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NOTE: There is an updated version of this document dated June 2015. Please see document number EPA 530-R-15-004. This previous version is being retained for historical reference.

Industrial Waste Management Evaluation Model (IWEM) Technical Background Document

Office of Solid Waste and Emergency Response (5305W)
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Office of Solid Waste and Emergency Response (5305W)
U.S. Environmental Protection Agency Washington, DC
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ACRONYMS AND ABBREVIATIONS

1-D	One-dimensional
3-D	Three-dimensional
API	American Petroleum Institute
CDF	Cumulative (Probability) Density Function
cm/sec	centimeters per second
CQA	Construction Quality Assurance
CSF	Cancer Slope Factor
CSFi	Inhalation Cancer Slope Factor
CSFo	Oral Cancer Slope Factor
DAF	Dilution and Attenuation Factor
DOM	Dissolved Organic Matter
EPA	Environmental Protection Agency
EPACMTP	EPA-Composite Model for Leachate Migration with Transformation Products
FeOOH	Goethite
FeOx	Ferric oxide
GUI	Graphical User Interface
HBN	Health-Based Number
HDPE	High-Density Polyethylene
HELP	Hydrologic Evaluation of Landfill Performance
HGDB	Hydrogeologic Database for Ground-Water Modeling
HQ	Hazard Quotient
HWIR	Hazardous Waste Identification Rule
in/yr	inches per year
IWEM	Industrial Waste Management Evaluation Model
k_d	Soil-Water Partition Coefficient
kg/m^3	kilograms per cubic meter
K_{oc}	Organic Carbon Partition Coefficient
L/kg	Liters per kilogram
LAI	Leaf Area Index
LAU	Land Application Unit
LCTV	Leachate Concentration Threshold Value
LDS	Leak Detection System

ACRONYMS AND ABBREVIATIONS (continued)

LF	Landfill
LOA	Leachate organic acids
m ² /yr	meters squared per year
MCL	Maximum Contaminant Level
mg/kg/day	milligram per kilogram per day
mg/L	Milligrams per liter
MINTEQA2	EPA's geochemical equilibrium speciation model for dilute aqueous systems
mm ²	Millimeters squared
Mton	Mega-ton
POM	Particulate Organic Matter
RfC	Reference Concentration
RfD	Reference Dose
RGC	Reference Ground-Water Concentration
SCL	Silty Clay Loam
SCS	Soil Conservation Service
SDWA	Safe Drinking Water Act
SI	Surface Impoundment
SLT	Silt Loam
SNL	Sandy Loam
SPLP	Synthetic Precipitation Leaching Procedure
TC	Toxicity Characteristic
TC Rule	Toxicity Characteristic Rule
TCLP	Toxicity Characteristic Leaching Procedure
TOC	Total Organic Carbon
URF	Unit Risk Factor
WMU	Waste Management Unit
WP	Waste Pile

EXECUTIVE SUMMARY

Objectives

This document provides technical background on the assumptions, methodologies and data used by the U.S. Environmental Protection Agency (EPA) to develop Tier 1 and Tier 2 ground-water impact evaluation tools as part of the Agency's Guide for Industrial Waste Management (hereafter, the Guide). The evaluation tools are combined in the Industrial Waste Management Evaluation Model (IWEM).

The EPA and representatives from 12 state environmental agencies have developed a voluntary Guide to recommend a baseline of protective design and operating practices to manage nonhazardous industrial waste throughout the country. The guidance was designed for facility managers, regulatory agency staff, and the public, and it reflects four underlying objectives:

- # Adopt a multimedia approach to protect human health and the environment;
- # Tailor management practices to risk using the innovative, user-friendly modeling tools provided in the Guide;
- # Affirm state and tribal leadership in ensuring protective industrial waste management, and use the Guide to complement state and tribal programs; and
- # Foster partnerships among facility managers, the public, and regulatory agencies.

The Guide recommends best management practices and key factors to consider to protect ground water, surface water, and ambient air quality in siting, operating, and designing waste management units (WMUs); monitoring WMUs' impact on the environment; determining necessary corrective action; closing WMUs; and providing post-closure care. In particular, the Guide recommends risk-based approaches to design liner systems, determine waste application rates for ground-water protection, and evaluate the need for air controls. The CD-ROM version of the Guide includes user-friendly air and ground-water models to conduct these risk evaluations. The IWEM software described in this Background Document is the ground-water tool that was developed to support the Guide.

The IWEM software helps determine the most appropriate WMU design to minimize or avoid adverse ground-water impacts, by evaluating one or more types of liners, the hydrogeologic conditions of the site, and the toxicity and expected leachate concentrations of the anticipated waste constituents.

For the ground-water pathway, the Guide recommends a tiered approach that is based on modeling the fate and transport of waste constituents through subsurface soils to a ground-water well¹ to produce a liner recommendation (or a recommendation concerning land application) that protects human health and the environment. The successive tiers in the analysis incorporate more site-specific data to tailor protective management practices to the particular circumstances at the modeled site:

- # Tier 1: A screening analysis based upon national distributions of data;
- # Tier 2: A location-adjusted analysis using a limited set of the most sensitive waste- and site-specific data; and
- # Tier 3: A comprehensive and detailed site assessment

The IWEM software is designed to support the Tier 1 and Tier 2 analyses. The IWEM tool compares the expected leachate concentration for each waste constituent entered by the user with leachate concentration threshold values (LCTVs) calculated by a ground-water fate and transport model for three standard liner types. The IWEM software compiles the results for all constituents expected in the leachate and then reports the minimum liner scenario that is protective for all constituents. Table EX-1 shows the WMU types and liner types that are evaluated in IWEM.

Table EX-1 IWEM WMU and Liner Combinations

WMU Type	Liner Type		
	No Liner (in-situ soil)	Single Clay Liner	Composite Liner
Landfill	U	U	U
Surface Impoundment	U	U	U
Waste Pile	U	U	U
Land Application Unit	U	N/A	N/A

N/A = Not Applicable

For land application units (LAUs) only the No Liner scenario is evaluated because liners are not typically used for this type of unit.

¹ In IWEM, the term “well” is used to represent an actual or hypothetical ground-water monitoring well or drinking-water well, located downgradient from a WMU.

Waste Management Units

Four WMUs are represented in the IWEM Tier 1 and Tier 2 tool and have the following key characteristics:

- # Landfill (LF). IWEM considers closed LFs with an earthen cover and either no-liner, a single clay liner, or a composite, clay-geomembrane liner. The release of waste constituents into the soil and ground water underneath the LF is caused by dissolution and leaching of the constituents due to precipitation which percolates through the LF. The type of liner which is present controls, to a large extent, the amount of leachate which is released from the unit. Because the LF is closed, the concentration of the waste constituents will diminish with time due to depletion of LF wastes. The leachate concentration value which is used as an IWEM input is the expected initial leachate concentration, when the waste is “fresh”.
- # Waste Pile (WP). WPs are typically used as temporary storage units for solid wastes. Due to their temporary nature, they typically will not be covered. IWEM does allow liners to be present, similar to LFs. In Tier 1 analyses, IWEM assumes that WPs have a fixed operational life of 40 years, after which the WP is removed. IWEM therefore models WPs as a temporary source.
- # Surface Impoundment (SI). In IWEM, SIs are ground level or below-ground level, flow-through units, which may be unlined, have a single clay liner, or a composite liner. Release of leachate is driven by the ponding of water in the impoundment, which creates a hydraulic head gradient with the ground water underneath the unit.
- # Land Application Unit (LAU). LAUs (or land treatment units) are areas of land which received regular applications of waste that can be either tilled or sprayed directly onto the soil and subsequently mixed with the soil. IWEM models the leaching of wastes after tilling with soil. IWEM does not account for the losses due to volatilization during or after waste application. Only the no-liner scenario is evaluated for LAUs because liners typically are not used for this type of unit.

Tier 1 and Tier 2 Evaluations

Tier 1 and Tier 2 evaluations in IWEM can be summarized as follows:

Tier 1: Using only the expected leachate concentrations of constituents in a waste, generic tables provide WMU design recommendations (liner system or maximum allowable leachate concentration). If the waste contains several constituents, the Tier 1 evaluation will choose the most protective design indicated for any of the constituents. This tier of the analysis uses national data and generally will recommend more stringent controls. The Tier 1 evaluation is designed to be protective for 90% of the potential waste sites across the United States.

Tier 2 : In Tier 2, site-specific data for up to twenty of the most sensitive WMU and hydrogeologic characteristics can be entered to assess whether a particular design will be protective. In addition, some default constituent fate parameters can be modified, including adding biodegradation. This tier is generally more representative because it allows the user to incorporate some site-specific information in the analysis.

In Tier 1, the only required IWEM inputs are the type of WMU to be evaluated, the waste constituents present in the leachate, and the expected leachate concentration value of each constituent.

In Tier 2, there are a small number of required site-specific user-input parameters in addition to the Tier 1 inputs, as well as a number of optional site-specific user-input parameters. The additional required site-specific Tier 2 parameters are:

- # WMU Area
- # WMU Depth (LF and SI)
- # WMU location (to select the appropriate climate parameters)

Optional site-specific Tier 2 inputs are:

- # Distance to the nearest surface water body (SI)
- # Depth of the base of the WMU below ground surface (LF, SI, and WP)
- # Operational Life of the WMU (SI, WP, and LAU)
- # Sludge Thickness (SI)
- # Waste Type (WP)
- # Leakage (infiltration) rate from the WMU
- # Distance to the nearest down-gradient well
- # Unsaturated zone soil type

- # Hydrogeologic Environment, and/or individual values of:
 - # Depth from the base of the WMU to the water table
 - # Saturated thickness of the upper aquifer
 - # Hydraulic conductivity in the saturated zone
 - # Regional hydraulic gradient in the saturated zone
 - # Ground-water pH
- # Constituent fate parameters:
 - # sorption coefficient (K_d)
 - # (bio-)degradation rate
- # Constituent-specific reference ground water concentrations, and corresponding exposure durations.

EPACMTP Ground Water Fate and Transport Model

IWEM uses the EPA's Composite Model for Leachate Migration with Transformation Products (EPACMTP) to model the fate and transport of constituents in the subsurface as they migrate through the subsurface. Figure EX.1 shows a conceptual, cross-sectional view of the aquifer system modeled by EPACMTP.

EPACMTP simulates fate and transport in both the unsaturated zone and the saturated zone (ground water) using the advection-dispersion equation with terms to account for equilibrium sorption and first-order transformation. The source of constituents is a WMU located at the ground surface overlying an unconfined aquifer. The base of the WMU can be below the actual ground surface. Waste constituents leach from the base of the WMU into the underlying soil. They migrate vertically downward until they reach the water table. As the leachate enters the ground water, it will mix with ambient ground water (which is assumed to be free of pollutants) and a ground-water plume will develop which extends in the direction of downgradient ground-water flow. EPACMTP accounts for the spreading of the plume in all three dimensions.

