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Soil Screening Guidance: User's Guide

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DISCLAIMER

Notice: The Soil Screening Guidance is based on policies set out in the Preamble to the Final Rule of the National Oil and Hazardous Substances Pollution Contingency Plan (NCP), which was published on March 8, 1990 (55 *Federal Register* 8666).

This guidance document sets forth recommended approaches based on EPA's best thinking to date with respect to soil screening. This document does not establish binding rules. Alternative approaches for screening may be found to be more appropriate at specific sites (e.g., where site circumstances do not match the underlying assumptions, conditions and models of the guidance). The decision whether to use an alternative approach and a description of any such approach should be placed in the Administrative Record for the site. Accordingly, if comments are received at individual sites questioning the use of the approaches recommended in this guidance, the comments should be considered and an explanation provided for the selected approach. The Soil Screening Guidance: Technical Background Document (TBD) may be helpful in responding to such comments.

The policies set out in both the Soil Screening Guidance: User's Guide and the supporting TBD are intended solely as guidance to the U.S. Environmental Protection Agency (EPA) personnel; they are not final EPA actions and do not constitute rulemaking. These policies are not intended, nor can they be relied upon, to create any rights enforceable by any party in litigation with the United States government. EPA officials may decide to follow the guidance provided in this document, or to act at variance with the guidance, based on an analysis of specific site circumstances. EPA also reserves the right to change the guidance at any time without public notice.

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LIST OF ACRONYMS

ARAR	Applicable or Relevant and Appropriate Requirement
ASTM	American Society for Testing and Materials
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CLP	Contract Laboratory Program
CSM	Conceptual Site Model
CV	Coefficient of Variation
DAF	Dilution Attenuation Factor
DNAPL	Dense Nonaqueous Phase Liquid
DQA	Data Quality Assessment
DQO	Data Quality Objective
EA	Exposure Area
EPA	Environmental Protection Agency
HBL	Health Based Limit
HEAST	Health Effects Assessment Summary Table
HELP	Hydrological Evaluation of Landfill Performance
HHEM	Human Health Evaluation Manual
HQ	Hazard Quotient
IRIS	Integrated Risk Information System
ISC2	Industrial Source Complex Model
MCL	Maximum Contaminant Level
MCLG	Maximum Contaminant Level Goal
NAPL	Nonaqueous Phase Liquid
NOAEL	No-Observed-Adverse-Effect Level
NPL	National Priorities List
NTIS	National Technical Information Service
OERR	Office of Emergency and Remedial Response
PA/SI	Preliminary Assessment/Site Inspection
PCB	Polychlorinated Biphenyl
PEF	Particulate Emission Factor
PRG	Preliminary Remediation Goal
Q/C	Site-Specific Dispersion Model
QA/QC	Quality Assurance/Quality Control
QL	Quantitation Limit
RAGS	Risk Assessment Guidance for Superfund
RCRA	Resource Conservation and Recovery Act
RfC	Reference Concentration
RfD	Reference Dose
RI	Remedial Investigation
RI/FS	Remedial Investigation/Feasibility Study
RME	Reasonable Maximum Exposure
ROD	Record of Decision
SAB	Science Advisory Board
SAP	Sampling and Analysis Plan
SPLP	Synthetic Precipitation Leaching Procedure
SSL	Soil Screening Level
TBD	Technical Background Document
TCLP	Toxicity Characteristic Leaching Procedure
USDA	U.S. Department of Agriculture
VF	Volatilization Factor
VOC	Volatile Organic Compound

1.0 INTRODUCTION

1.1 Purpose

The Soil Screening Guidance is a tool that the U.S. Environmental Protection Agency (EPA) developed to help standardize and accelerate the evaluation and cleanup of contaminated soils at sites on the National Priorities List (NPL) with future residential land use.[1] This guidance provides a methodology for environmental science/engineering professionals to calculate risk-based, site-specific, soil screening levels (SSLs) for contaminants in soil that may be used to identify areas needing further investigation at NPL sites.

SSLs are not national cleanup standards. SSLs alone do not trigger the need for response actions or define "unacceptable" levels of contaminants in soil. In this guidance, "screening" refers to the process of identifying and defining areas, contaminants, and conditions, at a particular site that do not require further Federal attention. Generally, at sites where contaminant concentrations fall below SSLs, no further action or study is warranted under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA). (Some States have developed screening numbers that are more stringent than the generic SSLs presented here; therefore, further study may be warranted under State programs.) Generally, where contaminant concentrations equal or exceed SSLs, further study or investigation, but not necessarily cleanup, is warranted.

SSLs are risk-based concentrations derived from equations combining exposure information assumptions with EPA toxicity data. This User's Guide focuses on the application of a simple site-specific approach by providing a step-by-step methodology to calculate site-specific SSLs and is part of a larger framework that includes both generic and more detailed approaches to calculating screening levels. The Technical Background Document (TBD) (EPA, 1996), provides more information about these other approaches. Generic SSLs for the most common contaminants found at NPL sites are included in the TBD. Generic SSLs are calculated from the same equations presented in this guidance, but are based on a number of default assumptions chosen to be protective of human health for most site conditions. Generic SSLs can be used in place of site-specific screening levels; however, in general, they are expected to be more conservative than site-specific levels. The site manager should weigh the cost of collecting the data necessary to develop site-specific SSLs with the potential for deriving a higher SSL that provides an appropriate level of protection.

The framework presented in the TBD also includes more detailed modeling approaches for developing screening levels that take into account more complex site conditions than the simple site-specific methodology emphasized in this guidance. More detailed approaches may be appropriate when site conditions (e.g., a thick vadose zone) are different from those assumed in the simple site-specific methodology presented here. The technical details supporting the methodology used in this guidance are provided in the TBD.

SSLs developed in accordance with this guidance are based on future residential land use assumptions and related exposure scenarios. Using this guidance for sites where residential land use assumptions do not apply could result in overly conservative screening levels; however, EPA recognizes that some parties responsible for sites with non-residential land use might still find benefit in using the SSLs as a tool to conduct a conservative initial screening.

SSLs developed in accordance with this guidance could also be used for Resource Conservation and Recovery Act (RCRA) corrective action sites as "action levels," since the RCRA corrective action program currently views the role of action levels as generally fulfilling the same purpose as soil screening levels.[2] In addition, States may use this guidance in their voluntary cleanup programs, to the extent they deem appropriate. When applying SSLs to RCRA corrective action sites or for sites under State voluntary cleanup programs, users of this guidance should recognize, as stated above, that SSLs are based on residential land use assumptions. Where these assumptions do not apply, other approaches

1. Note that the Superfund program defines "soil" as having a particle size under 2mm, while the RCRA program allows for particles under 9mm in size.

2 Further information on the role of action levels in the RCRA corrective action program is available in an Advance Notice of Proposed Rulemaking (signed April 1996).

for determining the need for further study might be more appropriate.

1.2 Role of Soil Screening Levels

In identifying and managing risks at sites, EPA considers a spectrum of contaminant concentrations. The level of concern associated with those concentrations depends on the likelihood of exposure to soil contamination at levels of potential concern to human health or to ecological receptors.

Exhibit 1 illustrates the spectrum of soil contamination encountered at Superfund sites and the conceptual range of risk management responses. At one end are levels of contamination that clearly warrant a response action; at the other end are levels that are below regulatory concern. Screening levels identify the lower bound of the spectrum—levels below which EPA believes there is no concern under CERCLA, provided conditions associated with the SSLs are met. Appropriate cleanup goals for a particular site may fall anywhere within this range depending on site-specific conditions.

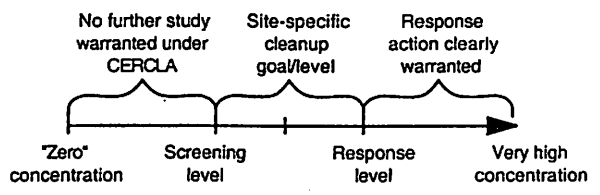


Exhibit 1. Conceptual Risk Management Spectrum for Contaminated Soil

EPA anticipates the use of SSLs as a tool to facilitate prompt identification of contaminants and exposure areas of concern during both remedial actions and some removal actions under CERCLA. However, the application of this or any screening methodology is not mandatory at sites being addressed under CERCLA or RCRA. The framework leaves discretion to the site manager and technical experts (e.g., risk assessors, hydrogeologists) to determine whether a screening approach is appropriate for the site and, if screening is to be used, the proper method of implementation. If comments are received at individual sites questioning the use of the approaches recommended in this guidance, the comments should be considered and an explanation provided as part of the site's Record of Decision (ROD). The decision to use a screening approach should be made early in the process of investigation at the site.

EPA developed the Soil Screening Guidance to be consistent with and to enhance the current Superfund investigation process and anticipates its primary use during the early stages of a remedial investigation (RI) at NPL sites. It does not replace the Remedial Investigation/Feasibility Study (RI/FS) or risk assessment, but use of screening levels can focus the RI and risk assessment on aspects of the site that are more likely to be a concern under CERCLA. By screening out areas of sites, potential chemicals of concern, or exposure pathways from further investigation, site managers and technical experts can limit the scope of the remedial investigation or risk assessment. SSLs can save resources by helping to determine which areas do not require additional Federal attention early in the process. Furthermore, data gathered during the soil screening process can be used in later Superfund phases, such as the baseline risk assessment, feasibility study, treatability study, and remedial design. This guidance may also be appropriate for use by the removal program when demarcation of soils above residential risk-based numbers coincides with the purpose and scope of the removal action.

The process presented in this guidance to develop and apply simple, site-specific soil screening levels is likely to be most useful where it is difficult to determine whether areas of soil are contaminated to an extent that warrants further investigation or response (e.g., whether areas of soil at an NPL site require further investigation under CERCLA through an RI/FS). As noted above, the screening levels have been developed assuming residential land use. Although some of the models and methods presented in this guidance could be modified to address exposures under other land uses, EPA has not yet standardized assumptions for those other uses.

Applying site-specific screening levels involves developing a conceptual site model (CSM), collecting a few easily obtained site-specific soil parameters (such as the dry bulk density and percent

moisture), and sampling to measure contaminant levels in surface and subsurface soils. Often, much of the information needed to develop the CSM can be derived from previous site investigations [e.g., the Preliminary Assessment/Site Inspection (PA/SI)] and, if properly planned, SSL sampling can be accomplished in one mobilization.

An important part of this guidance is a recommended sampling approach that balances the need for more data to reduce uncertainty with the need to limit data collection costs. Where data are limited such that use of the "maximum test" (Max test) presented here is not appropriate, the guidance provides direction on the use of other conservative estimates of contaminant concentrations for comparison with the SSLs.

This guidance provides the information needed to calculate SSLs for 110 chemicals. Sufficient information may not be available to develop soil screening levels for additional chemicals. These chemicals should not be screened out, but should be addressed in the baseline risk assessment for the site. The *Risk Assessment Guidance for Superfund* (RAGS), *Volume 1: Human Health Evaluation Manual* (HHEM), *Part A, Interim Final.* (U.S. EPA, 1989a) provides guidance on conducting baseline risk assessments for NPL sites. In addition, the baseline risk assessment should address the chemicals, exposure pathways, and areas at the site that are not screened out.

Although SSLs are "risk-based," they do not eliminate the need to conduct a site-specific risk assessment. SSLs are concentrations of contaminants in soil that are designed to be protective of exposures in a residential setting. A site-specific risk assessment is an evaluation of the risk posed by exposure to site contaminants in various media. To calculate SSLs, the exposure equations and pathway models are run in reverse to backcalculate an "acceptable level" of a contaminant in soil. For the ingestion, dermal, and inhalation pathways, toxicity criteria are used to define an acceptable level of contamination in soil, based on a one-in-a-million (10^{-6}) individual excess cancer risk for carcinogens and a hazard quotient (HQ) of 1 for non-carcinogens. SSLs are backcalculated for migration to ground water pathways using ground water concentration limits [nonzero maximum contaminant level goals (MCLGs), maximum contaminant levels (MCLs), or health-based limits (HBLs) (10^{-6} cancer risk or a HQ of 1) where MCLs are not available].

SSLs can be used as Preliminary Remediation Goals (PRGs) provided appropriate conditions are met (i.e., conditions found at a specific site are similar to conditions assumed in developing the SSLs). The concept of calculating risk-based contaminant levels in soils for use as PRGs (or "draft" cleanup levels) was introduced in the RAGS HHEM, *Part B, Development of Risk-Based Preliminary Remediation Goals.* (U.S. EPA, 1991c). **The models, equations, and assumptions presented in the Soil Screening Guidance to address <u>inhalation</u> exposures supersede those described in RAGS HHEM, Part B, for residential soils. In addition, this guidance presents methodologies to address the leaching of contaminants through soil to an underlying potable aquifer. This pathway should be addressed in the development of PRGs.**

PRGs may then be used as the basis for developing final cleanup levels based on the nine-criteria analysis described in the National Contingency Plan [Section 300.430 (3)(2)(I)(A)]. The directive entitled *Role of the Baseline Risk Assessment in Superfund Remedy Selection Decisions* (U.S. EPA, 1991d) discusses the modification of PRGs to generate cleanup levels. The SSLs should only be used as cleanup levels when a site-specific nine-criteria evaluation of the SSLs as PRGs for soils indicates that a selected remedy achieving the SSLs is protective, complies with Applicable or Relevant and Appropriate Requirements (ARARs), and appropriately balances the other criteria, including cost.

1.3 Scope of Soil Screening Guidance

In a residential setting, potential pathways of exposure to contaminants in soil are as follows (see Exhibit 2):

- Direct ingestion
- Inhalation of volatiles and fugitive dusts

- Ingestion of contaminated ground water caused by migration of chemicals through soil to an underlying potable aquifer
- Dermal absorption
- Ingestion of homegrown produce that has been contaminated via plant uptake
- Migration of volatiles into basements.

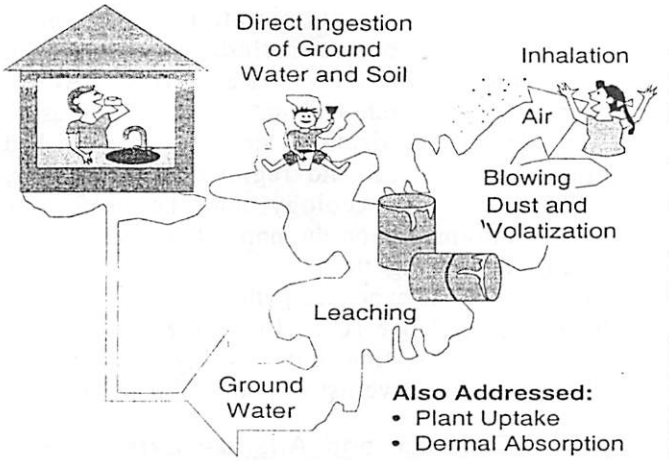


Exhibit 2. Exposure Pathways Addressed by SSLs.

The Soil Screening Guidance addresses each of these pathways to the greatest extent practical. The first three pathways -- direct ingestion, inhalation of volatiles and fugitive dusts, and ingestion of potable ground water -- are the most common routes of human exposure to contaminants in the residential setting. These pathways have generally accepted methods, models, and assumptions that lend themselves to a standardized approach. The additional pathways of exposure to soil contaminants, dermal absorption, plant uptake, and migration of volatiles into basements, may also contribute to the risk to human health from exposure to specific contaminants in a residential setting. This guidance addresses these pathways to a limited extent based on available empirical data. (See Step 5 and the TBD for further discussion).

The Soil Screening Guidance addresses the human exposure pathways listed previously and will be appropriate for most residential settings. The presence of additional pathways or unusual site conditions does not preclude the use of SSLs in areas of the site that are currently residential or likely to be residential in the future. However, the risks associated with additional pathways or conditions (e.g., fish consumption, raising of livestock, a heavy truck traffic on unpaved roads) should be considered in the RI/FS to determine whether SSLs are adequately protective.

An ecological assessment should also be performed as part of the RI/FS to evaluate potential risks to ecological receptors.

The Soil Screening Guidance should not be used for areas with radioactive contaminants.

Exhibit 3 provides key attributes of the Soil Screening Guidance: User's Guide.

Exhibit 3: Key Attributes of the User's Guide

- Standardized equations are presented to address human exposure pathways in a residential setting consistent with Superfund's concept of "Reasonable Maximum Exposure" (RME).
- Source size (area and depth) can be considered on a site-specific basis using mass-limit models.
- Parameters are identified for which site-specific information is needed to develop SSLs.
- Default values are provided to calculate generic SSLs when site-specific information is not available.
- SSLs are based on a 10^{-6} risk for carcinogens or a hazard quotient of 1 for noncarcinogens. SSLs for migration to ground water are based on (in order of preference): nonzero maximum contaminant level goals (MCLGs), maximum contaminant levels (MCLs), or the aforementioned risk-based targets.

2.0 SOIL SCREENING PROCESS

The soil screening process (Exhibit 4) is a step-by-step approach that involves:

- Developing a conceptual site model (CSM)
- Comparing the CSM to the SSL scenario
- Defining data collection needs
- Sampling and analyzing soils at site
- Calculating site-specific SSLs
- Comparing site soil contaminant concentrations to calculated SSLs
- Determining which areas of the site require further study.

It is important to follow this process to implement the Soil Screening Guidance properly. The remainder of this guidance discusses each activity in detail.

2.1 Step 1: Developing a Conceptual Site Model

The CSM is a three-dimensional "picture" of site conditions that illustrates contaminant distributions, release mechanisms, exposure pathways and migration routes, and potential receptors. The CSM documents current site conditions and is supported by maps, cross sections, and site diagrams that illustrate human and environmental exposure through contaminant release and migration to potential receptors. Developing an accurate CSM is critical to proper implementation of the Soil Screening Guidance.

As a key component of the RI/FS and EPA's Data Quality Objectives (DQO) process, the CSM should be updated and revised as investigations produce new information about a site. *Data Quality Objectives for Superfund: Interim Final Guidance* (U.S. EPA, 1993a) and *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA* (U.S. EPA, 1989c) provide a general discussion about the development and use of the CSM during RIs. Developing the CSM involves several steps, discussed in the following subsections.

2.1.1 Collect Existing Site Data. The initial design of the CSM is based on existing site data compiled during previous studies. These data may include site sampling data, historical records, aerial photographs, maps, and State soil surveys, as well as information on local and regional conditions relevant to contaminant migration and potential receptors. Data sources include Superfund site assessment documents (i.e., the PA/SI), documentation of removal actions, and records of other site characterizations or actions. Published information on local and regional climate, soils, hydrogeology, and ecology may be useful. In addition, information on the population and land use at and surrounding the site will be important to identify potential exposure pathways and receptors. The RI/FS guidance (U.S. EPA, 1989c) discusses collection of existing data during RI scoping, including an extensive list of potential data sources.

2.1.2 Organize and Analyze Existing Site Data. One of the most important aspects of the CSM development process is to identify and characterize all potential exposure pathways and receptors at the site by considering site conditions, relevant exposure scenarios, and the properties of contaminants present in site soils.

Attachment A, the Conceptual Site Model Summary, provides four forms for organizing site data for soil screening purposes. The CSM summary organizes site data according to general site information, soil contaminant source characteristics, exposure pathways and receptors.

Note: If a CSM has already been developed for the site in question, use the summary forms in Attachment A to ensure that it is adequate.

2.1.3 Construct a Preliminary Diagram of the CSM. Once the existing site data have been organized and a basic understanding of the site has been attained, draw a preliminary "sketch" of the site conditions, highlighting source areas, potential exposure pathways, and receptors.

Exhibit 4

Soil Screening Process

Step One: **Develop Conceptual Site Model**

- Collect existing site data (historical records, aerial photographs, maps, PA/SI data, available background information, State soil surveys, etc.)
- Organize and analyze existing site data
  - Identify known sources of contamination
  - Identify affected media
  - Identify potential migration routes, exposure pathways, and receptors
- Construct a preliminary diagram of the CSM
- Perform site reconnaissance
  - Confirm and/or modify CSM
  - Identify remaining data gaps

Step Two: **Compare Soil Component of CSM to Soil Screening Scenario**

- Confirm that future residential land use is a reasonable assumption for the site
- Identify pathways present at the site that are addressed by the guidance
- Identify additional pathways present at the site not addressed by the guidance
- Compare pathway-specific generic SSLs with available concentration data
- Estimate whether background levels exceed generic SSLs

Step Three: **Define Data Collection Needs for Soils to Determine Which Site Areas Exceed SSLs**

- Develop hypothesis about distribution of soil contamination (i.e., which areas of the site have soil contamination that exceed appropriate SSLs?)
- Develop sampling and analysis plan for determining soil contaminant concentrations
  - Sampling strategy for surface soils (includes defining study boundaries, developing a decision rule, specifying limits on decision errors, and optimizing the design)
  - Sampling strategy for subsurface soils (includes defining study boundaries, developing a decision rule, specifying limits on decision errors, and optimizing the design)
  - Sampling to measure soil characteristics (bulk density, moisture content, organic carbon content, porosity, pH)
- Determine appropriate field methods and establish QA/QC protocols

Step Four: **Sample and Analyze Soils at Site**

- Identify contaminants
- Delineate area and depth of sources
- Determine soil characteristics
- Revise CSM, as appropriate

Step Five: **Derive Site-specific SSLs, if needed**

- Identify SSL equations for relevant pathways
- Identify chemical of concern for dermal exposure and plant uptake
- Obtain site-specific input parameters from CSM summary
- Replace variables in SSL equations with site-specific data gathered in Step 4
- Calculate SSLs
  - Account for exposure to multiple contaminants

Step Six: **Compare Site Soil Contaminant Concentrations to Calculated SSLs**

- For surface soils, screen out exposure areas where all composite samples do not exceed SSLs by a factor of 2
- For subsurface soils, screen out source areas where the highest average soil core concentration does not exceed the SSLs
- Evaluate whether background levels exceed SSLs

Step Seven: **Decide How to Address Areas Identified for Further Study**

- Consider likelihood that additional areas can be screened out with more data
- Integrate soil data with other media in the baseline risk assessment to estimate cumulative risk at the site
- Determine the need for action
- Use SSLs as PRGs

Ultimately, when site investigations are complete, this sketch will be refined into a three-dimensional diagram that summarizes the data. Also, a brief summary of the contamination problem should accompany the CSM. Attachment A provides an example of a complete CSM summary.

2.1.4 Perform Site Reconnaissance. At this point, a site visit would be useful because conditions at the site may have changed since the PA/SI was performed (e.g., removal actions may have been taken). During site reconnaissance, update site sketches/topographic maps with the locations of buildings, source areas, wells, and sensitive environments. Anecdotal information from nearby residents or site workers may reveal undocumented disposal practices and thus previously unknown areas of contamination that may affect the current CSM interpretation.

Based on the new information gained from site reconnaissance, update the CSM as appropriate. Identify any remaining data gaps in the CSM so that these data needs can be incorporated into the Sampling and Analysis Plan (SAP).

2.2 Step 2: Comparing CSM to SSL Scenario

The Soil Screening Guidance is likely to be appropriate for sites where residential land use is reasonably anticipated. However, the CSM may include other sources and exposure pathways that are not covered by this guidance. Compare the CSM with the assumptions and limitations inherent in the SSLs to determine whether additional or more detailed assessments are needed for any exposure pathways or chemicals. Early identification of areas or conditions where SSLs are not applicable is important so that other characterization and response efforts can be considered when planning the sampling strategy.

2.2.1 Identify Pathways Present at the Site Addressed by Guidance. The following are potential pathways of exposure to soil contaminants in a residential setting and are addressed by this guidance document:

- Direct ingestion
- Inhalation of volatiles and fugitive dusts
- Ingestion of contaminated ground water caused by migration of chemicals through soil to an underlying potable aquifer
- Dermal absorption
- Ingestion of homegrown produce that has been contaminated via plant uptake
- Migration of volatiles into basements.

This guidance quantitatively addresses the ingestion, inhalation, and migration to ground water pathways and also addresses, more qualitatively, the potential for dermal absorption and plant uptake based on limited empirical data. Whether some or all of the pathways are relevant at the site depends upon the contaminants and conditions at the site.

For **surface** soils under the residential land use assumption, routinely consider the direct ingestion route in the soil screening decision. Inhalation of fugitive dusts and dermal absorption can be of concern for certain chemicals and site conditions.

For **subsurface** soils, risks from inhalation of volatile contaminants and migration of soil contaminants to an underlying aquifer are potential concerns for this scenario. The inhalation pathway may be eliminated from further analysis if the presence of volatile contaminants are not suspected in the subsurface soils. Likewise, consideration of the ground water pathway may be eliminated if ground water beneath or adjacent to the site is not a potential source of drinking water. Coordinate this decision on a site-specific basis with State or local authorities responsible for ground water use and classification. The rationale for excluding this exposure pathway should be consistent with EPA ground water policy (U.S. EPA, 1988a, 1990a, 1992a, 1992c, and 1993b).

The potential for plant uptake of contaminants should be addressed for both surface and subsurface soils.

In addition to the more common pathways of exposure in a residential setting, concerns have been raised regarding the potential for migration of

volatile organic compounds (VOCs) from subsurface soils into basements. The Johnson and Ettinger model (1991) was developed to address this pathway, and an analysis of the potential use of this model for soil screening is provided in the TBD (U.S. EPA, 1996). The analysis suggests that the use of the model is limited due to its sensitivity to a number of parameters such as distance from the source to the building, building ventilation rate and the number and size of cracks in the basement wall. Such data are difficult to obtain for a current use scenario, and extremely uncertain for any future use scenario. Thus, instead of relying exclusively on the model, data from a comprehensive soil-gas survey are recommended to address the potential for migration of VOCs in the subsurface. Soil-gas data and site-specific information on soil permeability can be used to replace default parameters in the Johnson and Ettinger model to obtain a more reliable estimate for the impact of this pathway on site risk.

