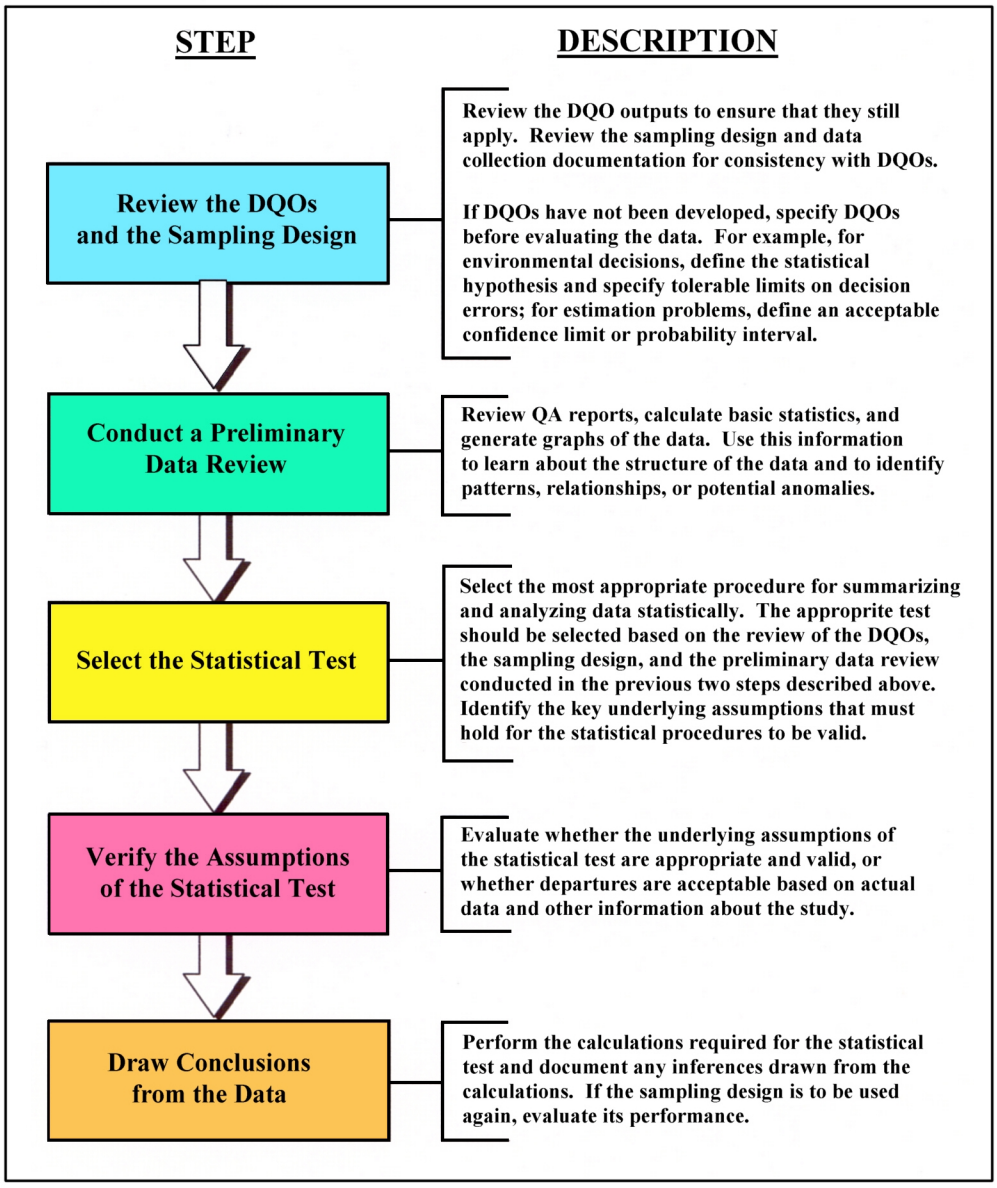
Default area screening tests were developed using DQOs for three categories of media: surface soil, subsurface soil, and ground water (see Figure 3-2).

- Surface soil is defined as the top 6 inches of soil. Any surface soil sampling conducted under RISC must be representative of the top 6 inches of soil at the site.

Table 3-3. QA/QC Requirements

Minimum Sampling QA/QC Requirements
Chain-of-custody form
Date and time each sample was collected
Map indicating sampling locations
Documentation of any field measurements and notable observations
Use of equipment blanks and trip blanks
Use of field duplicates, matrix duplicates, and matrix spike duplicates
Laboratory Required QC Information
Completed chain-of-custody form
Date and time of receipt
Sample condition upon receipt
Sample identification number
Sample preparation, extraction, cleanup, or digestion method
Analytical method
The precision, accuracy (or bias), representativeness, comparability, and completeness (PARCC) requirements for each target analyte (including calibration requirements)
Analytical results, including appropriate level of laboratory data quality deliverables
Case narrative indicating any deviations from standard analytical procedures
Corrective action criteria for any deficiencies noted by a review of QA/QC procedures and the DQA

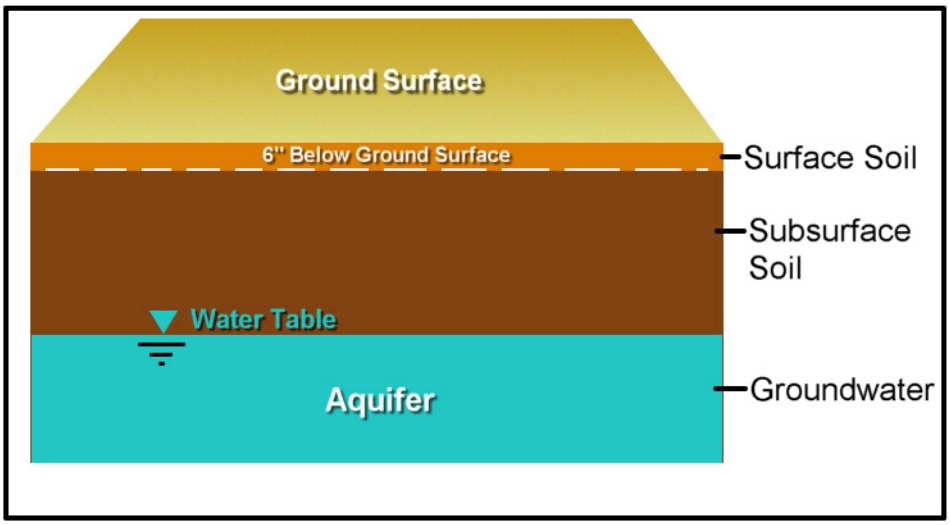
Figure 3-1. The DQA Process



- Subsurface soil is defined as soil in the interval extending from 6 inches below the surface to the water table. Subsurface soil sampling should not include the smear zone, which may be present at the water table.

- Ground water is defined as water that exists at saturation in the interstitial voids of soil or rock.

Figure 3-2



The smear zone represents the seasonal limits of ground water fluctuation (that is, the top of the water table). The smear zone is not sampled for area screening purposes. The soil-to-groundwater partitioning model used to calculate closure levels for migration to ground water only evaluates the *potential* for leaching from soil *above the water table*. Contamination in the smear zone may introduce more dissolved COC into the ground water, and this increase in contamination may result in plume stability test failure (see Appendix 3). In such cases, evaluating the smear zone and treating the source may be required to achieve plume stability.

3.3.2 Chemical versus Petroleum Sites

As previously noted, default area screening procedures under RISC are different for petroleum releases than for other chemical releases. A petroleum release site is one where product petroleum lubricating oil or fuel has been released. A chemical release site is one where other types of chemical contamination occurs. At petroleum release sites, such as a leaking underground storage tank (LUST) site, the type,

location, and source of contamination are often known. As a result, screening and determination of the nature and extent are combined during the investigation of subsurface soils. Chapter 3 of the RISC User's Guide provides more information on Leaking Underground Storage Tank (LUST) sites. The identification and determination of the nature and extent of contamination at chemical release sites are rarely so well known or predicted. Because issues involved in chemical releases vary from site to site, this document outlines more appropriate assessment methods.

3.3.3 Classifying Site Areas Correctly

It is important to classify site areas correctly. Three classifications are available (see Section 2.9):

- Areas unlikely to be contaminated
- Areas known to be contaminated
- Areas that may be contaminated

Appropriate classification is essential to determine if COC concentrations in an investigated area exceed closure levels and to determine the next steps in the RISC process. Documentation of site area classification should be submitted for IDEM's review.

Table 3-4 outlines surface soil sampling procedures for the three area classifications. The procedures are presented for volatile and nonvolatile constituents. Default screening of source areas that may be contaminated must be limited to ½ acre. Larger areas may be partitioned into ½-acre source areas for surface soil sampling. In addition, the screening instrument must be demonstrated to be reliable and appropriate for the constituent.

3.3.4 Assessing Site Features

Before determining the most appropriate sample locations for screening a source area, significant features of the site and the site area should be assessed. In particular, background sampling locations should be determined, preferential pathways as well as erosional and depositional areas should be identified, and the surrounding vicinity should be evaluated for the presence of environmentally sensitive areas.

Table 3-4. Area Screening Tests for Surface Soils

Area Classification	Sampling Nonvolatile Compounds	Sampling Volatile/Nonvolatile Compounds
Areas unlikely to be contaminated	No investigation is required; however, documentation must support this classification. No closure document is issued for these areas.	
Areas known to be contaminated	Proceed to determination of the nature and extent of contamination; if the nature and extent are known, select a default or nondefault approach and proceed with closure.	
Areas that may be contaminated	Max test • Divide each source area into four sections • Take one random sample from each of the four sections to make one composite; repeat eight times for a total of eight composites • Compare the highest composite concentration value to 2 times the value in the default closure table (see Appendix 1) • Conduct DQA	Chen test • Divide each source area into four sections • Take three random samples per section for a total of 12 samples; do not composite the samples • Follow the procedure for Chen test

3.3.4.1 Preferential Pathways and Surface Water Erosion and Deposition

If preferential pathways exist at a site (such as drainage tiles, karst features, utility conduits, or sand lenses), or if surface water erosional or depositional areas exist (such as gullies and flood plains), these areas should be identified and sampled if they could be affected by site COCs.

Preferential pathways may allow COCs to migrate beyond the potential source area of the site, possibly in unexpected directions. Because preferential pathways may transport COCs rapidly across long distances, these site features require special investigation and may require different sampling methods.

Erosional and depositional areas of surface water systems should be evaluated to determine if COCs that migrate off site are likely to be deposited in sediments or carried away from the site through surface water surges, floods, and scouring mechanisms.

3.3.4.2 Environmentally Sensitive Areas

The area surrounding the site should be investigated to determine if any sensitive off-site features exist. Sensitive features may include residential areas, residential and municipal wells, recreational areas, day care facilities, schools, play grounds, nursing homes, senior citizen centers, surface water systems, aquatic wildlife reproduction areas, endangered species habitats, or agricultural areas. Potential COC migration pathways should be evaluated; ultimately, sampling and analysis may be required.

3.4 Sampling Procedures for Area Screening

This section discusses the following sampling strategies and procedures that should be used when screening potential source areas for COCs:

- Determining sample locations
- Surface soil screening procedures
- Subsurface soil screening procedures
- Evaluating PEC soil screening data
- Ground water screening procedures

3.4.1 Determining Sample Locations

Selecting appropriate sampling locations is essential for evaluating chemical constituent concentrations at any site. Locations can be selected by random methods or by judgmental sampling. The purpose of the sampling is the most important consideration in selecting locations.

Two basic sampling methodologies are appropriate for collecting environmental samples: (1) **statistical** (Random Sampling) and (2) **judgmental** sampling. Most contamination in soils tends to be highly variable in its distribution. Therefore, if Simple Random Sampling is used to identify contamination in a large area, a large number of samples may be required to ensure that COCs are found and accurately characterized.

Distinct areas at a site may have different constituent concentrations or characteristics. For this reason, horizontal stratification of the site is necessary, and each source area should be evaluated individually. Statistical sampling is usually the best method when there is little information about an area or strata. This method may be varied to include systematic random sampling.

Details of statistical sampling methodologies and sample placement options can be found starting on page 102 of the EPA *Soil Screening Guidance: Technical Background Document (*1996).

Judgmental sampling may be appropriate when a great deal of information is available regarding site contamination. Judgmental sampling selects sample locations based on knowledge of the site and the physical or chemical characteristics of the known COCs. Determining locations for soil and ground water sampling is based in part on site history. Using judgmental sampling to investigate a site relies on any current and historical information sources that may provide site-related data on operations at the site.

Judgemental Positioning of Samples - Visual Assessment

If a site strata or area shows signs of contamination (unexplained stressed vegetation, staining, or other evidence), then a sample should be taken in the area that appears to be most contaminated. If a leachate seep is observed, there is probably a contaminated ground water plume. This situation would require sampling of both ground water and leachate. The plume should be delineated using the guidance in Section 4.4.2 for ground water characterization.

Horizontal Positioning of Samples

The first sample should be collected from the area suspected of having the highest COC concentrations in each known or potential source area. Additional sample locations should be selected to delineate the extent of the contamination and should progress outward from the source area until chemical concentrations are less than the default closure levels. At least one sample must be collected upgradient of the source area, and at least one sample must be collected from downgradient and each of the two side-gradient locations.

The following methods are available to determine the horizontal extent of contamination:

- Visual assessment
- Geophysical survey methods
- Soil gas surveys
- Push-probe devices
- Immunoassay screening
- Colorimetric field kits
- X-Ray fluorescence (XRF)
- Photoionization detector (PID) screening

- Flame ionization detector (FID) screening

Screening results must be recorded on the boring logs and field sampling sheets. Results of screening soil with the field methods listed above may or may not indicate the depth of contamination, and there may be no direct relationship between field screening and analytical results. Instead, the information generated from field screening should be used in conjunction with laboratory results to better evaluate the nature and extent of contamination.

The remainder of this section provides information on sampling objectives and volatile and nonvolatile sampling.

3.4.1.1 Sampling Objectives

The sampling objectives of screening are stated in the introduction to this chapter. Some additional considerations are listed below.

Because COCs can move through the soil and react with air and other soil constituents, multiple environmental media may require sampling to (1) identify the COC source area, (2) evaluate COC migration pathways, and (3) determine the chemical fate of the COCs (for example, how COCs may have reacted with soil, water and air constituents and the resulting products of such reactions).

Sampling is generally not required under buildings, paved roads, or other site features where it would cause significant destruction of the existing structures. In such cases, nondestructive methods can often be used to obtain samples in these areas. A Licensed Professional Geologist should evaluate and record soil boring cores.

3.4.1.2 Volatile and Nonvolatile Sampling

The primary difference between sampling for volatile and nonvolatile compounds is that volatile samples cannot be composited. In general, even for nonvolatile samples, unrestricted composite sampling and soil homogenization are not acceptable. Too much homogenization of composite samples collected over a large area tends to introduce a negative bias in the analytical results, possible underestimating actual

COC concentrations. If compositing is to be used, the following limitations apply:

- Soil samples should never be composited or homogenized when they will be analyzed for volatile compounds, including total petroleum hydrocarbons. The physical act of mixing the sample will cause the loss of many volatile organic compounds.

- Soil samples collected for analysis of semivolatile organic compounds (SVOC), diesel fuel, pesticides, polychlorinated biphenyls (PCB), metals, and other analytes with low volatility may be suitable for restricted compositing.

Guidance on sampling procedures is available in *Preparation of Soil Sampling Protocols: Sampling Techniques and Strategies* (EPA 1992).

3.4.2 Surface Soil Screening Procedures

For both volatiles and nonvolatiles, the surface soil screening test for areas that may be contaminated is based on a statistical analysis of the data; site data are then compared to the appropriate default closure levels.

The strategy for nonvolatile COC sampling in areas that may be contaminated involves compositing samples across the entire source area. The ideal strategy for sampling surface soils would be to determine the true population mean of COC concentrations in the potential source area. However, determining the true mean would require extensive sampling and potentially high costs. As an alternative, the Max Test from the EPA Soil Screening Guidance is used. The Chen Test is used for volatiles, although it may also be used for nonvolatiles.

Data obtained from limited sampling will not perfectly represent the true mean at a site. Nevertheless, some uncertainty in the data is acceptable if the data are treated conservatively. The DQO process allows the degree of acceptable uncertainty in the sampling to be determined, thereby establishing a conservative yet reasonable approach. In essence, the DQO process sets limits on the probabilities of making an incorrect decision.

A decision (see Table 3-2) is usually defined in terms of whether or not to investigate the site further. Such a decision should be based on whether the potential exposure concentrations (PECs) in a source area exceed, or are less than, default closure levels as follows:

- If the site PECs exceed default closure levels, the nature and extent of contamination must be determined (see Section 3.4.4).

- If the site PECs are less than default closure levels, no further investigation is required. In such cases, the user may pursue closure if COC concentrations in other media in the area are also less than closure levels.

Incorrect decisions at a site can have two outcomes: (1) deciding that a site is not contaminated when it is (Type I error) and (2) deciding that a site is contaminated when it is not (Type II error). Both the Max and Chen tests are designed to limit these errors to at least a 5 percent probability of a Type I error and 25 percent probability of a Type II error.

Guidance on selecting appropriate sampling procedures is available in the following EPA documents: *Soil Screening Guidance: Technical Background Document (1996)* and the *Soil Screening Guidance: Users Guide (1996).*

3.4.2.1 Max Test for Nonvolatile Compounds in Areas that May Be Contaminated

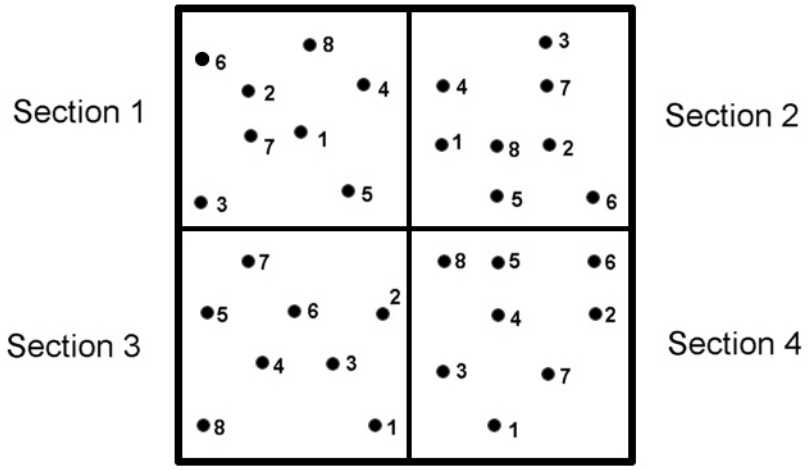
The Max test is recommended for sampling surface soil for nonvolatile compounds in areas that may be contaminated. The Max test sampling strategy involves the following:

1. Divide the unknown area (up to ½ acre) into four sections, each roughly the same size.

2. Collect eight composite samples, each consisting of a discrete sample from each of the four sections delineated in Step 1 (see Figure 3-3).

3. Perform comparison testing.

Figure 3-3. Example Random Sampling Pattern



The text on the following pages provides specific procedures and examples for using the Max test to determine if a surface area is contaminated, when the chemical of concern is a nonvolatile compound.

Max Test General Procedure for Nonvolatile Compounds

1. Divide the potential source area into four sections covering a total of no more than a ½-acre area.

2. Repeat steps 2A to 2C eight times, to obtain eight composite samples (x_1 ..., x_8) (see Figure 3-3):

   2A. Take one random sample from each of the four sections.

   2B. Mix those four samples into one composite sample

   2C. Measure each COC concentration in the composite to yield x_i

   The specific individual samples to be composited into one sample should be chosen at random (for example, with a random number table).

3. Compare the maximum value for each chemical from the eight composites with twice the default Closure Level (CL) for the chemical.

   3A. If the highest value for a chemical exceeds 2 times the CL for that chemical, the source area requires further investigation of the nature and extent of contamination.

3B. If the highest value for a chemical is less than the CL divided by the square root of the number of samples in each composite (**x_{max} < CL / / k**), the surface soil is eligible for closure for that chemical.

3C. If the highest value for a chemical is less than 2 times the CL for that chemical, *and* it is greater than the CL divided by the square root of the number of samples in each composite, (**x_{max} $ CL/ / k**), the evaluation is not complete. Proceed to Step 4.

4. Calculate the following to evaluate the sample size *n*:

4A. The sample mean of the eight composite sample concentrations, 0:

$$0 = 3\ x/n, \quad \text{Where } n = 8 \text{ composite samples}$$

4B. The sample standard deviation, *s*:

$$s = \sqrt{\frac{\sum (x-\bar{x})^2}{n-1}} = \sqrt{\frac{\sum x^2 - \left[\left(\sum x\right)^2 / n\right]}{n-1}}$$

4C. The estimated coefficient of variation (***CV***) (EPA 1996):

$$CV = \frac{s\sqrt{k}}{\bar{x}}$$

Where ***k*** is the number of individual samples in each composite (in this case, *k = 4*)

4D. Use the following table to find the minimum number of composited samples required (***n_{min}***) for various values of *CV*:

CV	1	1.5	2	2.5	3	3.5	4
n_{min}	8	8	8	8	8	9	11

For *CV* values that fall between two values in the table, use the sample size for the next higher *CV*. The table is based on a four-specimen composite (*k = 4*).

5. Evaluate the *CV* as follows:

If *CV* **< 3.0** *and* ***n* = 8**, the area may be eligible for surface soil closure for that COC.

If *CV* **> 3.0** *and* ***n* # 8**, additional samples are required as indicated in the table above.

If *CV* **> 4.0** *and* ***n* # 8**, contact IDEM for advice.

Reference: EPA. 1996. *Soil Screening Guidance: Technical Background Document*. Washington, DC, 20460, US Environmental Protection Agency, Office of Research and Development. Report No. 9355.4-17A; EPA/540/R-95/128; PB96-963502.

Example 1:

1. An area is sampled for arsenic, for which the default CL for surface soil in an industrial/ commercial application is 19.6 milligrams per kilogram (mg/kg).

2. The eight composited samples (each a composite of one individual sample from each of four sub-areas) yield the following concentrations (x_1 ..., x_8):

   4.49, 4.29, 8.19, 2.70, 1.88, 0.83, 2.64, and 7.35 mg /kg

3. The largest of these, x_{max} = 8.19, and the comparison value is :

   $$2 \times CL = 2 \times 19.6 = 39.2$$

   $$x_{max} < 39.2,$$

   Next, checking the sample size:

   $$x_{max} < CL / \sqrt{k}$$

   In this case, $8.19 < 19.6 / \sqrt{4} = 9.8$

   Because this condition is also met, this surface area may be eligible for surface soil closure for arsenic.

Example 2:

1. An area is sampled for arsenic, for which the default CL for surface soil in an industrial/ commercial application is19.6 mg/kg.

2. The eight composited samples (each a composite of one individual sample from each of four sub-areas) yield the following concentrations (x_1 ..., x_8):

   22.45, 21.45, 44.95, 13.5, 9.4, 4.15, 13.2, and 36.75 mg/kg

3. In this case, the maximum composite concentration, x_{max} = 44.95 mg/kg, exceeds the comparison value of:

   $$2 \times CL = 2 \times 19.6 = 39.2$$

   Therefore further investigation is required, and a determination of the nature and extent of contamination is necessary.

Example 3:

1. An area is sampled for arsenic, for which the default CL for surface soil in an industrial/ commercial?] application is 19.6 mg/kg.

2. The eight composited samples (each a composite of one individual sample from each of four sub-areas) yield the following concentrations (x_1 ..., x_8):

   11.23, 10.73, 20.48, 6.75, 4.7, 2.08, 6.6, and 18.38 mg/kg

3. In this case, $x_{max} < 2 \times CL$ (20.48 < 39.2), so the first condition is met.

and

$$x_{max} > CL / \sqrt{k}, \quad 20.48 > 9.8$$

Where $CL / \sqrt{k} = 19.6 / \sqrt{4} = 9.8$

Because $x_{max} > CL / \sqrt{k}$, calculate for following:

$\bar{x}$ = 10.12 (see Equation 4A) and s = 6.4909 (see Equation 4B), so

$$CV = \frac{s\sqrt{k}}{\bar{x}} = \frac{6.4909\sqrt{4}}{10.12} = 1.28$$

Evaluating using the CV Table, CV = 1.28, which is less than 3, *and* the number of samples per composite (k = 4) and the number of composite samples, (n = 8) match the table assumptions. Because this condition is also met, this area may be eligible for surface soil closure for arsenic.

3.4.2.2 Chen Test for Volatiles in Areas that May Be Contaminated

The Chen test is recommended for volatile compounds because it tests the same error rates in a statistically valid manner using single samples rather than composites. Composite samples are not appropriate for volatile compounds. The Chen test may also be used for nonvolatile compounds. The Chen sampling strategy involves the following:

1. Divide the unknown area (up to ½ acre) into four sections, each roughly the same size. If the Max test was used, the same areas delineated for the Max test may be used for the Chen test.

2. Take three random samples per section. Use sampling methods and equipment appropriate for the chemicals of concern, and do not composite the samples.

3. Follow the procedures and consult the examples provided in the text below and on the following pages to determine if the area requires further investigation.

Chen Test General Procedure for Volatile and Nonvolatile Compounds

1. Using all 12 samples, calculate the sample mean, *0*:

$$0 = 3x / n ,$$

2. Calculate the sample standard deviation, *s*:

$$s = \sqrt{\frac{\sum (x-\bar{x})^2}{n-1}} = \sqrt{\frac{\sum x^2 - \left[\left(\sum x\right)^2 / n\right]}{n-1}}$$

3. Calculate a measure of skewness, *b*:

$$b = \left[\frac{n}{(n-1)(n-2)}\right]\frac{\sum (x-\bar{x})^3}{s^3} = \left[\frac{n}{(n-1)(n-2)}\right]\frac{\sum x^3 - 3\bar{x}\sum x^2 + 3\bar{x}^2\sum x - n\bar{x}^3}{s^3}$$

4. Calculate the coefficient, *a:*

$$a = b/\left(6\sqrt{n}\right)$$

5. Calculate the Student's *t* statistic, using the default CL (*t*):

$$t = \left(\frac{\bar{x} - \mu_0}{s}\right)\sqrt{n}$$

Where: μ_o = 0.5 CL

6. Calculate Chen's *t* statistic (t_2):

$$t_2 = t + a\,(1 + 2t^2) + 4a^2\,(t + 2t^3).$$

7. Perform the t_2 evaluation, using a normal *z* value = 0.842:

7A. If t_2 $ 0.842, then the surface area requires further investigation.

7B If $t_2 < 0.842$, the area may be eligible for closure if a second condition is met:

The test must have adequate power to reject the null hypothesis when it is false (see Step 8).

$$n_{power} = 2.75\left(\frac{s}{\mathrm{CL}}\right)^2$$

8. To test for power, calculate the sample size (n_{power}) as follows, ensuring the required power:

8A. If n_{power} is smaller than the number of samples (n), then the surface area may be eligible for closure.

8B. If n_{power} is larger than n, then:

8B1. More samples should be taken to bring the total to at least n_{power}, and

8B2. Both tests should be repeated, based on the augmented data set.

Examples Using the Chen Test

Example 1:

Suppose the following measurements are obtained for benzene, for which the default CL for surface soil in an industrial/commerical application is 13 mg/kg (see Appendix 1).

Section 1	Section 2	Section 3	Section 4
6.6	20.7	56.3	8.4
18.1	11.1	73.1	16.9
5.0	7.9	33.0	23.1

1. Calculate the sample mean:

$$\bar{x} = \frac{\sum x}{n} = \frac{6.6+18.1+5.0+20.7+11.1+7.9+56.3+73.1+33+8.4+16.9+23.1+280.2}{12} = 23.35$$

2. Calculate the standard deviation:

$$s = \sqrt{\frac{\sum (x - \bar{x})^2}{n-1}} = \sqrt{\frac{\begin{array}{l}(6.6-23.35)^2+(18.1-23.35)^2+(5-23.35)^2+(20.7-23.35)^2+(11.1-23.35)^2+(7.9-23.35)^2 \\ +(56.3-23.35)^2+(73.1-23.35)^2+(33-23.35)^2+(8.4-23.35)^2+(16.9-23.35)^2+(23.1-23.35)^2\end{array}}{12-1}}$$

$$s = 21.234$$

3. Calculate the measure of skewness (b):

$$b = \left(\frac{n}{(n-1)(n-2)}\right)\frac{\sum (x - \bar{x})^3}{s^3} = \left(\frac{n}{(n-1)(n-2)}\right)\frac{\sum x^3 - 3\bar{x}\sum x^2 + 3\bar{x}^2\sum x - n\bar{x}^3}{s^3}$$

$$b = \left(\frac{12}{(12-1)(12-2)}\right)\frac{\left(\begin{array}{l}(6.6-23.35)^3+(18.1-23.35)^3+(5-23.35)^3+(20.7-23.35)^3+(11.1-23.35)^3+(7.9-23.35)^3 \\ +(56.3-23.35)^3+(73.1-23.35)^3+(33-23.35)^3+(8.4-23.35)^3+(16.9-23.35)^3+(23.1-23.35)^3\end{array}\right)}{(21.234)^3} = 1.591$$

4. Calculate a:

$$a = b/\left(6\sqrt{n}\right)\frac{1.5910}{6\sqrt{12}} = \frac{1.5910}{20.78} = 0.0765$$

5. Calculate t, where $\mu_o = 0.5$ CL:

$$t = \left(\frac{\bar{x} - \mu_0}{s}\right)\sqrt{n} = \left(\frac{23.35 - 0.5(13)}{21.234}\right)\sqrt{12} = \frac{58.37}{21.234} = 2.749$$

6. Calculate the Chen's t_2 statistic:

$$t_2 = t + a(1 + 2t^2) + 4a^2(t + 2t^3)$$

$$t_2 = 2.749 + 0.0765(1 + 2 * 2.749^2) + 4 * 0.0765^2 * (2.749 + 2 * 2.749^3) = 5.0204$$

7 Evaluation: Because $t_2 = 5.0$ is greater than 0.842, the area requires further investigation and a determination of the nature and extent of contamination.

Example 2:

Suppose the following measurements are obtained for benzene, for which the CL is 13 mg/kg (see Appendix 1).

Section 1	Section 2	Section 3	Section 4
2.2	6.9	18.9	2.8
6.1	3.7	24.5	5.7
1.7	2.6	11.1	7.7

Steps 1 through 6 For these data, the statistics are calculated as in the example above and have the following values:

$0 = 7.825$, $s = 7.1256$, $b = 1.5881$, $a = 0.0764$, $t = 0.6441$, and $t_2 = 0.812$, with $F_0 = 6.5$.

7. Evaluation: $t_2 = 0.812$, and $0.812 < 0.842$, so the sample concentrations appear to be less than the contamination threshold of 6.5 mg/kg.

8. Calculate n_{power}:

$$n_{power} = 2.75\left(\frac{s}{\mathrm{CL}}\right)^2 = 2.75\left(\frac{7.221}{13}\right)^2 = 0.84.$$

Evaluation: The 12 samples are clearly adequate to ensure the specified power (12 > 0.84) for the Chen test, so both conditions are met. Hence, the area may be eligible for surface soil closure, although investigation of other media should continue.

3.4.3 Subsurface Soil Screening Procedures

The purpose of subsurface soil screening is to try to find the most severely contaminated areas and evaluate whether further investigation is warranted. Screening subsurface soils is usually less complex than screening surface soils, but in many cases, it is more important. Subsurface soil closure levels are often the "driver" of a cleanup.

The default model used to develop closure levels is based on a source area no greater than ½ acre. Source areas larger than ½ acre require nondefault closure evaluations and may require different sampling procedures (see Chapter 7).

A simple default procedure for determining the size of the source area is to measure the length of the longest distance between soil borings where COC concentrations are less than or equal to the default closure levels. This length is then squared, and the resulting area should be compared to the area of ½ acre (21,780 ft^2). Alternately, actual configuration of the contaminated area can be used to calculate the size of the source area.

The screening procedure for subsurface soils does not include a determination of the nature and extent of soil contamination. The extent of contamination is determined after the screening tests. Nevertheless, it is wise to keep in mind source size considerations while performing screening.

Subsurface soils should be sampled at areas of known contamination, based on the surface soil sampling and other information (such as visibly stained soils, knowledge of previous site activities, or knowledge of buried COC sources). Samples should be collected at locations within the source areas that are expected to have the highest COC concentrations. In general, three borings in a ½-acre source area meet screening needs. In a smaller area, fewer borings may be adequate.

Proper evaluation of subsurface soil characteristics requires taking a continuous soil core from the ground surface to the depth of interest. In almost all cases, the core should extend to the water table. Obtaining a soil core to the depth of the water table allows for a thorough evaluation of the relationship between the properties of the COC and the properties of the soil. When the soil core has been thoroughly evaluated, the representativeness of samples taken from it can be assessed.

The soil evaluation consists of a description of the source area and soil features based on the following:

- Visual and tactile observation
- Field tests or measurements that involve relatively simple procedures and equipment
- Methods for collecting undisturbed or minimally disturbed samples for physical, chemical, and microbiological characterization (where appropriate) in the laboratory

Subsurface sampling has three goals: (1) to identify the depth at which contamination begins and ends, (2) to evaluate the presence of preferential pathways to ground water, and (3) to quantify the level of contamination. Sampling that meets these goals makes it possible to determine if the source area poses a potential risk that requires further investigation. This approach requires that soil samples quantify COC concentrations from the ground surface to the depth where concentrations are less than the land use-specific closure levels. For both volatile and nonvolatile subsurface sampling, a ground water sample should be collected from each boring (see Section 3.4.5).

3.4.3.1 Sampling Subsurface Soils for Volatile Compounds

The default procedure for collecting subsurface soils where volatile compounds are present consists of four steps:

1. Take three soil borings in areas with the highest suspected COC concentrations.

2. Use a field instrument (such as a photoionization detector or flame ionization detector) to field-screen each 2-foot sampling increment to determine the highest reading within the boring.

3. Collect a sample from the increment with the highest reading and submit it for laboratory analysis.

4. Compare the average of the three soil boring samples to the default closure guidelines. If more than 3 borings are sampled, use the average of the three highest samples.

Another option for volatile sampling in subsurface soil is to calculate a weighted average. Section 3.4.4 provides more information on PECs.

Additional guidance on the procedures and statistical evaluations is available in the EPA publications: *Soil Screening Guidance: Technical Background Document (1996)* and the *Soil Screening Guidance: Users Guide (1996)*.

3.4.3.2 Sampling Subsurface Soils for Nonvolatile Compounds

The default method for screening subsurface soil for nonvolatile substances is based on a thorough evaluation of the soil stratigraphy and type. A general overview of the default procedure for selecting sample locations within a soil core is outlined below in a four-step process. The overview is not comprehensive and does not discuss sampling procedures. The discussion below provides a basic understanding of the subsurface sampling approach for nonvolatiles that IDEM considers acceptable and appropriate. In instances when these default methods are not appropriate, the site must be evaluated using nondefault methods.

- **Step 1 - Obtain a Soil Core**

Soil cores are usually obtained using a push probe, split-spoon, or similar technology. Several sampling methods are available, and almost any generally accepted method of obtaining undisturbed or minimally disturbed soil cores may be appropriate.

- **Step 2 - Evaluate the Soil Core**

The primary activities involved in evaluating the soil core include identifying the soil strata and describing the soils. The USDA Soil Texture Classification System and the "Description and Sampling of Contaminated Soils" (EPA/625/12-91/002) provide a framework for this process. Not all of the information recommended in these documents may be required at every source area; conversely, additional information may be required for some. At a minimum, Munsell soil charts should be used to evaluate and describe the soil color, and observations should include texture, consistence, structure, inclusions, and boundary characteristics. Additional information on sample equipment and handling is also typically recorded.

- **Step 3 - Collect Field Measurements**

When they are available for the chemicals of concern, appropriate field instruments and measurements can provide extremely useful information for the selection of sample locations. The instrument or method *must* be appropriate for the constituents being evaluated.

Field measurements should be used to find locations within the soil core that appear to contain the highest constituent concentrations. Locations with the highest apparent constituent concentrations should be sampled *in addition to* other appropriate locations determined based on the stratigraphy and constituent characteristics. Use of field instruments may ultimately reduce the total number of samples required.

There are generally two distinct objectives for performing field measurements: (1) to gather health and safety information to monitor safe working conditions at the site and (2) to quantify the concentration of constituents present in site media. Field instruments do not generally provide the level of accuracy required for quantification. Although they can be used as an aid in this process, they cannot constitute the only analytical method. Nevertheless, when used properly, these instruments can help simplify the sampling process.

- **Step 4 - Selection of Stratum-Based Sample Points**

In almost all cases it will be necessary to collect stratum-based samples for nonvolatiles, especially when a field instrument is not available, does not detect COCs, or does not detect COCs in a range that provides reasonable instrument accuracy. The basis for selecting sample locations must be provided to IDEM.

Appropriate Sample Intervals and Locations

- Sample locations should be chosen to represent the most contaminated area at the site. The following conditions typically indicate that a location may be appropriate for sampling:

- **Visibly Stained Soil** — Soil that is discolored, oily, shiny, or visibly altered should be sampled.

- **Likely Soil Strata —** Soil samples should be chosen to focus on the most likely location of the COC in the soil core, based on the COC characteristics and soil type. Typical considerations include the potential accumulation of metals in clay or silt, accumulation on the top of clay strata or at the bottom of sand strata, or other locations *based on the expected behavior of the COC in the environment.*

- **Sample Points Within A Stratum —** The selection of sample locations within a soil stratum varies with COC and soil characteristics. Thin layers of interbedded material caused by depositional cycles may often be treated as a single stratum, although additional samples may be required. Strata thicker than 6 inches are generally sampled individually. The number of samples in a thick stratum may vary. One sample in a 2- to 3- foot stratum is probably adequate, but a thicker stratum may require two to three samples, depending on the soil type and the COCs.

- **Topography —** Many times the topography will provide useful information for locating areas of potentially high COC concentrations. For example, runoff areas, depressions, and other low-lying areas may have accumulated chemicals from nearby source areas.

- **The Smear Zone —** The soil column must be evaluated carefully to identify the smear zone. The smear zone is the area between the top of the water table at its highest level and

the top of the water table at its lowest level. Because COCs in the smear zone may have already leached to ground water, this area is not considered when evaluating leaching potential. The smear zone can sometimes be identified by soil staining, a visible change from oxidized soil to reduced soil, or other visual means; in some instances, other methods may be needed. In areas with very shallow ground water, it may be necessary to modify sampling procedures. Both of these situations will generally require a nondefault evaluation of site soil and ground water.

3.4.4 Evaluating Potential Exposure Concentration (PEC) Soil Screening Data

The PEC is the constituent concentration in surface and subsurface soil that is either representative of the site mean (based on random sampling), or the highest concentrations at the sample location (based on judgmental sampling). PECs are calculated from screening, nature and extent and closure sample analyses for comparison with corresponding closure levels for both direct soil contact and migration to ground water. Default closure levels are listed in the Default Closure Table (see Appendix 1). The sampling process generates a PEC for each constituent within each of the sampled media. Within the default approach, PEC soil screening analytical data must be evaluated as follows:

Surface soil

1. Volatile constituents
   - Statistical sampling methods - utilize the Chen test
   - Judgmental sampling methods - compare each sample analytical result to the appropriate closure level
2. Nonvolatile constituents
   - Statistical sampling methods - utilize the Max test, or use the Chen test for better information on where the constituents are located
   - Judgmental sampling methods - compare each sample analytical result to the appropriate closure level

Subsurface soil (judgmental)

1. Volatile constituents
   - Follow the procedure outlined in chapter 3.4.3.1 for sample collection (steps 1-3) and PEC evaluation (step 4).
2. Nonvolatile constituents
   - Follow the procedure outlined in chapter 3.4.3.2 for sample collection

- Using only analytical results from strata with detections, average the data within each boring. If the intervals are not all of the same length, then the calculation of the average concentration must account for the different lengths of the intervals - see EPA Soil Screening Guidance Technical Background Document chapter 4.2.8.
- Compare each boring analytical average to the appropriate closure level(s)

If all PECs for a source area are less than default closure levels, no further action is necessary with respect to the source area. If any PECs at a site exceed default closure levels, the nature and extent of site contamination must be determined for each COC that failed the screening test (see Chapter 4).

3.4.5 Ground Water Screening Procedures

Where volatile compounds are detected at any concentration in the soil, ground water screening or a determination of the nature and extent of ground water contamination must be completed (see RISC User's Guide for exceptions). A minimum of one boring is required within each source area. At least one ground water sample should be taken from each boring. Push-probe technology is suitable for acquiring ground water screening samples.

In all cases where one of the following conditions exist, ground water samples must be collected:

- The site geology may allow COC migration through a preferential pathway to the water table.
- Highly permeable soil conditions exist at the site.

If the conditions above do not exist, and the only site COCs are nonvolatile, ground water sampling may not be necessary if either of the following is true:

- The water table is extremely deep.
- Subsurface soil is not contaminated to the water table; that is, at least two consecutive stratigraphy-based increments comprising at least four feet of clean soil are present at the base of the boring.

If a nonvolatile COC is detected in ground water, the nature and extent of ground water contamination must be determined (see Chapter 4).

Chapter 4 Characterizing the Nature and Extent of Contamination

Overview of Chapter 4

- Introduction
- Applicability and Scope
- Planning: Developing a Strategy
- Planning: Revising a QAPP
- Implementation: Field Investigations
- Assessment: Data Validation and Usability

4.0 Introduction

If screening does not reveal contamination at concentrations that exceed land use-specific criteria, the screened area may be eligible for closure without further investigation. However, if screening or historical information indicates that further site investigation is warranted, it is appropriate to proceed with the characterization of the nature and extent of contamination.

Nature and extent characterization must address all affected media (certain program limitations apply - see RISC User's Guide) but the purpose of characterizing each of the media is different. Surface soil is characterized to evaluate direct contact, whereas subsurface soil characterization focuses primarily on the potential for COCs to leach to ground water. Ground water contamination is characterized (1) to determine if the ground water has been or potentially could be degraded and (2) to evaluate potential routes for human exposure.

In all cases, the potential for ecological impacts must also be evaluated. A thorough nature and extent characterization defines the size of the source area, provides data to determine the potential exposure concentration (PEC), and establishes source area boundaries for remedial activities. The nature and extent characterization process should be consistent with remediation and closure objectives for the site.

4.1 Applicability and Scope

For soils, the "nature" of contamination is defined as those site related chemicals of concern and their respective concentrations. The "extent" is defined as the vertical and horizontal distribution of chemicals of concern whose concentrations exceed residential closure levels. For large sites with multiple source areas, it may be appropriate to delineate to commercial/industrial closure levels on each individual source area, and demonstrate residential levels are not exceeded at the property line. The vertical extent is defined as the distribution of contaminant concentrations that exceed the land use specific closure level.

If COC concentrations for surface and subsurface soils are less than the closure levels, a nature and extent determination is generally not required. However, if COCs are detected in ground water at *any* level during screening, the nature and extent of ground water contamination must be characterized. Because ground water is mobile, it is not

possible to determine whether any individual sample is located in an area of higher concentration or lower concentration within the ground water plume.

An evaluation of the nature and extent of contamination should include the following tasks:

- Identify affected media (surface soil, subsurface soil, ground water, surface water, sediments, and air)
- Identify COCs
- Delineate the vertical and horizontal extent of contamination in each medium
- Determine potential human and ecological receptors and exposure pathways
- Provide sufficient information to make preliminary decisions on remedies and default or nondefault closure options available for the source area

Characterizing the nature and extent of contamination involves three basic steps (see Figure 4-1):

- Planning

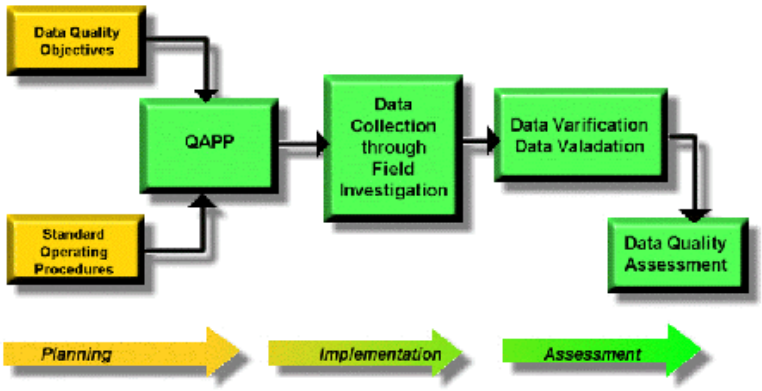


Figure 4-1. Site Characterization Process

  – Develop a strategy to characterize the nature and extent of contamination

  - Update the Quality Assurance Project Plan (QAPP)

- Implementation
  - Conduct field investigations

- Assessment
  - Validate and assess data to determine how to proceed

These steps present a logical approach to use during every round of sampling. Although the approach (planning, implementation, and assessment) is basically the same for both nature and extent and closure sampling, the specific requirements for collecting samples differ. This chapter discusses the specific requirements for characterizing the nature and extent of contamination; Chapter 6 discusses closure sampling.

Planning

Developing a site characterization strategy continues the process of compiling and reviewing information gained during presampling and area screening. Such information should be used to update the conceptual site model (CSM) to include any identified source areas and contaminated ground water. The updated CSM can be used to help identify data gaps and to establish initial objectives for continuing the nature and extent evaluation.

The next iterative step in the process involves developing a QAPP. If a QAPP was developed for the area screening evaluation, it should be revised or expanded to address the requirements for characterizing the nature and extent of contamination. Section 3.2 provides more details regarding the required QAPPs.

When applicable, the following issues should also be considered:

- When determining partitioning coefficients for metals and a limited group of ionizing compounds, soil pH in the source area should be considered. These constituents include but are not limited to arsenic; cadmium; chromium; 2-chlorophenol; 2,4-dichlorphenol; and others (see Appendix 1). This simple measurement may be made in the field with a pH meter in a soil/water slurry (McLean 1982).

- For areas where bedrock occurs less than 10 feet from the COC source area, the default soil to ground water partitioning model may not be applicable.

- Permission may be needed to investigate an adjacent property. IDEM may, at its discretion, assist in gaining property access. IDEM may also assist in determining appropriate alternative actions.

Implementation

The next step in characterizing the nature and extent of contamination involves the field investigation. Data from samples collected in accordance with the QAPP can be used to define the vertical and horizontal extent of contamination in the affected media. In addition, the user should gather any other site data, such as soil pH, applicability of the default ground water partitioning model, and property access necessary to establish potential remedies or models for the risk assessments.

Assessment

Data validation and useability reviews are the final steps in characterizing the nature and extent of contamination. The CSM should be updated as needed based on field investigation data. Data gaps should be identified, and the QAPP should be revised to address the gaps. For instance, surface soil COC concentrations may be higher than expected, or the lateral extent of contamination may be greater than expected. These differences may require that preliminary remedies be reconsidered.

The site characterization process outlined above should be repeated in an iterative fashion until all source areas and ground water plumes are fully characterized. When characterization is complete, the model should be finalized. At that point, an informed decision can be made regarding remedy and closure options (default or nondefault) for the site.

Sections 4.2 through 4.5 provide additional details and specific guidance on how this process is applied to characterize site contamination.

4.2 Planning: Developing a Strategy to Characterize the Nature and Extent of Contamination

When developing a site characterization strategy, it is necessary to understand and make use of all the site information, observations, and data collected to date. The appropriate tool for organizing this information is the CSM, which provides a complete "picture" of site contamination (see Section 2.10). Understanding the type of contamination present and its potential risks to human health and ecological receptors are the most important aspects of developing the model.

A holistic approach to a site or source area within a site may be appropriate for COC characterization and closure. An example of a holistic approach is establishing a single boundary of compliance to evaluate a number of potentially contaminated areas at a site. If applicable, this approach (rather than an individual source area approach), may reduce costs and increase efficiency while still protecting the environment.

The remainder of Section 4.2 provides more details on updating the CSM, considering potential remedies and nondefault options, and identifying data gaps.

4.2.1 Update and Expand the CSM

If area screening data was collected, the preliminary CSM developed during presampling should be updated and expanded before additional field activities are conducted. The updated model should include a top view site plan, cross-sectional drawings depicting site geology and hydrology, and any data on subsurface COC concentrations. The RISC portion of the IDEM website (www.state.in.us/dem/olq/risc) includes risk assessment software that contains information for developing a CSM. The model should include updated information on each of the five categories below, as applicable:

1. **General site information** such as location, size of property, source location, ownership, years of operation, contractors, and other relevant background information

2. **Site characteristics** such as hydrogeological features, hydraulic conductivity, gradient, aquifer thickness, infiltration rate, characteristics of surrounding sites, water use, meteorological conditions, fraction of vegetative cover, and other relevant features

3. **Exposure pathways and receptors** such as current site use, surrounding land uses, projected future land use, exposure areas, source of releases, affected media, plant consumption, affected populations, sensitive subpopulations, ecological concerns, or other pathway and receptor information

4. **Contamination source characteristics** such as spills, drum storage activities, solvents used, waste oil handling, history of contamination, any remedial actions, source depth, area, and presence of free product

5. **Concentrations and types of COCs**, including approximate concentrations detected during screening or previous sampling efforts

4.2.2 Consider Potential Remedies and Nondefault Options

The revised CSM can be used to consider potential remedies and default or nondefault options that may be appropriate for achieving closure based on available information. At this point, the data needed and the statistical methods and models that may be appropriate for the remedies and closure options should be considered.

In many cases, samples required for the various remedies and risk assessments may be collected during sampling efforts to determine the horizontal and vertical extent of contamination. This approach may save time and money.

For example, if a site-specific soil saturation limit is going to be calculated as part of a nondefault risk assessment, samples from each soil boring may be collected using an appropriate methodology, such as split-spoon sampling (see Chapter 7). One sample could be analyzed for COC concentrations and the other analyzed for relevant soil characteristics. In this example, the following site-specific soil information would be required: dry soil bulk density, fraction of organic carbon, water-filled soil porosity, and air-filled soil porosity. This information should be representative of the whole source area and must be analyzed by a soil laboratory using accepted and appropriate methods. Alternatively, if a nondefault risk assessment using a fate and transport model is desired, additional hydrogeological data may be needed (see Chapter 7).

4.2.3 Identify Data Gaps

As noted above, completely characterizing a source area requires determining the vertical and horizontal extent of all COCs in all media, including surface water, sediments, or air. Compiling a list of needed data should identify the probable locations and number of samples to be taken in each of the affected media. Careful assessment of data gaps may save time and money.

In some cases, data needs will be quite simple; in other cases, the required investigation may be quite complex. For example, if a highly mobile COC reached ground water and could potentially affect surface water, the investigation may require an evaluation of regional water uses, land uses, ecological impacts, potential migration to sediments or surface water, recreational exposures, and possible air emissions. These potential effects require additional data collection for all media and receptors that may be affected. Conversely, if a leaking underground storage tank were removed, and the area screening evaluation indicated that contamination was limited to the subsurface soil immediately surrounding the tank, with no ground water impact, then the investigation of the nature and extent of contamination would not need to consider the effects of the release on regional water wells or aquatic species near to the site.

Whatever degree of complexity is required for an investigation, the CSM should provide the information needed to determine the most appropriate type of investigation. The model should also show how the contamination may be linked to various exposure pathways and receptors.

4.3 Planning: Revising a QAPP

The next step in the site characterization process involves modifying elements of the QAPP to gather the data needed to support the required investigation.

As described in Section 3.2, a QAPP should be revised to include a detailed description of where and how samples are collected, the type and number of samples, and an assessment of results. The QAPP should contain the following elements:

- Data Quality Objectives (DQOs)
- Health and Safety Plan (HASP)

- Sampling and Analysis Plan (SAP), including Quality Assurance/Quality Control (QA/QC)

- Data Quality Assessment (DQA)

If a QAPP was established for area screening, it can be modified or expanded to address any additional data collection elements.

Data Quality Objectives

The initial characterization of source areas often raises as many questions as it answers. Field screening methods (such as the use of colorimetric field kits, photoionization detectors, and flame ionization detectors) may require that the sampling plan be redirected or the proposed remedies be reevaluated.

A general description of DQOs and the process used to develop them is included in Section 3.2.1. The DQO process for determining the vertical and horizontal extent of contamination is fairly straightforward.

The first step of the process is to state the problem in terms of the nature and extent of contamination at the site. COCs, their concentrations, and the matrix of each COC should be determined. The next step is to determine the amount of sampling needed. As a general rule, if no constituent is detected at concentrations exceeding the levels defined in 4-1, sampling is complete because the horizontal and vertical extent of contamination has been determined.

The next step involves specifying limits on decision errors. To limit decision errors, specific analytical methods and sample protocols are required. An array of analytical protocols that meet quantification criteria is provided in Appendix 2.

Additional DQOs may be required for other types of sampling performed to completely characterize the site, such as gathering data on soil characteristics for a risk assessment. The DQO process will need to be applied individually to each media and COC being considered. This approach will result in working through the elements in the process several times for each area of contamination. The QAPP should incorporate the sampling needed to support all of the DQOs. This approach will help indicate where data needs overlap and where the same data or samples can be used for a variety of objectives, minimizing sampling and analysis costs.

Health and Safety Plan

Guidance on the health and safety portion of the QAPP appears in Section 3.2.2. If the HASP was prepared in support of an area screening evaluation, it should be reviewed and updated to address any additional sampling and field activities to be performed. In all cases, the HASP must comply with the requirements of 29 CFR 1910.120.

Sampling and Analysis Plan

After DQOs are established, a SAP should be developed. The SAP should identify where samples will be taken and how they will be collected and analyzed. Implementation of the SAP should follow the requirements of the field investigation for each media and for background sampling (see Section 4.4).

A key element of the SAP is the description of QA/QC requirements. Section 3.2.4 provides minimum QA/QC requirements for various IDEM programs. A general discussion of the contents of the SAP also appears in Section 3.2.3.

Data Quality Assessment

The discussion of DQA provided in Section 3.2.5 also applies to the characterization of the nature and extent of contamination. DQA should be appropriate for the DQOs established to determine the nature and extent of contamination.

4.4 Implementation: Field Investigations

The goal of sampling activities identified in the sample design is to provide data to support decisions that meet DQOs. The following are examples of some common goals:

- Determine the vertical and horizontal extent and concentration of COCs
- Gather information to meet additional source area requirements
- Study the migration and transformation of COCs

Selecting sample locations to determine the nature and extent of contamination is a critical step in evaluating concentrations at a source

area. Two basic sample methodologies are available for collecting environmental samples: *statistical* and *judgmental*. Several distinct site areas may have different COC concentrations or characteristics. For this reason, horizontal stratification of the site is necessary, and each area should be evaluated individually.

Statistical sampling is usually the best method when little information is available about an area or stratum. Most contamination in soils tends to be highly variable in its distribution. Therefore, if simple random sampling (SRS) is used to identify contamination in a large area, a large number of samples may be required to ensure that contaminated areas are found and characterized accurately. See Chapter 1, page 1-14 for a discussion of using the coefficient of variation to evaluate samples. Details of statistical sampling methodologies and sample placement options can be found starting on page 102 of the EPA *Soil Screening Guidance: Technical Background Document* (1996).

Judgmental sampling may be appropriate when a great deal of information is available regarding site contamination. Judgmental sampling selects sample locations based on knowledge of the site and the physical or chemical characteristics of the known COCs. Determining locations for horizontal sampling of soil and ground water is based in part on an evaluation of the site history. Using judgmental sampling to investigate a site relies on any current and past information sources that may provide site-related data on current and historical operations.

4.4.1 Field Investigation of the Nature and Extent of Soil Contamination

Evaluating the nature and extent of contamination will provide potential exposure concentrations (PECs) that can be compared with closure levels to determine the need for remedial action.

The surface soil sampling strategy should be designed to collect data that will be useful for evaluating PECs for direct contact (direct ingestion, dermal absorption, and inhalation of fugitive dust). Historical information (see Section 2.2) and the revised CSM (see Section 4.2) may be useful in identifying specific locations for evaluation. Sampling results from the Chen test may provide specific locations to sample if COC concentrations in tested areas exceed default closure values.

To determine the horizontal extent of soil contamination, IDEM recommends that samples be collected from at least 14 borings in each 0.5-acre source area. The 14 borings should include 10 source area borings that define the PECs. The other four borings should be located along each of the four general geographic directions (upgradient, downgradient, and the two side gradients) to define COC boundaries. The analyses from these four sampled borings are not used in the PEC evaluation. For smaller source areas, the minimum recommended number of borings is indicated in Table 4-1.

Table 4-1. Minimum Number of Soil Borings to Calculate a PEC

Source Area (Acres)	Number of Borings for Concentration Gradient	Number of Borings for Geographic Characterization	Total Number of Definitive Borings
1/10	3	4	7
¼	5	4	9
½	10	4	14

To determine the vertical extent of contamination in subsurface soil, refer to Section 3.4.3. To determine the vertical extent of contamination, samples may be collected from the same borings identified in Table 4-1.

4.4.2 Field Investigation of the Nature and Extent of Ground Water Contamination

An investigation of ground water contamination includes determining the extent of contamination and the perimeter of compliance (POC). The requirements for each determination are presented below.

4.4.2.1 Determining the Extent of Ground Water Contamination

Ground water contamination is always be evaluated horizontally to the point where concentrations in affected media are less than residential default closure levels. IDEM recommends first defining the horizontal extent of contamination outward from the source using intrusive (push-probe) methods. To define the vertical extent of contamination, exploratory borings may be converted into monitoring wells with depth-specific screened intervals. Information from the initial

investigation can be used to plan the location and installation of monitoring wells or piezometers to determine hydraulic characteristics and the extent of contamination. Monitoring wells may be required for confirmation and closure sampling. The Indiana Department of Natural Resources' rule 312 IAC 13 is a good source of information on the construction of ground water monitoring wells.

A minimum of three wells or piezometers is needed to determine the local horizontal hydraulic gradient and flow direction of an aquifer. IDEM recommends a minimum of one well upgradient of a COC source. The upgradient well should be located so that it is not influenced by the source when conditions change due to seasonal variability or other factors.

Information on additional aquifer characteristics, such as vertical hydraulic gradient and vertical extent of contamination, may also be needed. The need for this information depends on COC types, program requirements, and factors that may influence flow, such as well fields or a leaky aquifer.

Monitoring wells may be placed downgradient of a source for multiple purposes, including determining the extent of a contaminant plume, POC, or changes in flow direction. Permanent closure of a site with a ground water contaminant plume requires that wells be located in the interior of the plume (see Appendix 3 for guidance).

Pump or slug testing may be necessary to determine hydrogeologic conditions such as conductivity, storativity, and transmissivity of the source area. The following questions must be answered to adequately characterize ground water impacts:

- Are the aquifers and transmissive zones in the area reasonably mapped?
- Is there concern about leaky aquifer conditions (that is, can water and COCs move from one aquifer to another)?
- Is there a vertical hydraulic gradient or perched ground water?

4.4.2.2 Determining the Perimeter of Compliance

IDEM's ground water policy requires "no further degradation" of ground water, which means that the plume is either stable or shrinking with respect to chemical concentration and spatial extent. Samples taken outside the boundary of such a plume must meet the default land use closure levels for each COC.

Location of POC

When there is human or ecological exposure within the contaminant plume area, the POC is established as the location where exposure occurs. When there is neither human nor ecological exposure within the contaminant plume area, the POC is defined as the perimeter that is representative of the point at which ground water COC concentrations are equal to or less than land use-specific closure levels (see Figure 4-2).

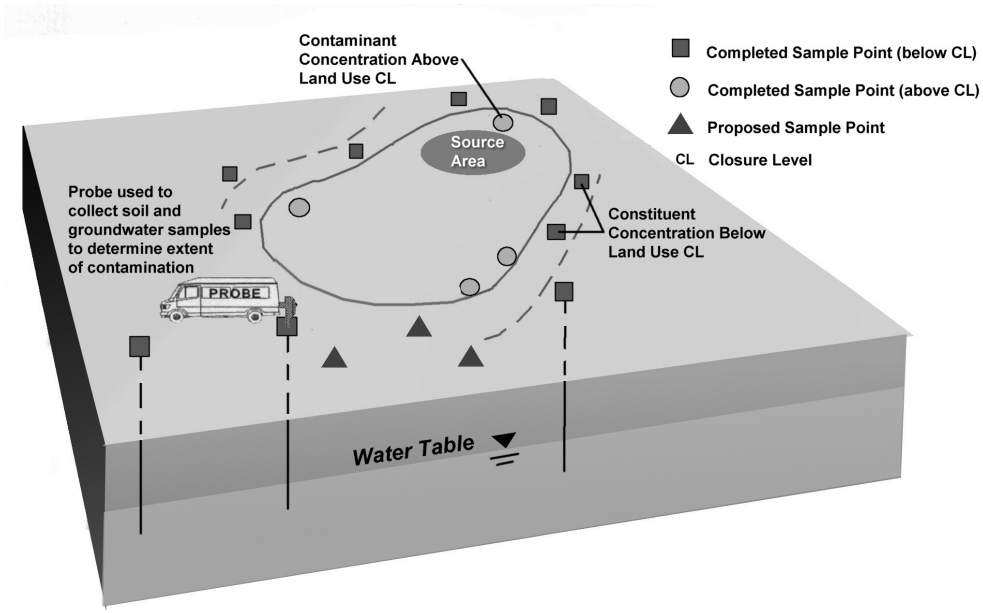


Figure 4-2. Establishing the Perimeter of Compliance

Additional POC Requirements

Establishing the POC is contingent on the following conditions:

- There is no human exposure to ground water COCs (constituents at concentrations that exceed residential default closure levels).

- At the time of initial discovery of chemical constituents in the ground water, a well managed investigation should be conducted to ensure that there is no further degradation of the ground water from constituents associated with source areas inside the POC. POC wells will be placed in appropriate locations at the conclusion of a thorough and timely investigation of the ground water.

- The site poses no threat from flammable vapors.
- All free product is recovered to the extent practicable.
- The established POC is not in conflict with susceptible area requirements.
- IDEM may require full COC cleanup, even at the source, if necessary to protect human health and the environment.
- All present and future land uses must be considered and addressed by (1) providing verification that no change in future water supply use is anticipated within the POC and (2) providing an institutional control to restrict exposure to COCs.
- All COC isopleth maps clearly depict the POC.
- POC wells will be utilized, as appropriate, as sampling points for plume stability demonstrations (see Appendix 3).
- Multi-constituent plumes present special challenges. Often an indicator constituent can be selected to guide the location of the POC. This indicator constituent should be selected in consultation with IDEM staff, and should be based on chemical behavior and constituent concentration data. IDEM generally does not require multiple POCs for a multi-constituent plume.

Under certain conditions, IDEM may approve requests to maintain an off-site POC

POC with Property Control

"Control" of all property affected by the ground water plume must be demonstrated. Property control is defined as the demonstrable capacity to monitor and restrict access to the affected media through institutional or engineering controls. Evidence of control is typically documented in the form of an institutional control recorded on the deed of the affected property (see Figure 4-3).

POC without Property Control

If a plume extends into an area that is not controlled by the site owner or operator or if it extends into an area for which access has not been granted, the POC will be placed at the site property line (or at the point property control ends). Contamination outside of the POC must be

remediated to residential closure levels. In such cases, a POC remedial plan must be designed and implemented (see Figure 4-4).

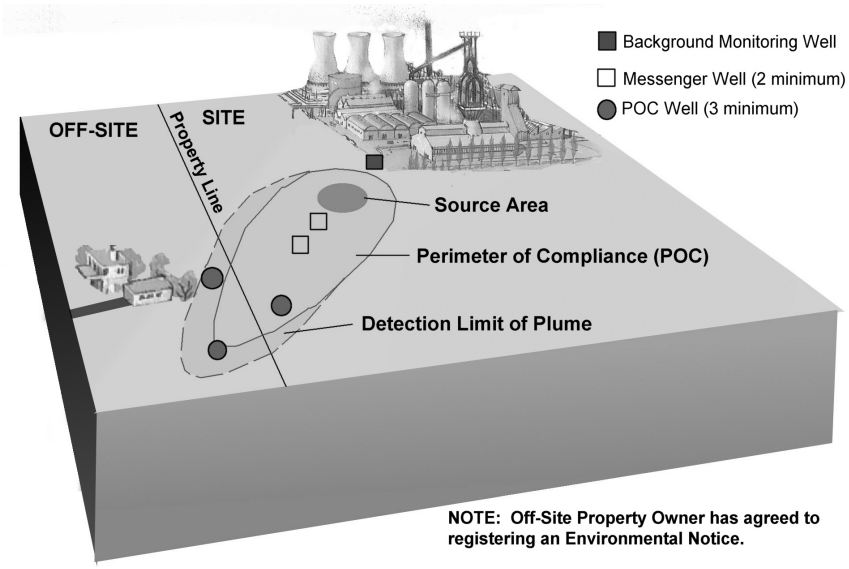


Figure 4-3. Off-Site POC with Property Control

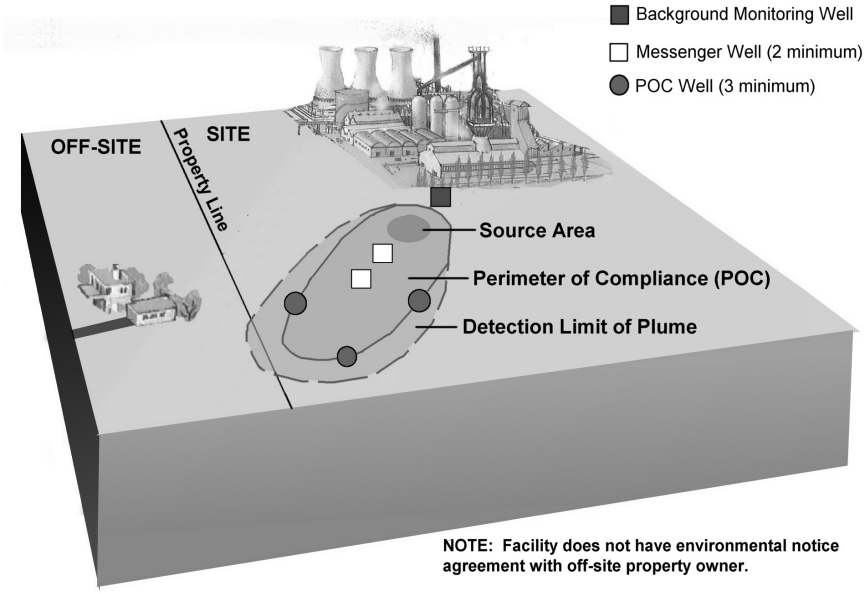


Figure 4-4. POC without Property Control

POC Remedial Plan

It may be necessary to develop and implement a remedial plan if COC concentrations increase significantly at the POC during quarterly sampling events. The remedial plan should include an implementation and compliance schedule. The goal of the remedial plan is to stabilize the plume at the POC and demonstrate that the plume will stabilize or decrease in concentration when remediation is complete. The POC remedial plan must be submitted to the appropriate IDEM program within 60 days of determining that contamination exceeds closure levels at the POC. The plan should address applicable programmatic remedial options, which may include COC source reductions, hydraulic control of a plume, or a nondefault assessment to model and monitor future stability and compliance with the POC.

4.4.3 Field Investigation of the Nature and Extent of Contamination in Other Media

The nature and extent of contamination in other media may need to be determined. Determining the nature and extent of contamination in surface water, sediments, and air is discussed below.

4.4.3.1 Surface Water

Evidence of drainage or discharge to surface water near a source area should be reviewed carefully. Surface waters include but are not limited to rivers, streams, creeks, reservoirs, lakes, ponds, wetlands, and free-flowing underground streams. Under RISC, surface water is considered an ecologically susceptible area. Evidence of impacts to surface water will require a nondefault risk assessment to evaluate impacts to biota. Surface water closure levels are not included in this version of RISC.

4.4.3.2 Sediments

A common problem associated with surface water contamination is sediment contamination and its associated affect on aquatic organisms particularly in their larval or juvenile life stages. Sediments may be a major repository for some of the more persistent constituents released into the overlying surface waters. Sediments primarily consist of particulate matter, typically mixtures of clay, silt, sand, organic matter, and minerals. This matrix of materials can be relatively heterogeneous in terms of physical, chemical, and biological characteristics.

Many factors determine the relative partitioning or sorption of a compound between water and sediment. A few of these factors

include the compound's aqueous solubility, pH, affinity for sediment organic carbon and dissolved organic carbon, and oxidation-reduction potential, as well as the grain size of the sediment. Evidence of COC migration from surface waters to sediment should be reviewed carefully. Evidence of impacts to sediment will require a nondefault risk assessment. Sediment closure levels are not included in this version of RISC. A possible sediment closure level may be identified using the RCRA QAPP, Instructions, EPA Region 5, April 1998, Appendix C.

4.4.3.3 Air

Ambient and indoor air contamination is another area that is not specifically addressed under default RISC closure levels. In the default exposure equations, RISC considers volatilization and inhalation from soils and inhalation from indoor exposure to ground water. However, issues such as excessive fugitive dust and ambient and indoor air concentrations are not considered. Where applicable, care should be taken to characterize these potential pathways (such as volatilization from surface impoundments, excessive wind blown dust, and vapor intrusions). Any suspected air emissions must be characterized. Evidence of air contamination will require a nondefault risk assessment. Air closure levels are not included in this version of RISC.

4.5 Assessment: Data Validation and Usability

After field investigation data is collected, it should be evaluated for its conformity with DQOs. If data conform to DQOs, the data should be incorporated into the CSM. When the horizontal and vertical extent of contamination is fully depicted in the CSM, the need for any additional sampling should be clear.

Based on this information, potential remedies and additional analyses appropriate for the area should be considered, as well as if any additional sampling is necessary. The fate of each COC should be considered carefully, and the COC should either be addressed or eliminated from further consideration. The evaluation of exposure pathways and transport mechanisms should also be reviewed carefully, and temporal trends should be analyzed. By reviewing and considering all relevant information, a more informed decision can be made regarding how to proceed with closure.

Overview of Chapter 5

- Introduction
- Geologically Susceptible Areas
- Wellhead Protection Areas
- Ecologically Susceptible Areas
- Baseline Ecological Evaluation
- Limited Ecological Assessment
- Ecological Risk Assessment

5.0 Introduction

This chapter discusses special requirements for three types of areas that are especially vulnerable to harm from contamination:

- Geologically susceptible areas
- Wellhead protection areas
- Ecologically susceptible areas

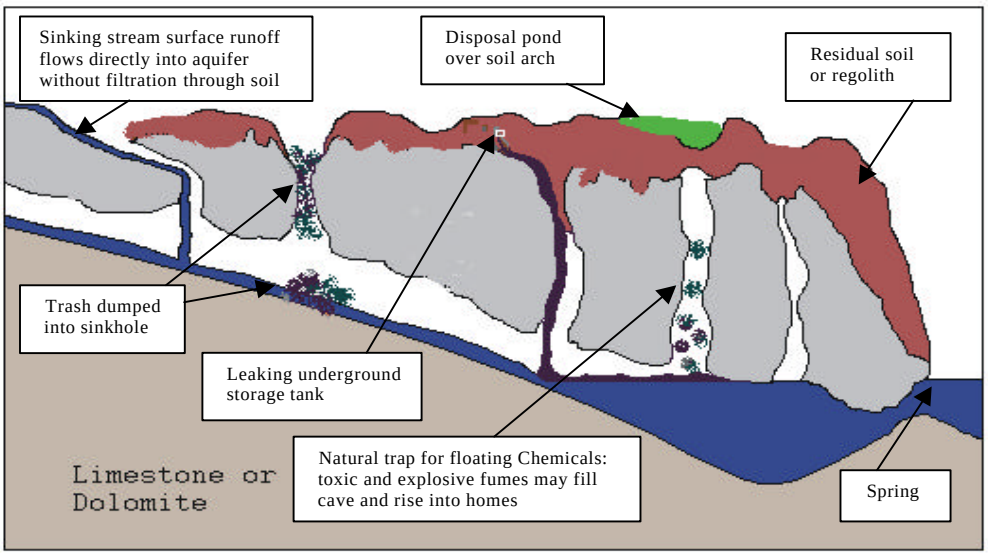
RISC has established these types of areas because people and some sensitive species are more likely to be affected by contamination released to a susceptible area. These areas are considered susceptible based on the characteristic unpredictability of contaminant transport mechanisms, the exceptional value of their environmental resources, or increased human or ecological risks that may result from contamination.

If COC concentrations detected in a geologically or ecologically susceptible area exceed estimated quantitation limits (EQL), the area must be evaluated through a nondefault risk assessment; the nondefault risk assessment must be designed for the unique conditions in the susceptible area. The risk assessment must include potential COC transport mechanisms to determine how contamination could potentially affect the susceptible area. Transport mechanisms include any means that allow contamination to migrate, such as any natural or constructed conduit that contamination may follow between points. Examples of transport mechanisms include wind erosion, leaching through soils and backfill, and transport through sewers and drainage ditches.

The following sections discuss the three types of susceptible areas and the special considerations and requirements associated with each of them.

5.1 Geologically Susceptible Areas

Geologically susceptible areas (see Figure 5-1) are characterized by conditions that allow contaminants to migrate away from the source area in such a manner that invalidates the assumptions of the soil-to-groundwater partitioning model used to calculate the default closure levels.



Modified from Hoffman, W. 1989. Karst Landscape of Warren County

Figure 5-1. Geologically Susceptible Area

Examples of geologically susceptible areas include karst terrain, mined areas, and other fractured rock geology where conduit ground water flow occurs.

Definition of Karst Terrain

The Federal Register notice provides the following definition of karst terrain (40 CFR 258.15(b)(5), October 9, 1991):

"Karst Terrains" means areas where karst topography, with its characteristic surface and subterranean features, is developed as the result of dissolution of limestone, dolomite, or other soluble rock. Characteristic physiographic features present in karst terrains include but are not limited to sinkholes, sinking streams, caves, large springs, and blind valleys.

Karst terrains are prevalent in southern Indiana. The presence of *any* of the distinctive surface or subsurface features listed below is sufficient to identify a terrain as karst. However, the lack (or apparent lack) of surface topographic karstic features does not mean an area is not a karst terrain. Karst terrains are typically characterized by the following:

- Sinkholes — Any closed depression, with or without a discrete opening at the bottom, formed by dissolution or collapse of bedrock, with flushing or collapse of soil into a subjacent cavity and internal drainage to the ground water system

- Dry valleys in humid climates

- Springs draining carbonate, sulfate, or halide rocks

- Sinking streams that flow underground at a hole known as a swallet or swallow hole

- Caves — Open to the surface or accidentally encountered during drilling

- Joints or bedding planes enlarged by dissolution (as seen in drilling cores or outcrops)

- Grikes — Soil-filled joints or grooves enlarged by dissolution, also known as cutters or soil karren

- Karren — Dissolutionally, subaerially, water-carved grooves on rock, commonly subparallel

Karst terrains are especially susceptible to contamination because the openings and conduits formed by the disintegration of rock allow contaminants to enter and move rapidly through a ground water system. Furthermore, ground water systems in karst terrains are typically quite complex and may disperse contamination unpredictably. An example of karst terrain in southern Indiana is the Lost River System.

If contamination is present which could affect a geologically susceptible area, special consideration must be given when determining appropriate closure levels for affected media. The soil-to-ground water partitioning model for evaluating indirect contact exposure is not valid for such areas. Likewise, an evaluation of ground water plume stability may not be possible using the default guidance. As a result, default closure levels for indirect contact and the default stability monitoring approach do not apply at these areas.

5.2 Wellhead Protection Areas

Records and locations of Wellhead Protection Areas can be obtained from the Drinking Water Branch of the Indiana Department of Environmental Management. Figure 5-2 illustrates a typical wellhead protection area.

Definition of Wellhead Protection Areas

The Indiana Wellhead Protection Rule (codified at 327 IAC 8-4.1) defines a wellhead protection area as follows:

Wellhead Protection Area means the surface and subsurface area, delineated by fixed radius, hydrogeological mapping, analytical, semianalytical, or numerical flow/solute transport methods, which contributes water to a community public water supply system production well or wellfield and through which contaminants are likely to move and reach the well within a specified period.

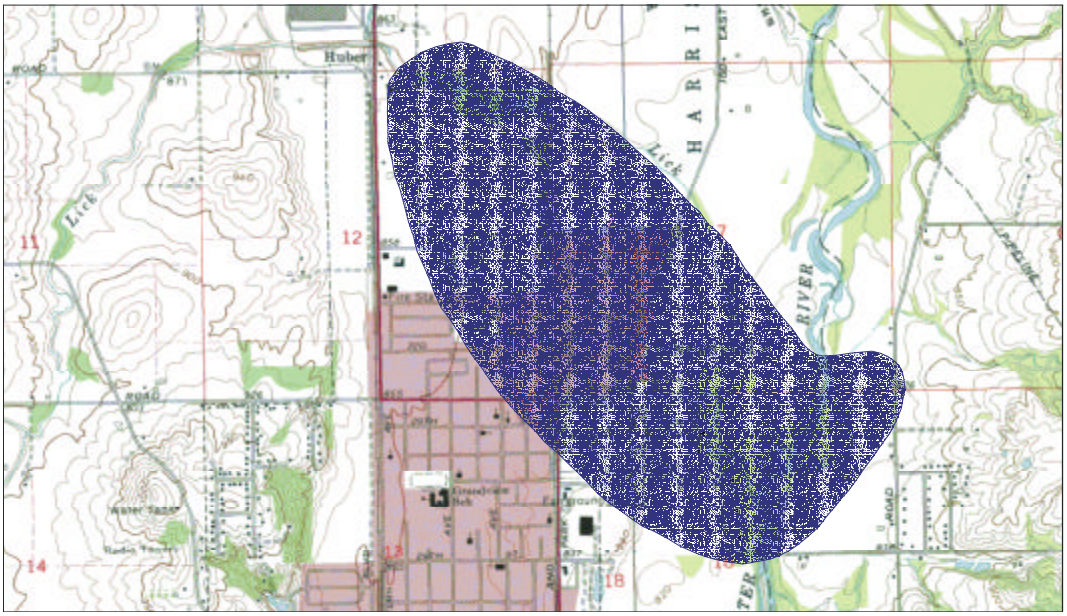


Figure 5-2. Wellhead Protection Area

In cases where ground water contamination is demonstrated to be stable or declining, it may be possible to pursue site closure through implementation of institutional controls. However, because Wellhead Protection Areas provide actual sources of drinking water, they present a high probability for human exposure. As a result, within a Wellhead Protection Area, closure with institutional controls is generally not appropriate. For sites where it can be demonstrated that COCs will attenuate before they migrate to any wellpoint within a Wellhead Protection Area, it may be possible to implement a closure with institutional controls, with the concurrence of the public water supply authority and IDEM. For other sites, it may be feasible to install a treatment system at the wellhead with the concurrence of the public water supply authority.

5.3 Ecologically Susceptible Areas

Ecologically susceptible areas are areas with special habitats where the effects of contamination on nonhuman receptors must be considered. Figure 5-3 illustrates a typical area that may be ecologically susceptible. The box below provides additional information that may be useful for defining ecologically susceptible areas.

Additional Information Useful for Defining Ecologically Susceptible Areas

Surface Waters of the State

Surface waters of the state include rivers, streams, creeks, free-flowing underground streams, reservoirs, lakes, and wetlands, (see 327 IAC 2-1-9[42] and 327 IAC 2-1.5-2[79]. All surface waters of the state must comply with all water quality standards contained under 327 IAC 2, including use designations, numeric and narrative water quality criteria, and the antidegradation standard.

Some examples of ecologically susceptible areas include the following:

- National and state parks, forests, and wildlife refuges
- Designated state nature preserves and other protected areas

- Critical habitats for endangered or threatened species, or species of special concern
- Prairie areas
- Dune areas (such as those near Lake Michigan)

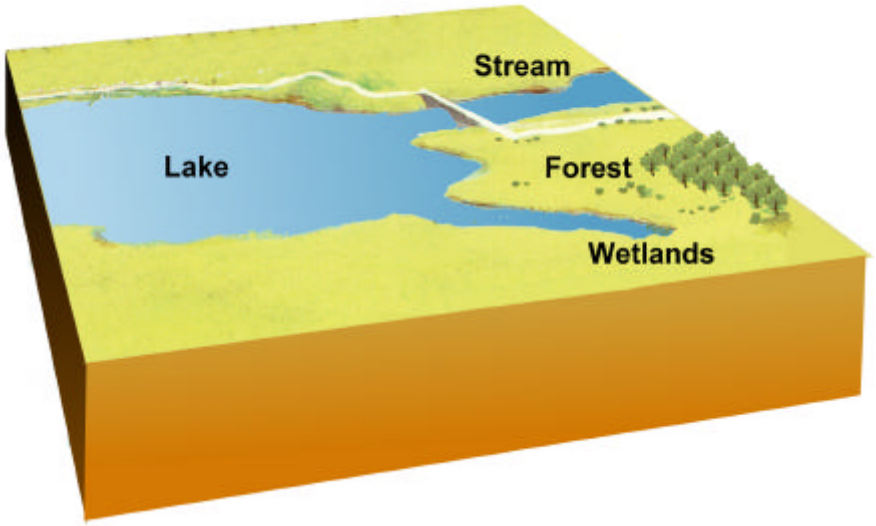


Figure 5.3 Ecologically Susceptible Area

- Surface waters of the state, including wetlands and free-flowing underground streams
- Sinkholes or karst recharge areas *(These areas may be ecologically susceptible in addition to being geologically susceptible.)*
- Riparian areas
- Breeding areas for nesting birds, aquatic birds, aquatic mammals, amphibians, or reptiles
- Migratory areas for shorebirds, aquatic birds, raptors, or passerines
- Wintering areas for migratory waterfowl or other aquatic birds
- Hatcheries

- Reservoir areas
- Recreation areas
- Other designated critical biological resource areas

The box below provides contact information for (1) national parks, forests, and wildlife refuges; (2) state parks, nature preserves, and other protected areas; and (3) endangered, threatened, and rare species and species of concern.

For a listing of national parks, forests, and wildlife refuges, contact the following:		
U.S. Department of Fish and Wildlife Bloomington Field Office 620 South Walker Street Bloomington, IN 47403 (812) 334-4261 http://www.fws.gov	U.S. Park Service Midwest Region 1709 Jackson Street Omaha, NE 68102 http://www.nps.gov	U.S. Forest Service 310 Wisconsin Avenue Room 500 Milwaukee, WI 53203 http://www.fs.fed.us
For a listing of state parks, nature preserves, and other protected areas, contact the following:		
Indiana Department of Natural Resources 402 West Washington Street Room W298 Indianapolis, IN 46204 (317) 232-4020 http://www.state.in.us/dnr		
For a listing of endangered, threatened, and rare species and species of special concern, contact the following:		
Indiana Department of Natural Resources 402 West Washington Street Room W273 Indianapolis, IN 46204 (317) 232-4091 http://www.state.in.us/dnr	U.S. Department of Fish and Wildlife Bloomington Field Office 620 South Walker Street Bloomington, IN 47403 (812) 334-4261 http://www.fws.gov	

5.3.1 Baseline Ecological Evaluation

The applicability of human health-based closure levels at every site is contingent upon a determination that ecological concerns have been accounted for. This may be accomplished without conducting a comprehensive ecological risk assessment at every site. The procedure outlined on the following pages is intended to provide a relatively simple approach for making this determination. The first step in this

procedure is to conduct a baseline ecological evaluation.

A baseline ecological evaluation is included as part of the presampling activities (see Chapter 2). The baseline ecological evaluation consists of a desktop review and site inspection to determine if ecologically susceptible areas are present in the site vicinity, and if such areas could potentially be affected by COCs at the site.

If ecologically susceptible areas are not in the site vicinity, and if there is no potential for ecologically susceptible areas beyond the site vicinity to be affected by COCs at the site, default closure levels can be used. If ecologically susceptible areas could potentially be affected by the source area, a limited ecological assessment must be conducted. Figure 5-4 provides a flow chart depicting the steps involved in evaluating ecologically susceptible areas.

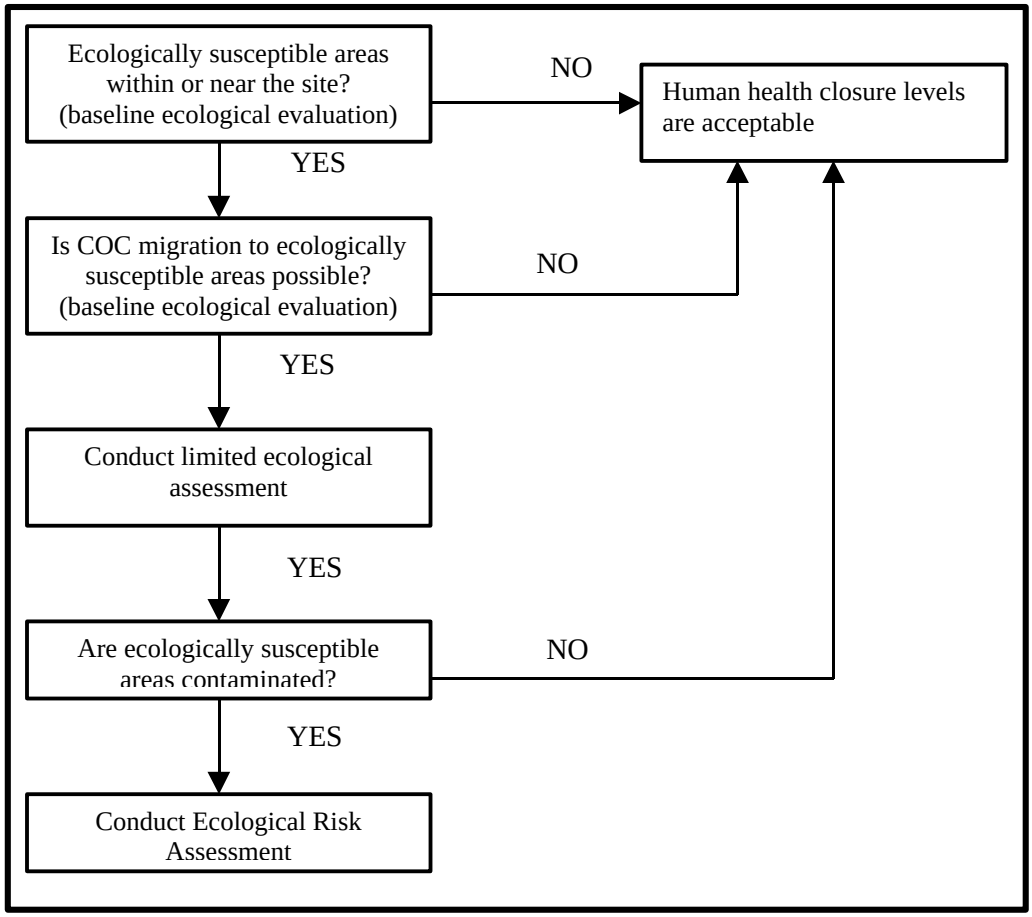


Figure 5-4. Steps Involved in Evaluating Ecologically Susceptible Areas

5.3.2 Limited Ecological Assessment

If ecologically susceptible areas are present onsite, or if there is a potential for COCs to migrate to an ecologically susceptible area, the impact or potential impact of contamination must be assessed. As appropriate, the limited ecological assessment should include sampling of soil, sediments, surface water, and ground water at the ecologically susceptible area, and along areas that may serve as a pathway from the site to any ecologically susceptible areas. Impact or potential impact will be assumed if sampling results indicate (1) that a COC is present in the ecologically susceptible area or (2) there is a potential for a COC to migrate to any ecologically susceptible area.

If actual or potential impacts are discovered, an ecological risk assessment will be necessary to establish appropriate closure levels.

5.3.3 Ecological Risk Assessment

If results of the limited ecological risk assessment indicate an actual or potential impact to an ecologically susceptible area an appropriate ecological risk assessment should be conducted. This should be performed by an environmental professional experienced in ecological risk assessments. While ecological risk assessment guidance is not offered within this Technical Guide, IDEM suggests following procedures outlined in “Guidelines for Ecological Risk Assessment” (EPA 1998) as well as other appropriate EPA guidance documents.

Overview of Chapter 6

- Introduction
- Chemical of Concern Additivity
- Closure Requirements and Institutional Controls
- Closure Requirements by Media
- Programmatic Closure

6.0 Introduction

RISC provides flexibility in selecting the type of remedy that best achieves closure goals for the site. Closure can be achieved with or without institutional controls.

The goal of RISC procedures is to reach closure, which is defined as:

> IDEM's written recognition that a party has demonstrated attainment of specific remedial or screening objectives (closure levels) for COCs at a particular area.
>
> Note: Under the Resource Conservation and Recovery Act (RCRA), the term closure refers to a series of formal procedures required to end the operation of a permitted treatment, storage, or disposal (TSD) unit.

IDEM remedial programs may provide closure in the following situations:

1. For source areas that pass area screening tests

2. If a determination of the nature and extent of contamination indicates that constituent concentrations in all source areas are less than residential closure levels and additivity has been considered

3. If COC concentrations exceed residential closure levels but are less than industrial closure levels, provided appropriate institutional controls are in place and additivity has been considered

The RISC User's Guide should be consulted for program-specific variations to the above criteria.

The default closure tables (Appendix 1) provide the concentration standards mentioned above. For those compounds not listed in the Appendix 1 tables, concentration standards for closure may be calculated using the default equations (Table C), and substituting the appropriate exposure assumptions (Table D), the physical and chemical parameters from the references listed in Appendix 1 page 2 (in order of preference) and the toxicity criteria from the references listed in Appendix 1 page 4 (in order of preference).

IDEM recognizes closure by issuing various documents, depending on the program involved. Table 6-1 indicates the documentation different remediation programs issue to recognize that closure is granted to the extent of that program's authority.

The closure document indicates the extent of completion of the task. New information about the presence of contaminants at a site may require post-closure responses. IDEM may invalidate any closure upon the discovery of new information that indicates a potential threat to human health or the environment. In addition, closure documents are not issued for parts of a site that have not been sampled. The sections below discuss additivity, closure requirements and institutional controls, closure requirements by media, and programmatic closure considerations.

Table 6-1. Closure Documentation by Program

IDEM Program	Form of Closure Documentation
Leaking Underground Storage Tanks (LUST)	No Further Action (NFA) Letter
State Cleanup	No Further Action (NFA) Letter
RCRA Permitting	Approval of Closure Certification
RCRA Corrective Action	NFA Letter
Voluntary Remediation Program (VRP)	Certificate of Completion and Covenant Not to Sue

6.1 Chemical of Concern Additivity

More than one chemical may be present in a source area. RISC assumes that each individual chemical in a mixture acts in an additive fashion by contributing to a single common toxic effect; this assumption applies to both carcinogenic and noncarcinogenic compounds (except as indicated below). However, it may be possible to demonstrate that the effects of certain mixtures are not additive; in such cases, closure levels for the COCs in question need *not* be adjusted for additivity. Otherwise, additivity must be evaluated quantitatively as indicated below.