Leachate generation is driven by the infiltration of precipitation that has percolated through the waste unit, from the base of the WMU into the soil. Different liner designs control the rate of infiltration that can occur. EPACMTP models flow in the unsaturated zone, and in the saturated zone as steady-state processes, that is, representing long-term average conditions.

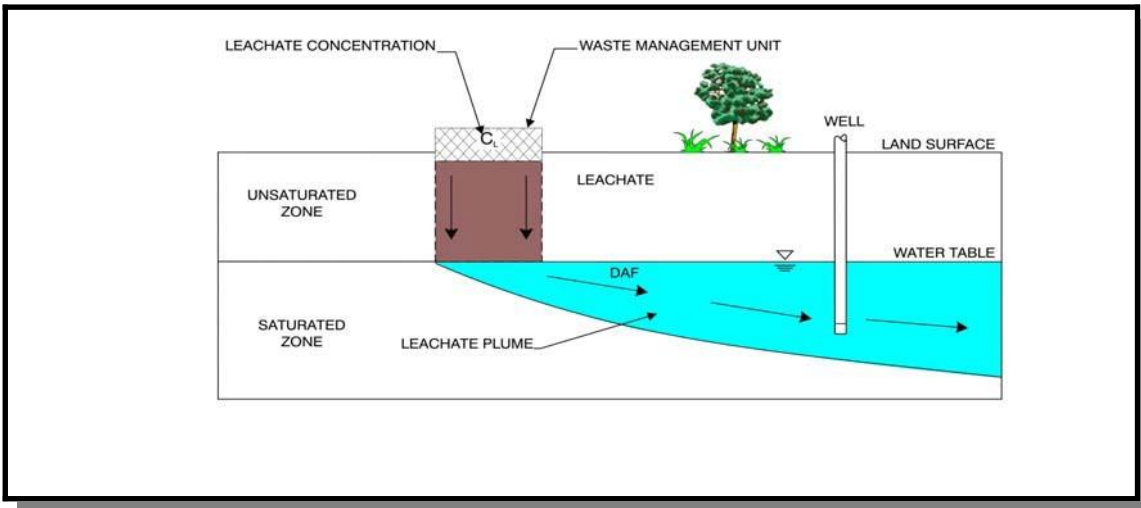


Figure EX.1 Conceptual Cross-Section View of the Subsurface System Simulated by EPACMTP.

In addition to dilution of the constituent concentration caused by the mixing of the leachate with ground water, EPACMTP accounts for attenuation due to sorption of waste constituents in the leachate onto soil and aquifer solids, and for bio-chemical transformation (degradation) processes in the unsaturated and saturated zone. In Tier 1, and by default in Tier 2, EPACMTP only accounts for chemical transformations caused by hydrolysis reactions. In Tier 2 analyses, however, you can use site-specific biodegradation rates. EPACMTP simulates all transformation processes as first-order reactions, that is, as processes that can be characterized with a half-life.

For organic constituents, EPACMTP models sorption between the constituents and the organic matter in the soil or aquifer, based on constituent-specific organic carbon partition coefficients, and a site-specific organic carbon fraction in the soil and aquifer. In the case of metals, EPACMTP accounts for more complex geochemical reactions by using effective sorption isotherms for a range of aquifer geochemical conditions, generated using EPA's geochemical equilibrium speciation model for dilute aqueous systems (MINTEQA2).

The output from EPACMTP is the predicted maximum ground-water exposure concentration, measured at a well situated down-gradient from a WMU. In Tier 1 the well is always located on the plume centerline at a fixed distance of 150 meters from the downgradient edge of the WMU. In Tier 2, the well is also restricted to be on the plume centerline, but the distance (up to one mile) can be entered as a site-specific value.

Monte Carlo Implementation

In developing the Tier 1 and Tier 2 evaluation, EPA uses Monte Carlo simulation to determine the probability distribution of predicted ground-water concentrations, as a function of the variability of modeling input parameters. The Monte Carlo technique is based on the repeated random sampling of input parameters from their respective frequency distribution, executing the EPACMTP fate and transport model for each realization of input parameter values. At the conclusion of the Monte Carlo analysis, it is then possible to construct a probability distribution of ground-water concentration values and associated ground-water dilution and attenuation factors (DAFs). Tier 1 and Tier 2 results are based on Monte Carlo analyses of 10,000 realizations.

For Tier 1, we used a series of databases that describe the expected nationwide variations in climate, soil, and hydrogeological conditions. In order to determine Tier 1 WMU design recommendations, we used the 90th percentile of the predicted nationwide distribution of ground-water concentration values. Tier 1 results are therefore designed to be protective of 90% of waste sites in the United States. The advantage of a Tier 1 evaluation is that it is very rapid and does not require site-specific information. The trade-off is that while the Tier 1 evaluation will provide a protective screening assessment for the majority of waste sites, it is not possible to guarantee that it will be protective at all sites.

A Tier 2 evaluation uses information on waste site location and other site-specific data, to perform a more precise (less uncertain) assessment. If appropriate for site conditions (e.g., an arid climate), it may be possible to avoid unnecessarily costly WMU designs. It may also provide an additional level of certainty that liner designs are protective of sites in vulnerable settings, such as high rainfall and shallow ground water. If site-specific data for ground-water modeling parameters are not available, values are drawn randomly (except for the required parameters that the user must input). The underlying assumption at Tier 2 is that if a site-specific parameter value is not available, the uncertainty in the value of the parameter is captured by the nationwide range in values of that parameter. The resulting location-specific Tier 2 predicted ground-water concentrations therefore represent a 90th percentile protection level for the specified site conditions.

Reference Ground-Water Concentrations

Reference Ground-Water Concentrations (RGCs) are maximum allowable concentrations of constituents in ground water. The IWEM Tier 1 and Tier 2 evaluations incorporate two types of RGCs:

- 1) Maximum Contaminant Levels (MCLs). MCLs are available for some IWEM constituents. MCLs are maximum permissible constituent concentrations allowed in public drinking water and are established under the Safe Drinking Water Act (SDWA). In developing MCLs, EPA considers not only a constituent's health effects, but also additional factors, such as the cost of treatment.
- 2) Health-based numbers (HBNs). EPA developed HBNs for residential exposures via ingestion and inhalation routes of exposure. HBNs are the maximum constituent concentrations in ground water that we expect will not usually cause adverse noncancer health effects in the general population (including sensitive subgroups), or that will not result in an additional incidence of cancer in more than approximately one in one million individuals exposed to the constituent.

HBNs were developed for carcinogenic and non-carcinogenic effects. In the case of inhalation, this exposure route was evaluated for volatile organic constituents and mercury. HBN values were calculated by "rearranging" standard EPA risk equations to calculate constituent concentration, rather than cancer risk or noncancer hazard. The IWEM HBNs correspond to a "target risk" and a "target hazard quotient (HQ)." The target risk for carcinogens is 1×10^{-6} (one in one million). The target HQ for noncarcinogens is 1 (unitless). A HQ of 1 indicates that the estimated dose is equal to the Reference Dose (RfD) and, therefore, a HQ of 1 is frequently EPA's threshold of concern for noncancer effects. These targets were used to calculate separate HBNs for each constituent of concern, and separate HBNs for each exposure route of concern (ingestion or inhalation). The Tier 1 and Tier 2 evaluations do not consider combined exposure from ground-water ingestion (from drinking water) and ground-water inhalation (from showering), nor do they consider the potential for additive exposure to multiple constituents.

Leachate Concentration Threshold Values and Liner Recommendations

The IWEM tool provides recommendations for waste management in terms of LCTVs and type of liner. LCTVs represent the highest concentration in leachate that is protective of human health for a particular WMU and liner scenario. In Tier 1, the liner recommendations are based on comparing expected waste leachate concentrations to tabulated LCTVs. In Tier 2, IWEM uses ground-water modeling to predict expected waste- and site-specific ground-water exposure concentrations for all waste constituents. IWEM then compares the exposure concentrations to RGCs to determine whether or not a liner design is protective. In the Tier 2 analysis, IWEM calculates LCTVs to help users determine whether waste minimization may be appropriate to meet a specific liner design. Because the Tier 2 analysis includes site-specific considerations, LCTVs from this analysis are not applicable to other sites. The basic calculation of LCTVs can be summarized as follows:

$$\text{LCTV} = \text{DAF} \times \text{RGC}$$

where:

LCTV = Leachate Concentration Threshold Value

DAF = Dilution and Attenuation Factor

RGC = Reference Ground-Water Concentration

In this relationship, DAF represents the reduction in constituent concentration between the WMU leachate, and the eventual ground-water exposure concentration at a downgradient ground-water receptor well. The DAF is chemical- and site-specific and is calculated using EPACMTP. DAF values used in IWEM represent 90th percentile levels. In other words, the LCTVs are designed to be protective with a 90% certainty.

The RGC accounts for a constituent's regulatory (MCL) or risk-based (HBN) standard. As expressed in the relationship above, the LCTV is directly proportional to the RGC. Thus, LCTVs for constituents with similar DAFs will differ based on the difference in the regulatory or risk-based standards.

For some constituents, the LCTVs are based not only on toxicity and DAFs, but also on other criteria that are applied to cap the model-calculated values. IWEM caps leachate concentrations from an industrial solid WMU at a level no higher than 1000 mg/l for any single constituent. Concentrations higher than this level may indicate the pressure of free-product conditions which are outside the validity of IWEM.

The 39 hazardous waste toxicity characteristic (TC) constituents are capped at their TC levels because concentrations above those levels are hazardous waste. For the 18 constituents that hydrolyze, LCTVs may be capped by toxic daughter products. The final LCTVs are then calculated such that they accommodate both the parent constituent as well as any toxic daughter products. For instance, if a parent waste constituent rapidly hydrolyzes into a persistent daughter product, the ground-water exposure caused by the parent itself may be minimal (it has already degraded before it reaches the well), but the final LCTV and liner recommendation generated by IWEM would be based on the exposure caused by the daughter product, under the assumption that the parent compound fully transforms into the daughter product. If a IWEM constituent has more than one toxic daughter product, the final LCTV and liner recommendation take all daughter products into account.

The final IWEM liner recommendations are based on the minimum liner design that is protective for all constituents. In applying the IWEM tool, a Tier 1 screening evaluation is typically performed first. If the expected leachate concentrations of all waste constituents are lower than their respective no-liner LCTVs, the proposed WMU does not need a liner to protect ground water. If any constituent concentration is higher than the corresponding no-liner LCTV, than a single or composite liner would be recommended. If any constituent is higher than the corresponding single liner LCTV, than the recommendation is at least a composite liner. Because a Tier 1 evaluation is designed to be protective of sites across the United States, if the analysis indicates that no liner is recommended, it is generally not necessary to proceed to a Tier 2 evaluation. On the other hand, if the Tier 1 analysis indicates a liner is recommended, a user may wish to confirm this recommendation by proceeding to a Tier 2 (or Tier 3) analysis for at least those constituents whose expected leachate concentrations indicate that a liner is recommended.