2.2.2 Identify Additional Pathways Present at the Site Not Addressed by Guidance. The presence of additional pathways does not preclude the use of SSLs in site areas that are currently residential or likely to be residential in the future. However, the risks associated with these additional pathways should also be considered in the RI/FS to determine whether SSLs are adequately protective. Where the following conditions exist, a more detailed site-specific study should be performed:

- The site is **adjacent to bodies of surface water** where the potential for contamination of surface water by overland flow or release of contaminated ground water into surface water through seeps should be considered.
- There are potential terrestrial or aquatic **ecological concerns.**
- There are **other likely human exposure pathways** that were not considered in development of the SSLs (e.g., local fish consumption, raising of beef, dairy, or other livestock).
- There are **unusual site conditions** such as the presence of nonaqueous phase liquids (NAPLs), large areas of contamination, unusually high fugitive dust levels due to soil being tilled for agricultural use, or heavy traffic on unpaved roads.
- There are **certain subsurface site conditions** such as karst, fractured rock aquifers, or contamination extending below the water table, that result in the screening models not being sufficiently conservative.

2.2.3 Compare Available Data to Background. EPA may be concerned with two types of background at sites: naturally occurring and anthropogenic. Natural background is usually limited to metals; whereas, anthropogenic (i.e., man-made) background can include both organic and inorganic contaminants. A comparison of available data (e.g., State soil surveys) on local background concentrations with generic SSLs may indicate whether background concentrations at the site are elevated. Although background concentrations exceeding generic SSLs do not necessarily indicate that a health threat exists, further investigation may be necessary.

Generally, EPA does not cleanup below natural background levels; however, where anthropogenic background levels exceed SSLs and EPA has determined that a response action is necessary and feasible, EPA's goal will be to develop a comprehensive response to address area soils. This will often require coordination with different authorities that have jurisdiction over other sources of contamination in the area (such as a regional air board or RCRA program). This will help avoid response actions that create "clean islands" amid widespread contamination.

To determine the need for a response action, the site investigation should include gathering site-specific background data for any potential chemicals of concern and their speciation, because contaminant solubility in water and bioavailability (absorption into an organism) are important considerations for the risk assessment. Speciation of compounds such as metals and congener-specific analysis of similar organic chemicals [e.g., dioxins, polychlorinated biphenyls (PCBs)] can sometimes provide improved estimates of exposure and subsequent toxicity of chemically related compounds. While water solubility is not often a

good predictor of uptake of a toxicant into the blood of an exposed receptor for physiological reasons, relative bioavailability and toxicity can sometimes be estimated through analytical speciation of related compounds. For example, various forms of metals are more or less toxic and can behave as quite disparate compounds in terms of exposure and risk. Inorganic forms of metals are not likely to cross biological membranes as easily or may not bioaccumulate as readily as organometallics. Different valences of metals can produce dramatically different toxicities (e.g., chromium). Different matrices can render metals more or less bioaccessible (e.g., lead in auto emissions from leaded gas vs. lead in mine wastes). Similarly, the position and number of halogens on complex organic molecules can affect uptake and toxicity (e.g., dioxins). When applying these concepts to a screening analysis, the risk assessor should establish a credible rationale based on relevant literature and site data that supports actual differences in uptake and/or toxicity, since one cannot predict bioavailability from simple solubility studies. More likely, such an in-depth evaluation of chemical speciation and bioavailability would be conducted as part of a more detailed site-specific risk assessment.

2.3 Step 3: Defining Data Collection Needs for Soils

Once the CSM has been developed and the site manager has determined that the Soil Screening Guidance is appropriate to use at a site, an SAP should be developed. Attachment A, the Conceptual Site Model Summary, lists the data needed to apply the Soil Screening Guidance. The summary will help identify data gaps in the CSM that require collection of site-specific data. The soil SAP is likely to contain different sampling strategies that address:

- Surface soil
- Subsurface soil
- Soil characteristics

To develop sampling strategies that will properly assess site contamination, EPA recommends that site managers consult with the technical experts in their Region, including risk assessors, toxicologists, chemists and hydrogeologists. These experts can assist the site manager to use the DQO process to satisfy Superfund program objectives. The DQO process is a systematic planning process developed by EPA to ensure that sufficient data are collected to support EPA decision making. A full discussion of the DQO process is provided in *Data Quality Objectives for Superfund: Interim Final Guidance* (U.S. EPA, 1993a) and the *Guidance for the Data Quality Objectives Process* (U.S. EPA, 1994a).

Most key elements of the DQO process have already been incorporated as part of this Soil Screening Guidance (see Exhibits 5 through 8 and Attachment B). The remaining elements involve identifying the site-specific information needed to calculate SSLs. For example, the dry bulk density and the fraction of organic carbon content will need to be collected for the subsurface soil investigation.

The following sections present an overview of the sampling strategies needed to use the Soil Screening Guidance. For a more detailed discussion, see the supporting TBD.

2.3.1 Stratify the Site Based on Existing Data. At this point in the soil screening process, existing data can be used to stratify the site into three types of areas requiring different levels of investigation:

- Areas unlikely to be contaminated
- Areas known to be highly contaminated
- Areas that may be contaminated and cannot be ruled out.

Areas that are unlikely to be contaminated generally will not require further investigation if historical site use information or other site data, which are reasonably complete and accurate, confirm this assumption. These may be areas of the site that were completely undisturbed by hazardous-waste-generating activities.

Exhibit 5: Data Quality Objectives Process

1. State the Problem

Summarize the contamination problem that will require new environmental data, and identify the resources available to resolve the problem.

2. Identify the Decision

Identify the decision that requires new environmental data to address the contamination problem.

3. Identify Inputs to the Decision

Identify the information needed to support the decision, and specify which inputs require new environmental measurements.

4. Define the Study Boundaries

Specify the spatial and temporal aspects of the environmental media that the data must represent to support the decision.

Expanded in Exhibit 6

5. Develop a Decision Rule

Develop a logical "if ... then ..." statement that defines the conditions that would cause the decision maker to choose among alternative actions.

6. Specify Limits on Decision Errors

Specify the decision maker's acceptable limits on decision errors, which are used to establish performance goals for limiting uncertainty in the data.

7. Optimize the Design for Obtaining Data

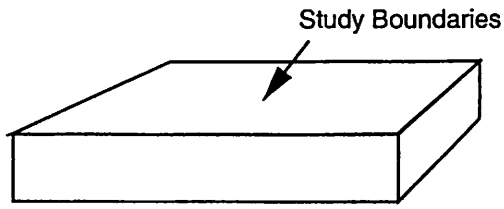
Identify the most resource-effective sampling and analysis design for generating data that are expected to satisfy the DQOs.

Surface Soils Expanded in Exhibit 7

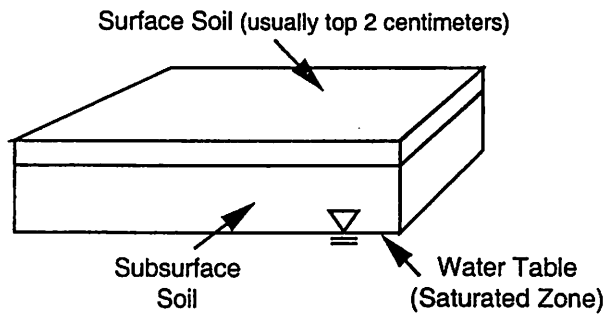
Subsurface Soils Expanded in Exhibit 8

Exhibit 6: Defining the Study Boundaries

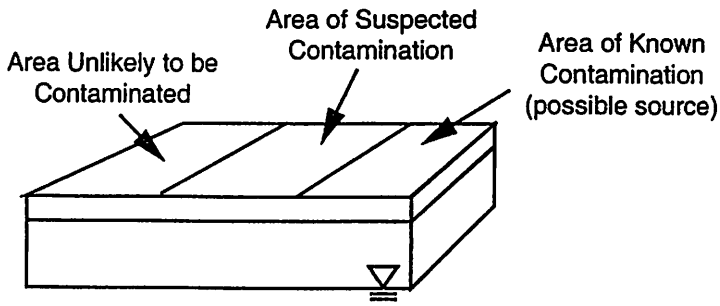
1. Define Geographic Area of the Investigation



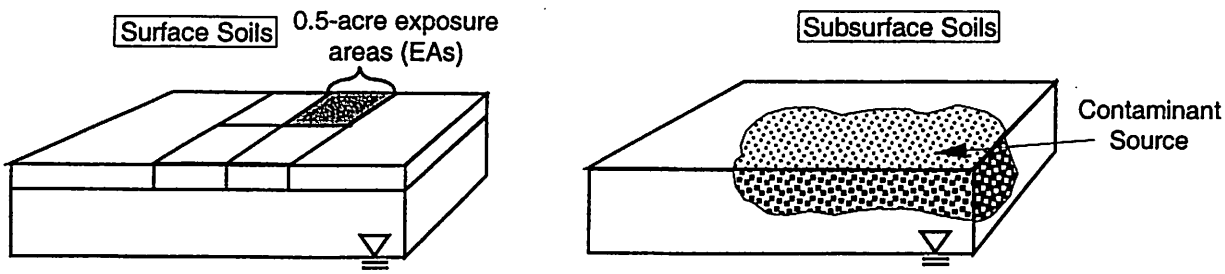
2. Define Population of Interest



3. Stratify the Site



4. Define Scale of Decision Making for Surface or Subsurface Soils



Back to Exhibit 5, Step 5, "Develop a Decision Rule"

A crude estimate of the degree of soil contamination can be made for other areas of the site by comparing site concentrations to the generic SSLs in Appendix A of the TBD. Generic SSLs have been calculated for 110 chemicals using default values in the SSL equations, resulting in conservative values that will be protective for the majority of site conditions.

The pathway-specific generic SSLs can be compared with available concentration data from previous site investigations or removal actions to help divide the site into areas with similar levels of soil contamination and develop appropriate sampling strategies.

The surface soil sampling strategy discussed in this document is most appropriate for those areas that may be contaminated and can not be designated as uncontaminated. Areas which are known to be contaminated (based on existing data) will be investigated and characterized in the RI/FS.

2.3.2 Develop Sampling and Analysis Plan for Surface Soil. The surface soil sampling strategy is designed to collect the data needed to evaluate exposures via direct ingestion, dermal absorption, and inhalation of fugitive dusts.

As explained in the *Supplemental Guidance to* RAGS: *Calculating the Concentration Term* (U.S. EPA, 1992d), an individual is assumed to move randomly across an **exposure area (EA)** over time, spending equivalent amounts of time in each location. Thus, the concentration contacted over time is best represented by the spatially averaged concentration over the EA. Ideally, the surface soil sampling strategy would determine the true population mean of contaminant concentrations in an EA. Because determination of the "true" mean would require extensive sampling at high costs, the maximum contaminant concentration from composite samples is used as a conservative estimate of the mean.

This Max test strategy compares the results of composite samples with the SSLs. Another, more complex strategy called the Chen test is presented in Part 4 of the TBD.

The User's Guide uses the Max test rather than the Chen test because the Max test is based on a statistical null hypothesis that is more appropriate for NPL sites (i.e., the EA requires further investigation). Although the Chen test is not well suited for screening decisions at NPL sites, it may be useful in a non-NPL, voluntary cleanup context.

The depth over which surface soils are sampled should reflect the type of exposures expected at the site. The *Urban Soil Lead Abatement Demonstration Project* (U.S. EPA 1993d) defined the top 2 centimeters as the depth of soil where direct contact predominantly occurs. The decision to sample soils below 2 centimeters depends on the likelihood of deeper soils being disturbed and brought to the surface (e.g., from gardening, landscaping or construction activities).

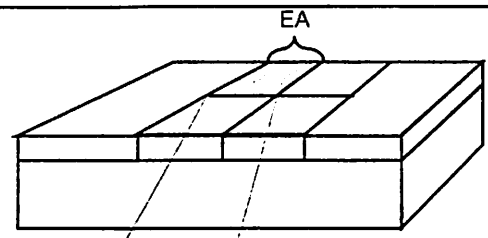
Note that the size, shape, and orientation of sampling volume (i.e., "support") for heterogenous media have a significant effect on reported measurement values. For instance, particle size has a varying affect on the transport and fate of contaminants in the environment and on the potential receptors. Comparison of data from methods that are based on different supports can be difficult. Defining the sampling support is important in the early stages of site characterization. This may be accomplished through the DQO process with existing knowledge of the site, contamination, and identification of the exposure pathways that need to be characterized. Refer to *Preparation of Soil Sampling Protocols: Sampling Techniques and Strategies* (U.S. EPA, 1992e) for more information about soil sampling support.

The SAP developed for surface soils should specify sampling and analytical procedures as well as the development of QA/QC procedures. To identify the appropriate analytical procedures, the screening levels must be known. If data are not available to calculate site-specific SSLs (Section 2.5.1), then the generic SSLs in Appendix A of the TBD should be used.

The following strategy can be used for **surface soils** to estimate the mean concentration of semivolatiles, inorganics, and pesticides in an exposure area. Volatiles are not included in the estimations because they are not expected to remain at the surface for an extended period of time.

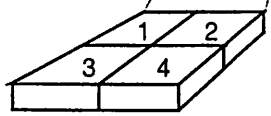
Exhibit 7: Designing a Sampling and Analysis Plan for Surface Soils

1. Subdivide Site Into EAs



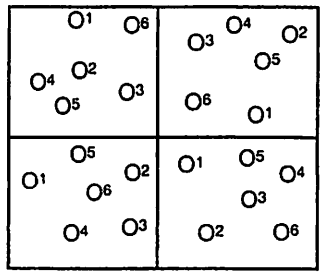
For surface soils, the individual unit for decision making is an "EA," or exposure area. It measures 0.5 acre in area or less.

2. Divide EA Into a Grid



This step defines the number of specimens (N) that will make up one composite sample.

3. Organize Surface Sampling Program for EA



Placement of sample locations on the grid was developed using a default sample size of 6 (which is based on acceptable error rates for a CV of 2.5) and a stratified random sampling pattern.

If the EA CV is suspected to be greater than 2.5, use the table below to select an adequate sample size or refer to the TBD for other sample design options.

Probability of Decision Error at 0.5 SSL and 2 SSL Using Max Test

	CV=2.5[a]		CV=3.0		CV=3.5		CV=4.0	
Sample Size [b]	$E_{0.5}$[c]	$E_{2.0}$[d]	$E_{0.5}$	$E_{2.0}$	$E_{0.5}$	$E_{2.0}$	$E_{0.5}$	$E_{2.0}$
	C = 4 specimens per composite[e]							
6	**0.21**	**0.08**	0.28	0.11	0.31	0.11	0.35	0.16
7	0.25	0.05	0.31	0.08	0.36	0.09	0.41	0.15
8	0.25	0.04	0.36	0.05	0.42	0.07	0.41	0.09
9	0.28	0.03	0.36	0.04	0.44	0.07	0.48	0.08

[a] The CV is the coefficient of variation for individual, uncomposited measurements across the entire EA, including measurement error.
[b] Sample size (N) = number of composite samples
[c] $E_{0.5}$ = Probability of requiring further investigation when the EA mean is 0.5 SSL
[d] $E_{2.0}$ = Probability of not requiring further investigation when the EA mean is 2.0 SSL
[e] C = number of specimens per composite sample, when each composite consists of points from a stratified random or systemic grid sample from across the entire EA.

NOTE: All decision error rates are based on 1,000 simulations that assume that each composite is representative of the entire EA, half the EA has concentrations below the limit of detection, and half the EA has concentrations that follow a gamma distribution (a conservative distributional assumption).

- Divide areas to be sampled in the screening process into 0.5-acre exposure areas, the size of a suburban residential lot. If the site is currently residential, the exposure area should be the actual residential lot size. The exposure areas should not be laid out in such a way that they unnecessarily combine areas of high and low levels of contamination. The orientation and exact location of the EA, relative to the distribution of the contaminant in the soil, can lead to instances where sampling the EA may have contaminant concentration results above the mean, and in other instances, results below the mean. Try to avoid straddling contaminant "distribution units" within the 0.5-acre EA.

- Composite surface soil samples. Because the objective of surface soil screening is to estimate the mean contaminant concentration, the physical "averaging" that occurs during compositing is consistent with the intended use of the data. Compositing allows sampling of a larger number of locations while controlling analytical costs, since several individual samples are physically mixed (homogenized) and one or more subsamples are drawn from the mixture and submitted for analysis.

- Strive to achieve a false negative error rate of 5 percent (i.e., in only 5 percent of the cases, soil contamination is assumed to be below the screening level when it is really above the screening level). EPA also strives to achieve a 20 percent false positive error rate (i.e., in only 20 percent of the cases, soil contamination is assumed to be above the screening level when it is really below the screening level). These error rate goals influence the number of samples to be collected in each exposure area. For this guidance, EPA has defined the "gray region" as one-half to 2 times the SSL. Refer to Section 2.6 for further discussion.

- The default sample size chosen for this guidance (see Exhibit 7) provides adequate coverage for a coefficient of variation (CV) based upon 250 percent variability in contaminant values (CV=2.5). (If a CV larger than 2.5 is expected, use an appropriate sample size from the table in Exhibit 7 of the User's Guide, or tables in the TBD.)

- Take six composite samples, for each exposure area, with each composite sample made up of four individual samples. Exhibit 7 shows other sample sizes needed to achieve the decision error rates for other CVs. Collect the composites randomly across the EA and through the top 2 centimeters of soil, which are of greatest concern for incidental ingestion of soil, dermal contact, and inhalation of fugitive dust.

- Analyze the six samples per exposure area to determine the contaminants present and their concentrations.

For further information on compositing across or within EA sectors, developing a random sampling strategy, and determining sample sizes that control decision error rates, refer to the TBD.

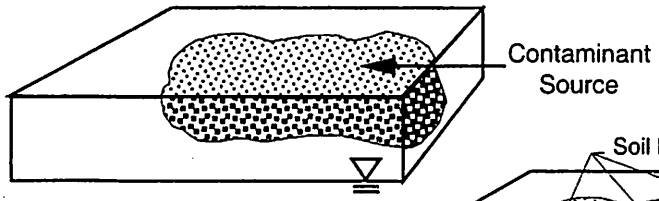
Note that the Max test requires a Data Quality Assessment (DQA) test following sampling and analysis (Section 2.4.2) to ensure that the DQOs (i.e., decision error rate goals) are achieved. If DQOs are not met, additional sampling may be required.

2.3.3 Develop Sampling and Analysis Plan for Subsurface Soils. The subsurface and surface soil sampling strategies differ because the exposure mechanisms differ. Exposure to surface contaminants occurs randomly as individuals move around a residential lot. The surface soil sampling strategy reflects this type of random exposure.

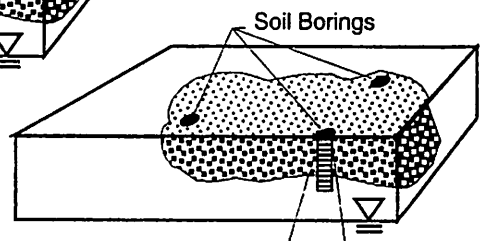
In general, exposure to subsurface contamination occurs when chemicals migrate up to the surface or down to an underlying aquifer. Thus, subsurface sampling focuses on collecting the data required for modeling the volatilization and migration to ground water pathways. Measurements of soil characteristics and estimates of the area and depth of contamination and the average contaminant concentration in each source area are needed to supply the data necessary to calculate the inhalation and migration to ground water SSLs.

Exhibit 8: Designing a Sampling and Analysis Plan for Subsurface Soils

1. Delineate Source Area

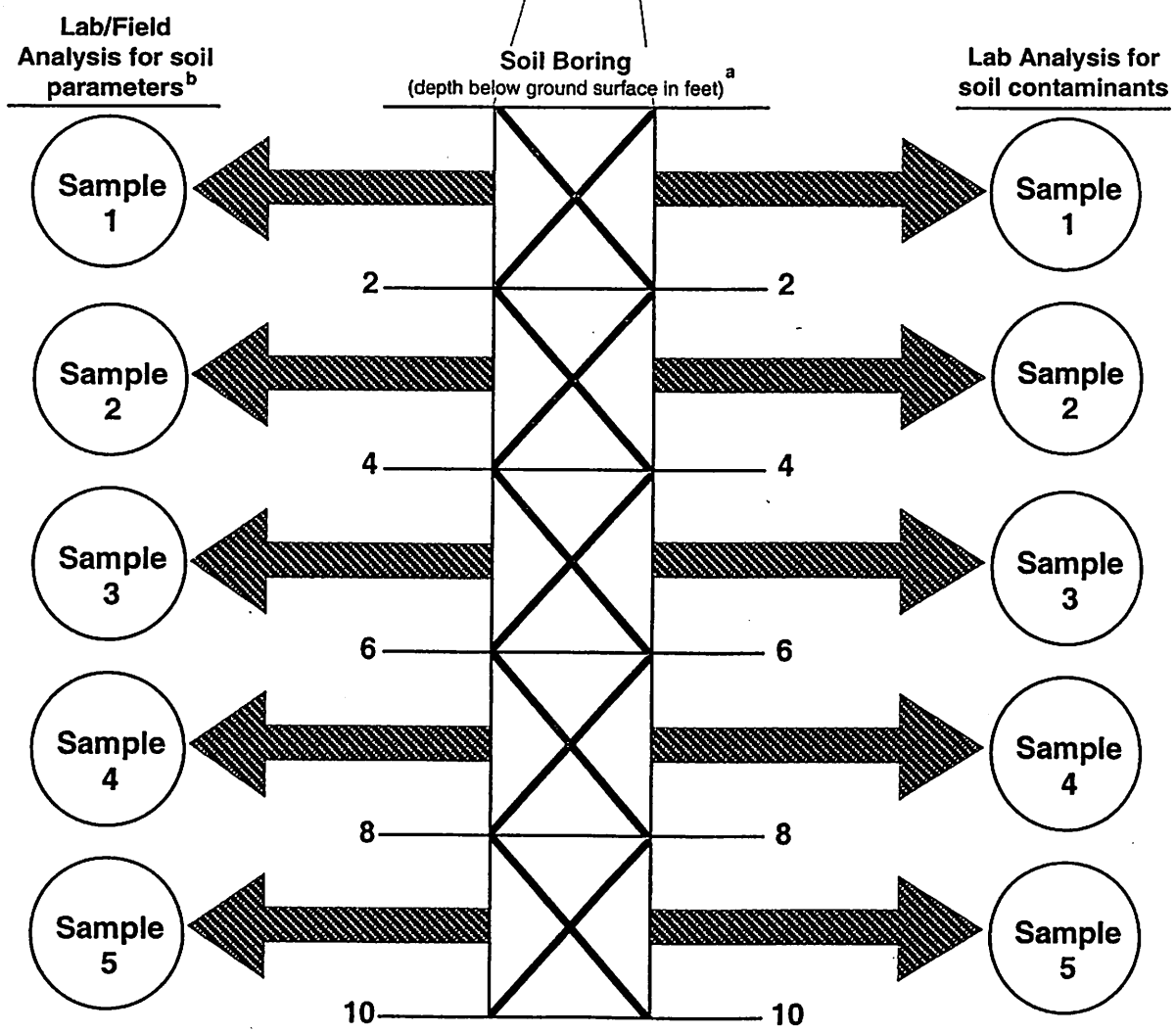


2. Choose Subsurface Soil Sampling Locations



For screening purposes, EPA recommends drilling 2 to 3 borings per source area in areas of highest suspected concentrations. Soil sampling should not extend past water table or saturated zone.

3. Design Subsurface Sampling and Analysis Plan



[a] Picture depicts a continuous boring with 2 foot segments. For information on other methods such as interval sampling and depth weighted analysis, please refer to 2.3.3 of the User's Guide or 4.2 of the TBD.

[b] Soil Texture, Dry Bulk Density, Soil Organic Carbon, pH. Retain samples for possible discrete contaminant sampling.

Source areas are the decision units for subsurface soils. A source area is defined by the horizontal extent, and vertical extent or depth of contamination. For this purpose, "contamination" is defined by either the Superfund's Contract Laboratory Program (CLP) practical quantitation limits (QLs) for each contaminant, or the SSL. **Sites with multiple sources should develop separate SSLs for each source.**

The SAP developed for subsurface soils should specify sampling and analytical procedures as well as the development of QA/QC procedures. To identify the appropriate procedures, the SSLs must be known. If data are not available to calculate site-specific SSLs (Section 2.5.2), then the generic SSLs in Appendix A of the TBD should be used.

The primary goal of the subsurface sampling strategy is to estimate the mean contaminant concentration and average soil characteristics within the source area. As with the surface soil sampling strategy, the subsurface soil sampling strategy follows the DQO process (see Exhibits 5, 6, and 8). The decision rule is based on comparing the mean contaminant concentration within each contaminant source with source-specific SSLs.

Current investigative techniques and statistical methods cannot accurately determine the mean concentration of subsurface soils within a contaminated source without a costly and intensive sampling program that is well beyond the level of effort generally appropriate for screening. Thus, conservative assumptions should be used to develop hypotheses on likely contaminant distributions.