6.1.1 Carcinogens

For all carcinogens, additivity should be determined as follows for the exposure pathways and media indicated:

- **soil direct contact** — Compounds in surface soil are additive.

- **soil migration to ground water** — Compounds are not additive.

- **ground water** — Compounds with no established maximum contaminant level (MCL) are additive.

The total risk from the combined exposure to multiple carcinogens must be less than the target risk level. Using Equation 6-1, the sum of the fractions representing the risk posed by each carcinogen must be less than or equal to 1.0.

Carcinogen Additivity

Equation 6-1. $$\frac{C_1}{CL_1} + \frac{C_2}{CL_2} + \frac{C_3}{CL_3} + \ldots\ldots \frac{C_n}{CL_n} \leq 1.0$$

Where

C_1, ...C_n = Concentration of carcinogenic chemicals in parts per million

CL_1, ...CL_n = Risk based closure level for the specific carcinogenic chemicals in parts per million

6.1.2 Noncarcinogens

All noncarcinogens are considered additive in the following manner:

- **Soil direct contact** — Compounds in surface soil are additive if they have the same critical effect category.

- **Soil migration to ground water** — Compounds are not additive.

- **Ground water** — Compounds with no established MCL are additive if they have the same critical effect.

Individual noncarcinogens may not exceed a hazard quotient of 1.0. In addition, using Equation 6-2, the sum of hazard quotients must be less than or equal to the hazard index of 1.0 per critical effects category (Appendix 1, Table G).

Noncarcinogen Additivity

Equation 6-2. $$\frac{NC_1}{NCL_1} + \frac{NC_2}{NCL_2} + \frac{NC_3}{NCL_3} + \cdots \frac{NC_n}{NCL_n} \leq 1.0$$

Where

NC_1, ...NC_n = Concentration of noncarcinogenic chemicals in parts per million
NCL_1, ...NCL_n = Risk based closure level for noncarcinogens in parts per million

6.2 Closure Requirements and Institutional Controls

After completing the risk assessment and any needed remediation, site conditions must meet the closure criteria listed in this section.

6.2.1 Closure With Institutional Controls

If engineering controls or restrictions of site activities are used to prevent exposure to site contamination, evidence of the suitability, effectiveness, and continued protection of those controls must be supplied. Institutional controls provide this evidence.

Closure with institutional controls generally requires the use of an Environmental Notice, which must provide information on the nature and extent of residual contamination and the methods used to control that contamination. The Environmental Notice must stipulate that the exposure prevention mechanism established at the site will be maintained, and it must prohibit future changes to the site that would interfere with any such mechanism. The Environmental Notice must be recorded on the deed of the affected property. An Environmental Notice is also required for any property where industrial criteria were used to achieve closure. Appendix 5 provides more information on Environmental Notice and ground water ordinance requirements. Nondefault institutional controls are discussed in Chapter 7.

Additional post-closure care activities are required for engineering controls and may be required for activity restrictions (see Chapter 6). In addition, property control must be obtained and demonstrated where a ground water plume has affected an off-site property. Sites where closure has been achieved with institutional controls may pursue closure without institutional controls at any time.

6.2.2 Closure Without Institutional Controls

Closure without institutional controls typically involves removing contaminated media or permanently reducing COC concentrations to less than residential closure levels (or background). COCs are typically remediated either by physical removal and disposal or by physical, chemical, or biological treatment.

6.3 Closure Requirements by Media

The default process requires a minimum number of sample locations to demonstrate that COC concentrations (the potential exposure concentrations) are less than closure levels (or background) for each affected media. Table 6-2 indicates the minimum number of sample locations recommended for closure areas covering 1/10, 1/4, and 1/2, acre. These recommendations apply to closure sampling in surface and subsurface soils. An additional consideration for evaluation of samples collected using random procedures is the coefficient of variation (CV). If the CV (see Chapter 7.9.3.3) for all of the random sample values exceeds 1.2, additional sampling or other actions may be required.

Table 6-2. Recommended Minimum Number of Soil Sample Locations

Closure Area Size	Number of Sample Locations or Borings
1/10 acre	3
1/4 acre	5
1/2 acre	10

The potential exposure concentration (PEC) is the constituent concentration in surface and subsurface soil that is representative of the site mean (based on random sampling), or the highest concentrations at the sample location (based on judgmental sampling). PECs are calculated for comparison of sample data with closure levels. Default closure levels are listed in the Default Closure Table (see Appendix 1). The sampling process generates a PEC for each COC within each of the sampled media. Within the default approach, PEC soil closure analytical data must be evaluated as outlined in the next two sections (chapter 6.3.1 and 6.3.2). Ground water closure criteria are outlined in chapter 6.3.3.

6.3.1 Surface Soil Sampling and Potential Exposure Concentration Evaluation

Surface soil samples should be collected using the most appropriate methodology for the chemical of concern. Numerous EPA and IDEM documents provide guidance on appropriate sampling methodology. Selecting sample locations may involve the use of field instruments, geological information, site history, information gathered during screening and nature and extent evaluations, information related to remedial activities, or other relevant information.

Closure at sites where surface soils have been contaminated requires that PECs be evaluated as follows:

- Judgmental samples – Each COC concentration in samples representing the most highly contaminated locations within the closure area must be less than the land use-specific closure level established for each COC.

- Random samples – The upper confidence limit (UCL) of the mean of COC concentrations in a representative random sample of the source area must be less than the land use-specific closure levels.

The UCL for random samples is calculated using Equation 6-3.

Upper Confidence Limit of the Mean

Equation 6-3. $$CL \geq \bar{x} + \frac{ts}{\sqrt{n}}$$

Where

CL	=	The closure level
$\bar{x}$	=	Mean of the sample set
s	=	Standard deviation of sample values
n	=	Number of samples
t	=	Appropriate value for Students “t” test

Samples collected using purely judgmental approaches may not be evaluated using the upper confidence limit. If judgmental sample data exceed closure levels, three courses of action are possible: (1) use random sampling methods to re-evaluate the source area (2) perform remediation, or (3) proceed to nondefault. If it can be demonstrated that the closure level is exceeded because of naturally occurring

background levels of specific chemicals of concerns, it may be possible to achieve closure even though the concentration exceeds the land-use specific closure level.

6.3.2 Subsurface Soil Sampling and Potential Exposure Concentration Evaluation

When subsurface soil is excavated as part of a remediation, sidewall samples should be taken every 20 feet around the excavation, or a minimum of one sample per sidewall should be collected in smaller excavations. In addition, an appropriate number of samples (see Table 6-2) should be collected from the floor of the excavation. The subsurface soil sampling procedure outlined in Chapters 3 and 4 should be followed.

Selection of soil increments may be based on information gathered during the investigation of the nature and extent of contamination (provided that such an investigation yielded adequate source area information).

Sampling subsurface soil to determine if further action is necessary requires an assessment of the entire source area. To determine the number of increments (or strata) necessary for a PEC determination, two courses of action are possible: (1) verify that two consecutive increments below the extent of contamination have concentrations below detection limits, or (2) collect samples to the depth where constituent concentrations are less than the land use-specific closure level. If the second option is utilized, a ground water sample must be collected from that boring to demonstrate the full extent (see Section 6.3.3).

The closure sampling procedure at sites where subsurface soils have been contaminated evaluates PECs as follows:

- Judgmental samples
  1. Volatile COCs
     - Follow the procedure outlined in chapter 3.4.3.1 for sample collection (steps 1-3) and PEC evaluation (step 4) using the appropriate number of samples as identified in Table 6-2.
  2. Nonvolatile COCs
     - Follow the procedure outlined in chapter 3.4.3.2 for sample collection
     - Using only analytical results from strata with detections, average the data within each boring. If the intervals are not all of the same length,

then the calculation of the average concentration must account for the different lengths of the intervals - see EPA Soil Screening Guidance Technical Background Document chapter 4.2.8.

- Compare each boring analytical average to the appropriate closure level(s).

- Random samples – The upper confidence limit (UCL) of the mean of COC concentrations from every sample collected in a representative random sample of the source area must be less than the land use-specific closure levels.

The UCL for random samples is calculated using Equation 6-3.

6.3.3 Ground Water Closure Requirements

Closure requirements for sites where ground water is affected will depend on site-specific circumstances and the nature of the chemicals of concern. For example, requirements differ for petroleum and chemical releases. For closure with institutional controls, the user must demonstrate that the contaminant plume is stable or shrinking (see Appendix 3). For closure without institutional controls, residential closure levels must be met at all points within the ground water plume.

6.3.3.1 Ground Water Closure Options

A site with ground water contamination may achieve closure using one of two default options:

- Option 1 – By demonstrating that the plume is stable or shrinking (following the procedures in Appendix 3), or

- Option 2 – By demonstrating that ground water concentrations of all COCs are less than closure levels throughout the plume

Closure using default Option 2 may be demonstrated in either of two ways:

1. After ground water remediation is complete, constituent concentrations in the source area must be verified as being less than closure levels. Concentrations may be verified by monitoring one or more wells, as appropriate for the site, in the area of highest constituent concentration. This area may be determined during the course of ground water remediation. To achieve closure in this manner, monitoring well data must

verify that constituent concentrations in ground water are less than closure levels for at least eight consecutive quarters.

2. This method is the same as above except that the UCL for the eight quarters of sampling data (see Equation 6-3) *for each appropriately located well* may be compared to the closure level. If the statistical evaluation indicates that constituent concentrations within the ground water plume are less than the closure level, the site is eligible for ground water closure.

For closure at industrial levels, the appropriate land use designation must be noted on the property deed.

6.3.3.2 Source Considerations

Care should be exercised in determining the appropriate area to evaluate for closure. Many compounds will migrate rapidly through the environment and may move downgradient of the source area.

Unless an area is screened out, the nature and extent of contamination must be determined before a the appropriate area can be delineated for closure sampling. If free product is discovered on ground water, it must be recovered to the extent practicable to reduce potential hazards and limit further COC migration.

6.4 Programmatic Closure Considerations

There may be programmatic closure requirements in addition to RISC considerations. If a source area is closed using engineering controls, activity restrictions, or land use designations, additional requirements may include closure care, assurance of financial responsibility, and reporting. See the RISC User's Guide for specific details regarding program applicability for any of these issues.

6.4.1 Closure Care for Engineering Controls

Engineering controls must be maintained so that they continue to be effective. A detailed description of the engineering controls, including a maintenance schedule, must be supplied to IDEM as part of closure documentation.

6.4.2 Financial Responsibility

A demonstration of financial responsibility may be required to ensure that funds are available to support any required closure care. Financial

responsibility requirements are determined by the specific program's guidance (or by rule).

6.4.3 Reporting

When institutional controls are used as an element of the closure, IDEM may require reporting. Such reporting should be submitted once every 2 years and may include the following:

- An inspection report discussing the condition of the property and maintenance of engineering controls
- The date and time of the inspection
- The name and employer of the inspector
- Any changes in land use since closure or the last report period
- Activities being performed on the property by employees, contractors, or the public
- Any construction activity that has taken place since closure or the previous report period
- A discussion of the effectiveness of the engineering or institutional controls and their effectiveness in preventing exposure to environmental or human health hazards
- A discussion of the soundness of the financial assurance instrument

Overview of Chapter 7

- Introduction
- Site-Specific Data
- Fate and Transport Modeling
- Modifying Exposure Assumptions
- Institutional Controls
- Considering Other Pathways, Exposures, and Media
- Sampling Soil and Ground water
- Carcinogen Target Risk Level
- Noncarcinogen Additivity Approach
- Nondefault Characterization and Closure Sampling

7.0 Introduction

The Risk Integrated System of Closure (RISC) Technical Guide focuses almost exclusively on the default approach to risk-based closure. Default is defined as *the use of any constant, equation, model, process, strategy, or evaluation as identified within the RISC Technical Guide.*

The default approach represents a standard that IDEM will usually accept, except in those circumstances where the use of a particular default is inappropriate (for example, a default plume stability demonstration in a karst environment). Using the default approach can save time and transaction costs because generally the methods and values involved will require less extensive documentation and justification. The default approach may include the standard process for any of the following:

- Area screening
- Plume stability evaluation
- Closure sampling
- Default closure level
- Other standard procedures or inputs

As a non-rule policy RISC does not have the effect of law or rule; however, the default values and approaches have a sound technical basis and are considered valid approaches when applied to a broad range of scenarios encountered at remediation sites. The reader may view the default procedures described in this document as the methods preferred by IDEM except where such procedures have basis in rule or statute and are therefore requirements. The default closure process attempts to be a “one size fits all” approach. The simplest way to think of the nondefault approach is that it includes any pertinent procedure with a valid technical or policy basis that is not listed as a default IDEM preference. As a result, the limitations on the nondefault closure process are subject to interpretation regarding what is valid from a technical and policy perspective, and the nondefault process must be negotiated with the appropriate authority.

IDEM acknowledges that the default approach may not fit all situations and has developed the nondefault approach to provide a much greater degree of flexibility. This chapter provides a framework for using nondefault approaches within RISC.

Nondefault refers to *the use of any constant, equation, model, process, strategy, or evaluation that is not prescribed in the RISC Technical Guide for general application as a standard.* The nondefault approach is neither superior nor inferior to the default process. However, there are many reasons to consider nondefault applications, including accuracy, cost, necessity, and flexibility.

If a nondefault approach is employed, there will be a greater need to interact with IDEM technical review staff throughout the closure process. For example, a rationale for the technical validity of the nondefault application may be required (such as the technical rationale for sampling differently from the default approach while demonstrating that closure objectives have been obtained). The nondefault approach may also involve little more than relatively simple changes where both default and nondefault procedures are incorporated within a submittal. Examples of combined default and nondefault procedures include the following:

- Eliminating the migration to ground water pathway from further consideration for surface soil
- Substituting a smaller dilution attenuation factor in the default soil to ground water partitioning model when the subsurface soil source area exceeds ½ acre
- Using soil sampling results obtained during screening or characterization for a closure demonstration

Because of the greater uncertainty associated with the nondefault approach, IDEM recommends that such approaches be reviewed in a meeting with IDEM technical staff to explore options and identify expectations before submitting the risk assessment.

In some cases, the nondefault approach may be more desirable than a default approach because the nondefault approach may be more accurate on a site-specific basis. In the nondefault approach, site-specific information can be substituted for generic default information, (which is biased conservatively so it can be applied to a broad range of sites). The substitution of site-specific information may result in a higher closure level and subsequently, a less expensive closure. Nevertheless, the nondefault process may be more cost-effective at some sites. For example, site conditions may support collecting fewer samples than what is suggested for default. In other cases, a nondefault approach may be necessary because the default approach does not support the site conditions (for example, evaluating a source area greater than ½ acre for migration to ground water). A nondefault

approach may also be necessary because the default approach does not consider an affected exposure pathway (such as ambient indoor air). For these and other reasons, nondefault procedures may be more applicable or advantageous at a particular site.

Potential disadvantages of using a nondefault approach should also be considered. Certain nondefault procedures will require greater technical sophistication on the part of the professional performing the evaluation (for example, probabilistic risk assessment). Other nondefault procedures may require more expensive technology (such as hydraulic conductivity testing for ground water modeling). Still other nondefault methods may require more specialized technical personnel (such as a toxicologist to evaluate dermal absorption factors, or a hydrogeologist to evaluate ground water modeling). The nondefault activity should be evaluated based on the value added by that activity. This outcome must balance protection of human health and the environment, cost, and public acceptance.

The guidance in this chapter covers general criteria that IDEM may use to evaluate a particular procedure as well as more specific detailed guidance on particular procedures.

7.1 Site-Specific Data That Can Be Used in the Default Equations

This section includes nondefault guidance for replacing default parameters in default equations with physical or chemical information that is specific to soil or ground water at a site.

A nondefault risk assessment allows closure levels to be derived using site-specific data in the soil-to-ground water partitioning model, the dilution attenuation factor (DAF) equation, the soil saturation limit equation, and the soil attenuation capacity equation. Site-specific data can also be used to determine the fraction of organic carbon and dry soil bulk density and soil porosity. Details on the use of site-specific values that can be used to replace default values are provided below.

7.1.1 Site-Specific Data for the Soil-to-Ground Water Partitioning Model

The soil-to-ground water partitioning model (see Equation 7-1 below) uses default ground water closure levels and site-specific soil data to calculate a migration to ground water soil constituent concentration. DAFs are used with the equation to account for natural constituent concentration reduction that occurs as constituents move through soil and ground water. Alternatively, a dilution factor may be substituted

into the equation in place of the DAF. The following site-specific factors may be determined and used in Equation 7-1 to calculate a nondefault closure level for the migration to ground water pathway in soils:

- Fraction of organic carbon, determined specifically for surface or subsurface soil, whichever is appropriate
- Soil porosity and dry bulk density
- A site-specific dilution factor (see Equation 7-2) calculated using aquifer hydraulic conductivity, hydraulic gradient, infiltration rate, mixing zone depth, source length parallel to ground water flow, and aquifer thickness

The potential for constituents to migrate from soil to ground water prompts many cleanups; in such cases, reevaluating site-specific variables used in the soil-to-ground water partitioning model (also known as the migration to ground water model) may significantly affect closure levels. The model is based primarily on two principles:

- The constituent's equilibrium distribution between fractions sorbed to particles and fractions dissolved in solution (aqueous partitioning)
- The constituent's potential to migrate through the soil. Constituents that sorb tightly to soil organic matter are less likely to partition into the water phase within the soil pore space and are subsequently less likely to leach to ground water

The soil-to-ground water partitioning model estimates leachability using Equation 7-1. The model is most sensitive to the fraction of organic carbon (f_{oc}). If the site-specific value for f_{oc} is greater than the default value of 0.002 gram per gram (g/g), more of the constituent will remain sorbed to organic carbon in the soil, and less of the constituent will be available to leach to ground water. Changes to the other equation parameters are less likely to significantly affect closure levels for organic constituents.

Soil-to-Ground Water Partitioning Model

Equation 7-1. $$CL = C_w \times DAF \times \left[K_d + \frac{q_w + q_a H'}{r_b} \right]$$

Where:

CL	=	Closure level
C_w	=	Closure level for ground water (constituent specific in milligrams per liter)
DAF	=	Dilution attenuation factor (default value is equal to 20 for ½ acre, and 30 for 1/4 acre, or a site-specific DF may be substituted
DF	=	Dilution factor
K_d	=	Soil-water partition coefficient

For organic compounds, K_d is equal to K_{oc} x f_{oc} where:

K_{oc}	=	*Soil organic carbon-water partition coefficient (constituent specific in liters per kilogram)*
f_{oc}	=	*Organic carbon fraction of soil (default at 0.002 g/g)*

2_w	=	Water-filled soil porosity (default at 0.3 L water/L soil)
2_a	=	Air-filled soil porosity (default at 0.13 L air/L soil)
H'	=	Henry's Law Constant (dimensionless)
D_b	=	Dry soil bulk density (default at 1.5 kg/L)

K_d is the most significant factor in determining the leachability of metals. The *Soil Screening Guidance: User's Guide* (see Appendix C, Table C-4) lists certain metal K_d values as a function of pH. Default K_d values were selected assuming neutral soil pH (6.8). To calculate a site-specific closure level for the nondefault approach, K_d values may be adjusted for pH by substituting the values in the EPA's *Soil Screening Guidance, User's Guide,* Table C-4, for the default K_d in Equation 7-1. The pH evaluation should focus on soil within and immediately underlying the source area.

IDEM evaluated a study published by Sheppard and Thibault (1990) to determine an appropriate default K_d for lead migration to ground water. The study cautions that literature values are adequate for

screening in simple systems, but such values should be used with caution, and preference should be given to site-specific information. In cases where the migration to ground water pathway is the limiting soil pathway for the migration of lead or other inorganics, IDEM suggests determining a site-specific leaching value using the Synthetic Precipitation Leaching Procedure (SPLP), EPA SW-846 Method 1312, EPA 1994d) or other appropriate analytical methods. IDEM recommends the following nondefault options for evaluating the migration to ground water pathway:

- Select a generic pH-specific K_d value (as referenced above)
- Use other leaching methods (such as SPLP) or other appropriate screen models that will measure or accurately predict site-specific leaching to ground water

7.1.2 Dilution Attenuation Factor

Both dilution and attenuation decrease the concentration of a constituent in ground water. Dilution occurs as the dissolved constituent disperses and mixes with less contaminated ground water. Attenuation occurs as the constituent is sorbed to soil or degrades through a variety of processes. To account for these processes, the soil-to-ground water partitioning model incorporates a DAF.

DAFs were selected based on the EPA *Soil Screening Guidance: Technical Background Document* (1996). DAFs represent conservative estimates of the dilution and attenuation that may occur at source areas of the sizes listed in Table 7-1 when the aquifer properties are homogeneous and isotropic.

Table 7-1. Dilution Attenuation Factors

Source Size	DAF
¼ acre or less	30
> ¼ acre to ½ acre	20
> ½ acre to 30 acres	10

Other DAFs may be proposed under a nondefault approach, provided adequate justification is given. For example, a particular source area may demonstrate a higher degree of dilution than is represented by the default DAFs. Equation 7-2 should be used to calculate a site-specific dilution factor which may then be substituted for the DAF in Equation 7-1. No default input values are presented because of the wide

variability in subsurface soil conditions that affect constituent migration.

Dilution Factor Equation

Equation 7-2. $$DilutionFactor = 1 + \frac{Kid}{IL}$$

Where: $$d = (0.0112L^2)^{0.5} + d_a(1 - \exp\{(-LI)/(Kid_a)\})$$

And where:

K	=	Aquifer hydraulic conductivity (m/yr)
i	=	Hydraulic gradient (m/m)
I	=	Infiltration rate m/yr (recharge rate m/yr)
d	=	Mixing zone depth (meters)
L	=	Source length parallel to ground water flow (meters)
d_a	=	Aquifer thickness (meters)

IDEM will use the following criteria to evaluate submittals that calculate a site-specific dilution factor using Equation 7-2:

- ***K*,** the hydraulic conductivity, should be determined from the best available information. Consideration should be based on the following: an average of at least three slug tests, a grain-size analysis, published sources, pump test data, and calculation of constituent movement.

- ***i*,** the hydraulic gradient, should be determined from at least three ground water wells (or piezometers), considering seasonal or other fluctuations.

- ***d_a*,** the aquifer thickness, must be based on the best available information and should always be accompanied by a competent and reasonable search of regional water well logs and should include well depths and their relation to aquifer thickness.

- ***I*,** the infiltration rate or recharge rate, should be based on the best available information and should reference values from the Natural Resource Conservation Maps of the Soil Conservation Service or other published sources.

- ***L***, the source length, should be characterized at the source area. L is the greatest source length parallel to the ground water flow.

7.1.3 Site-Specific Data for the Soil Saturation Limit Equation

The soil saturation limit equation (see Equation 7-3) is used to calculate the site-specific constituent soil saturation limit, which may be appropriate when the closure level is limited by the default soil saturation level. The soil saturation limit (C_{sat}) corresponds to the constituent concentration in soil at which the following limits have been reached: (1) the adsorptive limits of the soil particles, (2) the solubility limits of the soil pore water, and (3) saturation of soil pore air. At concentrations that exceed the soil saturation limit, soil COCs may be present in free phase. The following site-specific factors may be determined and used in Equation 7-3:

- Dry soil bulk density
- Fraction of organic carbon (specific to surface or subsurface soil, whichever is appropriate)
- Water-filled soil porosity
- Air-filled soil porosity
- Soil particle density

7.1.4 Site-Specific Data for the Soil Attenuation Capacity Equation

The soil attenuation capacity equation (see Equation 7-4) allows the calculation of a site-specific soil attenuation capacity, which is one of the constituent source limits that must be evaluated for each discrete soil sample. The default soil attenuation capacity concentration is 6,000 milligrams per kilogram (mg/kg) total organic constituent for surface soil and 2,000 mg/kg total organic constituent for subsurface soil. The only site-specific factor used to calculate the soil attenuation capacity is the fraction of organic carbon specific to surface or subsurface soil (whichever is appropriate). A nondefault concentration may be calculated using Equation 7-4.

Soil Saturation Limit Equation

Equation 7-3. $$C_{sat} = \frac{S}{r_b}\left(K_d r_b + q_w + H' q_a\right)$$

Where:

- C_{sat} = Soil saturation limit (constituent specific in milligrams per kilogram)
- D_b = Dry soil bulk density (default at 1.5 kilogram per liter)
- K_d = Soil-water partition coefficient in liters per kilogram where:
  - K_d = K_{oc} x f_{oc}
  - K_{oc} = Soil organic carbon partition coefficient (constituent specific in liters per kilogram)
  - f_{oc} = Fraction organic carbon (default at 0.006 g/g)
- 2_w = Water-filled soil porosity (default at 0.15 L water/L soil)
- 2_a = Air-filled soil porosity (default at n - 2_w L air/ L soil)
- n = Total soil porosity (1- D_b /D_s (L pore/L soil))
- D_s = Soil particle density (default at 2.65 kg/L)
- S = Solubility in water (constituent specific in milligrams per liter of water)
- H' = Henry's Law Constant (dimensionless)

Soil Attenuation Capacity

Equation 7-4. *Site-Specific Soil Attenuation Capacity* = f_{oc} x 10^6

Where:

- f_{oc} = Fraction of organic carbon in grams per gram

For example, 0.007 g/g fraction organic carbon x 10^6 = 7,000 mg/kg total soil attenuation capacity.

7.1.5 Site-Specific Data for Determining the Fraction of Organic Carbon

To determine the fraction of organic carbon (f_{oc}), soil samples must be collected from areas not affected by soil contamination to minimize interference from carbon-based constituents. Visual evidence, in conjunction with field screening and laboratory analyses, should be employed to locate areas not affected by constituents. Composite soil samples from at least two borings should be collected and analyzed separately to determine f_{oc}. The soil collected from these borings must

be of similar nature and composition as the soil affected by the contamination.

If more than one soil type is present at depths corresponding to the vertical extent of soil contamination, separate composite samples that are representative of the soil variation should be collected A weighted average f_{oc} representing the affected area should then be calculated. If the vertical extent of soil contamination is significant, more samples should be included in the composites of each soil type; collecting additional samples will more accurately assess vertical soil variation. Weighted averages for f_{oc} can be calculated using Equation 7-5.

Weighted Averages for f_{oc}

Equation 7-5.

$$\bar{c} = \frac{\sum_{i=1}^{n} l_i c_i}{\sum_{i=1}^{n} l_i}$$

Where:

$\bar{c}$	=	Weighted average soil concentration
c_i	=	Representative soil concentration in an interval
l_i	=	Soil interval length
n	=	Interval number

No single method is recommended for analyzing f_{oc}; however, the method should have a detection limit of 0.1 percent or less organic carbon; the soil-to-ground water partitioning model is not valid for soil that contains less than 0.1 percent organic matter. Some typical references for analytical methods for f_{oc} are presented below; some may apply to specific site conditions, such as glacial sediments:

- Allen-King, R. M., and others. 1997. "Organic Carbon Dominated Trichlorethene Sorption in a Clay-Rich Glacial Deposit." *Groundwater Journal*. Volume 35. Number 1. Pages 124 to 130.

- American Society for Testing and Materials. (1995). "Document D2974, Method C."

- Nelson, D. W., and Sommers, L. E. 1982. "Total Carbon, Organic Carbon, and Organic Matter." In *Methods of Soil Analysis. Part 2, Chemical and Microbiological Properties*. Second Edition. A.L. Page, editor. American Society of

Agronomy. Madison, Wisconsin. Volume 9. Number 2. Pages 539 to 579.

7.1.6 Site-Specific Data for Dry Soil Bulk Density and Soil Porosity

Discrete samples that are representative of the contaminated soil type must be collected to determine the dry soil bulk density and soil porosity. Because bulk density and porosity typically are not affected by most common constituents, sampling for these parameters may be possible in contaminated areas, depending on the constituent type and concentration. More than one sample per boring may be needed to completely characterize the soil. If more than one sample per boring is used, a weighted average should be calculated. If more than one soil type is present at depths corresponding to the vertical extent of contamination, the methodology outlined above for f_{oc} sample averaging should be followed. The following are commonly used method references for dry soil bulk density and porosity:

- American Society for Testing and Materials. 1996. "ASTM D2937." *Annual Book of ASTM Standards. Volume 4.08. Soil and Rock Building Stones*. Philadelphia, Pennsylvania.

- Klute, A. (editor). 1986. *Methods of Soil Analysis, Part 1. Physical and Mineralogical Methods.* Second Edition. American Society of Agronomy. Madison, Wisconsin.

7.2 Plume Stability and Fate & Transport Modeling

Plume stability is an objective of ground water closure and may be demonstrated using default or nondefault methods. The default procedure for plume stability demonstrations (Appendix 3) provides a detailed mechanism to determine whether ground water degradation is occurring with respect to certain constituents. If the default stability monitoring process determines that a plume is expanding, the following options are available:

1. Use a remediation method such as sparging, pump and treat, or monitored natural attenuation, as appropriate

2. Evaluate plume stability using a nondefault process

The subsections below discuss the nondefault process for demonstrating plume stability and the use of fate and transport modeling.

7.2.1 Nondefault Plume Stability

In some situations, it may be appropriate to make minor adjustments to the default stability monitoring procedure. Such adjustments are considered nondefault variations to the default procedure and will require IDEM program approval. Examples of nondefault variations include the following:

- Using existing historical ground water data that is incomplete (for example, if most ground water data is appropriate for the default procedure but some quarterly data may be missing)

- Proposing additional monitoring, reassessment, and evaluation using the default Mann-Kendall Test if a low percentage of sample results exceed closure levels

Other nondefault plume stability demonstrations may involve more rigorous methods; these would primarily involve alternate statistical evaluations that replace the Mann-Kendall evaluation as well as fate and transport modeling.

7.2.2 Fate and Transport Modeling

Fate and transport models may be useful in modeling potential constituent transport from one medium to another. Such models may also be useful in estimating constituent concentrations (either temporally or geographically) when sampling data are not available. IDEM anticipates that fate and transport modeling will be proposed for the following purposes:

- To evaluate potential exposure pathways (for example, to estimate possible ground water concentrations based on the soil-to-ground water pathway or to estimate possible air concentrations based on the soil-to-air pathway)

- To estimate possible constituent concentrations at different downgradient points (for example, based on ground water data collected at upgradient locations)

- To estimate the timeframe required for the following:

  - Meet applicable risk-based objectives
  - Complete the remedial action
  - Achieve plume stability
  - Achieve closure

- To demonstrate the effectiveness of a given remedial action plan or closure plan to meet applicable risk-based objectives

- To support other risk-based determinations, as appropriate

Fate and transport modeling involves two key determinations: (1) selecting a model appropriate for the situation and (2) selecting values for the model input parameters. In a nondefault submittal, the risk assessor may propose fate and transport models and appropriate input values specific to the source area and the model. IDEM will evaluate these submittals based on relevant EPA guidance and the following criteria and ASTM publications:

- Appropriateness for the site-specific conditions given the limitations inherent in the model

- Availability of sufficient data

- Adequacy of documentation

- Proper calibration, including sensitivity or error analyses

- Correct use of support assumptions about future conditions

- The following ASTM publications:

  - Standard Guide for Comparing Ground-Water Flow Model Simulations to Site-Specific Information (ASTM D5490-93e1)

  - Standard Guide for Documenting a Ground-Water Flow Model Application (ASTM D5718-95e1)

  - Standard Guide for Application of a Ground-Water Flow Model to a Site-Specific Problem (ASTM D5447-93)

- Standard Guide for Conducting a Sensitivity Analysis for a Ground-Water Flow Model Application (ASTM D5611-94e1)

- Standard Guide for Calibrating a Ground-Water Flow Model Application (ASTM D5981-96e1)

- Standard Guide for Defining Boundary Conditions in Ground-Water Flow Modeling (ASTM D5609-94e1)

- Standard Guide for Describing the Functionality of a Ground-Water Modeling Code (ASTM D6033-96)

- Standard Guide for Defining Initial Conditions in Ground-Water Flow Modeling (ASTM D5610-94e1)

- Standard Guide for Documenting a Ground-Water Modeling Code (ASTM D6171-97)

- ASTM Standards on Determining Subsurface Hydraulic Properties and Ground Water Modeling, 2nd Edition, International Standard Book Number (ISBN) 0-8031-27170

For all nondefault plume stability demonstrations, the appropriateness of other methods and the ensuing monitoring period will depend on site conditions, complexity, and the limitations of the approach.

7.3 Modifying Exposure Assumptions

A nondefault evaluation offers enough flexibility to tailor exposure assumptions to site-specific conditions or to modify exposure assumptions based on current peer-reviewed research. In a nondefault evaluation, industrial exposure equations and assumptions may be modified based on site-specific factors. However, IDEM considers potential long-term residential land use activities to be similar everywhere. Nevertheless, IDEM will consider changes to the residential exposure assumptions based on new and compelling information. Such changes will be “permanent” changes to the default approach and will be applied statewide and not on a site-specific basis. IDEM will evaluate submittals that propose modified exposure assumptions based on the following criteria:

- EPA acceptance

- Consistency with evaluation of Reasonable Maximum Exposure
- Reliance on institutional controls for limiting exposure
- Relative uncertainty
- Applicability and relevance

7.4 Institutional Controls

Two default institutional controls are available in RISC: (1) an Environmental Notice and (2) the demonstration of an appropriate ground water ordinance. However, IDEM recognizes that other mechanisms may reasonably accomplish the desired exposure control in a manner consistent with the default mechanisms. Nondefault institutional controls proposed as part of site closure will be evaluated against the following criteria:

- The control provides legal notice to current and future owners of the affected property of the nature and extent of the restrictions.

- The control is permanent in nature.

- The control is legally valid.

Nondefault institutional controls may be approved if they satisfy these criteria.

7.5 Considering Other Pathways, Exposures, and Media Not Included in the Default

The sections presented above describe modifications that may be made to default equations and models to reflect site-specific conditions. Other deviations from the default approach may be necessary because it may not address all appropriate pathways, exposures, and media. For example, risk-based closure criteria were calculated for soil and water media because constituent behavior in these media is generally well understood and easily measured. However, air pathways (including ambient outdoor air, odors, vapor intrusion through basements, and indoor air from sources other than basements) were not evaluated in the default approach.

RISC does not specifically offer guidance on how to evaluate these pathways, exposures, and media; nevertheless, they should be evaluated as appropriate because they may pose a significant risk at contaminated sites. This section is intended to identify those concerns

not otherwise addressed in the default approach. Default exposure pathways and exposure routes are presented in Table 7-2.

Table 7-2. Default Exposure Pathways and Routes

Exposure Pathway	Residential Land Use	Commercial or Industrial Land Use	Construction Worker Exposure
Direct Soil Contact	▪ Skin contact ▪ Ingestion of soil ▪ Inhalation of soil vapors and particulates		
Soil Leaching to Ground Water	▪ Ingestion of ground water contaminated by soil leachate		▪ Not evaluated
Ground Water	▪ Ingestion of ground water ▪ Inhalation of vapors released from ground water	▪ Ingestion of ground water	▪ Not evaluated

A nondefault evaluation must be used to assess current and future exposure pathways that are not addressed in the default approach. The default approach makes certain assumptions about land use, potential pathways, and routes of exposure. When site conditions fall outside the scope of the default approach, then a nondefault risk analysis must be performed. It is erroneous to assume that only default media and pathways require evaluation; nondefault media or pathways should also be evaluated if appropriate. Generally, determining exposure scenarios requires that four types of media be considered:

- Air
- Soil
- Ground water
- Surface water (and sediments)

Air exposure can occur through ambient outdoor air or indoor air. Soil exposure can occur by ingestion, dermal absorption, and inhalation of volatiles and particulate matter (integrated into one closure level — direct contact). Constituent migration from soil to ground water may result in ground water exposure. Ground water and surface water exposures may result from drinking water, bathing, cooking, or industrial process applications such as cooling. Surface water evaluations should also consider sediments because they may be contaminated with constituents that tend to partition out of surface water. In particular, sediments should be evaluated for bioaccumulative COCss because they tend to partition into sediment, where they then may enter the food web.

Biota exposures (including potential plant and animal COC uptake, with subsequent human consumption) should also be considered for each medium, if appropriate. Biota exposure pathways merit consideration when consumable plants and animals in the area may be affected. Other factors to be considered include the following:

- Constituent deposition from air to plants that are ultimately consumed
- Constituent deposition from air to surface water and soil
- Uptake through irrigation with contaminated water
- Uptake through livestock watering with contaminated water
- Consumption of forage grown on contaminated soil
- Aquatic species uptake in contaminated water and sediments

For example, if an area has been affected by constituents and it is used for grazing dairy cattle, it would be appropriate to evaluate plant uptake of the constituent for bioaccumulation in the dairy herds. As another example, if surface water has been contaminated, subsistence fishing should be evaluated to determine if this is a viable pathway for exposure. Additional information on indirect exposures is provided in *Exposure Assessment Guidance for RCRA Hazardous Waste Combustion Facilities* (1994).

Evaluating the applicability of these pathways and exposure routes is important in the nondefault approach. Potential exposure media and some of the associated nondefault pathways are summarized in Table 7-2. The vapor intrusion pathway is particularly important when volatiles are present in the vicinity of basements. Guidance on the evaluation of this and other air pathways is available in the *Soil Screening Guidance: Technical Background Document* (EPA 1996). Consultation with IDEM is recommended if any nondefault pathway must be evaluated.

Table 7-3 Nondefault Exposure Media and Associated Pathways

Exposure Media	Examples of Associated Pathways
Soil	▪ Runoff to surface water ▪ Vapor intrusion ▪ Biota – Commercial produce consumption – Plant uptake associated with meat, dairy, and game
Ground water	▪ Industrial process water ▪ Biota uptake in irrigated produce
Air	▪ Ambient – Particulate – Vapors ▪ Indoor air ▪ Particulate deposition on soil ▪ Biota uptake from air deposition on plants and soil ▪ Uptake by aquatic plants and animals from air deposition on surface waters
Surface water	▪ Recreational ▪ Drinking water ▪ Sediments ▪ Biota – Benthic uptake from sediments – Fish consumption – Uptake by irrigated produce

Determining which pathways or media can be eliminated from further consideration is largely a matter of investigating the potential for exposure. In a nondefault, site-specific approach, exposure pathways may be eliminated from further consideration with adequate justification. For instance, with appropriate institutional controls in place, the following pathways might be eliminated:

- Direct contact pathways for surface and subsurface soil if an asphalt surface or other barrier approved by IDEM effectively prevents direct contact with contaminated media
- Recreational exposure pathways in surface water if swimming and related exposures are prohibited or are demonstrated to be unrealistic
- Ingestion pathways for ground water

The evaluation criteria for submittals that rely on pathway elimination will include the following:

- Evidence for current exposure

- Potential for future exposure
- Effectiveness of institutional controls
- Overall protectiveness of the remedy

7.5.1 Source Areas Larger than ½ Acre

In screening, source areas larger than ½ acre may be partitioned into ½ acre increments to evaluate surface soil using the default Max and Chen procedures (see Chapter 3). After surface soil samples are collected in each ½ acre partitioned area (according to requirements of the Max or Chen tests), analytical results can be evaluated for each partitioned acre.

For characterization and closure sampling, the source area could similarly be partitioned into ½ acre increments. Each ½ acre increment could then be sampled in 10 locations to establish a concentration gradient; in this manner the perimeter of the entire source area could be established through sampling. As with screening, this sampling approach for characterization and closure could result in the collection and analysis of a large number of samples. More cost-effective strategies may be possible. Section 7.9.3 provides sampling strategies that may reduce the number of samples needed for larger source areas.

The default soil-to-ground water partitioning model used to evaluate constituent migration to ground water incorporates a dilution attenuation factor of 20 for source areas up to ½ acre. Any source area larger than ½ acre must be evaluated using a smaller DAF if the soil-to-ground water partitioning model is used. A dilution attenuation factor of 10 may be appropriate for source areas up to 30 acres in size, or a more appropriate model may be proposed to evaluate this pathway. IDEM recommends that regulatory support be sought from the appropriate remedial program for source areas larger than 30 acres.

7.5.2 Karst and Fractured Flow Geology

Karst terrain and fractured flow geology will require a nondefault approach to closure for (1) the soil constituent migration to ground water pathway and (2) the ground water ingestion pathway. Unconsolidated materials overlying fractured flow areas may be evaluated using default strategies for direct contact pathways. However, the soil-to-ground water partitioning model is not valid if applied to consolidated, heterogeneous, and nonisotropic materials. In

such cases, the evaluation of the migration to ground water pathway will require a nondefault approach that should be discussed with IDEM.

For the ground water ingestion pathway, the following activities are always site specific in karst terrains:

- Screening
- Delineating the nature and extent of contamination
- Closure sampling
- Plume stability demonstrations

The development of any ground water sampling strategy in fractured flow geology will require close coordination with IDEM to most efficiently address the uncertainty associated with these endeavors.

7.5.3 Impacts on Ecologically Susceptible Areas

For ecologically susceptible areas, a nondefault assessment is required if constituents are identified within these areas, or if contaminated areas are connected to such areas by an exposure pathway (for example, surface runoff connecting a source area to a wetland, stream, or lake). The following guidance may be helpful in conducting ecological risk assessments:

- Ecological Risk Assessment and Risk Management Principles for Superfund Sites (1999) - Available online at http://www.epa.gov/superfund/programs/risk/tooleco.htm

- Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments, Interim Final (1997) - Available online at http://www.epa.gov/superfund/programs/risk/ecorisk.htm

- Guidelines for Ecological Risk Assessment (1998) - Available online athttp://www.epa.gov/ncea/ecorsk.htm

- The Wildlife Exposure Factors Handbook - Available online at http://www.epa.gov/ncea/wefh.htm

- U.S. Fish and Wildlife Service provides information related to ecological risk assessment. The information is available at http://contaminants.fws.gov

7.5.4 Exposures of Acute or Subchronic Duration

The default approach does not address exposures of acute or subchronic duration. If these exposures are appropriate for evaluation (for example, air pathways), a meeting with IDEM is suggested before any proposal is submitted.

7.6 Sampling Soil and Ground Water

Chapters 3, 4, and 6 describe default sampling methods for screening, characterization of the nature and extent of contamination, and closure, respectively. Other methods or variations on the default methods may also be reasonable alternatives to the default guidance provided in those chapters. The purpose of this section is to offer guidance on nondefault approaches for sampling ground water and soil. Possible nondefault approaches and associated criteria are presented in Table 7-4.

See Section 7.9.4 for additional information on random sampling within a grid system.

7.7 Carcinogen Target Risk Level

IDEM has established a default target risk of 10^{-5} as protective of human health, when used in conjunction with the default equations, toxicity criteria, and measurement of potential exposure concentrations (PEC). In establishing the default, IDEM has defined a risk assessment that is generally applicable anywhere in the state. The level of uncertainty associated with PEC determinations and assumptions made in the default approach have been determined to be acceptable.

In order to deviate from the default target risk level associated with this predetermined level of uncertainty, a new site-specific risk assessment must be performed. In a nondefault risk assessment, IDEM will evaluate target risk proposals within the 10^{-4} to 10^{-6} risk range in a manner consistent with the National Contingency Plan (NCP) and EPA Office of Solid Waste and Emergency Response Directive 9355.0-30 “Role of the Baseline Risk Assessment in Superfund Remedy Selection Decisions.”

Table 7-4. Nondefault Sampling Criteria

Procedure	Nondefault Criteria
Screening surface and subsurface soil	1. Sample in a manner that provides sufficient information to determine if additional investigation is warranted for the area in question. 2. Evaluation criteria for the sampling data should be consistent with the sampling method. Judgmental samples are generally compared individually to the closure level. A statistical evaluation is performed on randomly selected samples.
Ground water screening	1. Sample in a manner that provides sufficient information to determine if additional investigation is warranted for the area in question.
Characterize the nature and extent of soil contamination	1. Collect an adequate number of samples to reasonably characterize constituent concentrations across the source area. 2. Evaluation criteria for the sampling data should be consistent with the sampling method. Judgmental samples are generally compared individually to the closure level. A statistical evaluation is performed on randomly selected samples. 3. For large, complex sites with multiple source areas, characterize each source area to where the extent of contamination meets the industrial closure level. Next, collect samples at the property line to determine if off-site areas have been contaminated at concentrations that exceed residential concentrations. Sampling at the property line may be conducted in lieu of delineating each source area laterally to where the extent of contamination meets residential concentrations.
Sampling soil for closure	1. Collect an adequate number of samples to reasonably characterize constituent concentrations across the source area. 2. Evaluation criteria for the sampling data should be consistent with the sampling method. Generally, judgmental samples are not appropriate for closure sampling if remediation has been performed.
Characterize the nature and extent of ground water contamination	1. Collect an adequate number of samples to reasonably characterize constituent concentrations across the source area.
Sampling ground water for closure	2. Collect an adequate number of samples to reasonably demonstrate that closure levels have been achieved. 3. To determine plume stability, collect samples in a manner consistent with the requirements of the appropriate ground water fate and transport model.

Any changes to the default exposure assumptions, pathways, PEC procedures, or other factors used in the risk assessment may introduce

greater uncertainty. This uncertainty should be evaluated either quantitatively, qualitatively, or both, and a decision should be made regarding the acceptable level of uncertainty to support the selection of a target risk.

- If the default pathway and additivity equation (see Appendix 1, Table C); default toxicity (see Table F); and default exposure criteria (see Table D); and default chemical constants (see Table B) are used, the default target risk level (10^{-5}) may be used without additional justification.

- If changes are proposed to any default pathway or additivity equation inputs, toxicity, or exposure criteria, the evaluation should select a target risk level within 10^{-4} to 10^{-6} based on the level of uncertainty introduced by the proposed change.

- When evaluating the appropriateness of a proposed target risk IDEM will consider uncertainties in a nondefault risk assessment for either multiple or single constituents. The more uncertainty that can be eliminated, the greater the consideration of a higher target risk level (10^{-4}). The more uncertainty that is added, the greater the consideration of a lower target risk level (10^{-6}).

IDEM believes this approach best incorporates the decision-making process associated with Superfund and IDEM's broad application of risk-based decision making across all cleanup programs.

7.8 Noncarcinogen Additivity Approach

Nondefault approaches can be taken by demonstrating that constituent effects are limited to a single organ, or that the toxic effects occur by separate, nonadditive mechanisms. Nondefault approaches will be assessed on a case-by-case basis and evaluated against a hazard index of 1.0.

7.9 Nondefault Characterization and Closure Sampling

Hazardous waste sites may cover several acres of land; however, constituent source areas may be smaller than ½ acre and could be managed using the default procedures outlined in Chapters 1 through 6. The following procedures may be used for any source area, including constituent source areas greater than ½ acre.

While the procedures outlined here have been found to be suitable at many sites, not all sites will be able to use every method. It is likely that greater interaction with IDEM technical staff will be required when selecting and using nondefault methods.

In general, the site is first divided into distinct source areas (horizontal strata), then a sampling plan is developed for each stratum, samples are collected, and analytical data are evaluated statistically. A broad look at hazardous waste closure decisions identifies the following activities as necessary steps in this process:

- **Define the sample area**. The waste site should be divided into sample areas (horizontal strata). Each sample area will be evaluated separately for attainment of closure levels and will require a separate statistical sample. It is important to ensure that sample areas are clearly defined during the data quality objectives (DQO) process (See Appendix 6).

- **Specify the constituents for which to test**. Constituents to be tested for in each soil unit should be listed (See Chapter 5).

- **Specify the sample handling and collection procedures**. An important task for any decision procedure is to define carefully how each parameter will be sampled and analyzed.

- **Establish the closure level.** Closure levels are determined by site-specific risk assessments, by guidance, or by rule (see Chapter 6.

- **Specify the parameter (statistic) to be compared to the cleanup standard**. For RISC we use the upper confidence limit of the mean for each stratum.

- **Specify the probability of mistakenly declaring the sample area clean**. Select and specify the false positive rate (see Glossary) for testing the site. It is recommended that all constituents in the sample area use the same rate. This rate is the maximum probability that the sample area will mistakenly be declared clean when it is actually dirty.

The following sections outline the process for determining whether the desired environmental concentrations have been attained and the site is eligible for closure:

1. Presampling activities
2. Horizontal stratification

3. Sample size determination
4. Selection of sample locations
5. Sample collection and analysis
6. Data quality assessment

7.9.1 Presampling Activities

As in the RISC default approach, the nondefault process is designed to achieve a high level of confidence in source area characterization by completing thorough presampling activities. Presampling activities include a review of site information, selecting an approach to sampling, determining the boundaries of the waste site, and obtaining or preparing a detailed map of the waste site (see Chapter 2). It may be advantageous to do some preliminary sampling during this step. The data obtained can be used to help develop an accurate approximation of the required sample size.

7.9.2 Horizontal Stratification

Unless constituents and concentrations are homogeneous throughout the entire site, the site must be stratified into source areas with similar characteristics.

Three key terms describe areas within the waste site:

- Source area
- Horizontal strata
- Sample location

For the purposes of this guidance manual, source areas and horizontal stratum generally identify surface areas designated for sampling. Subsurface samples are taken from vertical strata below the horizontal stratum. Because ground water is mobile, ground water samples may be required outside the area of soil contamination. A sample location is the point within an individual stratum at which one takes a sample. See Chapter 2 for more information on classifying areas of a site and developing a conceptual site model (CSM).

Proper stratification of a hazardous waste site ensures that samples are grouped to meet the project objectives of site characterization and closure in an effective yet efficient manner. The precision of statistical estimates is likely to be improved by dividing a large site into homogeneous strata. In this way, the variability due to soil, location, characteristics of the terrain can be controlled, thereby improving the precision of contamination level estimates.

The following can be used to define horizontal and vertical strata in an area:

- Sampling depth
- Constituent concentration
- Physiography and topography
- The presence of interferants that affect laboratory analytical techniques
- The history and sources of contamination at the site
- Previous cleanup attempts
- Weathering and run-off processes

Two concepts are central to the process of separating an area into strata:

- The strata must not overlap; no area within one stratum can be within another stratum (See Figure 7-1).
- The sum of the sizes of the strata must equal the total area to be evaluated.

Site characterization decisions should be made independently for each source area. It is important to ensure that source areas are clearly defined and agreed to by all. It is generally useful to define multiple source areas (horizontal strata) within a waste site or source area. These areas should be defined so that they are as homogeneous as possible with respect to prior waste management activities. For example, if a PCB transformer disposal area and a lead battery recycling area are located on the same site, they should generally not be included in the same source area unless contamination from the two sources overlaps. In that case, there would be three separate source areas for sampling, the PCB-contaminated area, the lead contaminated area, and the area contaminated by both.

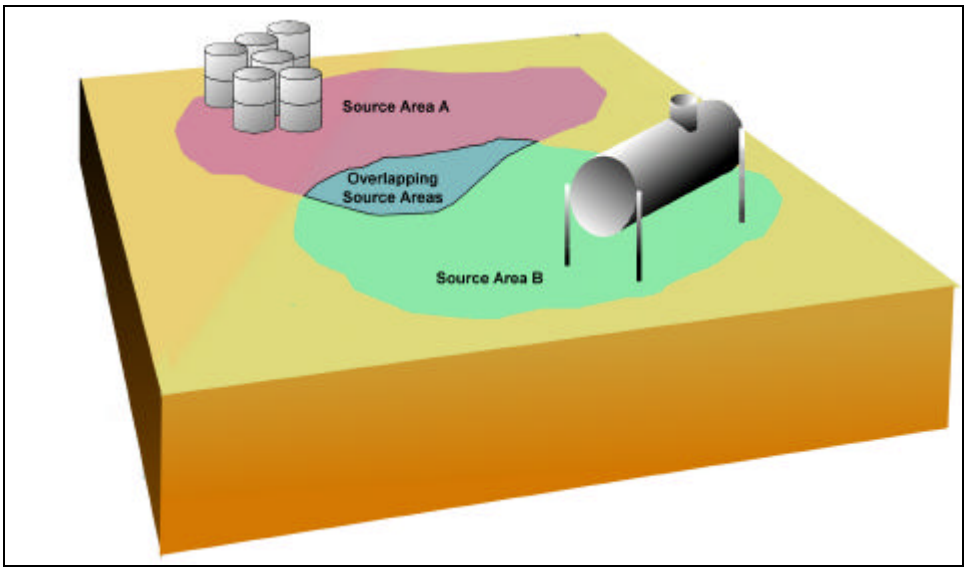


Figure 7-1 Overlapping Source Areas

Additionally, a site may be comprised of areas that require different sampling or treatment technologies. For example, disturbed versus natural soils, wetlands versus firm terrain, or sandy versus clay soils may suggest establishment of different sampling areas for stratification. Sample area definitions also require that the depth or depth intervals of interest be specified. Section 3.4.3 provides information on subsurface sampling.

7.9.3 Sample Size Determination

This section discusses types of sample size for closure and other useful calculations related to sample size.

7.9.3.1 Types of Samples

Three types of samples are taken in the RISC process: screening samples, characterization samples, and closure samples. RISC allows screening and characterization samples to be used for a closure decision under the following circumstances:

1. The samples are taken using a method that will determine the worse case scenario at the site, and all sample concentrations are less than the established cleanup level

2. Samples were collected in such a way that the sample mean is representative of the entire source area, and the upper confidence limit of the mean is below the closure level.

Guidance on a worst-case characterization is given in Section 3.4.1. In all cases, for source areas ½ acre or greater, the sample number will not be less than 10 characterization samples plus 4 samples (one each from upgradient, downgradient, and the two side gradient directions) that have constituent concentrations less than closure levels.

7.9.3.2 Calculating the Sample Size for Closure

Determining the appropriate sample size to make a closure decision requires some knowledge of the concentrations of environmental constituents for the source areas at the site. This can be acquired through preliminary sampling. Often this data is not available. The following two options can be used when no data are available:

1. Use the calculation $\sqrt[3]{n}$ (n = number of grid points in the sample area) as an initial sample number estimate, or

2. Estimate the mean and standard deviation for use in **Equation 7-6** below

Careful consideration must be given to which values are used. If the calculated sample size is too small, you will be required to obtain additional samples, if it is too large, costs increase unnecessarily.

The following equation is used to determine the appropriate sample size. Initially an estimate is calculated using **Equation 7-6**. When samples have been collected and analyzed, the calculation is repeated using the mean and standard deviation from the full data set to determine whether the sample size is adequate to make a closure decision.

It is advisable to collect and properly store a few additional samples while at the site, paying careful attention to preservation and maximum holding times. Then, if a final sample size calculation shows a need to analyze additional samples, the additional stored samples are available for analysis and the need to remobilize for sampling is limited. *The minimum sample size (definitive samples sent to the laboratory) for source areas greater than or equal to ½ acre will never be less than 14.*

Sample Size Calculation

Equation 7-6. $$n = \frac{(Z_a + Z_b)^2}{(C_s - m_1)^2} s^2 + \frac{Z_a^2}{2}$$

Where:

- n = The required number of samples
- $Z_{"}$ = The "Z" value for the selected alpha (" = Type I error, 1 - " = confidence limit)
- $Z_{\$}$ = The "Z" value for the selected beta ($ = Type II error, 1 - $ = power)
- C_s = The acceptable constituent level at the site
- μ_1 = The population mean at the site (often estimated by the sample mean)
- F^2 = The population variance (often estimated by the sample variance)

Note: " and $ are selected based on decision error limits

The sample number required varies depending on the standard deviation and the constituent level found at the site. As would be expected, if the site mean is close to the limit for a constituent, and the standard deviation is large, a large number of samples is required to provide confidence that the actual site mean (μ_1) is below the limit. EPA/600/R-96/084, Guidance For Data Quality Assessment.

7.9.3.3 Other Useful Calculations Related to Sample Size

The coefficient of variation and the calculation of the action level are two other useful calculations related to sample size. The closer the sample mean is to the closure level and the greater the variability in the sample data (large standard deviation), the greater the sample number required to confirm that the closure level is not exceeded. If the approximate mean and standard deviation are known it is possible to use a "rule of thumb" to evaluate whether a large sample number will be required. Population parameters are estimated using sample data.

Coefficient of Variation

Equation 7-7. $CV = \frac{s}{m_1}$

Where:

F	=	Population standard deviation
μ_1	=	Population mean

For the sample number to be reasonable, the coefficient of variation (CV) must satisfy one of the following conditions:

- CV # 0.5 if the sample mean is $0.7 of the limit
- CV #1.0 if the sample mean is $0.45 but #0.7 of the limit
- CV #1.5 if the sample mean is #0.45 of the limit

As the mean increases the CV must get smaller or the sample size must increase.

Consider the following two examples:

Closure Level = 72 parts per million (ppm)
mean = 90% of the limit or closure level
μ_1 = 64.8 ppm
F = 32.4
mean = 80% of the limit
μ_1 = 57.6 ppm
F = 28.8

The 90% values F and μ_1 given above (CV = 0.5) yield a sample number of about 127 as follows:

$$n = \frac{(1.645 + .842)^2}{(72 - 64.8)^2}(32.4)^2 + 1.35 \approx 127$$

If the site mean is 80% of the closure level with CV = 0.5, the sample number is about 25.

$$n = \frac{(1.645 + .842)^2}{(72 - 57.6)^2}(28.8)^2 + 1.35 \approx 26$$

When the site mean is close to the limit the required sample number is high, even with a fairly low coefficient of variation. A smaller standard deviation will result in a smaller number of required samples, but hazardous material cleanup sites often have significant variations in the constituent concentration of samples, and because of this a high standard deviation. This is especially true prior to any remedial efforts.

If preliminary sampling indicates that the site concentrations are near the limit it may, in the long run, be more cost effective to perform cleanup activities before attempting closure of the source area.

The calculation of the action level can be quite useful. In the example above (in which the site mean is at 90 percent of the acceptable constituent level and only 25 samples are taken) site concentrations exceed the action level. In the other example (in which the site mean is at 80 percent of the acceptable level) site concentrations are less than the action level, and 25 samples were adequate to establish that the site mean probably does not exceed the regulatory limit. These calculations are tools to help determine the approximate cleanup level and sample number required to close a site.

ASTM (D5792) Calculation for the Action Level

Equation 7-7. $AL = RT - Z_{0.05}\frac{S_w}{\sqrt{n}}$

Where:

AL	=	The action level
RT	=	The regulatory threshold
$Z_{0.05}$	=	The number from the Z table corresponding to the 95% confidence level
S_w	=	The sample standard deviation
n	=	The sample number

Using the examples above:

$AL = 72 - 1.645\frac{28.8}{\sqrt{25}} = 62.5\,ppm$ = action level for F = 28.8 and 25 samples

$AL = 72 - 1.645\frac{32.4}{\sqrt{25}} = 61.3\,ppm$ = action level for F = 32.4 and 25 samples

7.9.4 Selecting Appropriate Sample Locations

At a minimum, the following activities should be included in the sampling design:

- Review existing historical site information
- Perform a site reconnaissance
- Evaluate potential migration pathways and receptors
- Determine sampling objectives
- Establish DQOs
- Collect field screening data
- Select parameters for which to analyze
- Select an appropriate sampling approach
- Determine sampling locations

Randomization is necessary to make probability or confidence statements about the sampling results. Sample selection using the judgment of the sampler has no randomization. Results from such samples cannot be generalized to the whole sample area, and no probability statements can be made when judgmental sampling is used. However, judgmental sampling may be justified, for example, during the preliminary assessment and site investigation stages, if the sampler

has substantial knowledge of the sources and history of site contamination. However, judgmental samples should not be used to determine if the cleanup standard has been met (except as outlined above and in Chapters 3 and 6).

Random selection of sample points requires that each sample point be selected independent of the location of all other sample points. With random sampling, no pattern is expected in the distribution of the points. However, it is possible (purely by chance) that all of the sample points will be clustered in one or two quadrants of the site. This possibility is extremely small for larger sample sizes.

An alternative to random sampling is systematic sampling, which distributes the sample more uniformly over the site. A random starting point is selected, and samples are collected in a pattern covering the entire source area. Because the sample points follow a simple pattern and are separated by a fixed distance, locating the sample points in the field may be easier using a systematic sample than using a random sample. In many circumstances, estimates from systematic sampling may be preferred. More discussion of systematic versus random sampling can be found in *Finney (1948), Legg, et al. (1985), Cochran (1977), Osborne (1942), Palley and Horwitz (1961), Peshkova (1970), and Wolter (1984)*. Complete references for these sources are provided at the end of this chapter.

The procedures outlined below should ensure the following:

- The method of establishing soil sample locations in the field is consistent with the planned sample design.
- Each sample location is selected in a nonjudgmental and unbiased way.
- Complete documentation of all sampling steps is maintained.

The procedures assume that the sampling plan has been selected, the boundaries of the source areas and any strata have been defined, a detailed map of the waste site is available, and the required sample size is known.

Soil screening borings and sampling areas should be located in a manner that can determine with a high level of confidence if any previously specified constituents are present. Random sampling may be performed in a grid system. Judgmental sampling using default procedures should be performed at areas of suspected contamination, such as cracked areas of a containment structure, areas of known

spills, or suspected downslope, downwind, or runoff areas of a containment structure. Other directed or systematic sampling methods (such as sampling at uniform intervals) may be used if warranted on a site-specific basis. These methods may include a (1) circular pattern of sampling around a central point or (2) linear sampling along a drainage way, boundary, or perimeter of a container storage area.

7.9.4.1 Selecting the Sample Coordinates for a Simple Random Sample

A random sample of soil units within the sample area or stratum will be selected by generating a series of random (X,Y) coordinates (pairs), finding the location in the field associated with these (X,Y) coordinates, and following proper field procedures for collecting soil samples. If the waste site contains multiple horizontal strata, the procedure described here is used to generate random pairs of coordinates for each stratum. The number of soil samples to be collected must be specified for each stratum.

Establish a square or triangular grid pattern inside of a rectangle which covers the entire sampling area, then generate random coordinates (Xi,Yi) which will be the locations of the sample points.

For a systematic sample, the size of the sample area must be determined in order to calculate the distance between the sampling locations in the systematic grid. The area can be measured on a map using a planimeter. The units of the area measurement (such as square feet, hectares, square meters) should be recorded. In areas suspected of being contaminated the grid size is seldom greater than ten feet.

For random sampling, a grid can be set up using professional judgement. For each stratum determine the shortest interval between two points which would provide reasonably independent samples. Generally the distance is shorter in high concentration areas and longer in low concentration areas. Establish a grid with this distance as the grid size (for example, 10 feet between grid lines).

The sample coordinates (Xi,Yi) can be generated using a random number generator. If random numbers are generated which fall outside the range of coordinates within the stratum they are ignored.

7.9.4.2 Field Procedures for Determining the Exact Sampling Location

The grid points specified for the coordinate system provide the starting point for locating the sample points in the field. The location of a

sample point in the field will be approximate because the sampling coordinates were rounded to distances that are easy to measure, the measurement has some inaccuracies, and there is judgment on the part of the field staff in locating the sample point.

A procedure to locate the exact sample collection point is recommended to avoid subjective factors that may affect the results. Without this precaution, subtle factors such as the difficulty in collecting a sample, the presence of vegetation, or the color of the soil may affect where the sample is taken, and thus bias the results.

7.9.4.3 Sampling Across Depth

Methods for deciding how and where to subsample a soil core are important to understand and include in a sampling plan. These methods should be executed consistently throughout the site. The field methods used will depend on many things including the soil sampling device, the quantity of material needed for analysis, the constituents that are present, and the consistency of the solid or soils media that is being sampled. The details of how these considerations influence field procedures are not the subject of this discussion, but they are important. More detail can be obtained in Chapter 6 and the Soil Sampling Quality Assurance User's Guide (EPA 1984).

7.9.4.4 An Example of the Simple Grid Sampling Procedure

The following example illustrates a very simple grid sampling procedure:

1. Establish a grid that slightly overlaps the area to be sampled. The grid should not be limited to the boundaries of the area unless sampling would be obstructed by a building or other barriers. The grid interval may vary from site to site, but it will seldom be greater than 10 feet.

2. The number of sample borings required to adequately screen an area is determined by the sample size calculation (see Section 7.9.3.2). The minimum number of borings is three. The grid interval or number of sample borings may be modified if IDEM agrees that site-specific conditions warrant such changes.

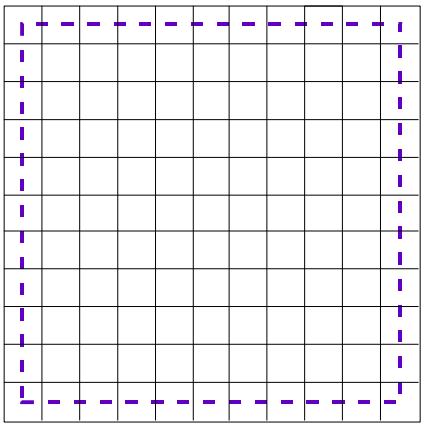
3. Number the grid intersections and use a random number generator to determine which grid points will be sampled (see

Section 7.9.4.1). Random numbers that indicate grid points outside the source area should be regenerated.

~~4.~~ Any proposal that includes this approach should include detailed drawings of the grid depicting sample locations.

EXAMPLE

The storage pad dimensions are 100 feet by 100 feet.
The grid interval is 10 feet.
The grid overlaps the pad by 5 feet on each side.
There are 144 grid intersections.
The number of borings should be equal to the cube root of 144.
(144^{3} = 5.2 or 6)



7.9.4.5 Ranked Set Sampling

Typically the most expensive part of the site evaluation process is laboratory analysis, while identification of potential sample units is a comparatively simple matter. We can therefore achieve great observational economy if we are able to identify a large number of sample units to represent the population of interest, yet only have to quantify a carefully selected subsample.

Ranked Set Sampling (RSS) is a method which can produce a better estimation of the site mean with the same number of observations, or an equal estimation of site mean with fewer observations. This can result in a significant reduction of costs. Since there will be fewer observations than with a simple random sample, correct ranking of potential laboratory samples is very important.

When is RSS Allowed?

The use of ranked set sampling is allowed under the following conditions:

The constituent distribution within a stratum is (1) continuous in nature; (2) not from isolated sources, such as buried drums or transformers; and (3) distributed throughout the stratum.

An acceptable ranking mechanism is available that (1) measures the appropriate constituents or (2) is an acceptable surrogate for the constituents and is accurate enough to correctly rank sets of samples.

Any statistical analysis performed is appropriate for the data distribution.

A Simple Example

As a simple introduction to the concept of RSS, consider the following example.

We wish to estimate the mean height of students at a university from a random sample of three students. Furthermore, to acknowledge the inherent uncertainty, we need to present this estimate as a confidence interval within which we expect the true population mean to lie with desired confidence.

The simplest way to obtain our sample is to randomly select three students from the university's population, then measure their heights. While the arithmetic average of the three heights is an unbiased point estimate of the population mean, the associated confidence interval can be very large, reflecting the high degree of uncertainty with estimating a large population mean with only three measurements. This is because we have no control over which individuals of the population enter the sample. For example, we may happen to grab two very short people and one very tall; or we may grab three very tall people. The only way to overcome such a problem with a simple random sample (SRS) is to increase the sample size.

On the other hand, we may obtain a ranked set sample. To do this, we may randomly invite three students to breakfast and visually rank them with respect to height. We then select the student we believe is shortest and actually measure his or her height. Repeating this process with lunch, we select the middle ranked person, and at dinner select the tallest ranked person. The resulting measurements of student heights constitute a ranked set sample. As with the SRS measurements, the

arithmetic average of the RSS measurements provides an unbiased point estimate of the population mean; however, the associated confidence interval can potentially be much smaller than that obtained with SRS measurements, thus reflecting decreased uncertainty.

This encouraging feature results because measurements obtained through RSS are likely to be more regularly spaced than those obtained through SRS and therefore are more representative of the population. The RSS procedure induces stratification of the whole population at the sample level; in effect, we are randomly sampling from the subpopulations of predominantly short, medium, and tall students without having to construct the subpopulation strata.

How is Ranked Set Sampling Applied at a Waste Site?

As mentioned previously, to create ranked sets we must partition the selected first phase sample into sets of equal size. In order to plan an RSS design, we must therefore choose a set size which is typically small, around 3 or 4, to minimize ranking error. Let's arbitrarily call this set size “m,” where “m” is the number of sample units allocated into each set. Proceed as follows:

1. Randomly select m^2 sample units from the population.

2. Allocate the m^2 selected units as randomly as possible into m sets, each of size m.

3. Without yet knowing specific values for the constituent of interest, rank the units within each set based on indicator values for this constituent. This may be based on field screening or done with measurements of a covariate which is correlated with the variable of interest.

4. Choose samples for definitive analysis by including the smallest ranked unit in the first set, then the second smallest ranked unit in the second set, continuing in this fashion until the largest ranked unit is selected in the last set.

5. Repeat steps 1 through 4 for “r” cycles until the desired sample size is obtained for analysis. The sample size is determined by the calculation in Section 7.9.3.

As an illustration, consider the set size m=3 with r=4 cycles. This situation is illustrated below where each row denotes an ordered set of samples within a cycle (S = sample selected for ranking but not

selected for definitive analysis, and the units selected for definitive analysis are designated by the letter “X”).

In each cycle three sets of three samples each are selected and ranked. In each cycle one sample from each set is selected for analysis; low from the first set, medium from the second set, and high from the third set.. Note that 36 units have been randomly selected in 4 cycles; however, only 12 units are actually analyzed to obtain the ranked set sample of measurements.

Low	**Med.**	**High**	
X	S	S	
S	X	S	⇦ 1st cycle
S	S	X	
X	S	S	
S	X	S	⇦ 2nd cycle
S	S	X	
X	S	S	
S	X	S	⇦ 3rd cycle
S	S	X	
X	S	S	
S	X	S	⇦ 4th cycle
S	S	X	

Continue selecting sample sets until enough cycles have been completed that the sample number is equal to or greater than the required sample number. For instance, if 47 samples were required you would select samples for six cycles (54 samples, 18 for analysis) so that an equal number of low, medium, and high samples is sent for definitive analysis.

Obtaining a sample in this manner results in maintaining the unbiased nature of simple random sampling. By incorporating “outside" information about the sample units, we are able to contribute a structure to the sample that increases its representativeness of the true underlying population.

If we quantified the same number of sample units, mr = 12, by a simple random sample, we have no control over which units enter the sample. Perhaps all the 12 units would come from the lower end of the range, or perhaps most would be clustered at the low end while one or two units would come from the middle or upper range. With simple random sampling, the only way to increase the prospect of covering the full range of possible values is to increase the sample size. With ranked set sampling, however, we increase the representativeness with a fixed number of sample units, thus saving considerably on quantification costs.

With the ranked set sample thus obtained, unbiased estimators of several important population parameters can be calculated, including the mean and, in the case of more than one sampling cycle, the variance.

Ranking Criteria

The real key to success lies in the ranking procedure. A hazardous waste site inspector may be able to reliably rank areas of soil with respect to concentrations of a toxic constituent, based on field screening methods or other low cost tests, for example a PCB field test kit.

On the other hand, if another characteristic is available that is highly correlated with the characteristic of interest but costs much less to obtain, then we may rank by the values of such a "covariate". For example, measurement of total organic halides (TOX) in soil in order to rank soil sampling units with respect to the concentration of volatile organic solvents. As an indicator variable, TOX is much less expensive to measure than specific organic compounds.

7.9.5 Sample Collection and Analysis

This section discusses the dynamic workplan and adaptive sampling process, adaptive sampling and analysis strategy, field measurements for constituents, representativeness, and measurement accuracy.

7.9.5.1 The Dynamic Workplan and Adaptive Sampling Process

In the traditional approach, major decisions concerning the direction of the site investigation or cleanup are generally made by the project manager after the field work has been completed. Typically, several field mobilizations occur, reports are written, and many meetings are held between the site owner, its environmental consulting company,

and regulatory agencies. In contrast, in an adaptive sampling and analysis program many of these same decisions are made in the field.

In constructing the dynamic workplan, it is important to determine prior to mobilization what decisions will be made, how these decisions will be made, and who will make them in the field. *To assure efficient, effective decision-making IDEM must be included in the development of the dynamic workplan. IDEM must approve all decisions related to sampling and closure.*

Activity 1: Select the core technical team whose responsibility it will be to prepare the dynamic workplan.

The technical team should possess expertise in analytical chemistry, geology, geochemistry, geophysics, hydrogeology, and risk analysis. The team helps with data management, QA/QC, risk assessment, fate and transport modeling, remedial action, community relations, and health and safety. This team will be composed of a mixture of site owner employees and IDEM staff. The technical team will be responsible for the following:

1. Gathering all available information for the site

2. Developing an initial "conceptual" model for the site

3. Identifying the technical objectives and goals to be accomplished

4. Supervising the field effort, making adjustments to the CSM based on the data produced in the field

5. Evaluating the conceptual model and decisions made with respect to federal, state, and local regulations

This core technical team will be responsible for making decisions in the field. One member of the team must have final decision making authority and responsibility. This helps keep the site investigation process moving forward at a reasonable pace. At least one member of the technical team should be on site at all times. This technical team member and an IDEM staff member must be on site when sampling activities take place. These people must have a working knowledge of all aspects of the investigation and cleanup DQOs, and must routinely communicate with other technical team members.

Field personnel (and off-site technical team members) should be in regular communication with appropriate staff from IDEM to ensure that decisions made in the field, typically under the pressures of time and field-resource utilization, are in conformance with the dynamic workplan framework and any other requirements placed on the site investigation.

Activities 2 through 6 are often considered to be part of the Quality Assurance Project Plan (QAPP).

Activity 2: Develop the Initial Conceptual Model and Decision Making Framework.

The CSM. The initial conceptual model contains the best information available at the start of the project. It depicts the three-dimensional site profile based on vadose zone and ground water flow systems that can exert influence on constituent movement. Key site features such as roads, buildings, hydrography, depth to bedrock, direction of ground water flow, and potential preferential pathways for constituent transport are mapped. Map cross sections should include water levels, high and low permeability zones, and aquifers. Chapter 2 and the RISC software provide a framework for developing the CSM.

The CSM is updated as additional data becomes available during the site investigation and cleanup process. It is the basis for the dynamic workplan. The CSM changes to reflect the increased site knowledge gained from field activities.

Stakeholders should (1) agree at the beginning on the most likely kinds of actions to be taken as a result of the field data, (2) implement the appropriate action on a daily basis as the data is generated, and (3) take new directions when the data suggests deviations from the conceptual model.

Site delineation is an iterative process and should be viewed as an ongoing experimental project.

The Decision Making Framework. The initial conceptual model is based on the DQO for the site. The DQO process involves a series of planning steps designed to ensure that the type, quantity, and quality of environmental data used in decision making are appropriate for the intended application. It relates data needs to specific decisions to be made.

See Appendix 6 and Chapter 6 for more information on developing DQOs.

Activity 3: Develop Standard Operating Procedures

The next step in developing a dynamic workplan is to establish standard operating procedures (SOP). SOPs for sample collection and analysis should be produced along with other SOPs required to answer site-specific questions, such as geophysical and hydrogeological surveys. The SOPs should be developed by the site owner's core technical team and approved by IDEM prior to initiating field activities.

Field methods should be performance based and provide data of sufficient quality to meet the DQOs. Because these technologies and methods may not be amenable to typical CLP or SW846 methods, QC procedures or data reporting formats, supporting data produced from the proposed field techniques should be provided to document data quality. *Note: While not always required for field data, CLP and SW-846 methods (as appropriate) are always required for laboratory samples.*

Activity 4: Develop the Data Management Plan

Critical to the success of the dynamic process is the ability to manage and easily use all of the data produced in the field. Data integration (chemical, physical, geological, hydrological), sampling, and analysis protocols should be incorporated into an overall data management plan. Protocols for sample logging, analysis, data reduction, and site mapping should be established. Several different organizations may be involved in this process. The data management plan should be established with rules and responsibilities defined prior to mobilization for the collection, assimilation, and presentation of the field generated data. As an example, computers housed in the laboratories can be electronically linked to the data management trailer on site.

Sample logging information and the results of the analyses can be managed through a Laboratory Information Management System or through the use of spread sheets. The data can then be downloaded to a computer containing site visualization software for conceptual model update and review. This easy access to analytical and site information simplifies the on-site decision making process.

Activity 5: Develop the Quality Assurance Project Plan

This document contains the sampling methods, analytical procedures, and appropriate quality assurance (QA) and quality control (QC) procedures. It describes the procedures to be used to monitor conformance with, or justification for departure from the SOPs. The overall goal is to ensure that data of known and adequate quality have been produced to support the decision making process.

Activity 6: Prepare the Health and Safety Plan

Finally, a health and safety plan is produced as part of the Dynamic Workplan/Adaptive Sampling and Analysis project. Procedures must be established for safe use of the field analytical tools and for the methods used to monitor worker and community safety.

7.9.5.2 Adaptive Sampling and Analysis Strategy

The number of sampling rounds made during a field mobilization is dependent on the DQO specifications for confirming the presence or absence of constituents. Once the soil contamination profile objectives have been met and a verified conceptual model is produced, the data should be capable of identifying which of the two categories a particular source area falls within:

- The site is clean or poses negligible risk, and no further action is required.
- The site is contaminated at concentrations that exceed action levels for negligible risk; remedial action or other measures are required.

For those constituents found in the first round of sampling, target compound analysis is performed in each subsequent sampling round. As the analyte list decreases, more samples for each specific constituent may be analyzed during the workday.

If site samples contain no detectable constituents above the closure levels established for the site, closure sampling may be done. Closure sampling is always done by random sample design with off-site laboratory analysis.

If site screening measurements result in COC concentrations greater than the closure levels, sampling continues and the conceptual model is refined until the site-specific DQOs are met. Once the site data and conceptual model are verified, risk-based decision making occurs with respect to human health and the environment. At this point, new workplans must be produced to address site remediation needs.

Sampling may be directed by geostatistical sampling tools which are able to predict where the next round of samples should be collected. Because quantitative measurements are made on-site, greater confidence should be obtained in the sampling. If screening quality data, such as enzyme kits are used for initial sampling, quantitative analytical data should be produced to verify the results from the site screening phase.

The number of locations within and surrounding each contaminated and non contaminated area as well as the depth of samples at each location should be determined by the core technical team. In an adaptive sampling and analysis program, contaminated areas are more heavily sampled than in traditional site characterization studies. Therefore, if semiquantitative or quantitative field analytics is performed, only 10 to 25 percent of the samples will need laboratory verification. The percentage depends on the specifications of the method used. These samples should be selected in a random manner.

Field results will differ from off-site laboratory results for volatile organic compound (VOC) contaminated soil samples, with field measurements generally producing higher measurement concentrations because of analyte loss during off-site sample transport and storage. Care must be taken when these types of comparisons are made. Because site investigation and cleanup decisions are made based on field data, off-site laboratory analysis should be restricted to about 10 percent of the samples analyzed when a quantitative field laboratory.

As additional data is obtained it will help refine the conceptual model and dictate future directions. Site work stops when answers to the questions posed in the workplan meet site-specific confidence levels established as part of the DQO process. To ensure that site-specific goals have been met, the project team should statistically evaluate the results of its findings . An adaptive sampling and analysis program focuses staff, equipment, and financial resources in areas where contamination exists, while providing a more limited evaluation in areas that pose little risk to human health and the environment.

7.9.5.3 Field Measurement for Chemicals of Concerns

The selection of field analytical methods is based on the need to make quick decisions in the field. Field analytical techniques should be capable of providing data in a matter of minutes. They should have documented measurement sensitivity, precision, and accuracy so that instruments can be matched with site investigation and cleanup DQOs.

The simpler the technique, the more likely it will be used in the field. Field instruments must be transportable, operate under adverse conditions, and provide improved cost/benefit over laboratory analysis. For projects of short duration and low sample volume, staff and equipment mobilization expenses may make field analytics a cost-prohibitive option. In addition, if quantitative measurements are required for all samples, field analytics may not provide a cost-effective means for obtaining site data.

The selected field method must demonstrate method detection limits at approximately half the cleanup level established for the site. Using field methods of this accuracy site decisions can be made, including:

- The Nature and Extent of Contamination – Field data supports the overall site investigation
- Risk to human health and the environment – Field data provides input into the risk assessment process
- Achievement of cleanup objectives – Field data supports site compliance with acceptable constituent levels

To insure that the field analytical instrumentation and methods selected in the workplan are amenable to a given site, site-specific method detection limit studies should be performed for each class of COCs (for example, VOCs, semivolatile organic compounds, and metals) using soil obtained from the site prior to the field investigation. This will help to determine whether matrix interferents or target compounds mask (for example, portable gas chromatograph [GC]) or cross-react (for example, enzyme/wet chemical kits) with targeted organics or metals (for example, by electrochemical detection).

7.9.5.4 Representativeness

Representativeness is the degree to which data accurately and precisely represents the frequency distribution of a specific variable. Measurement accuracy can be influenced by measurement sensitivity, selectivity, and precision whereas representativeness is affected by sampling location and sampling methods. The influence of sampling on analytical quality is extremely significant.

Sample values have little meaning unless they are representative of concentrations across the site. The following factors may affect sample representativeness:

- Geological Variability — Regional and local variability in the mineralogy of rocks and soils, the buffering capacity of soils, lithogic permeability, and variability in the sorptive capacity of the vadose zone

- COC Concentration Variability — Variations in the COC concentrations throughout the site

- Collection and Preparation Variability — Deviations in analytical results attributable to bias introduced during sample collection, preparation, and transportation

- Analytical Variability — Deviations in analytical results attributable to the manner in which the sample was stored, prepared, and analyzed by the on-site or off-site laboratory. Although analytical variability cannot be corrected through representative sampling, it can falsely lead to the conclusion that error is due to sample collection and handling procedures.

The variability in soil COC concentrations often makes it too costly to use traditional site investigative approaches because it may be difficult to collect the number of samples needed to have confidence that the extent, direction, concentration, and rate of COC movement have been correctly delineated. The adaptive sampling and analysis strategy helps to focus the intensive sampling efforts on areas where contamination has been identified, producing more data in the areas where it is needed.

7.9.5.5 Measurement Accuracy

Assuming representative samples have been collected, measurement accuracy is directly dependent on the relationship among three key analytical parameters: *precision, selectivity, and sensitivity*. Accurate results cannot be obtained unless the measurement technique produces selective detection and adequate sensitivity. Selectivity refers to the instrument's or method's ability to respond to target compounds in the presence of nontarget sample constituents.

For example, if the analytical technique responds to the presence of matrix interferents or cross-reactive target compounds, measurement identity is affected and thus, accuracy. Moreover, if the analyte concentrations in the sample are at or just below the method detection limit, the measured concentrations may show poor precision due to lack of sensitivity.

Measurement precision is the degree to which a set of analyses of the same parameter are repeatable. To achieve unambiguous analyte identification and the desired method detection limit, extensive sample preparation procedures may be required to remove matrix constituents, dilute, or pre-concentrate the sample extract. These additional steps lengthen the overall time of the analysis, reducing the sample throughput rate.

Generally, as one property of the equilateral triangle is improved, one or both of the remaining analytical properties can become distorted. For example, increasing the number of sample preparation steps prior to the analytical measurement can result in loss of analyte, which, in turn, can influence measurement sensitivity and thus, accuracy (false negative). Another example is the detection of nitrated explosives by selective reagents such as enzymes. Field-practical enzyme immunoassay kits can significantly reduce the time of analysis over laboratory high performance liquid chromatography (HPLC) methods by eliminating the need for sample cleanup procedures. False positive detection is possible, however, due to cross-reactivity with other nitrated organic compounds that might be present in the sample.

Although advancements in analytical methods have increased laboratory productivity, sample throughput rates and data quality are greatly influenced by interactions among selectivity, sensitivity, and precision. As increasingly more stringent measurement accuracy is specified, sample throughput rates decrease.

7.9.6 Quality Assessment

When the SRS or RSS has been collected, the samples are sent to the laboratory for analysis. Be sure that all QA/QC procedures appropriate to the desired sample quality are followed. The report from the laboratory should contain all information needed to perform data validation procedures.

Risk assessment and site management work relies heavily on statistics. There are five basic activities performed by the statistician during the data quality assessment process.

1. Review data quality objectives to ensure that appropriate environmental decision criteria are used, to define the statistical hypothesis, to specify tolerable limits for decision errors, and to define acceptable confidence limits or probability interval width.

2. Perform a preliminary data review which includes: a review of QA reports to ensure that data quality is appropriate, calculation of basic statistics (mean, standard deviation, range, and others), and generation of data graphs. This information is used to learn about the structure of the data and identify patterns, relationships, or potential anomalies.

3. Select the most appropriate procedure for summarizing and analyzing the data based on information gathered in activities 1 and 2. This includes identifying the underlying assumptions that must hold for the statistical procedures to be valid.

4. Verify the assumptions of the statistical tests. This includes an evaluation of whether the underlying assumptions hold, or whether departures are acceptable given the actual data and other available information.

5. Perform the calculations required for the statistical tests and draw conclusions from the data. Document the inferences drawn as a result of the calculations. If the design is to be used again, evaluate of the performance of the sampling design.

Data collection and laboratory analysis provide estimates of the environmental concentration of constituents. Statistics give assurance that the estimates are accurate within established limits.

7.9.7 Additional Information

This section provides additional references on dynamic workplans, soil sampling, and ranked set sampling.

Dynamic Workplan References

Robbat, A. 1998. “Dynamic Workplans and Field Analytics: The Keys to Cost-Effective Site Characterization and Cleanup” Written for EPA

EPA. 1991. “Removal Program Representative Sampling Guidance” OSWER Directive 9360.4-10

General Soil Sampling References

Barth, D. S., Mason, B. J., Starks, T. H., and K. W. Brown. 1989. Soil Sampling Quality Assurance User's Guide, Second Edition, EPA Cooperative Agreement No. CR 814701, Environmental Monitoring Systems Laboratory, Las Vegas, Nevada.

Bross, I. D. 1985. "Why Proof of Safety is Much More Difficult Than Proof of Hazard." Biometrics. Vol. 41: 785-793.

EPA. 1983. Preparation of Soil Sampling Protocol: Techniques and Strategies, Washington D.C., August 1983 (EPA 600/4-83-020).

EPA. 1984. Soil Sampling Quality Assurance User's Guide, First Edition, Washington, D.C., May 1984 (EPA 600/4-84-043).

EPA. 1985. Verification of PCB Spill Cleanup by Sampling and Analysis, Washington D.C., August 1985 (EPA 560/5-85-026).

EPA. 1986d. Superfund Public Health Evaluation Manual, Washington D.C.: EPA [October 1986].

EPA. 1987a. Data Quality Objectives For Remedial Response Activities: Development Process, Washington D.C., March 1987 (EPA 540/G-87/003).

EPA. 1987b. Data Quality Objectives For Remedial Response Activities: Example Senario RI/FS Activities at a Site with Contaminated Soils and Ground Water, Washington D.C., March 1987 (EPA 540/G-87/004).

EPA Center For Environmental Statistics, “Soils and Solid Media”

Finney, D. J. 1948. "Random and Systematic Sampling in Timber Surveys." Forestry. Vol. 22: 64-99.

Ford, P., and P. Turina. 1985. Characterization of Hazardous Waste Sites--A Methods Manual, Volume I--Site Investigations. Las Vegas, Nevada: EPA Environmental Monitoring Systems Laboratory, [April 1985].

Gilbert, R. O. 1982. Tran-Stat: Statistics for Environmental Studies, No. 19, Some Statistical Aspects of Finding Hot Spots and Buried Radioactivity. Richland, Wash.: Pacific Northwest Laboratory.

Gilbert, R. O. 1983. Tran-Stat: Statistics for Environmental Studies, No. 24, Field Sampling Designs, Simple Random and Stratified Random Sampling. Richland, Wash.: Battelle Pacific Northwest Labs.

Gilbert, R. O. 984. Tran-Stat: Statistics for Environmental Studies, No. 26, Field Sampling Designs: Systematic Sampling. Richland, Wa.: Battelle Memorial Institute, Pacific Northwest Laboratory.

Gilbert, R. O. 1987. Statistical Methods for Environmental Pollution Monitoring. New York: Van Nostrand Reinhold.

Gilbert, R. O., and P. G. Doctor. 1985. "Determining the Number and Size of Soil Aliquots for Assessing Particulate Contaminant Concentrations." Journal of Environmental Quality. Vol. 14: 286-292.

Gilbert, R. O., and R. R. Kinnison. 1981. "Statistical Methods for Estimating the Mean and Variance from Radionuclide Data Sets Containing Negative, Unreported or Less-Than Values." Health Physics. Vol. 40: 377-390.

Gilbert, R. O., Miller, M. L, and H. R. Meyer. 1989. "On the Design of a Sampling Plan to Verify Compliance with EPA Standards for Radium-226 in Soil at Uranium Mill Tailings Remedial-Action Sites." ASA/EPA Conference Proceedings on Interpretation of Environmental Data. IV Compliance Sampling, October 5-6, 1987 (EPA-230-03-047).

Palley, M. N., and L. G. Horwitz. 1961. "Properties of Some Random and Systematic Point Sampling Estimators." Forest Science. Vol. 77: 52-65.

Parkhurst, D. F. 1984. "Optimal Sampling Geometry for Hazardous Waste Sites." Environmental Science and Technology. Vol. 18, No. 7: 521-523.

Peshkova, N. V. 1970. "Comparison of Results of Determinations of the Density of Plant Populations by Systematic and by Restricted Random Sampling Procedures." Ecology (Ekologiya). Vol. 2: 180-181.

Singer, D. A. 1972. "Elipgrid. A Fortran IV Program for Calculating the Probability of Success in Locating Elliptical Targets With Square, Rectangular, and Hexagonal Grids." Geological Programs. Vol. 4: 1-16.

Singer, D. A. 1975. Relative Efficiencies of Square and Triangular Grids in the Search for Elliptically Shaped Resource Targets. Jour Research U. S. Geological Survey. Vol. 3, No. 2: 163-167.

Wolter, K. M. 1984. "Investigation of Some Estimators of Variance for Systematic Sampling." Journal of the American Statistical Association. Vol. 79, No. 388: 781-790.

Zirschky, J., and R. O. Gilbert. 1984. "Detecting Hot Spots at Hazardous Waste Sites." Chemical Engineering. Vol. 91: 97-100.