1.0 Introduction

This document provides technical background information on the Industrial Waste Management Evaluation Model (IWEM). A companion document, the IWEM User's Guide provides detailed information on how to install and use the IWEM software that is distributed as part of U.S. Environmental Protection Agency's (EPA's) Industrial Waste Management Guide.

1.1 Guide For Industrial Waste Management And IWEM

The EPA and representatives from 12 state environmental agencies have developed a voluntary Guide for Industrial Waste Management (hereafter, the Guide) to recommend a baseline of protective design and operating practices to manage nonhazardous industrial waste throughout the country. The guidance was designed for facility managers, regulatory agency staff, and the public, and it reflects four underlying objectives:

- # Adopt a multimedia approach to protect human health and the environment;
- # Tailor management practices to risk using the innovative, user-friendly modeling tools provided in the Guide;
- # Affirm state and tribal leadership in ensuring protective industrial waste management, and use the Guide to complement state and tribal programs; and
- # Foster partnerships among facility managers, the public, and regulatory agencies.

The Guide recommends best management practices and key factors to consider to protect ground-water, surface water, and ambient air quality in siting, operating, and designing waste management units (WMUs); monitoring WMUs' impact on the environment; determining necessary corrective action; closing WMUs; and providing postclosure care. In particular, the guidance recommends risk-based approaches to design liner systems and determine waste application rates for ground-water protection, and evaluate the need for air controls. The CD-ROM version of the Guide includes user-friendly air and ground-water models to conduct these risk evaluations. The IWEM model described in this document, is the ground-water tool that was developed to support the Guide.

The IWEM software helps determine the most appropriate WMU design to minimize or avoid adverse ground-water impacts by evaluating one or more types of liners, the hydrogeologic conditions of the site, and the toxicity and expected leachate concentrations of the anticipated waste constituents. The software can help compare the ground-water protection afforded by various liner systems with the anticipated waste leachate concentrations, so that you can determine the minimum recommended liner system that will be protective of human health and ground-water resources.

The anticipated users of the IWEM software are managers of proposed or existing units, state regulators, interested private citizens, and community groups. For example:

- # Managers of a proposed unit may use the software to determine what type of liner would be appropriate for the particular type of waste that is expected at the WMU and the particular hydrogeologic characteristics of the site.
- # Managers of an existing unit may use the software to determine whether or not to accept a particular waste at that WMU by evaluating the performance of the existing liner design.
- # State regulators may use the software in developing permit conditions for a WMU.
- # Interested members of the public or community groups may use the software to evaluate a particular WMU and participate during the permitting process.

In an effort to meet the needs of the various stakeholders, the guidance for the ground-water pathway recommends a tiered approach that is based on modeling the fate and transport of waste constituents through subsurface soils to a well² to produce a liner recommendation. The successive tiers in the analysis incorporate more site-specific data to tailor protective management practices to the particular circumstances at the site:

- # Tier 1: A screening analysis based upon national distributions of data;
- # Tier 2: A location-adjusted analysis using a limited set of the most sensitive waste- and site-specific data; and
- # Tier 3: A comprehensive and detailed site assessment

² In IWEM, the term “well” is used to represent an actual or hypothetical ground-water monitoring well or drinking water well, located downgradient from a WMU.

The IWEM software is designed to support the Tier 1 and Tier 2 analyses. The unique aspect of the IWEM software is that it allows the user to perform Tier 1 and Tier 2 analyses and obtain liner recommendations with minimal data requirements. Users interested in a Tier 3 analysis are directed to the Guide for information regarding the selection of an appropriate ground-water fate and transport model.

1.2 IWEM Design

1.2.1 What Does the Software Do?

IWEM helps you determine a recommended liner design for different types of Subtitle D WMUs that will minimize the potential for adverse ground-water impacts caused by the leaching of waste constituents. The IWEM tool compares the expected leachate concentration for each waste constituent that is entered by the user with the leachate concentration threshold value (LCTV) or exposure concentration calculated by a ground-water fate and transport model for three standard liner types. The IWEM software compiles the results for all constituents expected in the leachate and then reports the minimum liner scenario that is protective for all constituents. Table 1.1 shows the WMU types and liner types that are evaluated in IWEM.

Table 1.1 IWEM WMU and Liner Combinations

WMU Type	Liner Type		
	No Liner (in-situ soil)	Single Clay Liner	Composite Liner
Landfill	U	U	U
Surface Impoundment	U	U	U
Waste Pile	U	U	U
Land Application Unit	U	N/A	N/A

N/A = Not Applicable

For Land Application Units (LAUs) only the No Liner scenario is evaluated because liners are not typically used at this type of facility.

1.2.2 IWEM Components

The IWEM software consists of three main components (1) A graphical user interface (GUI) which guides you through a series of user-friendly screens to perform Tier 1 and Tier 2 evaluations; (2) the EPACMTP computational engine and integrated Monte Carlo processor that performs the ground-water fate and transport simulations for Tier 2 evaluations; and (3) a series of data bases that contain waste constituent

characteristics and WMU and ground-water modeling parameters. Each of these three components is discussed briefly below.

1. Graphical User Interface (GUI)

The IWEM GUI consists of a series of data input and display screens which allow you to define all aspects of a Tier 1 or Tier 2 evaluation. The user interface provides a tailored front-end to the EPACMTP computational engine and built-in databases for Tier 1 and Tier 2. The user interface module is described in detail in the IWEM User's Guide (U.S. EPA, 2002c).

2. EPACMTP Ground-Water Fate and Transport Simulation Model

EPACMTP is the computational engine of IWEM. EPACMTP simulates the migration of chemical waste constituents in leachate from land disposal units, through soil and ground water. Tier 1 leachate concentration thresholds were generated using EPACMTP. In a Tier 2 evaluation, the fate and transport simulation is performed directly inside the IWEM tool. EPACMTP is described in detail in the EPACMTP Technical Background Document (U.S. EPA, 2002a). This document discusses the application of EPACMTP as part of IWEM.

3. Databases

The third component of IWEM is an integrated set of databases that include Tier 1 lookup tables, as well as waste constituent properties and ground-water modeling parameters for Tier 2 evaluations. The waste constituent database includes 206 organics and 20 metals. Table 1.2 provides a list of the constituents in the database. The constituent databases includes physical and chemical data needed for ground-water transport modeling, as well as reference ground-water concentrations (RGCs), in the form of maximum constituent levels (MCLs) and cancer and non-cancer health-based numbers (HBNs) for ingestion of drinking water, and inhalation of volatiles during showering. Appendix B provides a complete list of all constituent property data.

In addition to constituent data, the IWEM tool includes a comprehensive database of ground-water modeling parameters, including infiltration rates for different WMU types and liner designs for a range of locations and climatic conditions throughout the United States, and soil and hydrogeological data for different soil types and aquifer conditions. Details of the databases are provided in this background document, and in the EPACMTP Parameters/Data Background Document (U.S. EPA, 2002b).

1.3 About This Document

The remainder of this document is organized as follows:

Section 2.0; Overview of the Tier 1 and Tier 2 Approach, presents the purpose of, and the methodology behind the Tier 1 and Tier 2 tools;

Section 3.0; What is the EPACMTP Model, provides an overview of the EPACMTP ground-water simulation model;

Section 4.0; How EPA Developed the Tier 1 and Tier 2 IWEM Tools, describes the application of EPACMTP for the development of the IWEM tools, in particular the input parameters used for Tier 1 and Tier 2;

Section 5.0; Establishing Reference Ground-water Concentrations, describes how we developed health-based reference concentrations (RfCs) based on ingestion and inhalation risks;

Section 6; How Does IWEM Calculate LCTVs and Make Liner Recommendations, describes the calculation of leachate concentration thresholds, including the development of RGCs;

Section 7.0; References, lists literature references;

Appendix A presents a glossary of technical terms used in this document;

Appendix B presents the list of waste constituents included in IWEM and the default values for the constituent-specific inputs (decay coefficient and organic carbon partition coefficient [K_{oc}]);

Appendix C presents tables of EPACMTP input parameters used in developing the Tier 1 LCTVs;

Appendix D presents infiltration rate data for each WMU and liner design combination;

Appendix E presents detailed information on the methodology we used to develop inhalation and ingestion HBNs; and

Appendix F presents the Tier 1 LCTV tables.

Table 1.2 IWEM Constituents

CAS Number	Constituent Name	CAS Number	Constituent Name
Organics			
83-32-9	Acenaphthene	510-15-6	Chlorobenzilate
75-07-0	Acetaldehyde [Ethanal]	124-48-1	Chlorodibromomethane
67-64-1	Acetone (2-propanone)	75-00-3	Chloroethane [Ethyl chloride]
75-05-8	Acetonitrile (methyl cyanide)	67-66-3	Chloroform
98-86-2	Acetophenone	74-87-3	Chloromethane
107-02-8	Acrolein	95-57-8	Chlorophenol 2-
79-06-1	Acrylamide	107-05-1	Chloropropene, 3- (Allyl Chloride)
79-10-7	Acrylic acid [propenoic acid]	218-01-9	Chrysene
107-13-1	Acrylonitrile	108-39-4	Cresol m-
309-00-2	Aldrin	95-48-7	Cresol o-
107-18-6	Allyl alcohol	106-44-5	Cresol p-
62-53-3	Aniline (benzeneamine)	1319-77-3	Cresols
120-12-7	Anthracene	98-82-8	Cumene
56-55-3	Benz{a}anthracene	108-93-0	Cyclohexanol
71-43-2	Benzene	108-94-1	Cyclohexanone
92-87-5	Benzidine	72-54-8	DDD
50-32-8	Benzo{a}pyrene	72-55-9	DDE
205-99-2	Benzo{b}fluoranthene	50-29-3	DDT, p,p'-
100-51-6	Benzyl alcohol	2303-16-4	Diallylate
100-44-7	Benzyl chloride	53-70-3	Dibenz{a,h}anthracene
111-44-4	Bis(2-chloroethyl)ether	96-12-8	Dibromo-3-chloropropane 1,2-
39638-32-9	Bis(2-chloroisopropyl)ether	95-50-1	Dichlorobenzene 1,2-
117-81-7	Bis(2-ethylhexyl)phthalate	106-46-7	Dichlorobenzene 1,4-
75-27-4	Bromodichloromethane	91-94-1	Dichlorobenzidine 3,3'-
74-83-9	Bromomethane	75-71-8	Dichlorodifluoromethane (Freon 12)
106-99-0	Butadiene, 1, 3-	75-34-3	Dichloroethane 1,1-
71-36-3	Butanol	107-06-2	Dichloroethane 1,2-
85-68-7	Butyl benzyl phthalate	156-59-2	Dichloroethylene cis-1,2-
88-85-7	Butyl-4,6-dinitrophenol, 2-sec-(Dinoseb)	156-60-5	Dichloroethylene trans-1,2-
75-15-0	Carbon disulfide	75-35-4	Dichloroethylene 1,1-
56-23-5	Carbon tetrachloride	120-83-2	Dichlorophenol 2,4-
57-74-9	Chlordane	94-75-7	Dichlorophenoxyacetic acid 2,4-(2,4-D)
126-99-8	Chloro-1,3-butadiene 2-(Chloroprene)	78-87-5	Dichloropropane 1,2-
106-47-8	Chloroaniline p-	542-75-6	Dichloropropene 1,3-(mixture of isomers)
108-90-7	Chlorobenzene	10061-01-5	Dichloropropene cis-1,3-
10061-02-6	Dichloropropene trans-1,3-	206-44-0	Fluoranthene
60-57-1	Dieldrin	50-00-0	Formaldehyde