This guidance bases the decision to investigate a source area further on the highest mean soil boring contaminant concentration within the source, reflecting the conservative assumption that the highest mean subsurface soil boring concentration among a set of borings taken from the source area represents the mean of the entire source area. Similarly, estimates of contaminant depths should be conservative. The investigation should include the maximum depth of contamination encountered within the source without going below the water table.

For each source, the guidance recommends taking 2 or 3 soil borings located in the areas suspected of having the highest contaminant concentrations within the source. These subsurface soil sampling locations are based primarily on knowledge of likely surface soil contamination patterns (see Exhibit 6) and subsurface conditions. However, buried sources may not be discernible at the surface. Information on past practices at the site included in the CSM can help identify subsurface source areas.

For sites contaminated with VOCs, the subsurface sampling strategy should include soil gas surveys as well as soil matrix sampling. VOCs are commonly found in vapor phase in the unsaturated zone, and soil matrix samples may yield results that are deceptively low. Soil gas data are needed to help locate sources, define source size, to place soil boring locations within a source, and can also be used in conjunction with modeling to address VOC transport in the vadose zone for both the volatilization and migration to ground water pathways.

Take soil cores from the soil boring using either split spoon sampling or other appropriate sampling methods. *Description and Sampling of Contaminated Soils: A Field Pocket Guide* (U.S. EPA, 1991f), and *Subsurface Characterization and Monitoring Techniques: A Desk Reference Guide, Vol. I & II* (U.S. EPA, 1993e), can be consulted for information on appropriate subsurface sampling methods.

Sampling should begin at the ground surface and continue until either no contamination is encountered or the water table is reached. **Subsurface sampling intervals can be adjusted at a site to accommodate site-specific information on subsurface contaminant distributions and geological conditions** (e.g., thick vadose zones in the West). The concept of "sampling support" introduced in Section 2.3.2 also applies to subsurface sampling. For example, sample splits and subsampling should be performed according to *Preparation of Soil Sampling Protocols: Sampling Techniques and Strategies* (U.S. EPA, 1992e).

If each subsurface soil core segment represents the same subsurface soil interval (e.g., 2 feet), then the average concentration from the surface to the depth of contamination is the simple arithmetic average of contaminant concentrations measured for core samples representative of each of the 2-foot segments from the surface to the depth of contamination. However, if the sample intervals are not all of the same length (e.g., some are 2 feet while others are 1 foot or 6 inches), then the calculation of the average concentration in the total core must account for the different lengths of the segments.

If c_i is the concentration measure in a core sample, representative of a core interval or segment of length l_i, and the n-th segment is considered to be the last segment sampled in the core (i.e., the n-th segment is at the depth of contamination), then the average concentration in the core from the surface to the depth of contamination should be calculated as the following depth-weighted average ($\bar{c}$).

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

Alternatively, the average boring concentration can be determined by adding the total contaminant masses together (from the sample results) for all sample segments to get the total contaminant mass for the boring. The total contaminant mass is then divided by the total dry weight of the core (as determined by the dry bulk density measurements) to estimate average soil boring concentration.

For the leach test option, collect discrete samples along a soil boring from within the zone of contamination and composite them to produce a sample representative of the average soil boring concentration. Take care to split each discrete sample before analysis so that information on contaminant distributions with depth will not be lost. A leach test may be conducted on each soil core.

Finally, the soil investigation for the migration to ground water pathway should not be conducted independently of ground water investigations. Contaminated ground water may indicate the presence of a nearby source area that would leach contaminants from soil into aquifer systems.

2.3.4 Develop Sampling and Analysis Plan to Determine Soil Characteristics. The soil parameters necessary for SSL calculations are soil texture, dry bulk density, soil organic carbon, and pH. Some can be measured in the field, while others require laboratory measurement. Although laboratory measurements of these parameters cannot be obtained under Superfund's CLP, independent soil testing laboratories across the country can perform these tests at a relatively low cost.

To appropriately apply the volatilization and migration-to-ground water models, average or typical soil properties should be used for a source in the SSL equations (see Step 5). Take samples for measuring soil parameters with samples for measuring contaminant concentrations. If possible, consider splitting single samples for contaminant and soil parameter measurements. Many soil testing laboratories can handle and test contaminated samples. However, if testing contaminated samples for soil parameters is a problem, samples may be obtained from clean areas of the site as long as they represent the same soil texture and are taken from approximately the same depth as the contaminant concentration samples.

Soil Texture. Soil texture class (e.g., loam, sand, silt loam) is necessary to estimate average soil moisture conditions and to apply the Hydrological Evaluation of Landfill Performance (HELP) model to estimate infiltration rates (see Attachment A). The appropriate texture classification is determined by a particle size analysis and the U.S. Department of Agriculture (USDA) soil textural triangle shown in Exhibit 9. This classification system is based on the USDA soil particle size classification.

The particle size analysis method in Gee and Bauder (1986) can provide this particle size distribution. Other methods are appropriate as long as they provide the same particle size breakpoints for sand/silt (0.05 mm) and silt/clay (0.002 mm). Field methods are an alternative for determining soil

textural class; Exhibit 9 presents an example from Brady (1990).

Dry Bulk Density. Dry soil bulk density (ρ_b) is used to calculate total soil porosity and can be determined for any soil horizon by weighing a thin-walled tube soil sample (e.g., Shelby tube) of known volume and subtracting the tube weight [American Society for Testing and Materials (ASTM) D 2937]. Determine moisture content (ASTM 2216) on a subsample of the tube sample to adjust field bulk density to dry bulk density. The other methods (e.g., ASTM D 1556, D 2167, D 2922) are generally applicable only to surface soil horizons and are not appropriate for subsurface characterization. ASTM soil testing methods are readily available in the *Annual Book of ASTM Standards, Volume 4.08, Soil and Rock; Building Stones*, available from ASTM, 100 Barr Harbor Drive, West Conshohocken, PA, 19428.

Organic Carbon and pH. Soil organic carbon is measured by burning off soil carbon in a controlled-temperature oven (Nelson and Sommers, 1982). This parameter is used to determine soil-water partition coefficients from the organic carbon soil-water partition coefficient, K_{oc}. Soil pH is used to select site-specific partition coefficients for metals (Table C-4, Attachment C) and ionizing organics (Table C-2, Attachment C). This simple measurement is made with a pH meter in a soil/water slurry (McLean, 1982) and may be measured in the field using a portable pH meter.

2.3.5 Determine Analytical Methods and Establish QA/QC Protocols. Assemble a list of feasible sampling and analytical methods during this step. Verify that a CLP method and a field method for analyzing the samples exist and that the analytical method QL or field method QL is appropriate for (i.e., is below) the site-specific or generic SSL. *Sampler's Guide to the Contract Laboratory Program* (U.S. EPA, 1990b) and *User's Guide to the Contract Laboratory Program* (U.S. EPA, 1991e) contain further information on CLP methods.

Field methods, such as soil gas surveys, immunoassay, or X-ray fluorescence, can be used if the field method quantitation limit is below the SSL. EPA recommends the use of field methods where applicable and appropriate. However, at least 10 percent of both the discrete samples and the composites should be split and sent to a CLP laboratory for confirmatory analysis. (*Quality Assurance for Superfund Environmental Data Collection Activities,* U.S. EPA, 1993c).

Because a great amount of variability and bias can exist in the collection, subsampling, and analysis of soil samples, some effort should be made to characterize this variability and bias. *A Rationale for the Assessment of Errors in the Sampling of Soils* (U.S. EPA, 1990c) outlines an approach that advocates the use of a suite of QA/QC samples to assess variability and bias. Field duplicates and splits are some of the best indicators of overall variability in the sampling and analytical processes.

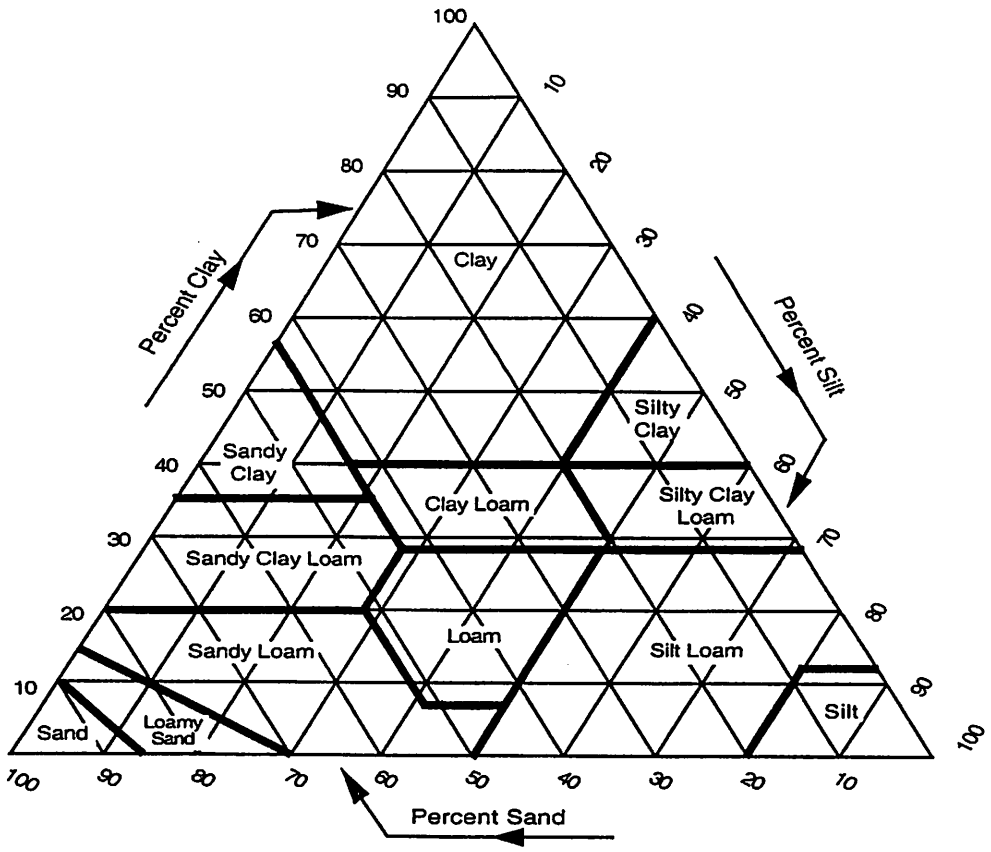
Field methods will be useful in defining the study boundaries (i.e., area and depth of contamination) during both site reconnaissance and sampling. The design and capabilities of field portable instrumentation are rapidly evolving. Documents describing the standard operating procedures for field instruments are available though the National Technical Information Service (NTIS).

Regardless of whether surface or subsurface soils are sampled, the Superfund quality assurance program guidance (U.S. EPA, 1993c) should be consulted. Standard limits on the precision and bias of sampling and analytical operations conducted during sampling do apply and should be followed to give consistent and defensible results.

2.4 Step 4: Sampling and Analyzing Site Soils & DQA

Once the sampling strategies have been developed and implemented, the samples should be analyzed according to the analytical laboratory and field methods specified in the SAP. Results of the analyses should identify the concentrations of potential contaminants of concern for which site-specific SSLs will be calculated.

Exhibit 9: U.S. Department of Agriculture soil texture classification.



Criteria Used with the Field Method for Determining Soil Texture Classes (Source: Brady, 1990)

Criterion	Sand	Sandy loam	Loam	Silt loam	Clay loam	Clay
1. Individual grains visible to eye	Yes	Yes	Some	Few	No	No
2. Stability of dry clods	Do not form	Do not form	Easily broken	Moderately easily broken	Hard and stable	Very hard and stable
3. Stability of wet clods	Unstable	Slightly stable	Moderately stable	Stable	Very stable	Very stable
4. Stability of "ribbon" when wet soil rubbed between thumb and fingers	Does not form	Does not form	Does not form	Broken appearance	Thin, will break	Very long, flexible

Particle Size, mm

	0.002		0.05	0.10	0.25	0.5	1.0	2.0	
U.S. Department of Agriculture	Clay	Silt	Very Fine	Fine	Med.	Coarse	Very Coarse		Gravel
			Sand						

Source: USDA.

2.4.1 Delineate Area and Depth of Source. Both spatial area and depth data, as well as soil characteristic data, are needed to calculate site-specific SSLs for the inhalation of volatiles and migration to ground water pathways in the subsurface. Site information from the CSM or soil gas surveys can be used to estimate the areal extent of the sources.

2.4.2 Perform DQA Using Sample Results. After sampling has been completed, a DQA should be conducted if all composite samples are less than 2 times the SSL. This is necessary to determine if the original CV estimate (2.5), and hence the number of samples collected (6), was adequate for screening surface soils.

To conduct the DQA for a composite sample whose mean is below 2 SSL, first calculate the sample CV for the EA in question from the sample mean ($\bar{x}$), the number of specimens per composite sample (C), and sample standard deviation (s) as follows:

$$CV = \frac{\sqrt{C}\,s}{\bar{x}} .$$

Use the sample size table in Exhibit 7 to check, for this CV, whether the sample size is adequate to meet the DQOs for the sampling effort. If sampling DQOs are not met, supplementary sampling may be needed to achieve DQOs.

However, for EAs with small sample means (e.g., all composites are less than the SSL), the sample CV calculated using the equation above may not be a reliable estimate of the population CV (i.e., as $\bar{x}$ approaches zero, the sample CV will approach infinity). To protect against unnecessary additional sampling in such cases, compare all composites against the formula SSL $/\sqrt{C}$. If the maximum composite sample concentration is below the value given by the equation, then the sample size may be assumed to be adequate and no further DQA is necessary. In other words, EPA believes that the default sample size will adequately support walk-away decisions when all composites are well below the SSL. The TBD describes the development of this formula and provides additional information on implementing the DQA process.

2.4.3 Revise the CSM. Because these analyses reveal new information about the site, update the CSM accordingly. This revision could include identification of site areas that exceed the generic SSLs.

2.5 Step 5: Calculating Site-specific SSLs

With the soil properties data collected in Step 4 of the screening process, site-specific soil screening levels can now be calculated using the equations presented in this section. For a description of how these equations were developed, as well as background on their assumptions and limitations, consult the TBD.

All SSL equations were developed to be consistent with RME in the residential setting. The Superfund program estimates the RME for chronic exposures on a site-specific basis by combining an average exposure-point concentration with reasonably conservative values for intake and duration (U.S. EPA, 1989a; RAGS HHEM, *Supplemental Guidance: Standard Default Exposure Factors*, U.S. EPA, 1991a). Thus, all site-specific parameters (soil, aquifer, and meteorologic parameters) used to calculate SSLs should reflect average or typical site conditions in order to calculate average exposure concentrations at the site.

Equations for calculating SSLs are presented for surface and subsurface soils in the following sections. **For each equation, site-specific input parameters are highlighted in bold and default values are provided for use when site-specific data are not available.** Although these defaults are not worst case, they are conservative. At most sites, higher, but still protective SSLs can be calculated using site-specific data. The TBD describes development of these default values and presents generic SSLs calculated using the default values.

Attachment D provides toxicity criteria for 110 chemicals commonly found at NPL sites. These criteria were obtained from Integrated Risk Information System (IRIS) (U.S. EPA, 1995b) or Health Effects Assessment Summary Tables (HEAST) (U.S. EPA, 1995a), which are regularly

updated. **Prior to calculating SSLs at a site, check all relevant chemical-specific values in Attachment D against values from IRIS or HEAST. Only the most current values should be used to calculate SSLs.**

Where toxicity values have been updated, the generic SSLs should also be recalculated with current toxicity information.

2.5.1 SSL Equations--Surface Soils.

Exposure pathways addressed in the process for screening surface soils include direct ingestion, dermal contact, and inhalation of fugitive dusts.

Direct Ingestion. The Soil Screening Guidance addresses chronic exposure to noncarcinogens and carcinogens through direct ingestion of contaminated soil in a residential setting. The approach for calculating noncarcinogenic SSLs presented in this guidance leads to screening levels that are approximately 3 times more conservative than PRGs calculated based on the approach presented in RAGS HHEM, Part B (i.e., using a 30-year, time-weighted average soil ingestion rate for comparison to chronic toxicity criteria). Because a number of studies have shown that inadvertent ingestion of soil is common among children age 6 and younger (Calabrese et al., 1989; Davis et al., 1990: Van Wijnen et al., 1990), several commenters suggested that screening values should be based on this increased exposure during childhood. However, other commenters believe that comparing a six-year exposure to a chronic reference dose (RfD) is unnecessarily conservative. In their analysis of this issue, the Science Advisory Board (SAB) stated that, for most chemicals, the approach of combining the higher six-year exposure for children with chronic toxicity criteria is overly protective (U.S. EPA, 1993f). However, they noted that the approach may be appropriate for chemicals with chronic RfDs based on toxic endpoints that are specific to children (e.g., fluoride and nitrates) or where the dose-response curve is steep [i.e., the difference between the no-observed-adverse-effect level (NOAEL) and the adverse effect level is small]. Thus for the purposes of screening, Office of Emergency Remedial Response (OERR) opted to base the generic SSLs for noncarcinogenic contaminants on the more conservative "childhood only" exposure (Equation 1). The issue of whether to maintain this more conservative approach throughout the Baseline Risk Assessment and establishing remediation goals will depend on how the specific chemical's toxicology relates to the issues raised by the SAB.

Equation 1: Screening Level Equation for Ingestion of Noncarcinogenic Contaminants in Residential Soil

$$\text{Screening Level (mg/kg)} = \frac{THQ \times BW \times AT \times 365\ d/yr}{1/RfD_o \times 10^{-6}\ kg/mg \times EF \times ED \times IR}$$

Parameter/Definition (units)	Default
THQ/target hazard quotient (unitless)	1
BW/body weight (kg)	15
AT/averaging time (yr)	6[a]
RfD_o/oral reference dose (mg/kg-d)	chemical-specific (Attachment D)
EF/exposure frequency (d/yr)	350
ED/exposure duration (yr)	6
IR/soil ingestion rate (mg/d)	200

[a] For noncarcinogens, averaging time equals to exposure duration.

For carcinogens, both the magnitude and duration of exposure are important. Duration is critical because the toxicity criteria are based on "lifetime average daily dose." Therefore, the total dose received, whether it be over 5 years or 50 years, is averaged over a lifetime of 70 years. To be protective of exposures to carcinogens in the residential setting, Superfund focuses on exposures to individuals who may live in the same residence for a high-end period of time (e.g., 30 years) because exposure to soil is higher during childhood and decreases with age. Equation 2 uses a time-weighted average soil ingestion rate for children and adults. The derivation of this time-weighted average is presented in U.S. EPA, 1991c.

Default values are used for all input parameters in the direct ingestion equations. The amount of data required to derive site-specific values for these parameters (e.g., soil ingestion rates, chemical-specific bioavailability) makes their collection and use impracticable for screening. Therefore, site-specific data are not generally available for this

exposure route. The generic ingestion SSLs presented in Appendix A of the TBD are recommended for all NPL sites.

Equation 2: Screening Level Equation for Ingestion of Carcinogenic Contaminants in Residential Soil	
Screening Level (mg/kg) =	$\frac{TR \times AT \times 365\ d/yr}{SF_o \times 10^{-6}\ kg/mg \times EF \times IF_{soil/adj}}$
Parameter/Definition (units)	**Default**
TR/target cancer risk (unitless)	10^{-6}
AT/averaging time (yr)	70
SF_o /oral slope factor $(mg/kg\text{-}d)^{-1}$	chemical-specific (Attachment D)
EF/exposure frequency (d/yr)	350
$IF_{soil/adj}$ /age-adjusted soil ingestion factor (mg-yr/kg-d)	114

Dermal Contact. Contaminant absorption through dermal contact may contribute risk to human health in a residential setting. However, incorporation of dermal exposures into the soil screening process is limited by the amount of data available to quantify dermal absorption from soil for specific chemicals. Previous EPA studies suggest that absorption via the dermal route must be greater than 10 percent to equal or exceed the ingestion exposure (assuming 100 percent absorption of a chemical via ingestion; *Dermal Exposure Assessment: Principles and Applications*, U.S. EPA, 1992b).

Of the 110 compounds evaluated, available data show greater than 10 percent dermal absorption for **pentachlorophenol** (Wester et al., 1993). Therefore, pentachlorophenol is the only chemical for which the Soil Screening Guidance directly considers dermal exposure. The ingestion SSL for pentachlorophenol should be divided in half to account for the assumption that exposure via the dermal route is equivalent to the ingestion route. Preliminary studies show that certain semivolatile compounds (e.g., benzo(*a*)pyrene) may also be of concern for this exposure route. As adequate dermal absorption data are developed for such chemicals, the ingestion SSLs may need to be adjusted. The Agency will provide updates on this issue as appropriate.

Inhalation of Fugitive Dusts. Inhalation of fugitive dusts is a consideration for semivolatile organics and metals in surface soils. However, generic fugitive dust SSLs for semivolatile organics are several orders of magnitude higher than the corresponding generic ingestion SSLs. EPA believes that since the ingestion route should always be considered in screening decisions for surface soils, and ingestion SSLs appear to be adequately protective for inhalation exposures to fugitive dusts for organic compounds, the fugitive dust exposure route need not be routinely considered for organic chemicals in surface soils.

Likewise, the ingestion SSLs are significantly more conservative than most of the generic fugitive dust SSLs. As a result, fugitive dust SSLs need not be calculated for most metals. However, chromium is an exception. For chromium, the generic fugitive dust SSL is below the ingestion SSL. This is due to the carcinogenicity of hexavalent chromium, Cr^{+6}, through the inhalation exposure route. For most sites, fugitive dust SSLs calculated using the conservative defaults will be adequately protective. However, if site conditions that will result in higher fugitive dust emissions than the defaults (e.g., dry, dusty soils; high average annual windspeeds; vegetative cover less than 50 percent) are likely, consider calculating a site-specific fugitive dust SSL.

Equations 3 and 4 are used to calculate fugitive dust SSLs for carcinogens and noncarcinogens. These equations require calculation of a particulate emission factor (PEF, Equation 5) that relates the concentration of contaminant in soil to the concentration of dust particles in air. This PEF represents an annual average emission rate based on wind erosion that should be compared with chronic health criteria. It is **not** appropriate for evaluating the potential for more acute exposures.

Both the emissions portion and the dispersion portion of the PEF equation have been updated since the first publication of RAGS HHEM, Part B, in 1991. As in Part B, the emissions part of the PEF equation is based on the "unlimited reservoir" model developed to estimate particulate emissions due to wind erosion (Cowherd et al., 1985). Additional information on the update of the PEF equation is provided in the TBD. Cowherd et al. (1985) present methods for site-specific measurement of the

parameters necessary to calculate a PEF. A site-specific dispersion model (Q/C) is then selected as described in the section on calculating SSLs for the volatile inhalation pathway later in this document.

Equation 3: Screening Level Equation for Inhalation of Carcinogenic Fugitive Dusts from Residential Soil

$$\text{Screening Level (mg/kg)} = \frac{TR \times AT \times 365\ d/yr}{URF \times 1{,}000\ \mu g/mg \times EF \times ED \times \frac{1}{PEF}}$$

Parameter/Definition (units)	Default
TR/target cancer risk (unitless)	10^{-6}
AT/averaging time (yr)	70
URF/inhalation unit risk factor $(\mu g/m^3)^{-1}$	chemical-specific (Attachment D)
EF/exposure frequency (d/yr)	350
ED/exposure duration (yr)	30
PEF/particulate emission factor (m^3/kg)	**1.32×10^9 (Equation 5)**

Equation 4: Screening Level Equation for Inhalation of Noncarcinogenic Fugitive Dusts from Residential Soil

$$\text{Screening Level (mg/kg)} = \frac{THQ \times AT \times 365\ d/yr}{EF \times ED \times \left[\frac{1}{RfC} \times \frac{1}{PEF}\right]}$$

Parameter/Definition (units)	Default
THQ/target hazard quotient (unitless)	1
AT/averaging time (yr)	30
EF/exposure frequency (d/yr)	350
ED/exposure duration (yr)	30
RfC/inhalation reference concentration (mg/m^3)	chemical-specific (Attachment D)
PEF/particulate emission factor (m^3/kg)	**1.32×10^9 (Equation 5)**

2.5.2 SSL Equations--Subsurface Soils.

The Soil Screening Guidance addresses two exposure pathways for subsurface soils: inhalation of volatiles and ingestion of ground water contaminated by the migration of contaminants through soil to an underlying potable aquifer. Because the equations developed to calculate SSLs for these pathways assume an infinite source, they can violate mass-balance considerations, especially for small sources.