Ranked Set Sampling References

U.S. EPA Observational Economy Series, Ranked Set Sampling, M.T. Boswell, S.D. Gore, G.D. Johnson, G.P. Patil, C. Taillie, Penn State University Center for Statistical Ecology and Environmental Statistics; John Fritzvold, Herbert Lacayo, Robert O'Brien, Brenda Odom, Barry Nussbaum, John Warren, U.S. EPA Project Officers.

Kaur, A., Patil, G. P., and Taillie, C. (1994). Unequal allocation model for ranked set sampling with skew distributions. Technical Report 94-0930, Center for Statistical Ecology and Environmental Statistics, Department of Statistics, Pennsylvania State University, University Park, PA.

Kaur, A., Patil, G. P., Sinha, A. K. and Taillie, C. (1995). Ranked set sampling: An annotated bibliography. Environmental and Ecological Statistics, 2(1) (to appear).

Patil, G. P., Sinha, A. K., and Taillie, C. (1994). Ranked set sampling. In Handbook of Statistics, Volume 12: Environmental Statistics, G. P. Patil and C. R. Rao, eds. North Holland/Elsevier Science Publishers.

Stokes, S. L. (1980a). Estimation of variance using judgment ordered ranked set samples. Biometrics, 36, 35-42.

Glossary

Absorption	The process by which toxicants cross body membranes and enter the bloodstream
Acid extractables	A group of organic analytes that are removed from acidified water with methylene chloride in EPA analytical method SW-846, 8270
Activity restriction	A formal restriction that limits specific activities that could result in exposure to chemicals of concern at levels unsafe for human health or the environment. This restriction is implemented through an institutional control.
Acute hazards (or exposures)	Environmental exposures that pose an imminent threat to human health or the environment over the short term (less than 2-week exposure)
Alternative hypothesis	A statement declaring an alternative to the null hypothesis, often symbolized by H_1
Attenuation	A reduction in constituent concentration or mass in ground water due to the combined effects of naturally occurring chemical and physical processes, including dispersion, sorption, and biodegradation
Blank	A sample analyzed to determine if all or a portion of an analyte detected in an environmental sample is the result of external contamination due to handling or other factors in the field or the laboratory; in such cases, the detected concentration of the analyte may not actually represent site conditions. *See Equipment Blank, Field Blank, Method Blank, and Trip Blank.*
Base-neutral extractables	A group of semivolatile organic compounds extractable from basic or neutral water solutions with organic solvents in EPA analytical method SW-846, 8270
Calibration	Routine quality control procedures performed daily or more frequently to maintain the accuracy of analytical instruments or measuring equipment

Calibration standard	A standard prepared by successive dilution of a standard working solution; calibration standards should cover the full concentration range associated with the analytical method
Chemicals of concern (COCs)	1. Chemicals that are the focus of screening, investigation, or closure 2. For petroleum sites, potentially harmful chemicals within a mixture that are present in sufficient quantity to serve as indicator compounds for that particular mixture
Closure	1. IDEM's written recognition that a party has demonstrated attainment of specific remedial or screening objectives (closure levels) for chemicals of concern at a particular area. The written instrument for this decision varies by remedial program (see RISC User's Guide). 2. Under the Resource Conservation and Recovery Act (RCRA), refers to a series of formal procedures required to end the operation of a permitted treatment, storage, or disposal (TSD) unit.
Closure level	A land use-specific chemical concentration in soil or ground water that is suitable for use both as a screening level and a remedial objective
Commercial/industrial land use	A property designation that includes all adjacent blocks and lots controlled by the same owner or operator that are used in conjunction with a business (and not used for human habitation), or vacant land not intended for future human habitation; defined by SIC codes (see Appendix 4)
Composite sample	A sample that consists of portions of several samples from a given area; the portions are thoroughly homogenized to represent the area sampled. Composite samples are not appropriate for volatile substances.
Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA)	Legislation that established the federal Superfund for response to uncontrolled releases of hazardous substances to the environment

Conceptual Site Model (CSM)	A comprehensive depiction of a site developed during pre-sampling using readily available information; the model is updated as additional site information is obtained. The model is used to identify all potential or suspected sources of contamination, types and concentrations of chemicals fo concern detected at the site, potentially contaminated media, potential exposure pathways, and receptors.
Confidence interval	A range, calculated from sample data, within which the mean of repeated sampling events would likely fall a given percentage of the time (for example, the 95 percent confidence interval)
Constituent	A chemical of concern that has been detected at a concentration lower than its land use-specific closure level, and therefore, poses negligible threat to human health and the environment
Construction worker exposure	Worker exposure that could potentially result from trenching or excavation activities at a site
Contaminant	1. A chemical of concern that has been detected at a concentration that exceeds its associated land use-specific closure level, posing an actual or potential threat to human health and the environment 2. Contaminant as defined by IC 13-11-2-42
Contract Laboratory Program (CLP)	EPA program that establishes laboratory specifications, analytical methods, and quality assurance/quality control protocols required for Superfund and related activities
Contract Required Detection Limit (CRDL)	Method detection limit required for a given analyte in a given matrix in the Contract Laboratory Program Statement of Work; generally refers to inorganic analytes
Contract Required Quantitation Limit (CRQL)	Similar to Contract Required Detection Limit (CRDL) but generally refers to organic compounds
Control Sample	A sample introduced into a data collection process to monitor the performance of the system

Critical effect	The first adverse effect, or its known precursor, that occurs to the most sensitive species as the dose increases during toxicity testing of a chemical.
Critical effects category	A group of organs or tissues with a common function or means of absorption, grouped together for the purpose of determining additivity of compounds by critical effect
Data collection design	The configuration of the environmental sampling effort to satisfy the Data Quality Objectives (DQO); it includes the types of samples to be collected; the conditions under which they should be collected; variables to be measured; and the quality assurance and quality control components that ensure acceptable sampling design and measurement error to meet the decision error rates specified in the DQOs. The data collection design is the principal part of the Quality Assurance Project Plan.
Data Quality Assessment (DQA)	The scientific and statistical evaluation of data obtained from environmental operations to determine if they are of the right type, quality, and quantity to support their intended use. The five steps of the process include (1) reviewing DQOs and the sampling design, (2) conducting a preliminary data review, (3) selecting the statistical test, (4) verifying the assumptions of the statistical test, and (5) drawing conclusions from the data.
Data Quality Assessment (DQA) Process	The evaluation of the data set (1) to assess the validity and performance of the data collection design and statistical test and (2) to establish whether a data set is adequate for its intended use
Data Quality Objectives (DQO)	Qualitative and quantitative statements that clarify a study's technical and quality objectives, define the appropriate type of data, and specify the tolerable levels of potential decision errors that will be used as the basis for establishing the quality and quantity of data needed to support decisions.
Decision error limits	The degree of Type I and Type II Error that is tolerable to the decision maker. Decision error goals in RISC are at least 5 percent for Type I Error and 25 percent for Type II Error.

Default	In RISC, the term refers to the use of any standard constant, equation, model, process, strategy, or evaluation that is prescribed for general application within the RISC Technical Guide
Default assessment	An evaluation under RISC using all of the standard constants, equations, models, processes, strategies, or evaluations that are prescribed for general application within the RISC Technical Guide
Default closure level	A land use-specific constituent concentration calculated to be protective of human health at any site. This concentration can be used as both a screening level and a closure level (see the default Closure Table in Appendix 1).
Default exposure assumptions	Standardized human health exposure criteria that assume human contact with contaminated environmental media based on anticipated activities associated with a particular land use. These assumptions are used to calculate default closure levels.
Definitive samples	Samples of environmental media, analyzed by a laboratory, that meet the Data Quality Objectives of the project
Dermal exposure	Skin contact with any contaminated medium
Dilution attenuation factor (DAF)	The ratio of constituent concentration in soil leachate to the concentration in ground water at the downgradient edge of the contaminated area (default value equals 20). This factor accounts for the reduction in constituent concentration that results from adsorption, chemical transformation, biological degradation, and dilution due to mixing of the leachate with ambient ground water.
Dilution factor	The ratio of constituent concentration in soil leachate to the concentration in ground water at a fixed point downgradient of the source (site specific, nondefault). This factor accounts for the reduction in constituent concentration that results from dilution due to mixing of the leachate with ambient ground water.

Direct contact	A grouping of soil exposure pathways that assumes human exposure to soil chemicals of concern through simultaneous skin contact, ingestion, and dust and volatile inhalation
Duplicate	A split sample or an independent second sample collected from, and representative of, the same sample location for the purpose of documenting precision. *See field duplicate, matrix duplicate, and matrix spike duplicate*.
Ecologically susceptible area	Areas of special habitats where it is appropriate to consider the effects of chemicals of concern on nonhuman receptors
Engineering controls	Physical barriers designed and maintained to prevent humans or other receptors from being exposed to contaminated environmental media
Environment	The complex of physical, chemical, and biologic factors which includes land; fish; wildlife; biota; air; water; ground water; drinking water supplies; and other similar natural resources as provided by IC 13-11-2-137 which act upon an organism or ecological community.
Environmental media	Material found in the outdoor, natural, physical environment (such as surface soil, subsurface soil, ground water, air, or surface water) through which constituents can move and contact organisms
Environmental Notice	A legal instrument recorded on the deed of the affected property and which serves to inform future property owners of certain restrictions or obligations regarding (1) land use designation, (2) activity restrictions, or (3) engineering controls. The property owner must record the environmental notice on the deed with the local county recorder's office.
Equipment blank	A sample of analyte-free reagent water used to rinse sampling equipment; the blank is collected after decontamination is complete at a decontamination sampling location and prior to sampling at the next sample location. The blank is analyzed to document that cross-contamination has not occurred between sampling locations. Also called an equipment rinsate.

Estimated Quantitation Limit (EQL)	The lowest concentration that can be reliably achieved within specified limits of precision and accuracy during routine laboratory operating conditions. Use of the word "estimated" emphasizes sample matrix dependence. Estimated Quantitation Limits have replaced Practical Quantitation Limits in SW-846 methods.
Exposure	An organism's contact with a chemical, physical, or biological agent (contaminant). Exposure is quantified as the concentration of the contaminant in the contact medium integrated over the time duration of that contact.
Exposure assessment	In RISC, the determination or estimation (qualitative or quantitative) of the magnitude, frequency, duration, and route of exposure to a chemical of concern in the environment
Exposure pathway	The course a contaminant takes from the source area to the point of contact with an exposed organism
Exposure route	The way a toxicant comes into contact with an organism, typically by means of dermal contact, ingestion, or inhalation; also known as the absorption route
Extent of contamination	The vertical and horizontal distribution of chemical of concern concentrations that exceed residential closure levels.
False negative decision error	A false negative decision error occurs when the null hypothesis is not rejected when it is false (Type II Error).
False positive decision error	A false positive decision error occurs when the null hypothesis is rejected when it is true (Type I Error).
Field blank	Analyte-free reagent water taken to the sampling site, transferred into a sample container on site, and then analyzed by the laboratory for the same parameters as the investigative samples. This sample is used to check for procedural contamination of samples.
Field duplicate	A split sample or an independent sample is collected from the same location or source, as closely as possible to the same point in space and time. This duplicate sample is stored in a separate container and analyzed separately to document the precision of

	the sampling process.
Free product	1. Any material that has been released from a container or process and presents a potential acute threat to human health or the environment 2. A material in excess of its solubility limit 3. In LUST and RCRA, it has the meaning in 329 IAC 9-1-23, a "regulated substance that is present as a nonaqueous phase liquid, for example, liquid not dissolved in water."
Gasoline	A volatile mixture of flammable liquid hydrocarbons derived chiefly from crude petroleum and used principally as a fuel and as a solvent, illuminant, and thinner. Chemicals of concern in gasoline include methyl tertiary butyl ether (MTBE), benzene, toluene, ethylbenzene, and xylenes (BTEX).
Geologically susceptible area	A geographical area is characterized by conditions that allow chemicals of concern to migrate away from the source area in such a manner that invalidates the assumptions of the soil-to-ground water partitioning model. Examples of geologically susceptible areas include karst terrain, mined areas, and other fractured rock geology where conduit ground water flow exceeds matrix ground water flow.
Ground water	Water located below the ground surface in interconnected voids and pore spaces in the zone of saturation
Hazard index (HI)	The sum of individual hazard quotients for multiple substances
Hazard quotient (HQ)	The ratio of a single substance exposure level over a specified period of time relative to a level that is considered protective, or the ratio of the exposure level to the default closure level
Holding time	Elapsed time, expressed in days from the date of sampling to the date of analysis, that a properly preserved sample may be stored before analysis
Hypothesis	A statement postulated as true for the purposes of investigation
Indoor Volatilization Constant (water to air)	A default constant that defines the relationship between the concentration of a chemical constituent in water and the average concentration of the volatilized constituent in air

Institutional controls	Administratively or legally enforceable measures that limit human exposure to chemicals of concern that exceed residential closure levels; institutional controls do not involve engineered solutions.
Interference	An element, compound, or other matrix effect present in a sample that interferes with the detection of a target analyte; such interferences may lead to inaccurate analytical results for target analyte concentrations.
Internal standards	Known compounds of known concentrations added to a sample by the laboratory prior to analysis to assist in qualifying and quantifying target analytes
Judgmental sampling	A method of selecting sample locations based on the professional judgment of the sampler. The history of the site, current site conditions, and terrain should guide these decisions.
Known to be contaminated	An area screening term used to describe areas where chemicals of concern are known to have been released. The initial classification is based on previous sampling data or records that document contamination, visibly stained soils, or other investigative data that indicate constituents are present.
Laboratory control sample	A known matrix spiked with compounds representative of the target analytes and used to document sample laboratory performance
Limits on decision errors	The tolerable decision error probabilities established by the decision maker. Potential economic, health, ecological, political, and social consequences of decision errors should be considered when setting such limits.
Matrix	The substance containing the analyte of interest. Examples include soil, sediment, sludge, ground water, surface water, drinking water, and air. Sometimes matrix types are simplified to consider only three main types: soil, water, and air.
Matrix duplicate	A duplicate field sample used to document the precision of sampling and the homogeneity of a given matrix; also known as a field duplicate

Matrix spike	An aliquot of sample spiked with a known concentration of target analytes to document method bias in a particular matrix. The spiking occurs prior to sample preparation and analysis.
Matrix spike duplicate	A split sample, both portions of which are spiked with identical concentrations of target analytes to determine method bias and precision in a particular sample matrix
Maximum Contaminant Levels (MCL)	Maximum concentration of a chemical allowed in drinking water systems by the National Primary Drinking Water regulations [40 CFR 141.11 (inorganic chemicals) and 141.12 (organic chemicals)]
May be contaminated	An area screening term used to describe any land parcels that cannot be classified as *unlikely* or *known to be contaminated*; this classification is based on site information that is incomplete, ambiguous, or inconclusive
Mean	The most common measure of central tendency, the sample mean is the arithmetic average of the sample data. As the sample number increases, the sample mean approximates the population mean.
Measurement error	The difference between the true value and the value reported for any sample measurement
Media	See environmental media
Method blank	A blank prepared to represent the sample matrix as closely as possible. A method blank is subjected to all the same analytical procedures as calibration standards, field samples, and quality control (QC) samples.
Method detection limit	The minimum concentration of an analyte that can be measured and reported with 99 percent confidence; the limit is determined by analyzing a sample with known concentrations at various dilutions; this limit is matrix specific (for example, the limit would differ for soil and water).
Migration to ground water	The soil exposure pathway that considers leaching of chemical constituents from soil into ground water

Nature of contamination	Site-related chemicals of concern detected during site characterization and their respective concentrations.
No further degradation	The concept that ground water contamination should not be allowed to increase with respect to spatial extent or chemical of concern concentration
Nondefault	Any constant, equation, model, process, strategy, or evaluation that is not prescribed for general application in the RISC Technical Guide
Nonvolatile organic compound	A group of organic compounds identified as base-neutral or acid extractable in EPA Method 8270 from SW-846.
Null hypothesis	In statistical hypothesis testing, the null hypothesis (H_o), is the theory to be tested. In environmental evaluations the null hypothesis is generally that the site is contaminated.
Percentile	The specific value of a distribution such that *p* percent of the distribution is equal to or below that value. For example, if p=95 for a specific value, it means that 95 percent of the values in the population (or statistical sample) are less than or equal to that value.
Petroleum	As per IC 13-11-2-160, petroleum is used for the following purposes: (1) IC 13-23, (2) IC 13-24-1, (3) IC 13-25-5. Those uses include petroleum and crude oil, or any part of petroleum or crude oil, that is liquid at standard temperature (60EF) and pressure (14.7 pounds per square inch absolute).
Plume stability	A closure objective or criteria for ground water in which the zone of constituent impact in the ground water (1) is not increasing in size or concentration and (2) is not migrating. Plume stability is demonstrated using a default or nondefault stability monitoring method.

Perimeter of Compliance (POC)	When there is human or ecological exposure within the contaminant plume area, the perimeter of compliance (POC) is established as the location where exposure occurs. When there is neither human nor ecological exposure within the contaminant plume area, the POC is defined as the perimeter that is representative of the point at which ground water chemical of concern concentrations are equal to or less than land use-specific default closure levels.
Population	The total collection of objects, media, or organisms to be studied and sampled
Potential exposure concentration	The quantitative measurement of chemical constituents in environmental media for the purpose of exposure assessment (in area screening, characterization of the nature and extent of contamination, and closure)
Power	The ability of a statistical test to reject the null hypothesis when it is false. Power ranges from 0.0 to 1.0. The higher the number, the greater the power of the test.
Precision	The agreement among a set of replicate measurements without considering the "true" or accurate value; indicates the variability between measurements of the same material for the same analyte, generally expressed in terms of the standard deviation
Priority pollutants	Specific list of inorganic and organic analytes commonly included in the National Pollution Discharge and Elimination System (NPDES) program
Property control	Control over land use or activities on a parcel of land, either through ownership or agreements with the owners, for the purpose of reducing or controlling exposure to chemicals of concern
Quality assurance (QA)	An integrated system of management activities involving planning, quality control, quality assessment, reporting, and quality improvement to ensure that a product or service (for example, environmental data) meets defined standards of quality with a stated level of confidence

Quality Assurance Project Plan (QAPP)	A formal technical document describing the detailed quality assurance/quality control and other technical procedures to ensure that the quality of environmental data will satisfy the stated performance criteria for the data collection activity
Quality control (QC)	A systematic approach that measures the attributes and performance of a process, item, or service against defined standards to verify that they are met
Quality Management Plan (QMP)	A formal document describing the management policies, objectives, principles, organizational authority, responsibilities, accountability, and implementation protocols of an agency, organization, or laboratory for ensuring quality in its products and utility to its users
Random sampling	Selecting sampling locations in such a way that every member of the population has an equal chance of being sampled
Range	The numerical difference between the minimum and maximum of a set of values
Release	This term has program-specific definitions by Indiana statute IC 13-11-2-184
Remedial plan	A document prepared to address soil or ground water contamination that exceeds closure levels or a ground water plume that may be expanding (as indicated by monitoring data). This plan may cover remedial actions or other alternatives that are available under RISC.
Representative sampling	A sampling strategy that leads to the collection of samples in a manner that is compatible with the goals of the sampling plan. For random sampling, the goal should be to determine the confidence interval within which the true mean of the constituent concentration lies, and to keep the confidence interval as small as possible. For judgmental sampling the goal should be to collect samples that represent the areas with the highest levels of contamination and to delineate the nature and extent of the contamination.
Residential exposure	Human contact with contaminated environmental media at a frequency and duration likely to occur at a residence

Residential land use	Any property used as a place of residence; any property defined by a primary SIC code that is within the commercial/ industrial category, but which is used in part for residential activities, such as a daycare center. Residential land use includes agricultural uses.
Resource Conservation and Recovery Act (RCRA)	Federal legislation that established cradle-to-grave accountability for hazardous wastes, from the point of generation to the point of disposal
Risk	The probability of deleterious health or environmental effects
Risk assessment	The collection and analysis of data that characterizes the nature and magnitude of risk posed by a specific toxic agent
Risk Integrated System of Closure (RISC)	Indiana's agency-wide environmental remediation policy that incorporates environmental risk assessment principles to protect human health and the environment
Risk management	The process of collecting, interpreting, and applying scientific data to ensure that risks to human health and the environment are reduced to a negligible level
Sample	1. In environmental field work, *sample* refers to a single item or specimen from a larger whole or group, such as any single sample of any medium. 2. In environmental statistics, *sample* refers to a set of representative individual specimens whose properties are studied to gain information about the whole population.
Sampling	The process of obtaining representative samples or measurements of a subset of a population
Sampling design error	The error due to observing only a limited number of total possible values that make up the population being studied. This error is distinguished from errors due to imperfect selection; bias in response; and errors of observation, measurement, or recording.
Sampling and Analysis	A site-specific plan detailing sampling rationale, protocols, and analyses. The protocols provide for documentation of all field

Plan (SAP)	work.
Screening levels	Land use-specific chemical concentrations suitable for identifying areas of a site that contain contaminated media and require further action (investigation or cleanup). RISC uses the default closure levels in Appendix 1 for this purpose.
Sediment	Particulate matter typically consisting of mixtures of clay, silt, sand, organic matter, and various minerals that usually lie below water. This matrix of materials can be relatively heterogeneous in terms of physical, chemical, and biological characteristics. Sediment frequently accumulates chemical constituents in concentrations that exceed those in overlying water; for this reason, sediment can be a persistent source of toxic materials for aquatic resources.
Selectivity	Uniqueness of a response in a given methodology
Sequential sampling	A method of sampling and analysis identifying contamination in an overlapping repeat events.
Sensitivity	The change in response per unit change in quantity and concentration of an analytical instrument or method
Site	1. The geographical area where environmental chemical of concern evaluation is desired. This may consist of an entire facility and surrounding property or a single area of concern within a facility or property, depending upon the applicable regulatory program. 2. For purposes of IC 13-25-5, *site* means a parcel of real property for which an application has been submitted under IC 13-25-5-2.
Site characterization	The process of determining the nature and extent of contamination in environmental media. This information is utilized to determine the potential exposure concentrations.
Site screening	The process of determining through sampling and analysis which areas of concern contain chemical concentrations that require additional action (either investigation or remediation)

Site specific	Nondefault application of RISC where specific chemical or physical parameters, models, equations, strategies, or assumptions are applied for any source area
Slope factors	A mathematically-derived value that posits a plausible upper-bound estimate of the probability of a cancer response per unit intake of a chemical over a lifetime. A specific slope factor is used to estimate an upper-bound probability that an individual will develop cancer as a result of a lifetime exposure to a particular concentration of a carcinogen.
Smear zone	The vertical zone of soil at the ground water interface which is repeatedly exposed to soluble and non-aqueous phase constituents in the ground water due to seasonal ground water elevation fluctuations.
Soil attenuation capacity (SAC)	A constituent source limit for organic chemicals that considers adsorption of the constituent to the soil organic carbon. Default values are 2,000 mg/kg for subsurface soil and 6,000 mg/kg for surface soil (based on fraction of organic carbon in soil).
Soil porosity	A measurement of the void areas between soil particles that may be filled with gas or liquid
Soil saturation limit	A constituent source limit that quantifies the chemical concentration in soil at which the absorptive limits of the soil particles, the solubility limits of the soil pore water, and saturation of soil pore air have been reached
Soil to ground water partitioning equation	The methodology for calculating closure levels for constituent migration from soil to ground water. The equation quantifies chemical concentrations in soil that have the potential to contaminate ground water (also referred to as the migration-to-ground water model).
Solubility limit	A constituent concentration limit for chemicals that quantifies the maximum concentration of a chemical that will dissolve in water
Source area	The horizontal and vertical geographical area where chemical of concern concentrations exceed default residential soil closure levels

Spike	A known volume of a solution of target analytes of known concentration added to a sample before analysis and used to document bias and accuracy in inorganic analysis; also referred to as an analytical spike or matrix spike
Split samples	Aliquots of samples taken from the same container and analyzed independently, usually after mixing or compositing; split samples are used to document precision and comparability.
Stability monitoring	A plume stability demonstration method involving a quantitative and temporal evaluation of ground water concentrations. This method attempts to demonstrate that a ground water plume is not increasing in size or concentration and is not migrating; the demonstration may use default or nondefault evaluation methods.
Standard deviation	The square root of the variance, representing the variability between individual sample measurements and the mean
Statistic	A numerical descriptive measure computed from a sample
Statistical test	Any statistical method used to determine which of several hypotheses are true
Storativity	The volume of water that a permeable unit will absorb or discharge from storage per unit of surface area per unit of change in head
Subsurface soil	The soil media contained in the interval from 6 inches below ground surface to the depth of the water table
Surface soil	The soil media contained in the top 6 inches of soil
Susceptible areas	Areas for which the default models and closure levels do not apply. Susceptible areas are classified as geologically susceptible areas, wellhead protection areas, and ecologically susceptible areas.
SW-846	Standard methods of analysis, sampling techniques, and Quality Assurance/ Quality Control (QA/QC) procedures as specified in EPA Test Methods for Evaluating Solid Waste, 1986, Third Edition, plus updates

Synthetic Precipitation Leachate Procedure (SPLP)	An analytical leaching method designed to determine the mobility of both organic and inorganic analytes present in liquids, soils, and wastes in accordance with Method 1312 SW-846, Update III, September 1994
Target risk	A value that is combined with exposure and toxicity information to calculate a risk-based concentration for a specific application (for example, a default closure level). For carcinogenic effects, the default target risk is a cancer risk of 10^{-5}. For noncarcinogenic effects, the target risk is a hazard index of 1 by target organ.
Transmissivity	A measure of the amount of water that can be transmitted horizontally by the full, saturated thickness of the aquifer with a hydraulic gradient of 1. Transmissivity is determined by multiplying the hydraulic conductivity of the aquifer by its saturated thickness.
Trip Blank	Analyte-free reagent water taken to the sampling site and analyzed by the laboratory for the same parameters as the investigative samples. This sample is used to check for procedural contamination of samples.
Type I error	A Type I Error occurs when the null hypothesis is rejected when it is true (False Positive).
Type II error	A Type II Error occurs when the null hypothesis is not rejected when it is false (False Negative).
Unlikely to be contaminated	An area screening term that is used to describe portions of a site where there is no reason to suspect contamination; historic site data is used in conjunction with best professional judgement to make this determination.
User	The person evaluating environmental contamination through the processes outlined in RISC
Variable	A quantity that may assume any one of a set of values
Variance	A measure of the variability of a random variable around its mean

Volatile organic compound (VOC)	A chemical with a boiling point of less than 200 EF that is not a base-neutral compound
Volatilization factor (soil to air)	The rate of change between the concentration of a chemical constituent in the soil and the flux of the volatilized constituent in the air
Wellhead Protection Area	The surface and subsurface area, delineated by fixed radius, hydrogeological mapping, analytical, semianalytical, or numerical flow/solute transport methods, that contributes water to a community public water supply system production well or wellfield and through which contaminants are likely to move and reach the well within a specified period

RISC Technical Guidance Manual
Acronyms

ASTM	American Society for Testing & Materials
BTEX	Benzene, Toluene, Ethyl Benzene, Xylene
CAS	Chemical Abstract Service
CERCLA	Comprehensive Environmental Response Compensation & Liability Act
CFR	Code of Federal Regulations
CL	Closure Level
CLP	Contract Laboratory Program
COC	Chemical of Concern
cPAHs	Carcinagenic Polynuclear Aromatic Hydrocarbons
CRDL	Contract Required Detection Limit
CRQL	Contract Required Quantitation Limit
CSM	Conceptual Site Model
CV	Coefficient of Variation
DAF	Dilution Attenuation Factor
DQA	Data Quality Assessment
DQO	Data Quality Objectives
EPA	Environmental Protection Agency
EQL	Estimated Quantitation Limit
FID	Flame Ionization Detector
GC/MS	Gas Chromatography / Mass Spectrometry
GIS	Geographic Information System
HASP	Health and Safety Plan
HEAST	Health Effects Assessment Summary Tables
IDEM	Indiana Department of Environmental Management
IRIS	Integrated Risk Information System
ISBN	International Standard Book Number
LUST	Leaking Underground Storage Tanks
MCL	Maximum Contaminant Level
MDL	Method Detection Limit
MS/MSD	Matrix Spike / Matrix Spike Duplicate
MTBE	Methyltertiary butyl ether
NCEA	National Center for Exposure Assessment
NCP	National Contingency Plan
NLM	National Library of Medicine
NOAEL	No Observed Adverse Effects Level
OSWER	Office of Solid Waste and Emergency Response
PCB	Polychlorinated Biphenyls
PEC	Potential Exposure Concentration
PID	Photoionization Detector
POC	Perimeter of Compliance
QA/QC	Quality Assurance / Quality Control
QAPP	Quality Assurance Project Plan
RAGS	Risk Assessment Guidance for Superfund

RCRA	Resource Conservation & Recovery Act
RFD	Reference Dose
RISC	Risk Intergrated System of Closure
RMSD	Root-Mean-Square Deviation
RSS	Ranked Set Sampling
SAP	Sampling & Analysis Plan
SOP	Standard Operating Procedures
SPLP	Synthetic Precipitation Leaching Procedure
SRS	Simple Random Sampling
StRS	Stratified Random Sampling
SVOC	Semivolatile Organic Compounds
SyGS/rs	Systematic Grid Sampling with a Random Starting Point
TAL	Target Analyte List
TCL	Target Compound List
TSD	Treatment, Storage, Disposal
UCL	Upper Confidence Limit
USGS	US Geographical Service
VOC	Volatile Organic Compound
VRP	Voluntary Remediation Program
XRF	X-Ray Fluorescence

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DQO	Data Quality Objectives
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GC/MS	Gas Chromatography / Mass Spectrometry
GIS	Geographic Information System
HASP	Health and Safety Plan
HEAST	Health Effects Assessment Summary Tables
IDEM	Indiana Department of Environmental Management
IRIS	Integrated Risk Information System
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MCL	Maximum Contaminant Level
MDL	Method Detection Limit
MS/MSD	Matrix Spike / Matrix Spike Duplicate
MTBE	Methyltertiary butyl ether
NCEA	National Center for Exposure Assessment
NCP	National Contingency Plan
NLM	National Library of Medicine
NOAEL	No Observed Adverse Effects Level
OSWER	Office of Solid Waste and Emergency Response
PCB	Polychlorinated Biphenyls
PEC	Potential Exposure Concentration
PID	Photoionization Detector
POC	Perimeter of Compliance
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RCRA	Resource Conservation & Recovery Act
RFD	Reference Dose
RISC	Risk Intergrated System of Closure
RMSD	Root-Mean-Square Deviation

RSS	Ranked Set Sampling
SAP	Sampling & Analysis Plan
SOP	Standard Operating Procedures
SPLP	Synthetic Precipitation Leaching Procedure
SRS	Simple Random Sampling
StRS	Stratified Random Sampling
SVOC	Semivolatile Organic Compounds
SyGS/rs	Systematic Grid Sampling with a Random Starting Point
TAL	Target Analyte List
TCL	Target Compound List
TSD	Treatment, Storage, Disposal
UCL	Upper Confidence Limit
USGS	US Geographical Service
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References

Allen-King, R. M., McKay, L. D. and Trudell, M. R. 1997. "Organic Carbon Dominated Trichlorethene Sorption in a Clay-rich Glacial Deposit." *Ground Water Journal*, **35**(1). P. 124-130.

American Society for Testing and Materials. 1996. "ASTM D2937." *Annual Book of ASTM Standards. Volume 4.08. Soil and Rock Building Stones*. Philadelphia, PA.

American Society for Testing and Materials. "Document D2974, Method C."

American Society for Testing and Materials. 1995. *Standard Guide for Risk-Based Corrective Action Applied at Petroleum Release Sites* (E 1739-95).

American Society for Testing and Materials.1994. *Standard Practice for Environmental Site Assessments: Phase 1 Environmental Site Assessment Process*. (ASTM E 1527 - 94).

American Society for Testing and Materials. Materials.1994. *Standard Practice for Environmental Site Assessments: Transaction Screen Process*. (ATSM E 1528 - 93).

Cothern, Richard C. 1996. *Handbook For Environmental Risk Decision Making*. Lewis Publishers, New York.

Klute, A. (ed.). 1986. *Methods of Soil Analysis, Part 1. Physical and Mineralogical Methods.* Second Edition. American Society of Agronomy, Madison, WI.

IDEM. July 1998. *Guidance to the Performance and Presentation of Analytical Chemistry Data*.

IDEM. July 1996. *Indiana Voluntary Remediation Program Resource Guide*. P. 1.

Miller, D. 1984. "Reducing Transformation Bias in Curve Fitting." *The American Statistician*, 38. P. 124-126.

Molak, Vlasta. 1997. *Fundamentals of Risk Analysis and Risk Management*. CRC Press, Boca Raton.

Nelson, D. W. and Sommers, L. E. 1982. "Total Carbon, Organic Carbon, and Organic Matter." In: A. L. Page (ed.), *Methods of Soil Analysis. Part 2, Chemical and Microbiological Properties*. Second Edition. 9(2). P. 539-79. American Society of Agronomy, Madison, WI.
Parkhurst, D. W. In press. "Arithmetic Versus Geometric Means for Environmental Concentration Data." *Environmental Science and Technology*.

The Presidential/Congressional Commission on Risk Assessment and Risk Management. 1997. *Framework for Environmental Health Risk Management, Volume 1 of Final Report*. Available

at: http://www.riskworld.com/Nreports/1996/risk_rpt/Rr6me001.htm.

The Presidential/Congressional Commission on Risk Assessment and Risk Management. 1997. *Risk Assessment and Risk Management in Regulatory Decision-making, Volume 2 of Final Report*. Available at: http://www.riskworld.com/Nreports/1996/risk_rpt/Rr6me001.htm.

Resource Conservation and Recovery Act (42 U.S.C 6901 et seq.), 329-IAC 2-2-1.

Rodricks, Joseph V. 1992. *Calculated Risks: The Toxicity and Human Health Risks of Chemicals in Our Environment*. Cambridge University Press, Great Britain.

Sheppard, Marsha I. and Thibault, D. H. 1990. Default Soil Solid/liquid Partition Coefficients, K_DS, for Four Major Soil Types: A Compendium. *Health Physics*, 59(4). P. 471-482.

US Army Corp of Engineers. 1986. *Laboratory Soils Testing.* EM 1110-02-1906.

USEPA. August 1987. *A Compendium of Superfund Field Operations Methods: Volume 1*. EPA/540/P-87/001a.

USEPA. September 1993. *Data Quality Objectives Process for Superfund, Interim Final Guidance*. EPA/540/R-93/071, PB96-963203.

USEPA. June 1997. *Ecological Risk Assessment Guidance for Superfund: Process for Design and Conducting Ecological Risk Assessments*. EPA/540/R/97/006.

USEPA. 1989. *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA*. EPA/540/G-89/004.

USEPA. July 1996. *Guidance for Data Quality Assessment, Section 3.3.3.1.* EPA/600/R-96/084.

USEPA. May 1998. *Guidelines for Ecological Risk Assessment, Final.* EPA/630/R-95/002F.

USEPA. March 1991. *Handbook of Suggested Design and Installation of Ground-Water Monitoring Wells*. EPA/600/4-89/034.

USEPA. *Land Use in the CERCLA Remedy Selection Process*. (OSWER Directive No. 9355.7-04).

USEPA. December 1988. *Methods for the Determination of Organic Compounds in Drinking Water*. EPA/600/4-88/039.

USEPA. July 1992. *Preparation of Soil Sampling Protocols: Sampling Techniques and Strategies*. EPA/600/R-92/128, PB92-220532INZ.
USEPA. December 1989. *Risk Assessment Guidance for Superfund: Volume 1 Human Health*

Evaluation Manual (Part A). EPA/540/1-89/002.

USEPA. December 1991. *Risk Assessment Guidance for Superfund: Volume 1 Human Health Evaluation Manual (Part B) Development of Risk-Based Preliminary Remediation Goals*, *Interim.* (OERR, publication 9285.7-01B).

USEPA. December 1994. *Soil Screening Guidance: Technical Background Document, Review Draft*. EPA/540/R-94/106, PB96-963532.

USEPA. May 1996. *Soil Screening Guidance: Technical Background Document*. EPA/540/R-95/128, PB96-963502.

USEPA. April 1996. *Soil Screening Guidance: User's Guide*. EPA/540/R-96/018, PB96-963505.

USEPA. July 1992. *Test Methods for Evaluating Solid Waste: Physical/Chemical Methods, 3rd Edition, Final Update*. Publication SW-846.

USEPA Region 5. 1998. Appendix C. *RCRA QAPP Instructions.* Revision: April 1998.

Overview of Appendix 1

- Table A - Default Closure Tables for Residential and Industrial Land Use Applications
- Table B - Chemical/Physical Properties
- Table C - Exposure Equations
- Table D - Exposure Assumptions
- Table E - Default Exposure Assumption References
- Table F - Human Health Toxicity Parameters
- Table G - Critical Toxic Effects and Categories

A1.0 Introduction

This appendix provides various tables of values needed to determine default closure levels under RISC. A short narrative describing each table is provided below; the tables are provided following the text.

Table A

Table A is divided into two main sections, Residential and Commercial/ Industrial. Each of these is further divided into two subsections, Soil and Ground Water. Each section presents applicable closure levels and footnotes.

Both the Industrial and Residential Soil Closure Level sections provide concentrations for soil saturation (Csat); soil attenuation capacity (SAC); and construction worker, direct, and migration to ground water pathways. A final column presents the Default Closure Level, as determined by the lowest of Csat; SAC; and construction worker, direct, or migration to ground water closure levels for a given chemical. Default closure levels are considered protective of human health.

The ground water section provides concentrations for water solubility limits, maximum contaminant levels (MCL), and the respective ground water pathway closure levels. The default closure level for residential settings is the MCL, if the MCL has been established; if not, the default closure level is the lowest of either the ground water pathway or the solubility limit. The ground water default closure level for the commercial/industrial setting is the solubility limit if it is lower than any other level; if not, the default closure level is the highest of either the MCL or the ground water pathway level.

The default closure levels for all compounds, except beryllium and mercury, are used over a default soil pH range of 6.0 to 8.0. If site soils have a pH within this range, the default closure levels can be applied. If not, a site-specific, pH-dependent closure level must be developed for any ionizing organics and metals at the site. The K_d-dependent pH range applies only to metals and ionizing organics. These compounds are identified in the default closure level tables by footnote 6. In general, carboxylic acids, phenols, and amines are considered “ionizing organics.” For those metals or ionizing organics not included in the table, a pH-specific K_{oc} or K_d will need to be determined. Guidance for determining the K_d or K_{oc} is presented in the 1996 EPA Soil Screening Guidance (EPA 540/R-95/128). K_d values for beryllium and mercury are very sensitive to slight changes

in pH; therefore, a site-specific pH must be established and used to determine the K_d for these compounds. This value can be calculated by using Table C-4, Metal K_d Values as a Function of pH, as presented in the EPA 1996 Soil Screening Guidance Users Guide (EPA/540/R-96-018).

Table B

Table B presents values for the following chemical and physical properties used to derive the values listed in Table A:

- Volatilization Factor
  - Diffusivity in air
  - Diffusivity in water
- K_{oc}/ Kd
- Henry's Law Constant
- Dermal absorbance
- Water solubility
- Maximum contaminant level (MCL)
- Melting point
- Boiling point
- Molecular weight

The chemical and physical parameter values were taken from the following references (in order of preference):

1. EPA. 1996. Soil Screening Guidance Document, Users Guide, 9355.4-23, EPA/540/R-96/018, April; Technical Background Document, 9355.4-17A, EPA/540/R-95/128, May.

2. Agency for Toxic Substances and Disease Registry Toxicological Profiles

3. EPA Region 9, Region 6, and Region 3 Preliminary Remediation Goals, Physical and Chemical Parameters; available online at: http://www.epa.gov/reg3hwmd/risk/riskmenu.htm http://www.epa.gov/region09/waste/sfund/prg/index.htm and http://www.epa.gov/earth1r6/6pd/cra_c/pd-n/screen.htm

4. Other EPA sources, including the Superfund Chemical Data Matrix

5. Other State agency sources

6. Other published literature

Table C

Table C presents mathematical equations used to derive closure levels. The RISC default process considers three media of exposure or pathways for commercial/industrial and residential land uses: surface soil, subsurface soil, and ground water. Subsurface soil is considered a medium because it presents a mechanism for contaminant transport to ground water when rain infiltrates and leaches material out of the soil. For this reason, the equations describing calculation of subsurface soil default closure levels are titled *Migration to Groundwater*; they are often referred to as "indirect" exposure pathway equations. The total exposure associated with each medium is the sum of the exposures from each significant absorption route (ingestion, dermal absorption, and inhalation) associated with that medium. The construction worker occupational exposure considers only soil exposure.

Residential and industrial direct soil exposure is determined by summing the intake from the ingestion, inhalation, and dermal absorption routes. Values listed for exposure resulting from soil contaminants migrating to ground water are protective for the ground water consumption pathway. Residential ground water exposure is determined by summing the intake from the inhalation and ingestion routes. Certain exposure routes in a given pathway were eliminated after considering potential exposure and dosage. The dermal route for residential ground water was assessed as an insignificant contributor to risk and was therefore eliminated from the calculation. Similarly, the inhalation route for industrial ground water was eliminated because industrial settings are typically well ventilated, and it is unlikely that most workers have any significant exposure.

Construction closure levels consider the intake from ingestion, dermal, and inhalation routes for direct soil contact. Water exposure was not considered because most utility or other construction work does not involve workers standing in water for long periods of time.

Separate equations are needed to determine carcinogenic and noncarcinogenic closure levels. Many compounds have both a carcinogenic and noncarcinogenic dose response. In such cases, each value was calculated separately, and the lowest result is used in the table.

Exposure to residential soil presents more significant exposure risks in children 6 years and younger. Children in this age group generally spend more time outdoors and ingest more soil than adults. To account for this special case, a "weighted approach" was used to calculate residential surface soil values. The body weight, exposure duration, skin-surface area, ingestion amounts, and inhalation rates were age-adjusted or "weighted" for each of the three principle soil absorption routes.

Five supporting models were used to account for the following factors: volatilization factor/particulate emissions, soil saturation, age adjustments for soil ingestion, skin contact, and vapor inhalation. The volatilization and particulate emission models account for exposure potential for emission of vapors and particulates from surface soils. The models and equations are taken from the EPA Soil Screening Guidance (1996). Similarly, the models used for soil saturation levels were also taken from the Soil Screening Guidance. The equations (models) used to adjust values based on age were mathematically derived using exposure duration, body weight, skin surface area, and ingestion and inhalation rates of children and adults.

Tables D and E

Table D presents the Default Exposure Assumptions used in the equations presented in Table C. Quantification of exposure variables (such as exposure frequency, exposure duration, and exposed surface area) will change depending on land use, application, and whether the receptors are adults or children. Table E lists a reference source verifying each default value.

Generally speaking, the default assumption values are set at the 90 to 95th percentile of available and reliable data. This approach is more protective than using the average value and it is generally accepted as a reasonable working boundary on the population of sampled measurements (see EPA Risk Assessment Guidance for Superfund, EPA/540/1-89/002).

Table F

Table F presents the reference doses and slope factors for all of the chemicals listed in the closure tables. These values were taken from the following references (in order of preference):

1. EPA Integrated Risk Information System (IRIS) — Certain route-to-route extrapolations are acceptable. Guidance is presented below.

2. Health Effects Assessment Summary Tables (HEAST) — Assuming HEAST continues to be updated (if not, then this source moves to "Other Literature Sources").

3. Agency for Toxic Substances and Disease Registry (ATSDR), National Center for Environmental Assessment, and EPA Regions 9 and 3 PRG Toxicity Values

4. Other literature sources — This may include derivations from literature sources.

5. Predictive Models — Predictive models such as Quantitative Structure and Activity Relationship (QSARS)

In general, the organic chemicals in the default tables have both an inhalation and an oral reference dose (RfD) or slope factor (SF). These values are taken directly from experimentally derived animal or human data (when available). When sufficient data on the route was not available, IDEM used a route-to-route extrapolation. This approach assumes that toxicity is similar for both routes. While it is unlikely that there is a direct 1-to-1 correlation between the inhalation and oral routes, extrapolation of inhalation RfDs from oral RfDs for the more volatile chemicals tends to be reasonably close when compared to experimentally derived inhalation RfDs (EPA Soil Screening Guidance 1996).

IDEM considers such extrapolations of values for the more volatile compounds to compare reasonably well and will use route-to-route extrapolations. As the volatility of the compounds decreases, route-to-route extrapolations become less certain (EPA Soil Screening Guidance 1996). However, these extrapolations do provide some assurance that the pathways are being addressed, and IDEM will also use route-to-route extrapolations for these compounds.

Route-to-route extrapolations do not work as well for inorganics. For the carcinogenic metals, specifically beryllium, chromium, nickel, and cadmium, the experimental evidence involving increased cancer risk appears to be limited to the respiratory pathway, and it is unlikely that ingestion would contribute to the carcinogenic response. Therefore, a route-to-route extrapolation has not been performed.

With respect to noncarcinogenic inorganics, considerable difference exists in the absorption and toxicity dynamics between routes. The differences are significant enough to eliminate them from consideration for route-to-route extrapolation. In addition, IDEM's

analysis of these compounds at default particulate exposure levels indicates that the particulate inhalation pathway is insignificant. IRIS and EPA Regions 3, 6, and 9 do not perform route-to-route extrapolations for inorganics. IDEM agrees with EPA and will not include the route-to-route extrapolation as a pathway for inorganic compounds. Therefore, route-to-route extrapolations were not performed for noncarcinogenic inorganic compounds.

Table G

The RISC default approach uses the "critical effect" of a noncarcinogenic chemical to establish the target organ. The critical effect is the first adverse effect, or its known precursor, that occurs to the most sensitive species as the dose is increased during toxicity testing. Therefore, it is a toxic effect on a target organ or tissue (for example, an increase in liver weight or nephrotoxicity). Each critical effect will be categorized into one or more "critical effects categories." A critical effects category is a group of target organs or tissues subject to common absorption or a group of organs with similar or common functions. In certain cases, an effect occurring in one system may indirectly affect another system, and it will be necessary to consider effects as additive within both systems. In other cases, a chemical at the RfD dose may affect more than one critical effects category. Many chemicals have both a carcinogenic and a noncarcinogenic toxic effect. If the default value in the closure table is based on the carcinogenic response, then the additivity of the chemical is assessed only as a carcinogen.

The box on the following page lists the 10 critical effects categories and examples of the target organs or effects considered in that category. The list of critical effects and categories for each chemical is given in Table G.

Critical Effects Categories and Target Organs

1. Systemic: Liver, kidney, urinary tract
2. Circulatory: Arteries, veins, heart, and blood
3. Gastrointestinal: Buccal cavity, esophagus, stomach, intestines, and gall bladder
4. Musculoskeletal: Muscles, bone, and connective tissues
5. Respiratory: Lungs, trachea, and nasal passageway
6. Immunological: Lymph and tissue fluid, spleen, and lymph nodes

7. Neurological: Brain, spinal cord, and neurons
8. Reproductive/Endocrine: Testes, ovaries, thyroid, adrenal, pituitary, pancreas, and parathyroid
9. Developmental: Teratology, growth retardation, structural malformations, and abnormal development
10. Dermal/ Ocular: Skin and eyes

The primary critical effect and target organ for each chemical was obtained using the following sources (in order of preference):

1. IRIS (EPA 2000)
2. HEAST (EPA 1997)
3. ATSDR Toxicological Profiles
4. Hazardous Substance Databank (http://toxnet.nlm.nih.gov)

Exceptions include the following critical effects and target organs:

- Some compounds have an RfD based on the No Observed Adverse Effects Level (NOAEL), and information on toxic effects at higher doses was not available. In these cases, the critical effect of a surrogate compound (similar in structure and type) was used.

- Some compounds have an RfD established with the NOAEL and some toxic effects information. The toxic effects information was used to establish the critical effect.

- Some compounds have experimentally derived oral and inhalation reference doses. Where these values were within an order of magnitude of each other, critical effects from both routes were listed. These compounds should be considered as additive in both categories.

- Some compounds did not have an easily identified target organ within the critical effects category. These compounds were classified within a category as “nonspecific.”

Table A

Residential Closure Levels
Commercial/Industrial Closure Levels

Table A Default Closure Table - Residential December 21,2001

Constituent	Soil									Ground Water				
	Soil Attenuation Capacity mg/kg	Soil Saturation mg/kg	Construction (mg/kg)		Direct (mg/kg)		Migration to G W (mg/kg)		Default Closure Level (mg/kg)	Solubility (mg/l)	MCL (mg/l)	Residential (mg/l)		Default Closure Level (mg/l)
Acenaphthene	6000/2000		50,000	NC	9,500	NC	130	NC	130	4.2		0.46	NC	0.46
Acetone (2-Propanone)	6000/2000	100,000	25,000	NC	3,900	NC	3.1	NC	3.1	1,000,000		0.77	NC	0.77
Acrolein[5]	6000/2000	28,000	1.2	NC	0.18	NC	0.00023	NC	0.00023	260,000		0.000055	NC	0.000055
Aldrin	6000/2000		27	NC	0.25	C	4.9	C	0.25	0.13		0.000050	C	0.000050
Anthracene	6000/2000		250,000	NC	47,000	NC	51	NC	51	0.043		2.3	NC	0.043
Antimony	10,000		460	NC	140	NC	5.4	NC	5.4		0.0060	0.015	NC	0.0060
Arsenic[3,6]	10,000		320	NC	3.9	C	29	C	3.9		0.050	0.00057	C	0.050
Barium[6]	10,000		79,000	NC	23,000	NC	1,600	NC	1,600		2.0	2.6	NC	2.0
Benz(a)anthracene	6000/2000		790	C	5.0	C	19	C	5.0	0.0094		0.0012	C	0.0012
Benzene[10]	6000/2000	870	120	NC	8.2	C	0.034	C	0.034	1,800	0.0050	0.0062	C	0.0050
Benzo(b)fluoranthene	6000/2000		790	C	5.0	C	57	C	5.0	0.0015		0.0012	C	0.0012
Benzo(k)fluoranthene	6000/2000		7,900	C	50	C	39	C	39	0.00080		0.012	C	0.00080
Benzoic acid[6]	6000/2000		1,000,000	NC	730,000	NC	590	NC	590	3,500		150	NC	150
Benzo(a)pyrene	6000/2000		79	C	0.50	C	8.2	C	0.50	0.0016	0.00020	0.00012	C	0.00020
Benzyl Alcohol	6000/2000	6,400	270,000	NC	55,000	NC	48	NC	48	40,000		11	NC	11
Beryllium[9]	10,000		2,300	NC	680	NC	63	C	63		0.0040	0.073	NC	0.0040
Bis(2-Chloroethyl)ether	6000/2000	3,300	280	C	1.6	C	0.00070	C	0.00070	17,000		0.00015	C	0.00015
Bis(2-chloroisopropyl)ether[5]	6000/2000	790	5,200	C	30	C	0.027	C	0.027	1,700		0.0042	C	0.0042
Bis(2-ethylhexyl)phthalate	6000/2000	31,000	18,000	NC	300	C	3,600	C	300	0.34	0.0060	0.061	C	0.0060
Bromodichloromethane[7]	6000/2000	3,000	2,100	C	10	C	0.63	C	0.63	6,700	0.100	0.0029	C	0.100
Bromoform(tribromomethane)	6000/2000	1,900	7,700	NC	280	C	0.75	C	0.75	3,100	0.100	0.11	C	0.100
N-Butanol	6000/2000	10,000	48,000	NC	8,200	NC	16	NC	16	74,000		3.7	NC	3.7
Butylbenzylphthalate	6000/2000	930	180,000	NC	37,000	NC	6,200	NC	930	2.7		7.3	NC	2.7
Cadmium[3,6]	10,000		570	NC	12	NC	7.5	C	7.5		0.0050	0.018	NC	0.0050
Carbazole	6000/2000		31,000	C	210	C	5.9	C	5.9	7.5		0.043	C	0.043
Carbon disulfide	6000/2000	720	6,200	NC	900	NC	10	NC	10	1,200		1.3	NC	1.3
Carbon tetrachloride	6000/2000	1,100	31	NC	3.3	C	0.066	C	0.066	790	0.0050	0.0026	C	0.0050
Chlordane	6000/2000		510	NC	17	C	9.6	C	9.6	0.056	0.0020	0.0024	C	0.0020
p-Chloroaniline[6]	6000/2000		3,600	NC	730	NC	0.97	NC	0.97	5,300		0.15	NC	0.15
Chlorobenzene	6000/2000	680	2,600	NC	380	NC	1.3	NC	1.3	470	0.100	0.13	NC	0.100
Chloroethane	6000/2000	1500	9,600	C	46	C	0.32	C	0.32	5,700		0.062	C	0.062
Chloroform	6000/2000	2,900	6.4	NC	0.91	NC	0.59	C	0.59	7,900	0.100	0.00084	NC	0.100
2-Chlorophenol[6]	6000/2000	53,000	2,200	NC	360	NC	0.75	NC	0.75	22,000		0.038	NC	0.038
Chromium III[6]	10,000		1,000,000	NC	520,000	NC	1,000,000	NC	10,000		0.100	55	NC	0.1
Chromium VI[6,12]	10,000		3,400	NC	430	C	38	C	38		0.100	0.11	NC	0.100
Chrysene	6000/2000		79,000	C	500	C	25	C	25	0.0016		0.12	C	0.0016
Copper[6]	10,000		42,000	NC	13,000	NC	580	NC	580	0	1.3	1.4	NC	1.3
Cyanide, Free[13]	10,000		18,000	NC	3,700	NC	40	NC	150	1,000,000	0.2	0.73	NC	0.2
Cyclohexane	6000/2000	140	170,000	NC	24,000	NC	1,100	NC	140	55		44	NC	44
DDD	6000/2000		3,100	C	28	C	140	C	28	0.090		0.0035	C	0.0035

Table A Default Closure Table - Residential December 21,2001

Constituent	Soil									Ground Water				
	Soil Attenuation Capacity mg/kg	Soil Saturation mg/kg	Construction (mg/kg)		Direct (mg/kg)		Migration to G W (mg/kg)		Default Closure Level (mg/kg)	Solubility (mg/l)	MCL (mg/l)	Residential (mg/l)		Default Closure Level (mg/l)
DDE	6000/2000		2,200	C	20	C	450	C	20	0.12		0.0025	C	0.0025
DDT	6000/2000		540	NC	20	C	260	C	20	0.025		0.0025	C	0.0025
Dibenzo(a,h)anthracene	6000/2000		79	C	0.50	C	18	C	0.50	0.0025		0.00012	C	0.00012
Di-n-butyl phthalate	6000/2000	2,300	89,000	NC	18,000	NC	5,000	NC	2,000	11		3.7	NC	3.7
1,2-Dichlorobenzene	6000/2000	600	18,000	NC	2,800	NC	17	NC	17	160	0.60	0.48	NC	0.60
1,3-Dichlorobenzene	6000/2000	310	180	NC	27	NC	0.13	NC	0.13	130		0.0069	NC	0.0069
1,4-Dichlorobenzene	6000/2000		8,000	C	42	C	2.2	C	2.2	74	0.075	0.0080	C	0.075
3,3-Dichlorobenzidine	6000/2000		1,400	C	9.5	C	0.062	C	0.062	3.1		0.0019	C	0.0019
1,1-Dichloroethane	6000/2000	1,700	8,600	NC	1,300	NC	5.6	NC	5.6	5,100		0.99	NC	0.99
1,2-Dichloroethane	6000/2000	1,800	150	NC	3.7	C	0.024	C	0.024	8,500	0.0050	0.0020	C	0.0050
1,1-Dichloroethylene	6000/2000	1,500	140	C	0.67	C	0.058	C	0.058	2,300	0.0070	0.00067	C	0.0070
cis-1,2-Dichloroethylene	6000/2000	1,200	750	NC	110	NC	0.40	NC	0.40	3,500	0.070	0.077	NC	0.070
trans-1,2-Dichloroethylene	6000/2000	3,100	1,200	NC	180	NC	0.68	NC	0.68	6,300	0.100	0.15	NC	0.100
2,4-Dichlorophenol[6]	6000/2000		2,700	NC	550	NC	1.1	NC	1.1	4,500		0.11	NC	0.11
1,2-Dichloropropane	6000/2000	1,100	100	NC	4.5	C	0.030	C	0.030	2,800	0.0050	0.0026	C	0.0050
1,3-Dichloropropene	6000/2000	1,400	290	NC	9.5	C	0.040	C	0.040	2,800		0.0056	C	0.0056
Dieldrin	6000/2000		39	C	0.27	C	0.046	C	0.046	0.20		0.000053	C	0.000053
Diethylphthalate	6000/2000	2,000	710,000	NC	150,000	NC	450	NC	450	1,100		29	NC	29
Dimethyl phthalate	6000/2000	1400	1,000,000	NC	1,000,000	NC	2000	NC	1400	4300		370	NC	370
2,4-Dimethylphenol[6]	6000/2000		18,000	NC	3,700	NC	9.0	NC	9.0	7,900		0.73	NC	0.73
2,4-Dinitrophenol[6]	6000/2000		1,800	NC	370	NC	0.29	NC	0.29	2,800		0.073	NC	0.073
Dinitrotoluene mixture	6000/2000		890	NC	6.3	C	0.0085	C	0.0085	180		0.0013	C	0.0013
Di-n-octyl phthalate	6000/2000	10,000	18,000	NC	3,700	NC	67,000	NC	2,000	0.020		0.73	NC	0.020
Endosulfan	6000/2000		5,300	NC	1,100	NC	20	NC	20	0.51		0.22	NC	0.22
Endrin	6000/2000		270	NC	55	NC	0.99	NC	0.99	0.25	0.0020	0.011	NC	0.0020
Ethylbenzene	6000/2000	400	29,000	NC	4,600	NC	13	NC	13	170	0.70	1.6	NC	0.70
Fluoranthene	6000/2000		33,000	NC	6,300	NC	880	NC	880	0.21		1.5	NC	0.21
Fluorene	6000/2000		33,000	NC	6,300	NC	170	NC	170	2.0		0.31	NC	0.31
Heptachlor	6000/2000		91	C	0.54	C	23	C	0.54	0.18	0.00040	0.00019	C	0.00040
Heptachlor epoxide	6000/2000		12	NC	0.47	C	0.67	C	0.47	0.20	0.00020	0.000094	C	0.00020
Hexachlorobenzene	6000/2000		390	C	2.7	C	2.2	C	2.2	6.2	0.00100	0.00053	C	0.00100
Hexachloro-1,3-butadiene	6000/2000	1,000	180	NC	37	NC	16	C	16	3.2		0.0073	NC	0.0073
alpha-HCH(alpha-BHC)	6000/2000		120	C	0.99	C	0.0072	C	0.0072	2.0		0.00014	C	0.00014
beta-HCH(beta-BHC)	6000/2000		410	C	3.5	C	0.026	C	0.026	0.24		0.00047	C	0.00047
gamma-HCH(Lindane)	6000/2000		310	NC	4.8	C	0.0094	C	0.0094	6.8	0.00020	0.00066	C	0.00020
Hexachlorocyclopentadiene	6000/2000	2,200	6,200	NC	1,300	NC	400	NC	400	1.8	0.050	0.26	NC	0.050
Hexachloroethane	6000/2000		660	NC	120	NC	2.8	C	2.8	50		0.037	NC	0.037
Indeno(1,2,3-cd)pyrene	6000/2000		790	C	5.0	C	3.1	C	3.1	0.000022		0.0012	C	0.000022
Isophorone	6000/2000	4,600	180,000	NC	4,500	C	5.3	C	5.3	12,000		0.90	C	0.90
Lead[8]	10,000		970		400		81		81			0.015		0.015

Table A Default Closure Table - Residential December 21,2001

Constituent	Soil									Ground Water				
	Soil Attenuation Capacity mg/kg	Soil Saturation mg/kg	Construction (mg/kg)		Direct (mg/kg)		Migration to G W (mg/kg)		Default Closure Level (mg/kg)	Solubility (mg/l)	MCL (mg/l)	Residential (mg/l)		Default Closure Level (mg/l)
Mercury[9]	10,000		270	NC	55	NC	2.1	NC	2.1		0.0020	0.011	NC	0.0020
Methoxychlor	6000/2000		4,400	NC	910	NC	160	NC	160	0.045	0.040	0.18	NC	0.040
Methyl bromide	6000/2000	3,200	69	NC	9.9	NC	0.052	NC	0.052	15,000		0.011	NC	0.011
Methylene chloride	6000/2000	2,400	22,000	C	120	C	0.023	C	0.023	13,000	0.0050	0.063	C	0.0050
Methyl ethyl ketone (MEK)	6000/2000	35,000	130,000	NC	20,000	NC	11	NC	11	270,000		2.5	NC	2.5
4-methyl-2-pentanone (MIBK)	6000/2000	4,100	7,200	NC	1,000	NC	0.99	NC	0.99	19,000		0.21	NC	0.21
2-Methylphenol(o-cresol) [6]	6000/2000		39,000	NC	7,500	NC	14	NC	14	26,000		1.8	NC	1.8
3-methylphenol (m-cresol) [6]	6000/2000	8,900	44,000	NC	9,100	NC	11	NC	11	23,000		1.8	NC	1.8
4-methylphenol (p-cresol) [6]	6000/2000		4,400	NC	910	NC	1.1	NC	1.1	22,000		0.18	NC	0.18
Methyl tertiary butyl ether (MTBE)	6000/2000	32,000	38,000	C	190	C	0.35	C	0.35	48,000		0.045	C	0.045
Naphthalene	6000/2000		17,000	NC	3,200	NC	0.70	NC	0.70	31		0.0083	NC	0.0083
Nickel[6]	10,000		23,000	NC	6,900	NC	950	C	950			0.73	NC	0.73
2-nitroaniline	6000/2000		51	NC	10	NC	0.011	NC	0.011	290		0.0021	NC	0.0021
Nitrobenzene	6000/2000	1,000	440	NC	91	NC	0.028	NC	0.028	2,100		0.0043	NC	0.0043
N-Nitrosodiphenylamine[6]	6000/2000		130,000	C	870	C	9.7	C	9.7	35		0.17	C	0.17
N-Nitrosodi-n-propylamine[5, 6]	6000/2000		89	C	0.61	C	0.00060	C	0.00060	9,900		0.00012	C	0.00012
PCBs[11]	6000/2000		16	NC	1.8	C	6.2	C	1.8	0.70	0.00050	0.00043	C	0.00050
Pentachlorophenol[6]	6000/2000		3,800	C	20	C	0.028	C	0.028	2,000	0.00100	0.0071	C	0.00100
Phenol[6]	6000/2000		460,000	NC	88,000	NC	110	NC	110	83,000		22	NC	22
Pyrene	6000/2000		27,000	NC	5,500	NC	570	NC	570	0.14		1.1	NC	0.14
Selenium[6]	10,000		5,700	NC	1,700	NC	5.2	NC	5.2		0.050	0.18	NC	0.050
Silver[6]	10,000		5,700	NC	1,700	NC	31	NC	31			0.18	NC	0.18
Styrene	6000/2000	1,500	68,000	NC	11,000	NC	3.5	NC	3.5	310	0.100	2.0	NC	0.100
1,1,2,2-Tetrachloroethane	6000/2000	2,000	960	C	5.0	C	0.0070	C	0.0070	3,000		0.00090	C	0.00090
1,1,1,2-Tetrachloroethane	6000/2000	640	7,900	C	37	C	0.05	C	0.05	1,100		0.0069	C	0.0069
Tetrachloroethylene (PCE)	6000/2000	230	4,200	NC	48	C	0.058	C	0.058	200	0.0050	0.014	C	0.0050
Thallium[6]	10,000		100	NC	31	NC	2.8	NC	2.8		0.0020	0.0033	NC	0.0020
Toluene	6000/2000	650	11,000	NC	1,700	NC	12	NC	12	530	1.0	0.93	NC	1.0
Toxaphene	6000/2000		560	C	3.9	C	31	C	3.9	0.74	0.0030	0.00077	C	0.0030
1,2,4-Trichlorobenzene	6000/2000	3,200	8,900	NC	1,800	NC	5.3	NC	5.3	300	0.070	0.22	NC	0.070
1,1,1-Trichloroethane	6000/2000	1,200	11,000	NC	1,800	NC	1.9	NC	1.9	1,300	0.20	0.88	NC	0.20
1,1,2-Trichloroethane	6000/2000	1,800	600	NC	9.4	C	0.030	C	0.030	4,400	0.0050	0.0032	C	0.0050
Trichloroethylene (TCE)	6000/2000	1,300	500	NC	45	C	0.057	C	0.057	1,100	0.0050	0.025	C	0.0050
2,4,5-Trichlorophenol[6]	6000/2000		89,000	NC	18,000	NC	250	NC	250	1,200		3.7	NC	3.7
2,4,6-Trichlorophenol[6]	6000/2000		57,000	C	390	C	1.5	C	1.5	800		0.077	C	0.077
Vinyl acetate	6000/2000	2,700	7,600	NC	1,100	NC	2.3	NC	2.3	20,000		0.55	NC	0.55
Vinyl chloride (chloroethene)	6000/2000	1,200	56	C	0.28	C	0.013	C	0.013	2,800	0.0020	0.00028	C	0.0020
Xylene mixed	6000/2000	410	34,000	NC	4,800	NC	190	NC	190	180	10	1.9	NC	10
Zinc[6]	10,000		340,000	NC	100,000	NC	14,000	NC	10,000			11	NC	11

Table A Default Closure Table - Industrial July 20, 2001

Constituent	Soil									Ground Water				
	Soil Attenuation Capacity mg/kg	Soil Saturation mg/kg	Construction (mg/kg)		Direct (mg/kg)		Migration to G W (mg/kg)		Default Closure Level (mg/kg)	Solubility (mg/l)	MCL (mg/l)	Industrial (mg/l)		Default Closure Level (mg/l)
Acenaphthene	6000/2000		50,000	NC	24,000	NC	1,200	NC	1,200	4.2		6.1	NC	4.2
Acetone (2-Propanone)	6000/2000	100,000	25,000	NC	5,600	NC	41	NC	41	1,000,000		10	NC	10
Acrolein[5]	6000/2000	28,000	1.2	NC	0.22	NC	8.3	NC	0.22	260,000		2.0	NC	2.0
Aldrin	6000/2000		27	NC	0.80	C	16	C	0.80	0.13		0.00017	C	0.00017
Anthracene	6000/2000		250,000	NC	120,000	NC	51	NC	51	0.043		31	NC	0.043
Antimony	10,000		460	NC	620	NC	37	NC	37		0.0060	0.041	NC	0.041
Arsenic[6]	10,000		320	NC	20	C	29	C	20		.050	0.0019	C	0.050
Barium[6]	10,000		79,000	NC	98,000	NC	5,900	NC	5,900		2.0	7.2	NC	7.2
Benz(a)anthracene	6000/2000		790	C	15	C	62	C	15	0.0094		0.0039	C	0.0039
Benzene[10]	6000/2000	870	120	NC	13	C	0.67	C	0.67	1,800	0.0050	0.099	C	0.099
Benzo(b)fluoranthene	6000/2000		790	C	15	C	74	C	15	0.0015		0.0039	C	0.0015
Benzo(k)fluoranthene	6000/2000		7,900	C	150	C	39	C	39	0.00080		0.039	C	0.00080
Benzoic acid[6]	6000/2000		1,000,000	NC	1,000,000	NC	1,600	NC	1,600	3,500		410	NC	410
Benzo(a)pyrene	6000/2000		79	C	1.5	C	16	C	1.5	0.0016	0.00020	0.00039	C	0.00039
Benzyl Alcohol	6000/2000	6,400	270,000	NC	150,000	NC	140	NC	140	40,000		31	NC	31
Beryllium[9]	10,000		2,300	NC	2,900	NC	3,200	C	2,300		0.0040	0.20	NC	0.20
Bis(2-Chloroethyl)ether	6000/2000	3,300	280	C	3.0	C	0.012	C	0.012	17,000		0.0026	C	0.0026
Bis(2-chloroisopropyl)ether[5]	6000/2000	790	5,200	C	61	C	0.26	C	0.26	1,700		0.041	C	0.041
Bis(2-ethylhexyl)phthalate	6000/2000	31,000	18,000	NC	980	C	120,000	C	980	0.34	0.0060	0.20	C	0.20
Bromodichloromethane[7]	6000/2000	3,000	2,100	C	17	C	0.63	C	0.63	6,700	0.100	0.046	C	0.100
Bromoform(tribromomethane)	6000/2000	1,900	7,700	NC	580	C	2.7	C	2.7	3,100	0.100	0.36	C	0.36
N-Butanol	6000/2000	10,000	48,000	NC	14,000	NC	44	NC	44	74,000		10	NC	10
Butylbenzylphthalate	6000/2000	930	180,000	NC	98,000	NC	6,200	NC	930	2.7		20	NC	2.7
Cadmium [6]	10,000		570	NC	780	NC	77	C	77		0.0050	0.051	NC	0.051
Carbazole	6000/2000		31,000	C	690	C	20	C	20	7.5		0.14	C	0.14
Carbon disulfide	6000/2000	720	6,200	NC	1,200	NC	82	NC	82	1,200		10	NC	10
Carbon tetrachloride	6000/2000	1,100	31	NC	5.2	C	0.29	C	0.29	790	0.0050	0.022	C	0.022
Chlordane	6000/2000		510	NC	68	C	39	C	39	0.056	0.0020	0.0082	C	0.0082
p-Chloroaniline[6]	6000/2000		3,600	NC	2,000	NC	2.7	NC	2.7	5,300		0.41	NC	0.41
Chlorobenzene	6000/2000	680	2,600	NC	510	NC	27	NC	27	470	0.100	2.0	NC	2.0
Chloroethane	6000/2000	1,500	9,600	C	71	C	5.2	C	5.2	5,700		0.99	C	0.99
Chloroform	6000/2000	2,900	6.4	NC	1.2	NC	2.7	C	1.2	7,900	0.100	0.47	C	0.47
2-Chlorophenol[6]	6000/2000	53,000	2,200	NC	580	NC	10.0	NC	10.0	22,000		0.51	NC	0.51
Chromium III[6]	10,000		1,000,000	NC	1,000,000	NC	1,000,000	NC	10,000		0.100	150	NC	150
Chromium VI[12, 6]	10,000		3,400	NC	650	C	120	C	120		0.100	0.31	NC	0.31
Chrysene	6000/2000		79,000	C	1,500	C	25	C	25	0.0016		0.39	C	0.0016
Copper[6]	10,000		42,000	NC	57,000	NC	1,700	NC	1,700		1.3	3.8	NC	3.8
Cyanide, Free[13]	10,000		18,000	NC	9,800	NC	410	NC	410	1,000,000	0.2	2.0	NC	2.0
Cyclohexane	6000/2000	140	170,000	NC	31,000	NC	1,400	NC	140	55		580	NC	55
DDD	6000/2000		3,100	C	120	C	480	C	120	0.090		0.012	C	0.012
DDE	6000/2000		2,200	C	86	C	1,500	C	86	0.12		0.0084	C	0.0084

Table A Default Closure Table - Industrial July 20, 2001

Constituent	Soil									Ground Water				
	Soil Attenuation Capacity mg/kg	Soil Saturation mg/kg	Construction (mg/kg)		Direct (mg/kg)		Migration to G W (mg/kg)		Default Closure Level (mg/kg)	Solubility (mg/l)	MCL (mg/l)	Industrial (mg/l)		Default Closure Level (mg/l)
DDT	6000/2000		540	NC	86	C	890	C	86	0.025		0.0084	C	0.0084
Dibenzo(a,h)anthracene	6000/2000		79	C	1.5	C	60	C	1.5	0.0025		0.00039	C	0.00039
Di-n-butyl phthalate	6000/2000	2,300	89,000	NC	49,000	NC	14,000	NC	2,000	11		10	NC	10
1,2-Dichlorobenzene	6000/2000	600	18,000	NC	3,900	NC	270	NC	270	160	0.60	9.2	NC	9.2
1,3-Dichlorobenzene	6000/2000	310	180	NC	38	NC	1.8	NC	1.8	130		0.092	NC	0.092
1,4-Dichlorobenzene	6000/2000		8,000	C	73	C	3.4	C	3.4	74	0.075	0.12	C	0.12
3,3-Dichlorobenzidine	6000/2000		1,400	C	31	C	0.21	C	0.21	3.1		0.0064	C	0.0064
1,1-Dichloroethane	6000/2000	1,700	8,600	NC	1,700	NC	58	NC	58	5,100		10	NC	10
1,2-Dichloroethane	6000/2000	1,800	150	NC	5.8	C	0.15	C	0.15	8,500	0.0050	0.031	C	0.031
1,1-Dichloroethylene	6000/2000	1,500	140	C	1.1	C	0.058	C	0.058	2,300	0.0070	0.0048	C	0.0070
cis-1,2-Dichloroethylene	6000/2000	1,200	750	NC	140	NC	5.8	NC	5.8	3,500	0.070	1.0	NC	1.0
trans-1,2-Dichloroethylene	6000/2000	3,100	1,200	NC	230	NC	14	NC	14	6,300	0.100	2.0	NC	2.0
2,4-Dichlorophenol[6]	6000/2000		2,700	NC	1,500	NC	3.0	NC	3.0	4,500		0.31	NC	0.31
1,2-Dichloropropane	6000/2000	1,100	100	NC	7.2	C	0.25	C	0.25	2,800	0.0050	0.042	C	0.042
1,3-Dichloropropene	6000/2000	1,400	290	NC	16	C	0.20	C	0.20	2,800		0.029	C	0.029
Dieldrin	6000/2000		39	C	0.86	C	0.15	C	0.15	0.20		0.00018	C	0.00018
Diethylphthalate	6000/2000	2,000	710,000	NC	390,000	NC	1,300	NC	1,300	1,100		82	NC	82
Dimethyl phthalate	6000/2000	1400	1,000,000	NC	1,000,000	NC	5,600	NC	1400	4300		1,000	NC	1000
2,4-Dimethylphenol[6]	6000/2000		18,000	NC	9,800	NC	25	NC	25	7,900		2.0	NC	2.0
2,4-Dinitrophenol[6]	6000/2000		1,800	NC	980	NC	0.82	NC	0.82	2,800		0.20	NC	0.20
Dinitrotoluene mixture	6000/2000		890	NC	20	C	0.028	C	0.028	180		0.0042	C	0.0042
Di-n-octyl phthalate	6000/2000	10,000	18,000	NC	9,800	NC	67,000	NC	2,000	0.020		2.0	NC	0.020
Endosulfan	6000/2000		5,300	NC	2,900	NC	46	NC	46	0.51		0.61	NC	0.51
Endrin	6000/2000		270	NC	150	NC	15	NC	15	0.25	0.0020	0.031	NC	0.031
Ethylbenzene	6000/2000	400	29,000	NC	6,800	NC	200	NC	200	170	0.70	10	NC	10
Fluoranthene	6000/2000		33,000	NC	16,000	NC	880	NC	880	0.21		4.1	NC	0.21
Fluorene	6000/2000		33,000	NC	16,000	NC	1,100	NC	1,100	2.0		4.1	NC	2.0
Heptachlor	6000/2000		91	C	1.2	C	36	C	1.2	0.18	0.00040	0.00064	C	0.00064
Heptachlor epoxide	6000/2000		12	NC	1.5	C	1.0	C	1.0	0.20	0.00020	0.00031	C	0.00031
Hexachlorobenzene	6000/2000		390	C	8.6	C	3.9	C	3.9	6.2	0.00100	0.0018	C	0.0018
Hexachloro-1,3-butadiene	6000/2000	1,000	180	NC	98	NC	44	C	44	3.2		0.020	NC	0.020
alpha-HCH(alpha-BHC)	6000/2000		120	C	4.0	C	0.024	C	0.024	2.0		0.00045	C	0.00045
beta-HCH(beta-BHC)	6000/2000		410	C	14	C	0.086	C	0.086	0.24		0.0016	C	0.0016
gamma-HCH(Lindane)	6000/2000		310	NC	19	C	0.10	C	0.10	6.8	0.00020	0.0022	C	0.0022
Hexachlorocyclopentadiene	6000/2000	2,200	6,200	NC	3,400	NC	5,700	NC	2,000	1.8	0.050	0.72	NC	0.72
Hexachloroethane	6000/2000		660	NC	240	NC	7.7	C	7.7	50		0.10	NC	0.10
Indeno(1,2,3-cd)pyrene	6000/2000		790	C	15	C	3.1	C	3.1	0.000022		0.0039	C	0.000022
Isophorone	6000/2000	4,600	180,000	NC	14,000	C	18	C	18	12,000		3.0	C	3.0
Lead[8,6]	10,000		970		1,300		230		230			0.042		0.042
Mercury[9]	10,000		270	NC	150	NC	32	NC	32		0.0020	0.031	NC	0.031
Methoxychlor	6000/2000		4,400	NC	2,500	NC	180	NC	180	0.045	0.040	0.51	NC	0.045
Methyl bromide	6000/2000	3,200	69	NC	13	NC	0.70	NC	0.70	15,000		0.14	NC	0.14
Methylene chloride	6000/2000	2,400	22,000	C	200	C	1.8	C	1.8	13,000	0.0050	0.38	C	0.38

Table A Default Closure Table - Industrial July 20, 2001

Constituent	Soil									Ground Water				
	Soil Attenuation Capacity mg/kg	Soil Saturation mg/kg	Construction (mg/kg)		Direct (mg/kg)		Migration to G W (mg/kg)		Default Closure Level (mg/kg)	Solubility (mg/l)	MCL (mg/l)	Industrial (mg/l)		Default Closure Level (mg/l)
Methyl ethyl ketone (MEK)	6000/2000	35,000	130,000	NC	28,000	NC	260	NC	260	270,000		61	NC	61
4-methyl-2-pentanone (MIBK)	6000/2000	4,100	7,200	NC	1,400	NC	39	NC	39	19,000		8.2	NC	8.2
2-Methylphenol(o-cresol) [6]	6000/2000		39,000	NC	17,000	NC	39	NC	39	26,000		5.1	NC	5.1
3-methylphenol (m-cresol) [6]	6000/2000	8,900	44,000	NC	25,000	NC	30	NC	30	23,000		5.1	NC	5.1
4-methylphenol (p-cresol) [6]	6000/2000		4,400	NC	2,500	NC	3.0	NC	3.0	22,000		0.51	NC	0.51
Methyl tertiary butyl ether (MTBE)	6000/2000	32,000	38,000	C	330	C	5.6	C	5.6	48,000		0.72	C	0.72
Naphthalene	6000/2000		17,000	NC	8,000	NC	170	NC	170	31		2.0	NC	2.0
Nickel[6]	10,000		23,000	NC	31,000	NC	2,700	C	2,700			2.0	NC	2.0
2-nitroaniline	6000/2000		51	NC	28	NC	0.029	NC	0.029	290		0.0058	NC	0.0058
Nitrobenzene	6000/2000	1,000	440	NC	250	NC	0.34	NC	0.34	2,100		0.051	NC	0.051
N-Nitrosodiphenylamine[6]	6000/2000		130,000	C	2,800	C	32	C	32	35		0.58	C	0.58
N-Nitrosodi-n-propylamine[5,6]	6000/2000		89	C	2.0	C	0.0020	C	0.0020	9,900		0.00041	C	0.00041
PCBs[11]	6000/2000		16	NC	5.3	C	18	C	5.3	0.70	0.00050	0.0014	C	0.0014
Pentachlorophenol[6]	6000/2000		3,800	C	54	C	0.66	C	0.66	2,000	0.00100	0.024	C	0.024
Phenol[6]	6000/2000		460,000	NC	190,000	NC	320	NC	320	83,000		61	NC	61
Pyrene	6000/2000		27,000	NC	15,000	NC	570	NC	570	0.14		3.1	NC	0.14
Selenium[6]	10,000		5,700	NC	7,800	NC	53	NC	53		0.050	0.51	NC	0.51
Silver[6]	10,000		5,700	NC	7,800	NC	87	NC	87			0.51	NC	0.51
Styrene	6000/2000	1,500	68,000	NC	16,000	NC	720	NC	720	310	0.100	20	NC	20
1,1,2,2-Tetrachloroethane	6000/2000	2,000	960	C	8.7	C	0.11	C	0.11	3,000		0.014	C	0.014
1,1,1,2-Tetrachloroethane	6000/2000	640	7900	C	63	C	0.79	C	0.79	1,100		0.11	C	0.11
Tetrachloroethylene (PCE)	6000/2000	230	4,200	NC	110	C	0.64	C	0.64	200	0.0050	0.055	C	0.055
Thallium[6]	10,000		100	NC	140	NC	13	NC	13		0.0020	0.0092	NC	0.0092
Toluene	6000/2000	650	11,000	NC	2,200	NC	240	NC	240	530	1.0	20	NC	20
Toxaphene	6000/2000		560	C	12	C	31	C	12	0.74	0.0030	0.0026	C	0.0030
1,2,4-Trichlorobenzene	6000/2000	3,200	8,900	NC	4,900	NC	77	NC	77	300	0.070	1.0	NC	1.0
1,1,1-Trichloroethane	6000/2000	1,200	11,000	NC	2,700	NC	35	NC	35	1,300	0.20	3.6	NC	3.6
1,1,2-Trichloroethane	6000/2000	1,800	600	NC	15	C	0.30	C	0.30	4,400	0.0050	0.050	C	0.050
Trichloroethylene (TCE)	6000/2000	1,300	500	NC	72	C	3.0	C	3.0	1,100	0.0050	0.26	C	0.26
2,4,5-Trichlorophenol[6]	6000/2000		89,000	NC	49,000	NC	690	NC	690	1,200		10	NC	10
2,4,6-Trichlorophenol[6]	6000/2000		57,000	C	1,300	C	5.0	C	5.0	800		0.26	C	0.26
Vinyl acetate	6000/2000	2,700	7,600	NC	1,400	NC	430	NC	430	20,000		100	NC	100
Vinyl chloride (chloroethene)	6000/2000	1,200	56	C	0.46	C	0.013	C	0.013	2,800	0.0020	0.0015	C	0.0020
Xylene mixed	6000/2000	410	34,000	NC	6,200	NC	3,400	NC	410	180	10	200	NC	180
Zinc[6]	10,000		340,000	NC	470,000	NC	38,000	NC	10,000			31	NC	31

Table A Footnotes

1. The default values for certain compounds may be listed as a carcinogen in one column and a non carcinogen in another column. This is the result of calculating both a carcinogenic and noncarcinogenic response for a given chemical and taking the lowest of the two. If a compound has a "C" next to the concentration, then the closure level is evaluated from a carcinogen endpoint, and the compound should be treated as a carcinogen when considering additivity. If a compound does not have a "C" next to the concentration, then the closure level is evaluated from a non-carcinogen endpoint, and the compound should be treated as noncarcinogenic when considering additivity.

2. Certain chemicals that are not liquid at normal soil temperature will not have C_{sat} values.

3. Soil direct contact values are based on the potential for soil-plant-human uptake.

4. Construction values are listed as the raw calculated values. When applying construction values to closures, care should be taken to recognize that values will be capped at the SAC value (defaulted at 6000 mg/kg and 10,000 mg/kg for organics and metals, respectively) or the C_{sat} whichever is less. Direct contact and Migration to ground water closure levels are listed as the raw calculated values. When applying these values separately to closure care should be taken to recognize that these values may be capped at the SAC (defaulted at 6000/2000 or 10,000 for organics and metals, respectively), the C_{sat} , or the construction value, whichever is less. Site specific values for SAC and Csat may be determined. The lesser of these values may then be used up to the raw calculated Construction or Direct/Migration values in these three columns. (note that non-default options also exist for changing the Direct/Migration columns See Chapter 7).

5. Acrolein, Bis(2-chloroethyl)ether, and N-Nitroso-di-n-propylamine may not have an analytical method available with a detection or quantitation limit able to meet the closure level for the matrix without modification. Appendix 2 should be consulted to verify analytical procedures.

6. Ionizing organics and metals Koc and Kd values will vary depending on pH. If the source area pH is outside of the range of 6.0-8.0 then see the discussion in Section A1.0, under "Table A", pages A.1-1 and A.1-2.

7. Under certain circumstances a "trihalomethane" standard may apply to bromoform, chloroform, and bromodichloromethane. The composite standard may reduce the closure level.

8. Lead values were calculated using the:

   1994 Integrated Exposure Uptake Biokinetic Model (see EPA/540/R-93/081, PB-963510) for residential exposures;

   The Methodology for Assessing Risks Associated with Adult Exposures to Lead

in Soil, SRC-GLD-FO162-209-DRAFT-7/21/96, and;

Review of A Methodology for Establishing Risk-Based Soil Remediation Goals for Commercial Areas of the California Gultch Site, USEPA, Technical Review Workgroup for Lead, October 26, 1995 for industrial and construction exposures, and;

The Drinking Water Regulation and Health Advisories EPA 822-R-96-001, February, 1996 action levels for residential ground water, and an extrapolation to determine industrial ground water levels.

The Kd value for lead was taken from Sheppard and Thibault (Default Soil Solid Liquid Partition Coefficients , Kds for Four Major Soil Types: A Compendium, Health Physics Vol 59, No. 4, pp 471-482, 1990) for sandy soils and is considered to be applicable anywhere in the state. IDEM recommends site specific determinations and/or use of the Synthetic Precipitation Leaching Procedure (SPLP) for lead (see section 7.1.1).

9. Closure levels for beryllium and mercury must be determined with a site specific pH. See discussion in section A1.0 under Table A, pages A.1-1 and A.1-2.

10. Benzene values may soon change. IRIS has listed the slope factor for this compound as a range and IDEM is currently determining the application to closure levels

11. PCBs are assumed to be a mixture and that Aroclor 1016 and 1254 are present.

12. Chromium VI should be used to represent total chromium unless a species specific ratio evaluation is made.

13. Cyanide values apply to free cyanide only. The closure levels are not applicable to copper cyanide or other complexed cyanides. Total cyanides may not be representative of free cyanide.

14. The SAC value of 10,000 mg/kg for metals is a ceiling value that addresses the potential for a high level of one chemical to impact multiple chemical exposure in such a way that the combined effect is likely to be greater than the sum of the individual effects.