CAS Number	Constituent Name	CAS Number	Constituent Name
84-66-2	Diethyl phthalate	64-18-6	Formic acid
56-53-1	Diethylstilbestrol	98-01-1	Furfural
60-51-5	Dimethoate	319-85-7	HCH beta-
119-90-4	Dimethoxybenzidine 3,3'-	58-89-9	HCH (Lindane) gamma-
68-12-2	Dimethyl formamide N,N- [DMF]	319-84-6	HCH alpha-
57-97-6	Dimethylbenz{a}anthracene 7,12-	76-44-8	Heptachlor
119-93-7	Dimethylbenzidine 3,3'-	1024-57-3	Heptachlor epoxide
105-67-9	Dimethylphenol 2,4-	87-68-3	Hexachloro-1,3-butadiene
84-74-2	Di-n-butyl phthalate	118-74-1	Hexachlorobenzene
99-65-0	Dinitrobenzene 1,3-	77-47-4	Hexachlorocyclopentadiene
51-28-5	Dinitrophenol 2,4-	55684-94-1	Hexachlorodibenzofurans [HxCDFs]
121-14-2	Dinitrotoluene 2,4-	34465-46-8	Hexachlorodibenzo-p-dioxins [HxCDDs]
606-20-2	Dinitrotoluene 2,6-	67-72-1	Hexachloroethane
117-84-0	Di-n-octyl phthalate	70-30-4	Hexachlorophene
123-91-1	Dioxane 1,4-	110-54-3	Hexane n-
122-39-4	Diphenylamine	7783-06-4	Hydrogen Sulfide
122-66-7	Diphenylhydrazine, 1, 2-	193-39-5	Indeno{1,2,3-cd}pyrene
298-04-4	Disulfoton	78-83-1	Isobutyl alcohol
115-29-7	Endosulfan (Endosulfan I and II, mixture)	78-59-1	Isophorone
72-20-8	Endrin	143-50-0	Kepone
106-89-8	Epichlorohydrin	126-98-7	Methacrylonitrile
106-88-7	Epoxybutane, 1, 2-	67-56-1	Methanol
110-80-5	Ethoxyethanol 2-	72-43-5	Methoxychlor
111-15-9	Ethoxyethanol acetate, 2-	109-86-4	Methoxyethanol 2-
141-78-6	Ethyl acetate	110-49-6	Methoxyethanol acetate 2-
60-29-7	Ethyl ether	78-93-3	Methyl ethyl ketone
97-63-2	Ethyl methacrylate	108-10-1	Methyl isobutyl ketone
62-50-0	Ethyl methanesulfonate	80-62-6	Methyl methacrylate
100-41-4	Ethylbenzene	298-00-0	Methyl parathion
106-93-4	Ethylene dibromide (1,2-Dibromoethane)	1634-04-4	Methyl tert-butyl ether [MTBE]
107-21-1	Ethylene glycol	56-49-5	Methylcholanthrene 3-
75-21-8	Ethylene oxide	74-95-3	Methylene bromide (Dibromomethane)
96-45-7	Ethylene thiourea	75-09-2	Methylene Chloride (Dichloromethane)
91-20-3	Naphthalene	1746-01-6	Tetrachlorodibenzo-p-dioxin, 2,3,7,8-
98-95-3	Nitrobenzene	630-20-6	Tetrachloroethane 1,1,1,2-
79-46-9	Nitropropane 2-	79-34-5	Tetrachloroethane 1,1,2,2-
55-18-5	Nitrosodiethylamine N-	127-18-4	Tetrachloroethylene
62-75-9	Nitrosodimethylamine N-	58-90-2	Tetrachlorophenol 2,3,4,6-

Table 1.2 IWEM Constituents (continued)

CAS Number	Constituent Name	CAS Number	Constituent Name
924-16-3	Nitroso-di-n-butylamine N-	3689-24-5	Tetraethyl dithiopyrophosphate (Sulfotep)
621-64-7	Nitroso-di-n-propylamine N-	137-26-8	Thiram [Thiuram]
86-30-6	Nitrosodiphenylamine N-	108-88-3	Toluene
10595-95-6	Nitrosomethylethylamine N-	95-80-7	Toluenediamine 2,4-
100-75-4	Nitrosopiperidine N-	95-53-4	Toluidine o-
930-55-2	Nitrosopyrrolidine N-	106-49-0	Toluidine p-
152-16-9	Octamethyl pyrophosphoramidate	8001-35-2	Toxaphene (chlorinated camphenes)
56-38-2	Parathion (ethyl)	75-25-2	Tribromomethane (Bromoform)
608-93-5	Pentachlorobenzene	76-13-1	Trichloro-1,2,2-trifluoro- ethane 1,1,2-
30402-15-4	Pentachlorodibenzofurans [PeCDFs]	120-82-1	Trichlorobenzene 1,2,4-
36088-22-9	Pentachlorodibenzo-p-dioxins [PeCDDs]	71-55-6	Trichloroethane 1,1,1-
82-68-8	Pentachloronitrobenzene (PCNB)	79-00-5	Trichloroethane 1,1,2-
87-86-5	Pentachlorophenol	79-01-6	Trichloroethylene
108-95-2	Phenol	75-69-4	Trichlorofluoromethane (Freon 11)
62-38-4	Phenyl mercuric acetate	95-95-4	Trichlorophenol 2,4,5-
108-45-2	Phenylenediamine 1,3-	88-06-2	Trichlorophenol 2,4,6-
298-02-2	Phorate	93-72-1	Trichlorophenoxy)propionic acid 2-
85-44-9	Phthalic anhydride	93-76-5	Trichlorophenoxyacetic acid 2,4,5-
1336-36-3	Polychlorinated biphenyls (Aroclors)	96-18-4	Trichloropropane 1,2,3-
23950-58-5	Pronamide	121-44-8	Triethylamine
75-56-9	Propylene oxide [1,2-Epoxypropane]	99-35-4	Trinitrobenzene
129-00-0	Pyrene	126-72-7	Tris(2,3-dibromopropyl)phosphate
110-86-1	Pyridine	108-05-4	Vinyl acetate
94-59-7	Safrole	75-01-4	Vinyl chloride
57-24-9	Strychnine and salts	108-38-3	Xylene m-
100-42-5	Styrene	95-47-6	Xylene o-
95-94-3	Tetrachlorobenzene 1,2,4,5-	106-42-3	Xylene p-
51207-31-9	Tetrachlorodibenzofuran, 2,3,7,8-	1330-20-7	Xylenes (total)

CAS Number	Constituent Name	CAS Number	Constituent Name
Metals			
7440-36-0	Antimony	7439-92-1	Lead
7440-38-2	Arsenic	7439-96-5	Manganese
7440-39-3	Barium	7439-97-6	Mercury
7440-41-7	Beryllium	7439-98-7	Molybdenum
7440-43-9	Cadmium	7440-02-0	Nickel
16065-83-1	Chromium (III)	7782-49-2	Selenium
18540-29-9	Chromium (VI)	7440-22-4	Silver
7440-48-4	Cobalt	7440-28-0	Thallium
7440-50-8	Copper	7440-62-2	Vanadium
16984-48-8	Fluoride	7440-66-6	Zinc

2.0 Overview of the Tier 1 And Tier 2 Approach

This section provides an overview of the methodology we used to develop the Tier 1 and Tier 2 tools. Section 2.1 discusses the purpose of the tools in terms of waste management scenarios addressed by IWEM. Section 2.2 presents the approach and parameters used for a Tier 1 and Tier 2 evaluation.

2.1 Purpose of The Tier 1 And Tier 2 Tools

IWEM analyzes the potential ground-water impacts of four types of WMU; LF, SI, waste pile (WP), and LAUs; and three liner scenarios: no liner, single clay liner, and composite liner. The purpose of both the Tier 1 and the Tier 2 evaluation is to determine the minimum recommended liner design that is protective of ground water for the waste of concern.

The primary method of controlling the release of waste constituents to the subsurface is to install a low permeability liner at the base of a WMU. A liner generally consists of a layer of clay or other material with a low hydraulic conductivity that is used to prevent or mitigate the flow of liquids from a WMU. However, the type of liner that is appropriate for a specific WMU is highly dependent upon a number of location-specific parameters, such as climate and hydrogeology. In addition, the amount of liquid that migrates into the subsurface from a WMU has been shown to be a highly sensitive parameter in predicting the release of constituents to ground-water. Therefore, one of the main objectives of the tiered modeling approach is to evaluate the appropriateness of a proposed liner design in the context of other location-specific parameters such as precipitation, evaporation, and the hydrogeologic characteristics of the soil and aquifer beneath a facility.

EPA chose to evaluate three types of liner designs, the no-liner, single-liner, and composite-liner designs. The no-liner design (Figure 2.1a) represents a WMU that is relying upon location-specific conditions such as low permeability native soils beneath the unit or low annual precipitation rates to mitigate the release of constituents to ground-water. The single-liner design represents a 3 foot thick clay liner with a low hydraulic conductivity (1×10^{-7} centimeters per second [cm/sec]) beneath a WMU (Figure 2.1b). A composite liner in IWEM consists of a 60 mil (1.5 millimeter) high-density polyethylene (HDPE) layer underlain by either a geosynthetic clay liner with a maximum hydraulic conductivity of 5×10^{-9} cm/sec or a three-foot compacted clay liner with a maximum hydraulic conductivity of 1×10^{-7} cm/sec. (Figure 2.1c).

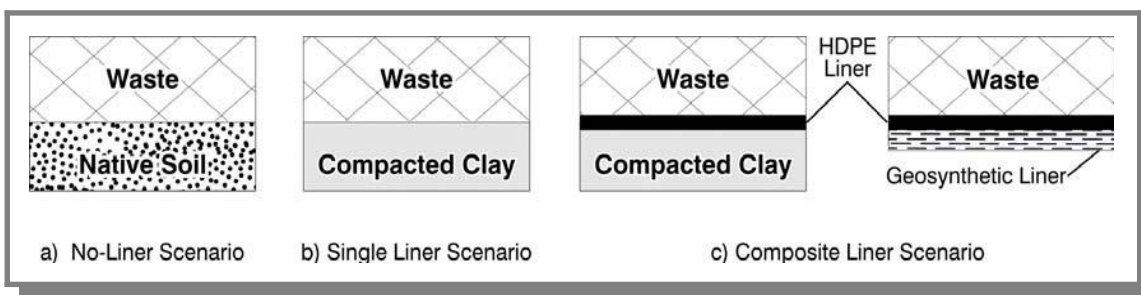


Figure 2.1 Three Liner Scenarios Considered in IWEM.