Equation 5: Derivation of the Particulate Emission Factor

$$PEF\ (m^3/kg) = Q/C \times \frac{3{,}600\ s/h}{0.036 \times (1-V) \times (U_m/U_t)^3 \times F(x)}$$

Parameter/Definition (units)	Default
PEF/particulate emission factor (m^3/kg)	1.32×10^9
Q/C/inverse of mean conc. at center of a 0.5-acre-square source (g/m^2-s per kg/m^3)	90.80
V/fraction of vegetative cover (unitless)	0.5 (50%)
U_m/mean annual windspeed (m/s)	4.69
U_t/equivalent threshold value of windspeed at 7 m (m/s)	11.32
F(x)/function dependent on U_m/U_t derived using Cowherd et al. (1985) (unitless)	0.194

To address this concern, the guidance also includes equations for calculating mass-limit SSLs for each of these pathways **when the size (i.e., area and depth) of the contaminated soil source is known or can be estimated with confidence.**

Attachment D provides the toxicity criteria and regulatory benchmarks for 110 chemicals commonly found at NPL sites. These criteria were obtained from IRIS (U.S. EPA, 1995b), HEAST (U.S. EPA, 1995a), and *Drinking Water Regulations and Health Advisories* (U.S. EPA, 1995c), which are regularly updated. **Prior to calculating SSLs at a site, all relevant chemical-specific values in Attachment D should be checked against the most recent version of their sources to ensure that they are up to date.**

Toxicity data are not available for all chemicals for the inhalation exposure route. At the request of commenters, EPA has looked into methods for extrapolating inhalation toxicity values from oral toxicity data. The TBD presents the results of this analysis along with information on current EPA

practices for conducting such route-to-route extrapolations.

Chemical properties necessary to calculate SSLs for the inhalation and migration to ground water pathways include solubility, air and water diffusivities, Henry's law constant, and soil/water partition coefficients. Attachment C provides values for 110 chemicals commonly found at NPL sites.

Site-specific parameters necessary to calculate SSLs for subsurface soils are listed on Exhibit 10, along with recommended sources and measurement methods. In addition to the soil parameters described in Step 3, other site-specific input parameters include soil moisture, infiltration rate, aquifer parameters, and meteorologic data. Guidance for collecting or estimating these other parameters at a site is provided on Exhibit 10 and in Attachment A.

Inhalation of Volatiles. Equations 6 and 7 are used to calculate SSLs for the inhalation of carcinogenic and noncarcinogenic volatile contaminants.To use these equations to calculate inhalation SSLs, a volatilization factor (VF) must be calculated.

The VF equation can be broken into two separate models: a model to estimate the emissions and a dispersion model (reduced to the term Q/C) that simulates the dispersion of contaminants in ambient air. In addition, a soil saturation limit (C_{sat}) must be calculated to ensure that the VF model is applicable to soil contaminant conditions at a site.

Volatilization Factor (VF). The soil-to-air VF (Equation 8) is used to define the relationship between the concentration of the contaminant in soil and the flux of the volatilized contaminant to air. **The Soil Screening Guidance replaces the Hwang and Falco (1986) model used as the basis for the RAGS HHEM, Part B, VF equation with the simplified equation developed by Jury et al. (1984).**

The Jury model calculates the maximum flux of a contaminant from contaminated soil and considers soil moisture conditions in calculating a VF. The models are similar in their assumptions of an infinite contaminant source and vapor phase diffusion as the only transport mechanism (i.e., no transport takes place via nonvapor-phase diffusion and there is no mass flow due to capillary action). In some situations, information about the size of the source is available and SSLs can be calculated using the mass-limit approach.

Equation 6: Screening Level Equation for Inhalation of Carcinogenic Volatile Contaminants in Residential Soil

$$\text{Screening Level (mg/kg)} = \frac{TR \times AT \times 365\ d/yr}{URF \times 1{,}000\ \mu g/mg \times EF \times ED \times \frac{1}{VF}}$$

Parameter/Definition (units)	Default
TR/target cancer risk (unitless)	10^{-6}
AT/averaging time (yr)	70
URF/inhalation unit risk factor $(\mu g/m^3)^{-1}$	chemical-specific (Attachment D)
EF/exposure frequency (d/yr)	350
ED/exposure duration (yr)	30
VF/soil-to-air volatilization factor (m^3/kg)	**chemical-specific (Equation 8)**

Equation 7: Screening Level Equation for Inhalation of Noncarcinogenic Volatile Contaminants in Residential Soil

$$\text{Screening Level (mg/kg)} = \frac{THQ \times AT \times 365\ d/yr}{EF \times ED \times \left[\frac{1}{RfC} \times \frac{1}{VF}\right]}$$

Parameter/Definition (units)	Default
THQ/target hazard quotient (unitless)	1
AT/averaging time (yr)	30
EF/exposure frequency (d/yr)	350
ED/exposure duration (yr)	30
RfC/inhalation reference concentration (mg/m^3)	chemical-specific (Attachment D)
VF/soil-to-air volatilization factor (m^3/kg)	**chemical-specific (Equation 8)**

Other than initial soil concentration, air-filled soil porosity is the most significant soil parameter affecting the final steady-state flux of volatile contaminants from soil (U.S. EPA, 1980). In other words, the higher the air-filled soil porosity, the greater the emission flux of volatile constituents.

Exhibit 10. Site-specific Parameters for Calculating Subsurface SSLs

Parameter	SSL Pathway: Inhalation	SSL Pathway: Migration to ground water	Data source	Method
Source Characteristics				
Source area (A)	●		Sampling data	Measure total area of contaminated soil
Source length (L)		●	Sampling data	Measure length of source parallel to ground water flow
Source depth	●	●	Sampling data	Measure depth of contamination or use conservative assumption
Soil Characteristics				
Soil texture	○	○	Lab measurement	Particle size analysis (Gee & Bauder, 1986) and USDA classification; used to estimate θ_w & I
Dry soil bulk density (ρ_b)	●	●	Field measurement	All soils: ASTM D 2937; shallow soils: ASTM D 1556, ASTM D 2167, ASTM D 2922
Soil moisture content (w)	○	○	Lab measurement	ASTM D 2216; used to estimate dry soil bulk density
Soil organic carbon (f_{oc})	●	●	Lab measurement	Nelson and Sommers (1982)
Soil pH	○	○	Field measurement	McLean (1982); used to select pH-specific K_{oc} (ionizable organics) and K_d (metals)
Moisture retention exponent (b)	○	○	Look-up	Attachment A; used to calculate θ_w
Saturated hydraulic conductivity (K_s)	○	○	Look-up	Attachment A; used to calculate θ_w
Avg. soil moisture content (θ_w)	●	●	Calculated	Attachment A
Meteorological Data				
Air dispersion factor (Q/C)	●		Q/C table (Table 5)	Select value corresponding to source area, climatic zone, and city with conditions similar to site
Hydrogeologic Characteristics (DAF)				
Hydrogeologic setting		○	Conceptual site model	Place site in hydrogeologic setting from Aller et al. (1987) for estimation of parameters below (see Attachment A)
Infiltration/recharge (I)		●	HELP model; Regional estimates	HELP (Schroeder et al., 1984) may be used for site-specific infiltration estimates; recharge estimates also may be taken from Aller et al. (1987) or may be estimated from knowledge of local meteorologic and hydrogeologic conditions
Hydraulic conductivity (K)		●	Field measurement; Regional estimates	Aquifer tests (i.e., pump tests, slug tests) preferred; estimates also may be taken from Aller et al. (1987) or Newell et al. (1990) or may be estimated from knowledge of local hydrogeologic conditions
Hydraulic gradient (i)		●	Field measurement; Regional estimates	Measured on map of site's water table (preferred); estimates also may be taken from Newell et al. (1990) or may be estimated from knowledge of local hydrogeologic conditions
Aquifer thickness (d)		●	Field measurement; Regional estimates	Site-specific measurement (i.e., from soil boring logs) preferred; estimates also may be taken from Newell et al. (1990) or may be estimated from knowledge of local hydrogeologic conditions

● Indicates parameters used in the SSL equations.
○ Indicates parameters/assumptions needed to estimate SSL equation parameters.

Equation 8: Derivation of the Volatilization Factor	
$VF\ (m^3/kg) = \frac{Q/C \times (3.14 \times D_A \times T)^{1/2} \times 10^{-4}\ (m^2/cm^2)}{(2 \times \rho_b \times D_A)}$ where $D_A = \frac{[(\theta_a^{10/3} D_i H' + \theta_w^{10/3} D_w)/n^2]}{\rho_b K_d + \theta_w + \theta_a H'}$	
Parameter/Definition (units)	**Default**
VF/volatilization factor (m^3/kg)	--
D_A /apparent diffusivity (cm^2/s)	--
Q/C/inverse of the mean conc. at the center of a 0.5-acre-square source (g/m^2-s per kg/m^3)	**68.81**
T/exposure interval (s)	9.5×10^8
ρ_b/dry soil bulk density (g/cm3)	**1.5**
θ_a /air-filled soil porosity (L_{air}/L_{soil})	$n - \theta_w$
n/total soil porosity (L_{pore}/L_{soil})	$1 - (\rho_b / \rho_s)$
θ_w/water-filled soil porosity (L_{water}/L_{soil})	**0.15**
ρ_s /soil particle density (g/cm^3)	2.65
D_i /diffusivity in air (cm^2/s)	chemical-specific[a]
H'/dimensionless Henry's law constant	chemical-specific[a]
D_w /diffusivity in water (cm^2/s)	chemical-specific[a]
K_d /soil-water partition coefficient (cm^3/g) = K_{oc} f_{oc} (organics)	chemical-specific[a]
K_{oc} /soil organic carbon partition coefficient (cm^3/g)	chemical-specific[a]
f_{oc}/fraction organic carbon in soil (g/g)	**0.006 (0.6%)**

[a]See Attachment C.

Among the soil parameters used in Equation 8, annual average water-filled soil porosity (θ_w) has the most significant effect on air-filled soil porosity (θ_a) and hence volatile contaminant emissions. Sensitivity analyses have shown that soil bulk density (ρ_b) has too limited a range for surface soils (generally between 1.3 and 1.7 g/cm^3) to affect results with nearly the significance of soil moisture content (U.S. EPA, 1996).

Dispersion Model (Q/C). The box model in RAGS HHEM, Part B has been replaced with a Q/C term derived from the modeling exercise using the AREA-ST model incorporated into EPA's Industrial Source Complex Model (ISC2) platform. The AREA-ST model was run with a full year of meteorological data for 29 U.S. locations selected to be representative of a range of meteorologic conditions across the Nation (EQ, 1993). The results of these modeling runs are presented in Exhibit 11 for square area sources of 0.5 to 30 acres in size. When developing a site-specific VF for the inhalation pathway, place the site into a climatic zone (see Attachment B). Then select a Q/C value from Exhibit 11 that best represents a site's size and meteorological conditions.

Soil Saturation Limit (C_{sat}). The soil saturation limit (Equation 9) is the contaminant concentration at which soil pore air and pore water are saturated with the chemical and the adsorptive limits of the soil particles have been reached. Above this concentration, the contaminant may be present in free phase. C_{sat} concentrations represent an upper limit to the applicability of the SSL VF model because a basic principle of the model (Henry's law) does not apply when contaminants are present in free phase. VF-based inhalation SSLs are reliable only if they are at or below C_{sat}.

Equation 9 is used to calculate the soil saturation limit for each organic chemical in site soils. As an update to RAGS HHEM, Part B, this equation takes into account the amount of contaminant that is in the vapor phase in the pore spaces of the soil in addition to the amount dissolved in the soil's pore water and sorbed to soil particles. C_{sat} values should be calculated using the same site-specific soil characteristics used to calculate SSLs (e.g., bulk density, average water content, and organic carbon content). Because VF-based SSLs are not accurate for soil concentrations above C_{sat}, these SSLs should be compared to C_{sat} concentrations before they are used for soil screening.

Exhibit 11. Q/C Values by Source Area, City, and Climatic Zone

	Q/C (g/m^2-s per kg/m^3)					
	0.5 Acre	1 Acre	2 Acre	5 Acre	10 Acre	30 Acre
Zone I						
Seattle	82.72	72.62	64.38	55.66	50.09	42.86
Salem	73.44	64.42	57.09	49.33	44.37	37.94
Zone II						
Fresno	62.00	54.37	48.16	41.57	37.36	31.90
Los Angeles	68.81	60.24	53.30	45.93	41.24	35.15
San Francisco	89.51	78.51	69.55	60.03	53.95	46.03
Zone III						
Las Vegas	95.55	83.87	74.38	64.32	57.90	49.56
Phoenix	64.04	56.07	49.59	42.72	38.35	32.68
Albuquerque	84.18	73.82	65.40	56.47	50.77	43.37
Zone IV						
Boise	69.41	60.88	53.94	46.57	41.87	35.75
Winnemucca	69.23	60.67	53.72	46.35	41.65	35.55
Salt Lake City	78.09	68.47	60.66	52.37	47.08	40.20
Casper	100.13	87.87	77.91	67.34	60.59	51.80
Denver	75.59	66.27	58.68	50.64	45.52	38.87
Zone V						
Bismark	83.39	73.07	64.71	55.82	50.16	42.79
Minneapolis	90.80	79.68	70.64	61.03	54.90	46.92
Lincoln	81.64	71.47	63.22	54.47	48.89	41.65
Zone VI						
Little Rock	73.63	64.51	57.10	49.23	44.19	37.64
Houston	79.25	69.47	61.53	53.11	47.74	40.76
Atlanta	77.08	67.56	59.83	51.62	46.37	39.54
Charleston	74.89	65.65	58.13	50.17	45.08	38.48
Raleigh-Durham	77.26	67.75	60.01	51.78	46.51	39.64
Zone VII						
Chicago	97.78	85.81	76.08	65.75	59.16	50.60
Cleveland	83.22	73.06	64.78	55.99	50.38	43.08
Huntington	53.89	47.24	41.83	36.10	32.43	27.67
Harrisburg	81.90	71.87	63.72	55.07	49.56	42.40
Zone VIII						
Portland	74.23	65.01	57.52	49.57	44.49	37.88
Hartford	71.35	62.55	55.40	47.83	43.00	36.73
Philadelphia	90.24	79.14	70.14	60.59	54.50	46.59
Zone IX						
Miami	85.61	74.97	66.33	57.17	51.33	43.74

Equation 9: Derivation of the Soil Saturation Limit	
$C_{sat} = \frac{S}{\rho_b} (K_d \rho_b + \theta_w + H' \theta_a)$	
Parameter/Definition (units)	**Default**
C_{sat}/soil saturation concentration (mg/kg)	--
S/solubility in water (mg/L-water)	chemical-specific[a]
ρ_b/dry soil bulk density (kg/L)	1.5
K_d /soil-water partition coefficient (L/kg)	$K_{oc} \times f_{oc}$ (chemical-specific[a])
K_{oc} /soil organic carbon/water partition coefficient (L/kg)	chemical-specific[a]
f_{oc}/fraction organic carbon in soil (g/g)	0.006 (0.6%)
θ_w/water-filled soil porosity (L_{water}/L_{soil})	0.15
H'/dimensionless Henry's law constant	chemical-specific[a]
θ_a /air-filled soil porosity (L_{air}/L_{soil})	$n - \theta_w$
n/total soil porosity (L_{pore}/L_{soil})	$1 - (\rho_b / \rho_s)$
ρ_s /soil particle density (kg/L)	2.65

[a]See Attachment C.

C_{sat} values represent chemical-physical limits in soil and are not risk based. However, since they represent the concentration at which soil pore air is saturated with a contaminant, volatile emissions reach their maximum at C_{sat}. In other words, at C_{sat} the emission flux from soil to air for a chemical reaches a plateau. Volatile emissions will not increase above this level no matter how much more chemical is added to the soil. Chemicals with VF-based SSLs above C_{sat} are not likely to present a significant volatile inhalation risk at any soil concentration. To illustrate this point, the TDB presents an analysis of the inhalation risk levels at C_{sat} for a number of chemicals commonly found at Superfund sites whose generic SSLs (calculated using the default parameters shown in Equation 9) are above C_{sat}.

The analysis indicates that these C_{sat} values are all well below the screening risk targets of a 10^{-6} cancer risk or an HQ of 1.

Although the inhalation risks appear to be negligible, C_{sat} does indicate a potential for nonaqueous phase liquid (NAPL) to be present in soil and a possible risk to ground water. Thus, EPA believes that further investigation is warranted. Table C-3 (Attachment C) provides the physical state, liquid or solid, of various compounds at ambient soil temperature. When an inhalation SSL exceeds C_{sat} for compounds that are liquid at ambient soil temperature, the SSL is set at C_{sat}. Where soil concentrations exceed a C_{sat}-based SSL, site managers should refer to EPA's guidance, *Estimating the Potential for Occurrence of DNAPL at Superfund Sites* (U.S. EPA, 1992c) for further information on determining the likelihood of dense nonaqueous phase liquid (DNAPL) in the subsurface. Note that free-phase contaminants may be present at concentrations below C_{sat} if multiple organic contaminants are present. The DNAPL guidance (U.S. EPA, 1992c) also provides tools for evaluating the potential for such multiple component mixtures in soil.

For organic compounds that are solid at ambient soil temperature, concentrations above C_{sat} do not pose a significant inhalation risk or a potential for NAPL occurrence. Thus, soil screening decisions should be based on the appropriate SSL for other site pathways (e.g., migration to ground water, direct ingestion).

Migration to Ground Water SSLs. The Soil Screening Guidance uses a simple linear equilibrium soil/water partition equation or a leach test to estimate contaminant release in soil leachate. It also uses a simple water-balance equation to calculate a dilution factor to account for reduction of soil leachate concentration from mixing in an aquifer.

The methodology for developing SSLs for the migration to ground water pathway was designed for use during the early stages of a site evaluation when information about subsurface conditions may be limited. Hence, the methodology is based on rather conservative, simplified assumptions about the release and transport of contaminants in the

subsurface (Exhibit 12). These assumptions are inherent in the SSL equations and should be reviewed for consistency with the conceptual site model (see Step 2) to determine the applicability of SSLs to the migration to ground water pathway.

Exhibit 12: Simplifying Assumptions for the SSL Migration to Ground Water Pathway

- Infinite source (i.e., steady-state concentrations are maintained over the exposure period)
- Uniformly distributed contamination from the surface to the top of the aquifer
- No contaminant attenuation (i.e., adsorption, biodegradation, chemical degradation) in soil
- Instantaneous and linear equilibrium soil/water partitioning
- Unconfined, unconsolidated aquifer with homogeneous and isotropic hydrologic properties
- Receptor well at the downgradient edge of the source and screened within the plume
- No contaminant attenuation in the aquifer
- No NAPLs present (if NAPLs are present, the SSLs do not apply).

To calculate SSLs for the migration to ground water pathway, multiply the acceptable ground water concentration by the dilution factor to obtain a target soil leachate concentration. For example, if the dilution factor is 10 and the acceptable ground water concentration is 0.05 mg/L, the target soil/water leachate concentration would be 0.5 mg/L. Next, the partition equation is used to calculate the total soil concentration (i.e., SSL) corresponding to this soil leachate concentration. Alternatively, if a leach test is used, compare the target soil leachate concentration to extract concentrations from the leach tests.

Equation 10: Soil Screening Level Partitioning Equation for Migration to Ground Water

$$\text{Screening Level in Soil (mg/kg)} = C_w \left[K_d + \frac{(\theta_w + \theta_a H')}{\rho_b} \right]$$

Parameter/Definition (units)	Default
C_w/target soil leachate concentration (mg/L)	nonzero MCLG, MCL, or HBL[a] × dilution factor
K_d/soil-water partition coefficient (L/kg)	chemical-specific[b]
K_{oc}/soil organic carbon/water partition coefficient (L/kg)	$K_{oc} \times f_{oc}$ (organics) chemical-specific[b]
f_{oc} /fraction organic carbon in soil (g/g)	0.002 (0.2%)
θ_w/water-filled soil porosity (L_{water}/L_{soil})	0.3
θ_a/air-filled soil porosity (L_{air}/L_{soil})	$n - \theta_w$
ρ_b/dry soil bulk density (kg/L)	1.5
n/soil porosity (L_{pore}/L_{soil})	$1-(\rho_b/\rho_s)$
ρ_s/soil particle density (kg/L)	2.65
H'/dimensionless Henry's law constant	chemical-specific[b] (assume to be zero for inorganic contaminants except mercury)

[a]Chemical-specific (see Attachment D).

[b]See Attachment C.

Soil/Water Partition Equation. The soil/water partition equation (Equation 10) relates concentrations of contaminants adsorbed to soil organic carbon to soil leachate concentrations in the zone of contamination. It calculates SSLs corresponding to target soil leachate contaminant concentrations (C_w). An adjustment has been added to the equation to relate sorbed concentration in soil to the measured total soil concentration. This adjustment assumes that soil-water, solids, and gas are conserved during sampling. If soil gas is lost during sampling, θ_a should be assumed to be zero. Likewise, for inorganic contaminants except

mercury, there is no significant vapor pressure and H′ may be assumed to be zero.

The use of the soil/water partition equation to calculate SSLs assumes an infinite source of contaminants extending to the top of the aquifer. More detailed models may be used to calculate higher SSLs that are still protective in some situations. For example, contaminants at sites with shallow sources, thick unsaturated zones, degradable contaminants, or unsaturated zone characteristics (e.g., clay layers) may attenuate before they reach ground water. The TBD provides information on the use of unsaturated zone models for soil screening. The decision to use such models should be based on balancing the additional investigative and modeling costs required to apply the more complex models against the cost savings that will result from higher SSLs.

Leach Test. A leach test may be used instead of the soil/water partition equation. In some instances, a leach test may be more useful than the partitioning method, depending on the constituents of concern and the possible presence of RCRA wastes. If this option is chosen, soil parameters are not needed for this pathway. However, a dilution factor must still be calculated. This guidance suggests using the EPA Synthetic Precipitation Leaching Procedure (SPLP, EPA SW-846 Method 1312, U.S. EPA, 1994d). The SPLP was developed to model an acid rain leaching environment and is generally appropriate for a contaminated soil scenario. Like most leach tests, the SPLP may not be appropriate for all situations (e.g., soils contaminated with oily constituents may not yield suitable results). Therefore, apply the SPLP with discretion.

EPA is aware that many leach tests are available for application at hazardous waste sites, some of which may be appropriate in specific situations (e.g., the Toxicity Characteristic Leaching Procedure (TCLP) models leaching in a municipal landfill environment). It is beyond the scope of this document to discuss in detail leaching procedures and the appropriateness of their use.

Stabilization/Solidification of CERCLA and RCRA Wastes (U.S. EPA, 1989b) and the EPA SAB's review of leaching tests (U.S. EPA, 1991b) discuss the application of various leach tests to various waste disposal scenarios. Consult these documents for further information.

See Step 3 for guidance on collecting subsurface soil samples that can be used for leach tests. To ensure adequate precision of leach test results, leach tests should be conducted in triplicate.

Dilution Factor Model. As soil leachate moves through soil and ground water, contaminant concentrations are attenuated by adsorption and degradation. In the aquifer, dilution by clean ground water further reduces concentrations before contaminants reach receptor points (i.e., drinking water wells). This reduction in concentration can be expressed by a dilution attenuation factor (DAF), defined as the ratio of soil leachate concentration to receptor point concentration. The lowest possible DAF is 1, corresponding to the situation where there is no dilution or attenuation of a contaminant (i.e., when the concentration in the receptor well is equal to the soil leachate concentration). On the other hand, high DAF values correspond to a large reduction in contaminant concentration from the contaminated soil to the receptor well.

The Soil Screening Guidance addresses only one of these dilution-attenuation processes: contaminant dilution in ground water. A simple mixing zone equation derived from a water-balance relationship (Equation 11) is used to calculate a site-specific dilution factor. Mixing-zone depth is estimated from Equation 12, which relates it to aquifer thickness along with the other parameters from Equation 11. Mixing zone depth should not exceed aquifer thickness (i.e., use aquifer thickness as the upper limit for mixing zone depth).

Because of the uncertainty resulting from the wide variability in subsurface conditions that affect contaminant migration in ground water, defaults are not provided for the dilution model equations. Instead, a default DAF of 20 has been selected as protective for contaminated soil sources up to 0.5 acre in size. Analyses using the mass-limit models described below suggest that a DAF of 20 may be protective of larger sources as well; however, this hypothesis should be evaluated on a site-specific basis. A discussion of the basis for the default DAF and a description of the mass-limit analysis is found in the TBD. However, since migration to ground

water SSLs are most sensitive to the DAF, site-specific dilution factors should be calculated.

Equation 11: Derivation of Dilution Factor	
$\text{dilution factor} = 1 + \frac{Kid}{IL}$	
Parameter/Definition (units)	**Default**
dilution factor (unitless)	20 (0.5-acre source)
K/aquifer hydraulic conductivity (m/yr)	
i/hydraulic gradient (m/m)	
I/infiltration rate (m/yr)	
d/mixing zone depth (m)	
L/source length parallel to ground water flow (m)	

Equation 12: Estimation of Mixing Zone Depth
$d = (0.0112\,L^2)^{0.5} + d_a\,\{1 - \exp[(-LI)/(Kid_a)]\}$
Parameter/Definition (units)
d/mixing zone depth (m)
L/source length parallel to ground water flow (m)
I/infiltration rate (m/yr)
K/aquifer hydraulic conductivity (m/yr)
i/hydraulic gradient (m/m)
d_a/aquifer thickness (m)

Mass-Limit SSLs. Use of infinite source models to estimate volatilization and migration to ground water can violate mass balance considerations, especially for small sources. To address this concern, the Soil Screening Guidance includes models for calculating mass-limit SSLs for each of these pathways (Equations 13 and 14) that provide a lower limit to SSLs **when the area and depth (i.e., volume) of the source are known or can be estimated reliably.**

A mass-limit SSL represents the level of contaminant in the subsurface that is still protective when the entire volume of contamination either volatilizes or leaches over the 30-year exposure duration and the level of contaminant at the receptor does not exceed the health-based limit.

To use mass-limit SSLs, determine the area and depth of the source, calculate both standard and mass-limit SSLs, compare them for each chemical of concern and select the higher of the two values. Analyze the inhalation and migration to ground water pathways separately.