15. Table A lists default closure levels for individual chemicals only. Additivity or the potential for combined effects of multiple chemical exposure should be evaluated when there is more than one chemical present (see section 6.1 Chemical of Concern Additivity)

TABLE B

Chemical/Physical Properties

Contaminant	Di,a cm^2/s	Di,w cm^2/s	Koc l/kg	K_D (Inorganic) l/kg	H' unitless	ABS unitless	S mg/l	MCL mg/l	MP ^oC	BP ^oC	MW g/mol
Acenaphthene	4.21e-02	7.69e-06	7.08e+03		6.36e-03	1.30e-01	4.24e+00		93	279	154
Acetone (2-Propanone)	1.24e-01	1.14e-05	5.75e-01		1.59e-03	1.00e-01	1.00e+06		-95	56.5	58.1
Acrolein	1.10e-01	1.20e-05	1.18e+00		4.90e-03	1.00e-01	2.60e+05		-88	53	56.1
Aldrin	1.32e-02	4.86e-06	2.45e+06		6.97e-03	1.00e-01	1.30e-01		104	145	364.9
Anthracene	3.24e-02	7.74e-06	2.95e+04		2.67e-03	1.30e-01	4.34e-02		215	340	178
Antimony				4.50e+01		1.00e-02		6.00e-03	630	1750	121.8
Arsenic				2.90e+01		3.00e-02		5.00e-02	817	615	74.9
Barium				4.10e+01		1.00e-02		2.00e+00	725	1640	182.2
Benz(a)anthracene	5.10e-02	9.00e-06	3.98e+05		1.37e-04	1.30e-01	9.40e-03		84	438	228.3
Benzene	8.80e-02	9.80e-06	5.89e+01		2.28e-01	1.00e-01	1.75e+03	5.00e-03	5.5	80.1	78.1
Benzo(b)fluoranthene	2.26e-02	5.56e-06	1.23e+06		4.55e-03	1.30e-01	1.50e-03		168	357	252.3
Benzo(k)fluoranthene	2.26e-02	5.56e-06	1.23e+06		3.40e-05	1.30e-01	8.00e-04		217	480	252.3
Benzoic acid	5.36e-02	7.97e-06	6.00e-01		6.31e-05	1.00e-01	3.50e+03		122	249.2	122
Benzo(a)pyrene	4.30e-02	9.00e-06	1.02e+06		4.63e-05	1.30e-01	1.62e-03	2.00e-04	177	495	252.3
Benzyl Alcohol	8.00e-02	8.00e-06	1.02e+01		1.38e-05	1.00e-01	4.00e+04		-15.2	205.3	108.1
Beryllium				7.90e+02		1.00e-02		4.00e-03	1278	2970	9
Bis(2-Chloroethyl)ether	6.92e-02	7.53e-06	1.55e+01		7.38e-04	1.00e-01	1.72e+04		-52	178	143.01
Bis(2-chloroisopropyl)ether	6.30e-02	6.40e-06	6.10e+01		4.60e-03	1.00e-01	1.70e+03		-97	187	171
Bis(2-ethylhexyl)phthalate	3.51e-02	3.66e-06	1.51e+07		4.18e-06	1.00e-01	3.40e-01	6.00e-03	-55	384	390.6

Contaminant	Di,a cm^2/s	Di,w cm^2/s	Koc l/kg	K_D (Inorganic) l/kg	H' unitless	ABS unitless	S mg/l	MCL mg/l	MP ^oC	BP ^oC	MW g/mol
Bromodichloromethane	2.98e-02	1.06e-05	5.50e+01		6.56e-02	1.00e-01	6.74e+03	1.00e-01	-57	90	163.8
Bromoform(tribromomethane)	1.49e-02	1.03e-05	8.71e+01		2.19e-02	1.00e-01	3.10e+03	1.00e-01	8	149	252.8
Butanol	8.00e-02	9.30e-06	6.92e+00		3.61e-04	1.00e-01	7.40e+04		-89.8	115	74.1
Butlybenzylphthalate	1.74e-02	4.83e-06	5.75e+04		5.17e-05	1.00e-01	2.69e+00		-35	370	312.4
Cadmium				7.50e+01		1.00e-02		5.00e-03	321	765	112.4
Carbazole	3.90e-02	7.03e-06	3.39e+03		6.26e-07	1.00e-01	7.48e+00		246.2	355	167.2
Carbon disulfide	1.04e-01	1.00e-05	4.57e+01		1.24e+00	1.00e-01	1.19e+03		-115	46.5	76.1
Carbon tetrachloride	7.80e-02	8.80e-06	1.74e+02		1.25e+00	1.00e-01	7.93e+02	5.00e-03	-23	76.7	153.9
Chlordane	1.18e-02	4.37e-06	1.20e+05		1.99e-03	4.00e-02	5.60e-02	2.00e-03	106	175	409.8
p-Chloroaniline	4.83e-02	1.01e-05	6.61e+01		1.36e-05	1.00e-01	5.30e+03		72.5	232	
Chlorobenzene	7.30e-02	8.70e-06	2.19e+02		1.52e-01	1.00e-01	4.72e+02	1.00e-01	-45.2	131.5	112.6
Chloroform	1.04e-01	1.00e-05	3.98e+01		1.50e-01	1.00e-01	7.92e+03	1.00e-01	-63.6	61.5	119.4
Chloroethane	1.00e-01	1.00e-05	1.54e+01		3.60e-01	1.00e-01	5.70e+03		-138.7	12.3	64.5
2-Chlorophenol	5.01e-02	9.46e-06	3.88e+02		1.60e-02	1.00e-01	2.20e+04		9.8	175	128.6
Chromium VI				1.90e+01		1.00e-02		1.00e-01	1900	2642	52
Chromium III				1.80e+06	---	1.00e-02		1.00e-01	1900	2642	52
Chrysene	2.48e-02	6.21e-06	3.98e+05		3.88e-03	1.30e-01	1.60e-03		258.2	448	228.3
Copper				2.22e+01		1.00e-02		1.30e+00	1083	2595	79.5
Cyanide, Free[1]	1.80e-01	2.00e-05		9.90e+00	5.31e-06	1.00e-01	1.00e+06		-13.4	-201	27

Contaminant	Di,a cm^2/s	Di,w cm^2/s	Koc l/kg	K_D (Inorganic) l/kg	H' unitless	ABS unitless	S mg/l	MCL mg/l	MP ^oC	BP ^oC	MW g/mol
DDD	1.69e-02	4.76e-06	1.00e+06		1.64e-04	3.00e-02	9.00e-02		109.5	193	320
DDE	1.44e-02	5.87e-06	4.47e+06		8.61e-04	3.00e-02	1.20e-01		89	316	518
DDT	1.37e-02	4.95e-06	2.63e+06		3.32e-04	3.00e-02	2.50e-02		108.5	260	354.5
Dibenzo(a,h)anthracene	2.02e-02	5.18e-06	3.80e+06		6.03e-07	1.30e-01	2.49e-03		269.5	524	278.4
Di-n-butylphthalate	4.38e-02	7.86e-06	3.39e+04		3.85e-08	1.00e-01	1.12e+01		-35	340	278.3
1,2-Dichlorobenzene	6.90e-02	7.90e-06	6.17e+02		7.79e-02	1.00e-01	1.56e+02	6.00e-01	-16.7	180.5	147
1,3-Dichlorobenzene	6.90e-02	7.90e-06	3.80e+02		1.29e-01	1.00e-01	1.30e+02		-25	173	147
1,4-Dichlorobenzene	6.90e-02	7.90e-06	6.17e+02		9.96e-02	1.00e-01	7.38e+01	7.50e-02	52.7	174	147
3,3-Dichlorobenzidine	1.94e-02	6.74e-06	7.24e+02		1.64e-07	1.00e-01	3.11e+00		132.5	368	253.1
1,1-Dichloroethane	7.42e-02	1.05e-05	3.16e+01		2.30e-01	1.00e-01	5.06e+03		-96.9	57.3	99
1,2-Dichloroethane	1.04e-01	9.90e-06	1.74e+01		4.01e-02	1.00e-01	8.52e+03	5.00e-03	-35.5	83.5	99
1,1-Dichloroethylene	9.00e-02	1.04e-05	5.89e+01		1.07e+00	1.00e-01	2.25e+03	7.00e-03	-122.5	31.7	97
cis-1,2-Dichloroethylene	7.36e-02	1.13e-05	3.55e+01		1.67e-01	1.00e-01	3.50e+03	7.00e-02	-80	60	97
trans-1,2-Dichloroethylene	7.07e-02	1.19e-05	5.25e+01		3.85e-01	1.00e-01	6.30e+03	1.00e-01	-49.8	49	97
2,4-Dichlorophenol	3.46e-02	8.77e-06	1.47e+02		1.30e-04	1.00e-01	4.50e+03		45	210	163
1,2-Dichloropropane	7.82e-02	8.73e-06	4.37e+01		1.15e-01	1.00e-01	2.80e+03	5.00e-03	-70	96.37	111
1,3-Dichloropropene	6.26e-02	1.00e-05	4.57e+01		7.26e-01	1.00e-01	2.80e+03		-60	108	110
Dieldrin	1.25e-02	4.74e-06	2.14e+04		6.19e-04	1.00e-01	1.95e-01		175.5	385	380.9
Diethylphthalate	2.56e-02	6.35e-06	2.88e+02		1.85e-05	1.00e-01	1.08e+03		-40.5	295	222.3

Contaminant	Di,a cm^2/s	Di,w cm^2/s	Koc l/kg	K_D (Inorganic) l/kg	H' unitless	ABS unitless	S mg/l	MCL mg/l	MP ^oC	BP ^oC	MW g/mol
Dimethylphthalate	6.70e-02	6.30e-06	3.70e+01		2.40e-05	1.00e-01	4.30e-03		5.5	283.7	194.2
2,4-Dimethylphenol	5.84e-02	8.69e-06	2.09e+02		8.20e-05	1.00e-01	7.87e+03		24.5	211	122.2
2,4-Dinitrophenol	2.73e-02	9.06e-06	1.00e-02		1.82e-05	1.00e-01	2.79e+03		116	>200	184
Dinitrotoluene mixture	1.18e-01	7.26e-06	6.92e+01		3.06e-05	1.00e-01	1.82e+02		71	300	182.2
Di-n-octyl phthalate	1.51e-02	3.58e-06	8.32e+07		2.74e-03	1.00e-01	2.00e-02		-30	220	390
Endosulfan	1.15e-02	4.55e-06	2.14e+03		4.59e-04	1.00e-01	5.10e-01		106	>200	406.9
Endrin	1.25e-02	4.74e-06	1.23e+04		3.08e-04	1.00e-01	2.50e-01	2.00e-03	200	245	380.9
Ethylbenzene	7.50e-02	7.80e-06	3.63e+02		3.23e-01	1.00e-01	1.69e+02	7.00e-01	-94.9	136.5	106.2
Fluoranthene	3.02e-02	6.35e-06	1.07e+05		6.60e-04	1.30e-01	2.06e-01		107.8	384	202.4
Fluorene	3.63e-02	7.88e-06	1.38e+04		2.61e-03	1.30e-01	1.98e+00		114.8	295	166.2
Heptachlor	1.12e-02	5.69e-06	1.41e+06		6.07e+01	1.00e-01	1.80e-01	4.00e-04	95.5	135	373.4
Heptachlor epoxide	1.32e-02	4.23e-06	8.32e+04		3.90e-04	1.00e-01	2.00e-01	2.00e-04	160	200	389.3
Hexachlorobenzene	5.42e-02	5.91e-06	5.50e+04		5.41e-02	1.00e-01	6.20e+00	1.00e-03	231.8	325	284.7
Hexachloro-1,3-butadiene	5.61e-02	6.16e-06	5.37e+04		3.34e-01	1.00e-01	3.23e+00		-21	215	260.7
alpha-HCH(alpha-BHC)	1.42e-02	7.34e-06	1.23e+03		4.35e-04	4.00e-02	2.00e+00		160	288	290.8
beta-HCH(beta-BHC)	1.42e-02	7.34e-06	1.26e+03		3.05e-05	4.00e-02	2.40e-01		315	600	290.8
gamma-HCH(Lindane)	1.42e-02	7.34e-06	1.07e+03		5.74e-04	4.00e-02	6.80e+00	2.00e-04	112.5	323	290.4
Hexachlorocyclopentadiene	1.61e-02	7.21e-06	2.00e+05		1.11e+00	1.00e-01	1.80e+00	5.00e-02	-9	239	272.8
Hexachloroethane	2.50e-03	6.80e-06	1.78e+03		1.59e-01	1.00e-01	5.00e+01		187	189	236.7

Contaminant	Di,a cm^2/s	Di,w cm^2/s	Koc l/kg	K_D (Inorganic) l/kg	H' unitless	ABS unitless	S mg/l	MCL mg/l	MP ^oC	BP ^oC	MW g/mol
Indeno(1,2,3-cd)pyrene	1.90e-02	5.66e-06	3.47e+06		6.56e-05	1.30e-01	2.20e-05		161.5	536	236.7
Isophorone	6.23e-02	6.76e-06	4.68e+01		2.72e-04	1.00e-01	1.20e+04		-8.1	215.3	138.2
Mercury	3.07e-02	6.30e-06		5.20e+01	4.50e-01	1.00e-01		2.00e-03	-38.87	357	200.6
Methoxychlor	1.56e-02	4.46e-06	9.77e+04		6.48e-04	1.00e-01	4.50e-02	4.00e-02	87	346	345.7
Methyl bromide	7.28e-02	1.21e-05	1.05e+01		2.56e-01	1.00e-01	1.52e+04		-93.7	3.56	95
Methylene chloride	1.01e-01	1.17e-05	1.17e+01		8.98e-02	1.00e-01	1.30e+04	5.00e-03	-95.1	39.75	84.9
Methyl ethyl ketone (MEK)	9.00e-02	9.80e-06	5.00e+00		1.00e-03	1.00e-01	2.70e+05		-86	80	72
2-Methylphenol(o-cresol)	7.40e-02	8.30e-06	9.12e+01		4.92e-05	1.00e-01	2.60e+04		29.8	191	108.1
4-methyl-2-pentanone	7.50e-02	7.80e-06	1.90e+01		5.64e-03	1.00e-01	1.90e+04		-80	117.4	100.2
3-methylphenol	7.40e-02	1.00e-05	4.78e+01		3.52e-05	1.00e-01	2.30e+04		11.8	202.2	108.1
4-methylphenol	7.40e-02	1.00e-05	4.61e+01		3.23e-05	1.00e-01	2.20e+04		35.5	201.9	108.1
MTBE	0.08	0.000008	94.4		0.0241	0.1	48000		-109	55.2	88.15
Naphthalene	5.90e-02	7.50e-06	2.00e+03		1.98e-02	1.30e-01	3.10e+01		80.2	218	128.2
Nickel				6.50e+01		1.00e-02			1455	2730	58.7
2-nitroaniline	7.40e-02	1.00e-05	3.93e+02		2.41e-06	1.00e-01	2.90e+02		71.2	284	138.1
Nitrobenzene	7.60e-02	8.60e-06	6.46e+01		9.84e-04	1.00e-01	2.09e+03		5.7	211	123.1
N-Nitrosodiphenylamine	3.12e-02	6.35e-06	1.29e+03		2.05e-04	1.00e-01	3.51e+01		66.5	268	74.1
N-Nitrosodi-n-propylamine	5.45e-02	8.17e-06	2.40e+01		9.23e-05	1.00e-01	9.89e+03		>24	206	130.22
PCBs	8.00e-02	8.00e-06	3.09e+05		1.06e-01	1.40e-01	7.00e-01	5.00e-04	>24	>200	268.4

Contaminant	Di,a cm^2/s	Di,w cm^2/s	Koc l/kg	K_D (Inorganic) l/kg	H' unitless	ABS unitless	S mg/l	MCL mg/l	MP ^oC	BP ^oC	MW g/mol
Pentachlorophenol	5.60e-02	6.10e-06	5.92e+02		1.00e-06	2.50e-01	1.95e+03	1.00e-03	174	310	266.4
Phenol	8.20e-02	9.10e-06	2.88e+01		1.63e-05	1.00e-01	8.28e+04		40.9	182	94.1
Pyrene	2.72e-02	7.24e-06	1.05e+05		4.51e-04	1.00e-01	1.35e-01		151.2	404	202.3
Selenium				5.00e+00		1.00e-02		5.00e-02	217	684	79
Silver				8.30e+00		1.00e-02			962	2212	107.9
Styrene	7.10e-02	8.00e-06	7.76e+02		1.13e-01	1.00e-01	3.10e+02	1.00e-01	-31	146	104.2
1,1,2,2-Tetrachloroethane	7.10e-02	7.90e-06	9.33e+01		1.41e-02	1.00e-01	2.97e+03		-43.8	146.5	167.9
1,1,1,2-Tetrachloroethane	7.10e-02	7.90e-06	8.00e+01		1.41e-02	1.00e-01	1.10e+03		-70	130.5	167.9
Tetrachloroethylene (PCE)	7.20e-02	8.20e-06	1.55e+02		7.54e-01	1.00e-01	2.00e+02	5.00e-03	-22.3	121	165.8
Thallium				7.10e+01		1.00e-02		2.00e-03	303.5	1457	204.4
Toluene	8.70e-02	8.60e-06	1.82e+02		2.72e-01	1.00e-01	5.26e+02	1.00e+00	-94.9	110.6	92.1
Toxaphene	1.16e-02	4.34e-06	2.57e+05		2.46e-04	1.00e-01	7.40e-01	3.00e-03	78	NA	181.4
1,2,4-Trichlorobenzene	3.00e-02	8.23e-06	1.78e+03		5.82e-02	1.00e-01	3.00e+02	7.00e-02	17	213	181.4
1,1,1-Trichloroethane	7.80e-02	8.80e-06	1.10e+02		7.05e-01	1.00e-01	1.33e+03	2.00e-01	-30.4	74.1	133.4
1,1,2-Trichloroethane	7.80e-02	8.80e-06	5.01e+01		3.74e-02	1.00e-01	4.42e+03	5.00e-03	-36.6	114	133.4
Trichloroethylene (TCE)	7.90e-02	9.10e-06	1.66e+02		4.22e-01	1.00e-01	1.10e+03	5.00e-03	-84.7	86.7	131.4
2,4,5-Trichlorophenol	2.91e-02	7.03e-06	1.60e+03		1.78e-04	1.00e-01	1.20e+03		69	253	197.5
2,4,6-Trichlorophenol	3.18e-02	6.25e-06	3.81e+02		3.19e-04	1.00e-01	8.00e+02		69	247	197.5
Vinyl acetate	8.50e-02	9.20e-06	5.25e+00		2.10e-02	1.00e-01	2.00e+04		-93.2	72.7	86.1

Contaminant	Di,a cm^2/s	Di,w cm^2/s	Koc l/kg	K_D (Inorganic) l/kg	H' unitless	ABS unitless	S mg/l	MCL mg/l	MP ^oC	BP ^oC	MW g/mol
Vinyl chloride (chloroethene)	1.06e-01	1.23e-06	1.86e+01		1.11e+00	1.00e-01	2.76e+03	2.00e-03	-153.7	-13	62.5
Xylene mixed	8.70e-02	1.00e-05	3.63e+02		2.13e-01	1.00e-01	1.78e+02	1.00e+01	-37	141	106.2
Zinc				6.20e+01		1.00e-02			419.5	908	65.4

Above parameters are listed for 25°C and 760 mm Hg.
Footnotes

1. Cyanide as CN- is assumed to be non-volatile as it is in pH 6.8 soil and nonacidic water.

Key of terms
Di,a-diffusivity in air
Di,w-diffusivity in water
Koc-soil organic carbon-water partitioning coefficient
Kd-soil-water partition coefficient
H'-Dimensionless Henry's Law constant (a measure of the affinity of a compound to volatilize from water)
ABS-fraction absorbed through skin
S-water solubility
MCL-Safe Drinking Water Act maximum contaminat level
MP-melting point
BP- boiling point
MW- molecular weight

Table C

Exposure Equations

Equation Number	Equation Name	Table C - Exposure Equations
A1-1	Residential Groundwater (Carcinogens)	$C_{gwrc} = \frac{TR \times BW_a \times AT_c \times 365\ {}^{day}/_{year}}{EF_r \times ED_r \times [(SF_o \times IngR_{raw}) + (SF_i \times InhR_{raa} \times K)]}$
A1-2	Residential Groundwater (Non-carcinogens)	$C_{gwrn} = \frac{THQ \times BW_a \times AT_n \times 365\ {}^{days}/_{year}}{EF_r \times ED_r \left[\left(\frac{IngR_{raw}}{RFD_o}\right) + \left(\frac{InhR_{raa}}{RFD_i} \times K\right)\right]}$
A1-3	Residential Soil Direct Contact (Carcinogens)	$C_{ssrc} = \frac{TR \times AT_c \times 365\ {}^{days}/_{year}}{EF_r \left[\frac{SF_o\left(IngF_{adj} + \left(SFS_{adj} \times ABS\right)\right)}{10^6\ {}^{mg}/_{kg}} + InhF_{adj} \times SF_i\left(\frac{1}{VF} + \frac{1}{PEF}\right)\right]}$
A 1-4	Residential Direct Contact (Non-carcinogens)	$C_{ssrn} = \frac{THQ \times AT_n \times 365\ {}^{days}/_{year}}{EF_r \left[\left(\frac{IngF_{adj} + (SFS_{adj} \times ABS)}{RFD_o \times 10^6\ {}^{mg}/_{kg}}\right) + \frac{InhF_{adj}}{RFD_i}\left(\frac{1}{VF} + \frac{1}{PEF}\right)\right]}$
A 1-5	Residential Soil Migration to GW (Carcinogens)	$C_{sbsrc} = C_{gwrc} \times 20\left[K_d + \frac{\theta_{w\rho} + (\theta_{a\rho} \times H')}{\rho_b}\right]$

Equation Number	Equation Name	Table C - Exposure Equations
A 1-6	Residential Soil Migration to GW (Non-carcinogens)	$C_{sbsrn} = C_{gwrn} \times 20\left[K_d + \frac{\theta_{w\rho} + (\theta_{a\rho} \times H')}{\rho_b}\right]$
A 1-7	Commercial / Industrial Groundwater (Carcinogens)	$C_{gwic} = \frac{TR \times BW_a \times AT_c \times 365\ {}^{days}/_{year}}{EF_i \times ED_i \times (SF_o \times IngR_{iaw})}$
A 1-8	Commercial/ Industrial Groundwater (Non-carcinogens)	$C_{gwin} = \frac{THQ \times BW_a \times AT_n \times 365\ {}^{days}/_{year}}{EF_i \times ED_i\left(\frac{IngR_{iaw}}{RFD_o}\right)}$
A 1-9	Commercial/Industrial Soil Direct Contact (Carcinogens)	$C_{ssic} = \frac{TR \times BW_a \times AT_c \times 365\ {}^{days}/_{year}}{EF_i \times ED_i\left[SF_o \times \left(\frac{IngR_{ias} + (SA_{ias} \times M \times ABS)}{10^6\ {}^{mg}/_{kg}}\right) + SF_i \times InhR_{iaa}\left(\frac{1}{VF} + \frac{1}{PEF}\right)\right]}$
A1-10	Commercial/ Industrial Soil Direct Contact (Non-carcinogens)	$C_{ssin} = \frac{THQ \times BW_a \times AT_n \times 365\ {}^{days}/_{year}}{EF_i \times ED_i\left[\frac{(IngR_{ias} + (SA_{ias} \times M \times ABS))}{RFD_o\left(10^6\ {}^{mg}/_{kg}\right)} + \frac{InhR_{iaa}}{RFD_i}\left(\frac{1}{VF} + \frac{1}{PEF}\right)\right]}$

Equation Number	Equation Name	Table C - Exposure Equations
A1-11	Commercial/ Industrial Soil Migration to GW (Carcinogens)	$C_{sbsic} = C_{gwic} \times 20\left[K_d + \frac{\theta_{w\rho} + (\theta_{a\rho} \times H')}{\rho_b}\right]$
A 1-12	Commercial/Industrial Migration to GW Contact (Non-carcinogens)	$C_{sbsin} = C_{gwin} \times 20\left[K_d + \frac{\theta_{w\rho} + (\theta_{a\rho} \times H')}{\rho_b}\right]$
A 1-13	Construction Soils (Carcinogens)	$C_{sscc} = \frac{TR \times BW_a \times AT_c \times 365\ {}^{days}/_{year}}{EF_{co} \times ED_{co}\left[SF_o \times \frac{(IngR_{cas} + (SA_{cas} \times M \times ABS))}{10^6\ {}^{mg}/_{kg}} + SF_i \times InhR_{caa}\left[\frac{1}{VF} + \frac{1}{PEF}\right]\right]}$
A 1-14	Construction Soils (Non-carcinogens)	$C_{sscn} = \frac{THQ \times BW_a \times AT_n \times 365\ {}^{days}/_{year}}{ED_{co} \times EF_{co}\left[\frac{(IngR_{cas} + (SA_{cas} \times M \times ABS))}{RFD_o\left(10^6\ {}^{mg}/_{kg}\right)} + \frac{InhR_{caa}}{RFD_i}\left[\frac{1}{VF} + \frac{1}{PEF}\right]\right]}$

Equation Number	Equation Name	Table C - Exposure Equations
A 1-15	Volatilization Factor	$VF = \dfrac{\dfrac{Q}{C_{vf}} \times (3.14 \times D_a \times T)^{\frac{1}{2}} \times 10^{-4}\ {}^{m^2}/_{cm^2}}{(2 \times \rho_b \times D_a)}$ Where: $D_a = \dfrac{\left[\dfrac{\left(\theta_{avf}{}^{10/3} D_i H' + \theta_{wvf}{}^{10/3} D_w\right)}{n^2}\right]}{\rho_b K_d + \theta_{wvf} + \theta_{avf} H'}$
A 1-16	Particulate Emission Factor Equation	$PEF = {}^{Q}/_{C_\rho} \times \left[\dfrac{3{,}600\ s/h}{0.036 \times (1 - V) \times \left(\dfrac{U_m}{U_t}\right)^3 \times F(x)}\right]$
A 1-17	Ingestion Soil - Age Adjusted	$IngF_{adj}\ \dfrac{mg\text{-}yr}{Kg\text{-}day} = \dfrac{ED_{ch} \times IngR_{rcs}}{BW_c} + \dfrac{(ED_r - ED_{ch}) \times IngR_{ras}}{BW_a}$
A 1-18	Skin Contact - Age Adjusted	$SFS_{adj}\ \dfrac{mg\text{-}yr}{Kg\text{-}day} = \dfrac{ED_{ch} \times M \times SA_{rcs}}{BW_c} + \dfrac{(ED_r - ED_{ch}) \times M \times SA_{ras}}{BW_a}$

Equation Number	Equation Name	Table C - Exposure Equations
A 1-19	Inhalation - Age Adjusted	$\mathrm{InhF_{adj}}\ \frac{\mathrm{M^3\text{-}yr}}{\mathrm{Kg\text{-}day}} = \frac{\mathrm{ED_{ch}} \times \mathrm{InhR_{rca}}}{\mathrm{BW_c}} + \frac{(\mathrm{ED_r} - \mathrm{ED_{ch}}) \times \mathrm{InhR_{raa}}}{\mathrm{BW_a}}$
7-1	Soil to Groundwater Partitioning Model	$\mathrm{CCL} = \mathrm{C_w} \times DAF \times \left[K_\mathrm{d} + \frac{\theta_\mathrm{w} + \theta_\mathrm{a} H'}{\rho_\mathrm{b}} \right]$
7-3	Soil Saturation Limit Equation	$C_\mathrm{sat} = \frac{S}{\rho_\mathrm{b}} (K_\mathrm{d} \rho_\mathrm{b} + \theta_\mathrm{w} + H' \theta_\mathrm{a})$
7-4	Soil Attenuation Capacity	Site Specific Soil Attenuation Capacity = f_{oc} X 10^6

TABLE D

Equation Parameters/Exposure Assumptions

Symbol	Parameter	Value
θ_{ap}	Air Filled Soil Porosity Partitioning model	0.134 l air/l soil
θ_{avf}	Air Filled Soil Porosity - volatilization	0.284 l air /l soil
θ_{wp}	Water Filled Soil Porosity Partitioning model	0.3 l water/l soil
θ_{wvf}	Water Filled Soil Porosity - volatilization	0.15 l water /l soil
ABS	Skin Absorbance Factor (Absorbed fraction)	Chemical Specific (unitless see Table B)
AT_c AT_n	Averaging Time (subscript dictates chemical type)	C = 70 Years carcinogens N = 30 Years residential non-carcinogens 25 years industrial noncarcinogens 1 year construction noncarcinogens
BW_a	Body Weight Adult	70 kg
BW_c	Body Weight Child	15 kg
C	Carcinogen	Chemical Specific
CCL	Carcinogen Closure Level	Chemical Specific
C_{gwrc}	Default Level Groundwater Concentration for Residential Carcinogen	Chemical Specific (mg/l)
C_{gwrn}	Default Level Groundwater Concentration for Residential Non-carcinogen	Chemical Specific (mg/l)
C_{igwc}	Default Level Commercial/Industrial Groundwater Concentration for Carcinogen	Chemical Specific mg/l
C_{igwn}	Default Level Commercial/Industrial Groundwater Concentration for Non-carcinogen	Chemical Specific mg/l
C_{sat}	Soil Saturation Limit	Chemical Specific (mg/kg)
C_{sbrsc}	Subsurface Soil Residential Carcinogen	Chemical Specific (mg/kg)
C_{sbrsn}	Subsurface Soil Residential Non-carcinogen	Chemical Specific (mg/kg)
C_{sbsic}	Default Closure Level Subsurface Soil Commercial/Industrial Carcinogen	Chemical Specific (mg/kg)

Symbol	Parameter	Value
C_{sbsin}	Default Closure Level Subsurface Soil Commercial/Industrial Non-carcinogen	Chemical Specific (mg/kg)
C_{scc}	Default Closure Level Soil Concentration Construction Carcinogenic	Chemical specific (mg/kg)
C_{scn}	Default Closure Level Soil Concentration Construction Non-carcinogenic	Chemical specific (mg/kg)
C_{ssic}	Default Closure Level Surface Soil Commercial/Industrial Carcinogen	Chemical Specific (mg/kg)
C_{ssin}	Default Closure Level Surface Soil Commercial/Industrial Non-carcinogen	Chemical Specific (mg/kg)
C_{ssrc}	Default Closure Level Residential Surface Soil Concentration Carcinogenic (direct contact)	Chemical specific (mg/kg)
C_{ssrn}	Default Closure Level Residential Surface Soil Concentration Non-carcinogenic (direct contact)	Chemical specific (mg/kg)
D_a	Apparent Diffusivity	Chemical Specific cm^2/s
D_i	Diffusivity in Air	Chemical Specific cm^2/s
D_w	Diffusivity in Water	Chemical Specific cm^2/s
ED_{ch}	Exposure Duration Child	6 years
ED_{co}	Exposure Duration Construction	1 year
ED_i	Exposure Duration Commercial/Industrial	25 years
ED_r	Exposure Duration Residential	30 years
EF_{co}	Exposure Frequency Construction	45 days
EF_i	Exposure Frequency Commercial/Industrial	250 days/yr
EF_r	Exposure Frequency Residential	350 days/year
EF_{rs}	Exposure Frequency Residential Soil	250 days/year
F(x)	Function dependent on U_m/U_t	0.194 (unitless)
f_{oc}	Fraction Soil Organic Carbon (Fraction)	0.002 for subsurface soil 0.006 for surface soil

Symbol	Parameter	Value
H'	Henry's Law Constant x 41	Chemical Specific (unitless)
$IngF_{adj}$	Ingestion Factor Soil Age Adjusted	114 mg-yr/kg-day
$IngR_{cas}$	Ingestion Rate Construction Adult Soil	480 mg/day
$IngR_{ias}$	Ingestion Rate Commercial/Industrial Adult Soil	50 mg/day
$IngR_{iaw}$	Ingestion Rate Commercial/Industrial Adult Water	1.0 l/day
$IngR_{ras}$	Ingestion Rate Residential Adult Soil	100 mg/day
$IngR_{raw}$	Ingestion Rate Residential Adult Water	2.0 1/day
$IngR_{rcs}$	Ingestion Rate Residential Child Soil	200 mg/day
$InhF_{adj}$	Inhalation Factor Age Adjusted	10.9 m^3-yr/kg-day
$InhR_{caa}$	Inhalation Rate Construction Adult Air	20 m^3/day
$InhR_{iaa}$	Inhalation Rate Commercial/Industrial Adult Air	20 m^3/day
$InhR_{raa}$	Inhalation Rate Residential Adult Air	15 m^3/day Indoor 20 m^3/day Outdoor
$InhR_{rca}$	Inhalation Rate Residential Child Air	10 m^3/day
K	Indoor Volatilization Factor (Inhalation from volatiles in groundwater)	0.5 (unitless)
K_d	Soil/Water Partition Coefficient(See Table B) K_d = Table Values for Metals(See Table B) $K_d = K_{oc} \times f_{oc}$ for Organics(See Table B)	Chemical Specific (l/kg) Chemical Specific (l/kg) Chemical Specific (l/kg)
K_{oc}	Soil Organic Carbon/Water Partition Coefficient(See Table B)	Chemical Specific (l/kg)
l	Length of sampling interval	site specific
M	Soil to Skin Adherence Factor	0.5 mg/cm^2-day
n	Number of site samples	Chemical Specific
NC	Non-carcinogen	Chemical Specific
NCL	Non-carcinogen Closure Level	Chemical Specific

Symbol	Parameter	Value
P_b	Dry Soil Bulk Density	1.5 kg/l
PEF	Particulate Emission Factor (See Table C)	1.316×10^9 m^3/kg
P_s	Soil particle density	2.65 g/cm^3
Q/C_{vf}	Inverse of the mean concentration at the center of a 0.5 acre source - volatilization factor	$\frac{68.81\ g/m^2\text{-}s}{kg/m^3}$
Q/C_p	Inverse of the mean concentration at the center of a 0.5 acre source - particulates	$\frac{90.80\ g/m^2\text{-}Sec}{kg/m^3}$
RFD_i	Reference Dose Inhalation	Chemical Specific (mg/Kg - day)
RFD_o	Reference Dose Oral	Chemical Specific (mg/Kg - day)
s	Standard deviation of site sample set	Chemical Specific
S	Solubility in Water	Chemical Specific (mg/l-water)
SA_{cas}	Surface Area Construction Exposed Adult Skin	3160 cm^2
SA_{ias}	Surface Area Commercial/Industrial Exposed Adult Skin	3160 cm^2
SA_{ras}	Surface Area Residential Exposed Adult Skin	5000 cm^2
SA_{rcs}	Surface Area Residential Exposed Child Skin	2000 cm^2
SF_i	Carcinogenic Potency Slope Inhalation	Chemical Specific $(mg/Kg - day)^{-1}$
SF_o	Carcinogenic Potency Slope Oral	Chemical Specific $(mg/Kg - day)^{-1}$
SFS_{adj}	Skin Factor Soil Age Adjusted (See Table C)	1257 mg-yr/kg-day
t	Students' t value corresponding to n at the 95% confidence level (one tailed test)	Chemical Specific
T	Exposure interval Volatilization Equation	9.5×10^8 s
THQ	Target Hazard Quotient	1 (unitless)
TR	Target Risk	1×10^{-5} (unitless)
U_m	Mean annual wind speed	4.69 m/s
U_t	Equivalent threshold value of wind speed at 7 m	11.32 m/s
V	Fraction of vegetative cover	0.5 (unitless, = 50%)

Symbol	Parameter	Value
VF	Volatilization Factor (See Table C)	Chemical Specific m^3/kg
$\bar{x}$	Average of site samples	Chemical Specific

TABLE E

Default Exposure Assumption References

Table E DEFAULT EXPOSURE ASSUMPTION REFERENCES		
PARAMETER	**VALUE**	**REFERENCE**
Target Risk	10^{-5} (unitless)	IDEM draft policy
Target Hazard Quotient	1.0	IDEM draft policy
Target Hazard Index	1.0	IDEM draft policy
Cancer Slope Factor	Chemical Specific Oral or Inhalation $(mg/kg\text{-}day)^{-1}$	IRIS, HEAST, NCEA, Regions 3, 6, 9
Reference Dose Oral or Inhalation	Chemical Specific (mg/kg-day)	IRIS, HEAST, NCEA, Regions 3, 6, 9
Body Weight Adult	70kg	RAGS (Part A) EPA 1989 EPA/540/1-89/002
Averaging Time	Carcinogen-70 yrs Noncarcinogen-Exposure Duration	RAGS (Part A) EPA 1989 EPA/540/1-89/002
Skin Surface Area Adult	5000 cm^2(25%)	Exposure Factors, EPA 1989 OSWER No. 9285.6-03
Skin Surface Area Child	2000 cm^2(25%)	Dermal Assessment, EPA 1992 EPA/600/8-91/011B
Skin Surface Area Adult Construction in Industrial	3160 cm^2	Dermal Assessment 1992, Construction , (heads, hands, forearms)
Adherence Factor	0.5 mg/cm^{-5}-day	Dermal Assessment, EPA 1992
Skin Absorption	0.1 most organics 0.01 most metals (Select compounds have other values)	EPA, Cal-EPA-(DTSC, 1994)
Inhalation Rate Adult Residential Indoor Inhalation Rate Adult Residential Outdoor	15 m^3/day 20 m^3/ day	RAGS Part B OSHWER No. 9285.6-03

Table E DEFAULT EXPOSURE ASSUMPTION REFERENCES		
PARAMETER	**VALUE**	**REFERENCE**
Inhalation Rate Adult Occupational	20 m^3/day	RAGS Part B OSHWER No. 9285.6-03
Inhalation Rate Child	10 m^3/day	EPA Region 6, 9 (Referencing RAGS Part A, EPA/540/1-89/002)
Drinking Water Ingestion Adult	2.0 1/day	RAGS Part A
Drinking Water Ingestion Child	1.0 1/day	PEA, Cal-EPA (DTSC, 1994)
Drinking Water Ingestion Occupational	1.0 1/day	IDEM VRP (OER, October 1995)
Soil Ingestion Adult	100 mg/day	OSHWER No. 9285.6-03 RAGS 1989
Soil Ingestion Child	200 mg/day	OSHWER No. 9285.6-03 RAGS 1989
Soil Ingestion Adult Occupational	50 mg/day	OSHWER No. 9285.6-03
Soil Ingestion Adult Construction	480 mg/day	OSWER Directive: 9285.6-03 Attachment B
Exposure Frequency Residential	350 days/yr	OSHWER No. 9285.6-03
Exposure Frequency Occupational	250 days/yr	OSHWER No. 9285.6-03
Exposure Frequency Construction	45 days/yr	IDEM Policy Region V RCRA Correspondence 9/30/96
Exposure Frequency Residential soil	250 days	IDEM Policy EPA 1984, EPA/600/8-84/031
Exposure Duration Residential	30 years	OSWER Directive: 9285.6-03
Exposure Duration Occupational	25 years	OSWER Directive: 9285.6-03

Table E DEFAULT EXPOSURE ASSUMPTION REFERENCES		
PARAMETER	**VALUE**	**REFERENCE**
Exposure Duration Construction	1 year	IDEM Policy Region V RCRA Correspondence 9/30/96
Indoor Volatilization Factor	0.5	RAGS Part B
Particulate Emission Factor Model	1.32×10^9 m^3/kg	EPA 1996, EPA 540/R-96/18 Defaults as listed in same
Volatilization Factor Outdoor Soil Model	Chemical Specific m^3/kg	EPA 1996, EPA 540/R-96/18 Defaults as listed in same
Soil Partition to Groundwater Model	Chemical Specific mg/kg	EPA 1996, EPA 540/R-96/18 Defaults as listed in same
Soil Saturation Limit	Chemical Specific mg/kg	EPA 1996, EPA 540/R-96/18 Defaults as listed in same
Age Adjusted Factors		
Ingestion soils	114 mg-yr/kg-day	RAGS Part B
Skin Contact	1257 mg-yr/kg-day	RAGS Part B by analogy
Inhalation	10.9 m^3 -yr/kg-day	RAGS Part B by analogy

TABLE F

Human Health Toxicity Parameters

		SFo (mg/kg-day)$^{-1}$		Rfdo mg/kg-day		SFi (mg/kg-day)$^{-1}$		RfDi mg/kg-day	
Chemical	**CAS**	**Value**	**Source**	**Value**	**Source**	**Value**	**Source**	**Value**	**Source**
Acenaphthene	83-32-9			6.0e-02	I			6.0e-02	6,9 R
Acetone (2-propanone)	67-64-1			1.0e-01	I			1.0e-01	6,9 R
Acrolein	107-02-8			2.0e-02	H			5.7e-06	I
Aldrin	309-00-2	1.7e+01	I	3.0e-05	I	1.7e+01	I	3.0e-05	6,9 R
Anthracene	120-12-7			3.0e-01	I			3.0e-01	6,9 R
Antimony	7440-36-0			4.0e-04	I				
Arsenic	7440-38-2	1.5e+00	I	3.0e-04	I	1.5e+01	I		
Barium	7440-39-3			7.0e-02	I			1.4e-04	H
Benz(a)anthracene	56-55-3	7.3e-01	3,6,9 N			3.1e-01	6,9 N		
Benzene	71-43-2	2.9e-02	9	3.0e-03	3,6,9 (N)	2.9e-02	R	1.7e-03	3,6,9 N
Benzo(b)fluoranthene	205-99-2	7.3e-01	3,6,9 N			3.1e-01	6,9 N		
Benzo(k)fluoranthene	207-08-9	7.3e-02	3,6,9 N			3.1e-02	6,9 N		
Benzoic acid	65-85-0			4.0e+00	I			4.0e+00	6,9 R
Benzo(a)pyrene	50-32-8	7.3e+00	I			3.1e+00	3,6,9 N		
Benzyl alcohol	100-51-6			3.0e-01	H			3.0e-01	6,9 R
Beryllium	7440-41-7			2.0e-03	I	8.4e+00	I	5.7e-06	I
Bis(2-chloroethyl)ether	111-44-4	1.1e+00	I			1.2e+00	I		
Bis(2-chloroisopropyl)ether	108-60-1	7.0e-02	H	4.0e-02	I	3.5e-02	H	4.0e-02	6,9 R
Bis(2-ethylhexyl)phthalate	117-81-7	1.4e-02	I	2.0e-02	I	1.4e-02	3,6,9 R	2.2e-02	6,9 (R)
Bromodichloromethane	75-27-4	6.2e-02	I	2.0e-02	I	6.2e-02	6,9 R	2.0e-02	6,9 R
Bromoform(tribromomethane)	75-25-2	7.9e-03	I	2.0e-02	I	3.9e-03	I	2.0e-02	6,9 R
Butanol	71-36-3			1.0e-01	I			1.0e-01	6,9 R
Butylbenzylphthalate	85-68-7			2.0e-01	I			2.0e-01	6,9 R
Cadmium	7440-43-9			5.0e-04	I	6.3e+00	I	5.7e-05	3 N
Carbazole	86-74-8	2.0e-02	H			2.0e-02	6,9 R		
Carbon disulfide	75-15-0			1.0e-01	I			2.0e-01	I
Carbon tetrachloride	56-23-5	1.3e-01	I	7.0e-04	I	5.3e-02	I	5.7e-04	3 N
Chlordane	12789-03-6	3.5e-01	I	5.0e-04	I	3.5e-01	I	2.0e-04	I
p-Chloroaniline	106-47-8			4.0e-03	I			4.0e-03	6,9 R
Chlorobenzene	108-90-7			2.0e-02	I			1.7e-02	3,9 N

		SFo (mg/kg-day)$^{-1}$		Rfdo mg/kg-day		SFi (mg/kg-day)$^{-1}$		RfDi mg/kg-day	
Chemical	**CAS**	**Value**	**Source**	**Value**	**Source**	**Value**	**Source**	**Value**	**Source**
Chloroethane	75-00-3	2.9e-03	3,9 N	4.0e-01	3,6,9 N	2.9e-03	9 R	2.9e+00	I
Chloroform	67-66-3	6.1e-03	I	1.0e-02	I	8.1e-02	I	8.6e-05	3,9 N
2-Chlorophenol	95-57-8			5.0e-03	I			5.0e-03	6,9 R
Chromium III	16065-83-1			1.5e+00	I				
Chromium VI	18540-29-9			3.0e-03	I	2.9e+02	I	2.9e-05	I
Chrysene	218-01-9	7.3e-03	3,6,9 N			3.1e-03	6,9 N		
Copper	7440-50-8			3.7e-02	9 (H)				
Cyanide (free)	74-90-8			2.0e-02	I				
DDD	72-54-8	2.4e-01	I			2.4e-01	6,9 R		
DDE	72-55-9	3.4e-01	I			3.4e-01	6,9 R		
DDT	50-29-3	3.4e-01	I	5.0e-04	I	3.4e-01	I	5.0e-04	6,9 R
Dibenzo(a,h)anthracene	53-70-3	7.3e+00	3,6,9 N			3.1e+00	6,9 N		
Di-n-butylphthalate	84-74-2			1.0e-01	I			1.0e-01	6,9 R
1,2-Dichlorobenzene	95-50-1			9.0e-02	I			5.7e-02	H
1,3-Dichlorobenzene	541-73-1			9.0e-04	3,9 N			9.0e-04	9 R
1,4-Dichlorobenzene	106-46-7	2.4e-02	H	3.0e-02	3,9 N	2.2e-02	3,9 N	**2.3e-01**	I
3,3-Dichlorobenzidine	91-94-1	4.5e-01	I			4.5e-01	6,9 R		
1,1-Dichloroethane	75-34-3			1.0e-01	H			1.4e-01	H
1,2-Dichloroethane	107-06-2	9.1e-02	I	3.0e-02	3,9 N	9.1e-02	I	1.4e-03	3,9 N
1,1-Dichloroethylene	75-35-4	6.0e-01	I	9.0e-03	I	1.8e-01	I	9.0e-03	6,9 R
cis-1,2-Dichloroethylene	156-59-2			1.0e-02	H			1.0e-02	6,9 R
trans-1,2-Dichloroethylene	156-60-5			2.0e-02	I			2.0e-02	6,9 R
2,4-Dichlorophenol	120-83-2			3.0e-03	I			3.0e-03	6,9 R
1,2-Dichloropropane	78-87-5	6.8e-02	H	1.1e-03	6,9 R	6.8e-02	6,9 R	1.1e-03	I
1,3-Dichloropropene	542-75-6	1.0e-01	I	3.0e-02	I	**1.4e-02**	I	5.7e-03	I
Dieldrin	60-57-1	1.6e+01	I	5.0e-05	I	1.6e+01	I	5.0e-05	6,9 R
Diethylphthalate	84-66-2			8.0e-01	I			8.0e-01	6,9 R
2,4-Dimethylphenol	105-67-9			2.0e-02	I			2.0e-02	6,9 R
Dimethyl phthalate	131-11-3			1.0e+01	6,9 (H)			1.0e+01	6,9 R
2,4-Dinitrophenol	51-28-5			2.0e-03	I			2.0e-03	6,9 R

		SFo (mg/kg-day)$^{-1}$		Rfdo mg/kg-day		SFi (mg/kg-day)$^{-1}$		RfDi mg/kg-day	
Chemical	**CAS**	**Value**	**Source**	**Value**	**Source**	**Value**	**Source**	**Value**	**Source**
Dinitrotoluene mixture	25321-14-6	6.8e-01	I	1.0e-03	H	6.8e-01	6,9 R	1.0e-03	R
Di-n-Octyl phthalate	117-84-0			2.0e-02	H			2.0e-02	6,9 R
Endosulfan	115-29-7			6.0e-03	I			6.0e-03	6,9 R
Endrin	72-20-8			3.0e-04	I			3.0e-04	6,9 R
Ethylbenzene	100-41-4			1.0e-01	I			2.9e-01	I
Fluoranthene	206-44-0			4.0e-02	I			4.0e-02	6,9 R
Fluorene	86-73-7			4.0e-02	I			4.0e-02	6,9 R
Heptachlor	76-44-8	4.5e+00	I	5.0e-04	I	4.6e+00	I	5.0e-04	6,9 R
Heptachlor epoxide	1024-57-3	9.1e+00	I	1.3e-05	I	9.1e+00	I	1.3e-05	6,9 R
Hexachlorobenzene	118-74-1	1.6e+00	I	8.0e-04	I	1.6e+00	I	8.0e-04	6,9 R
Hexachloro-1,3-butadiene	87-68-3	7.8e-02	I	2.0e-04	H	7.8e-02	I	2.0e-04	6,9 R
alpha-HCH (alpha-BHC)	319-84-6	6.3e+00	I			6.3e+00	I		
beta-HCH (beta-BHC)	319-85-7	1.8e+00	I			1.8e+00	I		
gamma-HCH (Lindane)	58-89-9	1.3e+00	H	3.0e-04	I	1.3e+00	6,9 R	3.0e-04	6,9 R
Hexachlorocyclopentadiene	77-47-4			7.0e-03	I			2.0e-05	H
Hexachloroethane	67-72-1	1.4e-02	I	1.0e-03	I	1.4e-02	I	1.0e-03	6,9 R
Indeno(1,2,3-cd)pyrene	193-39-5	7.3e-01	3,6,9 N			3.1e-01	6,9 N		
Isophorone	78-59-1	9.5e-04	I	2.0e-01	I	9.5e-04	6,9 R	2.0e-01	6,9 R
Mercury	7439-97-6			3.0e-04	I			8.6e-05	I
Methoxychlor	72-43-5			5.0e-03	I			5.0e-03	6,9 R
Methyl bromide	74-83-9			1.4e-03	I			1.4e-03	I
Methylene chloride	75-09-2	7.5e-03	I	6.0e-02	I	1.6e-03	I	8.6e-01	H
Methyl ethyl ketone (MEK)	78-93-3			6.0e-01	I			2.9e-01	I
4-Methyl-2-pentanone (MIBK)	108-10-1			8.0e-02	H			2.3e-02	H
2-Methylphenol(o-cresol)	95-48-7			5.0e-02	I			5.0e-02	6,9 R
3-Methylphenol (m-cresol)	108-39-4			5.0e-02	I			5.0e-02	6,9 R
4-Methylphenol (p-cresol)	106-44-5			5.0e-03	H			5.0e-03	6,9 R
Methyl tertbutyl ether	1634-04–4	4.0e-03	IDEM	8.6e-01	R	4.0e-03	IDEM	8.6e-01	I
Naphthalene	91-20-3			2.0e-02	I			8.6e-04	I
Nickel	7440-02-0			2.0e-02	I	8.4e-01	I		

		SFo (mg/kg-day)$^{-1}$		Rfdo mg/kg-day		SFi (mg/kg-day)$^{-1}$		RfDi mg/kg-day	
Chemical	**CAS**	**Value**	**Source**	**Value**	**Source**	**Value**	**Source**	**Value**	**Source**
2-Nitroaniline	88-74-4			5.7e-05	6,9 R			5.7e-05	H
Nitrobenzene	98-95-3			5.0e-04	I			**1.1e-01**	H
N-Nitrosodiphenylamine	86-30-6	4.9e-03	I			4.9e-03	6,9 R		
N-Nitrosodi-n-propylamine	621-64-7	7.0e+00	I			7.0e+00	6,9 R		
Polychlorinated biphenyls (PCB)	1336-36-3	2.0e+00	I	2.0e-05	I	2.0e+00	I	2..0e-05	R
Pentachlorophenol	87-86-5	1.2e-01	I	3.0e-02	I	1.2e-01	6,9 R	3.0e-02	6,9 R
Phenol	108-95-2			6.0e-01	I			6.0e-01	6,9 R
Pyrene	129-00-0			3.0e-02	I			3.0e-02	6,9 R
Selenium	7782-49-2			5.0e-03	I				
Silver	7440-22-4			5.0e-03	I				
Styrene	100-42-5			2.0e-01	I			2.9e-01	I
1,1,2,2-Tetrachloroethane	79-34-5	2.0e-01	I	6.0e-02	3,9 N	2.0e-01	I	6.0e-02	9 R
1,1,1,2-Tetrachloroethane	630-20-6	2.6e-02	I	3.0e-02	I	2.6e-02	I	3.0e-02	6,9 R
Tetrachloroethylene (PCE)	127-18-4	5.2e-02	3,6,9 N	1.0e-02	I	2.0e-03	3,6,9 N	1.1e-01	3,6,9 N
Thallium (nitrate)	10102-45-1			9.0e-05	I				
Toluene	108-88-3			2.0e-01	I			1.1e-01	I
Toxaphene	8001-35-2	1.1e+00	I			1.1e+00	I		
1,2,4-Trichlorobenzene	120-82-1			1.0e-02	I			5.7e-02	6,9 (H)
1,1,1-Trichloroethane	71-55-6			3.5e-02	6,9 (N)			2.9e-01	6,9 (N)
1,1,2-Trichloroethane	79-00-5	5.7e-02	I	4.0e-03	I	5.6e-02	I	4.0e-03	6,9 R
Trichloroethylene (TCE)	79-01-6	1.1e-02	3,6,9 N	6.0e-03	reg 6,9	6.0e-03	3,6,9 N	6.0e-03	6,9 R
2,4,5-Trichlorophenol	95-95-4			1.0e-01	I			1.0e-01	6,9 R
2,4,6-Trichlorophenol	88-06-2	1.1e-02	I			1.1e-02	I		
Vinyl acetate	108-05-4			1.0e+00	H			5.7e-02	I
Vinyl chloride (chloroethene)	75-01-4	1.9e+00	H			3.0e-01	H		
Xylene (mixed)	1330-20-7			2.0e+00	I			2.0e-01	reg 9
Zinc	7440-66-6			3.0e-01	I				

CAS = Chemical Abstract Service
H = Heast
I = IRIS
N = NCEA
R = Route to Route Extrapolation
SFi = Inhalation Slope Factor
SFo = Oral Slope Factor
RfDi = Inhalation Reference Dose
RfDo = Oral Reference Dose
3,6,9 = EPA Regions 3,6,9 Screening Tables

PCB Slope Factor and RfD assume a mixture of PCB congeners including Aroclor 1016 and 1254.

Table G

Critical Effects

TABLE G
CRITICAL EFFECTS

Chemical	Critical EffectsCategory Primary Critical Effect	Source
Acenaphthene	Systemic (Liver)	IRIS
Acenaphthylene	Systemic (Liver)	Similar PAHs
Acetone	Systemic (Kidney, liver)	IRIS
Acrolein	Respiratory (Nasal passageway)	IRIS
Anthracene	Systemic (Liver)	Similar PAHs
Antimony	Circulatory (Heart) Systemic (Nonspecific)	IRIS
Barium	Systemic (Kidney)	IRIS
Benzoic acid	Systemic (Liver, Kidney) Respiratory(Trachea, Lung)	HSDB
Benzyl alcohol	Gastrointestinal (Forestomach)	HEAST
Butanol	Neurological (Central nervous system)	IRIS
Butylbenzyl phthalate	Systemic (Liver)	IRIS
Cadmium	Systemic (Kidney)	IRIS
Carbon disulfide	Neurological (Peripheral nervous system) Developmental (Nonspecific)	IRIS
4-Chloroaniline	Musculoskeletal (Connective tissue)	IRIS
Chlorobenzene	Systemic (Liver)	IRIS
Chloroethane (Ethyl Chloride)	Developmental (Growth Retardation)	IRIS
2-chloronapthalene	Dermal/Ocular (Skin)	HSDB
2-Chlorophenol	Reproductive (Nonspecific)	IRIS
Chromium III	Respiratory(Lung)	ATSDR
Copper	Systemic (Liver/kidney) Circulatory (Blood)	ATSDR
Cyanide	Endocrine (Thyroid) Neurological (Neurons)	IRIS
Di-n-butyl phthalate	Developmental (Teratology)	IRIS
1,2-Dichlorobenzene	Systemic (Liver)	IRIS
1,3-Dichlorobenzene	Systemic (Liver)	1,2-Dichlorobenzene
1,1-Dichloroethane	Systemic (Liver, kidney) Neurological (Central nervous system)	HSDB HEAST
cis-1,2-Dichloroethene	Circulatory (Blood)	HEAST
trans-1,2-Dichloroethene	Circulatory (Blood)	IRIS
2,4-Dichlorophenol	Immunological (Lymph)	IRIS
Diethyl phthalate	Developmental (Teratology) [2]	IRIS
Dimethyl phthalate	Systemic (Kidney, liver)	HSDB
2,4-Dimethylphenol	Neurological (Central nervous system) Circulatory (Blood)	IRIS

Chemical	Critical EffectsCategory Primary Critical Effect	Source
2,4-Dinitrophenol	Dermal/Ocular (eye)	IRIS
Di-n-octyl phthalate	Systemic (Liver) Immunological (Spleen) Developmental (Teratology)	HSDB
Endosulfan	Systemic (Kidney) Circulatory (Blood vessel)	IRIS
Endrin	Systemic (Liver)	IRIS
Ethylbenzene	Systemic (Liver, kidney) Developmental (Teratology)	IRIS
Fluoranthene	Systemic (Liver, kidney) Circulatory (Blood)	IRIS
Fluorene	Circulatory (Blood)	IRIS
Hexachlorocyclopentadiene	Gastrointestinal (Stomach)	IRIS
Lead	Neurological (Central nervous system)	ATSDR
Mercury	Neurological (Central nervous system) Systemic (Kidney)	IRIS
Methoxychlor	Developmental (Nonspecific)	IRIS
Methyl bromide (Bromomethane)	Gastrointestinal (Stomach) Respiratory (Nasal)	IRIS
Methyl ethyl ketone (2-Butanone)	Developmental (Nonspecific)	IRIS
4-Methyl-2-pentanone (Methyl isobutyl ketone)	Systemic (Liver, Kidney)	HEAST
2-Methylphenol	Neurological (Central nervous system)	IRIS
3-Methylphenol	Neurological (Central nervous system)	IRIS
4-Methylphenol	Neurological (Central nervous system)[1]	ATSDR
Naphthalene	Respiratory (Nasal)	IRIS
Nickel	Circulatory (Heart) Systemic (Liver) Immunological (Spleen)	IRIS
2-Nitroaniline	Circulatory (Blood) Systemic (Liver, kidney) Endocrine (Adrenals)	HEAST
Nitrobenzene	Systemic (Liver, kidney) Endocrine (Adrenals) Circulatory (Blood)	IRIS
Phenol	Developmental (Nonspecific)	IRIS
Pyrene	Systemic (Kidney)	IRIS
Selenium	Dermal/Ocular (Skin) Neurological (Central nervous system)	IRIS

Chemical	Critical EffectsCategory Primary Critical Effect	Source
Silver	Dermal/Ocular (Skin)	IRIS
Styrene	Circulatory(Blood) Systemic (Liver) Neurological (Central nervous system)	IRIS
Thallium	Systemic (Liver)	IRIS
Toluene	Systemic (Liver, Kidney) Neurological (Central nervous system)	IRIS
1,2,4-Trichlorobenzene	Endocrine (Adrenal)	IRIS
1,1,1-Trichloroethane	Circulatory (Heart) Neurological (Central nervous system)	ATSDR
2,4,5-Trichlorophenol	Systemic (Liver, kidney)	IRIS
Vinyl acetate	Respiratory (Nasal)	IRIS
Xylenes	Neurological (Central nervous system)	IRIS
Zinc	Circulatory (Blood)	IRIS

Critical Effects Categories and Target Organs

1. Systemic: Liver, kidney, urinary tract
2. Circulatory: Arteries, veins, heart, and blood
3. Gastrointestinal: Buccal cavity, esophagus, stomach, intestines, and gall bladder
4. Musculoskeletal: Muscles, bone, and connective tissues
5. Respiratory: Lungs, trachea, and nasal passageway
6. Immunological: Lymph and tissue fluid, spleen, and lymph nodes
7. Neurological: Brain, spinal cord, neurons, and neuroglia
8. Reproductive/Endocrine: Testes, ovaries, thyroid, adrenal, pituitary, pancreas, and parathyroid
9. Developmental: Teratology, growth retardation, structural malformations, and abnormal development
10. Dermal/ Ocular: Skin and eyes

The primary critical effect and target organ for each chemical was obtained using the following sources (in order of preference):

1. IRIS (EPA 2000)
2. HEAST (EPA 1997)
3. ATSDR Toxicological Profiles
4. Hazardous Substance Databank (http://toxnet.nlm.nih.gov)

Exceptions include the following critical effects and target organs:

- Some compounds have an RfD based on the No Observed Adverse Effects Level (NOAEL), and information on toxic effects at higher doses was not available. In these cases, the critical effect of a surrogate compound (similar in structure and type) was used.
- Some compounds have an RfD established with the NOAEL and some toxic effects information. The toxic effects information was used to establish the critical effect.
- Some compounds have experimentally derived oral and inhalation reference doses. Where these values were within an order of magnitude of each other, critical effects from both routes were listed. These compounds should be considered as additive in both categories.
- Some compounds did not have an easily identified target organ within the critical effects category. These compounds were classified within a category as "nonspecific."

REFERENCES

Dermal Assessment

EPA, 1992	Dermal Exposure Assessment : Principles and Applications, EPA/600/8-91011B
EPA, 1994	Risk Analysis of TCDD Contaminated Soil, EPA/600/8-84/031
EPA, 1996	Soil Screening Guidance: Technical Background Document, EPA/540/R-95/128
EPA, 1992	Dermal Exposure Assessment Principles and Applications, EPA/600/8-91/011B
EPA Regions 3, 6, & 9	http://www.epa.gov/reg3hwmd/risk/riskmenu.htm; http://www.epa.gov/region09/waste/sfund/prg/index.htm; and, http://www.epa.gov/earth1r6/6pd/rcra_c/pd-n/screen.htm).
EPA, CAL-EPA-(DSTC, 1994)	California EPA, 1994. Preliminary Endangerment Assessment Manual, (PEA) Department of Toxic Substances Control, Sacramento California.
	Exposure Factors EPA, 1989 Exposure Factors Handbook, EPA/600/8-89/043
HEAST	Health Effects Assessment Summary Tables, FY 97 Update EPA-54–R-97-036
IDEM, VRP	Voluntary Remediation Program, Resource Guide, OER, IDEM October 1995.
IRIS	Integrated Risk Information System, EPA http://www.epa.gov/iris
NCEA	National Center for Exposure Assessment, http://www.epa.gov/ncea
NLM	National Library of Medicine (NLM). 2000. Hazardous Substances Databank (HSDB). Toxicology Information Network (TOXNET). http://toxnet.nlm.nih.gov. June 5.
OSWER No. 9285.6-03	Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual, Supplemental Guidance “Standard Default Exposure Factors”, March 25, 1991

RAGS Part A EPA, 1989 EPA/540/1-89/002	Risk Assessment Guidance for Superfund, Human Health Evaluation Manual Part A,
RAGS Part B	Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual, Part B Development of Risk Based Preliminary Remediation Goals, publication 9285.7-01B, December, 1991.
Reg V RCRA Correspondence	Risk Assessment Exposure Parameters Correspondence, Region V EPA Waste Management Branch, September 26, 1996

ANALYTICAL METHODOLOGY FOR RISK ASSESSMENT

Analytical methodology must be evaluated concurrently with factors related to sampling procedures, statistical treatment of data, and risk assessment processes to ensure that the established Data Quality Objectives (DQOs) can be attained. Responsible parties must determine the sampling methods, analytical methods, and quality control measures needed to meet the closure or remedial DQOs (for screening, determination of nature and extent, and confirmation of remediation, as applicable). These considerations must take into account the uncertainty associated with generating data and with determining that statistical criteria have been met. After the data have been generated they must be validated for conformance to quality assurance/quality control criteria, and assessed in terms of applicability to the overall project goal. In other words, data must be assessed as to whether the DQOs have been met.

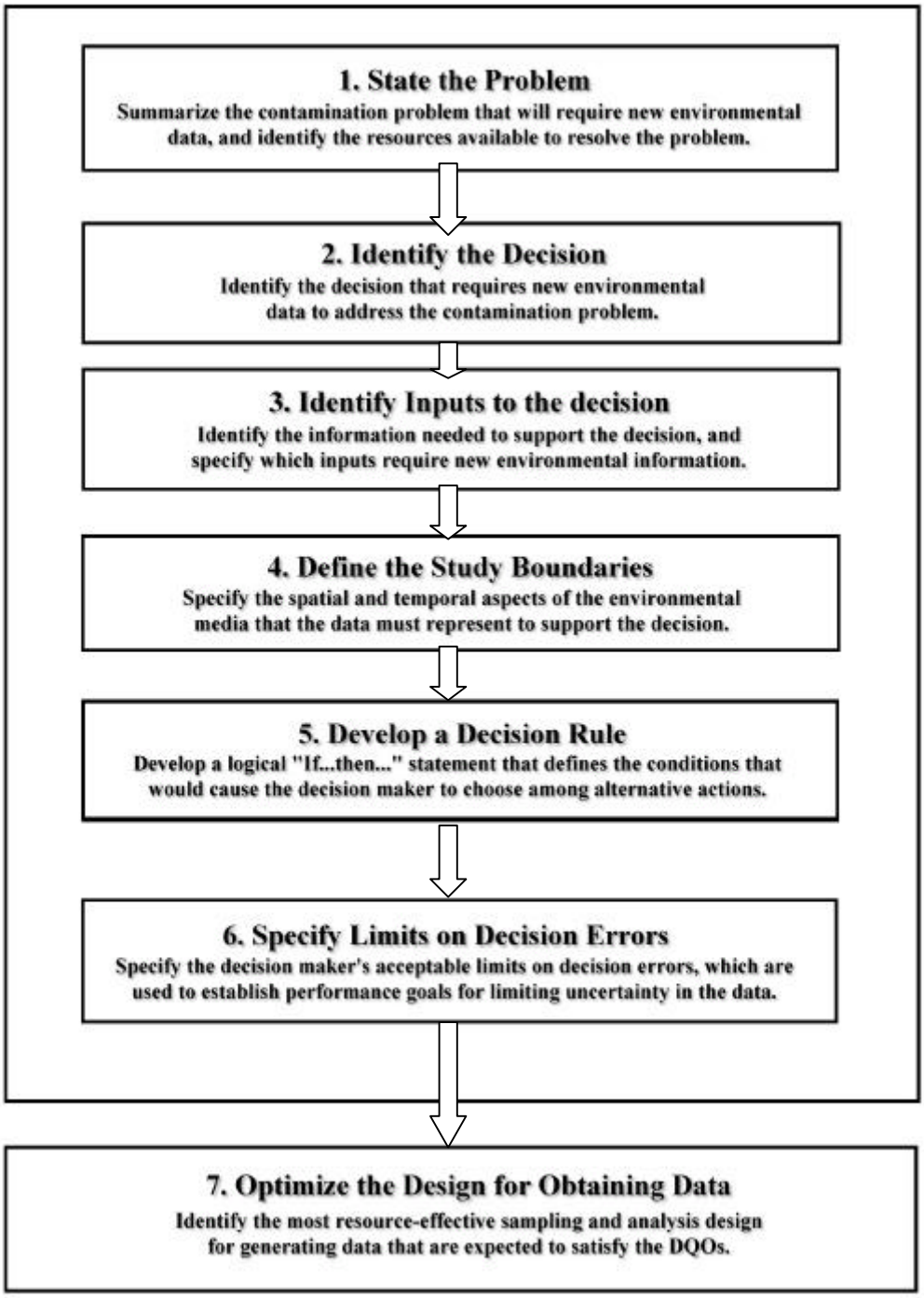
Remedial Objective and the Data Quality Objective Process

The USEPA (EPA) defines DQOs and the DQO development process as follows:

> **What is the DQO Process?** The DQO Process is a series of planning steps based on the Scientific Method that is designed to ensure that the type, quantity, and quality of environmental data used in decision making are appropriate for the intended application. The steps of the DQO Process are illustrated in Figure 1 [below].
>
> **What are DQOs?** DQOs are qualitative and quantitative statements derived from the outputs of each step of the DQO Process that:
>
> 1) Clarify the study objective;
> 2) Define the most appropriate type of data to collect;
> 3) Determine the most appropriate conditions from which to collect the data; and
> 4) Specify acceptable levels of decision errors that will be used as the basis for establishing the quantity and quality of data needed to support the decision.
>
> The DQOs are then used to develop a scientific and resource-effective sampling design.
>
> The process allows decision makers to define their data requirements and acceptable levels of decision errors (decision errors occur when variability or bias in data mislead the decision maker into choosing an incorrect course of action) during planning, <u>before</u> any data are collected. Application of the DQO Process should result in data collection designs that will yield results of appropriate quality for defensible decision making.[1]

[1]Environmental Protection Agency, Office of Emergency and Remedial Response, *Data Quality Objectives Process for Superfund: Interim Final Guidance*, 9355.9-01, EPA540-R-93-071, September 1993, p. 1, NTIS, PB94-963203.

Figure 1[2]
The Data Quality Objective Process



[2]Environmental Protection Agency, Office of Emergency and Remedial Response, *Data Quality Objectives Process for Superfund: Interim Final Guidance*, 9355.9-01, EPA540-R-93-071, September 1993, p. 2, NTIS, PB94-963203.

Choosing Analytical Methods to Reduce Costs

Once the source area COCs have been determined, it is desirable to reduce costs by selecting the most cost effective analytical methods to detect and quantitate those specific COCs. However, the analytical methods selected *must* having quantitation or detection limits that can meet the required Closure Levels for the COCs in the appropriate matrices. The attached table, **Analytical Methods with Reporting Limits for RISC**, lists the COCs from the Closure Look-up Table, their respective Closure Levels for soil and groundwater matrices, and standard (promulgated) EPA analytical methods that are capable of detecting the COC at the concentration of the Closure Level. For each COC methods are included that are generally used by the RCRA (SW-846), Superfund (CLP), and Water ("Water Methods") programs unless the program has no method for that COC. **A method that does not have a quantitation limit low enough to meet the Closure Level <u>cannot be used without adjustment or adaptation to lower the quantitation limit</u>.** Proposed method adaptations or suggested substitute methods must be included in the QAPP. Modified or substitute methods should also be validated prior to use for an environmental project A suggested format for method validation is presented in the IDEM manual, ***Guidance to the Performance and Presentation of Analytical Chemistry Data*** in the form of a checklist entitled "Performance-Based Measurement System (PBMS) Initial Demonstration of Method Performance."

Shaded boxes in the **Analytical Methods with Reporting Limits for RISC** table indicate that the methods for that program are not capable of meeting the Closure Level; the method(s) closest to meeting the Closure Level are listed. **<u>Methods in shaded boxes should not be used unless they are adapted or modified to provide a lower quantitation limit</u>**. Such modification or adaptation will be necessary if site COCs include bis(2-chloroethyl)ether, 2-nitroaniline, or N-nitroso-di-n-propylamine. There are no promulgated EPA methods that can currently meet the human health Closure Level for these analytes in one or both matrices.

Adapted, modified or alternate methods may also be required when the site affects an ecologically susceptible area. When an ecological risk assessment is required, alternate ecological protection levels must be used that often are lower than the human health Closure Levels**. If alternate ecological protection levels cannot be met by unmodified methods, <u>analytical methods must be adapted or modified, or alternate analytical methods must be found, to reach the lower ecological protection levels</u>.** This is true for ecological risk assessments even if the unmodified method does meet the human health Closure Level. Proposed method modifications or alternate methods must be included in the QAPP and should be validated prior to use for the ecological risk assessment using a format similar to the "Performance-Based Measurement System (PBMS) Initial Demonstration of Method Performance Checklist" suggested in the IDEM manual, ***Guidance to the Performance and Presentation of Analytical Chemistry Data***.

To minimize analytical costs yet achieve quantitation limits below the risk-based Closure Levels, it may be necessary to select analytical methodology different than the methods that are most familiar to environmental project managers. For example, many environmental professionals are accustomed to using the SW-846 gas chromatography/mass spectrometry (GC/MS) Methods 8260 for volatile organic compounds (VOCs) and 8270 for semivolatile organic compounds

(SVOCs). However, standard GC/MS procedures usually have higher EQLs than GC using detectors other than MS, meaning that the GC/MS quantitation limits may not meet the required Closure Levels. Another chromatography technique used to analyze semivolatile and nonvolatile organic compounds, high performance liquid chromatography (HPLC), also tends to have lower EQLs than GC/MS methods and may be preferred for some analytes (COCs). In addition, GC/MS methods may be more expensive than GC or HPLC. This is because the larger number of analytes typically targeted in standard GC/MS methods can increase calibration and quality control sample costs. (Note: Limiting the number of analytes by telling your laboratory contact, *prior to analysis*, the exact COC list you must report, might reduce the analysis cost. If you merely request a certain method, the laboratory will analyze for the full list of analytes published in the method.)

In contrast, HPLC methods or GC methods employing detection techniques such as photoionization (PID) or electron capture (ECD) may be preferable when the site-specific chemicals of concern (COCs) are few in number and well known (so as to reduce cost), or when lower detection limits are needed to meet risk-based Closure Levels. These GC and HPLC methods group analytes by *individual (or closely related) chemical class.* They cannot group diverse chemical classes into one analysis (like GC/MS).

To minimize costs, the project manager should consult the laboratory chemist to determine the best analysis or suite of analyses to meet the project DQOs for the site-specific COCs identified in the QAPP.

Consider the following objectives for a petroleum release site:

- Identify Hazardous Substances and Media

  A default risk assessment will be performed for a petroleum-release site where diesel fuel was stored. No non-petroleum chemicals were ever used at the site, and diesel fuel is a high-end liquid hydrocarbon fuel, so the site-specific COCs are the class B2-carcinogenic polynuclear aromatic hydrocarbons (cPAHs) and BTEX. Per the QAPP, sampling will be performed on subsurface soils and groundwater, and concentrations will be compared to residential Closure Levels.

- Identify Chemicals of Concern (COCs)

  The cPAH group (a subset of the larger class of chemicals, SVOCs) consists of the following compounds: benzo[a]anthracene, benzo[a]pyrene, benzo[b]fluoranthene, benzo[k]fluoranthene, chrysene, dibenzo[a,h]anthracene, and indeno[1,2,3-cd]pyrene. All of these compounds are on the analyte list for Method 8270C, but they also appear on the compound list for Method 8310, a high performance liquid chromatography (HPLC) technique specifically for polynuclear aromatic hydrocarbons. Benzene, toluene, ethyl benzene, and xylene (BTEX) are volatile organic compounds appearing on the Method 8260B compound list. The BTEX compounds are also listed for Method 8021B, "Aromatic and Halogenated Volatiles by Gas Chromatography." Which methods should be used?

• Identify Analytical Methods

First, the Closure Levels for the COCs in subsurface soil and groundwater should be compared to the estimated quantitation limits (EQLs) for the COCs in the applicable methods. The following table compares the default residential Closure Levels for the COCs in our example to the EQLs for Methods 8260B and 8021B (BTEX) and Methods 8270C and 8310 (cPAHs):

Residential Closure Level/EQL Comparison Table (Petroleum)

Compound	SS Soil Closure Level, mg/kg	8260B EQL, soils, mg/kg	8021B EQL soils, mg/kg	GW Closure Level, mg/L	8260B EQL, mg/L (purge: 5 mL/25 mL)	8021B EQL, aqueous, mg/L
BTEX						
Benzene	33.8	5	0.09	5.	5* / 1	0.09
Toluene	11,700.	5	0.10	1,000.	5 / 1	0.10
Ethylbenzene	13,400.	5	0.05	700.	5 / 1	0.05
Xylene	200,000.	5	0.20	10,000.	5 / 1	0.20
cPAHs						
Benzo[a]anthracene	4,620	660	8.78	1.17	10	0.13
Benzo[a]pyrene	462	660	16	0.2	10	0.2
Benzo[b]fluoranthene	4,620	660	12	1.17	10	0.18
Benzo[k]fluoranthene	39,400	660	12	0.8	10	0.17
Chrysene	25,500	660	100	1.6	10	1.5
Dibenzo[a,h]anthracene	462	660	20	0.12	10	(MDL) 0.03*
Indeno[1,2,3-cd]pyrene	3,050	660	30	0.022	10	(MDL) 0.04**

*Special care required.
**Method adaptation and special care required.

The first inclination of the project manager may be to ask the laboratory to run Methods 8260 and 8270. Looking at the table, we can see the following: The BTEX section indicates that Method 8260 EQLs are sufficiently low to meet the BTEX Closure Levels for both sub-surface soil and ground water. Next the project manager calls the laboratory to obtain pricing for Method 8260 and BTEX by Method 8021. Prices are quoted at $200 for the standard 8260 analyte list and $80 for BTEX by 8021.

The laboratory contact also informs the project manager that to run BTEX compounds alone by 8260 would cost $85-$90. The chemist explains that this is because the benzene analysis by 8260 will require special attention: The laboratory normally purges a 5 mL sample, yielding a 5 µg/L EQL for Method 8260 analytes. The benzene Closure Level (based on the MCL) is also 5 µg/L. An EQL equal to but no lower than the Closure Level leaves no room

for uncertainty, such as matrix interference or random variability. To minimize the possibility of false positive or false negative results, it would be advisable to purge 25 mL sample for the benzene analysis, so that an EQL of 1 µg/L would be obtained. The project manager considers the information supplied by the laboratory chemist and decides on Method 8021, both to save money and to ensure adequate detection levels for benzene.

Next, looking at the cPAH section, we can see that Method 8270 is not suitable for the default risk assessment because EQLs exceed the Closure Levels for all COCs in groundwater and two COCs in subsurface soil (Dibenzo[a,h]anthracene and indeno[1,2,3-cd]pyrene). The project manager requests the laboratory to run Method 8310 for cPAHs, explaining the detection limits that are needed to meet the Closure Levels. The laboratory contact may explain that additional charges will be incurred to adapt the method to lower detection limits for Dibenzo[a,h]anthracene and indeno[1,2,3-cd]pyrene in ground water or suggest an alternate method, if one is available.

Similar reasoning can be applied to objectives for a chemical release site. For example:

- Identify Hazardous Substances and Media

A default risk assessment will be performed for a chemical-release site where paint and varnish waste was processed. A variety of solvents and paint removers were also used at the site. Some of the paints contained inorganic pigments. Sampling will be performed on surface and subsurface soils, and concentrations will be compared to *non*-residential Closure Levels.

- Identify Chemicals of Concern (COCs)

Based on previous sampling, MSDS sheets, and other records, the COCs were determined to be: (1) solvents (used independently and as paint and paint remover components): n-butanol, methyl ethyl ketone (MEK), benzene, toluene, methylene chloride; and (2) metals (from inorganic pigments): titanium, copper, and chromium. The following table compares the default Non-residential Closure Levels for the COCs in this example to the EQLs for SW-846 methods appropriate for the analysis of solvents and metals.

- Identify Analytical Methods

First, the Closure Levels for the COCs in subsurface soil and groundwater should be compared to the estimated quantitation limits (EQLs) for the COCs in the applicable methods. The solvents are all on the 8260 list. Benzene, toluene, and methylene chloride can also be run by Method 8021B, but not by 8015B. MEK and n-butanol can be run by Method 8015B but not by 8021B. The EQLs for all these volatile organic compounds in each appropriate method are lower than the Closure Levels. The project manager may choose to run all these volatile organic compounds by 8260 or may choose to combine methods 8015B and 8021B; the choice depends on which has the lower cost.

Chromium, copper, and titanium are all on the analyte list for Method 6010B, Inductively Coupled Plasma Atomic Emission Spectroscopy (ICP). Copper and chromium can also be run by Atomic Absorption Spectroscopy (AA) methods; there is no AA method for titanium. Either method choice is sufficient to meet the Closure Levels for chromium.

Copper and titanium do not have Closure Levels. However, analyses will be run to measure site concentrations, and site-specific Closure Levels will be calculated. All three metals may be run by ICP, or the project manager may choose AA for copper and chromium, depending on which analysis costs least.

Non-Residential Closure Level/EQL Comparison Table (Paint Chemicals)

Solvents							
Compound	**SS Closure Level, mg/kg**	**Surface Closure Level, mg/kg**	**8260B EQL, soils, mg/kg**	**8021B EQL, soils, mg/kg**	***GW Closure Level, mg/L***	***8260B EQL, mg/L***	***8021B EQL, mg/L***
Benzene	*668*	*13,000*	*5*	*0.09*	*98.7*	*5*	*0.09*
Toluene	*240,000*	*654,000*	*5*	*0.10*	*20,400.*	*5*	*0.10*
Methylene chloride	*1,770.*	*197,000*	*5*	*0.05*	*382.*	*5*	*0.05*
Compound	***SS Closure Level***	***Surface Closure Level***	***8260B***	***8015B***	***GW Closure Level***	***8260B***	***8015B***
Butanol	*43,700*	*1,000,000*	*100*	*2300*	*10,200*	*100*	*70*
MEK	*279,000*	*1,000,000*	*100*	*2700*	*61,300*	*100*	*50*
Metals							
Compound	***SS Closure Level***	***Surf Closure Level***	***6010(ICP)***	***AA method***	***GW Closure Level***	***6010(ICP)***	***AA method***
Chromium	*196,000*	*1,000,000*	*1000*	*1000*	*511*	*10*	*50*
Copper	*none*	*none*	*1000*	*1000*	*none*	*20*	*20*
Titanium	*none*	*none*	*5000*	*none*	*none*	*50*	*none*

Sampling Design and Quality Assurance/Quality Control

Sampling design and sampling field procedures must be supportive of the project DQOs. A Sampling and Analysis Plan (SAP) should be prepared as part of the QAPP. Accurate field notes should be taken. Sampling methods from source documents published by the USEPA, American Society for Testing and Materials (ASTM), U.S. Department of the Interior, National Ground-water Association (NGWA), American Petroleum Institute (API), or other recognized organizations with appropriate expertise should be used, if possible. Field quality control procedures and collection of field quality control samples are necessary to ensure that the precision and accuracy of the measured COC concentrations can be determined. In general the following field QA/QC measures will be required:

- Chain-of-custody
- Trip blank (for volatile organics compounds, one for each day of sampling)
- Field blank
- Equipment blank (rinsate blank)
- Field duplicates (a minimum of one duplicate for every 20 or fewer samples)

- Documentation of field events (sampling procedures, locations, conditions, and characteristics of samples collected)

Appropriate sample containers; preservatives; and handling, storage, and transportation techniques should also be used to maintain the integrity of the samples and analytical data. The control criteria that the field QA/QC measures should meet can be found in the IDEM manual, ***Guidance to the Performance and Presentation of Analytical Chemistry Data.*** **The field QA/QC measures must be documented and should be submitted as supporting documentation to the risk assessment along with the analytical results.**

Analytical Quality Assurance/Quality Control

The QA/QC procedures described in the analytical method chosen should be followed to ensure that Closure Level criteria and other project DQOs can be met. In general, the following measures will be required:

- Chain-of-custody
- Holding time requirements
- Instrument tuning
- Instrument calibration records
- Initial and continuing calibration verifications
- Laboratory control samples
- Matrix spike/matrix spike duplicate samples
- Raw data

The control criteria that the analytical QA/QC measures should meet can be found in the IDEM manual, ***Guidance to the Performance and Presentation of Analytical Chemistry***. **The laboratory QA/QC measures and their results must be documented and should be submitted as supporting documentation to the risk assessment along with the analytical report of sample results**.

Documentation Requirements

Documentation requirements for analytical data, field QA/QC measures, and laboratory QA/QC results are listed below. General requirements applicable to all samples are followed by requirements specific to analysis type.

GENERAL Sampling Quality Control Data and Information:

- Chain-of-Custody
- Date and time each sample was taken
- Map or diagram indicating sample locations
- Field measurements made (and results)
- Any notable observations *(*color, clarity, texture, reaction with preservatives, etc.)
- Trip blank (or field blank)

- Equipment blank (rinsate blank)
- Identity of field duplicates (a minimum of one duplicate for every 20 or fewer samples)

GENERAL Laboratory Quality Control Data and Information:

- Completed Chain-of-Custody
- Date and time of receipt at the laboratory
- Condition of samples upon receipt at the laboratory
- Sample identification number or designation
- Laboratory sample numbers corresponding to facility sample identification
- Sample preparation, extraction, cleanup, or digestion method(s) and date(s)
- Analytical method (name, number, and source) and date of analysis
- Final analytical results
- Case narrative (Includes deviations from standard analytical or preparatory procedure(s); quality control problems encountered--whether stemming from system, instrumentation, analyst error, or sample matrix; corrective measures taken; if corrective measures as called for in the method were not taken; results of corrective measures taken; etc.)

SPECIFIC ANALYSES

Metals and General Inorganic Analyses

TOTAL AND DISSOLVED METALS by Inductively Coupled Plasma Atomic Emission Spectroscopy (ICP) or Atomic Absorption Spectroscopy (AA) and GENERAL INORGANIC ANALYSES

- Method/sample quantitation limits
- Instrument detection limits
- Calibration records and results:
- Blank results
- Matrix spike (sample number of sample spiked, sample concentration for analyte, concentration of spike added, results and % Recovery)
- Matrix spike duplicate or laboratory duplicate (results and Relative Percent Difference [RPD]; if matrix spike duplicate, also report %Recovery)
- Laboratory control sample (QC standard or lab-fortified blank: results and %Recovery)
- Additional deliverables for ICP analysis (if applicable): Interference check sample (results and % recovery), serial dilution results (five-fold analysis), ICP Linear Range, and inter-element correction factors
- Method of Standard Addition (MSA) results (if applicable)
- **Raw data**: To include instrument numerical printouts, instrument peak printouts (all AA and general inorganic, where applicable), lab worksheets, strip chart recordings, sample preparation records, and record of dilutions.

Organic Analyses

VOLATILE ORGANIC ANALYSIS (VOA) and SEMIVOLATILE ORGANIC ANALYSIS (SVOA) BY GAS CHROMATOGRAPHY/MASS SPECTROMETRY (GC/MS)

- Tuning criteria and results

- Initial calibration data and results
- Initial and Continuing Calibration Verification data and results (beginning of run and every twelve hours:
- Method blank summary sheet with results, including detections
- Detection/quantitation limit for each compound
- Internal standards summary
- Surrogate (System Monitoring Compound) results (concentration of surrogate spikes added, measured concentrations, and % Recoveries of all surrogates) for each sample
- Matrix Spike/Matrix Spike Duplicate (MS/MSD) results (sample concentration for analyte, concentration of spike added, results, % Recovery for each compound, and Relative Percent Difference between MS and MSD for each compound)
- **Raw Data** for each sample, field duplicate, blank, matrix spike/matrix spike duplicate.

ANALYSIS OF VOLATILE ORGANIC COMPOUNDS and SEMIVOLATILE ORGANIC COMPOUNDS BY GAS CHROMATOGRAPHY (GC) Using Method-Specified Detectors (FID, PID, HECD, etc.)

- Initial Calibration, data and results
- Retention Time (RT) Summary to include:
  --- RT measured for each target compound from three separate injections over a 72-hour period
  --- Mean and standard deviations of the three RTs measured (over the 72-hour period)
  --- RT window for each target compound (mean ± three standard deviations)
  --- Date and time of injections (or introduction by purge-and-trap)
- Initial and Continuing Calibration Verification (ICV and CCV)
- Method of sample introduction (direct injection or purge-and-trap)
- Detection/quantitation limit for each compound
- Method blank summary and chromatograms
- Surrogate recoveries for samples, blanks, and spikes
- Matrix spike/matrix spike duplicate (MS/MSD) analysis or lab duplicates
- **Raw Data** for each sample, standard, field duplicate, blank, matrix spike, and matrix spike duplicate, including dilutions made, chromatograms and preparatory records.
- Confirmation by GC/MS or on second GC column, if required by determinative method or if interference is suspected. Include results and raw data.

QUALITY ASSURANCE/QUALITY CONTROL INFORMATION FOR ANALYSIS OF PESTICIDES and PCBS BY GAS CHROMATOGRAPHY (GC) WITH ELECTRON CAPTURE DETECTOR (ECD) OR ELECTROLYTIC CONDUCTIVITY DETECTOR (ELCD OR HECD)

- Initial Calibration
- Method blank summary and chromatograms
- Detection/quantitation limit for each compound (in each sample)
- Surrogate recoveries for samples, blanks, and spikes
- Matrix spike/matrix spike duplicate (MS/MSD) analysis or laboratory duplicates
- **Raw Data** for each sample, standard, field duplicate, blank, matrix spike, and matrix spike duplicate, including dilutions made, preparatory records, and chromatograms

- Confirmation of detection **required**: on second GC column *OR* by GC/MS with supporting documentation

Data Validation

Validation is the evaluation of the technical usability of the data in light of its intended use: whether the methods used and results obtained make sense and are scientifically defensible given the study objectives. This is done through a "**PARCC**" evaluation: **precision, accuracy, representativeness, completeness, and comparability**.

- **Precision** is the measurement of agreement of a set of replicate results among themselves without assumption of any prior information as to the true result. Precision is assessed through the analysis or duplicate or replicate samples.
- **Accuracy** is the nearness of a result or the nearness of the mean of a set of results to the true value. Accuracy is assessed through the analysis of reference samples or the introduction of reference materials to field samples and measurement of percent recovery of the known value.
- **Representativeness** is an assessment as to how well the field samples collected reflect the actual site conditions.
- **Completeness** is an assessment as to whether sufficient information has been provided. It includes aspects from whether a sufficient number of samples were collected to whether enough analytical documentation of laboratory operations was provided.
- **Comparability** is how well the data corresponds to data collected in previous sampling events at the site or to site samples from the same event analyzed at different laboratories.

The PARCC evaluation is accomplished through a comprehensive QA/QC review of the data, providing an estimate of the uncertainty in the data values. Guidelines for performing a comprehensive data review are listed below.

Data Review Guidelines

The criteria listed in the *USEPA Contract Laboratory Program National Functional Guidelines for Organic Data Review*[3] **and the *USEPA Contract Laboratory Program Guidelines for Inorganic Data Review***[4]9240.1-05-01, EPA-540/R-94-013, February1994, NTIS: PB94-963502 **provide a good starting point for data review. However, an unmodified "CLP review" is <u>not</u> sufficient for validating data to be used in support of risk assessments**. A "CLP review" results in data that are flagged by "data qualifiers," that is, letter symbols denoting a general category of data quality, such as "estimated" (J) or "unusable" (R). These qualifiers do not explain the scientific evidence in the data leading to the qualification and do not provide a

[3]Environmental Protection Agency, Office of Solid Waste and Emergency Response, Publication 9240.1-05, EPA-540/R-94/012, February 1993, NTIS: PB94-963501.

[4]Environmental Protection Agency, Office of Solid Waste and Emergency Response, Publication 9240.1-05-01, EPA-540/R-94-013, February 1994, NTIS: PB94-963502

measurement or estimate of the uncertainty in the data values, and thereby, their application to the Closure Level values.

Data validation for risk assessment involves reviewing the data using criteria similar to those listed in the CLP *National Functional Guidelines* but going on to document the evidence for qualification and measure or estimate the statistical error or uncertainty. The following is a suggested review process. It can be applied to any type of analytical method used:

1. **Review every criterion listed in the *National Functional Guidelines* for the applicable QC measure and use the evaluation procedure listed, with these exceptions:**

   a. Substitute the control limits/criteria specified in the actual analytical method followed for the CLP limits in the *National Functional Guidelines.* If the actual method followed does not specify set control limits, use the CLP control limits.

   b. After evaluating all applicable criteria for the analysis type, qualify the data if appropriate. To do this, rather than just adding a CLP qualifier (like "J" or "R") to the reported result, write a memo or report explaining in words why the data is estimated or unusable:

      - Go into detail in the text of the review report, listing <u>all</u> criteria or reasons justifying the qualification as estimated or unusable. Explain whether it is a sample matrix problem, a laboratory precision or accuracy problem, a sampling problem, etc.

      - Do this separately for each analyte. However, groups of analytes of the same general class (e.g., "metals" or "semivolatile organics") that have the exact same QC problems for the exact same samples or monitoring wells can be grouped together.

      - If the QC problem affects analysis of *all* samples for that analyte, say so and qualify all. If the problem can be identified as being limited to particular samples, list which samples they are (and do not qualify the others).

      - Provide an abbreviated summary of the reasons in a "Table of Estimated Analytes" to be included at the end of the report.

   c. In the case of accuracy problems, assign a direction of bias where possible. If possible, also attempt to quantify the bias as a percentage or number of measurement units.

   d. In the case of precision problems, state that it is a precision problem in some way–e.g.: "the duplicates compare (or do not compare) well," "results exhibit high variability," "results exhibit poor repeatability," etc.–and that the direction of bias cannot be determined. Again, when possible, estimate the uncertainty expressed as a range: +/- a percentage value or +/- some number of measurement units.

2. **Review <u>100%</u> of the raw data and base your findings mainly on the raw data.**

- Do not rely solely on the certificates of analysis (or "analytical reports"), QA reports, and "Case Narratives" for your determinations. These can be incomplete or include errors.

- Check calculations.

- Look for trends–in matrix effects, blank results, calibration check samples, etc., and use these to help you evaluate the data.

3. **Always keep in mind the question the data is supposed to answer and the objective of the review.** Data submitted for an environmental project is not reviewed in the same way as a data intended to determine a laboratory's conformance to contract requirements. What we are looking for in the data validation is the answer to these questions: Is the quality of the data sufficient to meet the project objectives? What does the data tell us about the site? What relationship does this data have to the exposure assumptions?

The data validation process supports the subsequent Data Quality Assessment activities.

Data Quality Assessment Process (DQA)

Data Quality Assessment is the scientific and statistical process that determines whether environmental data are of the right type, quality, and quantity to support project decisions. DQA is built on a fundamental premise: data **quality**, as a concept, is meaningful only when it relates to the intended use of the data. *"Data quality does not exist without some frame of reference. The context in which the data will be used in order to establish a yardstick for judging whether or not the data set is adequate."*[5] **The DQA tells us if the data has answered the questions the project was intended to ask about the site.**

Definitions of Words and Acronyms appearing in the Analytical Methods with Reporting Limits for RISC Table:

Analyte The substance (element or compound) being identified and measured in the sample. It may be a suspected contaminant, contaminant of concern, or natural background component.

CAS No. Chemical Abstract Service (CAS) registry number. A unique numerical identifier that specifies a particular substance no matter what chemical name or synonym is used.
E.g.: *79-01-6 = Trichloroethene = Trichloroethylene = "Tricloran" = "TCE"
*71-55-6 = 1,1,1-Trichloroethane = Methyl chloroform ="Chlorothene"="TCA"
"TCE" and "TCA" are not the same compound.

[5]Environmental Protection Agency, Office of Research and Development, *The EPA Quality System*, EPA QA/G-0 Final, August 1997, p. 9-1.

Quantitation Limit (QL) The lowest concentration that can be *reliably* achieved within specified limits of precsion and accuracy during routine laboratory operating conditions. Individual sample QLs are highly matrix dependent and may vary widely.