For a given waste management scenario and waste leachate concentration, IWEM uses ground-water modeling to predict the exposure concentration at a well located downgradient from the WMU, and then compares the predicted exposure concentration to established regulatory or health-based RGCs. The recommended liner design is the minimum liner for which the predicted ground-water concentration of all constituents is less than their RGC. For land application, the model evaluates whether wastes can be protectively land applied, based on leachate constituent concentrations. The Tier 1 and Tier 2 evaluations can be summarized as follows:

Tier 1: Using only expected leachate concentrations of constituents in a waste, generic tables provide design recommendations (liner system or maximum allowable leachate concentrations). If the waste contains several constituents, choose the most protective design indicated for any of the constituents. This tier of analysis uses national data and is designed to be protective for 90% of the possible combinations of waste sites and environmental settings across the United States; Tier 1 results will therefore be protective for the majority of sites.

Tier 2: You can enter site-specific data for up to twenty of the most sensitive WMU and hydrogeologic characteristics to assess whether an alternative design will be protective. In addition, you can modify the default constituent fate parameters, including adding biodegradation. This tier is generally more representative than Tier 1 because it allows the user to incorporate site-specific information in the analysis.

2.2 Approach Used to Develop Tier 1 And Tier 2 Tools

There are several important concepts that are critical to the understanding of how IWEM functions. These concepts include 90th percentile exposure concentration, dilution and attenuations factors (DAFs), reference ground-water concentrations (RGCs), and leachate concentration threshold values (LCTVs). This section presents how we used these concepts in developing IWEM, and the similarities and differences between Tier 1 and Tier 2.

2.2.1 Tier 1

We developed Tier 1 of IWEM around the concept of Leachate Concentration Threshold Values (LCTVs). An LCTV is the maximum leachate concentration that is protective of ground-water. That is, the LCTV will result in a ground-water exposure concentration that does not exceed RGCs. The basic calculation that is performed to develop LCTVs can be summarized as follows:

$$LCTV = DAF \times RGC$$

where:

LCTV =	Leachate Concentration Threshold Value
DAF =	Dilution and Attenuation Factor
RGC =	Reference Ground-water Concentration (e.g., MCL or HBN)

In this relationship, DAF represents the reduction in constituent concentration between the point of release at the base of the WMU, and the eventual ground-water exposure concentration at a downgradient well. IWEM uses the EPACMTP ground-water fate and transport model to calculate expected ground-water well concentrations from which the DAFs are determined. EPACMTP and its application under IWEM are discussed in detail in Sections 3 and 4 of this document. The DAF is chemical- and site-specific and is defined as the ratio of the constituent concentration in the waste leachate to the concentration at the monitoring well, or:

$$DAF = \frac{C_L}{C_{RW}}$$

where:

C_L	= is the leachate concentration (milligrams per liter [mg/L])
C_{RW}	= is the well concentration (mg/L).

The ground-water exposure is evaluated at a well located downgradient from the WMU. The distance between the WMU and the well can vary, but IWEM assumes the well is always located on the centerline of the ground-water plume.

The magnitude of a DAF reflects the combined effect of all dilution and attenuation processes that occur in the unsaturated and saturated zone. The lowest possible value of DAF is one; a DAF value of one means that there is no dilution or attenuation at all; the concentration at the well is the same as that in the waste leachate. High values of DAF on the other hand correspond to a high degree of dilution and attenuation and mean that the expected concentration at the well will be much lower than the concentration in the leachate.

IWEM uses EPACMTP in a probabilistic (Monte Carlo) mode to generate a probability distribution of well concentrations that reflects the variability in the various modeling parameters, for instance the variation of rainfall rate across the United States. IWEM uses the 90th percentile exposure concentration to represent the estimated constituent concentration at a well for a given leachate concentration to determine the DAF that is used in the calculation of LCTVs. The 90th percentile exposure concentration is determined by running EPACMTP in a Monte Carlo mode for 10,000 realizations. For each realization, EPACMTP calculates a maximum time-averaged concentration at a well, depending on the exposure duration of the reference ground-water concentration (RGC) of interest. For example, IWEM assumes a 30-year exposure duration for carcinogens, and therefore, the maximum time-averaged concentration is the highest 30-year average across the modeling horizon. After calculating the maximum time-averaged concentrations across the 10,000 realizations, the concentrations are arrayed from lowest to highest and the 90th percentile of this distribution is selected as the constituent exposure concentration for IWEM. In Tier 1, the EPACMTP modeling used data on WMUs collected throughout the United States. LCTVs used in Tier 1 are therefore designed to be protective with a 90% certainty considering the range of variability associated with waste sites across the United States.

We performed EPACMTP Monte Carlo simulations to determine constituent-specific DAF values for each combination of WMU type and liner listed in Table 1.1. We then multiplied these DAFs with constituent-specific RGCs to obtain the Tier 1 LCTVs. The RGCs included Maximum Contaminant Levels (MCLs) as established under the Safe Drinking Water Act (SDWA) and HBNs, calculated from constituent-specific toxicity data, using standard exposure assumptions for residential receptors (see Section 5.2 of this document). IWEM incorporates HBNs for exposures due to drinking water ingestion and inhalation of volatiles while showering. Constituent-specific HBNs in IWEM correspond to a cancer risk of 10^{-6} , and non-cancer hazard quotient (HQ) of 1, respectively. The relationship shown at the beginning of this section expresses how the LCTV is directly proportional to the RGC and that the LCTV will be lower for constituents with lower MCLs or HBNs even if they have the same fate and transport characteristics (same DAF).

After calculating the Tier 1 LCTVs as outlined above, we applied a series of caps that:

- # Restrict LCTVs to not exceed 1,000 mg/L,
- # Restrict LCTVs to not exceed Toxicity Characteristic (TC) Rule leachate levels (for the 39 constituents identified in the TC Rule), and
- # Account for transformation of leachate constituents into toxic hydrolysis daughter products.

Section 6 discusses these caps in more detail. The final result is a set of nationwide leachate screening values. The final Tier 1 LCTVs are listed in Appendix F of this document. They are also incorporated as a series of lookup tables in the IWEM software.

To perform a Tier 1 evaluation only the following information is needed:

- # WMU type;
- # Constituents present in the leachate; and
- # Expected leachate concentration of each constituent.

The IWEM software will compare expected leachate concentrations with LCTVs for each constituent, and determine a minimum recommended liner design that is protective for all waste constituents.

2.2.2 Tier 2

A Tier 2 evaluation is also based on a 90th percentile ground-water protection level, but takes into account site-specific factors. If appropriate for site conditions (for example, an arid climate), it may be possible to avoid unnecessarily costly WMU designs. It may also provide an additional level of certainty that liner designs are protective of sites in vulnerable settings, such as high rainfall and shallow ground-water. In Tier 2, EPACMTP uses site-specific information to determine the expected 90th percentile exposure concentration for each waste constituent and liner scenario. IWEM then directly compares these exposure concentrations to RGCs to determine whether a particular liner scenario is protective or not. If the ground-water exposure concentration of each constituent is less than its RGC, then the liner scenario being evaluated is protective. If the exposure concentration of any waste constituent exceeds its RGC, then the liner scenario is not protective. In the Tier 2 analysis, IWEM also calculates LCTVs. These are provided to help users determine whether waste minimization may be appropriate to meet a specific liner design. For example, a facility may find it more cost effective to reduce the concentration of constituents in waste and design a clay-lined LF than to dispose of the current waste in a LF with a composite liner. The LCTVs

calculated for the Tier 2 analysis is based on the expected exposure concentration for a specific site, and LCTVs from this analysis are not applicable to other sites. The trade-off in performing a Tier 2 evaluation is that although a more site-specific result is generated, the fate and transport simulations which are performed inside the IWEM software are computationally very demanding and can take hours to complete, even on high-speed desk top computers.

For Tier 2, the same inputs as Tier 1 are required. In addition, there are several more required site-specific parameters, as well as other optional parameters. The required additional site-specific parameters that a user must input for Tier 2 are:

- # Geographic location of the WMU;
- # Footprint area of the WMU, and
- # Depth of the WMU (LF or SI)

If sufficient site-specific data is available, the user may also provide the following optional Tier 2 site-specific characteristics:

- # Distance to the nearest surface waterbody (SI)
- # Depth of the base of the WMU below ground surface (LF, SI, and WP)
- # Operational life of the WMU (SI, WP and LAU)
- # Sludge thickness (SI)
- # Waste type (WP)
- # Leakage (infiltration) rate from the WMU
- # Distance to the nearest down-gradient well
- # Unsaturated zone soil type
- # Subsurface environment type, and/or individual of values of:
 - # Depth from ground surface to the water table
 - # Saturated thickness of the upper aquifer
 - # Hydraulic conductivity in the saturated zone
 - # Regional hydraulic gradient
 - # Ground water pH
- # Constituent fate parameters:
 - # Sorption coefficient (k_d)
 - # (Bio-) degradation rate
- # Constituent-specific RGC values and corresponding exposure durations

As in Tier 1, liner recommendations and LCTVs are based not only on toxicity and DAFs, but also incorporate other criteria to cap the model-calculated values. IWEM caps leachate concentrations from an industrial solid WMU at a level no higher than 1000 mg/L for any single constituent. The 39 constituents covered by the TC Rule are capped at their TC levels because concentrations above those levels mean that the waste is classified as hazardous waste. The final liner recommendations and LCTVs

accommodate both the parent constituent as well as any toxic daughter products. For instance, if a parent waste constituent rapidly hydrolyzes into a persistent daughter product, the ground-water exposure caused by the parent itself may be minimal (for example, it has already degraded before it reaches the ground-water well), but the final liner recommendation and LCTV generated by IWEM would be based on the exposure caused by the daughter product.

3.0 What Is The EPACMTP Model?

EPACMTP is a subsurface fate and transport model used by EPA to evaluate migration of waste constituents through the ground-water pathway from land disposal units to wells and establish protective levels in waste.

Figure 3.1 depicts a cross-sectional view of the subsurface system simulated by EPACMTP. EPACMTP treats the subsurface aquifer system as a composite domain, consisting of an unsaturated (vadose) zone and an underlying saturated zone. The two zones are separated by the water table. EPACMTP simulates one-dimensional (1-D), vertically downward flow and transport of constituents in the unsaturated zone beneath a waste disposal unit as well as ground-water flow and three-dimensional (3-D) constituent transport in the underlying saturated zone. The unsaturated zone and saturated zone modules are computationally linked through continuity of flow and constituent concentration across the water table directly underneath the WMU. The model accounts for the following processes affecting constituent fate and transport: advection, hydrodynamic dispersion and molecular diffusion; linear or nonlinear equilibrium sorption; first-order decay and zero-order production reactions (to account for transformation breakdown products); and dilution from recharge in the saturated zone.