Equation 13: Mass-Limit Volatilization Factor	
$VF = Q/C \times \frac{[T \times (3.15 \times 10^7\ s/yr)]}{(\rho_b \times d_s \times 10^6\ g/Mg)}$	
Parameter/Definition (units)	**Default**
d_s/average source depth (m)	site-specific
T/exposure interval(yr)	30
Q/C/inverse of mean conc. at center of a square source (g/m^2-s per kg/m^3)	68.81
ρ_b/dry soil bulk density (kg/L or Mg/m^3)	1.5

Equation 14: Mass-Limit Soil Screening Level for Migration to Ground Water	
$\text{Screening Level in Soil (mg/kg)} = \frac{(C_w \times I \times ED)}{\rho_b \times d_s}$	
Parameter/Definition (units)	**Default**
C_w/target soil leachate concentration (mg/L)	(nonzero MCLG, MCL, or HBL)[a] × dilution factor
d_s/depth of source (m)	site-specific
I/infiltration rate (m/yr)	0.18
ED/exposure duration (yr)	70
ρ_b/dry soil bulk density (kg/L)	1.5

[a]Chemical-specific, see Attachment D.

Note that Equations 13 and 14 require a site-specific determination of the average depth of contamination in the source. Step 3 provides guidance for conducting subsurface sampling to determine source depth. Where the actual average depth of contamination is uncertain, a conservative estimate should be used (e.g., the maximum possible depth in the unsaturated zone). At many sites, the average water table depth may be used unless there is reason to believe that contamination extends below the water table. In this case SSLs do not apply and

further investigation of the source in question is needed.

Plant Uptake. Consumption of garden fruits and vegetables grown in contaminated residential soils can result in a risk to human health. This exposure pathway applies to both surface and subsurface soils.

The TBD includes an evaluation of the soil-plant-human pathway along with a discussion of the site-specific factors that influence plant uptake and plant contamination concentration. Generic screening levels are calculated for arsenic, cadmium, mercury, nickel, selenium, and zinc based on empirical data on the uptake (i.e., bioconcentration) of these inorganics into plants. In addition, levels of inorganics that have been reported to cause phytotoxicity (Will and Suter, 1994) are presented. Organic compounds are not addressed due to lack of empirical data.

The empirical data indicate that site-specific factors such as soil type, pH, plant type, and chemical form strongly influence the uptake of metals into plants. Where site conditions allow for the mobility and bioavailability of metals, the results of our generic analysis suggest that the soil-plant-human pathway may be of particular concern for sites with soils contaminated with cadmium and arsenic. However, the phytotoxicity of certain metals may limit the amount that can be bioconcentrated in plant tissues. The data on phytotoxicity suggest that, with the exception of arsenic, metal concentrations in soil that are considered toxic to plants are well below the levels that may impact human health through the soil-plant-human pathway. This implies that phytotoxic effects may prevent completion of this pathway for these metals. However, like plant uptake, phytotoxicity is also greatly influenced by the site-specific factors mentioned above. Thus, it is necessary to evaluate on a site-specific basis, the potential bioavailability of certain inorganics for the soil-plant-human pathway and the potential for phytotoxic effects in order to assess possible human health and ecological impacts through plant uptake.

2.5.3 Address Exposure to Multiple Chemicals. The SSLs generally correspond to a 10^{-6} risk level for carcinogens and a hazard quotient of 1 for noncarcinogens. This "target" hazard quotient is used to calculate a soil concentration below which it is unlikely that sensitive populations will experience adverse health effects. The potential for additive effects has not been "built in" to the SSLs through apportionment. For carcinogens, EPA believes that setting a 10^{-6} risk level for individual chemicals and pathways generally will lead to cumulative site risks within the 10^{-4} to 10^{-6} risk range for the combinations of chemicals typically found at NPL sites.

For noncarcinogens, there is no widely accepted risk range, and EPA recognizes that cumulative risks from noncarcinogenic contaminants at a site could exceed the target hazard quotient. However, EPA also recognizes that **noncancer risks should be added only for those chemicals with the same toxic endpoint or mechanism of action.**

Ideally, chemicals would be grouped according to their exact mechanism of action, and effect-specific toxicity criteria would be available for chemicals exhibiting multiple effects. Instead, data are often limited to gross toxicological effects in an organ (e.g., increased liver weight) or an entire organ system (e.g., neurotoxicity), and RfDs/reference concentrations (RfCs) are available for just one of the several possible endpoints of toxicity for a chemical.

Given the currently available criteria, noncarcinogenic contaminants should be grouped according to the critical effect listed as the basis for the RfD/RfC. If more than one chemical detected at a site affects the same target organ/system, SSLs for those chemicals should be divided by the number of chemicals present in the group. Exhibit 13 lists several chemicals with noncarcinogenic affects in the same target organ/system. However, the list is limited, and a toxicologist should be consulted prior to using SSLs on a site-specific basis.

If additive risks are being considered in developing site-specific SSLs for subsurface soils, recognize that, for certain chemicals, SSLs may be based on a "ceiling limit" concentration (C_{sat}) instead of toxicity. Because they are not risk-based, C_{sat}-based SSLs should not be modified to account for additivity.

2.6 Step 6: Comparing Site Soil Contaminant Concentrations to Calculated SSLs

Now that the site-specific SSLs have been calculated for the potential contaminants of concern, compare them with the site contaminant concentrations. At this point, it is reasonable to review the CSM with the actual site data to confirm its accuracy and the overall applicability of the Soil Screening Guidance.

In theory, an exposure area would be screened from further investigation when the true mean of the population of contaminant concentrations falls below the established screening level. However, EPA recognizes that data obtained from sampling and analysis are never perfectly representative and accurate, and that the cost of trying to achieve perfect results would be quite high. Consequently, EPA acknowledges that some uncertainty in data must be tolerated, and focuses on controlling the uncertainty which affects decisions based on those data. Thus, in the Soil Screening Guidance, EPA has developed an approach for surface soils to minimize the chance of incorrectly deciding to:

- Screen out areas when the correct decision would be to investigate further (Type I error); or
- Decide to investigate further when the correct decision would be to screen out the area (Type II error).

The approach sets limits on the probabilities of making such decision errors, and acknowledges that there is a range (i.e., gray region) of contaminant levels around the screening level where the variability in the data will make it difficult to determine whether the exposure area average concentration is actually above or below the screening level. The Type I and Type II decision error rates have been set at 5 percent and 20 percent, respectively, and the gray region has been set between one-half and two times the SSL. By specifying the upper edge of the gray region as twice the SSL, it is possible that exposure areas with mean contaminant concentration values slightly above the SSL may be screened from further study. Commenters have expressed concern that this is not adequately protective for SSLs based on noncarcinogenic effects. However, EPA believes that the approaches taken in this guidance to address chronic exposure to noncarcinogens are conservative enough for the majority of site contaminants (i.e., comparison of the 6 year "childhood only" exposure to the chronic RfD); and, use of maximum composite concentrations provide high coverage of the true population mean (i.e., there is high probability that the value equals or exceeds the true population mean).

Thus, for surface soils, the contaminant concentrations in each composite sample from an exposure area are compared to two times the SSL. Under the Soil Screening Guidance DQOs, areas are screened out from further study when contaminant concentrations in all of the composite samples are less than two times the SSLs. Use of this decision rule (comparing contaminant concentrations to twice the SSL) is appropriate only when the quantity and quality of data are comparable to the levels discussed in this guidance, and the toxicity of the chemical has been evaluated against the criteria presented in Section 2.5.1.

For existing data sets that may be more limited than those discussed in this guidance, the 95 percent upper-confidence limit on the arithmetic mean of contaminant concentrations in surface soils (i.e., the Land method as described in the *Supplemental Guidance to* RAGS*: Calculating the Concentration Term* (U.S. EPA, 1992d) should be used for comparison to the SSLs. The TBD discusses the strengths and weaknesses of using the Land method for making screening decisions.

Exhibit 13: SSL Chemicals with Noncarcinogenic Toxic Effects on Specific Target Organ/System

Target Organ/System	Effect
Kidney	
Acetone	Increased weight; nephrotoxicity
1,1-Dichloroethane	Kidney damage
Cadmium	Significant proteinuria
Chlorobenzene	Kidney effects
Di-*n*-octyl phthalate	Kidney effects
Endosulfan	Glomerulonephrosis
Ethylbenzene	Kidney toxicity
Fluoranthene	Nephropathy
Nitrobenzene	Renal and adrenal lesions
Pyrene	Kidney effects
Toluene	Changes in kidney weights
2,4,5-Trichlorophenol	Pathology
Vinyl acetate	Altered kidney weight
Liver	
Acenaphthene	Hepatotoxicity
Acetone	Increased weight
Butyl benzyl phthalate	Increased liver-to-body weight and liver-to-brain weight ratios
Chlorobenzene	Histopathology
Di-*n*-octyl phthalate	Increased weight; increased SGOT and SGPT activity
Endrin	Mild histological lesions in liver
Ethylbenzene	Liver toxicity
Flouranthene	Increased liver weight
Nitrobenzene	Lesions
Styrene	Liver effects
Toluene	Changes in liver weights
2,4,5-Trichlorophenol	Pathology
Central Nervous System	
Butanol	Hypoactivity and ataxia
Cyanide (amenable)	Weight loss, myelin degeneration
2,4 Dimethylphenol	Prostatration and ataxia
Endrin	Occasional convulsions
2-Methylphenol	Neurotoxicity
Mercury	Hand tremor, memory disturbances
Styrene	Neurotoxicity
Xylenes	Hyperactivity
Adrenal Gland	
Nitrobenzene	Adrenal lesions
1,2,4-Trichlorobenzene	Increased adrenal weights; vacuolization in cortex

Exhibit 13: (continued)	
Target Organ/System	**Effect**
Circulatory System	
Antimony	Altered blood chemistry and myocardial effects
Barium	Increased blood pressure
trans-1,2-Dichloroethene	Increased alkaline phosphatase level
cis-1,2-Dichloroethylene	Decreased hematocrit and hemoglobin
2,4-Dimethylphenol	Altered blood chemistry
Fluoranthene	Hematologic changes
Fluorene	Decreased RBC and hemoglobin
Nitrobenzene	Hematologic changes
Styrene	Red blood cell effects
Zinc	Decrease in erythrocyte superoxide dismutase (ESOD)
Reproductive System	
Barium	Fetotoxicity
Carbon disulfide	Fetal toxicity and malformations
2-Chlorophenol	Reproductive effects
Methoxychlor	Excessive loss of litters
Phenol	Reduced fetal body weight in rats
Respiratory System	
1,2-Dichloropropane	Hyperplasia of the nasal mucosa
Hexachlorocyclopentadiene	Squamous metaplasia
Methyl bromide	Lesions on the olfactory epithelium of the nasal cavity
Vinyl acetate	Nasal epithelial lesions
Gastrointestinal System	
Hexachlorocyclopentadiene	Stomach lesions
Methyl bromide	Epithelial hyperplasia of the forestomach
Immune System	
2,4-Dichlorophenol	Altered immune function
p-Chloroaniline	Nonneoplastic lesions of splenic capsule

Source: U.S. EPA, 1995b, U.S. EPA, 1995a

In this guidance, fewer samples are collected for subsurface soils than for surface soils; therefore, different decision rules apply.

Since subsurface soils are not characterized as well, there is less confidence that the concentrations measured are representative of the entire source. Thus, a more conservative approach to screening is warranted. Because it may not be protective to allow for comparison to values above the SSL, mean contaminant concentrations from each soil boring taken in a source area are compared with the calculated SSLs. Source areas with any mean soil boring contaminant concentration greater than the SSLs generally warrant further consideration. On the other hand, where the mean soil boring contaminant concentrations within a source are all less than the SSLs, that source area is generally screened out.

2.7 Step 7: Addressing Areas Identified for Further Study

The chemicals, exposure pathways, and areas that have been identified for further study become a subject of the RI/FS. The results of the baseline risk assessment conducted as part of the RI/FS will establish the basis for taking remedial action. The threshold for taking action differs from the criteria used for screening. As outlined in *Role of the Baseline Risk Assessment in Superfund Remedy Selection Decisions* (U.S. EPA, 1991d), remedial action at NPL sites is generally warranted where cumulative risks for current or future land use exceed 1×10^{-4} for carcinogens or a HQ of 1 for noncarcinogens. The data collected for soil screening are useful in the RI and baseline risk assessment. However, additional data will probably need to be collected during future site investigations.

Once the decision has been made to initiate remedial action, the SSLs can then serve as preliminary remediation goals. This process is referenced in Section 1.2 of this document.

FOR FURTHER INFORMATION

More detailed discussions of the technical background and assumptions supporting the development of the Soil Screening Guidance are presented in the *Soil Screening Guidance: Technical Background Document* (U.S. EPA, 1996). For additional copies of this guidance document, the Technical Background Document, or other EPA documents, call the National Technical Information Service (NTIS) at (703) 487-4650 or 1-800-553-NTIS (6847).

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Attachment A

Conceptual Site Model Summary

Attachment A

Conceptual Site Model Summary

Step 1 of the Soil Screening Guidance: User's Guide describes the development of a conceptual site model (CSM) to support the application of soil screening levels (SSLs) at a site. The CSM summary forms at the end of this attachment contain the information necessary to:

- Determine the applicability of SSLs to the site
- Calculate SSLs.

By identifying data gaps, these summary forms will help focus data collection and evaluation on the site-specific development and application of SSLs. The site investigator should use the summary forms during the SSL sampling effort to collect site-specific data and continually update the CSM with new information as appropriate.

The CSM summary forms indicate the information required for determining the applicability of the soil screening process to the site. Forms addressing source characteristics may be photocopied if more than one source is present at a site.

A site map showing contaminated soil sources and exposure areas (EAs) should be attached to the summary. If available, additional pages of other maps, summaries of analytical results, or more detailed descriptions of the site may be attached to the summary.

Form 1. General Site Information

The information included in this form is identical to the first page of the Site Inspection (SI) Data Summary form (page B-3 in *Guidance for Performing Site Inspections Under CERCLA*, U.S. EPA, 1992). However, the form should be updated to reflect any site activities conducted since the SI was completed.

Form 2. Site Characteristics

Form 2 indicates the information necessary to address the migration to ground water pathway and identify subsurface conditions that may limit the applicability of subsurface SSLs.

A hydrogeologic setting is defined as a unit with common hydrogeologic characteristics and therefore common vulnerability to contamination. Each setting provides a composite description of the hydrogeologic factors that control ground water movement and recharge. These factors can be used to make generalizations in the CSM about ground water conditions.

After placing the site into one of Heath's ground water regions (Heath, 1984), consider geologic and geomorphic features of the site and select a generic hydrogeologic setting from Aller et al. (1987) that is most similar to the site. If existing site information is not sufficient to definitively place the site in a setting, it should be possible to narrow the choice to two or three settings that will reduce the range of values necessary to develop SSLs. A copy of the setting diagram from Aller et al. (1987) should be attached to the CSM checklist to provide a general picture of subsurface site conditions.

Ground Water Flow Direction. The direction of ground water flow in the uppermost aquifer underlying each source is needed to determine source length parallel to that flow. If ground water flow direction is unknown or uncertain, assume it is parallel to the longest source dimension.

Aquifer Parameters. Aquifer parameters needed to estimate a site-specific dilution factor include hydraulic conductivity (K), hydraulic gradient (i), and aquifer thickness (d_a). Site-measured values for these parameters are the preferred alternative. Existing site documentation should be reviewed for in situ measurements of aquifer conductivity (i.e., from pump test data), water table maps that can be used to estimate hydraulic gradient, and boring logs that indicate the thickness of the uppermost aquifer. Detailed information on conducting and interpreting aquifer tests can be found in Nielsen (1991).

If site-measured values are not available, hydrogeologic knowledge of regional geologic conditions or measured values in the literature may be sources of reasonable estimates. Values from a similar site in the same region and hydrogeologic setting also may be used, but must be carefully reviewed to ensure that the subsurface conceptual models for the two sites show reasonable agreement. For all of these options, it is critical that the estimates and sources be reviewed by an experienced hydrogeologist knowledgeable of regional hydrogeologic conditions.

A third option is to obtain parameter estimates for the site's hydrogeologic setting from Aller et al. (1987) or from the American Petroleum Institute's (API's) hydrogeologic database (HGDB) (Newell et al., 1989, 1990). Aller et al. (1987) present ranges of values for K and i by hydrogeologic setting. The HGDB contains measured values for these parameters and aquifer depth for a number of sites in each hydrogeologic setting. If HGDB data are used, the median value presented for each setting should be used unless site-specific conditions indicate otherwise. Aquifer parameter values from these sources also can serve as a check of the validity of site-measured values or estimates obtained from other sources.

If outside sources such as Aller et al. (1987) are used to characterize site hydrogeologic conditions, the appropriate references and diagrams should be attached to the CSM checklist.

Infiltration Rate. Infiltration rate is used to calculate SSLs for subsurface soils (see Step 5). The simplest way to estimate infiltration rate (I) is to assume that infiltration is equal to recharge and obtain recharge estimates for the site's hydrogeologic setting from Aller et al. (1987). When using the Aller et al. (1987) estimates the user should recognize that these are estimates of average recharge conditions throughout the setting and site-specific values may differ to some extent. For example, areas within the setting with steeper than average slopes will tend to have lower infiltration rates and areas with flatter than average slopes will tend to have higher infiltration than average. An alternative is to use infiltration rates determined for a better-characterized site in the same hydrogeologic setting and with similar meteorological conditions as the site in question.

A third alternative is use the HELP model. Although HELP was originally written for hydrologic evaluation of landfills (Schroeder et al., 1984), inputs to the HELP program can be modified to estimate infiltration in undisturbed soils in natural settings. The most recent version of HELP and the most recent user's guide and documentation can be obtained by sending an address and two double-sided, high-density, DOS-formatted disks to:

attn. Eunice Burk
U.S. EPA
5995 Center Hill Ave.
Cincinnati, OH 45224
(513) 569-7871.

Meteorologic Parameters. Select a site-specific Q/C value from in the guidance for the volatilization factor (VF) equation or particulate emission factor (PEF) equation to place the site in a climatic zone (Figure A-1).

Several site-specific parameters are required to calculate a PEF if fugitive dusts are of concern at the site (see Step 5 for surface soils). The threshold windspeed at 7 meters above ground surface ($U_{t,7}$) is calculated from source area roughness height and the mode soil aggregate size as described in Cowherd et al. (1985). Mode soil aggregate size refers to the mode diameter of aggregated soil particles measured under field conditions.

Other site-specific variables necessary for calculating the PEF include fraction vegetative cover (V) and the mean annual windspeed (U_m). Fraction vegetative cover is estimated by visual observations of the surface of known or suspected source areas at the site. Mean annual windspeed can be obtained from the National Weather Service surface station nearest to the site.

Form 3. Exposure Pathways and Receptors

Form 3 includes information necessary to determine the applicability of the Soil Screening Guidance to a site (see Step 2 of the User's Guide). This form summarizes the site information necessary to identify and characterize potential exposure pathways and receptors at the site, such as site conditions, relevant exposure scenarios, and the properties of soil contaminants listed on Form 4. Table A-1 provides an example of exposure pathways that are not addressed by the guidance, but have relevance to CSM development.

Table A-1. Example Identification of Exposure Pathways Not Addressed by SSLs

Receptors/ Exposure Pathways	Contaminant Characteristics	Site Conditions
Human / Direct Pathways		
ingestion (acute exposure)	acute health effects (e.g., cyanide, phenol)	residential setting
inhalation - fugitive dusts (acute exposure)	acute health effects	high fugitive dusts (e.g., from soil tillage, heavy traffic on dirt roads; construction)
Human / Indirect Pathways		
consumption of meat or dairy products	bioaccumulation, biomagnification	nearby meat or dairy production
fish consumption	biomagnification	nearby surface waters with recreational or subsistence fishing
Ecological Pathways		
aquatic	aquatic toxicity	nearby surface waters or wetlands
terrestrial	toxicity to terrestrial organisms (e.g., DDT, Hg)	sensitive species on or near site

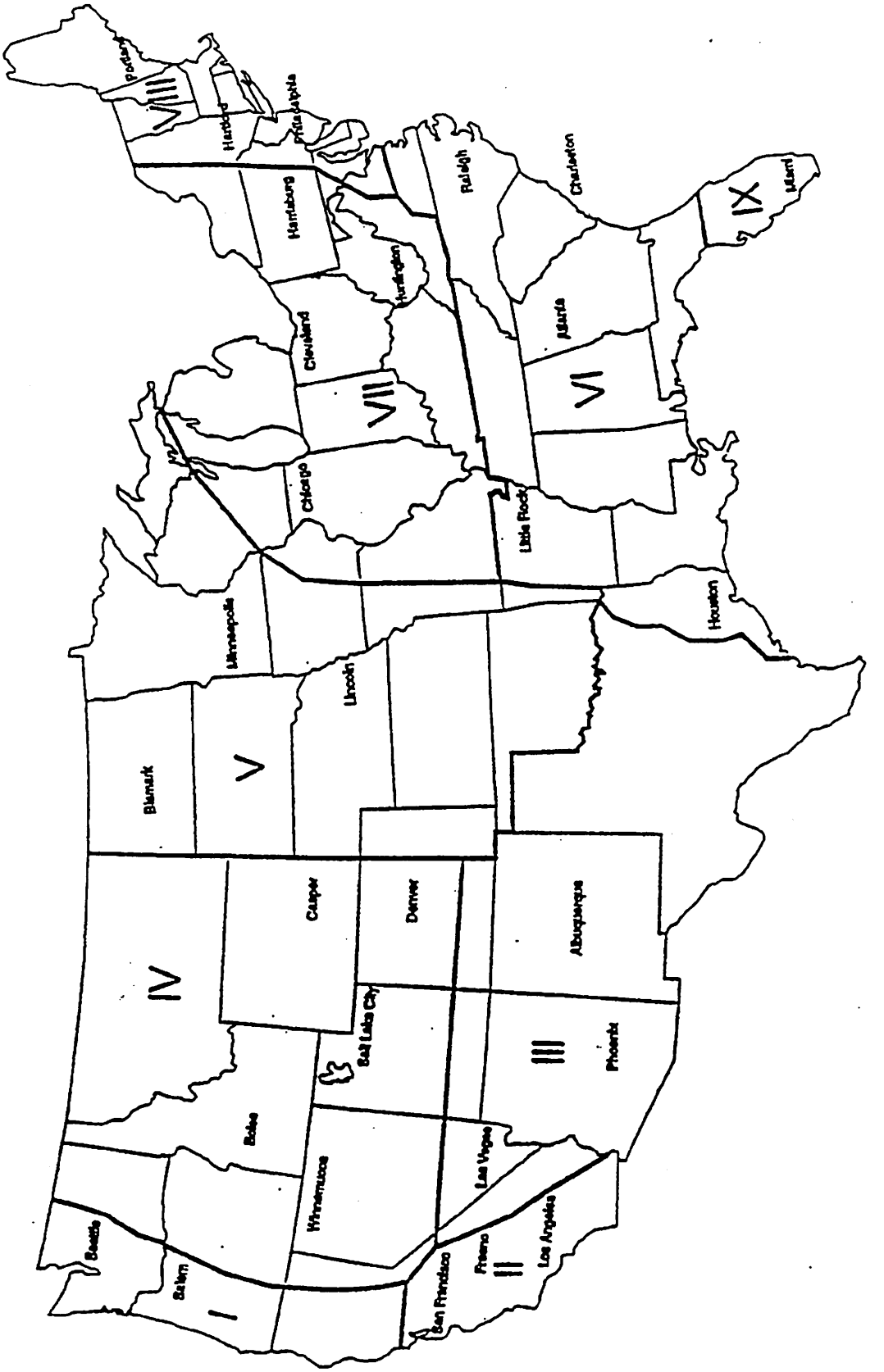

Figure A-1. U.S. climatic zones

Form 4. Soil Contaminant Source Characteristics

This form prompts the investigator to provide information on source characteristics, including soil contaminant levels and the physical and chemical parameters of site soils needed to calculate SSLs. One form should be completed for each contaminated soil source. Initially, the form should be filled out to the greatest extent possible with existing site information collected during CSM development (see Step 1 of the User's Guide). The forms should be updated after the SSL sampling effort is complete.

Measurement of contaminant levels and the soil parameters listed on this form is described in Step 3 of this guidance.

Average soil moisture content (θ_w) defines the fraction of total soil porosity that is filled by water and air. These parameters are necessary for determining the volatilization factor (VF) and the soil saturation limit (C_{sat}) and to apply the soil/water partition equation. It is important that the moisture content used to calculate these parameters represent the annual average soil moisture conditions. Moisture content measurements on discrete soil samples should not be used because they are affected by preceding rainfall events and thus may not represent average conditions. Volumetric average soil water content may be estimated by the following relationship developed by Clapp and Hornberger (1978) and presented in the *Superfund Exposure Assessment Manual* (U.S. EPA, 1988):

$$\theta_w = n\,(I/K_s)^{1/(2b+3)}$$

where

n = total soil porosity (L_{pore}/L_{soil})
I = infiltration rate (m/yr)
K_s = saturated hydraulic conductivity (m/yr)
b = soil-specific exponential parameter (unitless).

Total soil porosity (n) is estimated from dry soil bulk density (ρ_b) as follows:

$$n = 1 - (\rho_b/\rho_s)$$

where

ρ_s = soil particle density = 2.65 kg/L.