Method Reporting Limit The QL reported by the referenced methods manual for a specific substance analyzed by a specific method.

mg/kg Micrograms per kilogram. An expression of concentration as mass of analyte per unit mass of sample in "parts per billion." Used for soil, sediment, and waste samples.

mg/L Micrograms per liter. An expression of concentration as mass of analyte per unit volume of sample in "parts per billion." Used for aqueous samples.

Types of Method Reporting Limits referenced in this document and the Table:

- **EQL** *Estimated Quantitation Limit*. Specified in many SW-846 methods. Often set at 10 times the MDL or at the concentration of the lowest non-zero standard in the calibration curve. Use of the word "estimated" emphasizes matrix dependence: variation between samples will occur, and the EQL may not always be achievable.

- **CR(Q/D)L** *Contract Required Quantitation Limit (CRQL) or Contract Required Detection Limit (CRDL)*, as applicable. Used in the CLP Statements of Work. **CRDL:** Used for inorganic analytes; **CRQL:** Used for organic compounds.

- **MDL** *Method Detection Limit*. Minimum concentration of a substance that can be measured and reported with 99% confidence that the analyte concentration is greater than zero. Used in Drinking Water methods and some SW-846 methods. Often not achievable in routine analysis of field samples other than low concentration water samples.

References

U. S. Environmental Protection Agency. Office of Emergency and Remedial Response. *Data Quality Objectives Process for Superfund: Interim Final Guidance*. Publication 9355.9-01. EPA-540-R-93-071. NTIS PB94-963203. [Washington, D. C.]: U. S. Environmental Protection Agency, Office of Emergency and Remedial Response. September 1993.

U. S. Environmental Protection Agency. Office of Solid Waste and Emergency Response. *USEPA Contract Laboratory Program National Functional Guidelines for Organic Data Review*. Publication 9240.1-05. EPA-540/R-

94/012. NTIS: PB94-963501. [Washington, D. C.]: U. S. Environmental Protection Agency, Office of Solid Waste and Emergency Response. February 1993.

U. S. Environmental Protection Agency. Office of Solid Waste and Emergency Response. *USEPA Contract Laboratory Program National Functional Guidelines for Inorganic Data Review*. Publication 9240.1-05-01. EPA-540/R-94-013. NTIS: PB94-963502. [Washington, D. C.]: U. S. Environmental Protection Agency, Office of Solid Waste and Emergency Response. February 1994.

U. S. Environmental Protection Agency. Office of Research and Development. *The EPA Quality System, EPA QA/G-0, Final*. Pre-Publication Copy. Washington, D. C.: U. S. Environmental Protection Agency, Office of Research and Development. August 1997.

RESIDENTIAL CLOSURE - ANALYTICAL METHODS WITH REPORTING LIMITS FOR RISC (September 15, 2000)

Analyte	CAS No.	RESIDENTIAL SOIL (mg/kg)					RESIDENTIAL GROUND WATER (mg/L)						
		Default Closure Level[a], µg/kg	SW-846[1a]		CLP[2,3]		Default Closure Level[b], µg/L	SW-846[1a]		CLP[2,3]		EPA Drinking & Waste Water[4-12]	
			EQL	Method	CR(Q/D)L	Method		EQL	Method	CR(Q/D)L	Method	MDL	Method
Acenaphthene	83-32-9	130,000	660 18000	8270C 8310[N]	330	OLM04.2-D/SVOA	460	10 18	8270C 8310	10	OLM04.2-D/SVOA	1.8 1.9	610[7] 625[7]
Acetone *ynonym: 2-Propanone*	67-64-1	3,100	50 160	8260B[K,R] 8015B[N]	10	OLM04.2-D/VOA	770	5 160	8260B 8015B[N]	10	OLM04.2-D/VOA	—	—
Acrolein *ynonym: 2-Propenal*	107-02-8	0.23*	5	8260B[E]	—	---	0.055*	1	8260B[D]	—	—	0.7	603[7]
Aldrin	309-00-2	250	23	8081B[E,M]	1.7	OLM04.2-D/PEST	0.050	0.034	8081B[F]	0.050	OLM04.2-D/PEST	0.007 0.045	505[4] 525.2[4]
Anthracene	120-12-7	51,000	660 6600	8270C 8310[N]	330	OLM04.2-D/SVOA	43	10 6.6	8270C 8310	10	OLM04.2-D/VOA	0.18	525.2[4]
Antimony	7440-36-0	5,400	2100 200	6010B[G] 6020A[1b,G]	3200[C]	ILM04.0/200.7 CLP-M	6.0	3 0.4	7041 (7010[1b]) 6020[G]	3	ILM04.0/**204.2** CLP-M ***(furnace)***	3 0.4	204.2[5] 200.8[5]
Arsenic	7440-38-2	3,900	3500 600	6010B[G] 6020A[1b,G]	500[C]	ILM04.0/**206.2** CLP-M ***(furnace)***	5.0[J]	1 1.4	7060A(7010[1b]) 6020[G]	1	ILM04.0/**206.2** CLP-M ***(furnace)***	1 1.4	206.2[5] 200.8[5]
Barium	7440-39-3	1,600,000	100 400	6010B[G] 6020A[1b,G]	20000[C]	ILM04.0/200.7 CLP-M	2,000	1 0.8	6010B[G] 6020[G]	200	ILM04.0/200.7 CLP-M	1 0.8	200.7[5] 200.8[5]
Benz[a]anthracene	56-55-3	5,000	660 130	8270C 8310[N]	330	OLM04.2-D/SVOA	1.2	0.13	8310	10	OLM04.2-D/SVOA	0.20	525.2[4]
Benzene	71-43-2	34	0.09 5	8021B[E,N] 8260B[E]	10	OLM04.2-D/VOA	5.0	0.09 1	8021B[N] 8260B[D]	10	OLM04.2-D/VOA	0.02 0.04	502.2[4] 524.2[4]
Benzo[b]fluoranthene	205-99-2	5,000	660 180	8270C[E] 8310[N]	330	OLM04.2-D/SVOA	1.2	0.18	8310	10	OLM04.2-D/SVOA	0.3	525.2[4]
Benzo[k]fluoranthene	207-08-9	39,000	660 170	8270C 8310[N]	330	OLM04.2-D/SVOA	0.80	0.17	8310	10	OLM04.2-D/SVOA	0.3	525.2[4]
Benzoic acid	65-85-0	590,000	3300	8270C[V]	—	—	150,000	50	8270C[V]	—	—	50[H]	1625C[8]
Benzo[a]pyrene	50-32-8	500	230	8310[N]	330	OLM04.2-D/SVOA	0.20	0.02	8310[F]	10	OLM04.2-D/SVOA	0.1	525.2[4]
Benzyl alcohol	100-51-6	48,000	1300	8270C[V]	—	—	11,000	20	8270C[V]	—	—	50[H]	1625C[8]
Beryllium	7440-41-7	63,000	100 100	6010B[G] 6020A[1b,G]	500[C]	ILM04.0/200.7 CLP-M	4.0	0.3 0.3	6010B 6020A[1b,G]	0.2	ILM04.0/**210.2** CLP-M ***(furnace)***	0.7 0.3	200.7[5] 200.8[5]

RESIDENTIAL CLOSURE - ANALYTICAL METHODS WITH REPORTING LIMITS FOR RISC (September 15, 2000)

Analyte	CAS No.	RESIDENTIAL SOIL (mg/kg)					RESIDENTIAL GROUND WATER (mg/L)						
		Default Closure Level[a], µg/kg	SW-846[1a]		CLP[2,3]		Default Closure Level[b], µg/L	SW-846[1a]		CLP[2,3]		EPA Drinking & Waste Water[4-12]	
			EQL	Method	CR(Q/D)L	Method		EQL	Method	CR(Q/D)L	Method	MDL	Method
Bis(2-chloroethyl)ether *Syn: 1,1'-Oxybis(2-chloroethane)*	111-44-4	0.70	0.5	8410[E,L]	330	OLM04.2-D/SVOA	0.15*	0.3	8111[F,I,X]	10	OLM04.2-D/SVOA	0.3	611[7,X]
Bis(2-chloroisopropyl)ether *Syn: 2,2'-Oxybis(1-chloropropane)*	108-60-1	27	0.5	8410[E,L]	330	OLM04.2-D/SVOA	4.2	0.8	8111[F,I]	10	OLM04.2-D/SVOA	0.8	611[7]
Bis(2-ethylhexyl)phthalate *Syn.: Di(2-ethylhexyl)phthalate*	117-81-7	300,000	625 2700	8270C 8061A[N,R]	330	OLM04.2-D/SVOA	6.0	2.7	8061A[N]	10	OLM04.2-D/SVOA	0.8	525.2[4]
Bromodichloromethane	75-27-4	630	5 25	8260B[E] 8021B[N]	10	OLM04.2-D/VOA	100	5 0.2	8260B 8021B[N]	10	OLM04.2-D/VOA	0.02 0.08	502.2[4] 524.2[4]
Bromoform *Synonym: Tribromomethane*	75-25-2	750	5 16	8260B[E] 8021B[E,N]	10	OLM04.2-D/VOA	100	5 1.6	8260B 8021B[N]	10	OLM04.2-D/VOA	1.6 0.12	502.2[4] 524.2[4]
n-Butanol *Syn.: n-butyl alcohol, 1-butanol*	71-36-3	16,000	625 2300	8260B[R,U] 8015B[Q,U]	---	---	3,700	5 140	8260B[U] 8015B[U]	---	---	500	1666[12]
Butyl benzyl phthalate	85-68-7	930,000	660	8270C[R]	330	OLM04.2-D/SVOA	2,700	10	8270C	10	OLM04.2-D/SVOA	0.5	525.2[4]
Cadmium	7440-43-9	7,500	300 200	6010B[G] 6020A[1b,G]	500[C]	ILM04.0/200.7 CLP-M	5.0	0.1 5	7131A 6020	5	ILM04.0/200.7 CLP-M	1 0.5	200.7[5] 200.8[5]
Carbazole	86-74-8	5,900	[660 [1000	8270C][W] 8275A][P,W]	330	OLM04.2-D/SVOA	43	[10	8270C]	330	OLM04.2-D/SVOA	20	1625C[8]
Carbon disulfide	75-15-0	10,000	50	8260B[K]	10	OLM04.2-D/VOA	1,300	5	8260B	10	OLM04.2-D/VOA	0.09	524.2[4]
Carbon tetrachloride	56-23-5	66	5 13	8260B[E] 8021B[N]	10	OLM04.2-D/VOA	5.0	1 0.1	8260B[D] 8021B[N]	10	OLM04.2-D/VOA	0.01 0.21	502.2[4] 524.2[4]
Chlordane	57-74-9	9,600	370 (()	8081B[M,R]	1.7	OLM04.2-D/PEST	2.0	0.37(()	8081B[M]	0.05	OLM04.2-D/PEST	0.0015	508[4]
p-Chloroaniline *Synonym: 4-Chloroaniline*	106-47-8	970	440 1300	8131[E,N] 8270C[E,V]	330	OLM04.2-D/SVOA	150	46 20	8131 8270C	10	OLM04.2-D/SVOA	20	1625C[8]
Chlorobenzene	108-90-7	1,300	13 625	8021B[N,R] 8260B[N]	10	OLM04.2-D/VOA	100	0.1 5	8021B[N] 8260B	10	OLM04.2-D/VOA	0.01 0.04	502.2[4] 524.2[4]

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Analyte	CAS No.	RESIDENTIAL SOIL (mg/kg)					RESIDENTIAL GROUND WATER (mg/L)					
		Default Closure Level[a], µg/kg	SW-846[1a]		CLP[2,3]		Default Closure Level[b], µg/L	SW-846[1a]		CLP[2,3]		EPA Drinking & Waste Water[4-12]
			EQL	Method	CR(Q/D)L	Method		EQL	Method	CR(Q/D)L	Method	MDL / Method
Chloroethane	75-00-3	260	1 5	8021B[E,N] 8260B[E]	10	OLM04.2-D/VOA	50	1 5	8021B[N] 8260B	10	OLM04.2-D/VOA	0.1 502.2[4] 0.1 524.2[4]
Chloroform *ynonym:* *Trichloromethane*	67-66-3	590	25 5	8021B[N] 8260B[E]	10	OLM04.2-D/VOA	100	0.2 5	8021B[N] 8260B	10	OLM04.2-D/VOA	0.02 502.2[4] 0.03 524.2[4]
-Chlorophenol	95-57-8	750	660 210	8270C[E] 8041[E,M]	330	OLM04.2-D/SVOA	38	10 3.1	8270C 8041	10	OLM04.2-D/VOA	3.3 625[7] 0.58 604[7]
Total Chromium[T]	7440-47-3	38,000	500 400	6010B[G] 6020A[1b,G]	1000[C]	ILM04.0/200.7 CLP-M	100	10 0.9	6010B 6020	10	ILM04.0/200.7 CLP-M	4 200.7[5] 0.9 200.8[5]
Chromium III *(trivalent)*[S]	16065-83-1	10,000,000	*Calculate as difference: Total - hexavalent = tri (or use:)* 80	6020-SIM[S]	---	—	2,000	*Calculate as difference: Total - hexavalent=tri (or use:)* 0.08	6020-SIM[S]	---	—	*Calculate as difference: Total hexavalent=tri (or use:)* 0.2 1639[8] 0.9 200.8-SIM[5]
Chromium VI *(hexavalent)*[S]	18540-29-9	38,000	**Alkaline Digestion (Method 3060A)** + *one of the following*: 20000 12 80	7196A[G] 7199[G] 6020A-SIM[S]	---	---	100	**Alkaline Preservation** + *one of the following* 5 10 0.3 0.08	7195 7198 7199 6020A-SIM[S]	---	---	**Alkaline Preservation** ***(See Method 1669)***[8] + 10 218.4[9] 5 218.5[9] 0.4 218.6[10] 0.5 1636[8]
Chrysene	218-01-9	25,000	660 1500	8270C 8310[N]	330	OLM04.2-D/SVOA	1.6	1.5	8310	10	OLM04.2-D/SVOA	0.3 525.2[4]
Copper	7440-50-8	580,000	400 200	6010B[G] 6020A[1b,G]	2500[C]	ILM04.0/200.7 CLP-M	1,300	3 0.5	6010B 6020	25	ILM04.0/200.7 CLP-M	3 200.7[5] 0.5 200.8[5]
Cyanide, free	57-12-5	150,000	1000 2500	9014 *(free)* 9213 *(free)*	2500[C]	ILM04.0/**335.2** CLP-M *(total CN-)*		20 50	9014 *(free)* 9213 *(free)*	10	ILM04.0/335.2 CLP-M *(total CN-)*[Y]	5 335.4[6,Y] *(total CN-)*
,4'-DDD *(DDD)*	72-54-8	28,000	500	8081B[M]	3.3	OLM04.2-D/PEST	3.5	0.50	8081B[M]	0.10	OLM04.2-D/PEST	0.01 508[4]

RESIDENTIAL CLOSURE - ANALYTICAL METHODS WITH REPORTING LIMITS FOR RISC (September 15, 2000)

Analyte	CAS No.	RESIDENTIAL SOIL (mg/kg)					RESIDENTIAL GROUND WATER (mg/L)						
		Default Closure Level[a], µg/kg	SW-846[1a]		CLP[2,3]		Default Closure Level[b], µg/L	SW-846[1a]		CLP[2,3]		EPA Drinking & Waste Water[4-12]	
			EQL	Method	CR(Q/D)L	Method		EQL	Method	CR(Q/D)L	Method	MDL	Method
,4'-DDE *(DDE)*	72-55-9	20,000	580	8081B[M]	3.3	OLM04.2-D/PEST	2.5	0.58	8081B[M]	0.10	OLM04.2-D/PEST	0.02	508[4]
,4'-DDT *(DDT)*	50-29-3	20,000	810	8081B[M]	3.3	OLM04.2-D/PEST	2.5	0.81	8081B[M]	0.10	OLM04.2-D/PEST	0.06	508[4]
)ibenz[a,h]anthracene	53-70-3	500	20	8310[E,N]	330	OLM04.2-D/SVOA	0.12	0.03[F]	8310	10	OLM04.2-D/SVOA	0.1	525.2[4]
)i-n-butyl phthalate	84-74-2	2,000,000	3300 660	8061A[N,R] 8270C	330	OLM04.2-D/SVOA	3,700	3.3 10	8061A 8270C	10	OLM04.2-D/SVOA	4	525.2[4]
,2-Dichlorobenzene	95-50-1	17,000	0.5 5	8021B[N] 8260B	10	OLM04.2-D/VOA	600	2.7 5	8121 8260B	10	OLM04.2-D/SVOA	0.04 0.05	502.2[4] 524.2[4]
,3-Dichlorobenzene	541-73-1	130	0.2 5	8021B[N] 8260B[E]	10	OLM04.2-D/VOA	6.9	2.5 5	8121 8260B	10	OLM04.2-D/SVOA	0.07 0.05	502.2[4] 524.2[4]
,4-Dichlorobenzene	106-46-7	2,200	0.1 5	8021B[N] 8260B	10	OLM04.2-D/VOA	75	8.9 5	8121 8260B	10	OLM04.2-D/SVOA	0.04 0.04	502.2[4] 524.2[4]
,3'-Dichlorobenzidine	91-94-1	62	62	1625C[O,8]	330	OLM04.2-D/SVOA	1.9	1.4[F]	8325	10	OLM04.2-D/SVOA	0.13	605[7]
,1-Dichloroethane	75-34-3	5,600	0.7 5	8021B[N] 8260B	10	OLM04.2-D/VOA	990	0.7 5	8021B[N] 8260B	10	OLM04.2-D/VOA	0.03 0.04	502.2[4] 524.2[4]
,2-Dichloroethane	107-06-2	24	0.3 5	8021B[E,N] 8260B[E]	10	OLM04.2-D/VOA	5.0	0.3 5	8021B[N] 8260B	10	OLM04.2-D/VOA	0.03 0.06	502.2[4] 524.2[4]
,1-Dichloroethylene *ynonym: 1,1-* *)ichloroethene*	75-35-4	58	0.7 5	8021B[E,N] 8260B[E]	10	OLM04.2-D/VOA	7.0	0.7 5	8021B[N] 8260B	10	OLM04.2-D/VOA	0.04 0.12	502.2[4] 524.2[4]
is-1,2-Dichoroethene *yn.: cis-1,2-* *)ichloroethylene*	156-59-2	400	0.2 5	8021B[N] 8260B[E]	10	OLM04.2-D/VOA	70	0.2 5	8021B[N] 8260B	10	OLM04.2-D/VOA	0.05 0.12	502.2[4] 524.2[4]
rans-1,2-Dichoroethene *yn.: trans-1,2-* *)ichloroethylene*	156-60-5	680	0.5 5	8021B[N] 8260B[E]	10	OLM04.2-D/VOA	100	0.5 5	8021B[N] 8260B	10	OLM04.2-D/VOA	0.05 0.06	502.2[4] 524.2[4]
,4-Dichlorophenol	120-83-2	1,100	660 260	8270C[E] 8041[E,N]	330	OLM04.2-D/SVOA	110	10 3.9	8270C 8041	10	OLM04.2-D/SVOA	0.39 2.7	604[7] 625[7]
,2-Dichloropropane	78-87-5	30	0.06 5	8021B[N] 8260B[E]	10	OLM04.2-D/VOA	5.0	0.06 1	8021B[N] 8260B[D]	10	OLM04.2-D/VOA	0.03 0.04	502.2[4] 524.2[4]

RESIDENTIAL CLOSURE - ANALYTICAL METHODS WITH REPORTING LIMITS FOR RISC (September 15, 2000)

Analyte	CAS No.	RESIDENTIAL SOIL (mg/kg)					RESIDENTIAL GROUND WATER (mg/L)						
		Default Closure Level[a], µg/kg	SW-846[1a]		CLP[2,3]		Default Closure Level[b], µg/L	SW-846[1a]		CLP[2,3]		EPA Drinking & Waste Water[4-12]	
			EQL	Method	CR(Q/D)L	Method		EQL	Method	CR(Q/D)L	Method	MDL	Method
,3-Dichloropropene cis- and trans-)	542-75-6	40	0.3 5	8021B[E,N] 8260B[E]	10	OLM04.2-D/VOA	5.6	0.3 1	8021B[N] 8260B[D]	10	OLM04.2-D/VOA	0.1 0.1	502.2[4] 524.2[4]
)ieldrin	60-57-1	46	30	8081B[E,M]	3.3	OLM04.2-PEST	0.053	0.044	8081B[F,M]	0.10	OLM04.2-PEST	0.02	508[4]
)iethylphthalate	84-66-2	450,000	660 2500	8270C 8061A[N,R]	330	OLM04.2-D/SVOA	29,000	10 2.5	8270C 8061A	10	OLM04.2-D/SVOA	0.8	525.2[4]
)imethylphthalate	131-11-3	1,400,000	660 6400	8270C 8061A[N,R]	330	OLM04.2-D/SVOA	370,000	10 6.4	8270C 8061A	10	OLM04.2-D/SVOA	0.14 1.1	525.2[4] 506[4]
2,4-Dimethylphenol	105-67-9	9,000	660 220	8270C 8041[E,M]	330	OLM04.2-D/SVOA	730	10 3.2	8270C 8041	10	OLM04.2-D/SVOA	2.4	625[7]
)imethylphthalate	131-11-3	1,400,000	660 6400	8270C 8061A[N,R]	330	OLM04.2-D/SVOA	370,000	10 6.4	8270C 8061A	10	OLM04.2-D/SVOA	1.1	506
,4-Dinitrophenol	51-28-5	290	13	8041[F]	830	OLM04.2-D/SVOA	73	50	8270C[V]	25	OLM04.2-D/SVOA	42	625[7]
)initrotoluene mixture	25321-14-6	8.5	1	8410[L]	330	OLM04.2-D/SVOA	1.3	0.31	8330	10	OLM04.2-D/SVOA	0.02	609[7]
)i-n-octyl phthalate	117-84-0	2,000,000	660 490	8270C 8061A[N,R]	330	OLM04.2-D/SVOA	20	10 0.5	8270C 8061A	10	OLM04.2-D/SVOA	2.5	625[7]
:ndosulfan	115-29-7	20,000	400	8081B[M]	3.3	OLM04.2-D/PEST	220	0.4	8081B[M]	0.10	OLM04.2-PEST	0.015	508[4]
:ndrin	72-20-8	990	390	8081B[M]	3.3	OLM04.2-D/PEST	2.0	0.39	8081B[M]	0.10	OLM04.2-PEST	0.015	508[4]
:thylbenzene	100-41-4	13,000	5 0.05	8260B 8021B[N]	10	OLM04.2-D/VOA	700	5 0.05	8260B 8021B[N]	10	OLM04.2-D/VOA	0.002 0.06	503.1[4] 524.2[4]
'luoranthene	206-44-0	880,000	660 2100	8270C 8310[N]	330	OLM04.2-D/SVOA	210	10 2.1	8270C 8310	10	OLM04.2-D/SVOA	0.21 2.2	610[7] 625[7]
'luorene	86-73-7	170,000	660 2,100	8270C 8310[N]	330	OLM04.2-D/SVOA	310	10 2.1	8270C 8310	10	OLM04.2-D/SVOA	0.21 1.9	610[7] 625[7]
Heptachlor	76-44-8	540	27	8081B[E,M]	1.7	OLM04.2-D/PEST	0.40	0.40	8081B[M]	0.050	OLM04.2-D/PEST	0.01	508[4]
Heptachlor epoxide	1024-57-3	470	21	8081B[E,M]	1.7	OLM04.2-D/PEST	0.20	0.032	8081B[F,M]	0.050	OLM04.2-D/PEST	0.015	508[4]

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Analyte	CAS No.	RESIDENTIAL SOIL (mg/kg)					RESIDENTIAL GROUND WATER (mg/L)						
		Default Closure Level[a], µg/kg	SW-846[1a]		CLP[2,3]		Default Closure Level[b], µg/L	SW-846[1a]		CLP[2,3]		EPA Drinking & Waste Water[4-12]	
			EQL	Method	CR(Q/D)L	Method		EQL	Method	CR(Q/D)L	Method	MDL	Method
Hexachlorobenzene	118-74-1	2,200	660 56	8270C[E] 8121[N,R]	330	OLM04.2-D/SVOA	1.0	0.056	8121[N]	10	OLM04.2-D/SVOA	0.1	525.2[4]
Hexachloro-1,3-butadiene	87-68-3	16,000	660 14	8270C 8121[N,R]	330	OLM04.2-D/SVOA	7.3	0.014	8121[N]	10	OLM04.2-D/SVOA	0.05 0.11	502.2[4] 524.2[4]
-HCH (*"-BHC)*	319-84-6	7.2	1.9 7.4	8081B[F,M] 8121[E,N]	1.7	OLM04.2-D/PEST	0.14	0.04 0.11	8081B[F] 8121[N]	0.050	OLM04.2-D/PEST	0.025	508[4]
-HCH (*$-BHC)*	319-85-7	26	15 21	8081B[E,M] 8121[E,N]	1.7	OLM04.2-D/PEST	0.47	0.23 0.31	8081B[M] 8121[N]	0.050	OLM04.2-D/PEST	0.01	508[4]
-HCH (*(-BHC)* *ynonym: Lindane*	58-89-9	9.4	2 15	8081B[F,M] 8121[E,N]	1.7	OLM04.2-D/PEST	0.20	0.02 0.2	8081B[F] 8121[N]	0.050	OLM04.2-D/PEST	0.015	508[4]
Hexachlorocyclopentadiene	77-47-4	400,000	660 2400	8270C 8121[N,R]	330	OLM04.2-D/SVOA	50	10 2.4	8270C 8121[N]	10	OLM04.2-D/SVOA	0.1	525.2[4]
Hexachloroethane	67-72-1	2,800	660 16	8270C[E] 8121[N]	330	OLM04.2-D/SVOA	37	10 0.016	8270C 8121[N]	10	OLM04.2-D/SVOA	0.03	612[7]
ndeno[1,2,3-cd]pyrene	193-39-5	3,100	660 29	8270C[E] 8310[N]	330	OLM04.2-D/SVOA	0.022	0.043	8310[F,X]	10	OLM04.2-D/SVOA	0.02	525.2[4]
sophorone	78-59-1	5,300	660	8270C[E]	330	OLM04.2-D/SVOA	900	10	8270C	10	OLM04.2-D/SVOA	2.2	625[7]
ead	7439-92-1	81,000	2800 300	6010B[G] 6020A[1b,G]	4200[C]	ILM04.0/200.7 CLP-M	15	1 0.6	7421 6020	3	ILM04.0/200.7 CLP-M	10 0.6	200.7[5] 200.8[5]
Mercury	7439-97-6	2,100	200 200	7470/1A[G] 6020A[1b,G]	200[C]	ILM04.0/**245.5** CLP-M	2.0	0.2 0.1	7470 7472	0.2	ILM04.0/**245.1** or **245.2** CLP-M	0.2	245.1[6]
Methoxychlor	72-43-5	160,000	120	8081B[M]	17	OLM04.2-D/PEST	40	0.9	8081B[M]	0.50	OLM04.2-D/PEST	0.05	508[4]
Methyl bromide *ynonym: Bromomethane*	74-83-9	52	11 5	8021B[E,N] 8260B[E]	10	OLM04.2-D/VOA	11	5 11	8260B 8021B[N]	10	OLM04.2-D/VOA	0.19 0.11	502.2[4] 524.2[4]
Methylene chloride	75-09-2	23	0.2 5	8021B[E,N] 8260B[E]	10	OLM04.2-D/VOA	5.0	0.2 5	8021B[N] 8260B	10	OLM04.2-D/VOA	0.01 0.03	502.2[4] 524.2[4]
Methyl ethyl ketone *MEK)* *ynonym: 2-Butanone*	78-93-3	12,000	2700 50	8015B[Q] 8260B[K]	10	OLM04.2-D/VOA	2,500	500 50	8015B[K,N] 8260B[K]	10	OLM04.2-D/VOA	0.48 50	524.2[4] 1624C[8]

RESIDENTIAL CLOSURE - ANALYTICAL METHODS WITH REPORTING LIMITS FOR RISC (September 15, 2000)

Analyte	CAS No.	RESIDENTIAL SOIL (mg/kg)					RESIDENTIAL GROUND WATER (mg/L)						
		Default Closure Level[a], µg/kg	SW-846[1a]		CLP[2,3]		Default Closure Level[b], µg/L	SW-846[1a]		CLP[2,3]		EPA Drinking & Waste Water[4-12]	
			EQL	Method	CR(Q/D)L	Method		EQL	Method	CR(Q/D)L	Method	MDL	Method
-Methyl-2-pentanone *MIBK) synonym: Methyl sobutyl ketone*	108-10-1	990	200 50	8015B[K,N] 8260B[E,K]	10	OLM04.2-D/VOA	210	200 50	8015B[K,N] 8260B[E,K]	10	OLM04.2-D/VOA	0.09 50[H]	524.2[4] 1624C[8]
-Methylphenol *ynonym: o-Cresol*	95-48-7	14,000	660 220	8270C 8041[H,M]	330	OLM04.2-D/SVOA	1,800	10 3.2	8270C 8041[H,M]	10	OLM04.2-D/SVOA	10[H]	1625C[8]
-Methylphenol *ynonym: m-Cresol*	108-39-4	11,000	660 220	8270C 8041[H,M]	[330	OLM04.2-D/SVOA]	1,800	10 3.2	8270C 8041[H,M]	[10	OLM04.2-D/SVOA][W]	[10	1625C][V]
-Methylphenol *ynonym: p-Cresol*	106-44-5	1,100	660 220	8270C[E] 8041[H,M]	330	OLM04.2-D/SVOA	180	10 3.2	8270C 8041[H,M]	10	OLM04.2-D/SVOA	10[H]	1625C[8]
Methyl-t-butyl ether MTBE) yn.: Methyl tertiary-butyl ther	1634-04-4	350	5	8260B[E]	10	OLM04.2-D/VOA	45	5	8260B	10	OLM04.2-D/VOA	1.2	524.2[4]
Naphthalene	91-20-3	700	5 660	8260B 8270C[E]	330	OLM04.2-D/SVOA	8.3	5 0.6	8260B 8021B[E,N]	10	OLM04.2-D/SVOA	0.04 1.6	524.2[4] 625[7]
Nickel	7440-02-0	130,000	1000 200	6010B[G] 6020A[1b,G]	4000[C]	ILM04.0/200.7 CLP-M	100	10 0.5	6010B[G] 6020A[1b,G]	40	ILM04.0/200.7 CLP-M	5 0.5	200.7[5] 200.8[5]
-Nitroaniline	88-74-4	41	2	8410[L]	830	OLM04.2-D/SVOA	2.1	1.0	8131[F]	25	OLM04.2-D/SVOA	10	1625C
Nitrobenzene	98-95-3	120	1.3	8410[L]	330	OLM04.2-D/SVOA	18	6.4	8330	10	OLM04.2-D/SVOA	1.9	625[7]
N-Nitrosodiphenylamine	86-30-6	9,700	550 660	8070A[E,N] 8270C	330	OLM04.2-D/SVOA	170	8.1 10	8070A[N] 8270C	10	OLM04.2-D/SVOA	0.8 1.9	607[7] 625[7]
N-Nitroso-di-n-propylamine	621-64-7	0.60	0.25	8410[L]	330	OLM04.2-D/SVOA	0.12*	0.46	8070A[F,X]	10	OLM04.2-D/SVOA	0.46	607[X,7]
Polychlorinated biphenyl ompounds *(PCBs)*	1336-36-3	1,800	600	8082[M]	67	OLM04.2-D/PEST	0.50	0.054 *to* 0.90[X] 8082[F,P] *(as Aroclors)*		1.0 *to* 2.0	OLM04.2-D/PEST	0.065 0.15	1242 608[7] 1656
Pentachlorophenol	87-86-5	28	1.6 13	8151A[Q] GC/ECD 8151A[Q] GC/MS	830	OLM04.2-D/SVOA	1.0	0.76	8151A[N]	25	OLM04.2-D/SVOA	0.076	515.1[4]
Phenol	108-95-2	110,000	660	8270C	330	OLM04.2-D/SVOA	22,000	10	8270C	10	OLM04.2-D/SVOA	2.2	604[7]

RESIDENTIAL CLOSURE - ANALYTICAL METHODS WITH REPORTING LIMITS FOR RISC (September 15, 2000)

Analyte	CAS No.	RESIDENTIAL SOIL (mg/kg)					RESIDENTIAL GROUND WATER (mg/L)						
		Default Closure Level[a], µg/kg	SW-846[1a]		CLP[2,3]		Default Closure Level[b], µg/L	SW-846[1a]		CLP[2,3]		EPA Drinking & Waste Water[4-12]	
			EQL	Method	CR(Q/D)L	Method		EQL	Method	CR(Q/D)L	Method	MDL	Method
'yrene	129-00-0	570,000	660 2700	8270C 8310	330	OLM04.2-D/SVOA	140	10 2.7	8270C 8310	10	OLM04.2-D/SVOA	0.16	525.2[4]
;elenium	7782-49-2	5,200	5000 3200	6010B[G] 6020A[1b,G]	500[C]	ILM04.0/**270.2** CLP-M ***(furnace)***	50	2 8	7740 6020A	2	ILM04.0/**270.2** CLP-M ***(furnace)***	20 7.9	200.7[5] 200.8[5]
;ilver	7440-22-4	31,000	500 50	6010B[G] 6020A[1b,G]	1000[C]	ILM04.0/200.7 CLP-M	180	10 60	6010B 7760A	10	ILM04.0/200.7 CLP-M	2 0.1	200.7[5] 200.8[5]
;tyrene	100-42-5	3,500	13 5	8021B[N] 8260B	10	OLM04.2-D/VOA	100	0.1 5	8021B[N] 8260B	10	OLM04.2-D/VOA	0.06	524.2[4]
,1,1,2-Tetrachloroethane	630-20-6	50	6 5	8021B[N] 8260B[E]	---	—	6.9	0.05	8021B[N]	---	---	0.05	524.2[4]
,1,2,2-Tetrachloroethane	79-34-5	7.0	0.1 5	8021B[E,N] 8260B[E]	10	OLM04.2-D/VOA	0.90	0.1	8021B[N]	10	OLM04.2-D/VOA	0.02 0.20	502.2[4] 524.2[4]
'etrachloroethylene *(PCE)* *ynonym:* *'etrachloroethene*	127-18-4	58	0.5 5	8021B[E,N] 8260B[E]	10	OLM04.2-D/VOA	5.0	0.5 1	8021B[N] 8260B[D]	10	OLM04.2-D/VOA	0.02 0.14	502.2[4] 524.2[4]
'hallium	7440-28-0	2,800	2700 100	6020A[G] 6010B[1b,G]	500[C]	ILM04.0/**279.2** CLP-M ***(furnace)***	2.0	0.3 1	6020A[G] 7841	1	ILM04.0/**279.2** CLP-M *(furnace)*	0.3	200.8[5]
'oluene	108-88-3	12,000	13 5	8021B[N] 8260B	10	OLM04.2-D/VOA	1,000	0.1 5	8021B[N] 8260B	10	OLM04.2-D/VOA	0.11	524.2[4]
'oxaphene	8001-35-2	3,900	860	8081B[M,R]	170	OLM04.2-D/PEST	3.0	0.9	8081B[M]	5.0	OLM04.2-D/PEST	1.0	505[4]
,2,4-Trichlorobenzene	120-82-1	5,300	38 5	8021B[N] 8260B	10	OLM04.2-D/VOA	70	0.3 5	8021B[N] 8260B	10	OLM04.2-D/SVOA	0.08 0.20	502.2[4] 524.2[4]
,1,1-Trichloroethane	71-55-6	1,900	38 5	8021B[N] 8260B	10	OLM04.2-D/VOA	200	0.3 5	8021B[N] 8260B	10	OLM04.2-D/VOA	0.01 0.08	502.2[4] 524.2
,1,2-Trichloroethane	79-00-5	30	0.5 5	8021B[E,H] 8260B[E]	10	OLM04.2-D/VOA	5.0	0.5 1	8021B[H,N] 8260B	10	OLM04.2-D/VOA	0.04 0.10	502.2[4] 524.2[4]
'richloroethylene *(TCE)* *ynonym: Trichloroethene*	79-01-6	57	0.2 5	8021B[E,N] 8260B[E]	10	OLM04.2-D/VOA	5.0	0.2 1	8021B[N] 8260B[D]	10	OLM04.2-D/VOA	0.06 0.19	502.2[4] 524.2[4]
,4,5-Trichlorophenol	95-95-4	250,000	660 430	8270C 8041[H,M]	830	OLM04.2-D/SVOA	3,700	10 6.4	8270C 8041	25	OLM04.2-D/SVOA	10	1625C[8]
,4,6-Trichlorophenol	88-06-2	1,500	660 430	8270C[E] 8041[M]	330	OLM04.2-D/SVOA	77	10 6.4	8270C 8041	10	OLM04.2-D/SVOA	2.7	625[7]

RESIDENTIAL CLOSURE - ANALYTICAL METHODS WITH REPORTING LIMITS FOR RISC (September 15, 2000)

Analyte	CAS No.	RESIDENTIAL SOIL (mg/kg)					RESIDENTIAL GROUND WATER (mg/L)						
		Default Closure Level[a], µg/kg	SW-846[1a]		CLP[2,3]		Default Closure Level[b], µg/L	SW-846[1a]		CLP[2,3]		EPA Drinking & Waste Water[4-12]	
			EQL	Method	CR(Q/D)L	Method		EQL	Method	CR(Q/D)L	Method	MDL	Method
Vinyl acetate	108-05-4	2,300	5	8260B	—	—	550	5	8260B	---	---	10	1624C[8,1]
Vinyl chloride	75-01-4	13	5 0.2	8260B[E] 8021B[E,N]	10	OLM04.2-D/VOA	2.0	1 0.2	8260B[D] 8021B[N]	10	OLM04.2-D/VOA	0.18 0.17	502.2[4] 524.2[4]
Xylene mixture *(o-, m-, p-)*	1330-20-7	190,000	5 25	8260B 8021B[N]	10	OLM04.2-D/VOA	10,000	0.2 5	8021B[N] 8260B	10	OLM04.2-D/VOA	0.02 0.11	502.2[4] 524.2[4]
Zinc	7440-66-6	10,000,000	200 700	6010B[G] 6020A[1b,G]	2000[C]	ILM04.0/200.7 CLP-M	11,000	2	6010B[G]	20	ILM04.0/200.7 CLP-M	2 1.8	200.7[5] 200.8[5]

NOTES
Table Information

10 OLM04.2-D/VOA	Shaded cell with light print indicates quantitation limit exceeds Default Closure Level. Method will not meet DQO without analytical modification.

* Asterisk indicates that no standard EPA method is available with a detection or quantitation limit able to meet the Default Closure Level for that matrix without modification. For some methods, modifications to lower detection limits may be as simple as using a larger sample size, extra concentration of extracts, use of an alternate extraction method, or use of an alternate detector. Consult your laboratory and your IDEM chemist.

[a] Default Closure Level for RESIDENTIAL soil in units of µg/kg.

[b] Default Closure Level for RESIDENTIAL groundwater in units of µg/L.

[C]The CLP SOW does not list CRDLs for soil samples. Soil CRDLs have been estimated as follows. **Note: Detection limits will be higher for samples with dry weight < 100%.**

* **metals by ICP** - formula on page D-13 of ILM04.0 assuming 100% dry weight, 0.5 g sample size, 50 mL final volume of digestate, and the aqueous CRDL from page C-2 as the concentration in the digestate. If the estimated ICP detection limit on page D-25 exceeds the aqueous CRDL, the ICP detection limit is substituted as the concentration in digestate. If the calculation using the CRDL on page C-2 exceeds the RISC closure level and the ICP estimated detection limit on page D-25 is lower than the CRDL, the ICP detection limit is substituted for the concentration in the digestate.

* **metals when the ICP estimated detection limit will not meet the RISC closure level** - formula on page D-13 of ILM04.0 assuming 100% dry weight, 0.5 g sample size, 50 mL final volume of digestate, and the lowest concentration of the optimum range for the furnace method as the concentration in the digestate. (Notation ***furnace*** added after method number.)

* **mercury** - the formula on page D-59 of ILM04.0 assuming 100% dry weight, a 0.2 gram sample, 200 mL final volume after preparation, and the aqueous CRDL as the concentration read from the standard curve.

* **cyanide** - the formula on page D-76 of ILM04.0 assuming a 1 gram sample, 100% dry weight, and the aqueous CRDLas the concentration read from the standard curve.

[D] EQL obtained by purging 25 mL aqueous sample instead of 5 mL aqueous sample. (See SW-846 Method 8260B, Table 3, page 8260B-35, December 1996.)

[E] EQL or CRQL for **low level** soil procedure (required). Methods for semivolatile and nonvolatile compounds assume a Gel Permeation Chromatography (GPC) clean up of extract prior to analysis.

[F]Method Detection Limit (MDL) is listed rather than EQL.

[G] SW-846 metals methods reference instrument detection limits (IDLs) instead of quantitation limits. Therefore, a detection limit is listed rather than an EQL.
For **6010B**: (1) Aqueous detection limits are taken from the IDL table on page 6010B-19. (2) Soil detection limits have been calculated using the equation on page 6020A-9, assuming a 1gram sample (dry weight), 100 mL as the final digestate volume, and the aqueous IDLas the concentration in the digestate. All are rounded up to the next 100 µg/L or /kg.
For **6020A**: Method 6020A does not provide a table of IDLs. MDLs taken from the analogous EPA water method (200.8, Rev. 5.5) for the appropriate matrix are listed.

[H] Compound is listed in the method, but no MDL is provided. The MDL is estimated based on compounds of similar properties for which the method does provide a MDL.

[I] EQL or MDL for SW-846 method estimated by using MDL for analogous waste water method using same instrumentation. EQLs were calcualted by multiplying the MDL by standard SW-846 EQL matrix factors: (a) 10 for ground water, (b) 10 for low level soils in volatile organics methods, and (c) 670 for low level soils with GPC cleanup in semivolatile and nonvolatile organics methods. The analogous waste water method for SW-846 Method 8111 is 611.

[J] MCL for arsenic is scheduled to be changed to 5 mg/L (0.005 mg/L) from 50 mg/L (0.050 mg/L) on January 1, 2001.

[K] EQL multiplied a factor of 10 above method default EQL for matrix because of poor purging efficiency.

NOTES, continued
Table Information, continued

[L] Methods utilizing Fourier Transform-Infrared Spectroscopy (FT-IR) for detection reference identification limits instead of EQLs; therefore identification limit is listed instead of EQL. For soil and sediment samples the identification limit has been calculated from the aqueous identification limit listed in Table 1, page 8410-11, assuming a 10 gram sample, a 1mL final extract volume prior to drying, and 100% dry weight. For analytes with two identification limits listed, the value in parenthesis has been used.

[M] EQLs for Methods 8081B (01/98) and 8082 (12/96) are calculated using 8081 (09/94) MDLs multiplied by 8081B or 8082 matrix factors. (No MDLs in Methods 8081B and 8082.)
EQLs for Method 8041 (12/96) are calculated using MDLs and matrix factors from Method 8040A (07/92), an earlier form of the same method. (Method 8041 does not provide MDLs).

[N] EQL calculated by multiplying aqueous MDL (µg/L) by matrix factors listed in the method. If no table of EQL matrix factors is provided in the method, the aqueous MDLs have been multiplied by the following standard SW-846 EQL matrix factors: (a) Volatile organics methods - (i)10 for ground water, (ii) 10 for low level soils, and (iii) 1250 for high level soils; (b) Semivolatile organics methods - (i) 10 for ground water, (ii) 670 for low level soils with GPC cleanup, and (iii)10,000 for high level soils.

[O] No SW-846 method meets required detection limit for solid matrices. Method referenced is an EPA Office of Water sediment method.

[P] EQL(or MDL) is taken from text in the Scope and Application and/or Method Performance section of the method. (No MDL or EQL listed in tables for compound.)

[Q] EQL is calculated by multiplying MDL or EDL for solid matrix times 10.

[R] EQL or CRQL listed is for the high level (SW-846) or medium level (CLP) soils procedure: **If analytes requiring the low level soil procedure are also contaminants of concern for the method in question, the low level procedure should be run instead.** If a sample contains a mixture of high concentration and low concentration contaminants of concern, the low level soil procedure should be used to quantitate the low concentration analytes and, as needed, dilutions analyzed to quantitate the high concentration analytes.
SW-846: For methods other than 8260 and 8270, the high level EQL is the aqueous MDL times the high level soils factor. For 8260 and 8270, the high level EQL is the EQL for low level soils multiplied by: (a) 125 for volatiles (8260), or (b) 7.5 for semivolatiles (8270).
CLP: The medum level CRQL is the medium soil value listed in OLM04.2, Exhibit C.

[S] If speciated Chromium will be analyzed, a separate sample must be taken for hexavalent chromium analysis. Although ICP-MS in selective ion monitoring (SIM) mode should be able to distinguish between Cr(VI) and Cr(III), method development would be necessary at most laboratories (requiring much additional time and expense). Therefore, In most cases the easiest way to determine separate concentrations for hexavalent chromium and trivalent chromium will be to analyze for total chromium, do a special preparation and analysis for hexavalent chromium on a separate sample, and determine trivalent chromium by difference:
(1) For water samples, the sample for analysis of hexavalent chromium must be preserved with *sodium hydroxide*. **This will increase the holding time from 24 hours to 30 days.** (See EPA Method 1669, Section 8.4.5for instructions.) The sample to be analyzed for all other metals (except mercury), including total chromium (or trivalent, if a method is available) should be acid preserved.
b. For soil samples, the sample for hexavalent chromium must be digested by *Method 3060A,* and digestion must occur *within 30 days of sampling*. The sample to be analyzed for other metals can also be analyzed for total chromium (or trivalent chromium, if a method is available); this sample will undergo acid digestion, and the holding time is the usual six months

[T] If only total chromium will be run (i.e., hexavalent and/or trivalent chromium will not be analyzed for specifically), the default closure levels for hexavalent chromium will apply.

[U] Requires heated purge (80EC).

[V] The EQL listed for this analyte in Method 8270C is higher than the default 10µg/L (water) and 660 µg/kg (soil).

[W] [*EQL Method No.*] Analyte is not explicitly listed in method but is amenable to analysis by method. Analyte was listed in a previous version of the method, or analytes with similar properties are listed for the method.

[X] EQL or MDL exceeds closure level but is in within an order of magnitude. Method may be acceptable for use without modification. Consult the IDEM project chemist.

Notes continued

Table information Continued

[Y] Includes measurement of complexed cyanides. The CLP SOW and the EPA water methods do not include methods specifically for free cyanide. Measurement of total cyanide may lead to artificially high results.

NOTES, continued

References: Methods Manuals

[1a] *Test Methods for Evaluating Solid Wastes, Physical/Chemical Methods,* USEPA Publication SW-846, Third edition, Final Update III, [NTIS#: PB97-156111 (integrated 3rd edition through Update III)], June 1997 ***(unless otherwise noted)***.

[1b] *Test Methods for Evaluating Solid Wastes, Physical/Chemical Methods,* USEPA Publication SW-846, Third edition, Update IVA: Notice of Data Availability (NODA), published in the Federal Register on May 8, 1998 (63 FR 25430).

[2] *USEPA Contract Laboragory Program Statement of Work for Organics Analysis, Multi-Media, Multi-Concentration,* OLM04.2, [EPA web site: http://www.epa.gov/superfund/programs/clp/methods.htm], August 1994

[3] *USEPA Contract Laboragory Program Statement of Work for Inorganics Analysis, Multi-Media, Multi-Concentration,* ILM04.0, [NTIS#: PB95-963545], July 1995

[4] *Methods for the Determination of Organic Compounds in Drinking Water - Supplement III,* EPA/600/R-95/131, August 1995

[5] *Methods for the Determination of Metals in Environmental Samples,* EPA/6000/4-91/010, June 1991

[6] *Methods for the Determination o f Inorganic Substances in Environmental Samples,* EPA/600/R-93/100, August 1993

[7] Code of Federal Regulations, 40 CFR 136 - Revised as of July 1, 1995, Appendix A to Part 136 - "Methods for Organic Chemical Analysis of Municipal and Industrial Wastewater"

[8] Stand Alone Method (EPA Office of Water method that is not part of a compendium). Referenced from CD-ROM, "EPA Methods and Guidance for Analysis of Water" (1999), prepared for the USEPA Office of Water by DynCorp Consulting Services Division under EPA Contract 68-C3-0337.

[9] *Methods for Chemical Analysis of Water and Wastes* (MCAWW) EPA/600/4-79-020 - Revised March 1983

[10] *Methods for the Determination of Metals in Environmental Samples - Supplement I* - EPA/600/R-94-111- May 1994

[11] *Methods for the Determination of Nonconventional Pesticides in Municipal and Industrial Wastewater - Vol.I* - EPA-821-R-93-010-A August 1993, Revision 1

[12] *Analytical Methods for the Determination of Pollutants in Pharmaceutical Manufacturing Industry Wastewater, Revision A*, EPA-821-B-98-016 - July 1998

INDUSTRIAL CLOSURE - ANALYTICAL METHODS WITH REPORTING LIMITS FOR RISC

Analyte	CAS No.	INDUSTRIAL SOIL (mg/kg)					INDUSTRIAL GROUND WATER (mg/L)						
		Default Closure Level[a], µg/kg	SW-846[1a]		CLP[2,3]		Default Closure Level[b], µg/L	SW-846[1a]		CLP[2,3]		EPA Drinking & Waste Water[4-12]	
			EQL	Method	CR(Q/D)L	Method		EQL	Method	CR(Q/D)L	Method	MDL	Method
Acenaphthene	83-32-9	1,200,000	5000	8270C[R]	10000	OLM04.2-D/SVOA[R]	4,200	10	8270C	10	OLM04.2-D/SVOA	1.9	625[7]
Acetone *Synonym: 2-Propanone*	67-64-1	41,000	625 20000	8260B[R] 8015B[N,R]	1200	OLM04.2-D/VOA[R]	10,000	50 160	8260B[K] 8015B[N]	10	OLM04.2-D/VOA	50	1624C[8]
Acrolein *Synonym: 2-Propenal*	107-02-8	220	50	8260B[E,K]	—	---	2,000	5	8260B	—	—	50	1624C[8]
Aldrin	309-00-2	800	340	8081B[M,R]	1.7	OLM04.2-D/PEST	0.17	0.034	8081B[F]	0.050	OLM04.2-D/PEST	0.007 0.045	505[4] 525.2[4]
Anthracene	120-12-7	51,000	5000	8270C[R]	10000	OLM04.2-D/SVOA[R]	43	10	8270C	10	OLM04.2-D/VOA	0.18	525.2[4]
Antimony	7440-36-0	37,000	2100	6010B[G]	3200[C]	ILM04.0/200.7 CLP-M	41	3 21	7041 (7010[1b]) 6010B[G]	3	ILM04.0/**204.2** CLP-M ***(furnace)***	3 8	204.2[5] 200.7[5]
Arsenic	7440-38-2	20,000	3500	6010B[G]	5300[C]	ILM04.0/200.7 CLP-M	50	1 1.4	7060A(7010[1b]) 6020A[1b,G]	1	ILM04.0/**206.2** CLP-M ***(furnace)***	1 8	206.2[5] 200.7[5]
Barium	7440-39-3	5,900,000	100	6010B[G]	20000[C]	ILM04.0/200.7 CLP-M	7,200	1	6010B[G]	200	ILM04.0/200.7 CLP-M	1 0.8	200.7[5] 200.8[5]
Benz[a]anthracene	56-55-3	15,000	5000	8270C[R]	10000	OLM04.2-D/SVOA[R]	3.9	0.13	8310	10	OLM04.2-D/SVOA	0.20	525.2[4]
Benzene	71-43-2	670	5	8260B[E]	10	OLM04.2-D/VOA[E]	99	5	8260B	10	OLM04.2-D/VOA	0.02 0.04	502.2[4] 524.2[4]
Benzo[b]fluoranthene	205-99-2	15,000	5000	8270C[R]	10000	OLM04.2-D/SVOA[R]	1.5	0.18	8310	10	OLM04.2-D/SVOA	0.3	525.2[4]
Benzo[k]fluoranthene	207-08-9	39,000	5000	8270C[R]	10000	OLM04.2-D/SVOA[R]	0.80	0.17	8310	10	OLM04.2-D/SVOA	0.3	525.2[4]
Benzoic acid	65-85-0	1,600,000	25000	8270C[R,V]	—	—	410,000	50	8270C[V]	—	—	50[H]	1625C[8]
Benzo[a]pyrene	50-32-8	1,500	660	8270C[E]	330	OLM04.2-D/SVOA[E]	0.39	0.23	8310	10	OLM04.2-D/SVOA	0.1	525.2[4]
Benzyl alcohol	100-51-6	140,000	9800	8270C[R,V]	—	—	31,000	20	8270C[V]	—	—	50[H]	1625C[8]
Beryllium	7440-41-7	2,300,000	200	6010B[G]	500[C]	ILM04.0/200.7 CLP-M	200	0.2	6010B[G]	5	ILM04.0/200.7 CLP-M	0.7 0.3	200.7[5] 200.8[5]
Bis(2-chloroethyl)ether *Syn: 1,1'-Oxybis(2-chloroethane)*	111-44-4	12	3.5	8410[L]	330	OLM04.2-D/SVOA	2.6	3	8111[I,X]	10	OLM04.2-D/SVOA	0.3	611[7]

INDUSTRIAL CLOSURE - ANALYTICAL METHODS WITH REPORTING LIMITS FOR RISC

Analyte	CAS No.	INDUSTRIAL SOIL (mg/kg)					INDUSTRIAL GROUND WATER (mg/L)						
		Default Closure Level[a], µg/kg	SW-846[1a]		CLP[2,3]		Default Closure Level[b], µg/L	SW-846[1a]		CLP[2,3]		EPA Drinking & Waste Water[4-12]	
			EQL	Method	CR(Q/D)L	Method		EQL	Method	CR(Q/D)L	Method	MDL	Method
Bis(2-chloroisopropyl)ether *syn: 2,2'-Oxybis(1-chloropropane)*	108-60-1	260	2.5	8410[L]	330	OLM04.2-D/SVOA	41	8 25	8111B[I] 8410[L]	10	OLM04.2-D/SVOA	0.8	611[7]
Bis(2-ethylhexyl)phthalate *syn.: Di(2-ethylhexyl)phthalate*	117-81-7	980,000	5000	8270C[R]	10000	OLM04.2-D/SVOA[R]	200	2.7	8061A	10	OLM04.2-D/SVOA	0.8	525.2[4]
Bromodichloromethane	75-27-4	630	5	8260B[E]	10	OLM04.2-D/VOA[E]	100	5	8260B	10	OLM04.2-D/VOA	0.08	524.2[4]
Bromoform *synonym: Tribromomethane*	75-25-2	2,700	625	8260B[R]	1200	OLM04.2-D/VOA[R]	360	5	8260B	10	OLM04.2-D/VOA	0.12	524.2[4]
n-Butanol *syn.: n-butyl alcohol, 1-butanol*	71-36-3	44,000	625 9400	8260B[R,U] 8015B[U]	---	—	10,000	5 140	8260B 8015B[N]	---	---	500	1666[12]
Butyl benzyl phthalate	85-68-7	930,000	5000	8270C[R]	10000	OLM04.2-D/SVOA[R]	2,700	10	8270C	10	OLM04.2-D/SVOA	0.5	525.2[4]
Cadmium	7440-43-9	77,000	300	6010B[G]	500[C]	ILM04.0/200.7 CLP-M	51	0.1 5	7131A 6020A	5	ILM04.0/200.7 CLP-M	1 0.5	200.7[5] 200.8[5]
Carbazole	86-74-8	20,000	[5000 [1000	8270C][R,W] 8275A][P,W]	10000	OLM04.2-D/SVOA[R]	140	[10	8270C]	330	OLM04.2-D/SVOA	20	1625C[8]
Carbon disulfide	75-15-0	82,000	625	8260B[R]	1200	OLM04.2-D/VOA[R]	10,000	5	8260B	10	OLM04.2-D/VOA	0.09	524.2[4]
Carbon tetrachloride	56-23-5	290	5 13	8260B[E] 8021B[N]	10	OLM04.2-D/VOA[E]	22	1 0.1	8260B[D] 8021B[N]	10	OLM04.2-D/VOA	0.01 0.21	502.2[4] 524.2[4]
Chlordane	57-74-9	39,000	370 (()	8081B[M,R]	1.7	OLM04.2-D/PEST	0.082	0.37(()	8081B[M]	0.05	OLM04.2-D/PEST	0.0015	508[4]
p-Chloroaniline *synonym: 4-Chloroaniline*	106-47-8	2,700	440 1300	8131[E,N] 8270C[E,V]	330	OLM04.2-D/SVOA[E]	410	46 20	8131 8270C	10	OLM04.2-D/SVOA	20	1625C[8]
Chlorobenzene	108-90-7	27,000	625	8260B[R]	1200	OLM04.2-D/VOA[R]	2,000	5	8260B	10	OLM04.2-D/VOA	0.04	524.2[4]
Chloroethane	75-00-3	5,200	625	8260B[R]	1200	OLM04.2-D/VOA[R]	990	5	8260B	10	OLM04.2-D/VOA	0.1	524.2[4]
Chloroform *synonym: Trichloromethane*	67-66-3	1,200	625	8260B[R]	10	OLM04.2-D/VOA[E]	470	5	8260B	10	OLM04.2-D/VOA	0.03	524.2[4]
2-Chlorophenol	95-57-8	10,000	5000	8270C[R]	330	OLM04.2-D/SVOA[E]	510	10	8270C	10	OLM04.2-D/VOA	3.3	625[7]
Total Chromium[T]	7440-47-3	38,000	500	6010B[G]	1000[C]	ILM04.0/200.7 CLP-M	100	10	6010B	10	ILM04.0/200.7 CLP-M	4	200.7[5]

INDUSTRIAL CLOSURE - ANALYTICAL METHODS WITH REPORTING LIMITS FOR RISC

Analyte	CAS No.	INDUSTRIAL SOIL (mg/kg)					INDUSTRIAL GROUND WATER (mg/L)						
		Default Closure Level[a], µg/kg	SW-846[1a]		CLP[2,3]		Default Closure Level[b], µg/L	SW-846[1a]		CLP[2,3]		EPA Drinking & Waste Water[4-12]	
			EQL	Method	CR(Q/D)L	Method		EQL	Method	CR(Q/D)L	Method	MDL	Method
Chromium III *(trivalent)*[S]	16065-83-1	10,000,000	*Calculate as difference: Total - hexavalent = tri (or use:)* 80	6020-SIM[S]	---	—	150,000	*Calculate as difference: Total - hexavalent=tri (or use:)* 0.08	6020-SIM[S]	---	—	*Calculate as difference: Total - hexavalent=tri (or use:)* 0.2 0.9	1639[8] 200.8-SIM[5]
Chromium VI *(hexavalent)*[S]	18540-29-9	38,000	**Alkaline Digestion (Method 3060A)** *plus one of:* 20000 12 80	7196A 7199 6020-SIM[S]	---	---	100	**Alkaline Preservation *(See Method 1669[8])*** *plus one of:* 5 10 0.3 0.08	7195 7198 7199 6020-SIM[S]	---	---	**Alkaline Preservation *(See Method 1669 [8])*** *plus one of:* 10 5 0.4 0.5	218.4[9] 218.5[9] 218.6[10] 1636[8]
Chrysene	218-01-9	25,000	5000	8270C[R]	10000	OLM04.2-D/SVOA[R]	1.6	1.5	8310	10	OLM04.2-D/SVOA	0.3	525.2[4]
Copper	7440-50-8	1,700,000	400	6010B[G]	2500[C]	ILM04.0/200.7 CLP-M	3,800	3	6010B	25	ILM04.0/200.7 CLP-M	3	200.7[5]
Cyanide, free	57-12-5	410,000	1000 2500	9014 *(free)* 9213 *(free)*	2500[C]	ILM04.0/**335.2** CLP-M *(total CN-)*[Y]	2,000	20 50	9014 *(free)* 9213 *(free)*	10	ILM04.0/335.2 CLP-M *(total CN-)*[Y]	5	335.4[6] *(total CN-)*[Y]
4,4'-DDD *(DDD)*	72-54-8	120,000	500	8081B[M,R]	3.3	OLM04.2-D/PEST	12	0.50	8081B[M]	0.10	OLM04.2-D/PEST	0.01	508[4]
4,4'-DDE *(DDE)*	72-55-9	86,000	580	8081B[M,R]	3.3	OLM04.2-D/PEST	8.4	0.58	8081B[M]	0.10	OLM04.2-D/PEST	0.02	508[4]
4,4'-DDT *(DDT)*	50-29-3	86,000	810	8081B[M,R]	3.3	OLM04.2-D/PEST	8.4	0.81	8081B[M]	0.10	OLM04.2-D/PEST	0.06	508[4]
Dibenz[a,h]anthracene	53-70-3	1,500	660	8270C[E]	330	OLM04.2-D/SVOA[E]	0.39	0.03[F]	8310	10	OLM04.2-D/SVOA	0.1	525.2[4]
Di-n-butyl phthalate	84-74-2	2,000,000	5000	8270C[R]	10000	OLM04.2-D/SVOA[R]	10,000	10	8270C	10	OLM04.2-D/SVOA	4	525.2[4]
1,2-Dichlorobenzene	95-50-1	270,000	625	8260B[R]	1200	OLM04.2-D/VOA[R]	9,200	5	8260B	10	OLM04.2-D/SVOA	0.05	524.2[4]
1,3-Dichlorobenzene	541-73-1	1,800	625	8260B[R]	1200	OLM04.2-D/VOA[R]	92	5	8260B	10	OLM04.2-D/SVOA	0.05	524.2[4]
1,4-Dichlorobenzene	106-46-7	3,400	625	8260B[R]	1200	OLM04.2-D/VOA[R]	120	5	8260B	10	OLM04.2-D/SVOA	0.04	524.2[4]

INDUSTRIAL CLOSURE - ANALYTICAL METHODS WITH REPORTING LIMITS FOR RISC

Analyte	CAS No.	INDUSTRIAL SOIL (mg/kg)					INDUSTRIAL GROUND WATER (mg/L)						
		Default Closure Level[a], µg/kg	SW-846[1a]		CLP[2,3]		Default Closure Level[b], µg/L	SW-846[1a]		CLP[2,3]		EPA Drinking & Waste Water[4-12]	
			EQL	Method	CR(Q/D)L	Method		EQL	Method	CR(Q/D)L	Method	MDL	Method
3,3'-Dichlorobenzidine	91-94-1	210	62	1625C[O,8]	330	OLM04.2-D/SVOA	6.4	1.4[F]	8325	10	OLM04.2-D/SVOA	0.13	605[7]
1,1-Dichloroethane	75-34-3	58,000	625	8260B[R]	1200	OLM04.2-D/VOA[R]	10,000	5	8260B	10	OLM04.2-D/VOA	0.04	524.2[4]
1,2-Dichloroethane	107-06-2	150	5	8260B[E]	10	OLM04.2-D/VOA[E]	31	5	8260B	10	OLM04.2-D/VOA	0.06	524.2[4]
1,1-Dichloroethylene *ynonym: 1,1-Dichloroethene*	75-35-4	58	0.7 5	8021B[E,N] 8260B[E]	10	OLM04.2-D/VOA[E]	7.0	0.7 5	8021B[N] 8260B	10	OLM04.2-D/VOA	0.12	524.2[4]
cis-1,2-Dichoroethene *yn.: cis-1,2-Dichloroethylene*	156-59-2	5,800	625	8260B[R]	1200	OLM04.2-D/VOA[R]	1,000	5	8260B	10	OLM04.2-D/VOA	0.12	524.2[4]
rans-1,2-Dichoroethene *yn.: trans-1,2-Dichloroethylene*	156-60-5	14,000	625	8260B[R]	1200	OLM04.2-D/VOA[R]	2,000	5	8260B	10	OLM04.2-D/VOA	0.06	524.2[4]
2,4-Dichlorophenol	120-83-2	3,000	660	8270C[E]	330	OLM04.2-D/SVOA[E]	310	10	8270C	10	OLM04.2-D/SVOA	2.7	625[7]
1,2-Dichloropropane	78-87-5	250	5	8260B[E]	10	OLM04.2-D/VOA[E]	42	5	8260B	10	OLM04.2-D/VOA	0.04	524.2[4]
1,3-Dichloropropene (cis- and trans-)	542-75-6	200	5	8260B[E]	10	OLM04.2-D/VOA[E]	29	5	8260B	10	OLM04.2-D/VOA	0.1	524.2[4]
Dieldrin	60-57-1	150	30	8081B[E,M]	3.3	OLM04.2-PEST	0.18	0.044	8081B[F,M]	0.10	OLM04.2-PEST	0.02	508[4]
Diethylphthalate	84-66-2	1,300,000	5000	8270C[R]	10000	OLM04.2-D/SVOA[R]	82,000	10	8270C	10	OLM04.2-D/SVOA	0.8	525.2[4]
Dimethylphthalate	131-11-3	1,400,000	5000	8270C[R]	10000	OLM04.2-D/SVOA[R]	1,000,000	10	8270C	10	OLM04.2-D/SVOA	0.14	525.2[4]
2,4-Dimethylphenol	105-67-9	25,000	5000	8270C[R]	10000	OLM04.2-D/SVOA[R]	2,000	10	8270C	10	OLM04.2-D/SVOA	2.4	625[7]
2,4-Dinitrophenol	51-28-5	820	220 3300	8041[M] 8270C[V]	830	OLM04.2-D/SVOA[E,X]	200	50	8270C[V]	25	OLM04.2-D/SVOA	42	625[7]
Dinitrotoluene mixture	25321-14-6	28	1[L]	8410	330	OLM04.2-D/SVOA	4.2	0.31	8330	10	OLM04.2-D/SVOA	0.02	609[7]
Di-n-octyl phthalate	117-84-0	2,000,000	5000	8270C[R]	10000	OLM04.2-D/SVOA[R]	20	10	8270C	10	OLM04.2-D/SVOA	2.5	625[7]
Endosulfan	115-29-7	46,000	400	8081B[M]	3.3	OLM04.2-D/PEST	510	0.4	8081B[M]	0.10	OLM04.2-PEST	0.015	508[4]
Endrin	72-20-8	15,000	390	8081B[M]	3.3	OLM04.2-D/PEST	31	0.39	8081B[M]	0.10	OLM04.2-PEST	0.015	508[4]

INDUSTRIAL CLOSURE - ANALYTICAL METHODS WITH REPORTING LIMITS FOR RISC

Analyte	CAS No.	INDUSTRIAL SOIL (mg/kg)					INDUSTRIAL GROUND WATER (mg/L)						
		Default Closure Level[a], µg/kg	SW-846[1a]		CLP[2,3]		Default Closure Level[b], µg/L	SW-846[1a]		CLP[2,3]		EPA Drinking & Waste Water[4-12]	
			EQL	Method	CR(Q/D)L	Method		EQL	Method	CR(Q/D)L	Method	MDL	Method
Ethylbenzene	100-41-4	200,000	625	8260B[R]	1200	OLM04.2-D/VOA[R]	10,000	5	8260B	10	OLM04.2-D/VOA	0.06	524.2[4]
Fluoranthene	206-44-0	880,000	5000	8270C[R]	10000	OLM04.2-D/SVOA[R]	210	10	8270C	10	OLM04.2-D/SVOA	2.2	625[7]
Fluorene	86-73-7	1,100,000	5000	8270C[R]	10000	OLM04.2-D/SVOA[R]	2,000	10	8270C	10	OLM04.2-D/SVOA	1.9	625[7]
Heptachlor	76-44-8	1,200	400	8081B[M,R]	1.7	OLM04.2-D/PEST	0.64	0.40	8081B[M]	0.050	OLM04.2-D/PEST	0.01	508[4]
Heptachlor epoxide	1024-57-3	1,000	320	8081B[M,R]	1.7	OLM04.2-D/PEST	0.31	0.3	8081B[M]	0.050	OLM04.2-D/PEST	0.015	508[4]
Hexachlorobenzene	118-74-1	3,900	660	8270C[E]	330	OLM04.2-D/SVOA[E]	1.8	0.056	8121[N]	10	OLM04.2-D/SVOA	0.1	525.2[4]
Hexachloro-1,3-butadiene	87-68-3	44,000	5000	8270C[R]	10000	OLM04.2-D/SVOA[R]	20	10	8270C	10	OLM04.2-D/SVOA	0.9	625[7]
"-HCH *("-BHC)*	319-84-6	24	23	8081B[E,M]	1.7	OLM04.2-D/PEST	0.45	0.35	8081B[M]	0.050	OLM04.2-D/PEST	0.025	508[4]
$-HCH *($-BHC)*	319-85-7	86	15	8081B[E,M]	1.7	OLM04.2-D/PEST	1.6	0.23	8081B[M]	0.050	OLM04.2-D/PEST	0.01	508[4]
(-HCH *((-BHC)* *ynonym: Lindane*	58-89-9	100	17	8081B[E,M]	1.7	OLM04.2-D/PEST	2.2	0.25	8081B[M]	0.050	OLM04.2-D/PEST	0.015	508[4]
Hexachlorocyclopentadiene	77-47-4	2,000,000	5000	8270C[R]	10000	OLM04.2-D/SVOA[R]	720	10	8270C	10	OLM04.2-D/SVOA	0.1	525.2[4]
Hexachloroethane	67-72-1	7,700	5000	8270C[R]	330	OLM04.2-D/SVOA[E]	100	10	8270C	10	OLM04.2-D/SVOA	0.03	612[7]
Indeno[1,2,3-cd]pyrene	193-39-5	3,100	660	8270C[E]	330	OLM04.2-D/SVOA[E]	0.022	0.043	8310[F,X]	10	OLM04.2-D/SVOA	0.02	525.2[4]
Isophorone	78-59-1	18,000	5000	8270C[R]	10000	OLM04.2-D/SVOA[R]	3,000	10	8270C	10	OLM04.2-D/SVOA	2.2	625[7]
Lead	7439-92-1	230,000	2800	6010B[G]	4200[C]	ILM04.0/200.7 CLP-M	42	1 28	7421 6010B[G]	3	ILM04.0/200.7 CLP-M	10	200.7[5]
Mercury	7439-97-6	32,000	2000 200	6010B[G] 7471A	200[C]	ILM04.0/**245.5** CLP-M	31	0.2 0.2	7470 6020A[1b,G]	0.2	ILM04.0/**245.1** or **245.2** CLP-M	0.2	245.1[6]
Methoxychlor	72-43-5	180,000	860	8081B[M]	17	OLM04.2-D/PEST	45	0.9	8081B[M]	0.50	OLM04.2-D/PEST	0.05	508[4]

INDUSTRIAL CLOSURE - ANALYTICAL METHODS WITH REPORTING LIMITS FOR RISC

Analyte	CAS No.	INDUSTRIAL SOIL (mg/kg)					INDUSTRIAL GROUND WATER (mg/L)						
		Default Closure Level[a], µg/kg	SW-846[1a]		CLP[2,3]		Default Closure Level[b], µg/L	SW-846[1a]		CLP[2,3]		EPA Drinking & Waste Water[4-12]	
			EQL	Method	CR(Q/D)L	Method		EQL	Method	CR(Q/D)L	Method	MDL	Method
Methyl bromide *synonym: Bromomethane*	74-83-9	700	5	8260B[E]	10	OLM04.2-D/VOA[E]	140	5	8260B	10	OLM04.2-D/VOA	0.11	524.2[4]
Methylene chloride	75-09-2	1,800	625	8260B[R]	1200	OLM04.2-D/VOA[R]	380	5	8260B	10	OLM04.2-D/VOA	0.03	524.2[4]
Methyl ethyl ketone *(MEK)* *synonym: 2-Butanone*	78-93-3	260,000	6250	8260B[R,K]	1200	OLM04.2-D/VOA[R]	61,000	50	8260B[K]	10	OLM04.2-D/VOA	0.28	524.2[4]
4-Methyl-2-pentanone*(MIBK)* *syn.: Methyl isobutyl ketone*	108-10-1	39,000	6250	8260B[R,K]	1200	OLM04.2-D/VOA[R]	8,200	50	8260B[K]	10	OLM04.2-D/VOA	0.09	524.2[4]
2-Methylphenol *synonym: o-Cresol*	95-48-7	39,000	5000	8270C[R]	10000	OLM04.2-D/SVOA[R]	5,100	10	8270C	10	OLM04.2-D/SVOA	10[H]	1625C[8]
3-Methylphenol *synonym: m-Cresol*	108-39-4	30,000	5000	8270C[R]	[10000	OLM04.2-D/SVOA[R]]	5,100	10	8270C	[10	OLM04.2-D/SVOA][W]	[10	1625C[8]][W]
4-Methylphenol *synonym: p-Cresol*	106-44-5	3,000	5000	8270C[R]	10000	OLM04.2-D/SVOA[R]	510	10	8270C	10	OLM04.2-D/SVOA	10[H]	1625C[8]
Methyl-t-butyl ether *(MTBE)* *syn.: Methyl tertiary-butyl ether*	1634-04-4	5,600	625	8260B[R]	1200	OLM04.2-D/VOA[R]	720	5	8260B	10	OLM04.2-D/VOA	1.2	524.2[4]
Naphthalene	91-20-3	170,000	625 5000	8260B[R] 8270C[R]	10000	OLM04.2-D/SVOA[R]	2,000	5 10	8260B 8270	10	OLM04.2-D/SVOA	1.6	625[7]
Nickel	7440-02-0	2,700,000	1000	6010B[G]	4000[C]	ILM04.0/200.7 CLP-M	2,000	10	6010B[G]	40	ILM04.0/200.7 CLP-M	5	200.7[5]
2-Nitroaniline	88-74-4	110	2	8410[L]	830	OLM04.2-D/SVOA	5.8	1	8131[F]	25	OLM04.2-D/SVOA	10	1625C[8]
Nitrobenzene	98-95-3	340	260	8330[Q]	330	OLM04.2-D/SVOA	51	6.4	8330	10	OLM04.2-D/SVOA	1.9	625[7]
N-Nitrosodiphenylamine	86-30-6	32,000	5000	8270C[R]	10000	OLM04.2-D/SVOA[R]	580	10	8270C	10	OLM04.2-D/SVOA	1.9	625[7]
N-Nitroso-di-n-propylamine	621-64-7	2.0	0.25	8410[L]	330	OLM04.2-D/SVOA	0.41*	0.46	8070A[X]	10	OLM04.2-D/SVOA	0.46	607[X,7]
Polychlorinated biphenyl compounds *(PCBs)*	1336-36-3	5,300	600 660	8082[M] 8270C[E]	67	OLM04.2-D/PEST	1.4	0.90	8082[M]	1.0 *to* 2.0[X]	OLM04.2-D/PEST	0.065 0.15	1242 608[7] 1656
Pentachlorophenol	87-86-5	660	51 3300	8151A[N] 8270C[V]	830	OLM04.2-D/SVOA	24	0.76 50	8151A[N] 8270C[V]	25	OLM04.2-D/SVOA	3.6	625[7]
Phenol	108-95-2	320,000	5000	8270C[R]	10000	OLM04.2-D/SVOA[R]	61,000	10	8270C	10	OLM04.2-D/SVOA	3.0	625[7]
Pyrene	129-00-0	570,000	5000	8270C[R]	10000	OLM04.2-D/SVOA[R]	140	10	8270C	10	OLM04.2-D/SVOA	1.9	625[7]

INDUSTRIAL CLOSURE - ANALYTICAL METHODS WITH REPORTING LIMITS FOR RISC

Analyte	CAS No.	INDUSTRIAL SOIL (mg/kg)					INDUSTRIAL GROUND WATER (mg/L)						
		Default Closure Level[a], µg/kg	SW-846[1a]		CLP[2,3]		Default Closure Level[b], µg/L	SW-846[1a]		CLP[2,3]		EPA Drinking & Waste Water[4-12]	
			EQL	Method	CR(Q/D)L	Method		EQL	Method	CR(Q/D)L	Method	MDL	Method
Selenium	7782-49-2	53,000	5000	6010B[G]	7500[C]	ILM04.0/200.7 CLP-M	510	50	6010B[G]	75	ILM04.0/200.7 CLP-M	20	200.7[5]
Silver	7440-22-4	87,000	500	6010B[G]	1000[C]	ILM04.0/200.7 CLP-M	510	5	6010B[G]	10	ILM04.0/200.7 CLP-M	2	200.7[5]
Styrene	100-42-5	720,000	625	8260B[R]	1200	OLM04.2-D/VOA[R]	20,000	5	8260B	10	OLM04.2-D/VOA	0.06	524.2[4]
1,1,1,2-Tetrachloroethane	630-20-6	790	5	8260B	---	—	110	5	8260B	---	---	0.05	524.2[4]
1,1,2,2-Tetrachloroethane	79-34-5	110	5	8260B[E]	10	OLM04.2-D/VOA[E]	14	5	8260B	10	OLM04.2-D/VOA	6.9	624[7]
Tetrachloroethylene *(PCE)* *Synonym: Tetrachloroethene*	127-18-4	640	5	8260B[E]	10	OLM04.2-D/VOA[E]	55	5	8260B	10	OLM04.2-D/VOA	4.1	624[7]
Thallium	7440-28-0	13,000	2700	6010B[G]	4000[C]	ILM04.0/200.7 CLP-M	9.2	0.3 1	6020A[1b,G] 7841	1	ILM04.0/**279.2** CLP-M *(furnace)*	1	200.7[5]
Toluene	108-88-3	240,000	625	8260B[R]	1200	OLM04.2-D/VOA[R]	20,000	5	8260B	10	OLM04.2-D/VOA	6.0	624[7]
Toxaphene	8001-35-2	12,000	860	8081B[M,R]	170	OLM04.2-D/PEST	3.0	0.9	8081B[M]	5.0	OLM04.2-D/PEST	1.0	505[4]
1,2,4-Trichlorobenzene	120-82-1	77,000	625	8260B[R]	1200	OLM04.2-D/VOA[R]	1,000	5	8260B	10	OLM04.2-D/VOA	1.9	625[7]
1,1,1-Trichloroethane	71-55-6	35,000	625	8260B[R]	1200	OLM04.2-D/VOA[R]	3,600	5	8260B	10	OLM04.2-D/VOA	3.8	624[7]
1,1,2-Trichloroethane	79-00-5	300	5	8260B[E]	10	OLM04.2-D/VOA[E]	50	5	8260B	10	OLM04.2-D/VOA	5.0	624[7]
Trichloroethylene *(TCE)* *Synonym: Trichloroethene*	79-01-6	3,000	625	8260B[R]	1200	OLM04.2-D/VOA[R]	260	5	8260B	10	OLM04.2-D/VOA	1.9	624[7]
2,4,5-Trichlorophenol	95-95-4	690,000	5000	8270C[R]	25000	OLM04.2-D/SVOA[R]	10,000	10 6.4	8270C 8041	25	OLM04.2-D/SVOA	---	---
2,4,6-Trichlorophenol	88-06-2	5,000	660	8270C[E]	10000	OLM04.2-D/SVOA[R]	260	10 6.4	8270C 8041	10	OLM04.2-D/SVOA	2.7	625[7]
Vinyl acetate	108-05-4	430,000	625	8260B[R]	—	—	100,000	5	8260B	---	---	10	1624C[8,H]
Vinyl chloride	75-01-4	13	5 0.2	8260B[E] 8021B[E,N]	10	OLM04.2-D/VOA[E]	2.0	1 0.2	8260B[D] 8021B[N]	10	OLM04.2-D/VOA	0.18 0.17	502.2[4] 524.2[4]

INDUSTRIAL CLOSURE - ANALYTICAL METHODS WITH REPORTING LIMITS FOR RISC

Analyte	CAS No.	INDUSTRIAL SOIL (mg/kg)					INDUSTRIAL GROUND WATER (mg/L)						
		Default Closure Level[a], µg/kg	SW-846[1a]		CLP[2,3]		Default Closure Level[b], µg/L	SW-846[1a]		CLP[2,3]		EPA Drinking & Waste Water[4-12]	
			EQL	Method	CR(Q/D)L	Method		EQL	Method	CR(Q/D)L	Method	MDL	Method
Xylene mixture *(o-, m-, p-)*	1330-20-7	410,000	625	8260B[R]	1200	OLM04.2-D/VOA[R]	180,000	5	8260B	10	OLM04.2-D/VOA	0.11	524.2[4]
Zinc	7440-66-6	10,000,000	200	6010B	2000[C]	ILM04.0/200.7 CLP-M	31,000	2	6010B	20	ILM04.0/200.7 CLP-M	2	200.7[5]

NOTES
Table Information

10 OLM04.2-D/VOA	Shaded cell with light print indicates quantitation limit exceeds Default Closure Level. Method will not meet DQO without analytical modification.

* Asterisk indicates that no standard EPA method is available with a detection or quantitation limit able to meet the Default Closure Level for that matrix without modification. For some methods, modifications to lower detection limits may be as simple as using a larger sample size, extra concentration of extracts, use of an alternate extraction method, or use of an alternate detector. Consult your laboratory and your IDEM chemist.

[a] Default Closure Level for RESIDENTIAL soil in units of µg/kg.

[b] Default Closure Level for RESIDENTIAL groundwater in units of µg/L.

[C] The CLP SOW does not list CRDLs for soil samples. Soil CRDLs have been estimated as follows. **Note: Detection limits will be higher for samples with dry weight < 100%.**
***metals by ICP** - formula on page D-13 of ILM04.0 assuming 100% dry weight, 0.5 g sample size, 50 mL final volume of digestate, and the aqueous CRDL from page C-2 as the concentration in the digestate. If the estimated ICP detection limit on page D-25 exceeds the aqueous CRDL, the ICP detection limit is substituted as the concentration in digestate. If the calculation using the CRDL on page C-2 exceeds the RISC closure level and the ICP estimated detection limit on page D-25 is lower than the CRDL, the ICP detection limit is substituted for the concentration in the digestate.
metals when the ICP estimated detection limit will not meet the RISC closure level** - formula on page D-13 of ILM04.0 assuming 100% dry weight, 0.5 g sample size, 50 mL final volume of digestate, and the lowest concentration of the optimum range for the furnace method as the concentration in the digestate. (Notation ***furnace added after method number.)
***mercury** - the formula on page D-59 of ILM04.0 assuming 100% dry weight, a 0.2 gram sample, 200 mL final volume after preparation, and the aqueous CRDL as the concentration read from the standard curve.
***cyanide** - the formula on page D-76 of ILM04.0 assuming a 1 gram sample, 100% dry weight, and the aqueous CRDLas the concentration read from the standard curve.

[D] EQL obtained by purging 25 mL aqueous sample instead of 5 mL aqueous sample. (See SW-846 Method 8260B, Table 3, page 8260B-35, December 1996.)

[E] EQL or CRQL for **low level** soil procedure (required). Methods for semivolatile and nonvolatile compounds assume a Gel Permeation Chromatography (GPC) clean up of extract prior to analysis.

[F] Method Detection Limit (MDL) is listed rather than EQL.

[G] SW-846 metals methods reference instrument detection limits (IDLs) instead of quantitation limits. Therefore, a detection limit is listed rather than an EQL. For Method 6010B, detection limits were determined as follows: (1) Aqueous detection limits are taken from the IDL table on page 6010B-19. (2) Soil detection limits have been calculated using the equation on page 6020A-9, assuming a 1gram sample (dry weight), 100 mL as the final digestate volume, and the aqueous IDLas the concentration in the digestate. All are rounded to the nearest 100 µg/L or µg/kg. Method 6020A may be run instead of Method 6010B.

[H] Compound is listed in the method, but no MDL is provided. The MDL is estimated based on compounds of similar properties for which the method does provide a MDL.

[I] EQL or MDL for SW-846 method estimated by using MDL for analogous waste water method using same instrumentation. EQLs were calcualted by multiplying the MDL by standard SW-846 EQL matrix factors: (a) 10 for ground water, (b) 10 for low level soils in volatile organics methods, and (c) 670 for low level soils with GPC cleanup in semivolatile and nonvolatile organics methods. The analogous waste water method for SW-846 Method 8111 is 611.

[J] MCL for arsenic is scheduled to be changed to 5 mg/L (0.005 mg/L) from 50 mg/L (0.050 mg/L) on January 1, 2001.

[K] EQL multiplied a factor of 10 above method default EQL for matrix because of poor purging efficiency.

[L] Methods utilizing Fourier Transform-Infrared Spectroscopy (FT-IR) for detection reference identification limits instead of EQLs; therefore identification limit is listed instead of EQL. For soil and sediment samples the identification limit has been calculated from the aqueous identification limit listed in Table 1, page 8410-11, assuming a 10 gram sample, a 1mL final extract volume prior to drying, and 100% dry weight. For analytes with two identification limits listed, the value in parenthesis has been used.

Notes Continued
Table Information Continued

M EQLs for Methods 8081B (01/98) and 8082 (12/96) are calculated using 8081 (09/94) MDLs multiplied by 8081B or 8082 matrix factors. (No MDLs in Methods 8081B and 8082.). EQLs for Method 8041 (12/96) are calculated using MDLs and matrix factors from Method 8040A (07/92), an earlier form of the same method. (Method 8041 does not provide MDLs).

N EQL calculated by multiplying aqueous MDL (µg/L) by matrix factors listed in the method. If no table of EQL matrix factors is provided in the method, the aqueous MDLs have been multiplied by the following standard SW-846 EQL matrix factors: (a) Volatile organics methods - (i)10 for ground water, (ii) 10 for low level soils, and (iii) 1250 for high level soils; (b) Semivolatile organics methods - (i) 10 for ground water, (ii) 670 for low level soils with GPC cleanup, and (iii)10,000 for high level soils.

O No SW-846 method meets required detection limit for solid matrices. Method referenced is an EPA Office of Water sediment method.

P EQL is taken from text in the Scope and Application and/or Method Performance section of the method. (No MDL or EQL listed in tables for compound.)

Q EQL is calculated by multiplying MDL or EDL for solid matrix times 10.

R EQL or CRQL listed is for the high level (SW-846) or medium level (CLP) soils procedure: **If analytes requiring the low level soil procedure are also contaminants of concern for the method in question, the low level procedure should be run instead.** If a sample contains a mixture of high concentration and low concentration contaminants of concern, the low level soil procedure should be used to quantitate the low concentration analytes and, as needed, dilutions analyzed to quantitate the high concentration analytes.
SW-846: For methods other than 8260 and 8270, the high level EQL is the aqueous MDL times the high level soils factor. For 8260 and 8270, the high level EQL is the EQL for low level soils multiplied by: (a) 125 for volatiles (8260), or (b) 7.5 for semivolatiles (8270).
CLP: The medum level CRQL is the medium soil value listed in OLM04.2, Exhibit C.

S If speciated Chromium will be analyzed, a separate sample must be taken for hexavalent chromium analysis. Although ICP-MS in selective ion monitoring (SIM) mode should be able to distinguish between Cr(VI) and Cr(III), method development would be necessary at most laboratories (requiring much additional time and expense). Therefore, In most cases the easiest way to determine separate concentrations for hexavalent chromium and trivalent chromium will be to analyze for total chromium, do a special preparation and analysis for hexavalent chromium on a separate sample, and determine trivalent chromium by difference:
(1) For water samples, the sample for analysis of hexavalent chromium must be preserved with *sodium hydroxide*. **This will increase the holding time from 24 hours to 30 days.** (See EPA Method 1669, Section 8.4.5for instructions.) The sample to be analyzed for all other metals (except mercury), including total chromium (or trivalent, if a method is available) should be acid preserved.
b. For soil samples, the sample for hexavalent chromium must be digested by *Method 3060A,* and digestion must occur *within 30 days of sampling*. The sample to be analyzed for other metals can also be analyzed for total chromium (or trivalent chromium, if a method is available); this sample will undergo acid digestion, and the holding time is the usual six months

T If only total chromium will be run (i.e., hexavalent and/or trivalent chromium will not be analyzed for specifically), the default closure levels for hexavalent chromium will apply.

U Requires heated purge (80EC).

V The EQL listed for this analyte in Method 8270C is higher than the default 10 µg/L (water) and 660 µg/kg (soil).

W [*EQL Method No.*] Analyte is not explicitly listed in method but is amenable to analysis by method. Analyte was listed in a previous version of the method, or analytes with similar properties are listed for the method.

X EQL or MDL exceeds closure level but is in within an order of magnitude. Method may be acceptable for use without modification. Consult the IDEM project chemist.

Y Includes measurement of complexed cyanides. The CLP SOW and the EPA water methods do not include methods specifically for free cyanide. Measurement of total cyanide may lead to artificially high results.

NOTES, continued

References: Methods Manuals

[1a]*Test Methods for Evaluating Solid Wastes, Physical/Chemical Methods,* USEPA Publication SW-846, Third edition, Final Update III, [NTIS#: PB97-156111 (integrated 3rd edition through Update III)], June 1997 ***(unless otherwise noted)***.

[1b]*Test Methods for Evaluating Solid Wastes, Physical/Chemical Methods,* USEPA Publication SW-846, Third edition, Update IVA: Notice of Data Availability (NODA), published in the Federal Register on May 8, 1998 (63 FR 25430).

[2]*USEPA Contract Laboragory Program Statement of Work for Organics Analysis, Multi-Media, Multi-Concentration,* OLM04.2, [EPA web site: http://www.epa.gov/superfund/programs/clp/methods.htm], May 1999

[3]*USEPA Contract Laboragory Program Statement of Work for Inorganics Analysis, Multi-Media, Multi-Concentration,* ILM04.0, [NTIS#: PB95-963545], July 1995

[4]*Methods for the Determination of Organic Compounds in Drinking Water - Supplement III,* EPA/600/R-95/131, August 1995

[5]*Methods for the Determination of Metals in Environmental Samples,* EPA/6000/4-91/010, June 1991

[6]*Methods for the Determination o f Inorganic Substances in Environmental Samples,* EPA/600/R-93/100, August 1993

[7]Code of Federal Regulations, 40 CFR 136 - Revised as of July 1, 1995, Appendix A to Part 136 - "Methods for Organic Chemical Analysis of Municipal and Industrial Wastewater"

[8]Stand Alone Method (EPA Office of Water method that is not part of a compendium). Referenced from CD-ROM, "EPA Methods and Guidance for Analysis of Water" (1999), prepared for the USEPA Office of Water by DynCorp Consulting Services Division under EPA Contract 68-C3-0337.