EPACMTP consists of four major components:

- A source module that simulates the rate and concentration of leachate exiting from beneath a WMU and entering the unsaturated zone;
- An unsaturated zone module which simulates 1-D vertical flow of water and dissolved constituent transport in the unsaturated zone;
- A saturated zone model which simulates ground-water flow and dissolved constituent transport in the saturated zone; and
- A Monte Carlo module for randomly selecting input values to account for the effect of variations in model parameters on predicted ground-water well concentrations, and determining the probability distribution of predicted ground-water concentrations.

The primary input to the model is the rate of constituent release (leaching) from a WMU along with WMU design and site hydrogeological characteristics. The output from EPACMTP is a prediction of the constituent concentration arriving at a downgradient well. This can be either a steady-state concentration value, corresponding to a continuous source scenario, or a time-dependent concentration, corresponding to a finite source scenario. In the latter case, the model can calculate the peak concentration arriving at the well or a time-averaged concentration corresponding to a specified exposure duration (for example a 30-year average exposure time).

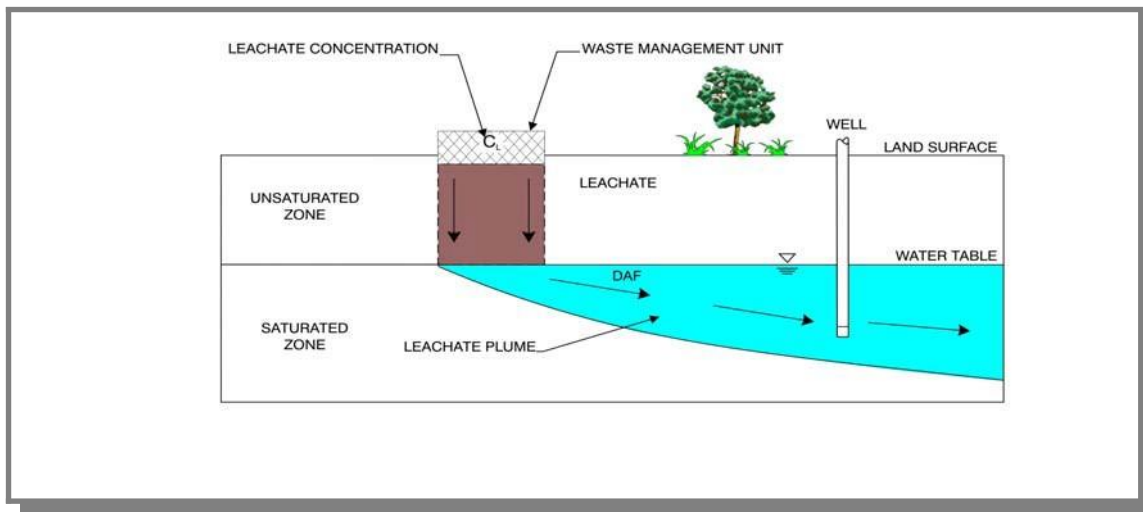


Figure 3.1 Conceptual Cross-Section View of the Subsurface System Simulated by EPACMTP.

The relationship between the constituent concentration leaching from a LF WMU and the resulting ground-water exposure at a well located down-gradient from the WMU is depicted in Figure 3.2. Figure 3.2a shows how the leachate concentration emanating from the LF unit gradually diminishes over time as a result of depletion of the waste mass remaining in the unit. As seen in Figure 3.2b, the constituent does not arrive at the well until some time after the leaching begins, but eventually the ground-water concentration will reach a peak value, and then begin to diminish because the leaching from the waste unit occurs only over a finite period of time. This curve is also called the breakthrough curve. The maximum constituent concentration at the well will generally be lower than the original leachate concentration as a result of various dilution and attenuation processes which occur during the transport through the unsaturated and saturated zones. EPACMTP has the capability to calculate the maximum average ground-water concentration over a specified time period, as depicted by the horizontal dashed line in Figure 3.2b.

The following sections describe the four main components, or modules, of EPACMTP and the role of each in simulating constituent fate and transport.

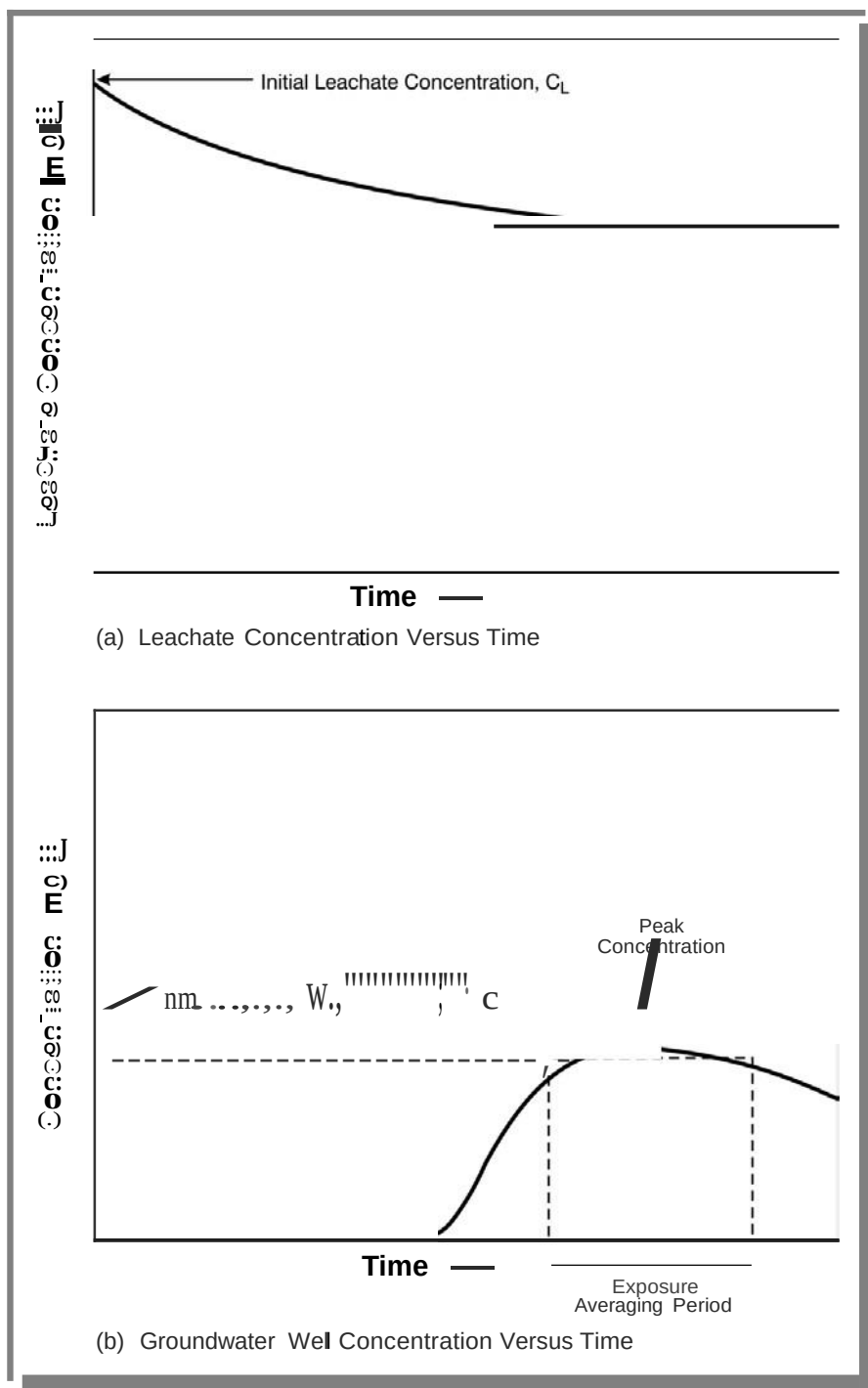


Figure 3.2 Conceptual Relationship Between Leachate Concentration (a) and Ground-Water Exposure Concentration (b).

3.1 WMU Source Module

This section describes how EPACMTP models the release of constituents from a WMU. Section 3.1.1 provides a general overview of the EPACMTP source module; Section 3.1.2 presents a discussion of how EPACMTP handles infiltration from SI units.

3.1.1 How EPACMTP Determines Releases From a Source

The purposes of the WMU source module in EPACMTP is to provide a leachate flux and concentration to the unsaturated zone. The source module is a function of both the design and operational characteristics of the WMU and the waste stream characteristics (quantity and concentrations) and is defined in terms of four primary parameters:

- 1) Area of the waste unit;
- 2) Leachate flux rate emanating from the waste unit (infiltration rate);
- 3) Constituent-specific leachate concentration; and
- 4) Leaching duration.

Based on these parameters, EPACMTP generates a rate of leaching and the constituent concentration in the leachate as a function of time from the bottom of the WMU.

Mathematically, EPACMTP regards the source as a rectangular planar area located between the bottom of the well and the top of the unsaturated zone column, through which leachate passes. The WMU source module determines the magnitude of the rate of water infiltration and constituent concentration crossing this plane. The model does not attempt to account explicitly for the multitude of physical and biochemical processes inside the waste unit that may control the release of waste constituents to the subsurface. Instead, the net result of these processes are used as inputs to the model. For instance, in developing the IWEM Tier 1 and Tier 2 evaluations for LFs, WPs, and LAUs, we used the Hydrologic Evaluation of LF Performance (HELP) model (Schroeder et al, 1994) to determine infiltration rates for unlined and single lined units outside of EPACMTP, and used these infiltration rates as inputs to EPACMTP. Likewise, the model does not explicitly account for the complex physical, biological, and geochemical processes that may influence leachate concentration. These processes are typically estimated outside the EPACMTP model using geochemical modeling software, equilibrium partitioning models, or analytical procedures such as the Toxicity Characteristic Leaching Procedure (TCLP) or Synthetic Precipitation Leaching Procedure (SPLP) test; the resulting leachate concentration is then used as an EPACMTP input.

3.1.2 EPACMTP models leaching processes in two ways: 1) as a depleting source; or 2) as a pulse source. In the depleting source scenario, the WMU is considered permanent and leaching continues until all waste that is originally present has been depleted. In the pulse source scenario, leaching occurs at a constant leachate concentration for a fixed period of time, after which leaching stops³. EPACMTP uses the pulse source scenario to model temporary WMUs; usually the leaching period represents the operational life of the unit. Under this scenario, we assume clean closure conditions and the leaching stops when the unit is closed.

Figure 3.3 graphically presents the leachate concentration under the depleting source scenario and the pulse source scenario. In the depleting source scenario, the leachate concentration gradually decreases over time. The user must provide a value for the initial leachate concentration (for example, a measured value from a leaching test) and EPACMTP will calculate the rate of depletion as a function of the infiltration rate through the unit. The EPACMTP Technical Background Document (U.S. EPA, 2002a) provides a detailed discussion of the depleting source scenario. In the pulse source scenario, the user must provide the value of the leachate concentration (for example, a measured value from a leaching test), and the duration of the leaching period. Based on these values, EPACMTP will calculate the leachate pulse.