Values for K_s and the exponential term 1/(2b+3) are shown in Table A-2 by soil texture class (soil class determination is discussed under Step 3).

Site-specific values for infiltration rate (I) may be estimated using the HELP model or may be assumed to be equivalent to recharge (see Form 2).

Table A-2. Parameter Estimates for Calculating Average Soil Moisture Content (θ_w)

Soil texture	K_s (m/yr)	1/(2b+3)
Sand	1,830	0.090
Loamy sand	540	0.085
Sandy loam	230	0.080
Silt loam	120	0.074
Loam	60	0.073
Sandy clay loam	40	0.058
Silt clay loam	13	0.054
Clay loam	20	0.050
Sandy clay	10	0.042
Silt clay	8	0.042
Clay	5	0.039

Source: U.S. EPA, 1988.

Worksheets

The worksheets following Forms 1 through 4 provide a convenient means of assembling chemical-specific parameters necessary to calculate SSLs for the contaminants of concern (Worksheet 1), existing site data on contaminant concentrations collected during CSM development or the SSL sampling effort (Worksheet 2), and SSLs calculated for EAs (Worksheet 3) or contaminant sources (Worksheet 4) of concern at the site.

CSM Diagram

The CSM diagram is a product of CSM development that represents the linkages among contaminant sources, release mechanisms, exposure pathways and routes, and receptors to summarize the current understanding of the soil contamination problem (see Step 1 of the guidance). An example SSL CSM diagram, Figure A-2 (U.S. EPA, 1989), and a site sketch, Figure A-3 (U.S. EPA, 1987) are provided following the Worksheets.

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Soil Screening Guidance
Conceptual Site Model Summary Forms

Form 1: General Site Information **Site Name** _____

EPA Region_____ Date_____

Contractor Name and Address: _____

_____

_____

State Contact: _____

1. CERCLIS ID No. _____
   Address _____City _____
   County_____ State _____ Zip Code _____ Congressional District_____

2. Owner Name _____Operator Name _____
   Owner Address _____Operator Address_____
   City _____ State _____City _____ State _____

3. Type of ownership (check all that apply):
   ☐ Private ☐ Federal Agency _____ ☐ State ☐ County ☐ Municipal
   Other _____Ref. _____

4. Approximate size of property _____ acres Ref. _____

5. Latitude ___ o___|___ . ___" Longitude ___ o ___ |___ . ___" Ref. _____

6. Site status ☐ Active ☐ Inactive ☐ Unknown Ref. _____

7. Years of operation From_____ To _____ ☐ Unknown Ref. _____

8. Previous investigations

Type	Agency/State/Contractor	Date	
_____	_____	_____	Ref. _____
_____	_____	_____	Ref. _____
_____	_____	_____	Ref. _____
_____	_____	_____	Ref. _____
_____	_____	_____	Ref. _____
_____	_____	_____	Ref. _____

Ref. = reference(s) on information source

Soil Screening Guidance
Conceptual Site Model Summary Forms

Figure A-1. U.S. climatic zones **Site Name** _____

Hydrogeologic Characteristics (migration to ground water pathway)

Is ground water of concern at the site? ☐ yes ☐ no (if no, move to Infiltration Rate below).

Heath region _____ **Hydrogeologic setting** _____

(attach setting diagram)

Check setting characteristics that apply: ☐ karst ☐ fractured rock ☐ solution limestone

Describe the stratigraphy and hydrogeologic characteristics of the site. (Attach available maps and cross-sections.)

_____

_____

_____

_____

Ref._____

Identify and describe nearby sites in similar settings that have already been characterized.

_____

_____

_____

_____

Ref._____

Aquifer Parameters	Unit	Typical	Min.	Max.	Reference or Source
hydraulic conductivity (K)	m/y				
hydraulic gradient (i)	m/m				
thickness (d_a)	m				

General direction of ground water flow across the site (e.g., NNE, SW): _____

(attach map.) Ref. _____

Infiltration rate (I) _____ m/yr Method _____

Meteorological Characteristics (inhalation pathway)

climatological zone: _____ (zone#, city) Q/C _____ (g/m^2-s per kg/m^3)

fract. vegetative cover (V)_____ (unitless) Reference _____

mean annual windspeed (U_m)_____ m/s Reference _____

equivalent threshold value of windspeed at 7 m (U_t) _____ m/s

fraction dependent on U_m/U_t _____ (unitless)

Comments:_____

_____

_____

Soil Screening Guidance
Conceptual Site Model Summary Forms

Form 3: Exposure Pathways and Receptors **Site Name** _____

Land Use Conditions

Current site use:	Surrounding land use:	Future land use:
__ residential	__ residential	__ residential
__ industrial	__ industrial	__ industrial
__ commercial	__ commercial	__ commercial
__ agricultural	__ agricultural	__ agricultural
__ recreational	__ recreational	__ recreational
__ other	__ other	__ other

Size of exposure areas (in acres) _____

Contaminant Release Mechanisms (check all that apply):

Source #___ ☐ leaching ☐ volatilization ☐ fugitive dusts ☐ erosion/runoff ☐ uptake by plants

Source #___ ☐ leaching ☐ volatilization ☐ fugitive dusts ☐ erosion/runoff ☐ uptake by plants

Source #___ ☐ leaching ☐ volatilization ☐ fugitive dusts ☐ erosion/runoff ☐ uptake by plants

(describe rationale for not including any of the above release mechanisms)

_____

_____

_____

Media affected (or potentially affected) by soil contamination.

Source #___ ☐ air ☐ ground water ☐ surface water ☐ sediments ☐ wetlands

Source #___ ☐ air ☐ ground water ☐ surface water ☐ sediments ☐ wetlands

Source #___ ☐ air ☐ ground water ☐ surface water ☐ sediments ☐ wetlands

Check if present on-site or on surrounding land (attach map showing locations)

☐ wetlands ☐ surface water ☐ subsistence fishing ☐ recreational fishing ☐ dairy/beef production

Check SSL exposure pathways applicable at site; describe basis for not including any pathway

☐ ingestion ☐ inhalation ☐ migration to ground water ☐ dermal ☐ soil-plant-human

Check Potential for:

☐ **Acute Effects (describe)**

☐ **Other Human Exposure Pathways (describe)**

☐ **Ecological concerns (describe)**

Soil Screening Guidance
Conceptual Site Model Summary Forms

Form 4: Soil Contaminant Source Characteristics **Site Name**_____

Source No.: _____

Name: _____ (e.g., drum storage area)

Type: _____ (e.g., spill, dump, wood treater)

Location:_____ (site map)

Waste type: _____ (e.g., solvents, waste oil)

Description (describe history of contamination, other information)

_____

_____

_____

_____

_____

Describe past/current remedial or removal actions

_____

_____

_____

_____

_____

Source depth:_____ m (☐ measures ☐ estimated) Ref. _____

Source area: _____ acres _____ m^2 (☐ measures ☐ estimated) Ref. _____

Source length parallel to ground water flow: _____ m (if uncertain, use longest source dimension)

Contaminant types (check all that apply): ☐ volatile organics ☐ other organics ☐ metals ☐ other inorganics

Soil Contaminants Present (list): _____

_____

_____

(attach Worksheet #1)

Describe previous soil analyses. (attach available results and map showing sample locations)

_____

_____

_____

_____

(attach Worksheet #2)

Are NAPLs suspected? ☐ **Yes** ☐ **No** Reason_____

_____

<u>Average Soil Characteristics</u>

average water content (θ_w)_____(L_{water}/L_{soil}) Ref. _____

fraction organic carbon (f_{oc}) _____g/g Ref. _____

dry bulk density (ρ_b) _____(kg/L) Ref. _____

pH _____ Ref. _____

Worksheet 1. Contaminant-specific properties **Site Name** _____

Regulatory and Human Health Benchmarks[1]

Contaminant	CAS #	MCLG, MCL, or HBL (mg/L)	Sources (no.)	RfD (mg/kg/-d)	SF_o $(mg/kg/-d)^{-1}$	URF $(\mu g/m^3)^{-1}$	RfC (mg/m^3)

Chemical Properties[2]

Contaminant	CAS #	Sources (no.)	K_{oc}[3] (L/kg)	K_d[4] (L/kg)	H[5]	D_{ia}[5] (cm^2/s)	D_{iw}[5] (cm^2/s)	S[5] (mg/L)

1. Attachment D
2. Attachment C
3. For organic compounds
4. For metals and inorganic compounds
5. Not applicable to metals except mercury

Worksheet 2. Contaminant concentrations by source **Site Name**_____

Source #:_____

Contaminant	CAS #	average	standard deviation	number of samples	minimum	maximum	variance

Source #:_____

Contaminant	CAS #	average	standard deviation	number of samples	minimum	maximum	variance

Worksheet 3. Surface SSLs by Exposure Area (EA) **Site Name**_____

EA #:_____ **SSL type:** ☐ **site-specific** ☐ **generic (default)**

Contaminant	CAS #	Soil Screening Level	
		ingestion	other (plant uptake; fugitive dust)

EA #:_____ **SSL type:** ☐ **site-specific** ☐ **generic (default)**

Contaminant	CAS #	Soil Screening Level	
		ingestion	other (plant uptake; fugitive dust)

Worksheet 4. Subsurface SSLs by source **Site Name** _____

Source #:_____ **SSL type:** ☐ **site-specific** ☐ **generic (default)**

Contaminant	CAS #	Soil Screening Level	
		inhalation of volatiles	migration to ground water

Source #:_____ **SSL type:** ☐ **site-specific** ☐ **generic (default)**

Contaminant	CAS #	Soil Screening Level	
		inhalation of volatiles	migration to ground water

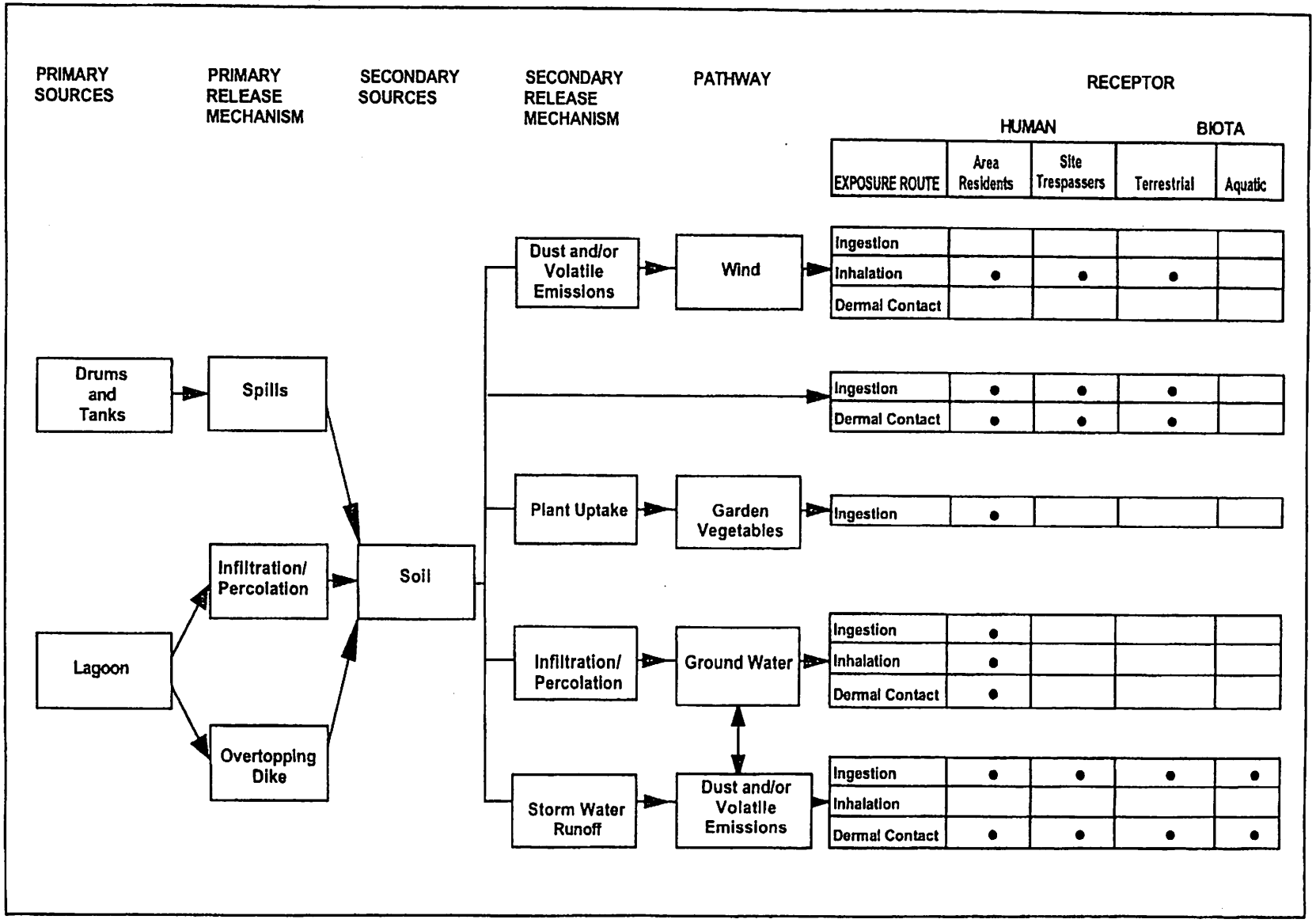
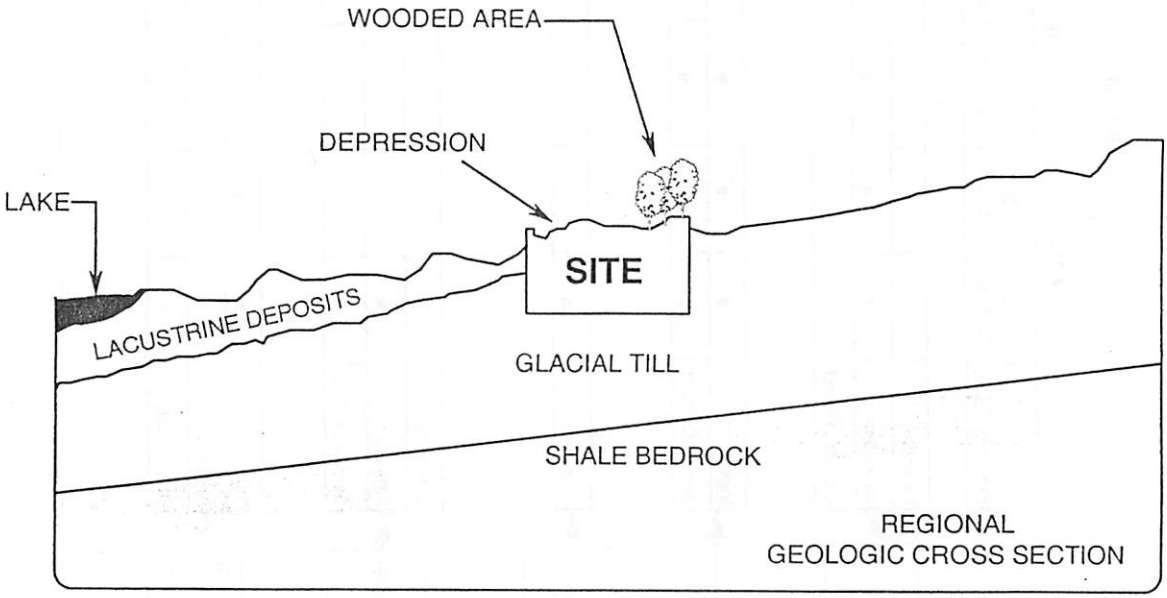


Figure A-2. Example conceptual site model diagram for contaminated soil (adapted from U.S. EPA, 1989).



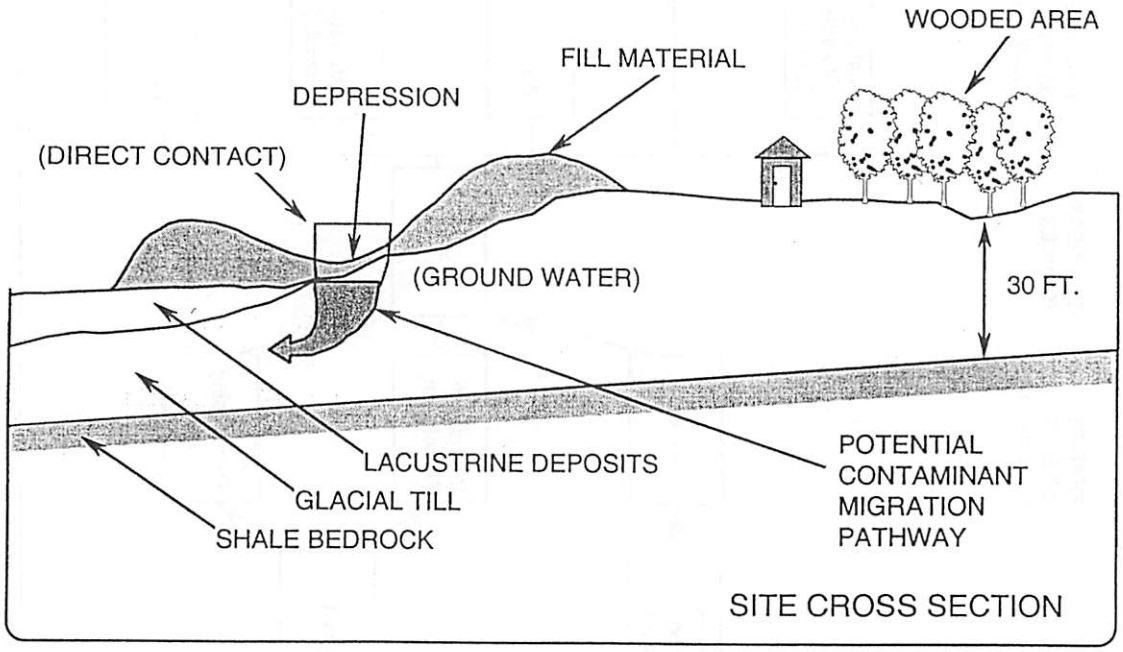


Figure A-3. Example Site Sketch (adapted from U.S. EPA, 1987)

Attachment B

Soil Screening DQOs for Surface Soils and Subsurface Soils

Soil Screening DQOs for Surface Soils Using the Max Test

DQO Process Steps	Soil Screening Inputs/Outputs
State the Problem	
Identify scoping team	Site manager and technical experts (e.g., toxicologists, risk assessors, statisticians)
Develop conceptual site model (CSM)	CSM development (described in Step 1)
Define exposure scenarios	Direct ingestion and inhalation of fugitive particulates in a residential setting; dermal contact and plant uptake for certain contaminants
Specify available resources	Sampling and analysis budget, scheduling constraints, and available personnel
Write brief summary of contamination problem	Summary of the surface soil contamination problem to be investigated at the site
Identify the Decision	
Identify decision	Do mean soil concentrations for particular contaminants (e.g., contaminants of potential concern) exceed appropriate screening levels?
Identify alternative actions	Eliminate area from further study under CERCLA or Plan and conduct further investigation
Identify Inputs to the Decision	
Identify inputs	Ingestion and particulate inhalation SSLs for specified contaminants Measurements of surface soil contaminant concentration
Define basis for screening	Soil Screening Guidance
Identify analytical methods	Feasible analytical methods (both field and laboratory) consistent with program-level requirements
Define the Study Boundaries	
Define geographic areas of field investigation	The entire NPL site, (which may include areas beyond facility boundaries), except for any areas with clear evidence that no contamination has occurred
Define population of interest	Surface soils (usually the top 2 centimeters, but may be deeper where activities could redistribute subsurface soils to the surface)
Divide site into strata	Strata may be defined so that contaminant concentrations are likely to be relatively homogeneous within each stratum based on the CSM and field measurements
Define scale of decision making	Exposure areas (EAs) no larger than 0.5 acre each (based on residential land use)
Define temporal boundaries of study	Temporal constraints on scheduling field visits
Identify practical constraints	Potential impediments to sample collection, such as access, health, and safety issues
Develop a Decision Rule	
Specify parameter of interest	"True mean" (μ) individual contaminant concentration in each EA. However, since the determination of the "true mean" would require the collection and analysis of many samples, another sample statistic, the maximum composite concentration, or "Max Test" is used.
Specify screening level	Screening levels calculated using available parameters and site data (or generic SSLs if site data are unavailable)
Specify "if..., then..." decision rule	Ideally, if the "true mean" EA concentration exceeds the screening level, then investigate the EA further. If the "true mean" is less than the screening level, then no further investigation of the EA is required under CERCLA.

Soil Screening DQOs for Surface Soils Using the Max Test (continued)

DQO Process Steps	Soil Screening Inputs/Outputs
Specify Limits on Decision Errors*	
Define baseline condition (null hypothesis)	The EA needs further investigation
Define the gray region**	From 0.5 SSL to 2 SSL
Define Type I and Type II decision errors	Type I error: Do not investigate further ("walk away from") an EA whose "true mean" exceeds the screening level of 2 SSL Type II error: Investigate further when an EA's "true mean" falls below the screening level of 0.5 SSL
Identify consequences	Type I error: potential public health consequences Type II error: unnecessary expenditure of resources to investigate further
Assign acceptable probabilities of Type I and Type II decision errors	Goals: Type I: 0.05 (5%) probability of not investigating further when "true mean" of the EA is 2 SSL Type II: 0.20 (20%) probability of investigating further when "true mean" of the EA is 0.5 SSL
Define QA/QC goals	CLP precision and bias requirements 10% CLP analyses for field methods
Optimize the Design	
Determine how to best estimate "true mean"	Samples composited across the EA as physical estimates of EA mean ($\bar{x}$). Use maximum composite concentration as a conservative estimate of the true EA mean.
Determine expected variability of EA surface soil contaminant concentrations	A conservatively large expected coefficient of variation (CV) from prior data for the site, field measurements, or data from other comparable sites and expert judgment. A minimum default CV of 2.5 should be used when information is insufficient to estimate the CV.
Design sampling strategy by evaluating costs and performance of alternatives	Lowest cost sampling design option (i.e., compositing scheme and number of composites) that will achieve acceptable decision error rates
Develop planning documents for the field investigation	Sampling and Analysis Plan (SAP) Quality Assurance Project Plan (QAPjP)

* Since the DQO process controls the degree to which uncertainty in data affects the outcome of decisions that are based on that data, specifying limits on decision errors will allow the decision maker to control the probability of making an incorrect decision when using the DQOs.

** The gray region represents the area where the consequences of decision errors are minor, (and uncertainty in sampling data makes decisions too close to call).

Soil Screening DQOs for Subsurface Soils

DQO Process Steps	Soil Screening Inputs/Outputs
State the Problem	
Identify scoping team	Site manager and technical experts (e.g., toxicologists, risk assessors, hydrogeologists, statisticians).
Develop conceptual site model (CSM)	CSM development (described in Step 1).
Define exposure scenarios	Inhalation of volatiles and migration of contaminants from soil to potable ground water (and plant uptake for certain contaminants).
Specify available resources	Sampling and analysis budget, scheduling constraints, and available personnel.
Write brief summary of contamination problem	Summary of the subsurface soil contamination problem to be investigated at the site.
Identify the Decision	
Identify decision	Do mean soil concentrations for particular contaminants (e.g., contaminants of potential concern) exceed appropriate SSLs?
Identify alternative actions	Eliminate area from further action or study under CERCLA or Plan and conduct further investigation.
Identify Inputs to the Decision	
Identify decision	Volatile inhalation and migration to ground water SSLs for specified contaminants Measurements of subsurface soil contaminant concentration
Define basis for screening	Soil Screening Guidance
Identify analytical methods	Feasible analytical methods (both field and laboratory) consistent with program-level requirements.
Specify the Study Boundaries	
Define geographic areas of field investigation	The entire NPL site (which may include areas beyond facility boundaries), except for any areas with clear evidence that no contamination has occurred.
Define population of interest	Subsurface soils
Define scale of decision making	Sources (areas of contiguous soil contamination, defined by the area and depth of contamination or to the water table, whichever is more shallow).
Subdivide site into decision units	Individual sources delineated (area and depth) using existing information or field measurements (several nearby sources may be combined into a single source).
Define temporal boundaries of study	Temporal constraints on scheduling field visits.
Identify (list) practical constraints	Potential impediments to sample collection, such as access, health, and safety issues.

Soil Screening DQOs for Subsurface Soils (continued)

Develop a Decision Rule	
Specify parameter of interest	Mean soil contaminant concentration in a source (i.e., discrete contaminant concentrations averaged within each boring).
Specify screening level	SSLs calculated using available parameters and site data (or generic SSLs if site data are unavailable).
Specify "if..., then..." decision rule	If the mean soil concentration exceeds the SSL, then investigate the source further. If mean soil concentration in a source is less than the SSL, then no further investigation is required under CERCLA.
Specify Limits on Decision Errors	
Define QA/QC goals	CLP precision and bias requirements 10% CLP analyses for field methods
Optimize the Design	
Determine how to estimate mean concentration in a source	For each source, the highest mean soil boring concentration (i.e., depth-weighted average of discrete contaminant concentrations within a boring).
Define subsurface sampling strategy by evaluating costs and site-specific conditions	Number of soil borings per source area; number of sampling intervals with depth.
Develop planning documents for the field investigation	Sampling and Analysis Plan (SAP) Quality Assurance Project Plan (QAPjP)

Attachment C

Chemical Properties for SSL Development

Attachment C

Chemical Properties

This attachment provides the chemical properties necessary to calculate inhalation and migration to ground water SSLs (see Section 2.5.2) for 110 chemicals commonly found at Superfund sites. The *Technical Background Document for Soil Screening Guidance* describes the derivation and sources for these property values.