[9]*Methods for Chemical Analysis of Water and Wastes* (MCAWW) EPA/600/4-79-020 - Revised March 1983

[10]*Methods for the Determination of Metals in Environmental Samples - Supplement I* - EPA/600/R-94-111- May 1994

[11]*Methods for the Determination of Nonconventional Pesticides in Municipal and Industrial Wastewater - Vol.I - Revision 1,* EPA-821-R-93-010-A, August 1993

[12]*Analytical Methods for the Determination of Pollutants in Pharmaceutical Manufacturing Industry Wastewater, Revision A*, EPA-821-B-98-016 - July 1998

Closure by Stability Monitoring and Petroleum Closure by Attenuation Modeling

A3.0 Introduction

When attempting to demonstrate plume stability for closure, stability monitoring must be conducted to ensure that constituents will not leave the area of property control at concentrations that exceed residential closure levels. Plume stability may be demonstrated by a default or a nondefault method. This appendix presents the default stability monitoring method to demonstrate plume stability.

All stability monitoring methods require that properly designed and installed ground water monitoring wells be placed at appropriate locations to correctly evaluate the plume. In the default method, a minimum of two types of monitoring wells are required: messenger wells and perimeter of compliance (POC) wells. Background wells and sentinel wells may also be required if upgradient and downgradient COC concentrations need to be evaluated. Figure A3-1 shows possible locations for the four types of monitoring wells. Requirements for each type of well are discussed below.

- **Messenger wells** are located in the internal area of the plume, downgradient from the source, within the 2-year ground water time-of-travel distance. At a minimum, one messenger well must be located adjacent to the source, and a second well must be located between the first messenger well and the 2-year time-of-travel distance of the plume. When petroleum closure by attenuation is being used (see Section A3.2), one messenger well must be located within 1-year travel time from the source. To demonstrate ground water closure, an area of concern will normally require two to four messenger wells. Some large, or multilobed contaminant plumes may require more than four messenger wells. All messenger wells must be located (1) as near to the center flow line or flow path as possible and (2) in an area where the COC concentrations are suspected to be highest and to significantly exceed closure levels.

- At least three **POC wells** should be located hydraulically downgradient from the messenger wells and from the principal closure areas. POC wells must be located as follows:

  – In an area of the plume where dissolved COC concentrations are expected to exceed estimated quantification limits (EQL) for at least 75 percent of the monitoring episodes

- In an area where COC concentrations approximate the closure level

- In an area where it is possible to monitor the contaminant plume after it has passed through the source and messenger well areas

- **Sentinel wells** should be installed if the potential exists for increased risks to any receptors. Sentinel wells are located hydraulically downgradient from the POC wells and along a line between the source and any potential receptors. Sentinel wells may not be required if no downgradient receptor exists; however, sentinel wells are highly recommended because they can clearly indicate an expanding plume.

- **Background wells** are placed upgradient of the area of concern and out of the zone of influence of the source. Background wells are essential to understanding the upgradient influence of COCs. If both upgradient and downgradient concerns exist at a site, a minimum of one background well is required. However, additional background wells may be recommended based on the discussions below.

Additional wells and piezometers may also be needed to characterize hydrogeologic conditions. If the wells do not meet appropriate criteria, or if site conditions change, previously installed wells may no longer produce samples that adequately represent the plume being monitored. In such cases, new wells may be required, or existing wells may be redesignated to serve a different monitoring function than originally intended.

Some wells must be located within specific ground water time-of-travel distances from the source. Before wells are installed, the advective flow velocity of ground water at the site must be estimated to ensure that the new wells will meet the ground water time-of-travel requirements. This approach will allow sufficient time during monitoring to ensure that ground water from the closure area reaches key monitoring wells.

In the default approach, the Mann-Kendall trend test must be used to define the COC concentration trend in individual monitoring wells (EPA 1996, EPA/600/R-96/084)

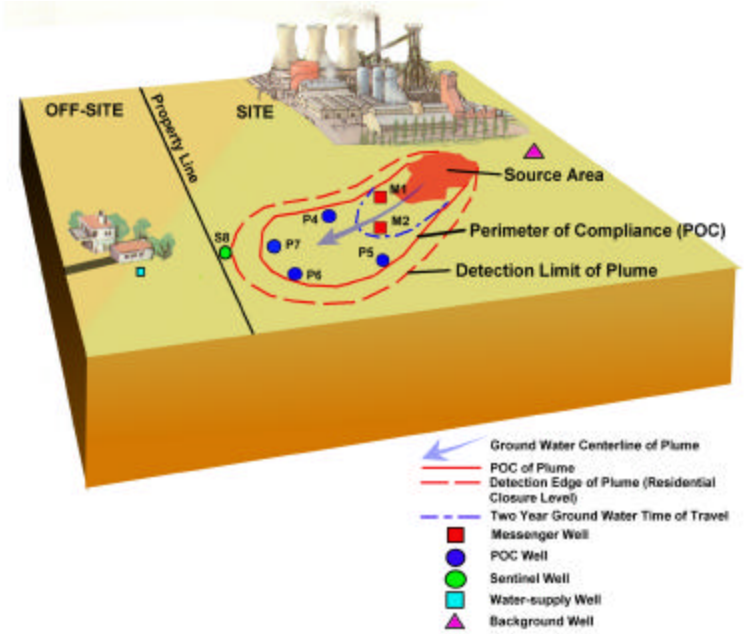

Figure A3-1. Monitoring Well Location

A graph of time versus concentration (time series plot) must be constructed and maintained for each COC at each well throughout the monitoring period. This will facilitate determining any potential trends in the data.

A3.1 Closure by Stability Monitoring

Stability monitoring evaluates screening data to determine the concentration trend for each COC at individual monitoring wells. The primary concern in a stability demonstration is whether COC concentrations are increasing or decreasing at individual monitoring wells. Numerical changes in COC concentration levels can often appear insignificant from one quarterly monitoring event to another. To determine if the contaminant plume is stable or migrating, ground water monitoring data must be analyzed statistically. The Mann-Kendall trend test is used to determine the concentration trend at each well for each COC. The plume is considered to be expanding if the trend test results indicate that any COC concentration is increasing as follows:

- Two or more messenger wells
- Any POC well
- Any sentinel well.

If the plume is expanding, a POC remedial plan must be developed and implemented. If the plume is stable (that is, no trend is indicated by the Mann-Kendall trend test) or decreasing (a negative trend in the Mann-Kendall trend test), then the plume is considered stable. In such cases, monitoring should continue and quarterly data should be evaluated for closure eligibility (see Section A3.1.5).

Closure by stability monitoring does not rely on any specific plume age considerations. Professional judgement should be applied to make the initial decision of whether a plume may be stable. The trend tests used to verify stability will not show a stable or decreasing trend if the plume has not had sufficient time to stabilize. Free product must be removed to the extent practicable, and any remaining COCs must not create an expanding plume.

Figure A3-2 shows a flowchart for stability monitoring. In general, the first step involves assessing the potential for plume stability. A minimum of 8 quarters of monitoring data must be evaluated at the messenger and POC wells. The Mann-Kendall trend test is used to assess the trend in the plume for each COC at each individual well. If this evaluation indicates that the plume is stable in COC concentrations, then the stability monitoring period can begin. The wells must then be monitored for the next 5 years and tested annually using the Mann-Kendall trend test to verify that the plume continues to remain stable or decrease in COC concentrations. If the above conditions are met at the end of the 5-year stability monitoring period (7 years total), the area of concern may be eligible for closure.

Stability monitoring closure for ground water contaminant plumes involves the following steps: (1) starting the stability clock, (2) stability monitoring, (3) the Mann-Kendall trend test, (4) additional data collection, and (5) closure eligibility.

A3.1.1 Starting the Stability Clock

The stability clock “starts” with the first quarterly sampling in the stability monitoring period. However, before stability monitoring can begin, the following activities must be performed:

1. A complete and adequate investigation of the nature and extent of contamination

2. Establishment of the POC

3. Placement and initial sampling of messenger and POC wells

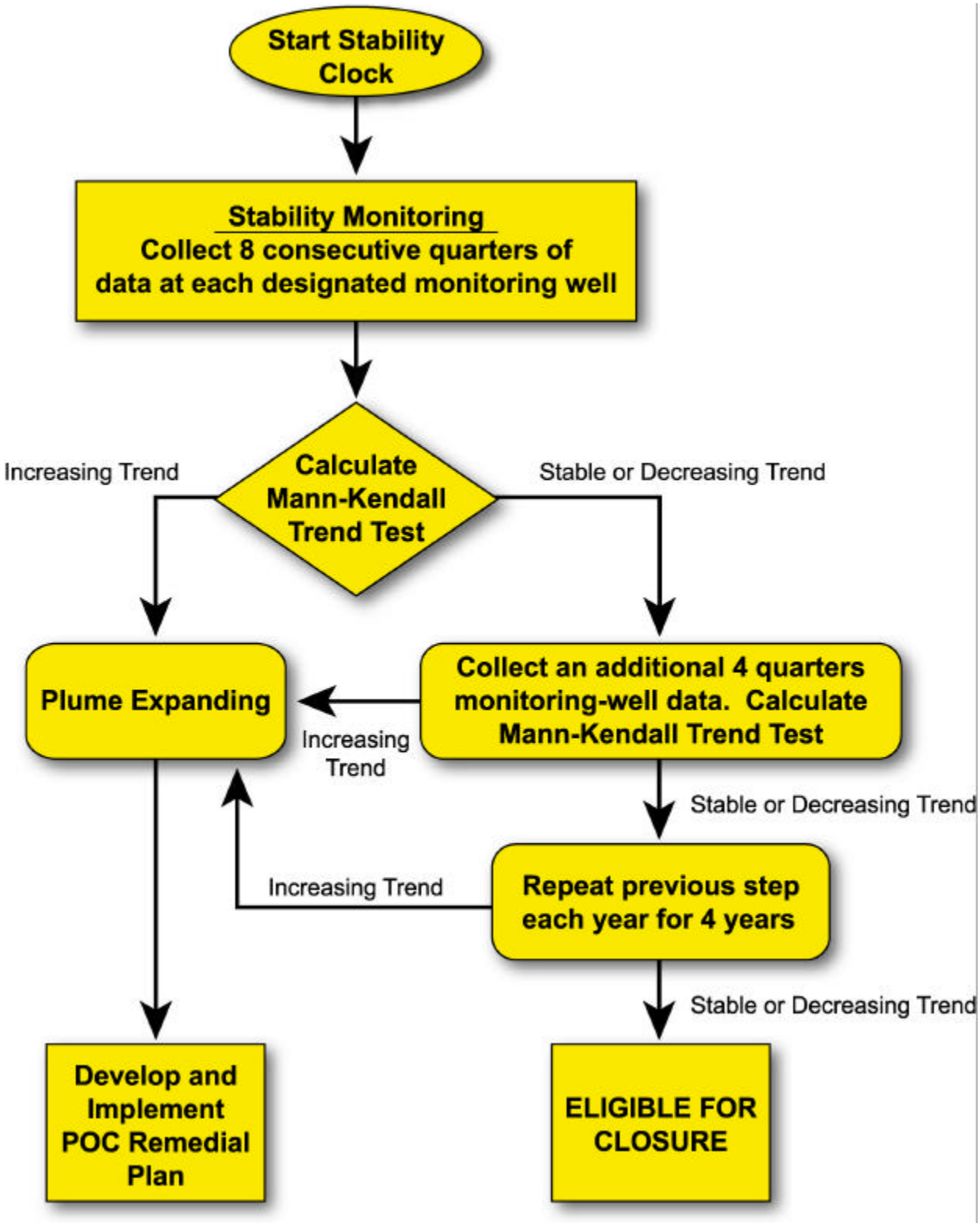

Figure A.3-2. Stability Monitoring Closure for Ground Water Contaminant Plumes

When evaluating an existing plume using historical monitoring data, the start date for the stability clock will be the first quarter of a consecutive and continuing trend of quarterly data showing stability (using the Mann-Kendall trend test). It may be more practical to begin with the most recent year's data and work back in time until the beginning of the stable trend is identified. Historical data should be treated in the same way that new data would be treated (see Section A3.1.2). In addition, existing site information must be evaluated to ensure that all of the required activities have been completed.

A3.1.2 Stability Monitoring

Stability monitoring requires 8 consecutive quarters of ground water monitoring data from wells designated for stability closure (messenger and POC wells). Eight quarters of data are required to provide sufficient data for trend tests. To minimize the possibility of an expanding plume during stability monitoring, a remedial plan must be developed and implemented if monitoring data indicate four consecutive increases at any POC well. If data from POC wells do not show four consecutive increases, the Mann-Kendall trend test may be conducted to further evaluate plume stability.

A3.1.3 Mann-Kendall Trend Test

This section gives a general procedure and examples for determining if COC concentrations are increasing at an individual ground water monitoring well. This determination is reached using the Mann-Kendall trend test. The general procedure for the test is provided in the box below.

Mann-Kendall Trend Test General Procedure

1. Collect ground water samples from each well for at least eight consecutive quarters.
2. List the data in the order collected over time: $x_1, x_2, \ldots x_n$, where x_i is the measured concentration at time t_i . For values below the EQL, use EQL/2. Construct a data matrix as shown in the Table A3-1 and examples.
3. Compute the signs of all the ordered differences, as shown in Table A3-1 and examples.
4. Compute the Mann-Kendall statistic, *S*, which is the number of positive changes minus the number of negative changes in the data sequence. Zeros that result from two consecutive values being identical do not enter into the calculation.
5. If there are between 8 and 10 measurements in the sequence, use Table A3-2 to find the trend probability *P* corresponding to sample size *n* and the absolute value of the Mann-Kendall *S*.

   If there are 11 or more measurements in the sequence, use the normal approximation in the Large Sample example to determine a *z (P)* value.
6. The " value for this test is 0.10 for the first two trend tests and 0.05 afterward. If $S > 0$ and $P <$ ", the null hypothesis of no increasing trend is rejected, and concentrations are considered to be increasing at this well. Otherwise, the well concentrations are considered stable.

Table A3-1. Data Matrix for Calculating the Mann-Kendall Statistic, *S*

Time	t_1	t_2	t_3	t_4	t_5	No. of + signs	No. of - signs
Conc.	x_1	x_2	x_3	x_4	x_5		
x_1		$x_2 - x_1$	$x_3 - x_1$	$x_4 - x_1$	$x_5 - x_1$		
x_2			$x_3 - x_2$	$x_4 - x_2$	$x_5 - x_2$		
x_3				$x_4 - x_3$	$x_5 - x_3$		
x_4					$x_5 - x_4$		
					Totals:	Total +'s	Total -'s

NOTE: For compactness, this table shows a sequence of five measurements; however, at least eight are required to demonstrate stability. When there are *n* measurements, there are *n* entries in the table. When two successive concentrations are identical, the resulting zero difference is neither positive nor negative, and it is ignored.

Two examples of using the Mann-Kendall trend test to calculate plume stability are provided below. The first example illustrates using the test for a small sample size (n = 10). The second example is for a larger sample size and is considered the normal approximation.

Small Sample Example

The following example has a sample size of 10 measurements (n = 10) in the data sequence:

Time	1	2	3	4	5	6	7	8	9	10	No. of +	No. of -
Conc.	9	9	11	5	12	20	18	18	17	22		
9		0	+	-	+	+	+	+	+	+	7	1
9			+	-	+	+	+	+	+	+	7	1
11				-	+	+	+	+	+	+	6	1
5					+	+	+	+	+	+	6	0
12						+	+	+	+	+	5	0
20							-	-	-	+	1	3
18								0	-	+	1	1
18									-	+	1	1
17										+	1	0
									Totals:		35	8

For this example, S = 35 - 8 = 27. With n = 10 and S = 27, Table A3-2 yields a probability value (P) = 0.0083.

Because P = 0.0083 is less than " = 0.10, concentrations are considered to be increasing for this well. Because the plume may be expanding, and a remedial plan may be required. See *Practical Methods for Data Analysis-EPA QA/G-9* (EPA 1984).

In cases yielding a P value greater than " = 0.10, no trend in concentrations would be demonstrated for this well.

Table A3-2: Probabilities for Small-Sample Mann-Kendall Trend Test

S	n = 4	n = 5	n = 8	n = 9	S =	n = 6	n = 7	n = 10
0	0.625	0.592	0.548	0.54	1	0.5	0.5	0.5
2	0.375	0.408	0.452	0.46	3	0.36	0.386	0.431
4	0.167	0.242	0.360	0.381	5	0.235	0.281	0.364
6	0.042	0.117	0.274	0.306	7	0.136	0.191	0.3
8		0.042	0.199	0.238	9	0.068	0.119	0.242
10		0.0083	0.138	0.179	11	0.028	0.068	0.19
12			0.089	0.130	13	0.0083	0.035	0.146
14			0.054	0.090	15	0.0014	0.015	0.108
16			0.031	0.060	17		0.0054	0.078
18			0.016	0.038	19		0.0014	0.054
20			0.0071	0.022	21		0.0002	0.036
22			0.0028	0.012	23			0.023
24			0.00087	0.0063	25			0.014
26			0.00019	0.0029	27			0.0083
28			0.000025	0.0012	29			0.0046
30				0.00043	31			0.0023
32				0.00012	33			0.0011
34				0.000025	35			0.00047
36				0.0000028	37			0.00018
					39			0.000045

Large Sample Example (Normal Approximation)

The example below is similar to the Small Sample test, but it applies to cases with 11 or more measurements in the sequence. The procedures are as follows:

Step 1:Calculate the Mann-Kendall *S* statistic.

Time	1	2	3	4	5	6	7	8	9	10	11	12	No. of +	No. of -
Conc.	9	9	11	5	7	11	12	20	18	18	18	22		
9		0	+	-	-	+	+	+	+	+	+	+	8	2
9			+	-	-	+	+	+	+	+	+	+	8	2
11				-	-	0	+	+	+	+	+	+	6	2
5					+	+	+	+	+	+	+	+	8	0
7						+	+	+	+	+	+	+	7	0
11							+	+	+	+	+	+	6	0
12								+	+	+	+	+	5	0
20									-	-	-	+	1	3
18										0	0	+	1	0
18											0	+	1	0
18												+	1	0
											Totals:		52	9

Hence, $S = 52 - 9 = 43$.

Here, The Mann-Kendall S statistic is calculated just as before, but a calculated normal approximation z value is substituted for the P value. To evaluate trends, the measured z value is then compared to the critical z value (from " = 0.10 or 0.05) to evaluate trends.

Step 2: Calculate SE_S

Calculate the standard error of S (SE_S) using one of the following formulas. If there are no repeated values (ties) use Equation A3-1 below.

Equation A3-1

$$SE_S = \left[\frac{n(n-1)(2n+5)}{18}\right]^{0.5}$$

If there are repeated values, use Equation A3-2.

Equation A3-2.

$$SE_S = \left\{ \frac{1}{18} \left[n(n-1)(2n+5) - \sum_{p=1}^{g} k_p (k_p - 1)(2k_p + 5) \right] \right\}^{0.5}$$

Where

g is the number of tied groups
k_p is the number of times the value in the group (p) is repeated

In the example above, n = 12, and g = 3 (for concentrations of 9, 11, and 18). There are 2 nines, 2 elevens, and 3 eighteens, so $k_1 = 2$, $k_2 = 2$, and $k_3 = 3$. Thus,

$$SE_S = \left[\frac{12(11)(29) - 2(1)(9) - 2(1)(9) - 3(2)(11)}{18} \right]^{0.5} = \sqrt{\frac{3726}{18}} = 14.3875$$

Step 3: Calculate z.

Calculate a standard normal z statistic, using the following equations and S values:

Equation A3-3a, b, and c

If S > 0, $z = \frac{S-1}{SE_s}$

If S = 0, z=0

If S < 0, $z = \frac{S+1}{SE_s}$

In the example given, S is positive, so the z value is calculated as follows:

$$z = \frac{43-1}{14.3875} = 2.919$$

Step 4: Compare z values

The critical z value z_{crit} = 1.282, based on a normal distribution with " = 0.10).

Because the calculated z (2.9) is greater than this critical z value (1.282), an increasing concentration trend is demonstrated for this well. Consequently, the plume may be expanding, and a remedial plan may be necessary.

In cases where the calculated z is smaller than z_{crit} , concentrations are considered stable. Stable individual wells contribute to a stable plume designation, which would allow stability monitoring to continue.

A3.1.4 Additional Data Collection

If the full stability monitoring period (7 years) has not passed, collect an additional four quarters of data at each well for each COC. For each COC at each well, calculate the Mann-Kendall trend test for (1) the most recent eight quarters of data and (2) all the data. The plume is considered to be expanding if test results indicate that any COC concentration is increasing at (1) two or more messenger wells, (2) any POC well, or (3) any sentinel well.

If the plume is expanding, a POC remedial plan must be developed and implemented. If the plume is not expanding, Step A3.1.3 should be repeated for each additional year remaining in the stability monitoring period.

A3.1.5 Closure Eligibility

If the plume is shrinking or stable, and the stability clock has been running for 7 years, the site may be eligible for closure under RISC. If the plume remains stable or demonstrates a decreasing trend for the full stability monitoring period, the site may be eligible for closure.

A3.2 Petroleum Closure By Attenuation Modeling

Research on petroleum indicates that a dissolved petroleum plume expands during the first 4 years regardless of site or area conditions; however, after several years, the leading edge of the plume will stabilize if attenuating conditions are present. Attenuation is defined as a reduction in petroleum constituent concentration or mass in ground water due to naturally occurring chemical and physical processes, including dispersion, sorption, biodegradation.

Attenuation modeling can only be performed for COCs originating from an eligible petroleum source, as described below. The model is simple and reliable if adequately calibrated and applied. In addition, it may allow closure of a site in as few as 3 years if the plume is decreasing. However, plume stability will not occur if free product or excess contamination exists at the source; therefore, all free product must be recovered to the extent practicable. Excavation and disposal of source material is one of the most effective strategies for ensuring eventual plume stability.

Sites eligible for attenuation modeling include the following:

1. The COC source was virgin petroleum fuel or virgin lubricating oil.

2. The contaminant plume is at least 4 years old. Responsible parties also may use this procedure if the plume age is unknown and is likely to be at least 4 years old.

3. Property control has been secured for all of the property affected by the contaminant plume, and proof of property control if provided to IDEM.

Data from petroleum-related plumes are subjected to statistical trend testing and monitoring to demonstrate plume stability. Sometimes the attenuation model will not accurately predict COC attenuation, in which case additional monitoring and stability testing will be needed. It may be necessary to adjust modeled attenuation rates to reflect actual attenuation rates for a period equal to the stability monitoring period (total time 7 years). In such cases, the area of concern may be eligible for closure by the standard stability monitoring procedures.

Before proceeding with attenuation modeling, all data must be reviewed to determine if the selected model is appropriate for the site conditions. The Mann-Kendall trend test, based solely on data from messenger wells, is generally the basis for determining if the model is appropriate.

Petroleum closure by attenuation modeling requires eight quarters of stable data. Once initial stability has been demonstrated, two options exist for pursuing petroleum closure: the stability monitoring method (see Section A3.1) or attenuation modeling.

When using the attenuation modeling option, a first-order decay model is applied to the stability monitoring data. Model results are then used to predict COC concentrations at each well for the following four quarters. If the predicted concentrations pass a goodness-of-fit test, data is collected for four additional quarters, and predicted and actual concentrations are compared statistically. If there is good agreement between the data sets (using the Root Mean Square Deviation Test), the site is eligible for closure.

The general procedure for petroleum closure by attenuation modeling is presented below. Overall, the procedure is similar to closure by stability monitoring; however, trend monitoring and decision data are subjected to different statistical tests. Attenuation modeling follows

the same initial steps as stability monitoring, including (1) starting the stability clock (see Section A3.1.1), (2) stability monitoring (see Section A3.1.2), and (3) the Mann-Kendall trend test.

The model is not recommended if one or more messenger wells show an increasing trend. IDEM recommends constructing a sample-concentration-versus-time plot of the messenger well monitoring data as a decision aid.

If it is determined that it is not appropriate to use a model after the first eight quarters of monitoring, it is possible to monitor for an additional four quarters and try again. This approach may be appropriate if previous data trends appeared to support modeling.

When four more quarters of data have been collected, the Mann-Kendall trend test is once again used. To distinguish between long- and short-term trends, the Mann-Kendall trend test is applied to two different sets of data: (1) the entire data set and (2) data from the most recent 8 quarters. If either test indicates an expanding trend, the remedial plan must be developed and implemented.

If a model is not used, this monitoring and testing cycle must be performed for a 7-year period during which the plume is stable (Option 1). Option 2 requires modeling the contamination trend . If the trend tests during this period indicate that the plume is stable, closure may be applied for as described in Section A3.1.5. The sections below discuss concentration trend modeling, the goodness-of-fit test and verification modeling by the root-mean-square deviation test.

A3.2.1 Concentration Trend Modeling

The method for calculating, testing, and verifying concentration trends may be predicted from the first-order decay model expressed in Equation A3-4.

Equation A3-4 $C = C_0 \exp^{(-kt)}$

Where

C	=	Concentration at time t
C_0	=	Concentration at time 0
k	=	Attenuation rate [day-1]
t	=	time [days]

Although this model is often calibrated by solving the equation in natural logs using linear regression on the logarithms, that procedure produces biased results that may not fit future values well (see Miller 1984). In addition, "transformation-bias correction" suggested by Miller and others does not work well, except with very large sample sizes (Parkhurst, ES&T 1998). Therefore, the model should be calibrated by nonlinear regression. This regression is accomplished by finding the values of C_0 and k that minimize the sum (S) of the squared deviations.

Equation A3-5. $S = \sum_{t=0}^{N} [C_i - C_0 \exp(-kt_i)]^2$

1. Combine with A3-4, add "S = sum of the squared deviations" to parameter list.
2. S is summed from i = 0 to N, not from N.

Note: C = Ci]

This calculation is included in the RISC software package.

The model is calibrated for "fit" using eight or more quarters of messenger well stability monitoring data. The resulting parameter values are then used in the model to predict concentrations at the messenger and POC wells for the next four quarters. Calibration and goodness-of-fit testing are discussed below.

A3.2.2 Goodness-of-fit Test (via Coefficient of Determination)

Two criteria must be met to verify that the data are sufficiently consistent with the first-order decay model:

1. The value of k obtained from the fitting process must be positive, indicating attenuation of the chemical over time.

2. The Coefficient of Determination of the regression (R^2) must be at least 0.80, indicating sufficiently good fit of the model to the data. In this context, R^2 is calculated as the square of the correlation coefficient between the measured concentration values and the corresponding values predicted by the model. Equation A3-6 is used to calculate R^2.

Equation A3-6.

$$R^2 = \left[\frac{\Sigma(C_i \hat{C}_i) - (\Sigma C_i)(\Sigma \hat{C}_i / N)}{(N-1) S_C S_{\hat{C}}} \right]^2$$

Where

Sums are all taken over i = 1,...N.

C_i	=	i^{th} measured concentration,
C^	=	Corresponding predicted value
S_C	=	Sample standard deviation of the N measured concentrations
$S_{\hat{C}}$	=	Sample standard deviation of the N corresponding predicted concentrations

The correlation coefficient (*r*) between two columns of numbers can easily be calculated directly by most popular spreadsheet software programs; the *r* value obtained must be squared to yield R^2.

If predictive data indicate a decreasing trend *and* R^2 $0.8, monitoring data should be collected over the next four quarters and compared with the model predictions. If either or both of these criteria are not met, the site is not appropriate for modeling. In such cases, closure may be pursued by (1) conducting stability monitoring (see Section A3.1), (2) collecting another four quarters of data and recalibrating the model (if the plume is stable), or (3) evaluating the plume using a nondefault approach.

Equation Set: (Ref: Introduction to Statistical Methods)

EQN 1 $$C_p = C_0 \exp^{(-kt)}$$

EQN 2 $$S = \sum_{t=0}^{N} \left[C_{pi} - C_0 \exp(-kt_i) \right]^2$$

EQN-3 $$R^2 = \left[\frac{\sum (C_m C_p) - (\sum C_m)(\sum C_p) / N}{(N-1) S_{C_m} S_{C_p}} \right]^2$$

ALSO,

EQN-3a $$R^2 = \left[\frac{S_{CmCp}}{\sqrt{S_{Cm} S_{Cp}}} \right]^2$$

EQN-3b $$S_C = \sum C^2 - \frac{\left(\sum C\right)^2}{N}$$

EQN-3c $$S_{CmCp} = \sum CmCp - \frac{\sum Cm \sum Cp}{N}$$

Where:

C_0	=	Initial Concentration (mg/l)
C_m	=	The measured concentration (mg/l)
C_p	=	The corresponding predicted concentration (mg/l)
S_{cm}	=	Sample standard deviation of the N measured concentrations
S_{Cp}	=	Sample standard deviation of the corresponding predicted concentrations
k	=	The attenuation rate (1/day)
t	=	Period of time between initial sample and sample C_m (days)
N	=	Number of measured samples

And,

S	=	First order minimization value
R^2	=	Coefficient of determination (correlation value)
RMSD	=	Root mean square deviation (prediction quality value)

S_c: Defined by R^2, EQN-3a
S_{cmcp}: Defined by R_2, EQN-3a

A3.2.3 Verification-Stage Monitoring by the Root-Mean-Square-Deviation Test

For verification modeling, samples are collected from the messenger wells for four more quarters. The Mann-Kendall trend test must be separately applied to the entire pool of data and to the last eight quarters of data for each COC at each well. If the trend continues to be stable or decreasing, verification modeling should be conducted.

Verification modeling by the Root-Mean-Square Deviation (RMSD) test measures how well the model predicts monitoring results after calibration. The RMSD is used for this comparison. Equation A3-7 is used to calculate the RMSD between a set of measured concentrations C_{mi} and the corresponding predicted concentrations C_{pi}.

Equation A3-7.

$$RMSD = \sqrt{\frac{\sum_{i=1}^{n}(C_{mi} - C_{pi})^2}{N}}$$

The RMSD value is calculated using two sets of data:

1. The calibration data used to fit the model (Stage 1 data)

2. The monitoring-stage data (Stage 2 data), using the values of C and k obtained from Stage 1

The site will be eligible for closure only if the ratio of the Stage 2 RMSD to the Stage 1 RMSD is less than or equal to 1.3 ($RMSD_2/RMSD_1 \leq 1.3$).

In other words, the model fit can be no more than 30 percent worse during the monitoring stage than it was during the modeling stage.

If the dissolved contaminant plume meets these conditions, the site is eligible for closure. If not, then the following should be considered: (1) recalibrate the model using additional data, (2) pursue closure using stability monitoring, or (3) evaluate the plume using a nondefault approach.

An example of verification modeling by the RMSD test is provided below.

Assume that eight ground water samples have been collected with the following concentrations:

$$C_m = 90.1, 90.3, 73.4, 57.6, 64.7, 53, 54.2, 44.6$$

The first order minimization equation, Equation A3-5, requires that an iterative device (such as a computer program or a spreadsheet) be used to solve the equation. Using Table A3-3, solve for k using the RISC software.

Table A3-3. Initial Inputs for First 8 Quarters

Row/Col	A	B	C	D	E	F	G
1			Monitoring	Measured	First Order		
2	Co =	90.1	Time Period	Conc.	Prediction		
3	k =	0.0011	t	Cm	Cp	Cm - Cp	$(Cm - Cp)^2$
4			(Days)	mg/l	mg/l		
5			10	90.1	91.9	0	0
6			290	90.3	82.9	8.6	75
7			180	73.4	74.8	-0.6	0.3
8			270	57.6	67.6	-9.4	89
9			360	64.7	61	4	15.7
10			450	53	55	-2	4.2
11			540	54.2	49.7	4.3	18.7
12			630	44.6	44.8	-0.6	0.4
						Sum =	203.2

The RISC software will yield results similar to Table A3-4 below.

Table A3-4. Optimize Initial Inputs for First 8 Quarters

Row/Col	A	B	C	D	E	F	G	H
1			Monitoring	Measured	First Order			
2	**Co =**	91.86	Time Period	Conc.	Predictions			
3	**k =**	0.001	t	Cm	Cp	Cm - Cp	$(Cm - Cp)^2$	Cm*Cp
4			(Days)	mg/l	mg/l			
5			0	90.1	91.9	-1.76	3.1	8280
6			90	90.3	82.9	7.39	54.6	7486
7			180	73.4	74.8	-1.44	2.1	5490
8			270	57.6	67.6	-9.95	99	3894
9			360	64.7	61	3.73	13.9	3947
10			450	53	55	-2.04	4.2	2915
11			540	54.2	49.7	4.52	20.4	2694
12			630	44.6	44.8	-0.24	0.1	1998
		SUM =		527.9	527.7	0.21	197.4	36704

Cells B2 and B3 now contain the least-squares Co and k estimates.

Goodness of Fit Test

Beginning with the values in the above spreadsheet, we can now check the goodness of fit using the equations below. With the object of solving Equation A3-8a, we solve Equation-A3-8b and Equation A3-8c.

Example solving Equation A3-6b:

1. Sum C_m^2 = $90.1^2+90.3^2+73.4^2+57.6^2+64.7^2+53^2+54.2^2+44.6^2$ = 36,900

2. Sum C_m = 527.9

3. N = 8

$$Sc_m = 36900 - \left(\frac{527.9^2}{8}\right) = 2{,}065$$

In a similar manner, use Equation A3-8b to solve for Sc_p:

$$Sc_p = 1898$$

Example solving Equation A3-6c:

1. Sum C_mC_p = 36,704
1. Sum C_m = 527.9
1. Sum C_p = 527.7
1. N = 8

$$Sc_m c_p = 36704 - \left(\frac{527.9 * 527.7}{8}\right) = 1{,}882$$

Example using Equation A3-6a to solve for R^2:

$$R^2 = \left[\frac{1882}{\sqrt{1898 * 2065}}\right]^2 = 0.904$$

Because R^2 = 0.9 is greater than 0.8, the assessment can continue with an evaluation of the prediction results, using RMSDs.

Using Equation A3-4 and the optimized k and C_o values, predict the concentrations of the next four monitoring events, days 720 through 990.

$$C_p = 40.5, 36.5, 33, 29.8$$

Collect the next four monitoring samples and analyze. Assume that results are as follows:

$$C_m = 49.5, 48.2, 40.9, 42.2$$

Table A3-5 shows the new data.

Table A3-5. Prediction Inputs and Prediction Results

	Row/Col	A	B	C	D	E	F	G	H
INPUTS	1			Monitoring	Measured	First Order			
	2	**Co =**	91.86	Time Period	Conc.	Conc. Fit			
	3	**k =**	0.001	t	Cm	Cp	Cm - Cp	$(Cm - Cp)^2$	Cm*Cp
	4			(Days)	mg/l	mg/l			
	5			0	90.1	91.9	-1.76	3.1	8280
	6			90	90.3	82.9	7.39	54.6	7486
	7			180	73.4	74.8	-1.44	2.1	5490
	8			270	57.6	67.6	-9.95	99	3894
	9			360	64.7	61	3.73	13.9	3947
	10			450	53	55	-2.04	4.2	2915
	11			540	54.2	49.7	4.52	20.4	2694
	12			630	44.6	44.8	-0.24	0.1	1998
	13		**SUM =**		527.9	527.7	0.21	197.4	36704
RESULTS	14			720	49.5	40.5	9	81.5	
	15			810	48.2	36.5	11.7	136.1	
	16			900	40.9	33	7.9	62.8	
	17			990	42.2	29.8	12.4	154.6	
	18		**SUM =**					435	

Note: Beginning with row 14, the concentration predictions (C_p) are evaluated against the four monitoring events (C_m) conducted after the initial monitoring period using the mean square deviation $(C_m - C_p)^2$.

Calculate the RMSD for the model input period (the initial eight quarters), $RMSD_1$, using Equation A3-7:

$$RMSD1 = \sqrt{\frac{\sum_{i=1}^{n}(C_m - C_p)^2}{N}} = \sqrt{\frac{197.31}{8}} = 4.97$$

Calculate the RMSD for the model prediction results period (the final four quarters), $RMSD_2$, using Equation A3-7:

$$RMSD_2 = \sqrt{\frac{\sum_{i=1}^{n}(C_m - C_p)^2}{N}} = \sqrt{\frac{434.9}{4}} = 10.4$$

Evaluate the model predictions against the monitoring results using the

RMSDs: $RMSD_2 / RMSD_1 = 2.1 > 1.3$.

Because the attenuation model has not adequately predicted plume behavior, monitoring must continue, or another closure option should be pursued.

A4.0 Introduction

The Standard Industrial Classification, commonly referred to as the SIC code, was developed by the U.S. Government in conjunction with U.S. business. It divides virtually all economic activity into 10 major divisions:

Agriculture, Forestry, and Fishing	01 — 09
Mining	10 — 14
Construction	15 — 17
Manufacturing	20 — 39
Transportation, Communications, Utilities	40 — 49
Wholesale Trade	50 — 51
Retail Trade	52 — 59
Finance, Insurance and Real Estate	60 — 67
Services	70 — 89
Public Administration	91 — 97
Non-Classifiable Establishments	99

The SIC places each line of business within one of these 10 divisions and assigns it a four-digit code. The first two digits describe the nature of the activity broadly:

15.....General Building Contractors

The third and fourth digits describe the activity specifically:

1521.....General House Contractors

The most significant attribute of the SIC system is that it is the one system most frequently used in presenting the basic data about the nation. No other system is as widely used nor does any other describe in detail the entire U.S. economy. Thus, the system provides the enterprising industrial marketer with a key to a wealth of valuable data. The following are examples of some critical questions the SIC system along with the other data can help you answer:

- How large is the market for my products and services? (i.e., How many companies are in the same business as those that typically buy my product/service?)
- Where are the greatest concentrations of potential buyers? How is the market dispersed geographically?
- How large are the establishments in those markets, in terms of sales and number of employees?
- Where should I locate my branches, retail outlet and service centers?
- How large is the day-time working population in a given geographical area?

Agriculture, Forestry, and Fishing

SIC Numbers 0100-0999

01	**Agricultural Production-Crops**
0111	Wheat Farm
0112	Rice Farm
0115	Corn Farm
0116	Soybean Farm
0119	Cash Grains, NEC
0131	Cotton Farm
0132	Tobacco Farm
0133	Sugarcane & Sugar Beet Farm
0134	Irish Potato Farm
0139	Field Crops Exc Cash, NEC
0161	Vegetable & Melon Farm
0171	Berry Crop Farm
0172	Grape Vineyard
0173	Tree Nut Grove
0174	Citrus Fruit Grove
0175	Deciduous Tree Fruit Orchard
0179	Fruit & Tree Nut, NEC
0181	Grow Flowers/Nursery Products
0182	Food Crops (Under Cover)
0191	General Farms
02	**Agricultural Production-Livestock**
0211	Beef Cattle Feedlots
0212	Beef Cattle, Exc Feedlots
0213	Hogs
0214	Sheep & Goats
0219	Livestock Exc Dairy/Poultry
0241	Dairy Farm
0251	Raising Cooking Chickens
0252	Chicken Eggs
0253	Turkeys & Turkey Eggs
0254	Poultry Hatcheries
0259	Poultry & Eggs, NEC
0271	Fur-Bearing Animal Farms
0272	Horses & Other Equines
0273	Animal Aquaculture
0279	Animal Specialties, NEC
0291	Livestock & Animal Farms
07	**Agricultural Services**
0711	Soil Preparation Svcs
0721	Crop Planing & Cultivating
0722	Crop Machine Harvesting Svcs
0723	Crops Preparation Exc Cot Gin
0724	Cotton Ginning
0741	Livestock Veterinary Svc
0742	Veterinary Svcs, Animals
0751	Livestock Svc Exc Veterinary
0752	Animal Svcs Exc Veterinary
0761	Farm Labor Contractors
0762	Farm Mgt Svcs
0781	Landscape Plan/Consult
0782	Lawn & Garden Svcs
0783	Ornamental Shrub & Tree Svcs
08	**Forestry**
0811	Timber Tracts
0831	Forest Nurseries & Products
0851	Forestry Svcs
09	**Fishing, Hunting and Trapping**
0912	Finfish
0913	Shellfish
0919	Misc Marine Products
0921	Fish Hatchery & Preserve
0971	Hunt/Trap/Propagation
10	**Metal Mining**
1011	Iron Ores
1031	Lead & Zinc Ores
1041	Gold Ores
1044	Silver Ores
1061	Ferroalloy Ores Exc Vanadium
1081	Metal Mining Services
1094	Uranium-Radium-Vanadium
1099	Misc Metal Ores, NEC
12	**Coal Mining**
1221	Bit/Lignite Surface Mining
1222	Bit Coal Underground Mining
1231	Anthracite Mining
1241	Coal Mining Svcs
12	**Oil and Gas Extraction**
1311	Crude Petroleum & Nat Gas
1321	Produce Natural Gas Liquids
1381	Drilling Oil & Gas Wells
1382	Oil/Gas Field Exploration Svc
1389	Oil/Gas Field Svcs, NEC
14	**Non-metallic Minerals, except Fuels**
1411	Dimension Stone
1422	Crushed/Broken Limestone
1423	Crushed/Broken Granite
1429	Crushed/Broken Stone, NEC
1442	Construction Sand & Gravel
1446	Industrial Sand
1455	Kaolin & Ball Clay
1459	Clay Refractory Minerals, NEC
1474	Potash/Soda/Borate Minerals
1475	Phosphate Rock
1479	Chemical Mineral Mining, NEC
1481	Non-Metal Minerals Exc Fuels
1499	Misc Non-Metals Exc Fuels

Construction

SIC Numbers 1500-1799

15	**General Building Contractors**
1521	General House Contractors
1522	Residential Bldgs Exc Houses
1531	Operative Builders
1541	Industrial Bldg/Warehouse
1542	Non-Residential Bldgs Exc Ind.
16	**Heavy Construction, Except Building**
1611	Road Construct Exc El Hways
1622	Bridge/Tunnel/El Hway Const
1623	Utility/Pwr Line Construction
1629	Heavy Construction, NEC
17	**Special Trade Contractors**
1711	Plumbing, Heating & A/C
1721	Painting & Paper Hanging
1731	Electrical Work
1741	Masonry/Stone Set/Other Work
1742	Plaster/Wall/Insulation Work
1743	Tile, Marble, Mosaic Work
1751	Carpentry Work
1752	Floor Work, NEC
1761	Roof/Siding/Sheet Metal Work
1771	Concrete Work
1781	Water Well Drilling
1791	Erect Structural Steel
1793	Glass & Glazing Work
1794	Excavation Work
1795	Wrecking & Demolition Work
1796	Install/Erect Bldg Equip, NEC
1799	Special Trade Contractors, NEC
20	**Food and Kindred Products**
2011	Meat Packing Plants
2013	Sausages/Prepared Products
2015	Slaughter/Process Poultry
2021	Creamery Butter
2022	Cheese
2023	Processed Dairy Products
2024	Ice Cream & Frozen Desserts
2026	Fluid Milk
2032	Canned Specialties
2033	Canned Preserves/Jams/Jellies
2034	Dried Fruit/Veggie/Soup Mixes
2035	Fruit/Veggies Seasoning/Sauces
2037	Frozen Fruits/Juices/Veggies
2038	Frozen Specialties, NEC
2041	Flour & Grain Mill Products
2043	Cereal Breakfast Foods
2044	Rice Milling
2045	Prepared Flour Mixes/Doughs
2046	Wet Corn Milling
2047	Dog & Cat Food
2048	Prepared Animal Feeds
2051	Bread Products Exc Cookie/Crkr
2052	Cookies & Crackers
2053	Frozen Bakery Prods Exc Bread
2061	Cane Sugar Exc Refining
2062	Cane Sugar Refining
2063	Beet Sugar
2064	Candy & Other Products
2066	Chocolate & Cocoa Products
2067	Chewing Gum
2068	Salt/Roast Nuts/Seeds
2074	Cottonseed Oil Mills
2075	Soybean Oil Mills
2076	Veg Oil Mills Exc Corn/Soy
2077	Animal/Marine Fats/Oils
2079	Margarine & Other Edible Fats
2082	Malt Beverages
2083	Malt
2084	Wines, Brandy & Brandy Spirits
2085	Distilled & Blended Liquors
2086	Soft Drinks/Water (Can/Bottle)
2087	Flavoring Extracts/Syrups, NEC
2091	Can/Cure Fish & Seafoods
2092	Fresh/Frozen Fish/Seafoods
2095	Roasted Coffee
2096	Potato/Corn Chips & Snacks
2097	Manufactured Ice
2098	Macaroni & Noodles
2099	Food Preparations, NEC
21	**Tobacco Products**
2111	Cigarettes
2121	Cigars
2131	Chewing/Smoking Tobacco/Snuff
2141	Tobacco Stemming/Redrying
22	**Textile Mill Products**
2211	Cotton Brdwoven Fabric Mills
2221	Brdwoven Man Fiber/Silk Mills
2231	Wool Brdwoven Fabric Mills
2241	Narrow Fabric/Smallwares Mills
2251	Hosiery Exc Socks, Female
2252	Hosiery, NEC
2253	Knit Outerwear Mills
2254	Knit Under/Nightwear Mills
2257	Weft Knit Fabric Mills
2258	Lace/Warp Knit Fabric Mills
2259	Knitting Mills NEC
2261	Finish Cotton Fabrics
2262	Finish Man Fiber/Silk Fabric
2269	Finishers of Textiles, NEC
2273	Carpets & Rugs
2281	Yarn Spinning Mills
2282	Yarn Mills
2284	Thread Mills
2295	Coated Fabrics, Not Rubber
2296	Tire Cord & Fabrics
2297	Nonwoven Fabrics
2298	Cordage & Twine
2299	Textile Goods, NEC

23	**Apparel and Other Textile Products**
2311	Suits/Coats/Overcoats, Male
2321	Shirts Exc Work Shirts, Male
2322	Underwear/Nightwear, Male
2323	Neckwear, Male
2325	Separate Trousers/Slacks, Male
2326	Work Clothing, Male
2329	Male Clothing, NEC
2331	Blouses/Shirts, Female
2335	Dresses, Female
2337	Suits/Skirts/Coats, Female
2339	Outerwear, Female, NEC
2341	Under/Nitewear, Female/Child
2342	Bras/Girdle/Garments
2353	Hats, Caps & Millinery
2361	Dresses/Blouses/Shirts, Child
2369	Child Outerwear, NEC
2371	Fur Goods
2381	Gloves no Knit/Leather
2384	Robes & Dressing Gowns
2385	Waterproof Outerwear
2386	Leather/Sheep-Lined Clothing
2387	Apparel Belts
2389	Apparel & Accessories, NEC
2391	Curtains & Draperies
2392	Housefurnishings
2393	Textile Bags
2394	Canvas & Related Products
2395	Decorative Stitching (Trade)
2396	Auto Trim/Apparel Findings
2397	Schiffli Machine Embroideries
2399	Fabric Textile Products, NEC
24	**Lumber and Wood Products**
2411	Logging
2421	General Planing/Saw Mills
2426	Hardwood Dimension/Floor Mills
2429	Special Product Sawmills, NEC
2431	Millwork
2434	Wood Kitchen Cabinets
2435	Hardwood Veneer & Plywood
2436	Softwood Veneer & Plywood
2439	Structural Wood, NEC
2441	Nail/Lock Corner Boxes/Shook
2448	Wood Pallets & Skids
2449	Wood Containers, NEC
2451	Mobile Homes
2452	Prefab Wood Bldgs/Components
2491	Wood Preserving
2493	Reconstituted Wood Products
2499	Wood Products, NEC
25	**Furniture and Fixtures**
2511	Wood Household Furniture
2512	Upholstered Wood Furniture
2514	Metal Household Furniture
2515	Mattresses/Convertible Beds
2517	Wood TV/Stereo/Sewing Cabinet
2519	Household Furniture, NEC
2521	Wood Office Furniture
2522	Office Furniture Exc Wood
2531	Public Bldg/Related Furniture
2541	Wood Store Fixtures
2542	Office Fixtures/Partitions
2591	Drapery Hardware/Windows Shades
2599	Furniture & Fixtures, NEC
26	**Paper and Allied Products**
2611	Pulp Mills
2621	Paper Mills
2631	Paperboard Mills
2652	Setup Paperboard Boxes
2653	Corrugated & Solid Fiber Boxes
2655	Fiber Cans/Tubes/Drums
2656	Sanitary Food Containers
2657	Folding Paperboard Boxes
2671	Coat/Laminate Paper Packaging
2672	Coated & Laminated Paper, NEC
2673	Plastic/Foil/Coated Paper Bags
2674	Uncoated Paper/Multiwall Bags
2675	Die-Cut Paper/Cardboard
2676	Sanitary Paper Products
2677	Envelopes
2678	Stationery/Related Products
2679	Converted Paper Products, NEC
27	**Printing and Publishing**
2711	Publish/Print Newspapers
2721	Publish/Print Periodicals
2731	Publish/Print Books
2732	Print Books
2741	Miscellaneous Publishing
2752	Lithographic Commerce Printing
2754	Commercial Printing, Gravure
2759	Commercial Printing, NEC
2761	Manifold Business Forms
2771	Greeting Cards
2782	Blankbooks/Looseleaf Binders
2789	Bookbinding & Related Work
2791	Typesetting
2796	Platemaking & Related Sves
28	**Chemical and Allied Products**
2812	Alkalies & Chlorine
2813	Industrial Gases
2816	Inorganic Pigments
2819	Ind Inorganic Chemicals, NEC
2821	Plastics Materials
2822	Synthetic Rubber
2823	Cellulosic Manmade Fibers
2824	Manmade Organic Fibers
2833	Medicine/Botanical Chemicals
2834	Pharmaceutical Preparations
2835	In Vitro/Vivo Diagnostics
2836	Biological Products
2841	Soap/Other Detergents
2842	Cleaning Preparations
2843	Surface Active/Finish Agents
2844	Cosmetics/Toilet Preparations
2851	Paint/Varnish/Other Products
2861	Gum & Wood Chemicals
2865	Cyclic Organic Crudes/Dyes
2869	Ind Organic Chemicals, NEC
2873	Nitrogenous Fertilizers
2874	Phosphatic Fertilizers
2875	Fertilizers, Mixing Only
2879	Pesticides/Farm Chemicals, NEC
2891	Adhesives & Sealants
2892	Explosives
2893	Printing Ink
2895	Carbon Black
2899	Chemicals & Preparations, NEC
29	**Petroleum and Coal Products**
2911	Petroleum Refining
2951	Asphalt Paving Mixture/Blocks
2952	Asphalt Felts & Coatings
2992	Lubricating Oils & Greases
2999	Petroleum/Coal Products, NEC
30	**Rubber and misc. Plastic Products**
3011	Tires & Inner Tubes
3021	Rubber & Plastics Footwear
3052	Rubber/Plastics Hose/Belting
3053	Gasket/Packing/Seal Devices
3061	Mechanical Rubber Goods
3069	Fabricated Rubber Prdts, NEC
3081	Plastics Film & Sheet
3082	Plastics Profile Shapes
3083	Laminated Plastics Shapes
3084	Plastics Pipe
3085	Plastics Bottles
3086	Plastics Foam Products
3087	Plastic Resins Custom Compnd'g
3088	Plastic Plumbing Fixture
3089	Plastic Products, NEC
31	**Leather and Leather Products**
3111	Leather Tanning & Finishing
3131	Boot/Shoe Cut Stock/Findings
3142	House Slippers
3143	Men's Footwear Exc Athletic
3144	Women's Footwear Exc Athletic
3149	Footwear Exc Rubber, NEC
3151	Leather Gloves & Mittens
3161	Luggage
3171	Women's Handbags/Purses
3172	Personal Leather Goods
3199	Leather Goods, NEC
32	**Stone, Clay, and Glass Products**
3211	Flat Glass
3221	Glass Containers
3229	Pressed/Blown Glassware, NEC
3231	Glass Products (Purchased)
3241	Cement, Hydraulic
3251	Brick & Structural Clay Tile
3253	Ceramic Wall & Floor Tile
3255	Clay Refractories
3259	Structural Clay Products, NEC
3261	China/Earth Plumbing Fixtures
3262	China Table/Kitchen Goods
3263	Whiteware Table/Kitchen Goods
3264	Porcelain Electrical Supplies
3269	Pottery Products, NEC
3271	Concrete Block & Brick
3272	Concrete Products
3273	Ready-Mix Concrete
3274	Lime
3275	Gypsum Products
3281	Cut Stone & Stone Products
3291	Abrasive Products
3292	Asbestos Products
3295	Ground/Treated Minerals/Earths
3296	Mineral Wool
3297	Nonclay Refractories
3299	Nonmetal Mineral Prdts, NEC
33	**Primary Metal Industries**
3312	Steel Works & Blast Furnaces
3313	Electrometallurgical Prdts
3315	Steel Wiredrawing/Nails/Spikes
3316	Cold-Rolled Steel Products
3317	Steel Pipe & Tubes
3321	Gray & Ductile Iron Foundries
3322	Malleable Iron Foundries
3324	Steel Investment Foundries
3325	Steel Foundries, NEC
3331	Smelt/Refine Copper
3334	Primary Production of Aluminum
3339	Smelt/Refine Nonferrous Metals
3341	Secondary Nonferrous Metals
3351	Roll/Draw/Extrude Copper
3353	Aluminum Sheet, Plate & Foil
3354	Aluminum Extruded Products
3355	Aluminum Roll/Drawing, NEC
3356	Roll/Draw/Extrude, Nonfer Metal
3357	Draw/Insulate Nonferrous Wire
3363	Aluminum Die-Castings
3364	Nonferrous Die-Castings
3365	Aluminum Foundries
3366	Copper Foundries
3369	Nonferr Foundry Exec Alum/Cop
3398	Metal Heat Treating
3399	Primary Metal Products, NEC
34	**Fabricated Metal Products**

3411	Metal Cans
3412	Metal Ship Barrels/Drums
3421	Cutlery
3423	Hand/Edge Tools
3425	Saw Blades & Handsaws
3429	Hardware, NEC
3431	Enameled Iron/Metal Ware
3432	Plumbing Fixture Parts
3433	Heating Equipment
3441	Fabricated Structural Metal
3442	Metal Doors/Molding/Trim
3443	Prefab Boiler Shop Plat Work
3444	Sheet Metalwork
3462	Iron & Steel Forgings
3463	Nonferrous Forgings
3465	Automotive Stampings
3466	Crowns & Closures
3469	Metal Stampings, NEC
3471	Electroplate/Polish/Color
3479	Coat/Engrave/Allied Sves, NEC
3482	Small Arms/Ammunition
3483	Ammo Exc Small Arms
3484	Small Arms
3489	Ordnances & Accessories, NEC
3491	Industrial Valves
2492	Fluid Power Valves/Hose
3493	Steel Springs, Exc Wire
3494	Valves & Pipe Fittings, NEC
3495	Wire Springs
3496	Misc Fabricated Wire Products
3497	Metal Foil & Leaf
3498	Fabricated Pipe/Fittings
3499	Fabricated Metal Products, NEC
35	**Industrial Machinery and Equipment**
3511	Turbines/Generator Sets
3519	Int Combustion Engines, NEC
3523	Farm Machinery & Equipment
3524	Lawn/Garden Tractors
3531	Construction Machinery
3532	Mining Machinery & Equip
3533	Oil/Gas Machinery & Equipment
3534	Elevators & Moving Stairways
3535	Conveyors/Conveying Equipment
3536	Overhead Traveling Systems
3537	Trucks/Tractors/Trailers
3541	Metal Cutting Machine Tools
3542	Metal Forming Machine Tools
3543	Industrial Patterns
3544	Special Dies & Tools
3545	Machine Tools/Accessories
3546	Power-Driven Handtools
3547	Rolling Mill Machinery/Equip
3548	Electric/Gas Weld/Solder Equip
3549	Metalworking Machinery, NEC
3552	Textile Machinery
3553	Woodworking Machinery
3554	Paper Industries Machinery
3555	Print Trade Machinery/Equip
3556	Food Products Machinery
3559	Special Industry Mach, NEC
3561	Pumps & Pumping Equipment
3562	Ball & Roller Bearings
3563	Air/Gas Compressor
3564	Fans/Blowers/Air Purification
3565	Packaging Machinery
3566	Hi Speed Drive/Gear Changers
3567	Indust Process Furnace/Oven
3568	Mechanical Transmissions, NEC
3569	Indust Machinery/Equip, NEC
3571	Electronic Computers
3572	Computer Storage Devices
3575	Computer Terminals
3577	Computer Peripherals, NEC
3578	Calculating Mach Exc Computers
3579	Office machines, NEC
3581	Automatic Vending Machines
3582	Dryclean/Pressing Machines
3585	A/C & Heating Equipment
3586	Measuring & Dispensing Pumps
3589	Svc Industry Machinery, NEC
3592	Carburetors/Pistons/Valves
3593	Fluid Power Cyl/Actuators
3594	Fluid Power Pumps 7 Motors
3596	Scales/Balances Exc Lab
3599	Industrial Equipment, NEC
36	**Electronic & other Electric Equipment**
3612	Power & Specialty Transformers
3613	Switchgear/board Apparatus
3621	Motors & Generators
3624	Carbon & Graphite Products
3625	Relays & Industrial Controls
3629	Electric Ind Apparatus, NEC
3631	Househld Cooking Equipment
3632	Househld Refrig/Freezers
3633	Househld Laundry Equipment
3634	Electric Housewares & Fans
3635	Househld Vacuums Cleaners
3639	Househld Appliances, NEC
3641	Electric Lamp Bulbs & Tubes
3643	Current-Carry Wiring Devices
3644	Noncurrent-Carry Wiring Dev
3645	Res Electric Lighting Fixtures
3646	Nonres Electric Lighting
3647	Vehicular Lighting Equipment
3648	Lighting Equipment, NEC
3651	Househld Audio/Video Equipment
3652	Records/Audio Tapes/Discs
3661	Telephone/Telegraph Apparatus
3663	Broadcast/Communications Equip
3669	Communications Equipment, NEC
3671	Electron Tubes
3672	printed Circuit Boards
3674	Semiconductor/Related Devices
3675	Electronic Capacitors
3676	Electronic Resistors
3677	Electronic Coils/Transformers
3678	Electronic Connectors
3679	Electronic Components, NEC
3691	Storage Batteries
3692	Primary Batteries, Dry & Wet
3694	Int Combust Eng Electric Equip
3695	Mag/Optical Recording Media
3699	Electrical Machinery, NEC
37	**Transportation Equipment**
3711	Motor Vehicles Bodies
3713	Truck & Bus Bodies
3714	Vehicle Parts/Accessories
3715	Truck Trailers
3716	Motor Homes
3721	Aircraft
3724	Aircraft Engines/Parts
3728	Aircraft Parts/Equip, NEC
3731	Ship Building & Repairing
3732	Boat Building & Repairing
3743	Railroad Equipment
3751	Motorcycles, Bicycles & Parts
3761	Guided Missiles/Space Vehicles
3764	Propulsion Unit Parts
3769	Missile/Space Parts/Equip
3792	Travel Trailers & Campers
3795	Tank & Tank Components
3799	Transportation Equipment, NEC
38	**Instruments and Related Products**
3812	Navigation/Guidance Equipment
3821	Lab Apparatus & Furniture
3822	Automatic Regulating Controls
3823	Display/Control Instruments
3824	Totalizing Fluid Meters
3825	Electricity Testers
3826	Lab Analytical Instruments
3827	Optical Instruments & Lenses
3829	Measure/Control Devices, NEC
3841	Surgical/Medical Instruments
3842	Orthopedic/Prosthetic Appl
3843	Dental Equipment & Supplies
3844	X-ray Apparatus/Tubes
3845	Electromed/therapy Apparatus
3851	Ophthalmic Goods
3861	Photographic Equip/Supplies
3873	Watches/Clocks Devices/Parts
39	**Miscellaneous Manufacturing Industries**
3911	Jewelry, Precious Metal
3914	Silver/Plated/Stainless Ware
3915	Jewelers' Findings/Materials
3931	Musical Instruments
3942	Dolls & Stuffed Toys
3944	Games & Toys
3949	Sporting & Athletic Goods, NEC
3951	Pens, Mech Pencils & Parts
3952	Lead Pencil/Artists' Mat'ls
3953	Marking Devices
3955	Carbon Paper & Inked Ribbons
3961	Costume Jewelry/Novelties
3965	Fastener/Button/Needle/Pin
3991	Brooms & Brushes
3993	Signs & Advertising
3995	Burial Caskets
3996	Hard Surface Floor Coverings
3999	Mfg Industries, NEC

Transportation, Communications, Utilities

SIC Numbers 4000-4999

40	**Railroad Transportation**
4011	Railroads, Line-Haul Operating
4013	RR Switching/Terminals
41	**Local and Interurban Passenger Transit**
4111	Local & Suburban Transit
4119	Local Passenger Transport, NEC
4121	Taxicabs
4131	Intercity/Rural Bus Transport
4141	Local Bus Charter Svc
4142	Bus Charter Svc, Exc. Local
4151	School Buses
4173	Vehicle Passenger Terminals
42	**Trucking and Warehousing**
4212	Local Trucking Without Storage
4213	Trucking Exc Local
4215	Courier Svcs, Exc. by Air
4221	Farm Prdt Warehse/Storage
4222	Refrigerated Warehouse/Storage
4225	General Warehousing & Storage
4226	Special Warehouse/Storage, NEC
4231	Motor Terminal Maint Facil
43	**U.S. Postal Service**
4311	United States Postal Svc
44	**Water Transportation**
4412	Sea Foreign Freight Trans

4424	Sea Domestic Freight Trans
4432	Great Lakes Freight Trans
4449	Water Freight Transport, NEC
4481	Sea Trans of Passengers
4482	Ferries
4489	Water Passenger Trans, NEC
4491	Marine Cargo Handling
4492	Towing & Tugboat Svcs
4493	Marinas
4499	Water Transport Svc, NEC
45	**Transportation by Air**
4512	Air Transportation, Scheduled
4513	Air Courier Svcs
4522	Air Transport, Non-scheduled
4581	Airport/Terminal Svcs
46	**Pipelines, Except Natural Gas**
4612	Crude Petroleum Pipelines
4613	Refined Petroleum Pipelines
4619	Pipelines, NEC
47	**Transportation Services**
4724	Travel Agencies
4725	Tour Operators
4729	Arrange Passenger Trans, NEC
4731	Arrange Trans Freight/Cargo
4741	Rental of Railroad Cars
4783	Packing & Crating
4785	Inspect/Weighing Svcs
4789	Transportation Svcs, NEC
48	**Communication**
4812	Radiotelephone Communications
4813	Phone Communications
4822	Telegraph/Other Message Comm
4832	Radio Broadcasting Stations
4833	TV Broadcasting Stations
4841	Cable & Other Pay TV Svcs
4899	Communications Svcs, NEC
49	**Electric, Gas, and Sanitary Services**
4911	Electric Svcs
4922	Natural Gas Transmission
4923	Nat. Gas Transmiss/Distribute
4924	Natural Gas Distribution
4925	Petroleum Gas Products
4931	Electric/Other Svcs Combined
4932	Gas & Other Svcs Combined
4939	Combination Utilities, NEC
4941	Water Supply
4952	Sewerage Systems
4953	Refuse Systems
4959	Sanitary Svcs, NEC
4961	Steam & A/C Supply
4971	Irrigation Systems

Wholesale Trade

SIC Numbers 5000-5199

50	**Wholesale Trade-Durable Goods**
5012	Auto & Other Motor Vehicles
5013	Vehicle Supplies & New Parts
5014	Tires & Tubes
5015	Motor Vehicle Parts, Used
5021	Furniture
5023	Home Furnishings
5031	Lumber/Plywood/Millwork
5032	Brick/Stone/Const Materials
5033	Roof/Siding/Insulation Mat ls
5039	Construction Materials, NEC
5043	Photo Equipment & Supplies
5044	Office Equipment
5045	Computers Equip/Software
5046	Commercial Equipment, NEC
5047	Medical/Dental Equip/Supplies
5048	Ophthalmic Goods
5049	Pro Equipment & Supplies, NEC
5051	Metals Svc Centers & Offices
5052	Coal & Other Minerals & Ores
5063	Electrical Equip/Wiring
5064	Electrical Appliances
5065	Electronic Parts/Equip, NEC
5072	Hardware
5074	Plumbing/Heating Equip/Supply
5075	Heating & A/C Equip/Supplies
5078	Refrigeration Equipment
5082	Construction & Mining Equip
5083	Farm/Garden Machinery/Equip
5084	Industrial Machinery/Equip
5085	Industrial Supplies
5087	Service Establishment Equip
5088	Transportation Equip/Supplies
5091	Sporting/Rec Goods & Supplies
5092	Toys & Hobby Goods & Supplies
5093	Scrap & Waste Materials
5094	Jewelry/Watches/Precious Mtl
5099	Durable Goods, NEC
51	**Wholesale Trade-Non-durable Goods**
5111	Printing & Writing Paper
5112	Stationery & Office Supplies
5113	Industry/Personal Svc Paper
5122	Drugs/Druggists Sundries
5131	Piece Goods/Other Dry Goods
5136	Clothing & Furnishings, Male
5137	Female/Child Clothing
5139	Footwear
5141	Groceries, General Line
5142	Packaged Frozen Foods
5143	Dairy Products
5144	Poultry & Poultry Products
5145	Confectionery
5146	Fish & Seafoods
5147	Meats & Meat Products
5148	Fresh Fruits & Vegetables
5149	Groceries/Related Prdts, NEC
5153	Grain & Field Beans
5154	Livestock
5159	Farm-Prdt Raw Materials, NEC
5162	Plastics Mat ls/Basic Forms
5169	Chemical/Allied Prdts, NEC
5171	Petroleum Bulk Terminal
5172	Petroleum/Prdts Wholesalers
5181	Beer & Ale
5182	Wine/Distilled Alcohol Bev
5191	Farm Supplies
5192	Book/Periodical/Newspaper
5193	Flowers/Florists Supplies
5194	Tobacco & Tobacco Products
5198	Paints, Varnishes & Supplies
5199	Non-Durable Goods, NEC

Retail Trade

SIC Numbers 5200-5999

52	**Building Materials and Garden Supplies**
5211	Lumber/Bldg Materials Dealers
5231	Paint/Glass/Wallpaper Stores
5251	Hardware Stores
5261	Lawn & Garden Supply Stores
5271	Mobile Home Dealers
53	**General Merchandise Stores**
5311	Department Stores
5331	Variety Stores
5399	Misc Gen Merchandise Stores
54	**Food Stores**
5411	Grocery Stores
5421	Meat/Seafood Markets
5431	Fruit & Vegetable Markets
5441	Candy/Confectionery Stores
5451	Dairy Products Stores
5461	Retail Bakeries
5499	Misc Food Stores
55	**Automotive Dealers and Service Stations**
5511	Motor Vehicle Dealers
5521	Used Motor Vehicle Dealers
5531	Auto & Home Supply Stores
5541	Gasoline Svc Stations
5551	Boat Dealers
5561	RV Dealers
5571	Motorcycle Dealers
5599	Automotive Dealers, NEC
56	**Apparel and Accessory Stores**
5611	Male Clothing/Accessory Stores
5621	Women s Clothing Stores
5632	Female Accessory Stores
5641	Child Wear Stores
5651	Family Clothing Stores
5661	Shoe Stores
5699	Misc Apparel/Accessory Stores
57	**Furniture and Home Furnishings Stores**
5712	Furniture Stores
5713	Floor Covering Stores
5714	Curtain & Upholstery Stores
5719	Misc Home Furnishings Stores
5722	Household Appliance Stores
5731	Consumer Electronics Stores
5734	Computer/Software Stores
5735	Record/Tape Stores
5736	Musical Instrument Stores
58	**Eating and Drinking Places**
5812	Eating Places
5813	Drinking Places (bars)
59	**Miscellaneous Retail**
5912	Drug Stores
5921	Liquor Stores
5932	Used Merchandise Stores
5941	Sporting Goods/Bike Shops
5942	Book Stores
5943	Stationery Stores
5944	Jewelry Stores
5945	Hobby, Toy & Game Shops
5946	Camera/Photo Supply Stores
5947	Gift, Novelty & Souvenir Shops
5948	Luggage & Leather Goods Stores
5949	Sewing & Piece Goods Stores
5961	Catalog & Mail-Order Houses
5962	Vending Machine Operators
5963	Direct Selling Establishments
5983	Fuel Oil Dealers
5984	Bottled Gas Dealers
5989	Fuel Dealers, NEC
5992	Florists
5993	Tobacco Stores & Stands
5994	News Dealers & Newsstands
5995	Optical Goods Stores
5999	Misc Retail Stores, NEC

Finance, Insurance and Real Estate

SIC Numbers 6000-6799

60	**Depository Institutions**
6011	Federal Reserve Banks
6019	Cent l Reserve Depository, NEC
6021	National Commercial Banks
6022	State Commercial Banks
6029	Commercial Banks, NEC
6035	Fed Chtr Saving Institutions
6036	Not Fed Savings Institutions
6061	Credit Unions, Fed Chartered
6062	Not Fed Credit Unions
6081	Foreign Bank Branch/Agency
6082	Foreign Trade/Int l Banks
6091	Non-Deposit Trust Facilities
6099	Depository Bank Functions, NEC
61	**Non-Depository Institutions**
6111	Fed/Sponsored Credit Agencies
6141	Personal Credit Institutions
6153	Short-Term Bus Credit Inst
6159	Misc Bus Credit Institutions
6162	Mortgage Banker/Loan Offices
6163	Loan Brokers
62	**Security and Commodity Brokers**
6211	Security Brokers/Flotation Cos
6221	Commodity Brokers/Dealers
6231	Security & Commodity Exchanges
6282	Investment Advice
6289	Sec/Commodity Exchange Svcs
63	**Insurance Carriers**
6311	Life Insurance
6321	Accident & Health Insurance
6324	Hospital & Medical Svc Plans
6331	Fire/Marina/Casualty Insurance
6351	Surety Insurance
6361	Title Insurance
6371	Pension/Health/Welfare Funds
6399	Insurance Carriers, NEC
64	**Insurance Agents, Brokers, and Service**
6411	Insurance Agent/Broker/Service
65	**Real Estate**
6512	Non-Residential Bldgs Operators
6513	Apartment Bldg Operator
6514	Dwellings (Not Apts) Operators
6515	Resid Mobile Homes, Operator
6517	Lessors of Railroad Property
6519	Lessors of Real Property, NEC
6531	Real Estate Agents & Managers
6541	Title Abstract Offices
6552	Land Subdividers/Developers
6553	Cemetery Subdiv/Developers
67	**Holding and Other Investment Offices**
6712	Bank Holding Cos Offices
6719	Bank Holding Cos Offices, NEC
6722	Mgt Invest Offices, Open-End
6726	Unit Investment Trusts
6732	Educ/Rel/Charitable Trusts
6733	Trusts Exc Educ/Rel/Charitable
6792	Oil Royalty Traders
6794	Patent Owners & Lessors
6798	Real Estate Investment Trusts
6799	Investors, NEC

Services

SIC Numbers 7000-8999

70	**Hotels and Other Lodging Places**
7011	Hotels & Motels
7021	Rooming & Boarding Houses
7032	Sporting & Recreational Camps
7033	RV Parks & Campsites
7041	Member Hotels/Lodging Houses
72	**Personal Services**
7211	Power Laundry, Family/Comm
7212	Garment Pressing (trade)
7213	Linen Supply
7215	Coin-Operated Laundries
6216	Drycleaning Plant Exc Rug
7217	Carpet & Upholstery Cleaning
7218	Industrial Launderers
7219	Laundry & Garment Svcs, NEC
7221	Photographic Studies, Portrait
7231	Beauty Shops
7241	Barber Shops
7251	Shoe Repair/Shine Shops
7261	Funeral Svc/Crematories
7291	Tax Return Preparation Svcs
7299	Misc Personal Svcs, NEC
73	**Business Services**
7311	Advertising Agencies
7312	Outdoor Advertising Svcs
7313	Radio/TV/Publishers Ad Rep
7319	Advertising, NEC
7322	Adjustment/Collection Svcs
7323	Credit Reporting Svcs
7331	Direct Mail Ad Svcs
7334	Photocopy/Duplicating Svcs
7335	Commercial Photography
7336	Commercial Art/Graphic Design
7338	Secretarial/Court Rpting Svc
7342	Disinfect/Pest Control Svc
7349	Bldg Cleaning/Maint Svc, NEC
7352	Medical Equip Rental/Leasing
7353	Heavy Const Equip Rent/Lease
7359	Equipment Rental/Leasing, NEC
7361	Employment Agencies
7363	Help Supply Svcs
7371	Computer Programming Svcs
7372	Prepackaged Software
7373	Computer Int Systems Design
7374	Computer Processing/Data Svc
7375	Information Retrieval Svcs
7376	Computer Facilities Mgt Svcs
7377	Computer Rental & Leasing
7378	Computer Maintenance & Repair
7379	Computer Related Svcs, NEC
7381	Detective/Guard/Armored Cars
7382	Security Systems Svcs
7383	News Syndicates
7384	Photofinishing Laboratories
7389	Business Svcs, NEC
75	**Auto Repair, Services, and Parking**
7513	Truck Rent/Lease, No Drivers
7514	Passenger Car Rental
7515	Passenger Car Leasing
7519	Utility Trailer & RV Rental
7521	Automobile Parking
7532	Top/Body Repair/Paint Shops
7533	Auto Exhaust Sys Repair Shops
7534	Tire Retreading & Repair Shops
7536	Auto Glass Replacement Shops
7537	Auto Transmission Repair Shops
7538	General Auto Repair Shops
7539	Automotive Repair Shops, NEC
7542	Carwashes
7549	Auto Svcs Exc Repair/Carwash
76	**Miscellaneous Repair Services**
7622	Radios & TV Repair Shops
7623	Refrigeration & A/C Svcs
7629	Elect/Electronic Repair, NEC
7631	Watch, Clock & Jewelry Repair
7641	Re-Upholstery/Furniture Repair
7692	Welding Repair
7694	Armature Rewinding Shops
7699	Repair Shops/Related Svcs, NEC
78	**Motion Pictures**
7812	Movie & Video Tape Production
7819	Movie Production Svcs
7822	Movie/Video Tape Distribution
7829	Svcs Allied to Movie Dist
7832	Movie Theaters, Exc Drive-In
7833	Drive-In Movie Theaters
7841	Video Tape Rental
79	**Amusement and Recreation Service**
7911	Dance Studios, Schools & Halls
7922	Movie Theatrical Producers
7929	Actors/Musicians, Entertainers
7933	Bowling Centers
7941	Pro Sports Clubs & Promoters
7948	Racing, Inc Track Operation
7991	Physical Fitness Facilities
7992	Public Golf Courses
7993	Coin Amusement Devices
7996	Amusement Parks
7997	Membership Sports/Rec Clubs
7999	Amusement/Rec Svcs, NEC
80	**Health Services**
8011	Offices of Doctors of Medicine
8021	Offices & Clinics of Dentists
8031	Offices, Doctors Osteopathy
8041	Offices, Chiropractors
8042	Offices, Optometrists
8043	Offices, Podiatrists
8049	Offices, health Pract'ers, NEC
8051	Skilled Nursing Care Facility
8052	Intermediate Care Facilities
8059	Nursing/Care Facilities, NEC
8062	Gen Medical/Surgical Hospitals
8063	Psychiatric Hospitals
8069	Specialty Hospitals
8071	Medical Laboratories
8072	Dental Laboratories
8082	Home Health Care Svcs
8092	Kidney Dialysis Centers
8093	Spec Outpatient Facility, NEC
8099	Health & Allied Svcs, NEC
81	**Legal Services**
8111	Legal Services
82	**Educational Services**
8211	Elementary & Secondary Schools
8221	Colleges/Univ/Pro Schools
8222	Jr Colleges/Tech Institutes
8231	Libraries
8243	Data Processing Schools
8244	Business & Secretarial Schools
8249	Vocational Schools, NEC
8299	Schools/Educational Svcs, NEC
83	**Social Services**
8322	Individual/Family Social Svcs
8331	Job Train/Vocational Rehab
8351	Child Day Care Svcs
8361	Residential Care
8399	Social Svcs, NEC
84	**Museums, Botanical, Zoological Garden**
8412	Museums & Art Galleries

8422	Arboreta/Bot Gardens/Zoos
86	**Membership Organizations**
8611	Business Assocs
8621	Professional Organizations
8631	Labor Union/Similar Labor Org
8641	Civic/Social/Fraternal Assoc
8651	Political Organizations
8661	Religious Organizations
8699	Membership Organizations, NEC
87	**Engineering and Management Services**
8711	Engineering Svcs
8712	Architectural Svcs
8713	Surveying Svcs
8721	Account/Audit/Bookkeeping Svc
8731	Comm/Phys/Biological Research
8732	Comm/Econ/Socio/Educ Research
8733	Noncommercial Research Orgs
8734	Testing Laboratories
8741	Management Services
8742	Mgt Consulting Svcs
8743	Public Relations Svcs
8744	Facilities Support Mgt Svcs
8748	Business Consulting Svcs, NEC
88	**Private Households**
8811	Private Households
89	**Services, not elsewhere classified**
8999	Services, NEC

Public Administration

SIC Numbers 9000-9721

91	**Executive, Legislative, and General**
9111	Executive Offices
9121	Legislative Bodies
9131	Exec/Leg Offices Combined
9199	General, NEC
92	**Justice, Public Order, and Safety**
9211	Courts
9221	Police Protection
9222	Legal Counsel & Prosecution
9223	Correctional Institutions
9224	Fire Protection
9229	Public Order & Safety, NEC
93	**Finance, Taxation, and Monetary Policy**
9311	Finance/Tax/Monetary Policy
94	**Administration of Human Resources**
9411	Admin of Educational Programs
9431	Admin, Public Health Programs
9441	Social/Human Res/Income Admin
9451	Vet Affairs Exc Health/Insur
95	**Environmental Quality and Housing**
9511	Air, Water & Solid Waste Mgt
9512	Land & Wildlife Conservation
9531	Admin of Housing Programs
9532	Admin, Urban Plan g/Rural Dev
96	**Administration of Economic Programs**
9611	Admin, Gen Economic Programs
9621	Reg/Admin Transport Programs
9631	Gov t Regulation of Utilities
9641	Reg Agric Mkt g/Commodities
9651	Reg Misc Commercial Secors
9661	Space Research & Technology
97	**National Security and International Affairs**
9711	National Security
9721	Int l Affairs

Non-Classifiable Establishments

99	**Non-Classifiable Establishments**
9999	Non-Classifiable Establishments

Appendix 5 Institutional Controls

Overview of Appendix 5

- Introduction
- Environmental Notice Criteria
- Minimum Environmental Notice Requirements and Language
- Environmental Notice Alternative for Ground Water Contamination
- Environmental Notice Generic Form

A5.0 Introduction

Institutional controls are non-engineered, administratively and legally enforceable measures that limit human exposure to environmental chemicals of concern (COCs). Institutional controls can serve several purposes, including:

- Notifying current and future owners about the environmental conditions of the property
- Limiting use of the land to prevent activities that could result in unacceptable exposures to receptors

Institutional controls are used when a cleanup leaves COC concentrations that exceed residential closure levels, and exposure to the remaining contamination must be prevented. Whenever institutional controls are used, a control requirement (or environmental notice) is recorded where a reasonably diligent inquiry into a property should uncover the existence of such a notice. Examples of institutional controls are land-use restrictions, deed restrictions, deed notices, and declarations of environmental restrictions.

A common method of recording an institutional control is the deed notice, or, for Risk Integrated System of Closure (RISC) purposes, an environmental notice. Under certain circumstances, a local ordinance can substitute for an environmental notice. The primary criteria for an institutional control are that it (1) provide legal notice to current and potential future property owners of the nature and extent of the restrictions, (2) be permanent, and (3) be legally valid.

An institutional control is required for the following situations:

- A commercial or industrial land-use designation
- An activity restriction used as part of a remedy
- An engineering control used as part of a remedy

The environmental notice notifies future owners or lessees of contamination present at a site and ensures that the restrictions and controls included in the approved remedy are legally recorded. A generic environmental notice form is provided at the end of this appendix.

The Indiana Department of Environmental Management (IDEM) does not have the statutory authority to enforce an environmental notice. However, if a current or subsequent property owner subject to an environmental notice creates or exposes a pathway protected by the environmental notice, IDEM has the authority to bring an enforcement action against that owner for causing a release into the environment.

An environmental notice can also be used when contamination has migrated to an off-site property if the off-site property owner agrees to accept the restrictions incorporated in the environmental notice. The environmental notice can be recorded using the generic form at the end of this appendix or using another customized format. Use of another format is acceptable as long as the information provided meets the criteria discussed below.

A5.1 Environmental Notice Criteria

Environmental notices must meet the criteria listed below.

1. Environmental notices must be recorded on the deed of the affected property by filing the environmental notice with the county recorder in the county in which the property is located.

2. Environmental notices must run with the land, meaning that conditions still apply after property ownership has transferred.

3. Environmental notices must identify the COCs where concentrations exceed closure levels, the media affected by the COCs, and the conditions or restrictions imposed on the property.

4. Environmental notices must state that performing restricted activities could result in unsafe exposure. Chapter 6 of the Technical Guide discuss closure requirements.

5. Environmental notices must be legally valid documents. They can be recorded on a form provided by IDEM or in an appropriate document drafted by the user and approved by IDEM. If the user drafts the environmental notice, it must meet the minimum requirements specified either in the rule (if one is published) or in the "Minimum Environmental Notice Requirements and Language" specified below.

6. Environmental notices must satisfy IDEM's concerns regarding permanence, legal validity, and informed consent.

7. Environmental notices must describe terms and procedures for modifying or removing the restrictions. This must include, at a minimum, a statement that the site must be reassessed and IDEM's approval must be granted before the restriction identified in the environmental notice can be modified. Such provision for compliance shall be evidenced by providing a true copy of the recorded environmental notice to IDEM.

A5.2 Minimum Environmental Notice Requirements and Language

An environmental notice must satisfy the minimum requirements below.

1. A legal description of the real estate must be provided accompanied by scaled maps showing the following:

   – Horizontal extent of contamination exceeding applicable remediation objectives

   – Legal boundaries of all properties where contamination exceeds applicable remediation objectives and that are subject to the restrictive covenant

2. The location where the public may review the approved remedial plan must be specified.

3. The environmental notice should list COCs in the remedial plan that will be left on the property at concentrations exceeding residential closure levels and the media (surface soil, subsurface soil, or ground water) impacted by the COCs.

4. A description must be provided of any limitations on the land-use designation (for example, commercial/industrial or residential).

5. A clear description in simple terms must be provided of each activity restriction within the proximity of the contaminated portion of the property. This description must identify any limitations on activities including, but not limited to, the following:

   – Ground water usage
   – Soil exposure through gardening
   – Digging into soil

6. A description must be provided of all actions necessary to maintain any engineered control measures established under the corrective action plan that render any potential exposure pathway incomplete. The description should include a demonstration of financial assurance mechanisms (if required under Resource Conservation and Recovery Act [RCRA]) for maintenance of the selected remedy and reporting requirements.

7. The environmental notice should include a statement that the environmental notice runs with the land.

8. The environmental notice should include a statement that any amendment, modification, or termination of the restrictions can be made only with IDEM's approval.

A5.3 Environmental Notice Alternative for Ground Water Contamination

An environmental notice to prevent exposure to contaminated ground water may not be necessary if an ordinance adopted by a unit of local government effectively prohibits exposure to ground water. An example of such an ordinance would require all residents to utilize the municipal water supply and would prohibit the installation of new drinking water supply wells in the county or municipality where the contaminated area is located.

The information below is required to support a request to replace the requirement for an environmental notice for ground water contamination:

1. The request must include the name and address of the local unit of government and a copy of the most current version of the ordinance restricting ground water use. An authorized official of the local unit of government must certify that the ordinance is complete, accurate, and in effect. The ordinance must demonstrate that exposure to ground water is prohibited.

2. A scaled map should delineate the areal extent of ground water (either measured or modeled) containing contamination that exceeds applicable closure levels. Information should be provided regarding COC concentrations in ground water that exceed applicable closure levels.

3. A scaled map should delineate the boundaries of all properties where COC concentrations in ground water exceed applicable closure levels.

4. The current owners and leaseholders of each property should be identified on the map that shows the ground water contamination.

The information above should also be provided in a notification to the local unit of government with authority over the ordinance and to each property owner and leaseholder identified in the scaled map. The notification must provide the following information:

- The site name, address, and IDEM site number
- Notification that IDEM is reviewing a request to use the ordinance restricting ground water use to substitute for an environmental notice
- A statement about the nature of the release and response actions taken
- A statement about where more information can be obtained about the ordinance

Copies of the notification submitted to the local unit of government, property owners, and leaseholders must also be provided to IDEM before the ordinance can be considered a substitute for an environmental notice.

Any approval by IDEM to replace the environmental notice with an ordinance will not become effective until it is recorded in the Office of the Recorder or Registrar of Titles of the county where the site is located. The person receiving the approval must obtain and submit to IDEM information demonstrating that the replacement was recorded.

The current owner, leaseholder, or successor of a site who receives approval to use an ordinance to replace the environmental notice must conduct the following activities:

1. Monitor activities of the unit of local government related to variance requests or changes in the ordinance regulating ground water use

2. Notify IDEM of any approved variance requests for ordinance changes within 30 days after the date such action was approved

3. Establish adequate controls when any approved variance requests or ordinance changes result in the diminishment or elimination of effective prohibition of exposure to ground water previously provided by the ordinance

If any of the following should occur, closure may be voided:

1. Repeal or other modification of the ordinance by the local unit of government

2. Approval of a site-specific request, such as a variance, that allows exposure to ground water

3. Violation of the terms of a recorded institutional control

Environmental Notice Generic Form

THIS COVENANT engineered this _____ day of _____, 20_____, made by [name and address of current property owners] (together with his/her/its/their successors and assigns, collectively "Owner").

WHEREAS: _____ owns real estate in the County of _____, Indiana, which is more particularly described in the attached Exhibit "A" and made a part hereof ("real estate");

WHEREAS: A corrective action plan was prepared and implemented in accordance with Indiana law as a result of a release of regulated or hazardous substances upon said real estate. The corrective action plan, as approved by the Indiana Department of Environmental Management ("the Department"), provides that the regulated or hazardous substances shall remain on or beneath the surface of the real estate and provides for institutional controls that shall ensure the protection of public health, safety, or welfare, and the environment. The corrective plan, a survey of the areas on said real estate affected, and a list of the chemicals of concern may be examined at the offices of the Department.

(*If the restriction is placed on a third party's property, the above paragraph should be modified to read as follows:*

WHEREAS: A corrective action plan was prepared and implemented in accordance with Indiana Law as a result of a release of regulated or hazardous substances upon the property described in the corrective action plan ("property"). The corrective action plan, as approved by the Indiana Department of Environmental Management ("the Department"), provides that the regulated or hazardous substances shall remain on or beneath the surface of the property and provides the Environmental Notice that shall ensure the protection of public health, safety, or welfare, and the environment. The corrective action plan, a survey of the areas of said property affected, and a list of the chemicals of concern left on the property may be examined at the offices of the Department.)

(*NOTE: The words "corrective action plan" can be deleted and replaced with the correct title of any plan that contains a Risk Integrated System of Closure (RISC) approach (for example, "closure plan").*

NOW THEREFORE, _____ (hereinafter referred to as "Owner"), hereby, in consideration for the promises herein contained and other good and valuable consideration, imposes restrictions on the Real Estate and covenants and agrees that:

1. The Owner shall prevent a conveyance of title, an easement, or any other interest in the real estate from being consummated without adequate and complete provision for compliance with the corrective action plan and prevention of exposure to regulated or hazardous substances as described in item 3 below.

2. The Owner shall grant to the Department and its designated representatives the right to enter the real estate at reasonable times for the purpose of determining and monitoring

compliance with the corrective action plan, including, but not limited to, the right to take samples, inspect the operation of the corrective action measures, and inspect records.

3. Specific restrictions that may apply shall be listed here (for example, no off-site placement of excavated subsurface soil, no wells installed, maintenance of asphalt cover, description of financial assurance mechanism, etc.)

4. The restrictions and other requirements described in this Environmental Notice shall run with the land and be binding on the owners successors, assignees, and lessees or their authorized agents, employees, or persons acting under their direction or control.

5. The restrictions shall apply until the Department determines that regulated or hazardous substances no longer present an unacceptable risk to the public health, safety, or welfare, or to the environment. This Environmental Notice shall not be amended, modified, or terminated except by written instrument executed between the Owner and the Department at the time of the proposed amendment, modification, or termination. Within five (5) days of executing an amendment, modification, or termination of the Environmental Notice, the Owner shall record such amendment, modification, or termination with _____ County Registrar of Deeds and within five (5) days thereafter, the Owner shall provide a true copy of the recorded amendment, modification, or termination to the Department.

6. If any provision of the Environmental Notice is also the subject of any laws or regulations established by any federal, state, or local government, the stricter of the two standards shall prevail.

7. In the event that the Risk Integrated System of Closure (RISC) is adopted by rule in Indiana, this Environmental Notice shall be modified, if necessary, to conform with the Indiana RISC regulations for the scope or specificity of the Environmental Notice. In no event shall this Environmental Notice be rendered null and void if Indiana's RISC guidelines for an Environmental Notice differ in form or content.

8. The undersigned persons executing the Environmental Notice on behalf of the Owner represent and certify that they are duly authorized and have been fully empowered to execute and deliver this Environmental Notice.

I hereby attest to the accuracy of the statements in this document and all attachments.

IN WITNESS WHEREOF, the said Owner of the real estate described above has caused the Environmental Notice to be executed on this _____ day of _____, 20___.

_____
Owner

(If Owner is an individual:)

STATE OF INDIANA

COUNTY OF *(county where document is executed)* }SS:

BEFORE ME, the undersigned, a Notary Public in an for said County and State, personally appeared _____ and _____, the _____ and _____, respectively, of _____, the Corporation that executed the foregoing instrument, who acknowledged and affirmed that they did sign said instrument as such officers, respectively, for and on behalf of said Corporation and by authority granted in its Articles of Incorporation and by it governing body, that the same is their free act and deed as said officers, and the free and corporate act and deed of said Corporation.

IN WITNESS WHEREOF, I have hereunto subscribed my name and affixed my official seal this _____ day of _____, 20___.

My county of residence is:
_____ County, Indiana _____
Signature of Notary Public

My commission expires:
_____ _____
Printed Name of Notary

(If Owner is a partnership:)

STATE OF INDIANA

COUNTY OF *(county where document is executed)* SS:

BEFORE ME, the undersigned, a Notary Public in and for said County and State, personally appeared *(name of person executing document on behalf of partnership)*, who acknowledged and affirmed that he/she is a general partner of *(name of partnership)*. The partnership named in this document, that he/she did sign said instrument in his/her capacity as a general partner of *(name of partnership),* and that the same is the free act and deed as said persons and of said partnership.