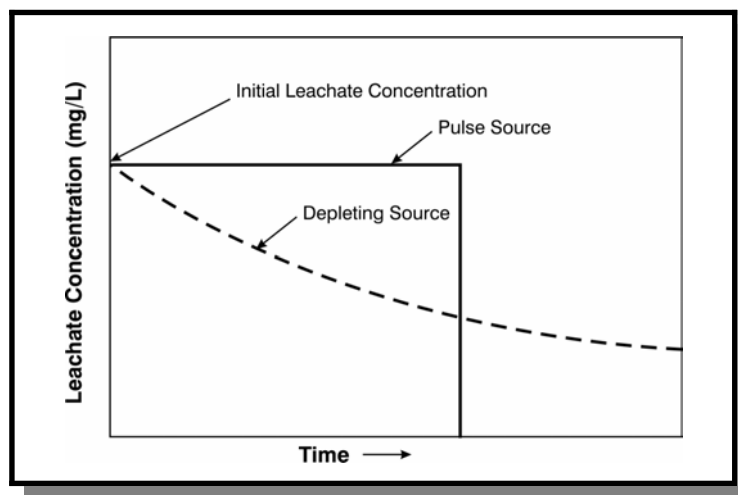


Figure 3.3 Leachate Concentration Versus Time for Pulse Source and Depleting Source Conditions.

³ If the leaching period is set to a very large value, EPACMTP will simulate continuous source conditions.

Because the infiltration rate from SIs is controlled primarily by the unit's engineering and operational characteristics rather than external climate factors, the EPACMTP source module includes the capability to calculate SI infiltration rates as a function of impoundment depth and other SI parameters. In particular, the SI module calculates the infiltration rate through a zone of reduced permeability materials (which may or may not include engineered liners) at the base of the impoundment. The various reduced permeability layers represented in the SI infiltration module are depicted graphically in Figure 3.4.

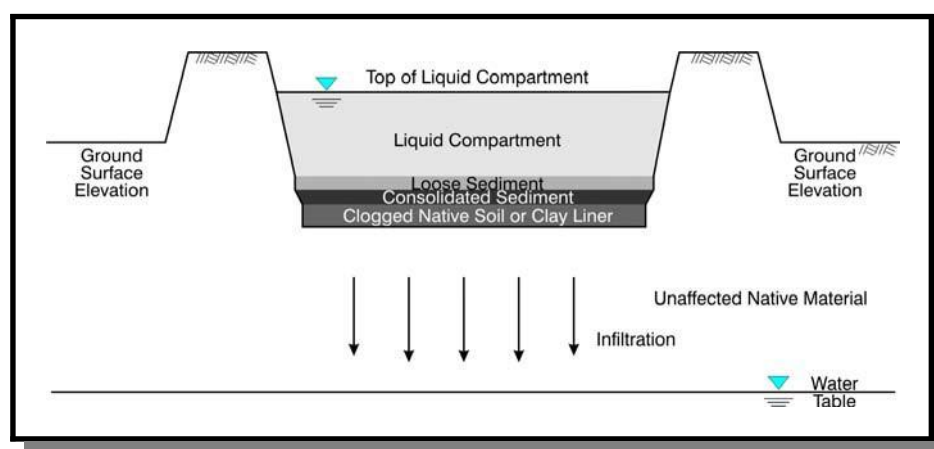


Figure 3.4 Surface Impoundment Infiltration Module.

EPACMTP assumes that while the impoundment is in operation, a layer of fine-grained sediment ('sludge') naturally accumulates at the bottom of the impoundment as the result of the settling of suspended solids in the waste liquid. The upper half of this layer consists of unconsolidated material; the lower half is consolidated (compacted) due to the weight of the sediment above it. EPACMTP calculates the effective hydraulic conductivity of the consolidated sediment layer as a function of its porosity, using an empirical relationship based on work of Lambe and Whitman (1969) which results in a calculated hydraulic conductivity on the order of 1×10^{-7} to 6×10^{-7} cm/s. The module also takes into account the hydraulic properties of a clay liner (if present) as well as the properties of the native soil underlying the impoundment. If no liner is present, EPACMTP assumes that over time, the upper soil layer becomes 'clogged' due to deposition of solids from the impoundment. The thickness of this clogged layer is always assigned a value of 0.5 meters, and the hydraulic conductivity of this clogged layer is assigned a value of 10% of the hydraulic conductivity of the native soil material.

3.1.2 How EPACMTP determines infiltration rate through clogged native material layers is depicted in Figure 3.4. If EPACMTP is used to model a lined SI, the thickness and hydraulic conductivity of the clay liner are model inputs. The EPACMTP SI module calculates the steady state infiltration rate through the multi-layer system of sediment-clogged native soil/clay liner-native soil by applying the 1-D Richards equation (Jury et al., 1991) with a constant head boundary condition, given by the SI ponding depth. EPACMTP uses the Richards equation to accommodate partially saturated conditions which may exist in the multi-layer system. For a detailed description of the solution of the Richards equation for the system, see the EPACMTP Technical Background Document (U.S. EPA, 2002a).

3.2 EPACMTP Unsaturated Zone Module

EPACMTP models water flow and solute transport in the unsaturated zone between the base of the WMU and the water table as a 1-D, vertically downward process. As shown in Figure 3.1, constituents migrate downward from the WMU through the unsaturated zone to the water table. EPACMTP assumes the flow rate is steady-state, that is, it does not change in time. The soil underneath the WMU is assumed to be uniform with hydraulic properties described by the Mualem-Van Genuchten model (Jury et al., 1991). The flow rate is determined by the long-term average infiltration rate through the WMU. Inputs to the unsaturated zone module are the rate of water and constituent leaching from the disposal facility, as well as soil hydraulic properties. EPACMTP solves the governing 1-D steady-state Richards flow equation (Jury et al., 1991) using a semi-numerical technique described in the EPACMTP Technical Background Document (U.S. EPA, 2002a).

Constituent transport in the unsaturated zone is assumed to occur by advection and dispersion⁴. The unsaturated zone is assumed to be initially constituent-free and constituents migrate vertically downward from the WMU. EPACMTP can simulate both steady-state and transient transport in the unsaturated zone with single-species or multiple-species chain decay reactions. The transport module can also simulate the effects of both linear and nonlinear sorption reactions. When decay reactions involve the formation of daughter products, EPACMTP has the capability to perform a multi-species transport simulation of a decay chain consisting of up to seven members. Mathematically the transport process is represented by the advection-dispersion equation:

⁴ In the case of metals which are subject to nonlinear sorption, EPACMTP uses a method-of-characteristics solution method that does not include dispersion. In this case, transport is dominated by the nonlinear sorption behavior and dispersion effects are minor.

$$\frac{\partial}{\partial z} \left(D \frac{\partial c}{\partial z} \right) - V \frac{\partial c}{\partial z} - \theta \lambda c = \theta R \frac{\partial c}{\partial t} + Q \quad (3.1)$$

here

- z = Soil depth coordinate (L),
- t = Time (T),
- c = Constituent concentration (M/L³),
- D = Dispersion coefficient, (L²/T),
- V = Darcy velocity (L/T),
- R = Retardation factor (dimensionless),
- λ = First-order decay constant (1/T),
- θ = Volumetric water content (dimensionless), and
- Q = Zero-order production term to account for transformation of parent constituents (M/(L³T)).

EPACMTP uses units of meters for L(ength), years for T(ime), and kilograms for M(ass). Consistent with common practice, EPACMTP uses units of mg/L for constituent concentration. Numerically, this is the same as kilograms per cubic meter (kg/m³).

The dispersion coefficient in the above transport equation accounts for the effects of hydrodynamic dispersion and molecular diffusion and is defined as:

$$D = \alpha V + D_m \quad (3.2)$$

where

- D = Dispersion coefficient (meter squared per year [m²/yr])
- α = Dispersivity (m)
- D_m = Molecular diffusion coefficient (m²/yr)
- V = Darcy velocity (m/yr)

The effective molecular diffusion coefficient is calculated using the Millington-Quirk relationship (Jury et al., 1991) as:

$$D_m = D_w 2^{10/3} / 2^2 \quad (3.3)$$

where

$$\begin{aligned} D_m &= \text{Effective molecular diffusion coefficient (m}^2\text{/yr)} \\ D_w &= \text{Free-water diffusion coefficient (m}^2\text{/yr)} \\ 2 &= \text{Volumetric water content (dimensionless)} \end{aligned}$$

The retardation factor R in the transport equation accounts for the effects of equilibrium sorption of dissolved constituents onto the solid phase as:

$$R = 1 + (D_b k_d) / 2 \quad (3.4)$$

where

$$\begin{aligned} R &= \text{Retardation factor (dimensionless)} \\ D_b &= \text{Bulk density (kg/L)} \\ k_d &= \text{Constituent-specific soil-water partition coefficient (L/kg)} \\ 2 &= \text{Volumetric water content (dimensionless)} \end{aligned}$$

EPACMTP's unsaturated zone module includes options for both linear and nonlinear sorption isotherms. In the first case, the partition coefficient, k_d is independent of the constituent concentration. In the second case, the value of the partition coefficient is a function of concentration. For linear sorption isotherms the partition coefficient can be entered as a single EPACMTP parameter, or the model can calculate its value from the fraction organic carbon in the soil and a constituent-specific organic carbon partition coefficient as:

$$k_d = f_{oc} \times K_{oc} \quad (3.5)$$

where:

$$\begin{aligned} k_d &= \text{Partition coefficient (L}^3\text{/kg)} \\ f_{oc} &= \text{Fraction organic carbon in the soil (dimensionless)} \\ K_{oc} &= \text{Constituent-specific organic carbon partition coefficient (L/kg)} \end{aligned}$$

When modeling constituents with non-linear sorption isotherms, the partition coefficient data are read in by EPACMTP as a table of paired concentration- k_d values. In principle, the user can employ a variety of methods for generating the concentration- k_d values including using measured data. In practice, EPACMTP applications typically use data generated using the MINTEQA2 geochemical speciation model (see Section 4.2.4.3.2).

The parameter 8 in the transport equation accounts for first-order transformation processes. Finally, the term Q in the equation is a source term that represents the production of a constituent species due to the transformation of parent constituents. This term is zero for parent constituents that are at the beginning of a decay chain, but non-zero for any transformation daughter products.

The output from the unsaturated zone transport solution is a time history (breakthrough curve) of the constituent concentration arriving at the water table, which provides the input for the saturated zone transport simulation.

3.3 Saturated Zone Module

The saturated zone module of EPACMTP is designed to simulate flow and transport in an unconfined aquifer with constant saturated thickness (see Figure 3.1). The model simulates regional flow in a horizontal direction with recharge and infiltration from the overlying unsaturated zone and WMU entering at the water table. The lower boundary of the aquifer is assumed to be impermeable.

EPACMTP assumes that flow in the saturated zone is steady-state. In other words, EPACMTP models long-term average flow conditions. EPACMTP accounts for different recharge rates beneath and outside the WMU area. Ground-water mounding beneath the source is represented in the flow system by increased head values at the top of the aquifer. It is important to realize that while EPACMTP calculates the degree of ground-water mounding that may occur underneath a WMU due to high infiltration rates, and will restrict the allowable infiltration rate to prevent physically unrealistic input parameter combinations (see Section 4.2.6), the actual saturated flow and transport modules in EPACMTP are based on the assumption of a constant saturated thickness, i.e. fixed water table position, and the only direct effect of ground-water mounding is to increase simulated ground-water velocities.