- Table C-1 provides soil organic carbon - water partition coefficients (K_{oc}), air and water diffusivities ($D_{i,a}$ and $D_{i,w}$), water solubilities (S), and dimensionless Henry's law constants (H').

- Table C-2 provides pH-specific K_{oc} values for organic contaminants that ionize under natural pH conditions. Site-specific soil pH measurements (see Section 2.3.5) can be used to select appropriate K_{oc} values for these chemicals. Where site-specific soil pH values are not available, values corresponding to a pH or 6.8 should be used (note that the K_{oc} values for these chemicals in Table C-1 are for a pH of 6.8).

- Table C-3 provides the physical state (liquid or solid) for organic contaminants. A contaminant's liquid or solid state is needed to apply and interpret soil saturation limit (C_{sat}) results (see Section 2.5.2, p.23).

- Table C-4 provides pH-specific soil-water partition coefficients (K_d) for metals. Site-specific soil pH measurements (see Section 2.3.5) can be used to select appropriate K_d values for these metals. Where site-specific soil pH values are not available, values corresponding to a pH of 6.8 should be used.

Except for air and water diffusivities, the chemical properties necessary to calculate SSLs for additional chemicals may be found in the Superfund Chemical Data Matrix (SCDM). Additional air and water diffusivities may be obtained from the CHEMDAT8 and WATER8 models, both of which can be downloaded off EPA's SCRAM electronic bulletin board system. Accessing information is

OAQPS SCRAM BBS
(919)541-5742 (24 hr/d, 7 d/wk except Monday AM)
Line Settings: 8 bits, no parity, 1 stop bit
Terminal emulation: VT100 or ANSI
System Operator: (919)541-5384 (normal business hours EST)

Table C-1. Chemical-Specific Properties used in SSL Calculations

CAS No.	Compound	K_{oc} (L/kg)	$D_{I,a}$ (cm^2/s)	$D_{I,w}$ (cm^2/s)	S (mg/L)	H' (dimensionless)
83-32-9	Acenaphthene	7.08E+03	4.21E-02	7.69E-06	4.24E+00	6.36E-03
67-64-1	Acetone	5.75E-01	1.24E-01	1.14E-05	1.00E+06	1.59E-03
309-00-2	Aldrin	2.45E+06	1.32E-02	4.86E-06	1.80E-01	6.97E-03
120-12-7	Anthracene	2.95E+04	3.24E-02	7.74E-06	4.34E-02	2.67E-03
56-55-3	Benz(*a*)anthracene	3.98E+05	5.10E-02	9.00E-06	9.40E-03	1.37E-04
71-43-2	Benzene	5.89E+01	8.80E-02	9.80E-06	1.75E+03	2.28E-01
205-99-2	Benzo(*b*)fluoranthene	1.23E+06	2.26E-02	5.56E-06	1.50E-03	4.55E-03
207-08-9	Benzo(*k*)fluoranthene	1.23E+06	2.26E-02	5.56E-06	8.00E-04	3.40E-05
65-85-0	Benzoic acid	6.00E-01	5.36E-02	7.97E-06	3.50E+03	6.31E-05
50-32-8	Benzo(*a*)pyrene	1.02E+06	4.30E-02	9.00E-06	1.62E-03	4.63E-05
111-44-4	Bis(2-chloroethyl)ether	1.55E+01	6.92E-02	7.53E-06	1.72E+04	7.38E-04
117-81-7	Bis(2-ethylhexyl)phthalate	1.51E+07	3.51E-02	3.66E-06	3.40E-01	4.18E-06
75-27-4	Bromodichloromethane	5.50E+01	2.98E-02	1.06E-05	6.74E+03	6.56E-02
75-25-2	Bromoform	8.71E+01	1.49E-02	1.03E-05	3.10E+03	2.19E-02
71-36-3	Butanol	6.92E+00	8.00E-02	9.30E-06	7.40E+04	3.61E-04
85-68-7	Butyl benzyl phthalate	5.75E+04	1.74E-02	4.83E-06	2.69E+00	5.17E-05
86-74-8	Carbazole	3.39E+03	3.90E-02	7.03E-06	7.48E+00	6.26E-07
75-15-0	Carbon disulfide	4.57E+01	1.04E-01	1.00E-05	1.19E+03	1.24E+00
56-23-5	Carbon tetrachloride	1.74E+02	7.80E-02	8.80E-06	7.93E+02	1.25E+00
57-74-9	Chlordane	1.20E+05	1.18E-02	4.37E-06	5.60E-02	1.99E-03
106-47-8	*p*-Chloroaniline	6.61E+01	4.83E-02	1.01E-05	5.30E+03	1.36E-05
108-90-7	Chlorobenzene	2.19E+02	7.30E-02	8.70E-06	4.72E+02	1.52E-01
124-48-1	Chlorodibromomethane	6.31E+01	1.96E-02	1.05E-05	2.60E+03	3.21E-02
67-66-3	Chloroform	3.98E+01	1.04E-01	1.00E-05	7.92E+03	1.50E-01
95-57-8	2-Chlorophenol	3.88E+02	5.01E-02	9.46E-06	2.20E+04	1.60E-02
218-01-9	Chrysene	3.98E+05	2.48E-02	6.21E-06	1.60E-03	3.88E-03
72-54-8	DDD	1.00E+06	1.69E-02	4.76E-06	9.00E-02	1.64E-04
72-55-9	DDE	4.47E+06	1.44E-02	5.87E-06	1.20E-01	8.61E-04
50-29-3	DDT	2.63E+06	1.37E-02	4.95E-06	2.50E-02	3.32E-04
53-70-3	Dibenz(*a,h*)anthracene	3.80E+06	2.02E-02	5.18E-06	2.49E-03	6.03E-07
84-74-2	Di-*n*-butyl phthalate	3.39E+04	4.38E-02	7.86E-06	1.12E+01	3.85E-08
95-50-1	1,2-Dichlorobenzene	6.17E+02	6.90E-02	7.90E-06	1.56E+02	7.79E-02
106-46-7	1,4-Dichlorobenzene	6.17E+02	6.90E-02	7.90E-06	7.38E+01	9.96E-02
91-94-1	3,3-Dichlorobenzidine	7.24E+02	1.94E-02	6.74E-06	3.11E+00	1.64E-07
75-34-3	1,1-Dichloroethane	3.16E+01	7.42E-02	1.05E-05	5.06E+03	2.30E-01
107-06-2	1,2-Dichloroethane	1.74E+01	1.04E-01	9.90E-06	8.52E+03	4.01E-02
75-35-4	1,1-Dichloroethylene	5.89E+01	9.00E-02	1.04E-05	2.25E+03	1.07E+00
156-59-2	*cis*-1,2-Dichloroethylene	3.55E+01	7.36E-02	1.13E-05	3.50E+03	1.67E-01
156-60-5	*trans*-1,2-Dichloroethylene	5.25E+01	7.07E-02	1.19E-05	6.30E+03	3.85E-01
120-83-2	2,4-Dichlorophenol	1.47E+02	3.46E-02	8.77E-06	4.50E+03	1.30E-04
78-87-5	1,2-Dichloropropane	4.37E+01	7.82E-02	8.73E-06	2.80E+03	1.15E-01
542-75-6	1,3-Dichloropropene	4.57E+01	6.26E-02	1.00E-05	2.80E+03	7.26E-01
60-57-1	Dieldrin	2.14E+04	1.25E-02	4.74E-06	1.95E-01	6.19E-04
84-66-2	Diethylphthalate	2.88E+02	2.56E-02	6.35E-06	1.08E+03	1.85E-05
105-67-9	2,4-Dimethylphenol	2.09E+02	5.84E-02	8.69E-06	7.87E+03	8.20E-05

Table C-1 (continued)

CAS No.	Compound	K_{oc} (L/kg)	$D_{l,a}$ (cm^2/s)	$D_{l,w}$ (cm^2/s)	S (mg/L)	H' (dimensionless)
51-28-5	2,4-Dinitrophenol	1.00E-02	2.73E-02	9.06E-06	2.79E+03	1.82E-05
121-14-2	2,4-Dinitrotoluene	9.55E+01	2.03E-01	7.06E-06	2.70E+02	3.80E-06
606-20-2	2,6-Dinitrotoluene	6.92E+01	3.27E-02	7.26E-06	1.82E+02	3.06E-05
117-84-0	Di-*n*-octyl phthalate	8.32E+07	1.51E-02	3.58E-06	2.00E-02	2.74E-03
115-29-7	Endosulfan	2.14E+03	1.15E-02	4.55E-06	5.10E-01	4.59E-04
72-20-8	Endrin	1.23E+04	1.25E-02	4.74E-06	2.50E-01	3.08E-04
100-41-4	Ethylbenzene	3.63E+02	7.50E-02	7.80E-06	1.69E+02	3.23E-01
206-44-0	Fluoranthene	1.07E+05	3.02E-02	6.35E-06	2.06E-01	6.60E-04
86-73-7	Fluorene	1.38E+04	3.63E-02	7.88E-06	1.98E+00	2.61E-03
76-44-8	Heptachlor	1.41E+06	1.12E-02	5.69E-06	1.80E-01	4.47E-02
1024-57-3	Heptachlor epoxide	8.32E+04	1.32E-02	4.23E-06	2.00E-01	3.90E-04
118-74-1	Hexachlorobenzene	5.50E+04	5.42E-02	5.91E-06	6.20E+00	5.41E-02
87-68-3	Hexachloro-1,3-butadiene	5.37E+04	5.61E-02	6.16E-06	3.23E+00	3.34E-01
319-84-6	α-HCH (α-BHC)	1.23E+03	1.42E-02	7.34E-06	2.00E+00	4.35E-04
319-85-7	ß-HCH (ß-BHC)	1.26E+03	1.42E-02	7.34E-06	2.40E-01	3.05E-05
58-89-9	γ-HCH (Lindane)	1.07E+03	1.42E-02	7.34E-06	6.80E+00	5.74E-04
77-47-4	Hexachlorocyclopentadiene	2.00E+05	1.61E-02	7.21E-06	1.80E+00	1.11E+00
67-72-1	Hexachloroethane	1.78E+03	2.50E-03	6.80E-06	5.00E+01	1.59E-01
193-39-5	Indeno(1,2,3-*cd*)pyrene	3.47E+06	1.90E-02	5.66E-06	2.20E-05	6.56E-05
78-59-1	Isophorone	4.68E+01	6.23E-02	6.76E-06	1.20E+04	2.72E-04
7439-97-6	Mercury	---	3.07E-02	6.30E-06	---	4.67E-01
72-43-5	Methoxychlor	9.77E+04	1.56E-02	4.46E-06	4.50E-02	6.48E-04
74-83-9	Methyl bromide	1.05E+01	7.28E-02	1.21E-05	1.52E+04	2.56E-01
75-09-2	Methylene chloride	1.17E+01	1.01E-01	1.17E-05	1.30E+04	8.98E-02
95-48-7	2-Methylphenol	9.12E+01	7.40E-02	8.30E-06	2.60E+04	4.92E-05
91-20-3	Naphthalene	2.00E+03	5.90E-02	7.50E-06	3.10E+01	1.98E-02
98-95-3	Nitrobenzene	6.46E+01	7.60E-02	8.60E-06	2.09E+03	9.84E-04
86-30-6	*N*-Nitrosodiphenylamine	1.29E+03	3.12E-02	6.35E-06	3.51E+01	2.05E-04
621-64-7	*N*-Nitrosodi-*n*-propylamine	2.40E+01	5.45E-02	8.17E-06	9.89E+03	9.23E-05
1336-36-3	PCBs	3.09E+05	---	---	7.00E-01	---
87-86-5	Pentachlorophenol	5.92E+02	5.60E-02	6.10E-06	1.95E+03	1.00E-06
108-95-2	Phenol	2.88E+01	8.20E-02	9.10E-06	8.28E+04	1.63E-05
129-00-0	Pyrene	1.05E+05	2.72E-02	7.24E-06	1.35E-01	4.51E-04
100-42-5	Styrene	7.76E+02	7.10E-02	8.00E-06	3.10E+02	1.13E-01
79-34-5	1,1,2,2-Tetrachloroethane	9.33E+01	7.10E-02	7.90E-06	2.97E+03	1.41E-02
127-18-4	Tetrachloroethylene	1.55E+02	7.20E-02	8.20E-06	2.00E+02	7.54E-01
108-88-3	Toluene	1.82E+02	8.70E-02	8.60E-06	5.26E+02	2.72E-01
8001-35-2	Toxaphene	2.57E+05	1.16E-02	4.34E-06	7.40E-01	2.46E-04
120-82-1	1,2,4-Trichlorobenzene	1.78E+03	3.00E-02	8.23E-06	3.00E+02	5.82E-02
71-55-6	1,1,1-Trichloroethane	1.10E+02	7.80E-02	8.80E-06	1.33E+03	7.05E-01
79-00-5	1,1,2-Trichloroethane	5.01E+01	7.80E-02	8.80E-06	4.42E+03	3.74E-02
79-01-6	Trichloroethylene	1.66E+02	7.90E-02	9.10E-06	1.10E+03	4.22E-01
95-95-4	2,4,5-Trichlorophenol	1.60E+03	2.91E-02	7.03E-06	1.20E+03	1.78E-04
88-06-2	2,4,6-Trichlorophenol	3.81E+02	3.18E-02	6.25E-06	8.00E+02	3.19E-04

Table C-1 (continued)

CAS No.	Compound	K_{oc} (L/kg)	$D_{i,a}$ (cm^2/s)	$D_{i,w}$ (cm^2/s)	S (mg/L)	H' (dimensionless)
108-05-4	Vinyl acetate	5.25E+00	8.50E-02	9.20E-06	2.00E+04	2.10E-02
75-01-4	Vinyl chloride	1.86E+01	1.06E-01	1.23E-06	2.76E+03	1.11E+00
108-38-3	*m*-Xylene	4.07E+02	7.00E-02	7.80E-06	1.61E+02	3.01E-01
95-47-6	*o*-Xylene	3.63E+02	8.70E-02	1.00E-05	1.78E+02	2.13E-01
106-42-3	*p*-Xylene	3.89E+02	7.69E-02	8.44E-06	1.85E+02	3.14E-01

K_{oc} = Soil organic carbon/water partition coefficient.
$D_{i,a}$ = Diffusivity in air (25 °C).
$D_{i,w}$ = Diffusivity in water (25 °C).
S = Solubility in water (20-25 °C).
H' = Dimensionless Henry's law constant (HLC [atm-m3/mol] * 41) (25 °C).
K_d = Soil-water partition coefficient.

Table C-2. Koc Values for Ionizing Organics as a Function of pH

pH	Benzoic Acid	2-Chloro-phenol	2,4-Dichloro-phenol	2,4-Dinitro-phenol	Pentachloro-phenol	2,3,4,5-Tetrachloro-phenol	2,3,4,6-Tetrachloro-phenol	2,4,5-Trichloro-phenol	2,4,6-Trichloro-phenol
4.9	5.54E+00	3.98E+02	1.59E+02	2.94E-02	9.05E+03	1.73E+04	4.45E+03	2.37E+03	1.04E+03
5.0	4.64E+00	3.98E+02	1.59E+02	2.55E-02	7.96E+03	1.72E+04	4.15E+03	2.36E+03	1.03E+03
5.1	3.88E+00	3.98E+02	1.59E+02	2.23E-02	6.93E+03	1.70E+04	3.83E+03	2.36E+03	1.02E+03
5.2	3.25E+00	3.98E+02	1.59E+02	1.98E-02	5.97E+03	1.67E+04	3.49E+03	2.35E+03	1.01E+03
5.3	2.72E+00	3.98E+02	1.59E+02	1.78E-02	5.10E+03	1.65E+04	3.14E+03	2.34E+03	9.99E+02
5.4	2.29E+00	3.98E+02	1.58E+02	1.62E-02	4.32E+03	1.61E+04	2.79E+03	2.33E+03	9.82E+02
5.5	1.94E+00	3.97E+02	1.58E+02	1.50E-02	3.65E+03	1.57E+04	2.45E+03	2.32E+03	9.62E+02
5.6	1.65E+00	3.97E+02	1.58E+02	1.40E-02	3.07E+03	1.52E+04	2.13E+03	2.31E+03	9.38E+02
5.7	1.42E+00	3.97E+02	1.58E+02	1.32E-02	2.58E+03	1.47E+04	1.83E+03	2.29E+03	9.10E+02
5.8	1.24E+00	3.97E+02	1.58E+02	1.25E-02	2.18E+03	1.40E+04	1.56E+03	2.27E+03	8.77E+02
5.9	1.09E+00	3.97E+02	1.57E+02	1.20E-02	1.84E+03	1.32E+04	1.32E+03	2.24E+03	8.39E+02
6.0	9.69E-01	3.96E+02	1.57E+02	1.16E-02	1.56E+03	1.24E+04	1.11E+03	2.21E+03	7.96E+02
6.1	8.75E-01	3.96E+02	1.57E+02	1.13E-02	1.33E+03	1.15E+04	9.27E+02	2.17E+03	7.48E+02
6.2	7.99E-01	3.96E+02	1.56E+02	1.10E-02	1.15E+03	1.05E+04	7.75E+02	2.12E+03	6.97E+02
6.3	7.36E-01	3.95E+02	1.55E+02	1.08E-02	9.98E+02	9.51E+03	6.47E+02	2.06E+03	6.44E+02
6.4	6.89E-01	3.94E+02	1.54E+02	1.06E-02	8.77E+02	8.48E+03	5.42E+02	1.99E+03	5.89E+02
6.5	6.51E-01	3.93E+02	1.53E+02	1.05E-02	7.81E+02	7.47E+03	4.55E+02	1.91E+03	5.33E+02
6.6	6.20E-01	3.92E+02	1.52E+02	1.04E-02	7.03E+02	6.49E+03	3.84E+02	1.82E+03	4.80E+02
6.7	5.95E-01	3.90E+02	1.50E+02	1.03E-02	6.40E+02	5.58E+03	3.27E+02	1.71E+03	4.29E+02
6.8	5.76E-01	3.88E+02	1.47E+02	1.02E-02	5.92E+02	4.74E+03	2.80E+02	1.60E+03	3.81E+02
6.9	5.60E-01	3.86E+02	1.45E+02	1.02E-02	5.52E+02	3.99E+03	2.42E+02	1.47E+03	3.38E+02
7.0	5.47E-01	3.83E+02	1.41E+02	1.02E-02	5.21E+02	3.33E+03	2.13E+02	1.34E+03	3.00E+02
7.1	5.38E-01	3.79E+02	1.38E+02	1.02E-02	4.96E+02	2.76E+03	1.88E+02	1.21E+03	2.67E+02
7.2	5.32E-01	3.75E+02	1.33E+02	1.01E-02	4.76E+02	2.28E+03	1.69E+02	1.07E+03	2.39E+02
7.3	5.25E-01	3.69E+02	1.28E+02	1.01E-02	4.61E+02	1.87E+03	1.53E+02	9.43E+02	2.15E+02
7.4	5.19E-01	3.62E+02	1.21E+02	1.01E-02	4.47E+02	1.53E+03	1.41E+02	8.19E+02	1.95E+02
7.5	5.16E-01	3.54E+02	1.14E+02	1.01E-02	4.37E+02	1.25E+03	1.31E+02	7.03E+02	1.78E+02
7.6	5.13E-01	3.44E+02	1.07E+02	1.01E-02	4.29E+02	1.02E+03	1.23E+02	5.99E+02	1.64E+02
7.7	5.09E-01	3.33E+02	9.84E+01	1.00E-02	4.23E+02	8.31E+02	1.17E+02	5.07E+02	1.53E+02
7.8	5.06E-01	3.19E+02	8.97E+01	1.00E-02	4.18E+02	6.79E+02	1.13E+02	4.26E+02	1.44E+02
7.9	5.06E-01	3.04E+02	8.07E+01	1.00E-02	4.14E+02	5.56E+02	1.08E+02	3.57E+02	1.37E+02
8.0	5.06E-01	2.86E+02	7.17E+01	1.00E-02	4.10E+02	4.58E+02	1.05E+02	2.98E+02	1.31E+02

Table C-3. Physical State of Organic SSL Chemicals

Compounds liquid at soil temperatures			Compounds solid at soil temperatures		
CAS No.	Chemical	Melting Point (°C)	CAS No.	Chemical	Melting Point (°C)
67-64-1	Acetone	-94.8	83-32-9	Acenaphthene	93.4
71-43-2	Benzene	5.5	309-00-2	Aldrin	104
117-81-7	Bis(2-ethylhexyl)phthalate	-55	120-12-7	Anthracene	215
111-44-4	Bis(2-chloroethyl)ether	-51.9	56-55-3	Benz(*a*)anthracene	84
75-27-4	Bromodichloromethane	-57	50-32-8	Benzo(*a*)pyrene	176.5
75-25-2	Bromoform	8	205-99-2	Benzo(*b*)fluoranthene	168
71-36-3	Butanol	-89.8	207-08-9	Benzo(*k*)fluoranthene	217
85-68-7	Butyl benzyl phthalate	-35	65-85-0	Benzoic acid	122.4
75-15-0	Carbon disulfide	-115	86-74-8	Carbazole	246.2
56-23-5	Carbon tetrachloride	-23	57-74-9	Chlordane	106
108-90-7	Chlorobenzene	-45.2	106-47-8	*p*-Chloroaniline	72.5
124-48-1	Chlorodibromomethane	-20	218-01-9	Chrysene	258.2
67-66-3	Chloroform	-63.6	72-54-8	DDD	109.5
95-57-8	2-Chlorophenol	9.8	72-55-9	DDE	89
84-74-2	Di-*n*-butyl phthalate	-35	50-29-3	DDT	108.5
95-50-1	1,2-Dichlorobenzene	-16.7	53-70-3	Dibenzo(*a,h*)anthracene	269.5
75-34-3	1,1-Dichloroethane	-96.9	106-46-7	1,4-Dichlorobenzene	52.7
107-06-2	1,2-Dichloroethane	-35.5	91-94-1	3,3-Dichlorobenzidine	132.5
75-35-4	1,1-Dichloroethylene	-122.5	120-83-2	2,4-Dichlorophenol	45
156-59-2	*cis*-1,2-Dichloroethylene	-80	60-57-1	Dieldrin	175.5
156-60-5	*trans*-1,2-Dichloroethylene	-49.8	105-67-9	2,4-Dimethylphenol	24.5
78-87-5	1,2-Dichloropropane	-70	51-28-5	2,4-Dinitrophenol	115-116
542-75-6	1,3-Dichloropropene	NA	121-14-2	2,4-Dinitrotoluene	71
84-66-2	Diethylphthalate	-40.5	606-20-2	2,6-Dinitrotoluene	66
117-84-0	Di-*n*-octyl phthalate	-30	72-20-8	Endrin	200
100-41-4	Ethylbenzene	-94.9	206-44-0	Fluoranthene	107.8
87-68-3	Hexachloro-1,3-butadiene	-21	86-73-7	Fluorene	114.8
77-47-4	Hexachlorocyclopentadiene	-9	76-44-8	Heptachlor	95.5
78-59-1	Isophorone	-8.1	1024-57-3	Heptachlor epoxide	160
74-83-9	Methyl bromide	-93.7	118-74-1	Hexachlorobenzene	231.8
75-09-2	Methylene chloride	-95.1	319-84-6	α-HCH (α-BHC)	160
98-95-3	Nitrobenzene	5.7	319-85-7	β-HCH (β-BHC)	315
100-42-5	Styrene	-31	58-89-9	γ-HCH (Lindane)	112.5
79-34-5	1,1,2,2-Tetrachloroethane	-43.8	67-72-1	Hexachloroethane	187
127-18-4	Tetrachloroethylene	-22.3	193-39-5	Indeno(1,2,3-*cd*)pyrene	161.5
108-88-3	Toluene	-94.9	72-43-5	Methoxychlor	87
120-82-1	1,2,4-Trichlorobenzene	17	95-48-7	2-Methylphenol	29.8
71-55-6	1,1,1-Trichloroethane	-30.4	621-64-7	*N*-Nitrosodi-*n*-propylamine	NA
79-00-5	1,1,2-Trichloroethane	-36.6	86-30-6	*N*-Nitrosodiphenylamine	66.5
79-01-6	Trichloroethylene	-84.7	91-20-3	Naphthalene	80.2
108-05-4	Vinyl acetate	-93.2	87-86-5	Pentachlorophenol	174
75-01-4	Vinyl chloride	-153.7	108-95-2	Phenol	40.9
108-38-3	*m*-Xylene	-47.8	129-00-0	Pyrene	151.2
95-47-6	*o*-Xylene	-25.2	8001-35-2	Toxaphene	65-90
106-42-3	*p*-Xylene	13.2	95-95-4	2,4,5-Trichlorophenol	69
			88-06-2	2,4,6-Trichlorophenol	69
			115-29-7	Endosulfan	106

NA = Not available.