IN WITNESS WHEREOF, I have hereunto subscribed my name and affixed my official seal this _____ day of _____, 20___.

My county of residence is:
_____ County, Indiana _____
Signature of Notary Public

My commission expires:
_____ _____
Printed Name of Notary

The owner of the property should use whatever notary jurat is applicable to the situation.

(If Owner is a corporation:)

STATE OF INDIANA

COUNTY OF *(county where document is executed)* SS:

BEFORE ME, the undersigned, a Notary Public in and for said County and State, personally appeared *(Owner's name)*, who acknowledged and affirmed the execution of the foregoing instrument.

IN WITNESS WHEREOF, I have hereunto subscribed my name and affixed my official seal this _____ day of _____, 20___.

My county of residence is:
_____ County, Indiana _____
Signature of Notary Public

My commission expires:
_____ _____
Printed Name of Notary

United States Environmental Protection Agency | Office of Research and Development Washington, D.C. 20460 | EPA/600/R-96/055 September 1994

GUIDANCE FOR THE DATA QUALITY OBJECTIVES PROCESS

EPA QA/G-4

GUIDANCE FOR THE DATA QUALITY OBJECTIVES PROCESS

EPA QA/G-4

United States Environmental Protection Agency
Quality Assurance Management Staff

Washington, DC 20460

FINAL

SEPTEMBER 1994
EPA/600/R-96/055

FOREWORD

The U.S. Environmental Protection Agency (EPA) has developed the Data Quality Objectives (DQO) Process as an important tool for project managers and planners to determine the type, quantity, and quality of data needed to support Agency decisions. This guidance is the culmination of experiences in applying DQOs in different Program Offices at the EPA. Many elements of prior guidance, advice, statistics, and scientific planning have been incorporated into this document. This guidance supersedes all previous guidance, including the EPA's "Development of Data Quality Objectives, Description of Stages I and II" (July 1986), and "Guidance for Planning for Data Collection in Support of Environmental Decision Making Using the Data Quality Objectives Process" (Interim Final, October 1993). This document is consistent with the Office of Emergency and Remedial Response guidance, "Data Quality Objectives for Superfund" (EPA 540-R-93-071).

The purpose of this document is to provide general guidance to organizations on developing data quality criteria and performance specifications for decision making. This guidance assumes that an appropriate Quality System has been established and is operational.

This guidance has been prepared in response to EPA Order 5360.1, entitled "Policy and Program Requirements to Implement the Quality Assurance Program," which establishes requirements for quality assurance when generating environmental data in support of Agency decisions. In addition, this guidance reflects the policy of the Agency to develop and implement the DQO Process as expressed by Deputy Administrator A. James Barnes in his memorandum on "Agency Institutionalization of Data Quality Objectives," dated November 1986.

This document is a product of the collaborative effort of many quality management professionals throughout the EPA and among the contractor community. It has been peer reviewed by the EPA Program Offices, Regional Offices, and Laboratories. Many valuable comments and suggestions have been incorporated to make it more useful.

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INTRODUCTION

Each year the U.S. Environmental Protection Agency (EPA) and the regulated community spend approximately $5 billion collecting environmental data for scientific research, regulatory decision making, and regulatory compliance. While these activities are necessary for effective environmental protection, it is the goal of EPA and the regulated community to minimize expenditures related to data collection by eliminating unnecessary, duplicative, or overly precise data. At the same time, the data collected should have sufficient quality and quantity to support defensible decision making. The most efficient way to accomplish both of these goals is to establish criteria for defensible decision making before the study begins, and then develop a data collection design based on these criteria. To facilitate this approach, the Quality Assurance Management Staff (QAMS) of EPA has developed the Data Quality Objectives (DQO) Process, a systematic planning tool based on the Scientific Method for establishing criteria for data quality and for developing data collection designs. By using the DQO Process to plan environmental data collection efforts, EPA can improve the effectiveness, efficiency, and defensibility of decisions in a resource-effective manner.

What are DQOs? DQOs are qualitative and quantitative statements derived from the outputs of the first six steps of the DQO Process that:

1) Clarify the study objective;

2) Define the most appropriate type of data to collect;

3) Determine the most appropriate conditions from which to collect the data; and

4) Specify tolerable limits on decision errors which will be used as the basis for establishing the quantity and quality of data needed to support the decision.

The DQOs are then used to develop a scientific and resource-effective data collection design.

What is the DQO Process? The DQO Process is a strategic planning approach based on the Scientific Method that is used to prepare for a data collection activity. It provides a systematic procedure for defining the criteria that a data collection design should satisfy, including when to collect samples, where to collect samples, the tolerable level of decision errors for the study, and how many samples to collect.

By using the DQO Process, the Agency will assure that the type, quantity, and quality of environmental data used in decision making will be appropriate for the intended application. In addition, the Agency will guard against committing resources to data collection efforts that do not support a defensible decision.

The DQO Process consists of seven steps, as shown in Figure 0-1. The output from each step influences the choices that will be made later in the Process. Even though the DQO Process is depicted as a linear sequence of steps, in practice it is iterative; the outputs from one step may lead to reconsideration of prior steps. This iteration should be encouraged since it will ultimately lead to a more efficient data collection design. During the first six steps of the DQO Process, the planning team will develop the decision performance criteria (DQOs) that will be used to develop the data collection design. The final step of the Process involves developing the data collection design based on the DQOs. The first six steps should be completed before the planning team attempts to develop the data collection design because this final step is dependent on a clear understanding of the first six steps taken as a whole. In Figure 0-1, the iterative link between the DQOs and the Optimize the Design step is illustrated by double arrows, which signify that it may be necessary to revisit any one or more of the first six steps to develop a feasible and appropriate data collection design. Above all, every step should be completed before data collection begins.

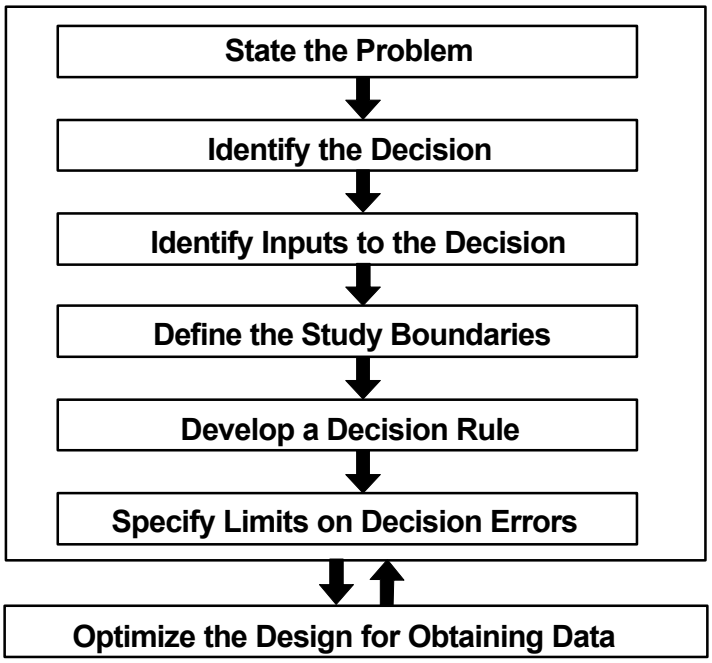


Figure 0-1. The Data Quality Objectives Process.

Each of the seven steps is described briefly below. A more detailed description can be found in the subsequent chapters of this guidance.

- Step 1: State the Problem — Concisely describe the problem to be studied. Review prior studies and existing information to gain a sufficient understanding to define the problem.

- Step 2: Identify the Decision — Identify what questions the study will attempt to resolve, and what actions may result.

- Step 3: Identify the Inputs to the Decision — Identify the information that needs to be obtained and the measurements that need to be taken to resolve the decision statement.

- Step 4: Define the Study Boundaries — Specify the time periods and spatial area to which decisions will apply. Determine when and where data should be collected.

- Step 5: Develop a Decision Rule — Define the statistical parameter of interest, specify the action level, and integrate the previous DQO outputs into a single statement that describes the logical basis for choosing among alternative actions.

- Step 6: Specify Tolerable Limits on Decision Errors — Define the decision maker's tolerable decision error rates [1] based on a consideration of the consequences of making an incorrect decision.

- Step 7: Optimize the Design — Evaluate information from the previous steps and generate alternative data collection designs. Choose the most resource-effective design that meets all DQOs.

Who should read the DQO guidance? This guidance is intended for project managers and other members of a planning team that will use the DQO Process to structure the data collection planning process and to develop an appropriate data collection design. In addition, the guidance may be relevant to other staff members who will participate in the study. Consult with an EPA Quality Assurance Manager, Quality Assurance Officer, or Quality Assurance Representative to obtain additional advice on who should read this guidance.

[1] A decision error rate is the probability of making an incorrect decision based on data that inaccurately estimate the true state of nature.

What projects are covered by this guidance? This guidance document covers all projects where:

1) the objective of the study is to collect environmental data in support of an Agency program, and

2) the results of the study will be used to make a specific decision.

Every step of this guidance may not be applicable to data collection activities where specific decisions cannot be identified, such as studies that are exploratory in nature. The reason for this distinction is that part of the DQO Process includes formulating statistical hypotheses. If a statistical hypothesis is not linked to a clear decision in which the decision maker can identify potential consequences of making a decision error, then some of the activities recommended in this guidance may not apply. Nonetheless, the DQO Process is still a valuable tool that can be used to help plan studies where the data are not directly used to support a specific decision. In these cases, it may be possible to frame a research type study question in the form of a decision or modify the activities described in this guidance to address the needs of the study.

What is the value of using the DQO Process?

- The DQO Process is a planning tool that can save resources by making data collection operations more resource-effective. Good planning will streamline the study process and increase the likelihood of efficiently collecting appropriate and useful data.

- The structure of the DQO Process provides a convenient way to document activities and decisions and to communicate the data collection design to others.

- The DQO Process enables data users and relevant technical experts to participate in data collection planning and to specify their particular needs prior to data collection. The DQO process fosters communication among all participants, one of the central tenets of quality management practices.

- The DQO Process provides a method for defining decision performance requirements that are appropriate for the intended use of the data. This is done by considering the consequences of decision errors and then placing tolerable limits on the probability that the data will mislead the decision maker into committing a decision error. A statistical sampling design can then be generated to provide the most efficient method for controlling decision errors and satisfying the DQOs.

- The DQO Process helps to focus studies by encouraging data users to clarify vague objectives and to limit the number of decisions that will be made.

When should the DQO Process be used? The DQO Process should be used during the planning stage of any study that requires data collection, before the data are collected. In general, EPA's policy is to use the DQO Process to plan all data collection efforts that will require or result in a substantial commitment of resources. The Quality Management Plans (QMPs) of the Agency's National Program Offices, Regional Offices, and Research and Development organizations will specify which studies require DQOs.

Can the DQO Process be used for small studies? The DQO Process applies to any study, regardless of its size. However, the depth and detail of DQO development will depend on the complexity of the study. The more complex a study, the more likely that it will have several decisions that could benefit from the DQO Process and that the decisions will require more intensive DQO development.

Should the DQO Process be applied as intensively to all situations? No, the DQO Process is a flexible planning tool that can be used more or less intensively as the situation requires. For projects that have multiple decisions, where the resolution of one decision only leads to the evaluation of subsequent decisions, the DQO Process can be used repeatedly throughout the life cycle of a project. Often, the decisions that are made early in the project will be preliminary in nature. They might require only a limited planning and evaluation effort. As the study nears conclusion and the possibility of making a decision error becomes more critical, however, the level of effort needed to resolve a decision generally will become greater. Figure 0-2 illustrates this point.

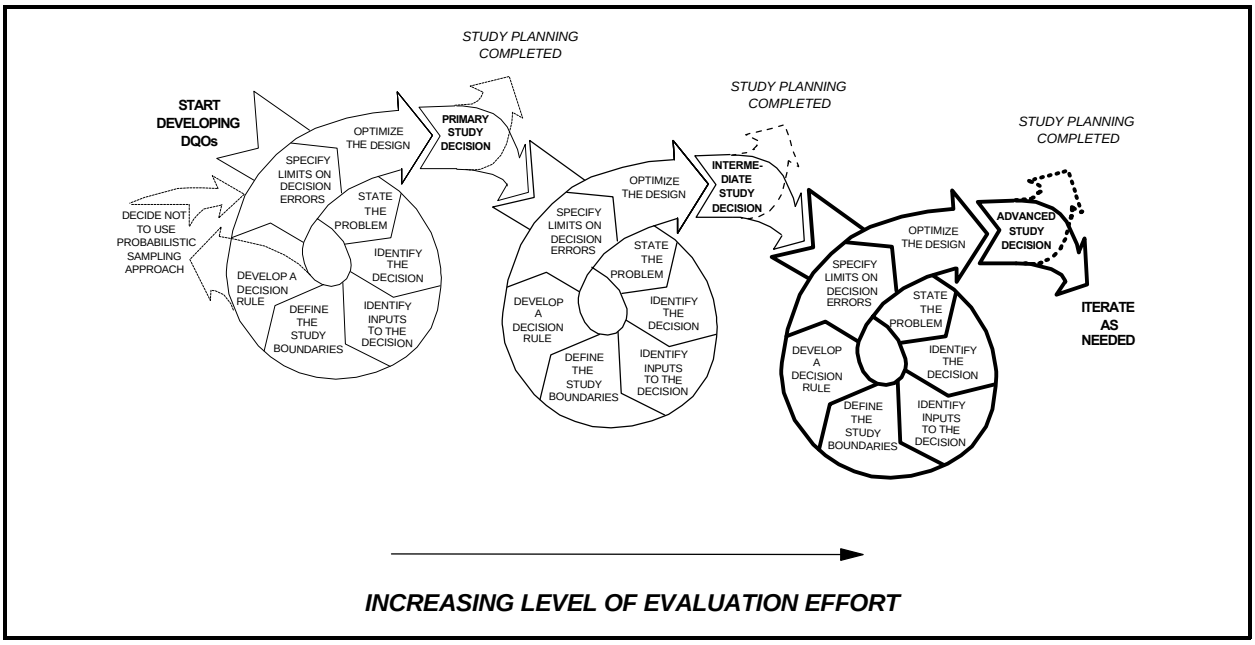


Figure 0-2. Repeated Application of the DQO Process Throughout the Life Cycle of a Single Project.

Who participates in the DQO Process? A DQO planning team generally consists of senior program staff, technical experts, senior managers, someone with statistical expertise, and a Quality Assurance (QA)/Quality Control (QC) advisor, such as a QA Manager. It is important that all of these people, including managers, participate (or stay informed) from the beginning of the DQO Process so that it can proceed efficiently.

What are the outputs of the DQO Process? The DQO Process leads to the development of a quantitative and qualitative framework for a study. Each step of the Process derives valuable criteria that will be used to establish the final data collection design. The first five steps of the DQO Process identify mostly qualitative criteria such as what problem has initiated the study and what decision it attempts to resolve. They also define the type of data that will be collected, where and when the data will be collected, and a decision rule that defines how the decision will be made. The sixth step defines quantitative criteria expressed as limits on decision errors that the decision maker can tolerate. The final step is used to develop a data collection design based on the criteria developed in the first six steps. The final product of the DQO Process is a data collection design that meets the quantitative and qualitative needs of the study.

Much of the information that is developed in the DQO Process will also be useful for the development of Quality Assurance Project Plans (QAPPs) and the implementation of the Data Quality Assessment (DQA) Process. The outputs of the DQO Process can be used directly and indirectly as inputs to a QAPP. To evaluate the data using the DQA Process, it is necessary to have first established decision quality criteria using the DQO Process or its equivalent. Therefore, the DQO Process not only helps plan a study, establish decision quality criteria, and develop a data collection design, but it also aids in the development of QAPPs and the DQA Process.

What is a data collection design? A data collection design specifies the final configuration of the environmental monitoring or measurement effort required to satisfy the DQOs. It designates the types and quantities of samples or monitoring information to be collected; where, when, and under what conditions they should be collected; what variables are to be measured; and the QA/QC procedures to ensure that sampling design and measurement errors are controlled sufficiently to meet the tolerable decision error rates specified in the DQOs. These QA/QC procedures are established in the QAPP.

Where does the DQO Process fit into EPA's Quality System? The DQO Process is the part of the Quality System that provides the basis for linking the intended use of the data to the QA/QC requirements for data collection and analysis. This document is one of a series of quality management requirements and guidance documents that the U.S. EPA Quality Assurance Management Staff (QAMS) has prepared to assist users in implementing the Agency-wide Quality System. The current document list contains:

EPA QA/R-1 EPA Quality System Requirements for Environmental Programs

EPA QA/G-1 Guidance for Developing, Implementing, and Evaluating Quality Systems for Environmental Programs

EPA QA/R-2 EPA Requirements for Quality Management Plans

EPA QA/G-2 Guidance for Preparing Quality Management Plans for Environmental Programs

EPA QA/G-4 Guidance for The Data Quality Objectives Process

EPA QA/R-5 EPA Requirements for Quality Assurance Project Plans for Environmental Data Operations

EPA QA/G-5 Guidance for Quality Assurance Project Plans

EPA QA/G-9 Guidance for Data Quality Assessments

Agency policy statements are found in the requirements documents (QA/R-xx series). Advisory papers are found in the guidance documents (QA/G-xx series).

Can existing data be used to support decisions using the DQO Process? Existing data can be very useful for supporting decisions using the DQO Process. There are three ways that existing data can be used:

1) If sufficient documentation is available, existing data may be used alone or combined with new data. Determining whether data can appropriately be combined can be a very complex operation that should be undertaken with great care. In many cases it will require the expertise of a statistician.

2) The existing data may provide valuable information (such as variability) that can be used in the development of the data collection design.

3) The existing data may be useful in guiding the selection of an efficient data collection design.

Will the use of the DQO Process always result in statistical/probabilistic sampling methods for data collection? No. While statistical methods for developing the data collection design are strongly encouraged, this guidance recognizes that not every problem can be evaluated using probabilistic techniques. The DQO Process, however, can and should be used as a planning tool for studies even if a statistical data collection design ultimately will not be used. In these cases, the planning team is encouraged to seek expert advice on how to develop a non-statistical datacollection design and on how to evaluate the result of the data collection. When non-probabilistic, judgemental, or quota sampling methods are used, be sure to consult with an EPA QA Manager, QA Officer, or QA Representative to ensure that program-specific QA requirements are satisfied.

How should this guidance be used? This guidance should be used as a tool to structure the planning activities for collecting environmental data. It should be used to organize meetings, focus the collection of background information, and facilitate communication between technical experts, program managers, and decision makers.

How is this guidance structured? This guidance contains seven chapters, four appendices, and a bibliography. Each of the remaining chapters describes one of the seven steps of the DQO Process. Each chapter is divided into four sections as follows:

(1) **Purpose** - This section explains the objective of the chapter.

(2) **Expected Outputs** - This section identifies the products expected upon completion of the DQO Process step.

(3) **Background** - This section provides background information on the DQO Process step, including the rationale for the activities in that step.

(4) **Activities** - This section describes the activities recommended for completing the DQO Process step, including how inputs to the step are used.

Appendix A provides a brief overview of both the Quality Assurance Project Plan (QAPP) development process, which is used to document the operational and QA/QC procedures needed to implement the data collection design, and the Data Quality Assessment (DQA) Process, which is used after the data have been collected to evaluate whether the DQOs have been satisfied. Appendix B is a case study in which the DQO Process is applied to an environmental problem. Appendix C provides a derivation of the sample size formula used in Appendix B. Appendix D provides a glossary of terms used in this guidance.

Where is it possible to get statistical support? Access to statistical support is available through the EPA Quality Assurance Management Staff (QAMS) at (202) 260-5763.

How long will this guidance be in effect? This guidance will remain in effect for five years from the publication date, unless superseded by an updated version.

Where is it possible to get more information about the DQO Process? A DQO training course is available through the EPA at the U.S. EPA Headquarters in Washington, D.C. Additional documents on DQO applications can be obtained from the Quality Assurance Management Staff at EPA Headquarters.

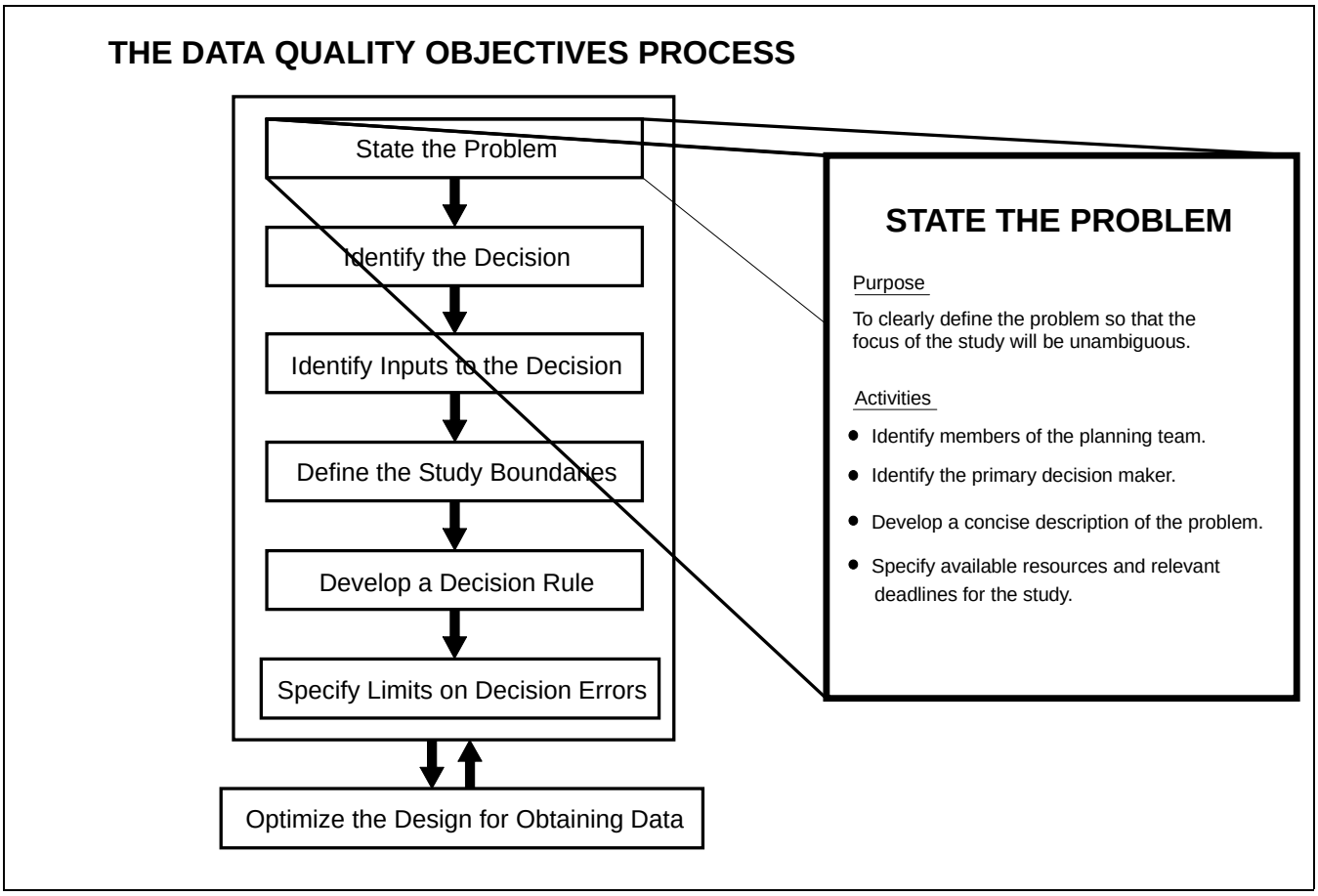
Two documents that can provide additional detail on the DQO Process are:

- U.S. Environmental Protection Agency. 1993. *Data Quality Objectives Process for Superfund: Interim Final Guidance* . EPA 540-R-93-071.

- Bates, D.J., R.O. Gilbert, N.L. Hassig, R.F. O'Brien, B.A. Pulsipher, 1993. Decision Performance Criteria: The Driver Behind The Data Quality Objectives Process — A Statistical Introduction (Draft). Pacific Northwest Laboratory, Richland, Washington.

CHAPTER 1

STEP 1: STATE THE PROBLEM



Purpose

The purpose of this step is to define the problem so that the focus of the study will be unambiguous.

Expected Outputs

- **A list of the planning team members and identification of the decision maker.**
- **A concise description of the problem.**
- **A summary of available resources and relevant deadlines for the study.**

Background

The first step in any decision making process is to define the problem that has initiated the study. Since most environmental problems present a complex interaction of technical, economic, social, and political factors, it is critical to the success of the process to define the problem completely and in an uncomplicated format. A problem will have the greatest chance of being solved when a multidisciplinary team of technical experts and stakeholders can help to recognize all of the important facets of the problem and ensure that complex issues are described accurately. Generally teams will function more effectively when they have one clearly identified decision maker.

This step in the DQO Process addresses development of a planning team that will define the problem and implement subsequent steps of the Process. It also calls for the identification of a decision maker who will lead the planning team and make final resolutions during the Process. The goal is to create a well-structured planning team that will work effectively and efficiently to develop a concise and complete description of the problem, which will provide the basis for the rest of the DQO development.

Activities

Identify members of the planning team. The planning team is the group that will develop DQOs for the study. The number of planning team members will be directly related to the size and complexity of the problem. The team should include representatives from all groups who are stakeholders in the project, including, but not limited to, samplers, chemists and other scientists and engineers, modelers, technical project managers, community representatives, administrative and executive managers, QA/QC experts (such as a QA Manager), data users, and decision makers. A reasonable effort should be made to include any decision makers who may use the study findings later. A statistician (or someone knowledgeable and experienced with environmental statistical design and analysis) should also be included on this team.

Identify the primary decision maker of the planning team and define each member's role and responsibility during the DQO Process. The planning team generally has a leader, referred to as the "decision maker." The decision maker has the ultimate authority for making final decisions based on the recommendations of the planning team. The decision maker is often the person with the most authority over the study, and may be responsible for assigning the roles and responsibilities to the planning team members. In cases where the decision maker cannot attend DQO planning meetings, a senior staff member should keep the decision maker informed of important planning issues.

Develop a concise description of the problem. The problem description provides background information on the fundamental issue to be addressed by the study. Below is a list of steps that may be helpful during this phase of DQO development.

- Describe the conditions or circumstances that are causing the problem and the reason for understanding the study. Typical examples for environmental problems include conditions that may pose a threat to human health or the environment, and circumstances of potential non-compliance with regulations.

- Describe the problem as it is currently understood by briefly summarizing existing information. (See Table 1-1 for a list of elements that may be appropriate to include in the problem description.)

- Conduct literature searches and examine past or ongoing studies to ensure that the problem is correctly defined and has not been solved previously. Organize and review relevant information, including preliminary studies, and indicate the source and reliability of the information. Take note of information about the performance of sampling and analytical methods observed in similar studies since this information may prove to be particularly valuable later in the DQO Process.

- If the problem is complex, consider breaking it into more manageable pieces. Identify those pieces that could be addressed by separate studies. Assign priorities to and logical relationships among the pieces of the problem.

Specify the available resources and relevant deadlines for the study. Stipulate the anticipated budget, available personnel, and contractual vehicles (if applicable). Also, enumerate any deadlines for completion of the study and any intermediate deadlines that may need to be met.

Elements of the Problem Description

The following elements may be appropriate to include in the problem description. Note: this list only provides the basic elements of the problem description. Your elements may be slightly different.

- Study objectives/regulatory context.
- Persons or organizations involved in the study.
- Persons or organizations that have an interest in the study.
- Political issues surrounding the study.
- Sources and amount of funding.
- Previous study results.
- Existing sampling design constraints (some aspects of sampling design may be specified in regulations or established through past planning efforts)

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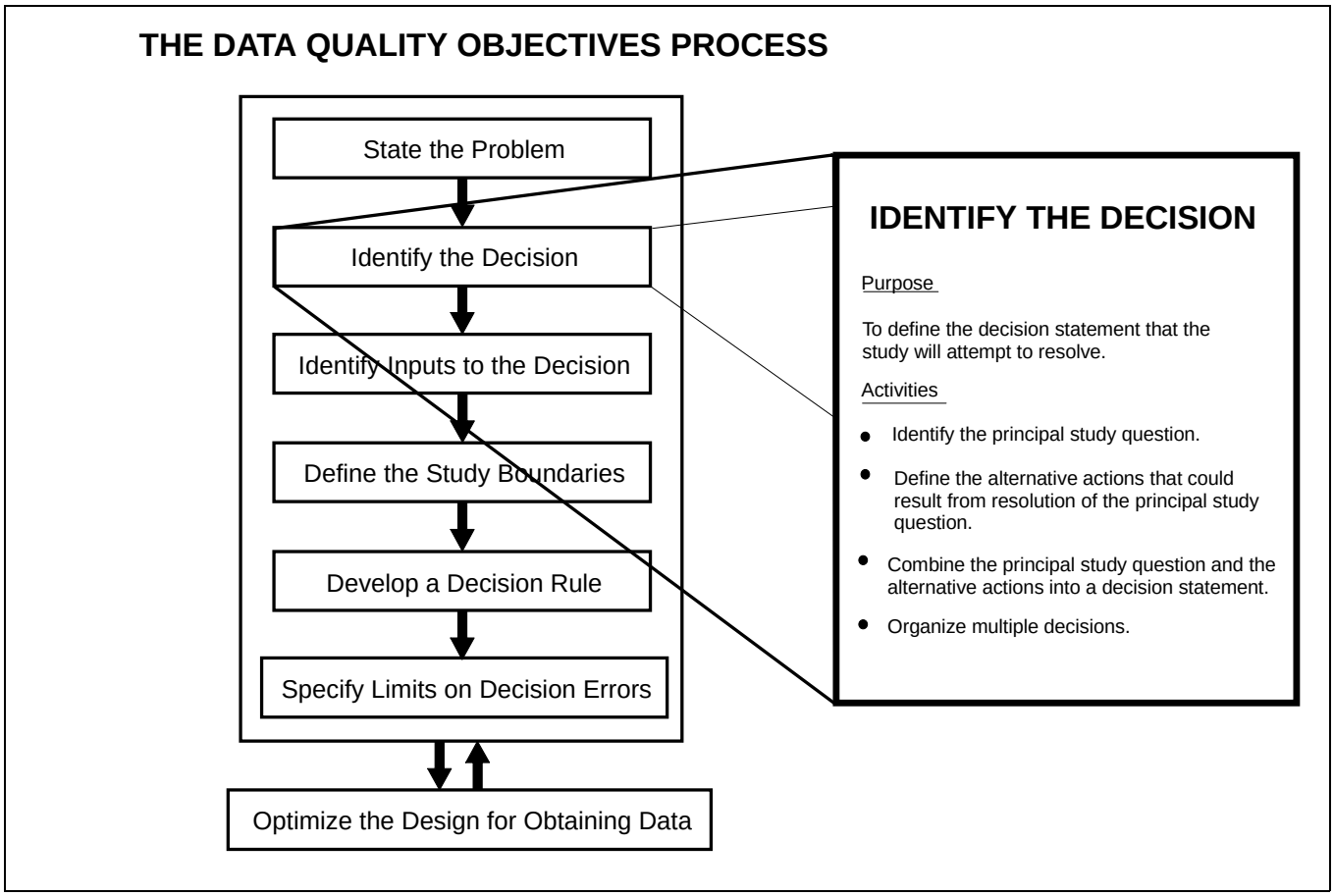
Table 1-1. Elements of the Problem Description

CHAPTER 2

STEP 2: IDENTIFY THE DECISION



Purpose

The purpose of this step is to define the decision statement that the study will attempt to resolve.

Expected Outputs

- **A decision statement that links the principal study question to possible actions that will solve the problem.**

Background

The goal of this step is to define the question that the study will attempt to resolve and identify the alternative actions that may be taken based on the outcome of the study. In the DQO Process the combination of these two elements is called the decision statement or decision. The decision statement is critical for defining decision performance criteria later in the Process.

The three activities in this chapter usually are most easily developed in the order that they appear. Sometimes, however, it is easier to identify alternative actions before the principal study question. In these cases, identify alternative actions that address the problem, then define the principal study question.

In some cases, several decision statements are appropriate to address the problem under investigation. In these instances, the planning team should organize the decision statements in order of priority and identify the most logical and efficient sequence for analyzing and resolving them. If the principal study question is not obvious and specific alterative actions cannot be identified, then the study may fall in the category of exploratory research, in which case this step of the DQO Process may not be applicable.

Activities

Identify the principal study question. Based on a review of the problem stated in Step 1, identify the principal study question and state it as specifically as possible. A specific statement of the principal study question narrows the search for information needed to address the problem. The principal study question identifies key unknown conditions or unresolved issues that reveal the solution to the problem being investigated. The following examples illustrate this point:

- "Is the permittee out of compliance with discharge limits?"
- "Does the pollutant concentration exceed the National Ambient Air Quality Standard?"
- "Is the contaminant concentration significantly above background levels (which would indicate that a release has occurred)?"

Note that, in each case, the answer to the principal study question will provide the basis for determining what course of action should be taken to solve the problem.

Define the alternative actions that could result from resolution of the principal study question. Identify the possible actions that may be taken to solve the problem, including the alternative that does not require action. The types of actions considered will depend logically on the possible answers to the principal study question. These alternative actions form the basis for defining decision performance criteria in Step 6: Specify Tolerable Limits on Decision Errors.

The following example illustrates how alternative actions are defined based on possible answers to the following principal study question: "Are the lead pellets that are fired by bird hunters and collect on the bottom of ponds contributing to the decrease in the duck population in Adelayed County?" Possible resolutions of the principal study question are 1) the lead pellets are a factor in the decrease of the duck population, or 2) the lead pellets are not a factor in the duck population's decrease. If the lead is a contributing factor, the action may be to remove the lead from the bottom of the ponds and, at the same time, regulate the type of pellets that hunters may use in the future. If lead pellets are not found to contribute to a decrease in the duck population, then no action will be taken.

Combine the principal study question and the alternative actions into a decision statement. Combine the alternative actions identified in the previous activity and the principal study question into a decision statement that expresses a choice among alternative actions. The following standard form may be helpful in drafting decision statements: "Determine whether or not [unknown environmental conditions/issues/criteria from the principal study question] require (or support) [taking alternative actions]."

To illustrate the decision statement framing activity, consider the previous example. The principal study question is, "Are lead pellets on the bottom of ponds in Adelayed County contributing to the decrease in the duck population?", and the alternative actions are to "remediate the lead and regulate the use of lead pellets for hunting," or "take no action." Therefore the decision statement is, "Determine whether or not lead pellets are contributing to the decrease in the duck population and require remediation and regulation." For a compliance monitoring problem, a decision statement that incorporates the principal study question and expresses a choice among alternative actions might be, "Determine whether or not the permittee is out of compliance with discharge limits and requires enforcement action."

Organize multiple decisions. If several separate decision statements must be defined to address the problem, list them and identify the sequence in which they should be resolved. It may be useful to document the decision resolution sequence and relationships in a diagram or flowchart (see example in Figure 2-1).

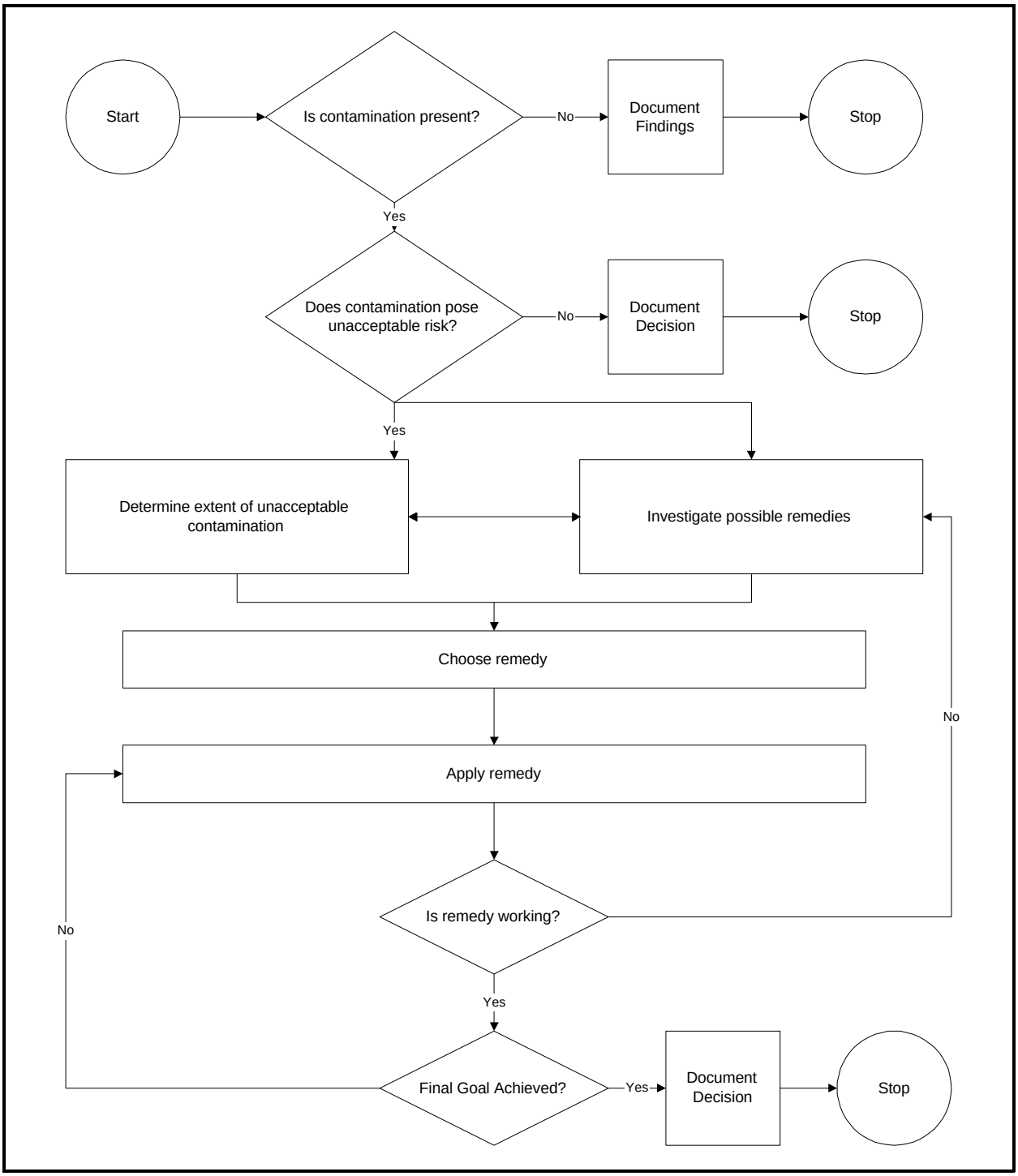
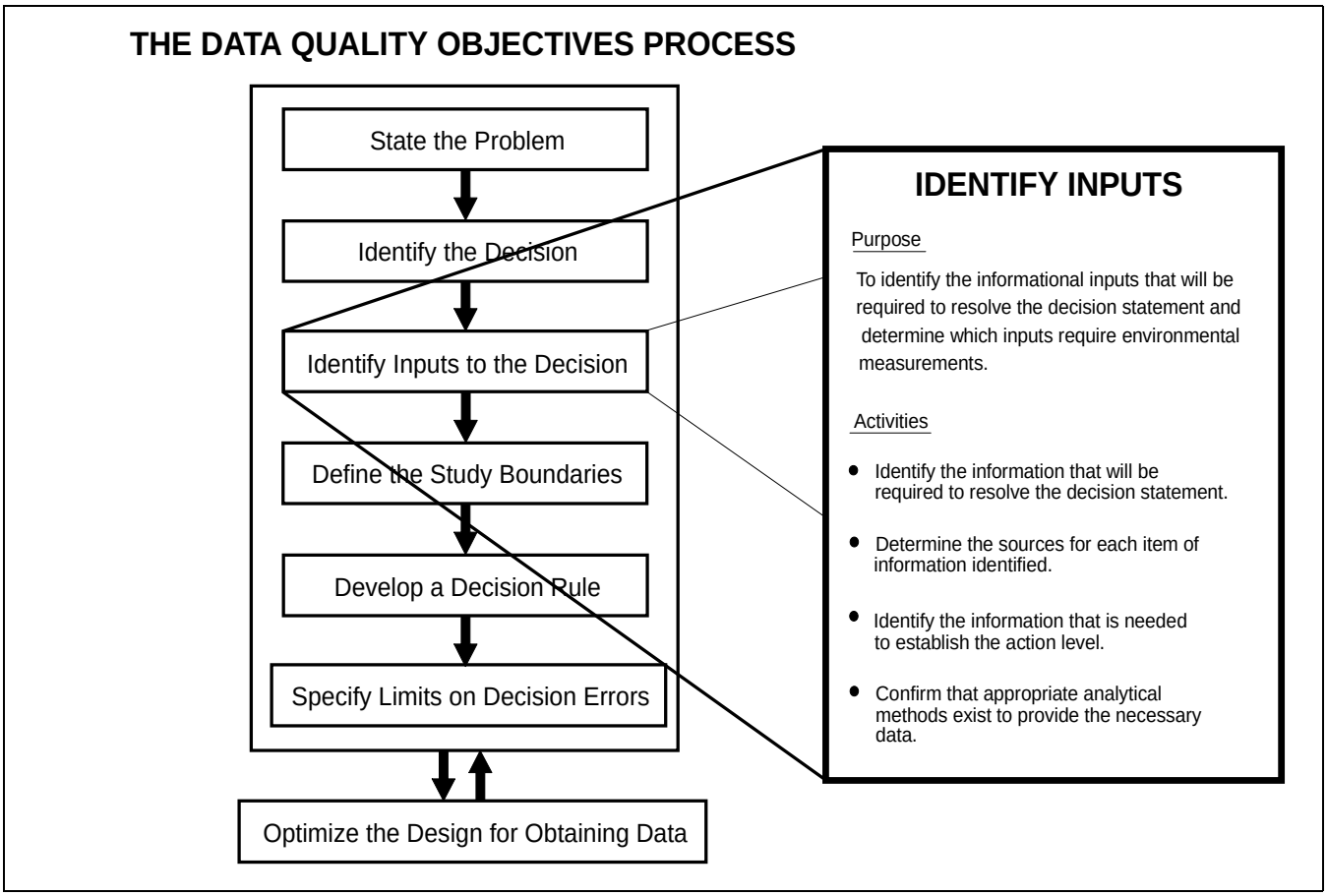


Figure 2-1. Example of Multiple Decisions Organized Into a Flowchart.

CHAPTER 3

STEP 3: IDENTIFY THE INPUTS TO THE DECISION



Purpose

The purpose of this step is to identify the informational inputs that will be required to resolve the decision statement and determine which inputs require environmental measurements.

Expected Outputs

- **A list of informational inputs needed to resolve the decision statement.**
- **A list of environmental variables or characteristics that will be measured.**

Background

To resolve most decision statements, it is necessary to collect data or information. In this step, the planning team identifies the different types of information that will be needed to resolve the decision statement. The key information requirements include the measurements that may be required, the source of data or information (e.g., historic or new data), and the basis for setting the action level. Once the planning team has determined what needs to be measured, they will refine the specifications and criteria for these measurements in later steps of the DQO Process.

Activities

Identify the information that will be required to resolve the decision statement. Determine which environmental variables or other information are needed to resolve the decision statement. Consider whether monitoring or modeling approaches, or a combination of both, will be used to acquire the information. Based on the selected data acquisition approach, identify the types of information needed to support the decision statement. Ask general questions such as, "Is information on the physical properties of the media required?" or "Is information on the chemical characteristics of the matrix needed?" These types of questions and their answers help identify the information needs. In compliance monitoring for pollutants discharged into surface water, examples of environmental variables of interest may include levels of lead, silver, total suspended solids, or temperature measurements.

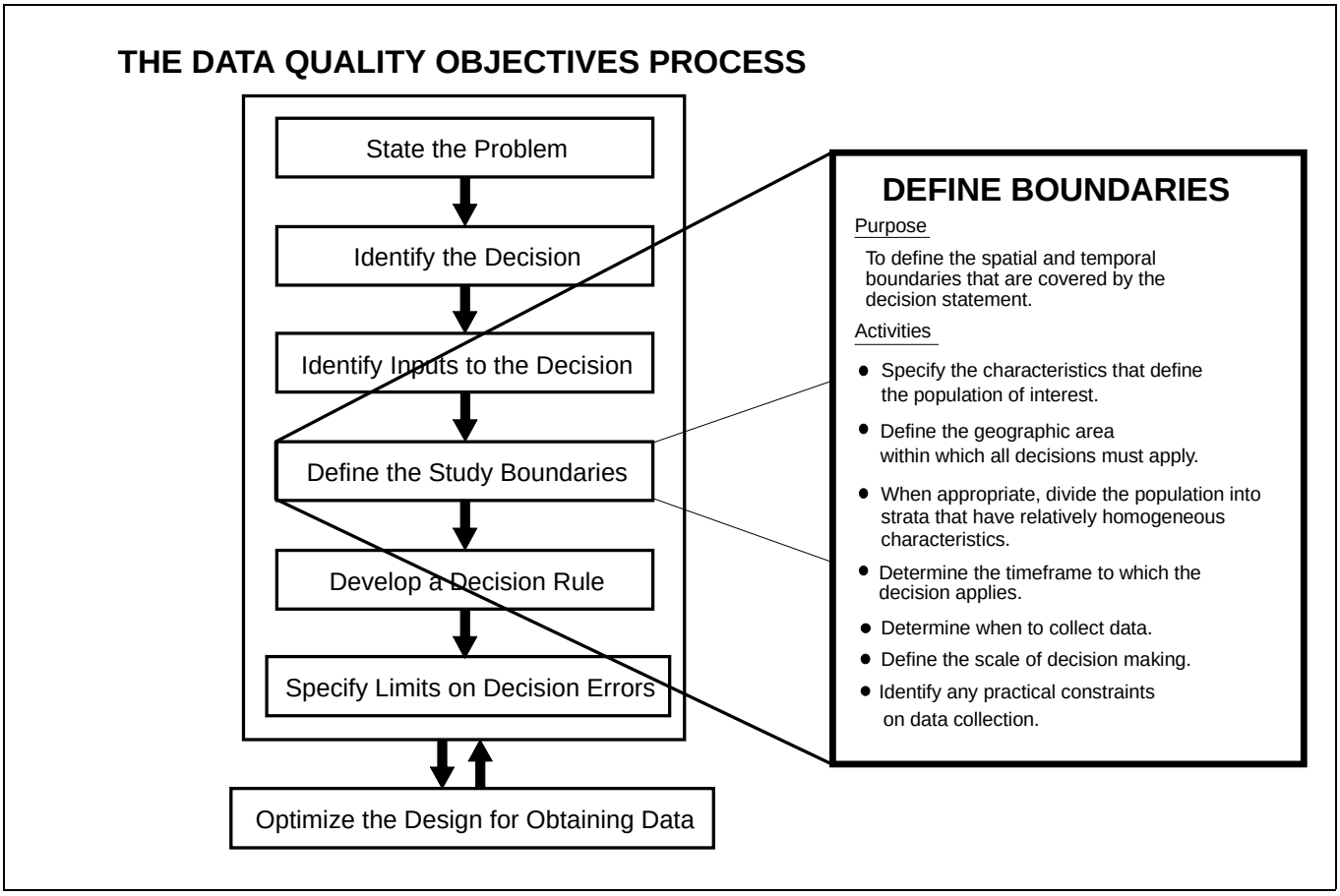
Determine the sources for each item of information identified above. Identify and list the sources for the information needed to resolve the decision statement. These sources may include results of previous data collections, historical records, regulatory guidance, professional judgement, scientific literature, or new data collections. Next, qualitatively evaluate whether any existing data are appropriate for the study. Existing data will be evaluated quantitatively in Step 7: Optimize the Design for Obtaining Data.

Identify the information that is needed to establish the action level. Define the basis for setting the action level. The action level is the threshold value which provides the criterion for choosing between alternative actions. Action levels may be based on regulatory thresholds or standards, or they may be derived from problem-specific considerations such as risk analysis. In this step, simply determine the criteria that will be used to set the numerical value. The actual numerical action level will be set in Step 5: Develop a Decision Rule.

Confirm that appropriate measurement methods exist to provide the necessary data. Use the list of environmental measurements identified earlier in this step to develop a list of potentially appropriate measurement methods. Note the method detection limit and limit of quantitation for each potential method; this performance information will be used in steps 5 and 7 of the DQO Process.

CHAPTER 4

STEP 4: DEFINE THE BOUNDARIES OF THE STUDY



Purpose

The purpose of this step is to define the spatial and temporal boundaries of the problem.

Expected Outputs

- **A detailed description of the spatial and temporal boundaries of the problem.**
- **Any practical constraints that may interfere with the study.**

Background

It is difficult to interpret data that have not been drawn from a well-defined population. The term "population" refers to the total collection or universe of objects or people to be studied, from which samples will be drawn. The purpose of this step is to define spatial and temporal components of the population that will be covered by the decision statement so that the data can be easily interpreted. These components include:

- Spatial boundaries that define the physical area to be studied and from where the samples should be taken, and

- Temporal boundaries that describe the timeframe the study data will represent and when the samples should be taken.

The boundaries will be used to ensure that the data collection design incorporates the time periods in which the study should be implemented, areas that should be sampled, and the time period to which the study results should apply. This will help ensure that the study data are representative of the population being studied. Defining boundaries before the data are collected can also prevent inappropriate pooling of data in a way that masks useful information.

Practical constraints that could interfere with sampling should also be identified in this step. A practical constraint is any hinderance or obstacle that potentially may interfere with the full implementation of the data collection design.

Activities

Specify the characteristics that define the population of interest. Specify the characteristics that define the population. It is important to clearly define the attributes that make up the population by stating them in a way that makes the focus of the study unambiguous. For example, the population may be PCB concentrations in soil, lead concentrations in the blood of children under the age of seven, or hourly ozone concentrations within the metropolitan area. There may be several ways to define a population; always choose the one that is most specific. For example, "tetrachlorodibenzodioxin" is more specific than "dioxin," and "hexavalent chromium" is more specific than "chromium".

Define the spatial boundary of the decision statement.

Define the geographic area to which the decision statement applies. The geographic area is a region distinctively marked by some physical features (i.e., volume, length, width, boundary). Some examples of geographic areas are the metropolitan city limits, the soil within the property boundaries down to a depth of six inches, or the natural habitat range of a particular animal species.

When appropriate, divide the population into strata that have relatively homogeneous characteristics. Using existing information, stratify or segregate the elements of the population into subsets or categories that exhibit relatively homogeneous properties or characteristics that may have an influence on the outcome of the study, such as contaminant concentrations, age, or height. Dividing the population into strata is desirable for studying sub-populations, reducing variability within subsets of data, or reducing the complexity of the problem by breaking it into more manageable pieces. See Figure 4-1 for an example of how to stratify a site with soil contamination.

Define the temporal boundary of the problem.

Determine the timeframe to which the decision applies. It may not be possible to collect data over the full time period to which the decision will apply. Therefore the planning team should determine the timeframe that the data should reflect; for example, "The data will reflect the condition of contaminant leaching into ground water over a period of a hundred years," or "The data will be used to reflect the risk conditions of an average resident over their average length of residence which is estimated to be eight years." Timeframes should be defined for the overall population and any sub-populations of interest.

Determine when to collect data. Conditions may vary over the course of a study, which may affect the success of data collection and the interpretation of data results. These factors may include weather, temperature, humidity, or amount of sunlight and wind. Determine when conditions will be most favorable for collecting data and select the most appropriate time period to collect data that reflect those conditions. For example, a study to measure ambient airborne particulate matter may give misleading information if the sampling is conducted in the wetter winter months rather than the drier summer months.

Define the scale of decision making. Define the smallest, most appropriate subsets of the population (sub-populations) for which decisions will be made based on the spatial or temporal boundaries. For example, in a study where the *decision statement* is, "Determine whether or not the concentration of lead in soil poses an unacceptable health risk to children and requires remediation", the *geographic area* is the top six inches of soil within the property boundaries, and the *population* is the lead concentration in surface soil. The *scale of decision making* could be set to an area which has a size that corresponds to the area where children derive the majority of their exposure (such as a play area or an average residential lot size if the future land use will be residential). Studying the site at this scale will be protective of children, a sensitive population in risk assessment. A temporal scale of decision making might be necessary for other types of studies. For example, in order to regulate water quality, it would be useful to set a scale of decision making that limits the time between sampling events. This would minimize the potential adverse effects in case the water quality was degraded between sampling events.

Identify any practical constraints on data collection. Identify any constraints or obstacles that could potentially interfere with the full implementation of the data collection design, such as seasonal or meteorological conditions when sampling is not possible, the inability to gain site access or informed consent, or the unavailability of personnel, time, or equipment. For example, it may not be possible to take surface soil samples beyond the east boundaries of a site under investigation because permission had not been granted by the owner of the adjacent property.

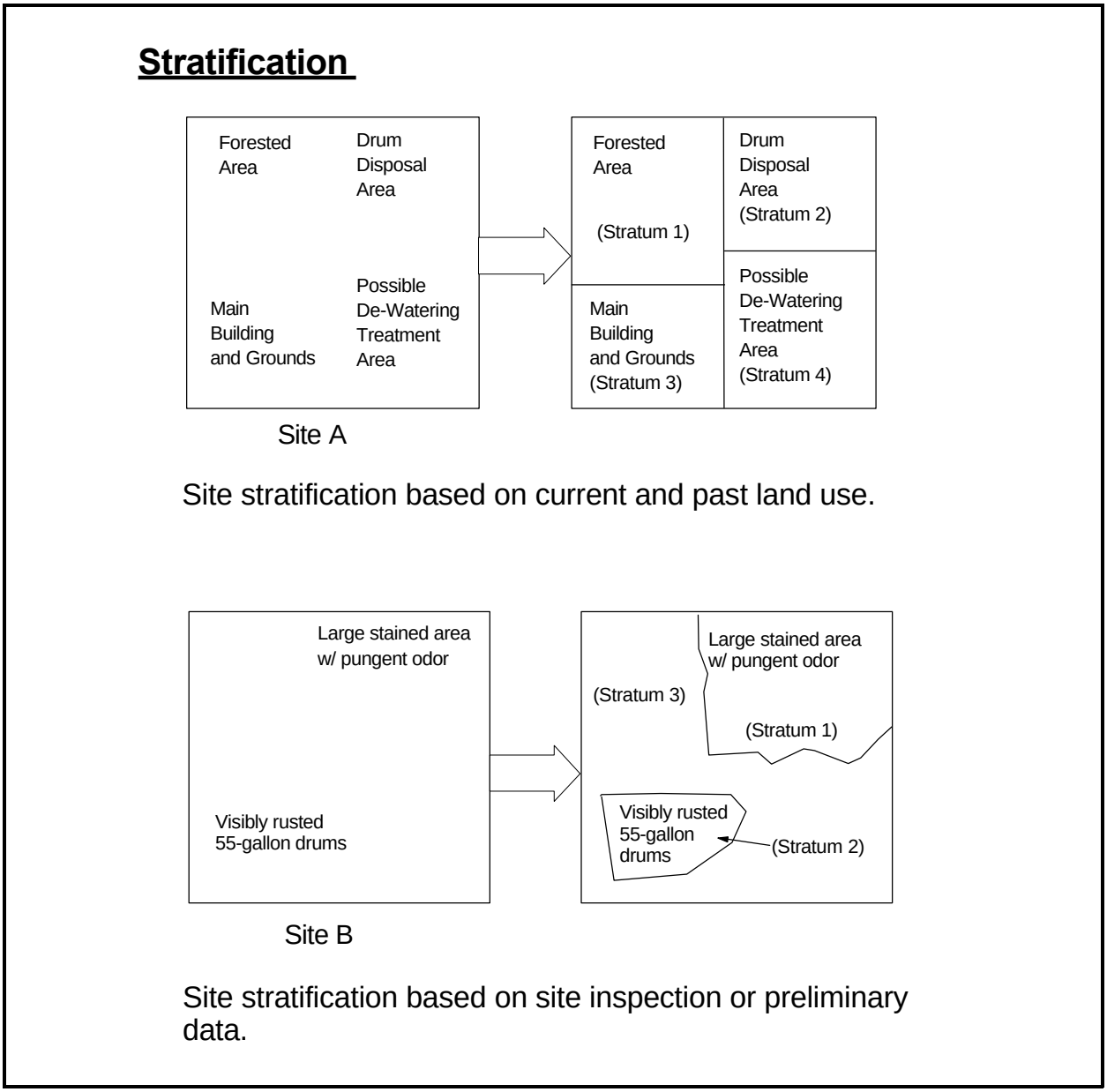
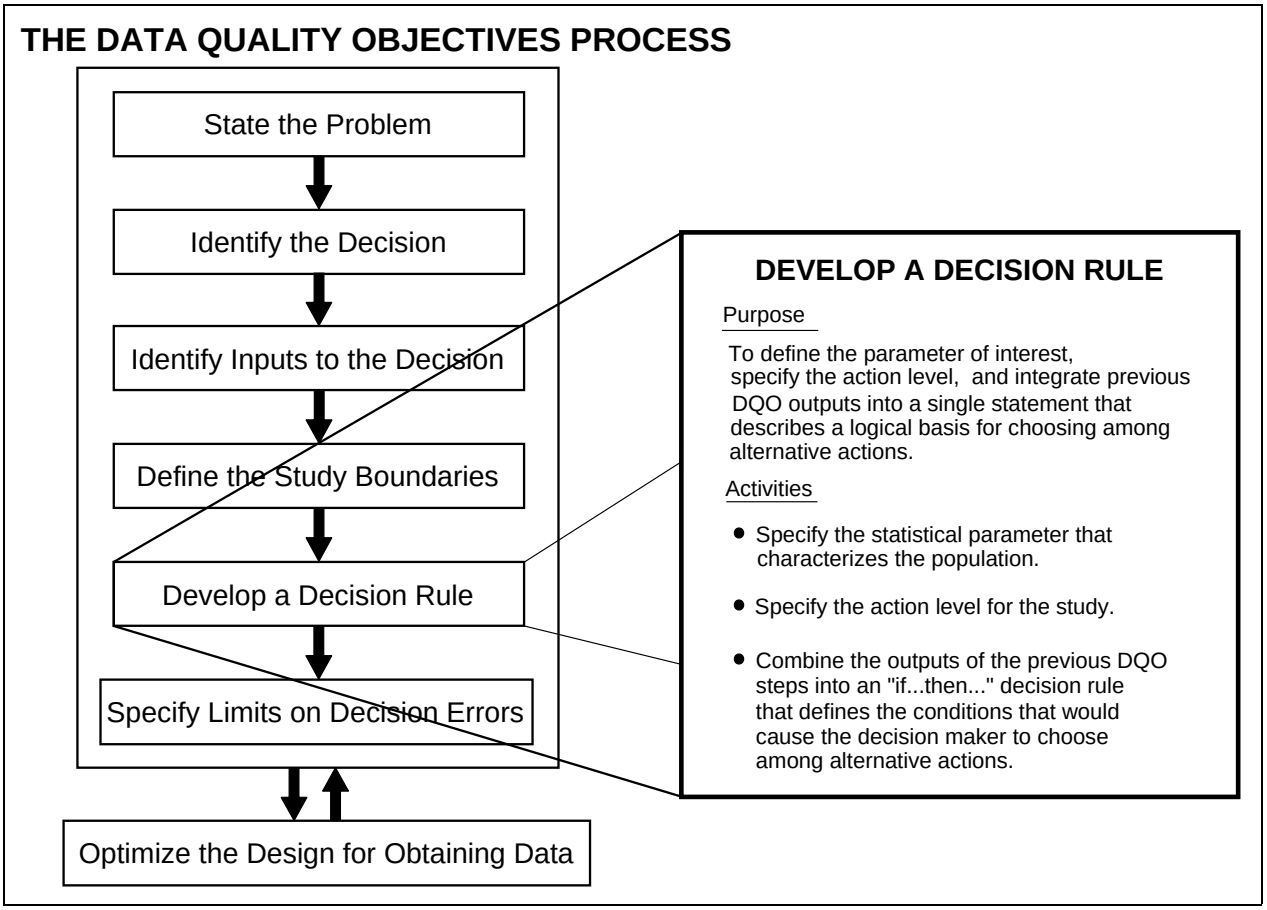


Figure 4-1. An Example of How to Stratify a Site with Soil Contamination.

CHAPTER 5

STEP 5: DEVELOP A DECISION RULE



Purpose

The purpose of this step is to define the parameter of interest, specify the action level, and integrate previous DQO outputs into a single statement that describes a logical basis for choosing among alternative actions.

Expected Outputs

- **The statistical parameter (the parameter of interest) that characterizes the population.**
- **The action level.**
- **An "if...then..." statement that defines the conditions that would cause the decision maker to choose among alternative actions.**

Background

The decision rule summarizes what attributes the decision maker wants to know about the population and how that knowledge would guide the selection of a course of action to solve the problem. The Decision Rule step combines criteria from past steps with the *parameter of interest* (statistical characteristic of the population) and the *action level* to provide a concise description of what action will be taken based on the results of the data collection.

There are four main elements to a decision rule:

(1) The *parameter of interest* , a descriptive measure (such as a mean, median, or proportion) that specifies the characteristic or attribute that the decision maker would like to know about the statistical population. The purpose of the data collection design is to produce environmental data that can be used to develop a reasonable estimate of the population parameter.

(2) The *scale of decision making* , the smallest, most appropriate subset (sub-population) for which separate decisions will be made. (The scale of decision making was defined in Step 4: Define the Boundaries of the Study.)

(3) The *action level*, a measurement threshold value of the parameter of interest that provides the criterion for choosing among alternative actions. The action level can be based on regulatory standards, an exposure assessment, technology based limits, or reference-based standards.

(4) The *alternative actions* , the actions that the decision maker would take, depending on the true value of the parameter of interest. (The alternative actions were identified in Step 2: Identify the Decision.)

Activities

Specify the statistical parameter that characterizes the population (the parameter of interest). The planning team should specify the parameter of interest (such as the mean, median, or percentile) whose true value the decision maker would like know and that the data will estimate. For example, to determine if the contamination level at a given site exceeds an action level, the planning team must specify the parameter that will be evaluated with respect to the action level (e.g., the mean concentration). Some regulations specify the parameter, but if this is not the case, it may be necessary to consult with a statistician to help select a parameter that is consistent with the intended application. Recognize that the parameter that is chosen in this step may be changed to an equivalent descriptive measure as more information becomes available based on statistical considerations in Step 7 of the DQO Process and in the Data Quality Assessment Process. Information about positive and negative attributes of commonly used parameters is provided at the end of this chapter.

Specify the action level for the study. The decision maker should specify the numerical value that would cause him/her to choose between alternative actions. For example, the decision maker would choose one action if the true value of the parameter of interest is above 1 mg/L, and a different action otherwise. Confirm that the action level is greater than the detection and quantitation limits for the potential measurement methods identified in Step 3: Identify the Inputs to the Decision.

Develop a decision rule. Develop a decision rule as an "if...then..." statement that incorporates the parameter of interest, the scale of decision making, the action level, and the action(s) that would result from resolution of the decision. These four elements are combined in the following way: If the parameter of interest (e.g., true mean concentration of lead) within the scale of decision making (e.g., 1-acre plots) is greater than the action level (e.g., 1 mg/Kg), then take alternative action A (e.g., remove the soil from the site); otherwise take alternative action B (e.g., leave the soil in place). For example, "If the true mean concentration of cadmium in the fly ash leachate within a container truck exceeds 1.0 mg/Kg, then the waste ash will be considered hazardous and will be disposed of in a RCRA hazardous waste landfill; otherwise, the waste ash will be disposed of in a municipal landfill." This statement is a functional decision rule that expresses what the decision maker ideally would like to resolve. It is not an operational decision rule which incorporates the decision maker's tolerable limits on decision errors and the statistical hypothesis, and describes how the data will be summarized. The operational decision rule is developed during the Data Quality Assessment Process, after the data have been collected (see Appendix A).

Attributes of Different Statistical Parameters

MEAN

Positive Attributes

- Useful when action level is based on long-term, average health effects (chronic conditions, carcinogenicity).
- Useful when the population is uniform with relatively small spread.
- Generally requires fewer samples than other parameters.

Negative Attributes

- Not a very representative measure of central tendency for highly skewed populations.
- Not useful when the population contains a large proportion of values that are less than measurement detection limits.

(continued)

Table 5-1. Attributes of Different Statistical Parameters to Characterize the Population

Attributes of Different Statistical Parameters (continued)

MEDIAN

Positive Attributes

- Useful when action level is based on long-term, average health effects (chronic conditions, carcinogenicity).
- Provides a more representative measure of central tendency than the mean for skewed populations.
- Useful when the population contains a large number of values that are less than measurement detection limits.
- Relies on few statistical assumptions.

Negative Attributes

- Will not protect against the effect of extreme values.
- Not a very representative measure of central tendency for highly skewed populations.

UPPER PROPORTION/PERCENTILE

Positive Attributes

- Useful for protection against extreme health effects.
- For highly variable populations, provides best control of the extreme values.
- Useful for skewed distributions.
- May be appropriate when the population contains a large number of values less than the measurement detection limit, as long as this limit is less than the action level.
- Relies on few statistical assumptions.

Negative Attributes

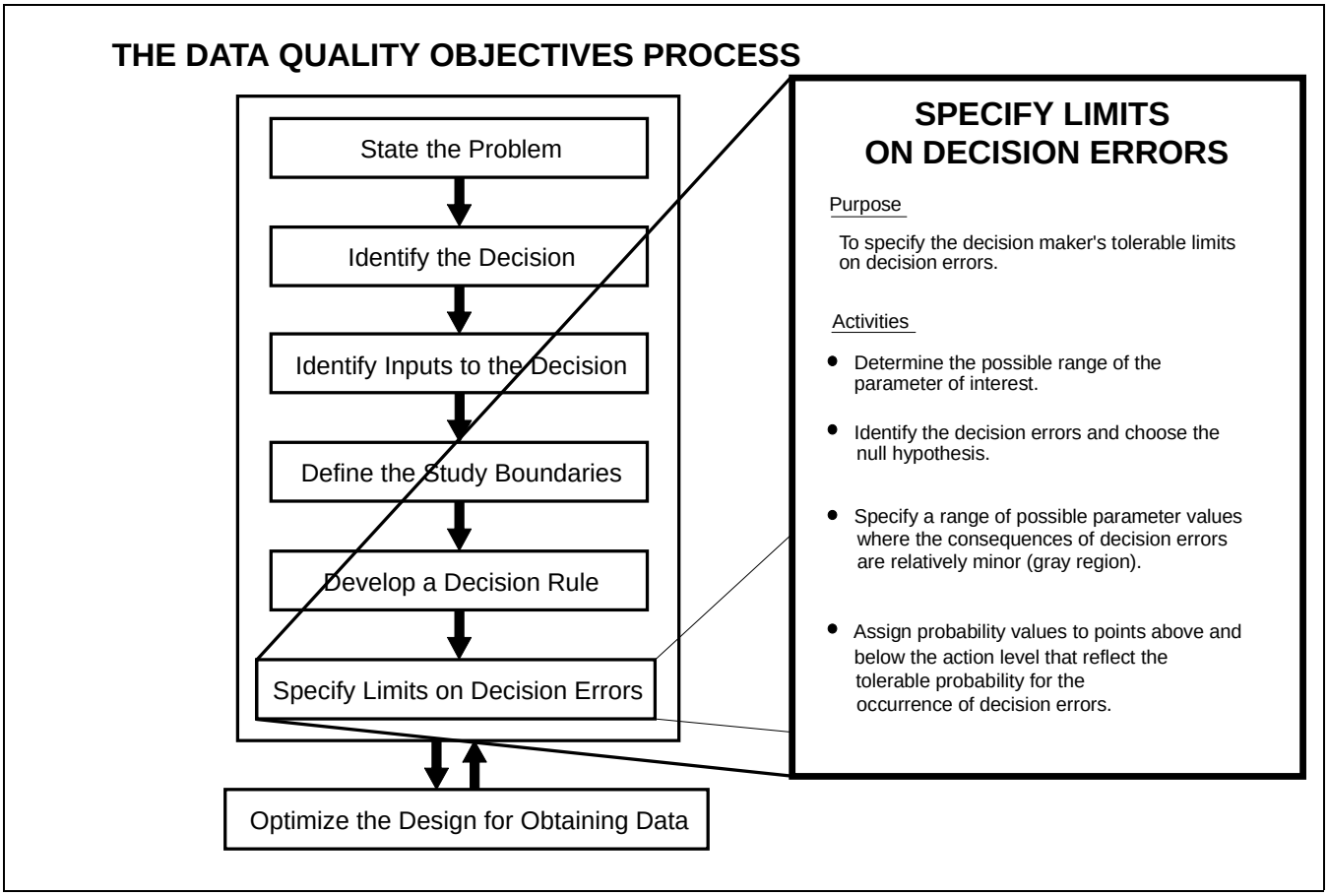
- Requires larger sample sizes than mean.

Reference: U.S. Environmental Protection Agency. 1989. *Methods for Evaluation Attainment of Cleanup Standards: Volume 1: Soils and Solid Media.* EPA 230/02-89-042, Office of Policy Planning and Evaluation.

Table 5-1. (cont.) Attributes of Different Statistical Parameters to Characterize the Population

CHAPTER 6

STEP 6: SPECIFY TOLERABLE LIMITS ON DECISION ERRORS



Purpose

The purpose of this step is to specify the decision maker's tolerable limits on decision errors, which are used to establish performance goals for the data collection design.

Expected Outputs

- **The decision maker's tolerable decision error rates based on a consideration of the consequences of making an incorrect decision.**

Background

Decision makers are interested in knowing the true state of some feature of the environment. Since data can only estimate this state, decisions that are based on measurement data could be in error (decision error). Most of the time the correct decision will be made; however, this chapter will focus on controlling the less likely possibility of making a decision error. The goal of the planning team is to develop a data collection design that reduces the chance of making a decision error to a tolerable level. This step of the DQO Process will provide a mechanism for allowing the decision maker to define tolerable limits on the probability of making a decision error.

There are two reasons why the decision maker cannot know the true value of a population parameter (i.e., the true state of some feature of the environment):

(1) The population of interest almost always varies over time and space. Limited sampling will miss some features of this natural variation because it is usually impossible or impractical to measure every point of a population. *Sampling design error* occurs when the sampling design is unable to capture the complete extent of natural variability that exists in the true state of the environment.

(2) Analytical methods and instruments are never absolutely perfect, hence a measurement can only estimate the true value of an environmental sample. *Measurement error* refers to a combination of random and systematic errors that inevitably arise during the various steps of the measurement process (for example, sample collection, sample handling, sample preparation, sample analysis, data reduction, and data handling).

The combination of sampling design error and measurement error is called *total study error,* which may lead to a decision error. Since it is impossible to eliminate error in measurement data, basing decisions on measurement data will lead to the possibility of making a decision error.

The probability of decision errors can be controlled by adopting a scientific approach. In this approach, the data are used to select between one condition of the environment (the *null hypothesis,* H_o) and an alternative condition (the *alternative hypothesis,* H_a). The null hypothesis is treated like a baseline condition that is presumed to be true in the absence of strong evidence to the contrary. This feature provides a way to guard against making the decision error that the decision maker considers to have the more undesirable consequences.

A decision error occurs when the decision maker rejects the null hypothesis when it is true, or fails to reject the null hypothesis when it is false. These two types of decision errors are classified as *false positive* and *false negative* decision errors, respectively. They are described below.

False Positive Decision Error — A false positive decision error occurs when the null hypothesis (H_o) is rejected when it is true. Consider an example where the decision maker presumes that a certain waste is hazardous (i.e., the null hypothesis or baseline condition is "the waste is hazardous"). If the decision maker concludes that there is insufficient evidence to classify the waste as hazardous when it truly is hazardous, then the decision maker would make a false positive decision error. A statistician usually refers to the false positive error as a "Type I" error. The measure of the size of this error is called alpha (α), the level of significance, or the size of the critical region.

False Negative Decision Error — A false negative decision error occurs when the null hypothesis is not rejected when it is false. In the above waste example, the false negative decision error occurs when the decision maker concludes that the waste is hazardous when it truly is not hazardous. A statistician usually refers to a false negative error as a "Type II" error. The measure of the size of this error is called beta (β), and is also known as the complement of the *power* of a hypothesis test.

The definition of false positive and false negative decision errors depends on the viewpoint of the decision maker. [1] Consider the viewpoint where a person has been presumed to be "innocent until proven guilty" (i.e., H_o is "innocent"; H_a is "guilty"). A false positive error would be convicting an innocent person; a false negative error would be not convicting the guilty person. From the viewpoint where a person is presumed to be "guilty until proven innocent" (i.e., H_o is "guilty"; H_a is "innocent"), the errors are reversed. Here, the false positive error would be not convicting the guilty person, and the false negative error would be convicting the innocent person.

While the possibility of a decision error can never be totally eliminated, it can be controlled. To control the possibility of making decision errors, the planning team must control total study error. There are many ways to accomplish this, including collecting a large number of samples (to control sampling design error), analyzing individual samples several times or using more precise laboratory methods (to control measurement error). Better sampling designs can also be developed to collect data that more accurately and efficiently represent the population of interest. Every study will use a slightly different method of controlling decision errors, depending on where the largest components of total study error exist in the data set and the ease of reducing those error components. Reducing the probability of making decision errors generally increases costs. In many cases controlling decision error within very small limits is unnecessary for making a decision that satisfies the decision maker's needs. For instance, if the consequences of decision errors are minor, a reasonable decision could be made based on relatively crude data (data with high total study

[1] Note that these definitions are not the same as false positive or false negative instrument readings, where similar terms are commonly used by laboratory or field personnel to describe a fault in a single result; false positive and false negative decision errors are defined in the context of hypothesis testing, where the terms are defined with respect to the null hypothesis.

error). On the other hand, if the consequences of decision errors are severe, the decision maker will want to control sampling design and measurement errors within very small limits.

To minimize unnecessary effort controlling decision errors, the planning team must determine whether reducing sampling design and measurement errors is necessary to meet the decision maker's needs. These needs are made explicit when the decision maker specifies probabilities of decision errors that are tolerable. Once these tolerable limits on decision errors are defined, then the effort necessary to analyze and reduce sampling design and measurement errors to satisfy these limits can be determined in Step 7: Optimize the Design for Obtaining Data. It may be necessary to iterate between these two steps before finding tolerable probabilities of decision errors that are feasible given resource constraints.

Activities

Determine the possible range of the parameter of interest. Establish the possible range of the parameter of interest by estimating its likely upper and lower bounds. This will help focus the remaining activities of this step on only the relevant values of the parameter. For example, the range of the parameter shown in Figures 6-1 and 6-2 at the end of this chapter is between 50 and 200 ppm. Historical and documented analytical data are of great help in establishing the potential parameter range.

Identify the decision errors and choose the null hypothesis. Define where each decision error occurs relative to the action level and establish which decision error should be defined as the null hypothesis (baseline condition). This process has four steps:

(1) *Define both types of decision errors and establish the true state of nature for each decision error.* Define both types of decision errors and determine which one occurs above and which one occurs below the action level. A decision error occurs when the data mislead the decision maker into concluding that the parameter of interest is on one side of the action level when the true value of the parameter is on the other side of the action level. For example, consider a situation in which a study is being conducted to determine if mercury contamination is creating a health hazard and EPA wants to take action if more than 5% of a population of fish have mercury levels above a risk-based action level. In this case, a decision error would occur if the data lead the decision maker to conclude that 95% of the mercury levels found in the fish population were below the action level (i.e., the parameter is the "95th percentile" of mercury levels in the fish population) when the true 95th percentile of mercury levels in the fish population was above the action level (which means that more than 5% of the fish population contain mercury levels greater than the action level). The other decision error for this example would be that the data lead the decision maker to conclude that the 95th percentile of mercury levels in the fish population is greater than the action level when the true 95th percentile is less than the action level.

The "true state of nature" is the actual condition or feature of the environment that exists, but is unknown to the decision maker. Each decision error consists of two parts, the true state of nature and the conclusion that the decision maker draws. Using the example above, the true state of nature for the first decision error is that the 95th percentile of mercury levels in the fish population is above the action level.

(2) *Specify and evaluate the potential consequences of each decision error.* Specify the likely consequences of making each decision error and evaluate their potential severity in terms of economic and social costs, human health and ecological effects, political and legal ramifications, and so on. Consider the alternative actions that would be taken under each decision error scenario, as well as secondary effects of those actions. For example, in determining whether or not 95% of a fish population contain mercury levels above a risk-based action level, there may be a variety of potential consequences of committing a decision error. In the first decision error described above, where the decision maker concludes that the 95th percentile is below when the true 95th percentile was above the action level, the decision maker may decide to continue to allow fishing in the waters and not undertake any cleanup activity. The resulting consequences might include human health and ecological effects from consumption of contaminated fish by humans and other animals, economic and social costs of health care and family disruption, and damaged credibility of EPA when (and if) the decision error is detected. If the other type of decision error is committed, where the decision maker decides that the 95th percentile exceeds the action level when the true 95th percentile is below the action level, the decision maker might ban all fishing in the local waters and initiate cleanup activities. The consequences might include economic and social costs of lost revenues and job displacement in the fishing industry, damaged credibility for EPA when the cleanup activities expose the nature of the decision error, and the threat of lawsuits by fishing interests.

Evaluate the severity of potential consequences of decision errors at different points within the domains of each type of decision error, since the severity of consequences may change as the parameter moves further away from the action level. Consider whether or not the consequences change abruptly at some value, such as a threshold health effect level; the decision maker may want to change the tolerable limit on the decision error at such a point.

(3) *Establish which decision error has more severe consequences near the action level.* Based on the evaluation of potential consequences of decision errors, the decision maker should determine which decision error causes greater concern when the true parameter value is near the action level. It is important to focus on the region near the action level because this is where the true parameter value is most likely to be when a decision error is made (in other words, when

the true parameter is far above or far below the action level, the data are much more likely to indicate the correct decision). This determination typically involves value judgements about the relative severity of different types of consequences within the context of the problem. In the fish contamination problem above, the decision maker would weigh the potential health consequences from allowing people to consume contaminated fish versus the economic and social disruption from banning all fishing in the community. In this case, the decision maker might carefully consider how uncertain or conservative the risk-based action level is.

(4) *Define the null hypothesis (baseline condition) and the alternative hypothesis and assign the terms "false positive" and "false negative" to the appropriate decision error.* In problems that concern regulatory compliance, human health, or ecological risk, the decision error that has the most adverse potential consequences should be defined as the null hypothesis (baseline condition). [2] In statistical hypothesis testing, the data must conclusively demonstrate that the null hypothesis is false. That is, the data must provide enough information to authoritatively reject the null hypothesis (disprove the baseline condition) in favor of the alternative. Therefore, by setting the null hypothesis equal to the true state of nature that exists when the more severe decision error occurs, the decision maker guards against making the more severe decision error by placing the burden of proof on demonstrating that the most adverse consequences will <u>not</u> be likely to occur.

It should be noted that the null and alternative hypotheses have been predetermined in many regulations. If not, the planning team should define the null hypothesis (baseline condition) to correspond to the true state of nature for the more severe decision error and define the alternative hypothesis to correspond to the true state of nature for the less severe decision error.

Using the definitions of null and alternative hypotheses, assign the term "false positive" to the decision error in which the decision maker rejects the null hypothesis when it is true, which corresponds to the decision error with the more severe consequences identified in task (3). Assign the term "false negative" to the decision error in which the decision maker fails to reject the

[2]Note that this differs somewhat from the conventional use of hypothesis testing in the context of planned experiments. There, the alternative hypothesis usually corresponds to what the experimenter hopes to prove, and the null hypothesis usually corresponds to some baseline condition that represents an "opposite" assumption. For instance, the experimenter may wish to prove that a new water treatment method works better than an existing accepted method. The experimenter might formulate the null hypothesis to correspond to "the new method performs no better than the accepted method," and the alternative hypothesis as "the new method performs better than the accepted method." The burden of proof would then be on the experimental data to show that the new method performs better than the accepted method, and that this result is not due to chance.

null hypothesis when it is false, which corresponds to the decision error with the less severe consequences identified in task (3).

Specify a range of possible parameter values where the consequences of decision errors are relatively minor (gray region). The gray region is a range of possible parameter values where the consequences of a false negative decision error are relatively minor. The gray region is bounded on one side by the action level and on the other side by that parameter value where the consequences of making a false negative decision error begin to be significant. Establish this boundary by evaluating the consequences of not rejecting the null hypothesis when it is false. The edge of the gray region should be placed where these consequences are severe enough to set a limit on the magnitude of this false negative decision error. Thus, the gray region is the area between this parameter value and the action level.

It is necessary to specify a gray region because variability in the population and unavoidable imprecision in the measurement system combine to produce variability in the data such that a decision may be "too close to call" when the true parameter value is very near the action level. Thus, the gray region (or "area of uncertainty") establishes the minimum distance from the action level where the decision maker would like to begin to control false negative decision errors. In statistics, the width of this interval is called the "minimum detectable difference" and is often expressed as the Greek letter delta (Δ). The width of the gray region is an essential part of the calculations for determining the number of samples needed to satisfy the DQOs, and represents one important aspect of the decision maker's concern for decision errors. A more narrow gray region implies a desire to detect conclusively the condition when the true parameter value is close to the action level ("close" relative to the variability in the data). When the true value of the parameter falls within the gray region, the decision maker may face a high probability of making a false negative decision error, since the data may not provide conclusive evidence for rejecting the null hypothesis, even though it is actually false (i.e., the data may be too variable to allow the decision maker to recognize that the presumed baseline condition is, in fact, <u>not</u> true).

From a practical standpoint, the gray region is an area where it will not be feasible or reasonable to control the false negative decision error rate to low levels because of high costs. Given the resources that would be required to reliably detect small differences between the action level and the true parameter value, the decision maker must balance the resources spent on data collection with the expected consequences of making that decision error. For example, when testing whether a parameter (such as the mean concentration) exceeds the action level, if the <u>true</u> parameter is near the action level (relative to the expected variability of the data), then the imperfect data will tend to be clustered around the action level, with some values above the action level and some below. In this situation, the likelihood of committing a false negative decision error will be large. To determine with confidence whether the true value of the parameter is above or below the action level, the decision maker would need to collect a large amount of data, increase the precision of the measurements, or both. If taken to an extreme, the cost of collecting data can exceed the cost of making a decision error, especially where the consequences of the decision error may be relatively

minor. Therefore, the decision maker should establish the gray region, or the region where it is not critical to control the false negative decision error, by balancing the resources needed to "make a close call" versus the consequences of making that decision error.

Assign probability limits to points above and below the gray region that reflect the tolerable probability for the occurrence of decision errors. Assign probability values to points above and below the gray region that reflect the decision maker's tolerable limits for making an incorrect decision. Select a possible value of the parameter; then choose a probability limit based on an evaluation of the seriousness of the potential consequences of making the decision error if the true parameter value is located at that point. At a minimum, the decision maker should specify a false positive decision error limit at the action level, and a false negative decision error limit at the other end of the gray region. For many situations, the decision maker may wish to specify additional probability limits at other possible parameter values. For example, consider a hypothetical toxic substance that has a regulatory action level of 10 ppm, and which produces threshold effects in humans exposed to mean concentrations above 100 ppm. In this situation, the decision maker may wish to specify more stringent probability limits at that threshold concentration of 100 ppm than those specified at 10 ppm. The tolerable decision error limits should decrease further away from the action level as the consequences of decision error become more severe.

Given the potentially high cost of controlling sampling design error and measurement error for environmental data, Agency decision making is rarely supported by decision error limits more stringent than 0.01 (1%) for both the false positive and false negative decision errors. This guidance recommends using 0.01 as the starting point for setting decision error rates. The most frequent reasons for setting limits greater (i.e., less stringent) than 0.01 are that the consequences of the decision errors may not be severe enough to warrant setting decision error rates that are this extreme. The value of 0.01 should <u>not</u> be considered a prescriptive value for setting decision error rates, nor should it be considered as the policy of EPA to encourage the use of any particular decision error rate. Rather, it should be viewed as a starting point from which to develop limits on decision errors that are applicable for each study. If the decision maker chooses to relax the decision error rates from 0.01 for false positive or false negative decision errors, the planning team should document the reasoning behind setting the less stringent decision error rate and the potential impacts on cost, resource expenditure, human health, and ecological conditions.

The combined information from the activities section of this chapter can be graphed onto a “Decision Performance Goal Diagram” or charted in a “Decision Error Limits Table” (see Figures 6-1 and 6-2 and Tables 6-1 and 6-2 below). Both are useful tools for visualizing and evaluating all of the outputs from this step. Figure 6-1 and Table 6-1 illustrate the case where the null hypothesis (baseline condition) is that the parameter of interest exceeds the action level (e.g., the waste is hazardous). Figure 6-2 and Table 6-2 illustrate the case where the null hypothesis (baseline condition) is that the parameter is less than the action level (e.g., the waste is not hazardous).

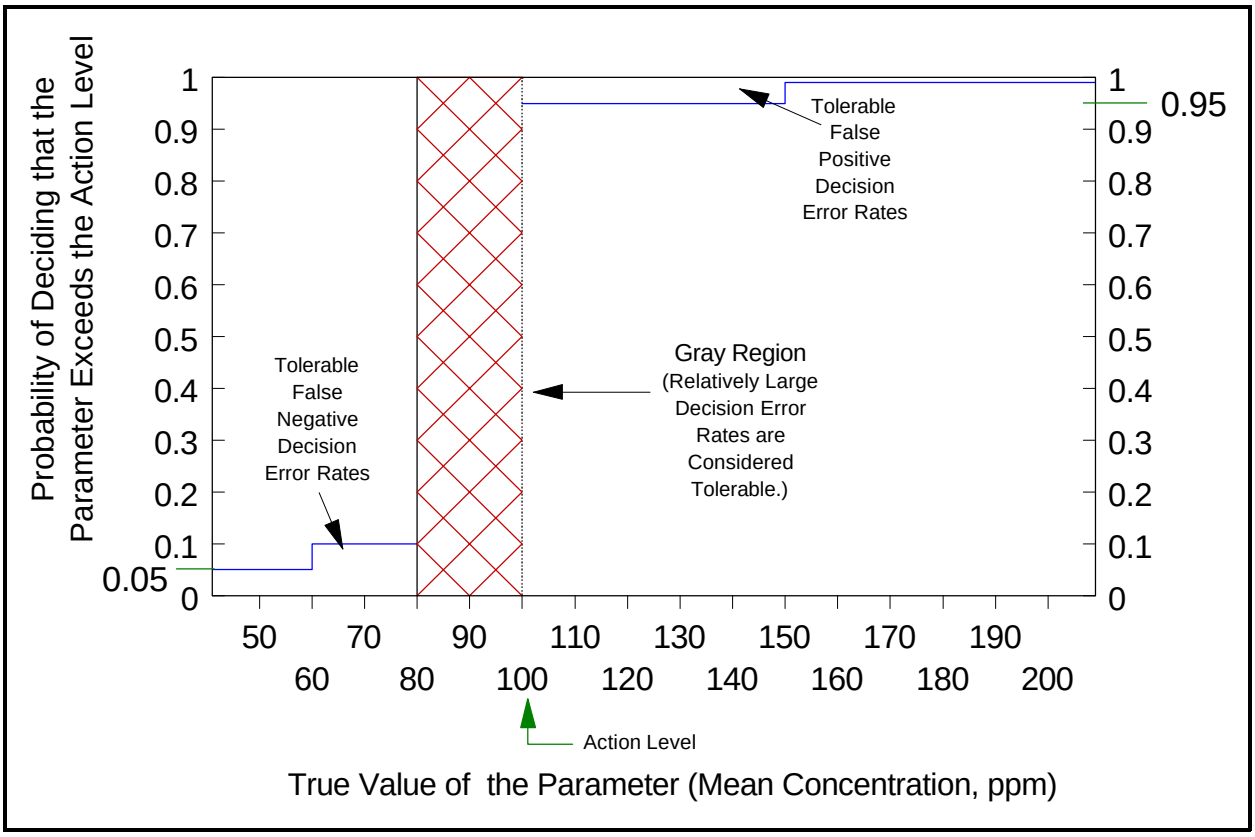


Figure 6-1. An Example of a Decision Performance Goal Diagram Baseline Condition: Parameter Exceeds Action Level.

True Concentration	Correct Decision	Type of Error	Tolerable Probability of Incorrect Decision
< 60 ppm	Not exceed	F(-)	5%
60 to 80	Not exceed	F(-)	10%
80 to 100	Not exceed	F(-)	gray region
100 to 150	Does exceed	F(+)	5%
> 150	Does exceed	F(+)	1%

Table 6-1. Decision Error Limits Table Corresponding to Figure 6-1. (Action Level = 100 ppm)

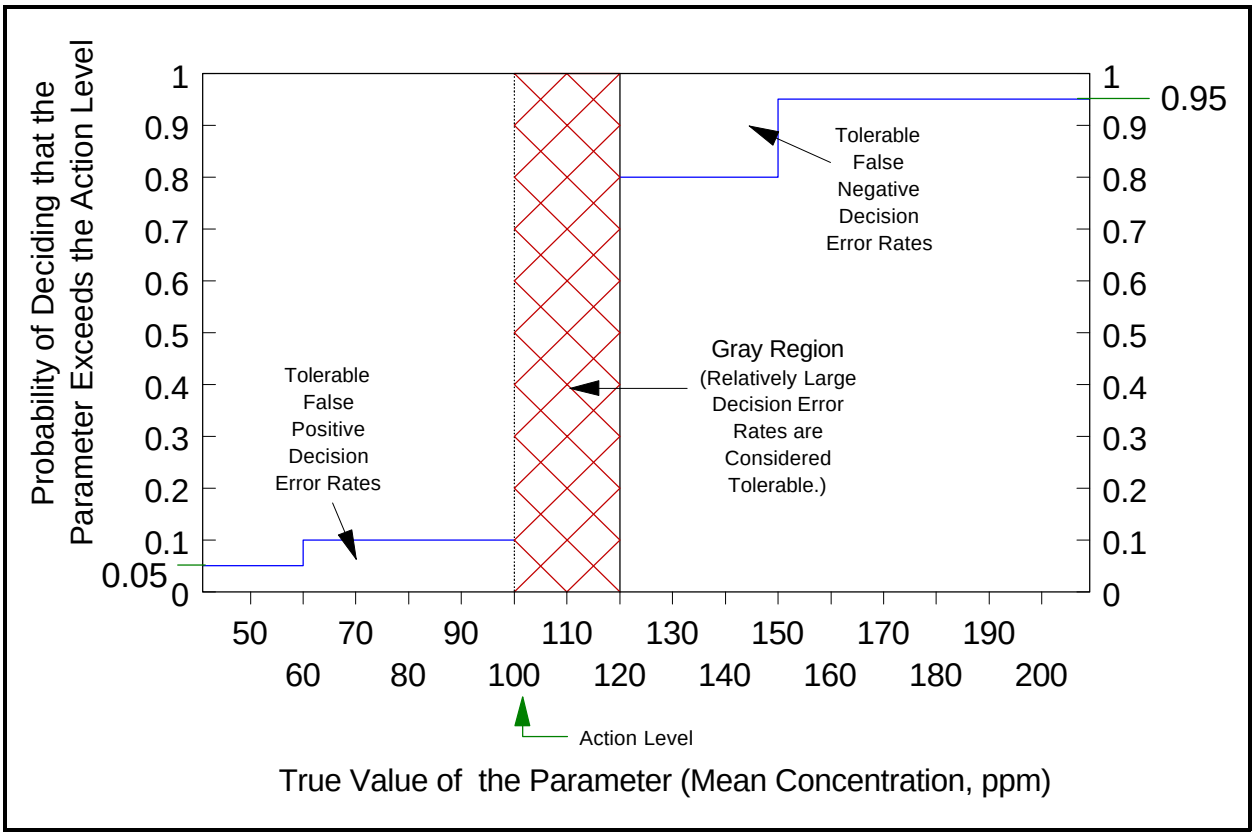


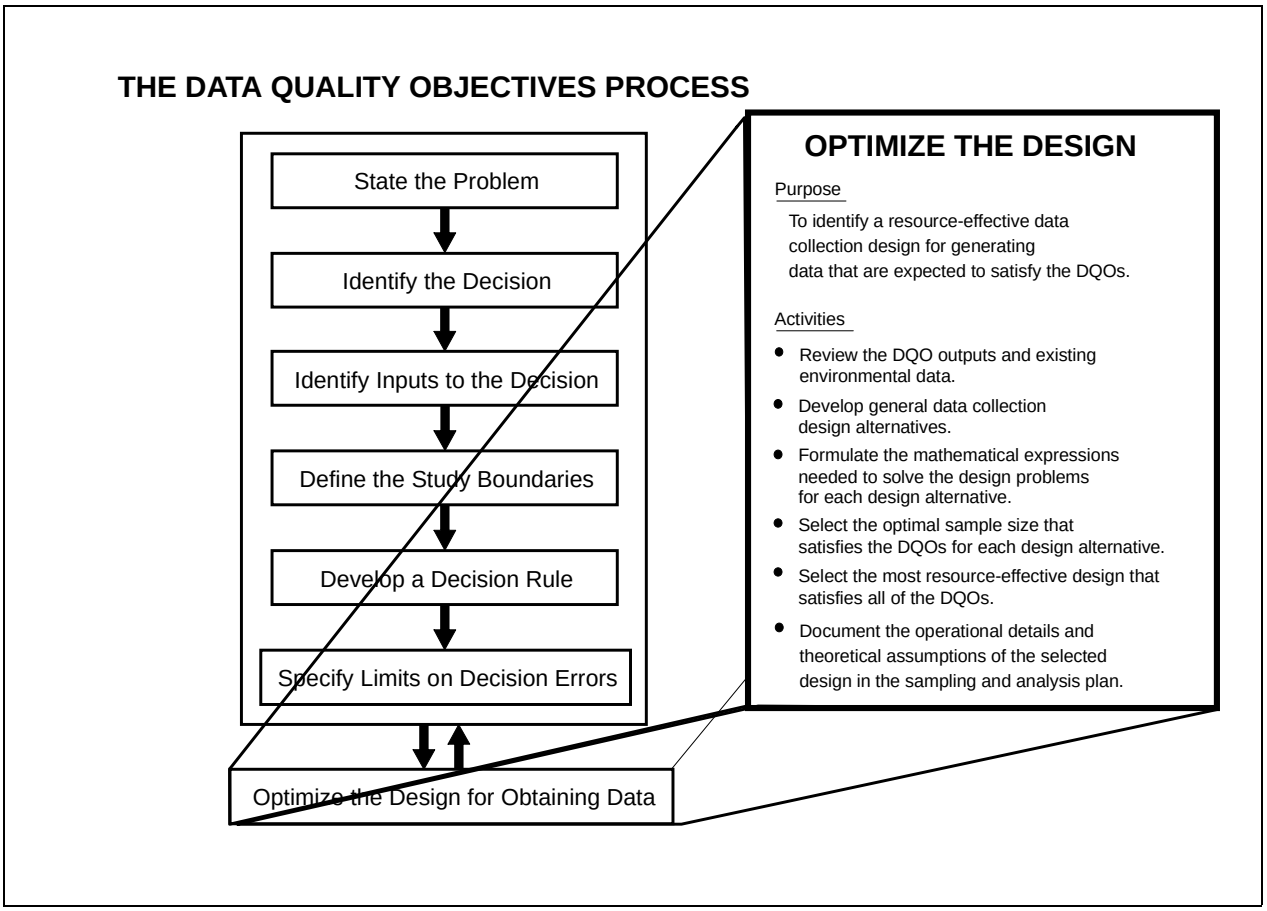
Figure 6-2. An Example of a Decision Performance Goal Diagram Baseline Condition: Parameter is Less Than Action Level.

True Concentration	Correct Decision	Type of Error	Tolerable Probability of Incorrect Decision
< 60 ppm	Not exceed	F(+)	5%
60 to 100	Not exceed	F(+)	10%
100 to 120	Does exceed	F(-)	gray region
120 to 150	Does exceed	F(-)	20%
> 150	Does exceed	F(-)	5%

Table 6-2. Decision Error Limits Table Corresponding to Figure 6-2. (Action Level = 100 ppm).

CHAPTER 7

STEP 7: OPTIMIZE THE DESIGN FOR OBTAINING DATA



Purpose

The purpose of this step is to identify a resource-effective data collection design for generating data that are expected to satisfy the DQOs.

Expected Outputs

- **The most resource-effective design for the study that is expected to achieve the DQOs.**

Background

In this step, statistical techniques are used to develop alternative data collection designs and evaluate their efficiency in meeting the DQOs. To develop the optimal design for this study, it may be necessary to work through this step more than once after revisiting previous steps of the DQO Process.

The objective of this step is to identify the most resource-effective data collection design expected to generate data that satisfy the DQOs specified in the preceding steps. While a full explanation of the procedures for developing a data collection design is beyond the scope of this guidance document, it does provide a broad overview of the steps that need to be accomplished to reach this goal. The example in Appendix B illustrates some of these activities in more detail.

Activities

Review the DQO outputs and existing environmental data. Review the DQO outputs generated in the preceding six steps to ensure that they are internally consistent. The DQOs should provide a succinct collection of information on the context of, requirements for, and constraints on the data collection design. Review existing data in more detail if it appears that they can be used to support the data collection design (e.g., analyze the variability in existing data if they appear to provide good information about the variance for the new data). If existing data are going to be combined with new data to support the decision, then determine if there are any gaps that can be filled or deficiencies that might be mitigated by including appropriate features in the new data collection design.

Develop general data collection design alternatives. Develop alternative data collection and analysis designs based on the DQO outputs and other relevant information, such as historical patterns of contaminant deposition, estimates of variance, and technical characteristics of the contaminants and media. Generally, the goal is to find cost-effective alternatives that balance sample size and measurement performance, given the feasible choices for sample collection techniques and analytical methods. In some cases where there is a relatively high spatial or temporal variability, it may be more cost-effective to use less expensive yet less precise analytical methods so that a relatively large number of samples can be taken, thereby controlling the sampling design error component of total study error. In other cases where the contaminant distribution is relatively homogeneous, or the action level is very near the method detection limit, it may be more cost-effective to use more expensive yet more precise and/or more sensitive analytical methods and collect fewer samples, thereby controlling the analytical measurement error component of total study error. Examples of general data collection design alternatives include:

- factorial design
- simple random sampling
- stratified random sampling
- sequential random sampling
- systematic sampling
- composite sampling (in conjunction with another sampling design)

Formulate the mathematical expressions needed to solve the design problem for each data collection design alternative. Develop the following three mathematical expressions needed to optimize the data collection design as follows:

(1) Define a suggested method for testing the statistical hypothesis and define a sample size formula that corresponds to the method if one exists (e.g., a Student's t-test).

(2) Develop a statistical model that describes the relationship of the measured value to the "true" value. Often the model will describe the components of error or bias that are believed to exist in the measured value.

(3) Develop a cost function that relates the number of samples to the total cost of sampling and analysis.

Select the optimal sample size that satisfies the DQOs for each data collection design alternative. Using the mathematical expressions from the previous activity, solve for the optimal sample size that satisfies the DQOs, including the decision maker's limits on decision errors. If no design will meet the limits on decision errors within the budget or other constraints, then the planning team will need to relax one or more constraints. For example:

- increase the budget for sampling and analysis;
- increase the width of the gray region;
- increase the tolerable decision error rates;
- relax other project constraints, such as the schedule; or
- change the boundaries; it may be possible to reduce sampling and analysis costs by changing or eliminating subgroups that will require separate decisions.

Select the most resource-effective data collection design that satisfies all of the DQOs. Evaluate the design options based on cost and ability to meet the DQO constraints. Choose the one that provides the best balance between cost (or expected cost) and ability to meet the DQOs.

The statistical concept of a power function is extremely useful in investigating the performance of alternative designs. The power function is the probability of rejecting the null hypothesis (H_o) when the null hypothesis is false (i.e., the alternative condition is true). If there was no error associated with a decision, the ideal power function would be 0 if H_o were true, and 1 if H_o were false. Since decisions are based on imperfect data, however, it is impossible to achieve this ideal power function. Instead, the power function will most likely yield values that are small when H_o is true and large when H_o is false. A performance curve is based on the graph of the power function. [1] The performance curve can be overlaid into

[1] In this guidance, the performance curve is based on either the power curve or the complement of the power curve. This ensures that the performance curve always rises from left to right.

the Decision Performance Goal Diagram to assess how well a test performs or to compare competing tests. A design that produces a very steep performance curve is preferred over one that is relatively flat. An example of a performance curve is shown in Figure 7-1.

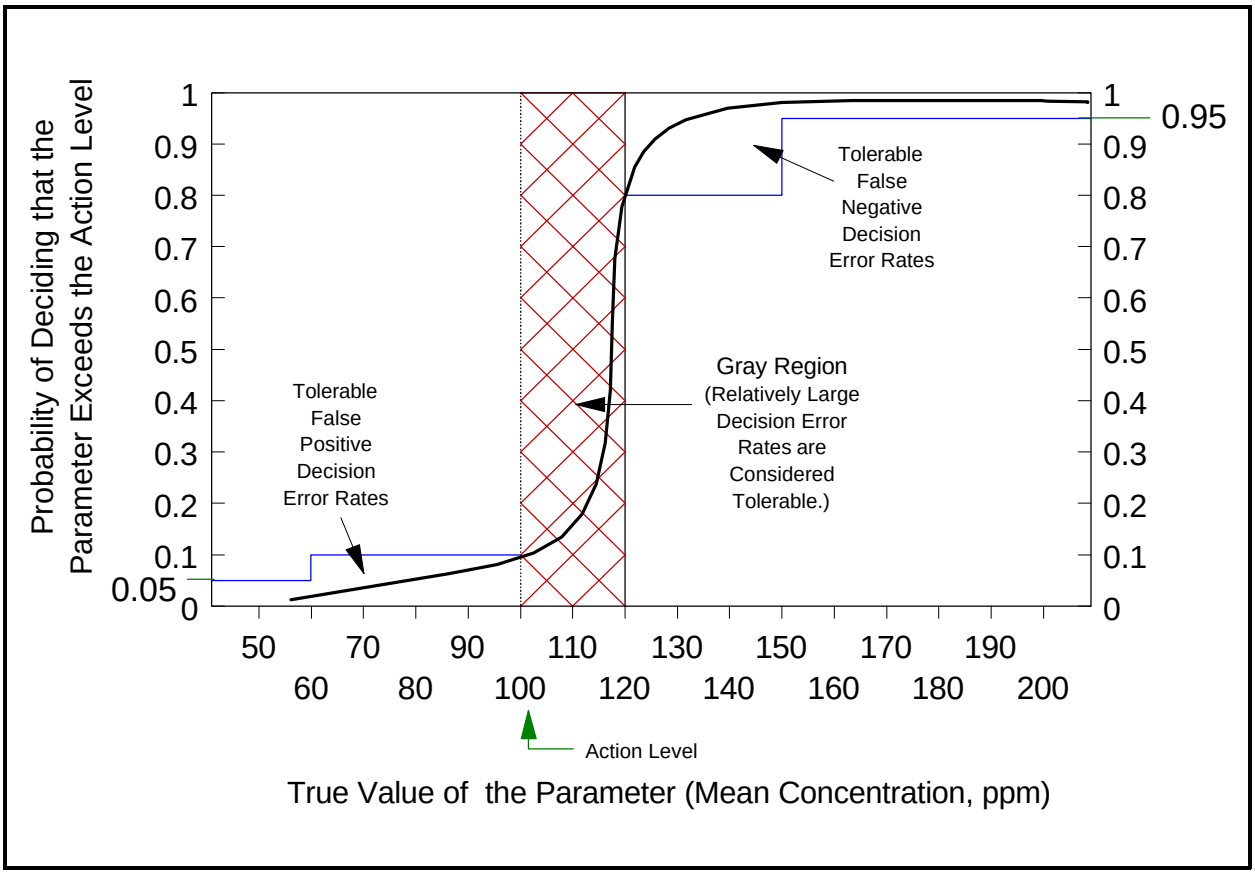


Figure 7-1. An Example of a Power Curve
Baseline Condition: Parameter is Less Than Action Level

Document the operational details and theoretical assumptions of the selected design in the sampling and analysis plan. Document the selected design's key features that must be implemented properly to allow for efficient and valid statistical interpretation of the data. It is particularly important to document the statistical assumptions that could be violated through errors in or practical constraints on field sample collection procedures or analytical methods.

After all the activities have been completed it may be helpful to enlist the advice and review of a statistician with expertise in data collection designs. This will be particularly useful if the initial data collection designs have been developed by an inexperienced statistician or an environmental scientist with limited statistical training. The experienced statistician may be able to offer innovative alternative data collection designs that may be more cost-effective or simpler to implement.

BIBLIOGRAPHY

Bates, D.J., R.O. Gilbert, N.L. Hassig, R.F. O'Brien, B.A. Pulsipher. November 1993. Decision Performance Criteria: The Driver Behind the Data Quality Objectives Process, A Statistical Introduction (Draft). Battelle Pacific Northwest Laboratory, Richland, Washington.

Cochran, W. 1977. *Sampling Techniques.* New York: John Wiley.

Desu, M.M., and D. Raghavarao. 1990. *Sample Size Methodology.* San Diego, CA: Academic Press.

Gilbert, Richard O. 1987. *Statistical Methods for Environmental Pollution Monitoring.* New York: Von Nostrand Reinhold.

Guenther, William C. 1977. *Sampling Inspection in Statistical Quality Control.* Griffin's Statistical Monographs and Courses, No. 37, London: Charles Griffin.

Guenther, William C. 1981. "Sample Size Formulas for Normal Theory T Test." *The American Statistician* . Vol. 35, No. 4.

U.S. Environmental Protection Agency. 1994. *EPA Quality System Requirements for Environmental Programs.* EPA QA/R-1.

U.S. Environmental Protection Agency. 1994. *EPA Requirements for Quality Assurance Project Plans for Environmental Data Operations.* EPA QA/R-5.

U.S. Environmental Protection Agency. 1994. *EPA Requirements for Quality Management Plans.* EPA QA/R-2.

U.S. Environmental Protection Agency. 1994. *Guidance for Data Quality Assessments.* EPA QA/G-9.

U.S. Environmental Protection Agency. 1993. *Guidance for Planning in Support of Environmental Decision Making Using the Data Quality Objectives Process* (Interim Final). Quality Assurance Management Staff.

U.S. Environmental Protection Agency. 1992. *Statistical Methods for Evaluating the Attainment of Cleanup Standards: Volume III: Reference-Based Standards for Soils and Solid Media.* EPA 230-R-94-004, Office of Policy, Planning and Evaluation.

U.S. Environmental Protection Agency. 1992. *Methods for Evaluating the Attainment of Cleanup Standards: Volume 2: Ground Water.* EPA 230-R-92-014, Office of Policy, Planning and Evaluation.

U.S. Environmental Protection Agency. 1989. *Methods for Evaluating Attainment of Cleanup Standards: Volume 1: Soils and Solid Media.* EPA 230/02-89-042, Office of Policy, Planning and Evaluation.

U.S. Environmental Protection Agency. 1986. *Development of Data Quality Objectives, Description of Stages I and II.* Quality Assurance Management Staff.

U.S. Environmental Protection Agency. April 1984. "Order 5360.1, Policy and Program Requirements to Implement the Mandatory Quality Assurance Program." Office of the Administrator.

APPENDIX A

BEYOND THE DQO PROCESS: THE QUALITY ASSURANCE PROJECT PLAN AND DATA QUALITY ASSESSMENT

Overview

This appendix explains some important QA management steps that occur after the DQO Process has been completed. The DQO Process is part of the planning phase of the data collection operation, as illustrated in Figure A-1. At the completion of the DQO Process, the planning team will have documented the project objectives and key performance requirements for the data operations in the DQOs, and will have identified a data collection design that is expected to achieve the DQOs. The data collection design and DQOs will then be used to develop the Quality Assurance Project Plan (QAPP), which provides the detailed project-specific objectives, specifications, and procedures needed to conduct a successful data collection activity. During the implementation phase of the data collection life cycle, the QAPP is executed and the data are collected. During the assessment phase, a Data Quality Assessment (DQA) is performed on the data to determine if the DQOs have been satisfied. The relationship between the DQO Process and these subsequent activities are explained in more detail below.

Quality Assurance Project Plan Development

The QAPP is a formal EPA project document that specifies the operational procedures and quality assurance/quality control (QA/QC) requirements for obtaining environmental data of sufficient quantity and quality to satisfy the project objectives. The QAPP is an important part of the EPA Quality System, and is required for all data collection activities that generate data for use by EPA. [1] The QAPP contains information on project management, measurement and data acquisition, assessment and oversight, and data validation and useability.

The DQO Process may be viewed as a preliminary step in the QAPP development process, as shown in the right half of Figure A-1. DQOs are a formal element of the QAPP, yet information contained in the DQOs relates indirectly to many other elements of the QAPP. In essence, the DQOs provide statements about the expectations and requirements of the data *user* (such as a decision maker). In the QAPP, these requirements are translated into measurement performance specifications and QA/QC procedures for the data *suppliers*, to

[1] U.S. Environmental Protection Agency. *EPA Requirements for Quality Assurance Project Plans for Environmental Data Operations*. EPA QA/R-5, 1994.

provide them with the information they need to satisfy the data user's needs. Thus, the QAPP integrates the DQOs, the data collection design, and QA/QC procedures into a coherent plan to be used for collecting defensible data that are of known quality and that is adequate for the data's intended use.

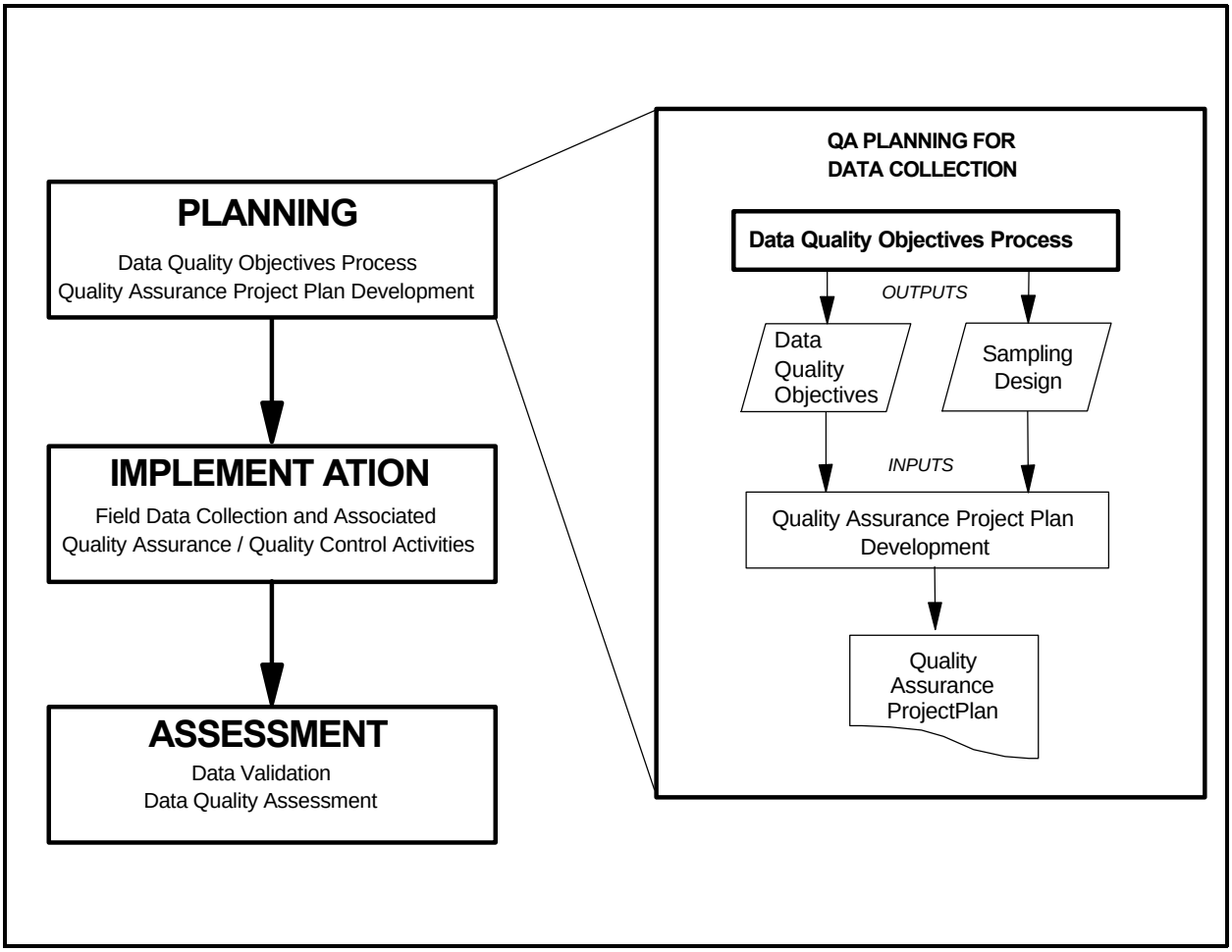


Figure A-1. QA Planning and the Data Life Cycle.

The QAPP is structured into three sections: the Introduction, Requirements, and Elements. The Elements are the individual requirements of the QAPP that are listed separately. The Elements are grouped into four categories: Project Management, Measurement/Data Acquisition, Assessment/Oversight, and Data Validation and Useability. The outputs of the DQO Process will provide information or inputs to elements in the Project Management section.

Data Quality Assessment

After the environmental data have been collected and validated in accordance with the QAPP, the data must be evaluated to determine whether the DQOs have been satisfied. EPA has developed guidance on Data Quality Assessment (DQA) to address this need (see Figure A-2).[2] DQA involves the application of statistical tools to determine:

- whether the data meet the assumptions under which the DQOs and the data collection design were developed; and

- whether the total error in the data is small enough to allow the decision maker to use the data to support the decision within the tolerable decision error rates expressed by the decision maker.

It is important to verify the assumptions that underlie the DQOs and the data collection design so that statistical calculations performed on the data relate to the decision maker's problem in a scientifically valid and meaningful way. If the data do not support the underlying assumptions, then corrective actions must be taken to ensure that the decision maker's needs are met. Corrective action may be as simple as selecting a different statistical approach that relies on assumptions that are in better agreement with the data, or it may be as complicated as revising the data collection design and collecting new data that satisfy the decision maker's needs.

If the data support the conclusion that the assumptions are reasonable, then the next step of a DQA can be taken, which is to evaluate how well the data support the actual decision. This is determined by evaluating whether the data conclusively demonstrate that the population parameter of interest is above (or below) the action level. In essence, this is where the decision maker applies a more specific or "operational" version of the decision rule that was developed in Step 5 of the DQO Process (in statistical terms, this is performing the hypothesis test). Whether the data are "conclusive" or not will depend on the estimated value and variability of the statistical parameter in relation to the gray region and the limits on decision errors that were specified in Step 6 of the DQO Process. If the decision cannot be made in accordance with the decision maker's DQOs, then the decision maker must decide whether to take corrective actions (such as collect more or better data), relax the DQOs, or make a decision anyway, without the benefit of adequate data.

[2] U. S. Environmental Protection Agency. *Guidance for Data Quality Assessments* . EPA QA/G-9, 1994.

Thus, DQA is an essential element of the data operation because it helps to bring closure to the issues raised at the beginning of the DQO Process. By verifying the assumptions required to draw scientifically valid and meaningful conclusions from the data, and by implementing the decision rule, DQA helps the decision maker determine whether the DQOs have been satisfied.

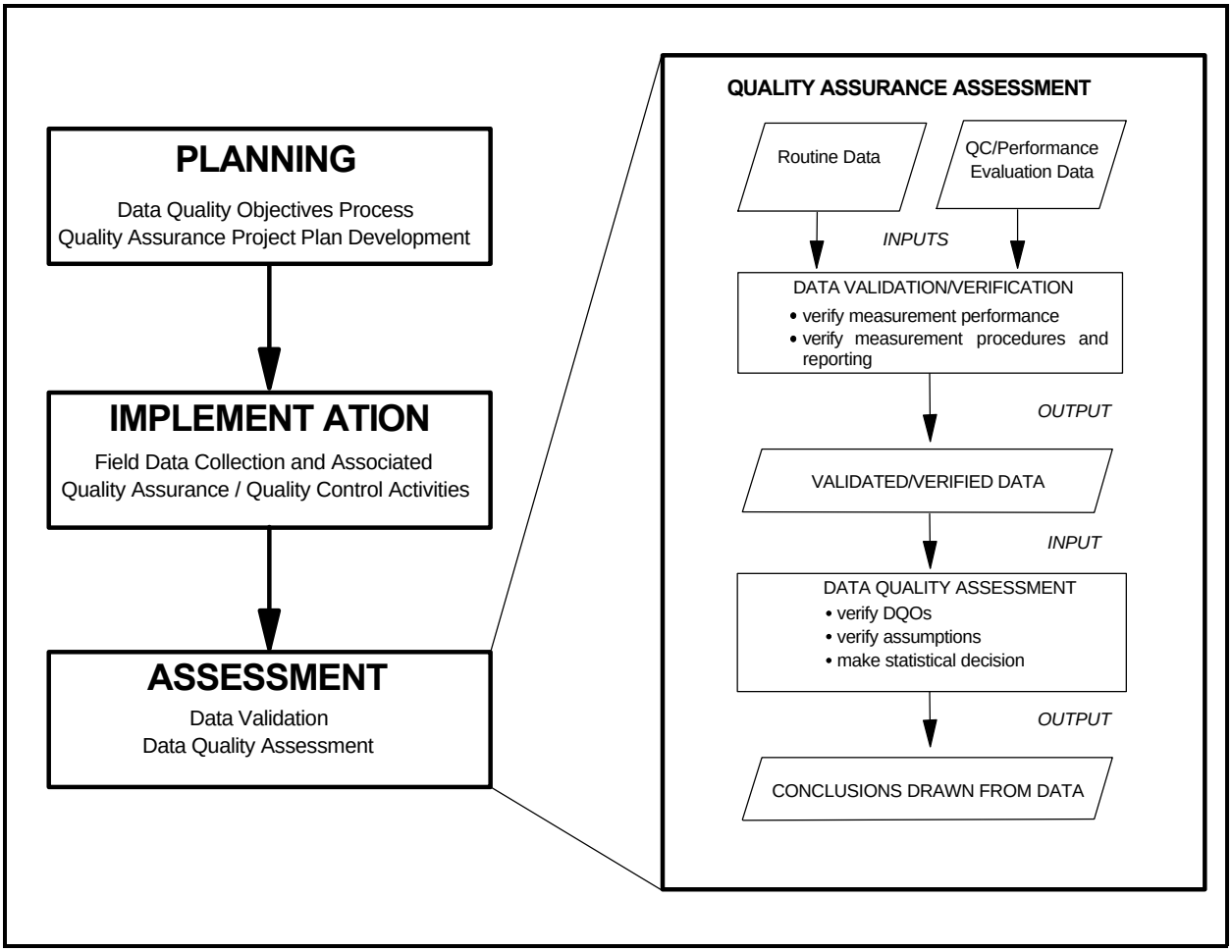


Figure A-2. Quality Assurance Assessment .

APPENDIX B
DQO CASE STUDY: CADMIUM-CONTAMINATED FLY ASH WASTE

Introduction

This appendix presents a functional, but realistic example of the DQO outputs for a decision that could be made within the Resource Conservation and Recovery Act (RCRA) hazardous waste management program. The example is intended to illustrate the types of outputs that are common to the DQO Process. It is not intended, however, to represent the policy of the RCRA program for actual situations that may be similar to the example. Please consult with a knowledgeable representative within the RCRA program office about the current policy for making waste classification decisions for fly ash or other types of hazardous waste.

The case study has been chosen because it is simple and straightforward, and because the outputs are uncomplicated. Although some of the outputs from this example may seem intuitive, this is not often the case in practice. For many studies, the DQO Process is complicated and thought-provoking. Even so, some steps will require more effort than others. Keep in mind that all of the steps in the DQO Process are necessary to develop a data collection design. Once the first six steps have been completed and thoroughly thought-out, then development of the most resource-effective data collection design can proceed.

Background

A waste incineration facility located in the Midwest routinely removes fly ash from its flue gas scrubber system and disposes of it in a local sanitary landfill. Previously it was determined that the ash was not hazardous according to RCRA program regulations. The incinerator, however, recently began treating a new waste stream. The representatives of the incineration company are concerned that the waste fly ash could now contain hazardous levels of cadmium from the new waste sources. They have decided to test the ash to determine whether it should be sent to a hazardous waste landfill or continue to be sent to the municipal landfill. They have decided to employ the DQO Process to help guide their decision making.

Cadmium is primarily used as corrosion protection on metal parts of cars and electrical appliances. It is also used in some batteries. Cadmium and cadmium salts have toxic effects for humans through both ingestion and inhalation exposures. Ingestion exposure usually causes mild to severe irritation of the gastrointestinal tract, which can be caused by concentrations as low as 0.1 mg/kg/day. Chronic (long-term) inhalation exposure can cause increased incidence of emphysema and chronic bronchitis, as well as kidney damage.

Under the current Code of Federal Regulations, 40 CFR, Part 261, a solid waste can be considered "hazardous" if it meets specific criteria of ignitability, corrosivity, reactivity, and toxicity. One method that is used to determine if a solid substance, such as fly ash, meets the criteria for toxicity under the RCRA program regulations is to test a "representative sample" of the waste and perform a Toxicity Characteristic Leaching Procedure (TCLP) described in 40 CFR, Pt. 261, App. II. During this process, the solid fly ash will be "extracted" using an acid solution. The extraction liquid (the TCLP leachate) will then be subjected to tests for specific metals and compounds. For this example, the only concern is with the concentration of cadmium in the leachate. The primary benefit of the DQO Process will be to establish the data collection design needed to determine if the waste is hazardous under RCRA regulations within tolerable decision error rates.

As a precursor to the DQO Process, the incineration company has conducted a pilot study of the fly ash to determine the variability in the concentration of cadmium between loads of ash leaving the facility. They have determined that each load is fairly homogeneous. There is a high variability between loads, however, due to the nature of the waste stream. Most of the fly ash produced is not hazardous and may be disposed of in a sanitary landfill. Thus, the company has decided that testing each individual waste load before it leaves the facility would be the most economical. Then they could send loads of ash that exceeded the regulated standards to the higher cost RCRA landfills and continue to send the others to the sanitary landfill.

DQO Development

The following is a representative example of the output from each step of the DQO Process for the fly ash toxicity problem.

State the Problem — a description of the problem(s) and specifications of available resources and relevant deadlines for the study.

(1) *Identify the members of the planning team* — The members of the planning team will include the incineration plant manager, a plant engineer, a statistician, a quality assurance officer, an EPA representative who works within the RCRA program, and a chemist with sampling experience.

(2) *Identify the primary decision maker* — There will not be a primary decision maker; decisions will be made by consensus.

(3) *Develop a concise description of the problem* — The problem is to determine which loads should be sent to a RCRA landfill versus a sanitary landfill.

(4) *Specify available resources and relevant deadlines for the study* — While the project will not by constrained by cost, the waste generator (the incineration company) wishes to hold sampling costs below $2,500. They have also requested that the waste testing be completed within 1 week for each container load.

Identify the Decision — a statement of the decision that will use environmental data and the actions that could result from this decision.

(1) *Identify the principal study question* — Is the fly ash waste considered hazardous under RCRA regulations?

(2) *Define alternative actions that could result from resolution of the principal study question* —

(a) The waste fly ash could be disposed of in a RCRA landfill.

(b) The waste fly ash could be disposed of in a sanitary landfill.

(3) *Combine the principal study question and the alternative actions into a decision statement* — Decide whether or not the fly ash waste is hazardous under RCRA and requires special disposal procedures.

(4) *Organize multiple decisions* — Only one decision is being evaluated.

Identify the Inputs to the Decision — a list of the environmental variables or characteristics that will be measured and other information needed to resolve the decision statement.

(1) *Identify the information that will be required to resolve the decision statement* — To resolve the decision statement, the planning team needs to obtain measurements of the cadmium concentration in the leachate resulting from TCLP extraction.

(2) *Determine the sources for each item of information identified* — The fly ash should be tested to determine if it meets RCRA regulated standards for toxicity using the test methods listed in 40 CFR, Pt. 261, App. II. Existing pilot study data provide information about variability, but do not provide enough information to resolve the decision statement.

(3) *Identify the information that is needed to establish the action level* — The action level will be based on the RCRA regulations for cadmium in TCLP leachate.

(4) *Confirm that appropriate measurement methods exist to provide the necessary data* — Cadmium can be measured in the leachate according to the method specified in 40 CFR, Pt. 261, App. II. The detection limit is below the standard.

Define the Boundaries of the Study — a detailed description of the spatial and temporal boundaries of the problem, characteristics that define the population of interest, and any practical considerations for the study.

(1) *Specify the characteristics that define the population of interest* — Fly ash waste from the hazardous waste incinerator will be analyzed. The fly ash should not be mixed with any other constituents except water that is used for dust control. Each load of ash should fill at least 70% of the waste trailer. In cases where the trailer is filled less than 70%, the trailer must wait on-site until more ash is produced and fills the trailer to the appropriate capacity.

(2) *Define the spatial boundary of the decision statement* —

(a) *Define the geographic area to which the decision statement applies* . Decisions will apply to each container load of fly ash waste.

(b) *When appropriate, divide the population into strata that have relatively homogeneous characteristics.* Stratification is not necessary since the waste ash is relatively homogeneous within each container.

(3) *Define the temporal boundary of the decision statement* —

(a) *Determine the timeframe to which the decision statement applies.* It will be assumed that the sampling data represent both the current and future concentration of cadmium within the ash.

(b) *Determine when to collect data.* Contained in the trucks, the waste does not pose a threat to humans or the environment. Additionally, since the fly ash is not subject to change, disintegration, or alteration, the decision about the waste characteristics does not warrant any temporal constraints. To expedite decision making, however, the planning team has placed deadlines on sampling and reporting. The fly ash waste will be tested within 48 hours of being loaded onto waste hauling trailers. The analytical results from each sampling round should be completed and reported within 5 working days of sampling. Until analysis is complete, the trailer cannot be used.

(4) *Define the scale of decision making* — The scale of decision making will be each container of waste ash.

(5) *Identify practical constraints on data collection* — The most important practical consideration that could interfere with the study is the ability to take samples from the fly ash that is stored in waste hauling trailers. Although the trailers have open access, special procedures and methods will have to be implemented for the samples to be representative of the entire depth of the ash. It has been suggested that core samples may be one practical solution to this problem. To get additional samples from each truck and to minimize the cost, compositing of core samples has been suggested.

Develop a Decision Rule — to define the parameter of interest, specify the action level and integrate previous DQO outputs into a single statement that describes a logical basis for choosing among alternative actions.

(1) *Specify the statistical parameter that characterizes the population of interest* — The planning team is interested in the true mean concentration of cadmium in the TCLP leachate for each container.

(2) *Specify the action level for the study* — The action level for the decision will be the RCRA regulatory standard for cadmium of 1.0 mg/L in the TCLP leachate.

(3) *Develop a decision rule (an "if...then..." statement)* — If the mean concentration of cadmium from the fly ash leachate in each container load is greater than 1.0 mg/L (using the TCLP method as defined in 40 CFR 261), then the waste will be considered hazardous and will be disposed of at a RCRA landfill. If the mean concentration of cadmium from the fly ash waste leachate is less than 1.0 mg/L (using the TCLP method as defined in 40 CFR 261), then the waste will be considered non-hazardous and will be disposed of in a sanitary landfill.

Specify Tolerable Limits on Decision Errors — the decision maker's tolerable decision error rates based on a consideration of the consequences of making a decision error.

(1) *Determine the possible range of the parameter of interest* — From analysis of records of similar studies of cadmium in environmental matrices, the range of the cadmium concentrations is expected to be from 0-2 mg/L. Therefore the mean concentration is expected to be between 0-2 mg/L for this investigation.

(2) *Identify the decision errors and choose the null hypothesis* —

(a) *Define both types of decision errors and establish the true state of nature for each decision error.* The planning team has determined that the two decision errors are (I) deciding that the waste is hazardous when it truly is not, and (ii) deciding that the waste is not hazardous when it truly is.

The true state of nature for decision error (i) is that the waste is not hazardous.

The true state of nature for decision error (ii) is that the waste is hazardous.

(b) *Specify and evaluate the potential consequences of each decision error.*

The consequences of deciding that the waste is hazardous when it truly is not will be that the incinerator company will have to pay more for the disposal of the fly ash at a RCRA facility than at a sanitary landfill.

The consequences of deciding that the waste is not hazardous when it truly is will be that the incinerator company will dispose of the waste in a sanitary landfill which could possibly endanger human health and the environment. In this situation, they may also be liable for future damages and environmental cleanup costs. Additionally, the reputation of the incinerator company may be compromised, jeopardizing its future profitability.

(c) *Establish which decision error has more severe consequences near the action level.* The planning team has concluded that decision error (ii) has the more severe consequences near the action level since the risk of jeopardizing human health outweighs the consequences of having to pay more for disposal.

(d) *Define the null hypothesis (baseline condition) and the alternative hypothesis and assign the terms "false positive" and "false negative" to the appropriate decision error.*

The baseline condition or null hypothesis (H_o) is "the waste is hazardous."

The alternative hypothesis (H_a) is "the waste is not hazardous."

The false positive decision error occurs when the null hypothesis is rejected when it is true. For this example, the false positive decision error occurs when the decision maker decides the waste is not hazardous when it truly is hazardous. The false negative decision error occurs when the null hypothesis is not rejected when it is false. For this example, the false negative decision error occurs when the decision maker decides that the waste is hazardous when it truly is not hazardous.

(3) *Specify a range of possible values of the parameter of interest where the consequences of decision errors are relatively minor (gray region)* — The gray region is the area adjacent to the action level where the planning team feels that the consequences of a false negative decision error are minimal. To decide how to set the width of the gray region, the planning team must decide where the consequences of a false negative decision error are minimal. Below the action level, even if the concentration of cadmium were very close to the action level, the monetary costs of disposing of the waste at a RCRA facility are the same as if the waste had a much lower concentration of cadmium. Clearly <u>any</u> false negative decision error (to the left of the action level) will cause the incinerator company and their customers to bear the cost of unnecessary expense (i.e., sending nonhazardous waste to a RCRA facility). The planning team, however, also realizes that they must define a reasonable gray region that balances the cost of sampling with risk to human health and the environment and the ability of measurement instruments to detect differences. Therefore the planning team has specified a width of 0.25 mg/L for this gray region based on their preferences to detect decision errors at a concentration of 0.75 mg/L (see Figure B-1).

(4) *Assign probability values to points above and below the action level that reflect the tolerable probability for the occurrence of decision errors* — For this example, RCRA regulations allow a 5% decision error rate at the action level. The planning team has set the decision error rate to 5% from 1 mg/L to 1.5 mg/L and 1% from 1.5 mg/L to 2 mg/L as the consequences of health effects from the waste disposed of in the municipal landfill increase. On the other side of the action level, the planning team has set the tolerable probability of making a false negative error at 20% when the true parameter is from 0.25 to 0.75 mg/L and 10% when it is below 0.25 mg/L, based on both experience and an economic analysis that shows that these decision error rates are reasonable to balance the cost of sampling versus the consequence of sending clean ash to the RCRA facility (see Figure B-1).

Optimize the Design — select the most resource-effective data collection and analysis design for generating data that are expected to satisfy the DQOs. Optimizing the design is the one step of the DQO Process that will most likely be completed by a statistician or someone who has data collection design expertise. Using the case study as an example, the following section has been included to provide the reader with a background on the overall process that the statistician might follow to optimize the final data collection design.

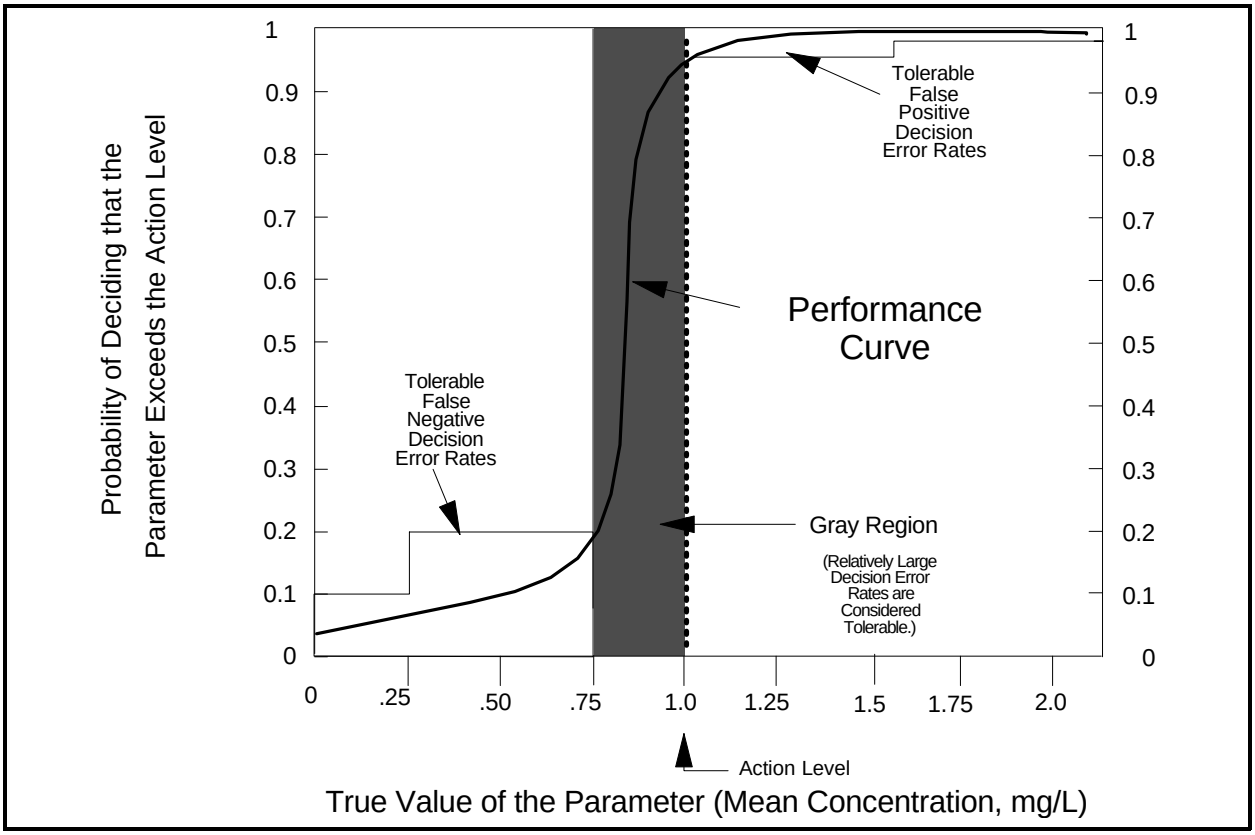


Figure B-1. Decision Performance Goal Diagram for Cadmium Compliance Testing Baseline Condition: Mean Exceeds Action Level

Overview

Developing a data collection design requires an understanding of the sampled medium and the information that was generated in previous DQO steps. The statistician's job is to review the background information, determine the appropriate statistical application to adequately solve the problem, and develop one or more appropriate data collection designs. Once this is complete, the statistician will compare the cost and performance of the different data collection designs. This process can be broken down into five distinct steps:

(1) Review the DQO outputs and existing environmental data.

(2) Develop general data collection design alternatives.

(3) For each data collection design alternative, select the optimal sample size that satisfies the DQOs.

(4) Select the most resource-effective data collection design that satisfies all of the DQOs.

(5) Document the operational details and theoretical assumptions of the selected design in the sampling and analysis plan.

Activities

(1) *Review the DQO outputs and existing environmental data* — Because the statistician has participated in the DQO Process for this problem, there is no need to review the DQO outputs further. The only existing data relevant to this problem are the pilot study data. Based on the pilot study, the incineration company has determined that each load of ash is fairly homogeneous, and has estimated the standard deviation in the concentration of cadmium within loads of ash to be 0.6 mg/L.

(2) *Develop general data collection design alternatives* — Generally, the design alternatives are based on a combination of design objectives developed in previous DQO Process steps and knowledge of statistical parameters about the medium or contaminant. Below are four examples of possible designs that could apply to the case study:

(a) Simple Random Sampling — The simplest type of probability sample is the simple random sample. With this type of sampling, every possible point in the sampling medium has an equal chance of being selected. Simple random samples are used primarily when the variability of the medium is relatively small and the cost of analysis is relatively inexpensive. Simple random sample locations are generally developed through the use of a random number table or through computer generation of pseudo-random numbers.

In the case of the cadmium-contaminated ash, a fixed number of random grab samples would be selected and analyzed. Standard lab splits and QC samples would be taken according to standard procedures for the RCRA program. Each sample would be chosen randomly in three dimensions. A Student's t-test is suggested as a possible method for testing the statistical hypothesis.

(b) Composite Simple Random Sampling (composite sampling) — This type of sampling consists of taking multiple samples, physically combining (compositing) them, and drawing one or more subsamples for analysis. Composite samples are taken primarily when an average concentration is sought and there is no need to detect peak concentrations. By compositing the samples, researchers are able to sample a larger number of locations than if compositing was not used, while reducing the cost of analysis by combining several samples.

In the case of the cadmium-contaminated ash, a fixed number of random grab samples would be taken and composited. The number of grab samples contained in a composite sample (g) is also fixed. To determine sampling locations within the composite, a container would be divided into "g" equal-volume strata and samples would be chosen randomly within each strata. The use of strata ensure full coverage of each container. Standard lab splits and QC samples would be taken according to standard procedures for the RCRA program. A Student's t-test is suggested as the possible method for testing the statistical hypothesis.

(c) Sequential Sampling — Sequential sampling involves making several rounds of sampling and analysis. A statistical test is performed after each analysis to arrive at one of three possible decisions: reject the null hypothesis, accept the null hypothesis,[1] or collect more samples. This strategy is applicable when sampling and/or analysis costs are high, when information concerning sampling and/or measurement variability is lacking, when the waste and site characteristics of interest are stable over the timeframe of the sampling effort, and when the objective of the sampling is to test a single hypothesis. By taking samples in sequence, the researcher can hold down the cost of sampling and analysis.

In the case of the cadmium-contaminated ash, a sequential probability sample could be performed. The samples in each sampling round would be chosen randomly in three dimensions. If the decision to stop sampling has not been made before the number of samples required for the simple random sample are taken, sampling would stop at this point and the simple random sample test would be performed. Standard laboratory splits and QC samples would be taken according to standard procedures for the RCRA program. An approximate ratio test is

[1]Decide not to reject the null based on tolerable decision error limits.

suggested after each round of sampling is complete to decide whether or not to conclude that the waste is hazardous or to continue sampling.

(d) Stratified Random Sampling — Stratified sampling involves dividing the study area into two or more non-overlapping subsets (strata) which cover the entire volume to be sampled. These strata should be defined so that physical samples within a stratum are more similar to each other than to samples from other strata. Sampling depth, concentration level, previous cleanup attempts, and confounding contaminants can be used as the basis for creating strata. Once the strata have been defined, each stratum is then sampled separately using one of the above designs. Stratification is often used to ensure that important areas of a site are represented in the sample. In addition, a stratified random sample may provide more precise estimates of contaminant levels than those obtained from a simple random sample. Even with imperfect information, a stratified sample can be more resource-effective.

Since the incineration company has already determined that each load of ash is fairly homogeneous, stratification does not have any advantages over a simple random sample. In addition, since the company has decided to test each waste load individually before it leaves the facility, stratifying each waste load would be difficult and unnecessary. Therefore, this data collection design will not be considered further.

(3) *For each data collection design alternative, select the optimal sample size that satisfies the DQOs* — The formula for determining the sample size (number of samples to be collected) is chosen based on the hypothesis test and data collection design. Standard formulas can be found in several references, including:

- Cochran, W. 1977. *Sampling Techniques.* New York: John Wiley.
- Desu, M.M., and D. Raghavarao. 1990. *Sample Size Methodology* . San Diego, CA: Academic Press.
- Gilbert, Richard O. 1987. *Statistical Methods for Environmental Pollution Monitoring*. New York: Van Nostrand Reinhold.
- U.S. Environmental Protection Agency. 1989. *Methods for Evaluating the Attainment of Cleanup Standards: Volume 1: Soils and Solid Media.* EPA 230/02-89-042, Office of Policy, Planning and Evaluation.
- U.S. Environmental Protection Agency. 1992. *Methods for Evaluating the Attainment of Cleanup Standards: Volume 2: Ground Water.* EPA 230-R-92-014, Office of Policy, Planning and Evaluation.

- U.S. Environmental Protection Agency. 1994. *Statistical Methods for Evaluating the Attainment of Clean-up Standards: Volume 3: Reference-Based Standards for Soils and Solid Media.* EPA 230-R-94-004. Office of Policy, Planning and Evalutaion.

These formulas can also be found in many basic statistics textbooks. Different formulas are necessary for each data collection design, for each parameter, and for each statistical test. These formulas are generally a function of α; β; the detection difference, Δ (delta); and the standard deviation, σ. The detection difference, Δ, is defined to be the difference between the action level (AL) and the other bound of the gray region (U); i.e., Δ = AL - U. In this case the standard deviation was derived from pilot data under approximately the same conditions as expected for the real facility.

For example, a formula for computing the sample size necessary to meet the DQO constraints for comparing a mean against a regulatory threshold, when a simple random sample is selected, is:

$$n = \frac{\hat{\sigma}^2 (z_{1-\beta} + z_{1-\alpha})^2}{\Delta^2} + (0.5) z_{1-\alpha}^2$$

where:

$\hat{\sigma}^2$ = estimated variance in measurements (from pilot study)
n = number of samples required,
z_p = the pth percentile of the standard normal distribution (from standard statistical tables), and
Δ = U - AL

<u>Simple Random Sample</u> — Using the formula above, it was determined that 37 samples are necessary to achieve the specified limits on decision errors. This sampling plan satisfies all the DQOs including budget, schedule, and practical constraints.

<u>Composite Sampling</u> — To determine sample sizes for a composite sample, it is necessary to compute the number of composites samples, n; the number of samples, g, within each composite; and the number of subsamples, m, to be measured for each composite. Usually m=1; however, since this design is to be used repeatedly, it is suggested that two subsamples from each composite sample be measured to estimate composite variability, which can then be used to re-optimize the number of samples m and g.

For a composite sample, with random sample locations, it has been determined that eight composite samples of eight samples each are sufficient to meet the limits on decision errors that have been specified. This design is more than sufficient to

achieve the specified limits on decision errors and satisfies all the DQOs including budget, schedule, and practical constraints.

Sequential Sampling — For the purposes of comparing costs, the average number of samples in a sequential sampling design can be estimated, but these estimates are only averages. The average sample size for concluding that the waste is hazardous is 16 and the average sample size for concluding the waste is not hazardous is 22. The average sizes are different because the burden of proof is placed on disproving the null hypothesis, thus, more samples on average are required to prove that the alternative hypothesis (the waste is not hazardous) is true. However, these sample sizes are only averages. In some cases, fewer samples are necessary; in others, more may be necessary. This sampling plan satisfies all the DQOs including budget, schedule, and practical constraints.

(4) *Select the most resource-effective data collection design that satisfies the DQOs* — Compare the overall efficiency of each model and choose the one that will solve the problem most effectively.

Cost Estimates for Each Design

First, the costs for the three designs alternatives will be evaluated:

Simple Random Sampling — A simple random sampling scheme can be implemented for each load of fly ash by first generating three-dimensional random sampling points. This can most easily be done by using a computer. Samples can then be taken using a special grab sampler which will be forced into the ash, opened to take the sample, then closed and removed. The difficulty with this type of sampling scheme is measuring sampling locations in three dimensions, and it may be difficult to gain access to the correct sampling locations.

This design meets all of the required limits on decision errors. The cost of this design is calculated based on the assumed cost of selecting a sample ($10), and the cost of analyzing a sample ($150). Since 37 samples need to be taken and analyzed, the cost of this design is:

$$\begin{aligned} \text{Cost}_{SRS} &= 37 \times \$10 + 37 \times \$150 \\ &= \$370 + \$5550 = \$5920 \end{aligned}$$

Composite Sampling — Composite sampling will be performed similarly to simple random sampling except that after eight random samples are collected (one from each stratum), they will be combined and homogenized. Two sample aliquots for analysis will then be drawn from the homogenized mixture. This process will be repeated eight times.

This design meets all of the required limits on decision errors. The cost of this design is based on the cost of selecting ($10) and analyzing ($150) a sample. Eight samples will be used to make each composite sample for a sampling cost of $80; two subsamples will be analyzed from this composite sample for a cost of $300. Therefore, each composite sample will cost $380. The total cost of this design is:

$$Cost_{CS} = 8 \times \$380 = \$3040.$$

Sequential Sampling — Sequential sampling will be performed similarly to random sampling. The primary difference is that the ultimate number of samples will be determined by the results of one or more sampling rounds.

This design has the potential to reduce the number of samples required in the simple random sampling design and still meet the decision error limits. The average costs of the two decisions are used below:

The ash is hazardous:	16 × ($160) = $2,560
The ash is non-hazardous:	22 × ($160) = $3,520

To determine the expected cost, estimate the number of loads of ash that should be sent to a RCRA facility versus the number of loads that can be sent to a municipal facility. Suppose 25% of the loads are hazardous and should be sent to a RCRA facility. Then the expected cost (EC_{SS}) of this design should be

$$EC_{SS} = 0.25 \times (\text{cost of sampling when ash is hazardous}) + (0.75 \times \text{cost of sampling when ash is non-hazardous})$$

$$= 0.25 \times (\$2{,}560) + 0.75 \times (\$3{,}520) = \$\ 3{,}280$$

Selection of a Design

Because the simple random sampling design requires that many samples be taken and analyzed, it is inefficient for the goals of this study. Sampling will cost almost as much to determine whether the waste is hazardous or nonhazardous as it would cost to send all the waste to a RCRA hazardous waste landfill. Therefore, this decision is not resource-effective.

The sequential data collection design is more resource-effective than the simple random sampling design. The potential savings over sending all waste to a RCRA hazardous waste facility is $6,750 - $3,280 = $3,470. The site owner has expressed disapproval for this sampling plan because of the time it may take before a decision can be made. If the ash was not homogeneous within a container, however, this data collection design may be the design of choice.

The composite sample design is the best option. It is the most resource-effective design and requires the least amount of time to implement. In addition, the use of strata ensures full coverage of each container. It is recommended that each of the eight composite samples have two subsamples analyzed. In the future, after sufficient data have been collected to estimate the variability within each composite sample, it may be possible to reduce the number of samples that will be necessary to make a decision about the waste contents.

(5) *Document the operational details and theoretical assumptions of the selected design in the sampling and analysis plan —* A composite sample design should be used to determine whether each container of ash should be sent to a RCRA landfill or to a municipal landfill. Eight composite samples, consisting of eight grab samples, should be taken from each container and two subsamples from each composite should be analyzed at the laboratory. To form the composite samples, the containers will be divided into eight strata of equal size and one grab sample will be taken randomly within each stratum and composited. Sample locations will be generated randomly using computer-generated random numbers. The model assumes that the variability within a composite sample is negligible. Data from the subsamples can be used to test this assumption and make corrections to the model.

Beyond the DQO Process - Evaluation of the Design using the DQA Process

For this study, the data were collected using the composite sampling design. Once the samples were collected and analyzed, the data were evaluated statistically and scientifically using the DQA Process to inspect for anomalies, confirm that the model assumptions were correct, select a statistical test, and verify that the test assumptions such as distribution and independence can be met. For this study, a t-test satisfied the DQOs, and inspection of the data indicated that there was no reason to believe that the data were not normally distributed or that there was correlation between data points. It was also verified that the within-composite variability was negligible.

After three weeks of sampling, approximately 30% of the waste loads leaving the incinerator were found to have hazardous concentrations of cadmium in the fly ash. The data collection design was determined to be cost-effective because the combined cost of sampling and disposal was less than sending all of the waste to a RCRA landfill.

APPENDIX C

DERIVATION OF SAMPLE SIZE FORMULA FOR TESTING MEAN OF NORMAL DISTRIBUTION VERSUS AN ACTION LEVEL

This appendix presents a mathematical derivation of the sample size formula used in the DQO example of Appendix B.

Let $X_1, X_2, ..., X_n$ denote a random sample from a normal distribution with unknown mean μ and known standard deviation σ. The decision maker wishes to test the null hypothesis $H_o: \mu = AL$ versus the alternative $H_A: \mu > AL$, where AL, the action level, is some prescribed constant; the false positive (Type I) error rate is α (i.e., probability of rejecting H_o when $\mu = AL$ is α); and for some fixed constant $U > AL$ (where U is the other bound of the gray region), the false negative (Type II) error rate is β (i.e., probability of rejecting H_o when $\mu = U$ is $1 - \beta$). Let $\bar{X}$ denote the sample mean of the Xs. It will have a normal distribution with mean μ and variance σ^2/n. Hence the random variable Z defined by

$$Z = \frac{(\bar{X} - \mu)\sqrt{n}}{\sigma} \tag{1}$$

will have a standard normal distribution (mean 0, variance 1). Let z_p denote the pth percentile of the standard normal distribution (available in most statistics books). Recall that the symmetry of the standard normal distribution implies that $z_p = -z_{1-P}$.

Case 1: Standard Deviation Known

The test of H_o versus H_A is performed by calculating the test statistic

$$T = \frac{(\bar{X} - AL)\sqrt{n}}{\sigma}. \tag{2}$$

If $T > z_{1-\alpha}$, the null hypothesis is rejected.

Note that

$$T = \frac{[(\bar{X} - \mu) + (\mu - AL)]\sqrt{n}}{\sigma} = Z + \epsilon(\mu) \tag{3}$$

where

$$\epsilon(\mu) = \frac{(\mu - AL)\sqrt{n}}{\sigma}. \tag{4}$$

Thus T has a normal distribution with mean $\epsilon(\mu)$ and variance 1, and in particular, $\epsilon(AL) = 0$. Hence the Type I error rate is

$$Pr[rejecting\ H_0|H_0] = Pr[T > z_{1-\alpha}|\mu = AL] = Pr[Z + \epsilon(AL) > z_{1-\alpha}] = Pr[Z > z_{1-\alpha}] = \alpha. \tag{5}$$

Achieving the desired power $1 - \beta$ when $\mu = U$ requires that

$$Pr[reject\ H_0|\mu = U] = 1 - \beta.$$

Therefore,

$$Pr[T \le z_{1-\alpha}|\mu = U] = Pr[Z + \epsilon(U) \le z_{1-\alpha}] = Pr[Z \le z_{1-a} - \epsilon(U)] = \beta \tag{6}$$

This implies

$$z_{1-\alpha} - \epsilon(U) = z_\beta,$$

or

$$z_{1-\alpha} - \frac{(U - AL)\sqrt{n}}{\sigma} = -z_{1-\beta}.$$

Let $\Delta = U - AL$, then rearrange terms to obtain

$$\left(z_{1-\alpha} + z_{1-\beta}\right)\sigma = \Delta\sqrt{n},$$

or

$$n = \frac{\left(z_{1-\alpha} + z_{1-\beta}\right)^2 \sigma^2}{\Delta^2}. \tag{7}$$

Case 2: Standard Deviation Unknown

If the standard deviation σ is unknown, then a test statistic like (2) is used except that σ is replaced by S, an estimate of the standard deviation calculated from the observed Xs. Such a statistic has a noncentral t distribution rather than a normal distribution, and the n computed by the above formula will be too small, although for large n (say n>40), the approximation is good. The particular noncentral t distribution involved in the calculation depends on the sample size n. Thus, determining the exact minimum n that will satisfy the

Type I and Type II error rate conditions requires an iterative approach in which the noncentral t probabilities are calculated for various n values until the desired properties are achieved. With the aid of a computer routine for calculating such probabilities, this is not difficult; however, a simple and direct approach for approximating n is available. This approach, whose derivation is described in the paragraphs below, leads to the following approximate but very accurate formula for n:

$$n = \frac{\left(z_{1-\alpha} + z_{1-\beta}\right)^2 \sigma^2}{\Delta^2} + \frac{1}{2} z_{1-\alpha}^2. \tag{8}$$

In practice, since σ is unknown, a prior estimate of it must be used in (8).

The approach is based on the assumption that, for a given constant k, the statistic X-kS is approximately normal with mean $\mu - k\sigma$ and variance $(\sigma^2/n)(1+k^2/2)$ (Guenther, 1977 and 1981).

The classical t-test rejects H_o when $T = [(\bar{X} - AL)/(S/\sqrt{n})] > D$, where the critical value D is chosen to achieve the desired Type I error rate α. The inequality can be rearranged as $\bar{X} - kS > AL$, where $k = D/\sqrt{n}$. Subtracting the mean (assuming H_o) and dividing by the standard deviation of $\bar{X} - kS$ on both sides of the inequality leads to

$$\frac{\bar{X} - kS - (AL - k\sigma)}{\left(\sigma/\sqrt{n}\right)\sqrt{1+k^2/2}} > \frac{AL - (AL - k\sigma)}{\left(\sigma/\sqrt{n}\right)\sqrt{1+k^2/2}} = \frac{k\sqrt{n}}{\sqrt{1+k^2/2}}. \tag{9}$$

By the distributional assumption on X-kS, the left side of (9) is approximately standard normal when $\mu = AL$, and the condition that the Type I error rate is α becomes

$$Pr\left[Z > k\sqrt{n}/\sqrt{1+k^2/2}\right] = \alpha, \tag{10}$$

$$i.e., \quad z_{1-\alpha} = k\sqrt{n}/\sqrt{1+k^2/2}. \tag{11}$$

One can show that (11) is equivalent to

$$1/[1+k^2/2] = 1 - z_{1-\alpha}^2/2n. \tag{12}$$

The condition that the Type II error rate is β (or that power is $1-\beta$) when $\mu = U$ means that the event of incorrectly accepting H_o given $\bar{X}\text{-}kS \le AL$ should have probability β. Subtracting the mean $(U - k\sigma)$ and dividing by the standard deviation of $\bar{X}$-kS on both sides of this inequality yields

$$\frac{\bar{X}-kS-(U-k\sigma)}{\left(\sigma/\sqrt{n}\right)\sqrt{1+k^2/2}} \le \frac{AL-(U-k\sigma)}{\left(\sigma/\sqrt{n}\right)\sqrt{1+k^2/2}}. \tag{13}$$

Again, the left side is approximately standard normal and the Type II error rate condition becomes

$$Pr\left[Z \le [AL-(U-k\sigma)]/[(\sigma/\sqrt{n})/\sqrt{1+k^2/2}]\right] = \beta,$$

which implies

$$-z_{1-\beta} = z_{\beta} = \frac{(AL-U)+k\sigma}{\left(\sigma/\sqrt{n}\right)\sqrt{1+k^2/2}}. \tag{14}$$

Subtracting (14) from (11) yields

$$z_{1-\alpha} + z_{1-\beta} = \frac{(U-AL)}{\left(\sigma/\sqrt{n}\right)\sqrt{1+k^2/2}}, \tag{15}$$

or

$$\frac{\left(z_{1-\alpha} + z_{1-\beta}\right)\sigma}{(U-AL)} = \frac{\sqrt{n}}{\sqrt{1+k^2/2}}. \tag{16}$$

Substituting (12) into the denominator on the right side of (16) yields

$$\frac{\left(z_{1-\alpha}+z_{1-\beta}\right)\sigma}{(U-AL)} = \sqrt{n}\sqrt{1-z_{1-\alpha}^2/2n}. \tag{17}$$

Squaring both sides of (17) and solving for n yields equation (8).

References

Guenther, William C. 1977. *Sampling Inspection in Statistical Quality Control.* Griffin's Statistical Monographs and Courses, No. 37, London: Charles Griffin.

Guenther, William C. 1981. "Sample Size Formulas for Normal Theory T Test." *The American Statistician* . Vol. 35, No. 4.

APPENDIX D

GLOSSARY OF TERMS

action level: the numerical value that causes the decision maker to choose one of the alternative actions (e.g., compliance or noncompliance). It may be a regulatory threshold standard, such as a Maximum Contaminant Level for drinking water; a risk-based concentration level; a technological limitation; or a reference-based standard. [Note: the action level is specified during the planning phase of a data collection activity; it is not calculated from the sampling data.]

alternative hypothesis: *See hypothesis.*

bias: the systematic or persistent distortion of a measurement process which causes errors in one direction (i.e., the expected sample measurement is different than the sample's true value).

boundaries: the spatial and temporal conditions and practical constraints under which environmental data are collected. Boundaries specify the area or volume (spatial boundary) and the time period (temporal boundary) to which the decision will apply. Samples are then collected within these boundaries.

data collection design: A data collection design specifies the configuration of the environmental monitoring effort to satisfy the DQOs. It includes the types of samples or monitoring information to be collected; where, when, and under what conditions they should be collected; what variables are to be measured; and the Quality Assurance and Quality Control (QA/QC) components that ensure acceptable sampling design error and measurement error to meet the decision error rates specified in the DQOs. The data collection design is the principal part of the QAPP.

Data Quality Assessment (DQA) Process: a statistical and scientific evaluation of the data set to assess the validity and performance of the data collection design and statistical test, and to establish whether a data set is adequate for its intended use.

Data Quality Objectives (DQOs): Qualitative and quantitative statements derived from the DQO Process that clarify study objectives, define the appropriate type of data, and specify the tolerable levels of potential decision errors that will be used as the basis for establishing the quality and quantity of data needed to support decisions.

Data Quality Objectives Process: a Quality Management tool based on the Scientific Method, developed by the U.S. Environmental Protection Agency to facilitate the planning of environmental data collection activities. The DQO Process enables planners to focus their planning efforts by specifying the intended use of the data (the decision), the decision criteria (action level), and the decision maker's tolerable decision error rates. The products of the DQO Process are the DQOs.

decision error: an error made when drawing an inference from data in the context of hypothesis testing, such that variability or bias in the data mislead the decision maker to draw a conclusion that is inconsistent with the true or actual state of the population under study. *See also false negative decision error, false positive decision error.*

defensible: the ability to withstand any reasonable challenge related to the veracity, integrity, or quality of the logical, technical, or scientific approach taken in a decision making process.

false negative decision error: a false negative decision error occurs when the decision maker does not reject the null hypothesis when the null hypothesis actually is false. In statistical terminology, a false negative decision error is also called a Type II error. The measure of the size of the error is expressed as a probability, usually referred to as "beta (β)"; this probability is also called the complement of power.

false positive decision error: a false positive decision error occurs when a decision maker rejects the null hypothesis when the null hypothesis actually is true. In statistical terminology, a false positive decision error is also called a Type I error. The measure of the size of the error is expressed as a probability, usually referred to as "alpha (α)," the "level of significance," or "size of the critical region."

gray region: a range of values of the population parameter of interest (such as mean contaminant concentration) where the consequences of making a decision error are relatively minor. The gray region is bounded on one side by the action level.

hypothesis: a tentative assumption made to draw out and test its logical or empirical consequences. In hypothesis testing, the hypothesis is labeled "null" or "alternative", depending on the decision maker's concerns for making a decision error.

limits on decision errors: the tolerable decision error probabilities established by the decision maker. Potential economic, health, ecological, political, and social consequences of decision errors should be considered when setting the limits.

mean: (i) a measure of central tendency of the population (population mean), or (ii) the arithmetic average of a set of values (sample mean).

measurement error: the difference between the true or actual state and that which is reported from measurements.

median: the middle value for an ordered set of n values; represented by the central value when n is odd or by the average of the two most central values when n is even. The median is the 50th percentile.

medium: a substance (e.g., air, water, soil) which serves as a carrier of the analytes of interest.

natural variability: the variability that is inherent or natural to the media, objects, or people being studied.

null hypothesis: *See hypothesis.*

parameter: a numerical descriptive measure of a population.

percentile: the specific value of a distribution that divides the distribution such that p percent of the distribution is equal to or below that value. Example for p=95: "The 95th percentile is X" means that 95% of the values in the population (or statistical sample) are less than or equal to X.

planning team: the group of people that will carry out the DQO Process. Members include the decision maker (senior manager), representatives of other data users, senior program and technical staff, someone with statistical expertise, and a QA/QC advisor (such as a QA Manager).

population: the total collection of objects, media, or people to be studied and from which a sample is to be drawn.

power function: the probability of rejecting the null hypothesis (H_o) over the range of possible population parameter values. The power function is used to assess the goodness of a hypothesis test or to compare two competing tests.

quality assurance (QA): an integrated system of management activities involving planning, quality control, quality assessment, reporting, and quality improvement to ensure that a product or service (e.g., environmental data) meets defined standards of quality with a stated level of confidence.

Quality Assurance Project Plan (QAPP): a formal technical document containing the detailed QA, QC and other technical procedures for assuring the quality of environmental data prepared for each EPA environmental data collection activity and approved prior to collecting the data.

quality control (QC): the overall system of technical activities that measures the attributes and performance of a process, item, or service against defined standards to verify that they meet the stated requirements established by the customer.

Quality Management Plan (QMP): a formal document describing the management policies, objectives, principles, organizational authority, responsibilities, accountability, and implementation protocols of an agency, organization, or laboratory for ensuring quality in its products and utility to its users. In EPA, QMPs are submitted to the Quality Assurance Management Staff (QAMS) for approval.

range: the numerical difference between the minimum and maximum of a set of values.

[1]**sample:** a single item or specimen from a larger whole or group, such as any single sample of any medium (air, water, soil, etc.).

[2]**sample:** a set of individual samples (specimens or readings), drawn from a population, whose properties are studied to gain information about the whole.

sampling: the process of obtaining representative samples and/or measurements of a subset of a population.

sampling design error: the error due to observing only a limited number of the total possible values that make up the population being studied. It should be distinguished from errors due to imperfect selection; bias in response; and errors of observation, measurement, or recording, etc.

scientific method: the principles and processes regarded as necessary for scientific investigation, including rules for concept or hypothesis formulation, conduct of experiments, and validation of hypotheses by analysis of observations.

standard deviation: the square root of the variance.

statistic: a function of the sample measurements; e.g., the sample mean or standard deviation.

statistical test: any statistical method that is used to determine which of several hypotheses are true.

total study error: the combination of sampling design error and measurement error.

true: being in accord with the actual state of affairs.

Type I error: A Type I error occurs when a decision maker rejects the null hypothesis when it is actually true. *See false positive decision error.*

Type II error: A Type II error occurs when the decision maker fails to reject the null hypothesis when it is actually false. *See false negative decision error.*

variable: The attribute of the environment that is indeterminant.

variance: a measure of (i) the variability or dispersion in a population (population variance), or (ii) the sum of the squared deviations of the measurements about their mean divided by the degrees of freedom (sample variance).

APPENDIX 7

LAND USE GUIDANCE

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

MAY 25 1995

OFFICE OF
SOLID WASTE AND EMERGENCY
RESPONSE

OSWER Directive No. 9355.7-04

MEMORANDUM

SUBJECT: Land Use in the CERCLA Remedy Selection Process

FROM: Elliott P. Laws
Assistant Administrator

TO: Director, Waste Management Division
Regions I, IV, V, VII
Director, Emergency and Remedial Response Division
Region II
Director, Hazardous Waste Management Division
Regions III, VI, VIII, IX
Director, Hazardous Waste Division,
Region X
Director, Environmental Services Division
Regions I, VI, VII

Purpose:

This directive presents additional information for considering land use in making remedy selection decisions under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) at National Priorities List (NPL) sites. The U.S. Environmental Protection Agency (EPA) believes that early community involvement, with a particular focus on the community's desired future uses of property associated with the CERCLA site, should result in a more democratic decisionmaking process; greater community support for remedies selected as a result of this process; and more expedited, cost-effective cleanups.

The major points of this directive are:

- Discussions with local land use planning authorities, appropriate officials, and the public, as appropriate, should be conducted as early as possible in the scoping phase of the Remedial Investigation/Feasibility Study (RI/FS). This will assist EPA in understanding the

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reasonably anticipated future uses of the land on which the Superfund site is located;

- If the site is located in a community that is likely to have environmental justice concerns, extra efforts should be made to reach out to and consult with segments of the community that are not necessarily reached by conventional communication vehicles or through local officials and planning commissions;

- Remedial action objectives developed during the RI/FS should reflect the reasonably anticipated future land use or uses;

- Future land use assumptions allow the baseline risk assessment and the feasibility study to be focused on developing practicable and cost effective remedial alternatives. These alternatives should lead to site activities which are consistent with the reasonably anticipated future land use. However, there may be reasons to analyze implications associated with additional land uses;

- Land uses that will be available following completion of remedial action are determined as part of the remedy selection process. During this process, the goal of realizing reasonably anticipated future land uses is considered along with other factors. Any combination of unrestricted uses, restricted uses, or use for long-term waste management may result.

Discussions with local land use authorities and other locally affected parties to make assumptions about future land use are also appropriate in the RCRA context. EPA recognizes that RCRA facilities typically are industrial properties that are actively managed, rather than the abandoned sites that are often addressed under CERCLA. Therefore, consideration of non-residential uses is especially likely to be appropriate for RCRA facility cleanups. Decisions regarding future land use that are made as part of RCRA corrective actions raise particular issues for RCRA (e.g., timing, property transfers, and the viability of long-term permit or other controls) in ensuring protection of human health and the environment. EPA intends to address the issue of future land use as it relates specifically to RCRA facility cleanups in subsequent guidance and/or rulemakings.

This guidance is also relevant for Federal Facility sites. Land use assumptions at sites that are undergoing base closure may be different than at sites where a Federal agency will be maintaining control of the facility. Most land management agency sites will remain in Federal ownership after remedial actions. In these cases, Forest Land Management Plans and other resource

management guidelines may help develop reasonable assumptions about future uses of the land. At all such sites, however, this document can focus the land use consideration toward appropriate options.[1]

Background:

Reasonably anticipated future use of the land at NPL sites is an important consideration in determining the appropriate extent of remediation. Future use of the land will affect the types of exposures and the frequency of exposures that may occur to any residual contamination remaining on the site, which in turn affects the nature of the remedy chosen. On the other hand, the alternatives selected through the National Oil and Hazardous Substance Contingency Plan (NCP) [55 Fed. Reg. 8666, March 8, 1990] process for CERCLA remedy selection determine the extent to which hazardous constituents remain at the site, and therefore affect subsequent available land and ground water uses.

The NCP preamble specifically discusses land use assumptions regarding the baseline risk assessment. The baseline risk assessment provides the basis for taking a remedial action at a Superfund site and supports the development of remedial action objectives. Land use assumptions affect the exposure pathways that are evaluated in the baseline risk assessment. Current land use is critical in determining whether there is a current risk associated with a Superfund site, and future land use is important in estimating potential future threats. The results of the risk assessment aid in determining the degree of remediation necessary to ensure long-term protection at NPL sites.

EPA has been criticized for too often assuming that future use will be residential. In many cases, residential use is the least restricted land use and where human activities are associated with the greatest potential for exposures. This directive is intended to facilitate future remedial decisions at NPL sites by outlining a public process and sources of information which should be considered in developing reasonable assumptions regarding future land use.

This directive expands on discussions provided in the preamble to the National Oil and Hazardous Substance Contingency Plan (NCP); "Risk Assessment Guidance for Superfund Vol. I, Human Health Evaluation Manual" (Part A) (EPA/540/1-89/002, Dec. 1989); "Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA" (OSWER Directive 9355.3-01, Oct. 1988); and

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[1] Federal agency responsibility under CERCLA 120(h)(3), which relates to additional clean up which may be required to allow for unrestricted use of the property, is not addressed in this guidance.

"Role of the Baseline Risk Assessment in Superfund Remedy Selection Decisions" (OSWER Directive 9355.0-30, April 22, 1991).

This land use directive may have the most relevance in situations where surface soil is the primary exposure pathway. Generally, where soil contamination is impacting ground water, protection of the ground water may drive soil cleanup levels. Consideration of future ground water use for CERCLA sites is not addressed in this document. There are separate expectations established for ground water in the NCP rule section 300.430 (a)(1)(iii)(F) that "EPA expects to return usable ground waters to their beneficial uses wherever practicable, within a timeframe that is reasonable given the particular circumstances of the site."

Objective

This directive has two primary objectives. First, this directive promotes early discussions with local land use planning authorities, local officials, and the public regarding reasonably anticipated future uses of the property on which an NPL site is located. Second, this directive promotes the use of that information to formulate realistic assumptions regarding future land use and clarifies how these assumptions fit in and influence the baseline risk assessment, the development of alternatives, and the CERCLA remedy selection process.

Implementation

The approach in this guidance is meant to be considered at current and future sites in the RI/FS pipeline, to the extent possible. This directive is not intended to suggest that previous remedy selection decisions should be re-opened.

Developing Assumptions About Future Land Use

In order to ensure use of realistic assumptions regarding future land uses at a site, EPA should discuss reasonably anticipated future uses of the site with local land use planning authorities, local officials, and the public, as appropriate, as early as possible during the scoping phase of the RI/FS. EPA should gain an understanding of the reasonably anticipated future land uses at a particular Superfund site to perform the risk assessment and select the appropriate remedy.

A visual inspection of the site and its surrounding area is a good starting point in developing assumptions regarding future land use. Discussions with the local land use authorities and appropriate officials should follow. Discussions with the public can be accomplished through a public meeting and/or other means. By developing realistic assumptions based on information gathered from these sources early in the RI/FS process, EPA may develop

remedial alternatives that are consistent with the anticipated future use.

The development of assumptions regarding the reasonably anticipated future land use should not become an extensive, independent research project. Site managers should use existing information to the extent possible, much of which will be available from local land use planning authorities. Sources and types of information that may aid EPA in determining the reasonably anticipated future land use include, but are not limited to:

- Current land use
- Zoning laws
- Zoning maps
- Comprehensive community master plans
- Population growth patterns and projections (e.g., Bureau of Census projections)
- Accessibility of site to existing infrastructure (e.g., transportation and public utilities)
- Institutional controls currently in place
- Site location in relation to urban, residential, commercial, industrial, agricultural and recreational areas
- Federal/State land use designation (Federal/State control over designated lands range from established uses for the general public, such as national parks or State recreational areas, to governmental facilities providing extensive site access restrictions, such as Department of Defense facilities
- Historical or recent development patterns
- Cultural factors (e.g., historical sites, Native American religious sites)
- Natural resources information
- Potential vulnerability of ground water to contaminants that might migrate from soil
- Environmental justice issues
- Location of on-site or nearby wetlands
- Proximity of site to a floodplain
- Proximity of site to critical habitats of endangered or threatened species
- Geographic and geologic information
- Location of Wellhead Protection areas, recharge areas, and other areas identified in a State's Comprehensive Ground-water Protection Program

These types of information should be considered when developing the assumptions about future land use. Interaction with the public, which includes all stakeholders affected by the site, should serve to increase the certainty in the assumptions made regarding future land use at an NPL site and increase the

confidence expectations about anticipated future land use are, in fact, reasonable.

For example, future industrial land use is likely to be a reasonable assumption where a site is currently used for industrial purposes, is located in an area where the surroundings are zoned for industrial use, and the comprehensive plan predicts the site will continue to be used for industrial purposes.

Community Involvement

NPL sites are located in diverse areas of the country, with great variability in land use planning practices. For some NPL sites, the future land use of a site may have been carefully considered through local, public, participatory, planning processes, such as zoning hearings, master plan approvals or other vehicles. When this is the case, local residents around the Superfund site are likely to demonstrate substantial agreement with the local land use planning authority on the future use of the property. Where there is substantial agreement among local residents and land use planning agencies, owners and developers, EPA can rely with a great deal of certainty on the future land use already anticipated for the site. For other NPL sites, however, the absence or nature of a local planning process may yield considerably less certainty about what assumptions regarding future use are reasonable. In some instances the local residents near the Superfund site may feel disenfranchised from the local land use planning and development process. This may be an especially important issue where there are concerns regarding environmental justice in the neighborhood around the NPL site. Consistent with the principle of fairness, EPA should make an extra effort to reach out to the local community to establish appropriate future land use assumptions at such sites.

Land Use Assumptions in the Baseline Risk Assessment

Future land use assumptions allow the baseline risk assessment and the feasibility study to focus on the development of practicable and cost-effective remedial alternatives, leading to site activities which are consistent with the reasonably anticipated future land use.

The baseline risk assessment generally needs only to consider the reasonably anticipated future land use; however, it may be valuable to evaluate risks associated with other land uses. The NCP preamble (55 Fed. Reg. 8710) states that in the baseline risk assessment, more than one future land use assumption may be considered when decision makers wish to understand the implications of unexpected exposures. Especially where there is some uncertainty regarding the anticipated future land use, it may be useful to compare the potential risks associated with several land use scenarios to estimate the impact

on human health and the environment should the land use unexpectedly change. The magnitude of such potential impacts may be an important consideration in determining whether and how institutional controls should be used to restrict future uses. If the baseline risk assessment evaluates a future use under which exposure is limited, it will not serve the traditional role, evaluating a "no action" scenario. A remedy, i.e. institutional controls to limit future exposure, will be required to protect human health and the environment. In addition to analyzing human health exposure scenarios associated with certain land uses, ecological exposures may also need to be considered.

Developing Remedial Action Objectives

Remedial action objectives provide the foundation upon which remedial cleanup alternatives are developed. In general, remedial action objectives should be developed in order to develop alternatives that would achieve cleanup levels associated with the reasonably anticipated future land use over as much of the site as possible. EPA recognizes, however, that achieving either the reasonably anticipated land use, or the land use preferred by the community, may not be practicable across the entire site, or in some cases, at all. For example, as RI/FS data become available, they may indicate that the remedial alternatives under consideration for achieving a level of cleanup consistent with the reasonably anticipated future land use are not cost-effective nor practicable. If this is the case, the remedial action objective may be revised which may result in different, more reasonable land use(s).

EPA's remedy selection expectations described in section 300.430(a)(1)(iii) of the NCP should also be considered when developing remedial action objectives. Where practicable, EPA expects to treat principal threats, to use engineering controls such as containment for low-level threats, to use institutional controls to supplement engineering controls, to consider the use of innovative technology, and to return usable ground waters to beneficial uses to protect human health and the environment. (Some types of applicable or relevant and appropriate requirements (ARARs) define protective cleanup levels which may, in turn, influence post-remediation land use potential.)

In cases where the future land use is relatively certain, the remedial action objective generally should reflect this land use. Generally, it need not include alternative land use scenarios unless, as discussed above, it is impracticable to provide a protective remedy that allows for that use. A landfill site is an example where it is highly likely that the future land use will remain unchanged (i.e., long-term waste management area), given the NCP's expectation that treatment of high volumes of waste generally will be impracticable and the fact that EPA's presumptive remedy for landfills is containment. In such a case,

a remedial action objective could be established with a very high degree of certainty to reflect the reasonably anticipated future land use.

In cases where the reasonably anticipated future land use is highly uncertain, a range of the reasonably likely future land uses should be considered in developing remedial action objectives. These likely future land uses can be reflected by developing a range of remedial alternatives that will achieve different land use potentials. The remedy selection process will determine which alternative is most appropriate for the site and, consequently, the land use(s) available following remediation.

As discussed in "Role of the Baseline Risk Assessment in Superfund Remedy Selection Decisions" (OSWER Directive 9355.0-30, April 22, 1991), EPA has established a risk range for carcinogens within which EPA strives to manage site risks. EPA recognizes that a specific cleanup level within the acceptable risk range may be associated with more than one land use (e.g., an industrial cleanup to 10^{-6} may also allow for residential use at a 10^{-4} risk level.) It is not EPA's intent that the risk range be partitioned into risk standards based solely on categories of land use (e.g., with residential cleanups at the 10^{-6} level and industrial cleanups at the 10^{-4} risk level.) Rather, the risk range provides the necessary flexibility to address the technical and cost limitations, and the performance and risk uncertainties inherent in all waste remediation efforts.

Land Use Considerations in Remedy Selection

As a result of the comparative analysis of alternatives with respect to EPA's nine evaluation criteria, EPA selects a site-specific remedy. The remedy determines the cleanup levels, the volume of contaminated material to be treated, and the volume of contaminated material to be contained. Consequently, the remedy selection decision determines the size of the area that can be returned to productive use and the particular types of uses that will be possible following remediation.

The volume and concentration of contaminants left on-site, and thus the degree of residual risk at a site, will affect future land use. For example, a remedial alternative may include leaving in place contaminants in soil at concentrations protective for industrial exposures, but not protective for residential exposures. In this case, institutional controls should be used to ensure that industrial use of the land is maintained and to prevent risks from residential exposures. Conversely, a remedial alternative may result in no waste left in place and allow for unrestricted use (e.g., residential use).

Results of Remedy Selection Process

Several potential land use situations could result from EPA's remedy selection decision. They are:

- The remedy achieves cleanup levels that allow the entire site to be available for the reasonably anticipated future land use in the baseline risk assessment (or, where future land use is uncertain, all uses that could reasonably be anticipated).

- The remedy achieves cleanup levels that allow most, but not all, of the site to be available for the reasonably anticipated future land use. For example, in order to be cost effective and practicable, the remedy may require creation of a long-term waste management area for containment of treatment residuals or low-level waste on a small portion of the site. The cleanup levels in this portion of the site might allow for a more restricted land use.

- The remedy achieves cleanup levels that require a more restricted land use than the reasonably anticipated future land use for the entire site. This situation occurs when no remedial alternative that is cost-effective or practicable will achieve the cleanup levels consistent with the reasonably anticipated future land use. The site may still be used for productive purposes, but the use would be more restricted than the reasonably anticipated future land use. Furthermore, the more restricted use could be a long-term waste management area over all or a portion of the site.

Institutional Controls

If any remedial alternative developed during the FS will require a restricted land use in order to be protective, it is essential that the alternative include components that will ensure that it remain protective. In particular, institutional controls will generally have to be included in the alternative to prevent an unanticipated change in land use that could result in unacceptable exposures to residual contamination, or, at a minimum, alert future users to the residual risks and monitor for any changes in use. In such cases, institutional controls will play a key role in ensuring long-term protectiveness and should be evaluated and implemented with the same degree of care as is given to other elements of the remedy. In developing remedial alternatives that include institutional controls, EPA should determine: the type of institutional control to be used, the existence of the authority to implement the institutional control, and the appropriate entity's resolve and ability to

implement the institutional control. An alternative may anticipate two or more options for establishing institutional controls, but should fully evaluate all such options. A variety of institutional controls may be used such as deed restrictions and deed notices, and adoption of land use controls by a local government. These controls either prohibit certain kinds of site uses or, at a minimum, notify potential owners or land users of the presence of hazardous substances remaining on site at levels that are not protective for all uses. Where exposure must be limited to assure protectiveness, a deed notice alone generally will not provide a sufficiently protective remedy. While the ROD need not always specify the precise type of control to be imposed, sufficient analysis should be shown in the FS and ROD to support a conclusion that effective implementation of institutional controls can reasonably be expected.

Suppose, for example, that a selected remedy will be protective for industrial land use and low levels of hazardous substances will remain on site. An industry may still be able to operate its business with the selected remedy in place. Institutional controls, however, generally will need to be established to ensure the land is not used for other, less restricted purposes, such as residential use, or to alert potential buyers of any remaining contamination.

Future Changes in Land Use

Where waste is left on-site at levels that would require limited use and restricted exposure, EPA will conduct reviews at least every five years to monitor the site for any changes. Such reviews should analyze the implementation and effectiveness of institutional controls with the same degree of care as other parts of the remedy. Should land use change, it will be necessary to evaluate the implications of that change for the selected remedy, and whether the remedy remains protective. EPA's role in any subsequent additional cleanup will be determined on a site-specific basis. If landowners or others decide at a future date to change the land use in such a way that makes further cleanup necessary to ensure protectiveness, CERCLA does not prevent them from conducting such a cleanup as long as protectiveness of the remedy is not compromised. (EPA may invoke CERCLA section 122(e)(6), if necessary, to prevent actions that are inconsistent with the original remedy.) In general, EPA would not expect to become involved actively in the conduct or oversight of such cleanups. EPA, however, retains its authority to take further response action where necessary to ensure protectiveness.

Further Information

If you have any questions concerning this directive, please call Sherri Clark at 703-603-9043.

NOTICE: The policies set out in this memorandum are intended solely as guidance. They are not intended, nor can they be relied upon, to create any rights enforceable by any party in litigation with the United States. EPA officials may decide to follow the guidance provided in this memorandum, or to act at variance with the guidance, based on an analysis of specific site circumstances. Remedy selection decisions are made and justified on a case-specific basis. The Agency also reserves the right to change this guidance at any time without public notice.