Table C-4. Metal K_d Values (L/kg) as a Function of pH[a]

pH	As	Ba	Be	Cd	Cr (+3)	Cr (+6)	Hg	Ni	Ag	Se	Tl	Zn
4.9	2.5E+01	1.1E+01	2.3E+01	1.5E+01	1.2E+03	3.1E+01	4.0E-02	1.6E+01	1.0E-01	1.8E+01	4.4E+01	1.6E+01
5.0	2.5E+01	1.2E+01	2.6E+01	1.7E+01	1.9E+03	3.1E+01	6.0E-02	1.8E+01	1.3E-01	1.7E+01	4.5E+01	1.8E+01
5.1	2.5E+01	1.4E+01	2.8E+01	1.9E+01	3.0E+03	3.0E+01	9.0E-02	2.0E+01	1.6E-01	1.6E+01	4.6E+01	1.9E+01
5.2	2.6E+01	1.5E+01	3.1E+01	2.1E+01	4.9E+03	2.9E+01	1.4E-01	2.2E+01	2.1E-01	1.5E+01	4.7E+01	2.1E+01
5.3	2.6E+01	1.7E+01	3.5E+01	2.3E+01	8.1E+03	2.8E+01	2.0E-01	2.4E+01	2.6E-01	1.4E+01	4.8E+01	2.3E+01
5.4	2.6E+01	1.9E+01	3.8E+01	2.5E+01	1.3E+04	2.7E+01	3.0E-01	2.6E+01	3.3E-01	1.3E+01	5.0E+01	2.5E+01
5.5	2.6E+01	2.1E+01	4.2E+01	2.7E+01	2.1E+04	2.7E+01	4.6E-01	2.8E+01	4.2E-01	1.2E+01	5.1E+01	2.6E+01
5.6	2.6E+01	2.2E+01	4.7E+01	2.9E+01	3.5E+04	2.6E+01	6.9E-01	3.0E+01	5.3E-01	1.1E+01	5.2E+01	2.8E+01
5.7	2.7E+01	2.4E+01	5.3E+01	3.1E+01	5.5E+04	2.5E+01	1.0E+00	3.2E+01	6.7E-01	1.1E+01	5.4E+01	3.0E+01
5.8	2.7E+01	2.6E+01	6.0E+01	3.3E+01	8.7E+04	2.5E+01	1.6E+00	3.4E+01	8.4E-01	9.8E+00	5.5E+01	3.2E+01
5.9	2.7E+01	2.8E+01	6.9E+01	3.5E+01	1.3E+05	2.4E+01	2.3E+00	3.6E+01	1.1E+00	9.2E+00	5.6E+01	3.4E+01
6.0	2.7E+01	3.0E+01	8.2E+01	3.7E+01	2.0E+05	2.3E+01	3.5E+00	3.8E+01	1.3E+00	8.6E+00	5.8E+01	3.6E+01
6.1	2.7E+01	3.1E+01	9.9E+01	4.0E+01	3.0E+05	2.3E+01	5.1E+00	4.0E+01	1.7E+00	8.0E+00	5.9E+01	3.9E+01
6.2	2.8E+01	3.3E+01	1.2E+02	4.2E+01	4.2E+05	2.2E+01	7.5E+00	4.2E+01	2.1E+00	7.5E+00	6.1E+01	4.2E+01
6.3	2.8E+01	3.5E+01	1.6E+02	4.4E+01	5.8E+05	2.2E+01	1.1E+01	4.5E+01	2.7E+00	7.0E+00	6.2E+01	4.4E+01
6.4	2.8E+01	3.6E+01	2.1E+02	4.8E+01	7.7E+05	2.1E+01	1.6E+01	4.7E+01	3.4E+00	6.5E+00	6.4E+01	4.7E+01
6.5	2.8E+01	3.7E+01	2.8E+02	5.2E+01	9.9E+05	2.0E+01	2.2E+01	5.0E+01	4.2E+00	6.1E+00	6.6E+01	5.1E+01
6.6	2.8E+01	3.9E+01	3.9E+02	5.7E+01	1.2E+06	2.0E+01	3.0E+01	5.4E+01	5.3E+00	5.7E+00	6.7E+01	5.4E+01
6.7	2.9E+01	4.0E+01	5.5E+02	6.4E+01	1.5E+06	1.9E+01	4.0E+01	5.8E+01	6.6E+00	5.3E+00	6.9E+01	5.8E+01
6.8	2.9E+01	4.1E+01	7.9E+02	7.5E+01	1.8E+06	1.9E+01	5.2E+01	6.5E+01	8.3E+00	5.0E+00	7.1E+01	6.2E+01
6.9	2.9E+01	4.2E+01	1.1E+03	9.1E+01	2.1E+06	1.8E+01	6.6E+01	7.4E+01	1.0E+01	4.7E+00	7.3E+01	6.8E+01
7.0	2.9E+01	4.2E+01	1.7E+03	1.1E+02	2.5E+06	1.8E+01	8.2E+01	8.8E+01	1.3E+01	4.3E+00	7.4E+01	7.5E+01
7.1	2.9E+01	4.3E+01	2.5E+03	1.5E+02	2.8E+06	1.7E+01	9.9E+01	1.1E+02	1.6E+01	4.1E+00	7.6E+01	8.3E+01
7.2	3.0E+01	4.4E+01	3.8E+03	2.0E+02	3.1E+06	1.7E+01	1.2E+02	1.4E+02	2.0E+01	3.8E+00	7.8E+01	9.5E+01
7.3	3.0E+01	4.4E+01	5.7E+03	2.8E+02	3.4E+06	1.6E+01	1.3E+02	1.8E+02	2.5E+01	3.5E+00	8.0E+01	1.1E+02
7.4	3.0E+01	4.5E+01	8.6E+03	4.0E+02	3.7E+06	1.6E+01	1.5E+02	2.5E+02	3.1E+01	3.3E+00	8.2E+01	1.3E+02
7.5	3.0E+01	4.6E+01	1.3E+04	5.9E+02	3.9E+06	1.6E+01	1.6E+02	3.5E+02	3.9E+01	3.1E+00	8.5E+01	1.6E+02
7.6	3.1E+01	4.6E+01	2.0E+04	8.7E+02	4.1E+06	1.5E+01	1.7E+02	4.9E+02	4.8E+01	2.9E+00	8.7E+01	1.9E+02
7.7	3.1E+01	4.7E+01	3.0E+04	1.3E+03	4.2E+06	1.5E+01	1.8E+02	7.0E+02	5.9E+01	2.7E+00	8.9E+01	2.4E+02
7.8	3.1E+01	4.9E+01	4.6E+04	1.9E+03	4.3E+06	1.4E+01	1.9E+02	9.9E+02	7.3E+01	2.5E+00	9.1E+01	3.1E+02
7.9	3.1E+01	5.0E+01	6.9E+04	2.9E+03	4.3E+06	1.4E+01	1.9E+02	1.4E+03	8.9E+01	2.4E+00	9.4E+01	4.0E+02
8.0	3.1E+01	5.2E+01	1.0E+05	4.3E+03	4.3E+06	1.4E+01	2.0E+02	1.9E+03	1.1E+02	2.2E+00	9.6E+01	5.3E+02

[a]non pH-dependent inorganic K_d values for antimony, cyanide, and vanadium are 45, 9.9, and 1,000 respectively.

4/10/01

HASAN KECELI

Annual Report

Month	Projects in house (1)	Projects completed for month (2)	Year-to date
Oct-00	2	10	10
Nov-00	7	3	13
Dec-00	2	5	18
Jan-01	0	2	20
Feb-01	0	0	20
15-Mar-01	1	1	21
Mar-01	1	0	21

Groundwater Protection Standards

Month	Projects in house (1)	Projects completed for month (2)	Year-to date
Oct-00	0	3	3
Nov-00	4	2	5
Dec-00	1	6	14
Jan-01	0	1	15
Feb-01	4	0	15
15-Mar-01	2	2	17
Mar-01	0	2	19

Technical Support

Month	Support
Oct-00	3
Nov-00	2
Dec-00	1
Jan-01	5
Feb-01	2
15-Mar-01	1
Mar-01	2

Note (1) - At month's end
Note (2) -Completed

Attachment D

Regulatory and Human Health Benchmarks Used for SSL Development

Attachment D

Regulatory and Human Health Benchmarks for SSL Development

This attachment provides regulatory and human health benchmarks necessary to calculate SSLs for 110 chemicals commonly found at National Priority List (NPL) sites. The sources of these values (shown in the following table) are regularly updated by EPA. Prior to calculating SSLs at a site, check all relevant chemical-specific values in this attachment against the most recent version of their sources to ensure that they are up-to-date.

Attachment D. Regulatory and Human Health Benchmarks Used for SSL Development

CAS Number	Chemical Name	Maximum Contaminant Level Goal (mg/L)		Maximum Contaminant Level (mg/L)		Water Health Based Limits (mg/L)		Cancer Slope Factor $(mg/kg\text{-}d)^{-1}$			Unit Risk Factor $(\mu g/m^3)^{-1}$			Reference Dose (mg/kg-d)		Reference Concentration (mg/m^3)	
		MCLG (PMCLG)	Ref. [a]	MCL (PMCL)	Ref. [a]	HBL [b]	Basis	Carc. Class [c]	SF_o	Ref. [a]	Carc. Class [c]	URF	Ref. [a]	RfD	Ref. [a]	RfC	Ref. [a]
83-32-9	Acenaphthene					2E+00	RfD							6.0E-02	1		
67-64-1	Acetone (2-Propanone)					4E+00	RfD	D			D			1.0E-01	1		
309-00-2	Aldrin					5E-06	SF_o	B2	1.7E+01	1	B2	4.9E-03	1	3.0E-05	1		
120-12-7	Anthracene					1E+01	RfD	D			D			3.0E-01	1		
7440-36-0	Antimony	6.0E-03	3	6.0E-03	3									4.0E-04	1		
7440-38-2	Arsenic			5.0E-02	3			A	1.5E+00	1	A	4.3E-03	1	3.0E-04	1		
7440-39-3	Barium	2.0E+00	3	2.0E+00	3									7.0E-02	1	5.0E-04	2
56-55-3	Benz(*a*)anthracene					1E-04	SF_o	B2	7.3E-01	4	B2						
71-43-2	Benzene			5.0E-03	3			A	2.9E-02	1	A	8.3E-06	1				
205-99-2	Benzo(*b*)fluoranthene					1E-04	SF_o	B2	7.3E-01	4	B2						
207-08-9	Benzo(*k*)fluoranthene					1E-03	SF_o	B2	7.3E-02	4	B2						
65-85-0	Benzoic acid					1E+02	RfD							4.0E+00	1		
50-32-8	Benzo(*a*)pyrene			2.0E-04	3			B2	7.3E+00	1	B2						
7440-41-7	Beryllium	4.0E-03	3	4.0E-03	3			B2	4.3E+00	1	B2	2.4E-03	1	5.0E-03	1		
111-44-4	Bis(2-chloroethyl)ether					8E-05	SF_o	B2	1.1E+00	1	B2	3.3E-04	1				
117-81-7	Bis(2-ethylhexyl)phthalate			6.0E-03	3			B2	1.4E-02	1	B2			2.0E-02	1		
75-27-4	Bromodichloromethane			1.0E-01 *	3			B2	6.2E-02	1	B2			2.0E-02	1		
75-25-2	Bromoform (tribromomethane)			1.0E-01 *	3			B2	7.9E-03	1	B2	1.1E-06	1	2.0E-02	1		
71-36-3	Butanol					4E+00	RfD	D			D			1.0E-01	1		
85-68-7	Butyl benzyl phthalate					7E+00	RfD	C			C			2.0E-01	1		
7440-43-9	Cadmium	5.0E-03	3	5.0E-03	3						B1	1.8E-03	1	1.0E-03**	1		
86-74-8	Carbazole					4E-03	SF_o	B2	2.0E-02	2							
75-15-0	Carbon disulfide					4E+00	RfD							1.0E-01	1	7.0E-01	1
56-23-5	Carbon tetrachloride			5.0E-03	3			B2	1.3E-01	1	B2	1.5E-05	1	7.0E-04	1		
57-74-9	Chlordane			2.0E-03	3			B2	1.3E+00	1	B2	3.7E-04	1	6.0E-05	1		
106-47-8	*p*-Chloroaniline					1E-01	RfD							4.0E-03	1		
108-90-7	Chlorobenzene	1.0E-01	3	1.0E-01	3			D			D			2.0E-02	1	2.0E-02	2
124-48-1	Chlorodibromomethane	6.0E-02	3	1.0E-01 *	3			C	8.4E-02	1	C			2.0E-02	1		
67-66-3	Chloroform			1.0E-01 *	3			B2	6.1E-03	1	B2	2.3E-05	1	1.0E-02	1		
95-57-8	2-Chlorophenol					2E-01	RfD							5.0E-03	1		

* Proposed MCL = 0.08 mg/L, *Drinking Water Regulations and Health Advisories*, U.S. EPA (1995).

** Cadmium RfD is based on dietary exposure.

Attachment D (continued)

CAS Number	Chemical Name	Maximum Contaminant Level Goal (mg/L)		Maximum Contaminant Level (mg/L)		Water Health Based Limits (mg/L)		Cancer Slope Factor $(mg/kg\text{-}d)^{-1}$			Unit Risk Factor $(\mu g/m^3)^{-1}$			Reference Dose (mg/kg-d)		Reference Concentration (mg/m^3)	
		MCLG (PMCLG)	Ref. [a]	MCL (PMCL)	Ref. [a]	HBL [b]	Basis	Carc. Class [c]	SF.	Ref. [a]	Carc. Class [c]	URF	Ref. [a]	RfD	Ref. [a]	RfC	Ref. [a]
7440-47-3	Chromium	1.0E-01	3	1.0E-01	3			A			A	1.2E-02	1	5.0E-03	1		
16065-83-1	Chromium (III)					4E+01	RfD							1.0E+00	1		
18540-29-9	Chromium (VI)			1.0E-01	3 *			A			A	1.2E-02	1	5.0E-03	1		
218-01-9	Chrysene					1E-02	SF.	B2	7.3E-03	4							
57-12-5	Cyanide (amenable)	(2.0E-01)	3	(2.0E-01)	3			D			D			2.0E-02	1		
72-54-8	DDD					4E-04	SF.	B2	2.4E-01	1	B2						
72-55-9	DDE					3E-04	SF.	B2	3.4E-01	1	B2						
50-29-3	DDT					3E-04	SF.	B2	3.4E-01	1	B2	9.7E-05	1	5.0E-04	1		
53-70-3	Dibenz(*a,h*)anthracene					1E-05	SF.	B2	7.3E+00	4	B2						
84-74-2	Di-*n*-butyl phthalate					4E+00	RfD	D			D			1.0E-01	1		
95-50-1	1,2-Dichlorobenzene	6.0E-01	3	6.0E-01	3			D			D			9.0E-02	1	2.0E-01	2
106-46-7	1,4-Dichlorobenzene	7.5E-02	3	7.5E-02	3			B2	2.4E-02	2	B2					8.0E-01	1
91-94-1	3,3-Dichlorobenzidine					2E-04	SF.	B2	4.5E-01	1	B2						
75-34-3	1,1-Dichloroethane					4E+00	RfD	C			C			1.0E-01	7	5.0E-01	2
107-06-2	1,2-Dichloroethane			5.0E-03	3			B2	9.1E-02	1	B2	2.6E-05	1				
75-35-4	1,1-Dichloroethylene	7.0E-03	3	7.0E-03	3			C	6.0E-01	1	C	5.0E-05	1	9.0E-03	1		
156-59-2	*cis*-1,2-Dichloroethylene	7.0E-02	3	7.0E-02	3			D			D			1.0E-02	2		
156-60-5	*trans*-1,2-Dichloroethylene	1.0E-01	3	1.0E-01	3									2.0E-02	1		
120-83-2	2,4-Dichlorophenol					1E-01	RfD							3.0E-03	1		
78-87-5	1,2-Dichloropropane			5.0E-03	3			B2	6.8E-02	2	B2					4.0E-03	1
542-75-6	1,3-Dichloropropene					5E-04	SF.	B2	1.8E-01	2	B2	3.7E-05	2	3.0E-04	1	2.0E-02	1
60-57-1	Dieldrin					5E-06	SF.	B2	1.6E+01	1	B2	4.6E-03	1	5.0E-05	1		
84-66-2	Diethylphthalate					3E+01	RfD	D			D			8.0E-01	1		
105-67-9	2,4-Dimethylphenol					7E-01	RfD							2.0E-02	1		
51-28-5	2,4-Dinitrophenol					4E-02	RfD							2.0E-03	1		
121-14-2	2,4-Dinitrotoluene**					1E-04	SF.	B2	6.8E-01	1				2.0E-03	1		
606-20-2	2,6-Dinitrotoluene**					1E-04	SF.	B2	6.8E-01	1				1.0E-03	2		
117-84-0	Di-*n*-octyl phthalate					7E-01	RfD							2.0E-02	2		
115-29-7	Endosulfan					2E-01	RfD							6.0E-03	2		
72-20-8	Endrin	2.0E-03	3	2.0E-03	3			D			D			3.0E-04	1		

* MCL for total chromium is based on Cr (VI) toxicity.

** Cancer Slope Factor is for 2,4-, 2,6-Dinitrotoluene mixture.

Attachment D (continued)

CAS Number	Chemical Name	Maximum Contaminant Level Goal (mg/L)		Maximum Contaminant Level (mg/L)		Water Health Based Limits (mg/L)		Cancer Slope Factor (mg/kg-d)$^{-1}$			Unit Risk Factor ($\mu g/m^3$)$^{-1}$			Reference Dose (mg/kg-d)		Reference Concentration (mg/m^3)	
		MCLG (PMCLG)	Ref. [a]	MCL (PMCL)	Ref. [a]	HBL [b]	Basis	Carc. Class [c]	SF_o	Ref. [a]	Carc. Class [c]	URF	Ref. [a]	RfD	Ref. [a]	RfC	Ref. [a]
100-41-4	Ethylbenzene	7.0E-01	3	7.0E-01	3			D			D			1.0E-01	1	1.0E+00	1
206-44-0	Fluoranthene					1E+00	RfD	D			D			4.0E-02	1		
86-73-7	Fluorene					1E+00	RfD	D						4.0E-02	1		
76-44-8	Heptachlor			4.0E-04	3			B2	4.5E+00	1	B2	1.3E-03	1	5.0E-04	1		
1024-57-3	Heptachlor epoxide			2.0E-04	3			B2	9.1E+00	1	B2	2.6E-03	1	1.3E-05	1		
118-74-1	Hexachlorobenzene			1.0E-03	3			B2	1.6E+00	1	B2	4.6E-04	1	8.0E-04	1		
87-68-3	Hexachloro-1,3-butadiene	1.0E-03	3			1E-03	SF_o	C	7.8E-02	1	C	2.2E-05	1	2.0E-04	2		
319-84-6	α-HCH (α-BHC)					1E-05	SF_o	B2	6.3E+00	1	B2	1.8E-03	1				
319-85-7	β-HCH (β-BHC)					5E-05	SF_o	C	1.8E+00	1	C	5.3E-04	1				
58-89-9	γ-HCH (Lindane)	2.0E-04	3	2.0E-04	3			B2	1.3E+00	2	C			3.0E-04	1		
77-47-4	Hexachlorocyclopentadiene	5.0E-02	3	5.0E-02	3			D			D			7.0E-03	1	7.0E-05	2
67-72-1	Hexachloroethane					6E-03	SF_o	C	1.4E-02	1	C	4.0E-06	1	1.0E-03	1		
193-39-5	Indeno(1,2,3-*cd*)pyrene					1E-04	SF_o	B2	7.3E-01	4	B2						
78-59-1	Isophorone					9E-02	SF_o	C	9.5E-04	1	C			2.0E-01	1		
7439-97-6	Mercury	2.0E-03	3	2.0E-03	3			D			D			3.0E-04	2	3.0E-04	2
72-43-5	Methoxychlor	4.0E-02	3	4.0E-02	3			D			D			5.0E-03	1		
74-83-9	Methyl bromide					5E-02	RfD	D			D			1.4E-03	1	5.0E-03	1
75-09-2	Methylene chloride			5.0E-03	3			B2	7.5E-03	1	B2	4.7E-07	1	6.0E-02	1	3.0E+00	2
95-48-7	2-Methylphenol (*o*-cresol)					2E+00	RfD	C			C			5.0E-02	1		
91-20-3	Naphthalene					1E+00	RfD	D			D			4.0E-02	6		
7440-02-0	Nickel					1E-01	HA [a]	A			A	2.4E-04	1	2.0E-02	1		
98-95-3	Nitrobenzene					2E-02	RfD	D			D			5.0E-04	1	2.0E-03	2
86-30-6	*N*-Nitrosodiphenylamine					2E-02	SF_o	B2	4.9E-03	1	B2						
621-64-7	*N*-Nitrosodi-*n*-propylamine					1E-05	SF_o	B2	7.0E+00	1	B2						
87-86-5	Pentachlorophenol			1.0E-03	3			B2	1.2E-01	1	B2			3.0E-02	1		
108-95-2	Phenol					2E+01	RfD	D			D			6.0E-01	1		
129-00-0	Pyrene					1E+00	RfD	D			D			3.0E-02	1		
7782-49-2	Selenium	5.0E-02	3	5.0E-02	3			D			D			5.0E-03	1		
7440-22-4	Silver					2E-01	RfD	D			D			5.0E-03	1		
100-42-5	Styrene	1.0E-01	3	1.0E-01	3									2.0E-01	1	1.0E+00	1
79-34-5	1,1,2,2-Tetrachloroethane					4E-04	SF_o	C	2.0E-01	1	C	5.8E-05	1				

[a] Health advisory for nickel (MCL is currently remanded); EPA Office of Science and Technology, 7/10/95.

Attachment D (continued)

CAS Number	Chemical Name	Maximum Contaminant Level Goal (mg/L)		Maximum Contaminant Level (mg/L)		Water Health Based Limits (mg/L)		Cancer Slope Factor $(mg/kg\text{-}d)^{-1}$			Unit Risk Factor $(\mu g/m^3)^{-1}$			Reference Dose (mg/kg-d)		Reference Concentration (mg/m^3)	
		MCLG (PMCLG)	Ref. [a]	MCL (PMCL)	Ref. [a]	HBL [b]	Basis	Carc. Class [c]	SF_o	Ref. [a]	Carc. Class [c]	URF	Ref. [a]	RfD	Ref. [a]	RfC	Ref. [a]
127-18-4	Tetrachloroethylene			5.0E-03	3				5.2E-02	5		5.8E-07	5	1.0E-02	1		
7440-28-0	Thallium	5.0E-04	3	2.0E-03	3												
108-88-3	Toluene	1.0E+00	3	1.0E+00	3			D			D			2.0E-01	1	4.0E-01	1
8001-35-2	Toxaphene			3.0E-03	3			B2	1.1E+00	1	B2	3.2E-04	1				
120-82-1	1,2,4-Trichlorobenzene	7.0E-02	3	7.0E-02	3			D			D			1.0E-02	1	2.0E-01	2
71-55-6	1,1,1-Trichloroethane	2.0E-01	3	2.0E-01	3			D			D					1.0E+00	5
79-00-5	1,1,2-Trichloroethane	3.0E-03	3	5.0E-03	3			C	5.7E-02	1	C	1.6E-05	1	4.0E-03	1		
79-01-6	Trichloroethylene	zero	3	5.0E-03	3				1.1E-02	5		1.7E-06	5				
95-95-4	2,4,5-Trichlorophenol					4E+00	RfD							1.0E-01	1		
88-06-2	2,4,6-Trichlorophenol					8E-03	SF_o	B2	1.1E-02	1	B2	3.1E-06	1				
7440-62-2	Vanadium					3E-01	RfD							7.0E-03	2		
108-05-4	Vinyl acetate					4E+01	RfD							1.0E+00	1	2.0E-01	1
75-01-4	Vinyl chloride (chloroethene)			2.0E-03	3			A	1.9E+00	2	A	8.4E-05	2				
108-38-3	*m* -Xylene	1.0E+01	3 *	1.0E+01	3 *			D			D			2.0E+00	2		
95-47-6	*o* -Xylene	1.0E+01	3 *	1.0E+01	3 *			D			D			2.0E+00	2		
106-42-3	*p* -Xylene	1.0E+01	3 *	1.0E+01	3 *			D			D			2.0E+00	1 **		
7440-66-6	Zinc					1E+01	RfD	D			D			3.0E-01	1		

* MCL for total xylenes [1330-20-7] is 10 mg/L.

** RfD for total xylenes is 2 mg/kg-day.

[a] References:
- 1 = IRIS, U.S. EPA (1995)
- 2 = HEAST, U.S. EPA (1995)
- 3 = U.S. EPA (1995)
- 4 = OHEA, U.S. EPA (1993)
- 5 = Interim toxicity criteria provided by Superfund Health Risk Techincal Support Center, Environmental Criteria Assessment Office (ECAO), Cincinnati, OH (1994)
- 6 = ECAO, U.S. EPA (1994i)
- 7 = ECAO, U.S. EPA (1994h)

[b] Health Based Limits calculated for 30-year exposure duration, 10^{-6} risk or hazard quotient = 1.

[c] Categorization of overall weight of evidence for human carcinogenicity:
- Group A: human carcinogen
- Group B: probable human carcinogen
  - B1: limited evidence from epidemiologic studies
  - B2: "sufficient" evidence from animal studies and "inadequate" evidence or "no data" from epidemiologic studies
- Group C: possible human carcinogen
- Group D: not classifiable as to health carcinogenicity
- Group E: evidence of noncarcinogenicity for humans