EPACMTP incorporates a number of different mathematical solutions for saturated zone flow and transport. The EPACMTP Technical Background Document (U.S. EPA, 2002a) discusses these in detail. Because of the high premium on computational efficiency in the IWEM Tier 2 Monte Carlo tool, we used a pseudo-3-D modeling approach in IWEM. The pseudo-3-D module simulates ground-water flow using a 1-D steady-state solution for predicting hydraulic head and Darcy velocities. The flow solution is formulated based on the Dupuit-Forchheimer's assumption of hydrostatic pressure distribution (de Marsily, 1986). The hydraulic head is also horizontally averaged in the cross-gradient direction.

EPACMTP models transport of dissolved constituents in the saturated zone using the advection-dispersion equation. The aquifer is assumed to be initially constituent-free,

and constituents enter the saturated zone only from the unsaturated zone directly beneath the WMU. In the pseudo-3-D option of EPACMTP used for IWEM, it is assumed that advection is predominantly along the longitudinal direction (direction along the ambient ground-water gradient), while dispersion occurs in three dimensions.

The pseudo-3-D transport option is based on the concept that when ground-water flow is dominantly in one direction, the movement of a dissolved constituent plume can be approximated as the product of three terms: The first term describes the movement by advection and dispersion along the direction of ground-water flow (the x-direction); the second and third terms account for the effect of dispersion in the horizontal transverse (y-) direction, and the vertical (z-) direction, respectively. The effects of constituent sorption and transformation are incorporated into the first term of the mathematical solution. The second (y-direction) and third (z-direction) terms in the solution can be regarded as adjustment factors that account for the reduction in concentration along the x-direction, due to dispersion into the y- and z-directions. The y- and z- solution terms are given by straight-forward error-functions that can be computed very quickly. From a computational point, the pseudo-3-D solution option therefore requires about the same effort as a 1-D solution.

The governing equation for transport in the saturated zone can be written as:

$$\frac{\partial}{\partial x_i} \left(D_{ij} \frac{\partial}{\partial x_j} \right) - V_x \frac{\partial c}{\partial x} - \phi \lambda c = \phi R \frac{\partial c}{\partial t} + Q \quad (3.6)$$

where

- i,j = Indices to represent different spatial directions; i,j = 1, 2, or 3
- x_i = Spatial coordinate (L)
- t = Time (T)
- c = Constituent concentration (M/L³)
- D_{ij} = Dispersion coefficient (L²/T),
- V_x = Ground-water flow rate in the x-direction (L/T)
- λ = First-order transformation coefficient (1/T)
- R = Retardation coefficient (dimensionless)
- N = Porosity (dimensionless)
- Q = Zero-order production term to account for transformation of parent constituents (M/L³/T)

EPACMTP uses units of meters for L(ength), years for T(ime), and kilograms for M(ass). Consistent with common practice, EPACMTP uses units mg/L for constituent concentration, which numerically is the same as kg/m³.

The transport processes modeled in the saturated zone module of EPACMTP are analogous to those in the unsaturated zone, but they are extended to three dimensions, instead of just one. The spatial coordinate, x_i , in equation 3.6 represents the three dimensions. The coordinate x_1 (or just x), represents the horizontal coordinate along the direction of ground-water flow. The coordinate x_2 (or y) represents the horizontal coordinate perpendicular to the flow direction; and the coordinate x_3 (or z) represents the vertical direction. The dispersion coefficient D_{ij} (where i and j can be 1, 2, or 3) is subscripted to indicate that this coefficient has components in all three directions. Conversely, the ground-water flow term, V_x , has only a single subscript to indicate the assumption in the pseudo-3-D option of EPACMTP, that ground-water flow is a 1-D process. The other terms in equation 3.6 are defined in the same way as in equation 3.1, except that the porosity, N , replaces the volumetric water content, θ . By definition, under fully saturated conditions, the water content of a porous medium is equal to its porosity, therefore using N instead of θ in equation 3.6 is just another way of stating that the system is water-saturated.

In many aquifers, only a portion of the total pore space is active in the transport process, so that the effective porosity (N_e) is less than the total porosity (N). EPACMTP uses the effective porosity in the calculation of ground-water seepage velocity, i.e.:

$$v_x = \frac{V_x}{\phi_e} \quad (3.7)$$

where

- v_x = Average pore water (seepage) velocity (m/y)
- V_x = Ground-water flow rate (Darcy velocity; m/y)
- N_e = Effective porosity (dimensionless)

The total porosity, N , is used in calculating the retardation coefficient, R :

$$R = 1 + \frac{\rho_b k_d}{\phi} \quad (3.8)$$

where

R	=	Retardation coefficient (dimensionless)
D _b	=	Saturated zone bulk density (kg/L)
k _d	=	Constituent-specific partition coefficient (L/kg)
N	=	Porosity (dimensionless)

In order to determine the value of N_e , EPACMTP uses a statistical distribution of the ratio N_e/N , which is presented in Section 4.2.3.3.

The dispersion coefficient (D_{ij}) in equation 3.6 accounts for hydrodynamic dispersion and molecular diffusion, and uses separate longitudinal, horizontal transverse and vertical dispersivities as described by Burnett and Frind (1987). The effect of molecular diffusion is incorporated using the Millington-Quirk equation, as described in the preceding section. Likewise, the retardation and transformation terms are modeled in the same way in the saturated zone module of EPACMTP as they are in the unsaturated zone module.

A key distinction between the way the saturated zone module handles constituent fate and transport, as compared to the unsaturated zone module, is the approach for constituents with nonlinear sorption isotherms. The saturated zone module only simulates linearized isotherms. For constituents with nonlinear sorption isotherms, the unsaturated zone module simulates partitioning by using concentration-dependent partitioning coefficient; the saturated zone module uses a linearized isotherm, based upon the maximum constituent concentration at the water table (see EPACMTP Technical Background Document; U.S. EPA, 2002a). The reason is that upon dilution of the leachate in the ambient ground-water as the leachate enters the saturated zone, concentrations will be reduced to a range in which constituent isotherms generally are linear.

3.4 Conducting Probabilistic Analyses Using EPACMTP

The final component of EPACMTP is a Monte Carlo module which allows the model to perform probabilistic analyses of constituent fate and transport. Monte Carlo simulation is a statistical technique by which a quantity is calculated repeatedly, using randomly selected parameter values for each calculation. The results approximate the full range of possible outcomes, and the likelihood of each. The Monte Carlo module in EPACMTP makes it possible to incorporate variability into the subsurface pathway modeling analysis, and to quantify the impact of parameter variability on well concentrations. In particular, we use Monte Carlo simulation to determine the likelihood, or probability, that the concentration of a constituent at a well, and hence exposure and risk, will be either above or below a certain value.

In a Monte Carlo simulation the values of the various source-specific, chemical-specific, unsaturated zone-specific and saturated zone-specific model parameters are represented as probability distributions, reflecting both the range of variation that may be encountered at different waste sites, as well as our uncertainty about the specific conditions at each site. Strictly speaking Monte Carlo analysis can accommodate only parameter variability, not uncertainty. Variability describes parameters whose values are not constant, but which we can measure and characterize with relative precision in terms of a frequency distribution. An example is annual rainfall in different parts of the country. Uncertainty pertains to parameters whose values we know only approximately, such as the hydraulic conductivity of an aquifer. In practice, we use probability distributions to describe both variability and uncertainty, and for the purpose of the EPACMTP Monte Carlo module, we treat them as more or less equivalent.

The Monte Carlo module in EPACMTP is described in detail in the EPACMTP Technical Background Document (U.S. EPA, 2002a), and the EPACMTP Parameters/ Data Background Document (U.S. EPA, 2002b). A general overview of the methodology is presented in the following paragraphs. The specific methodology we used to determine LCTVs for IWEM is presented in Section 6 of this document.

Figure 3.5 presents a graphical illustration of the Monte Carlo simulation process. The Monte Carlo method requires that for each input parameter, except constant parameters, a probability distribution be provided (Figure 3.5a). The method involves

EPACMTP Monte Carlo Bootstrap Analysis

In a Monte Carlo analysis the output percentile values depend on the number of realizations. For instance, if we perform a Monte Carlo analysis consisting of 10 realizations of randomly selected model input values, the 90th percentile of the model output can be determined by ordering the output values from low to high and then picking the 9th highest value. This 90th percentile value is likely to be different if we perform another Monte Carlo simulation of 10 realizations with randomly selected inputs, and different still if we simulate 1,000 realizations to calculate the 90th percentile output value.

Bootstrap analysis is a technique of replicated resampling of a large data set for estimating standard errors, biases, confidence intervals, or other measures of statistical accuracy. It can produce accuracy estimates in almost any situation without requiring subjective statistical assumptions about the original distribution. As part of the background for EPA's proposed 1995 Hazardous Waste Identification Rule (HWIR) we conducted a bootstrap analysis for the EPACMTP model to evaluate how Monte Carlo convergence improves with increasing numbers of realizations. The analysis was based on a continuous source, LF disposal scenario in which the 90th percentile DAF was 10. The bootstrap analysis results suggested that, with 10,000 realizations, the expected value of the 90th percentile DAF was 10 with a 95 percent confidence interval of 10 ± 0.7 . Decreasing the number of realizations to 5,000 increased the confidence interval to 10 ± 1.0 .

the repeated generation of random values of the input variables (drawn from the known distribution and within the range of any imposed bounds). The EPACMTP model (Figure 3.5b) is executed for each set of randomly generated model parameters and the corresponding ground-water well exposure concentration is calculated and stored. Each set of input values and corresponding well concentration is termed a realization. In using a Monte Carlo modeling approach, a higher number of realizations usually leads to a more stable and more accurate result. However, it is generally not possible to determine beforehand how many realizations are needed to achieve a specified degree of convergence (that is, stability) because the value can be highly dependent on parameter distributions. EPA has used an empirical technique called bootstrap analysis to determine the appropriate number of realizations for EPACMTP Monte Carlo analyses (see side bar box).

At the conclusion of the Monte Carlo simulation, the realizations are statistically analyzed to yield a cumulative (probability) density function (CDF) of the ground-water exposure concentration (Figure 3.5c). The construction of the CDF simply involves sorting the ground-water well concentrations calculated in each of the individual Monte Carlo realizations from low to high. In the example used to construct Figure 3.5, we assumed an EPACMTP input leachate concentration value of 10 mg/L and performed a Monte Carlo simulation of 10,000 realizations. The well concentration values simulated in the EPACMTP Monte Carlo process range from very low values to values that approach the leachate concentration. By examining how many of the 10,000 Monte Carlo realizations resulted in a high value of the predicted ground-water concentration, it is possible to assign a probability to these high-end events, or conversely determine what is the expected ground-water concentration corresponding to a specific probability of occurrence.

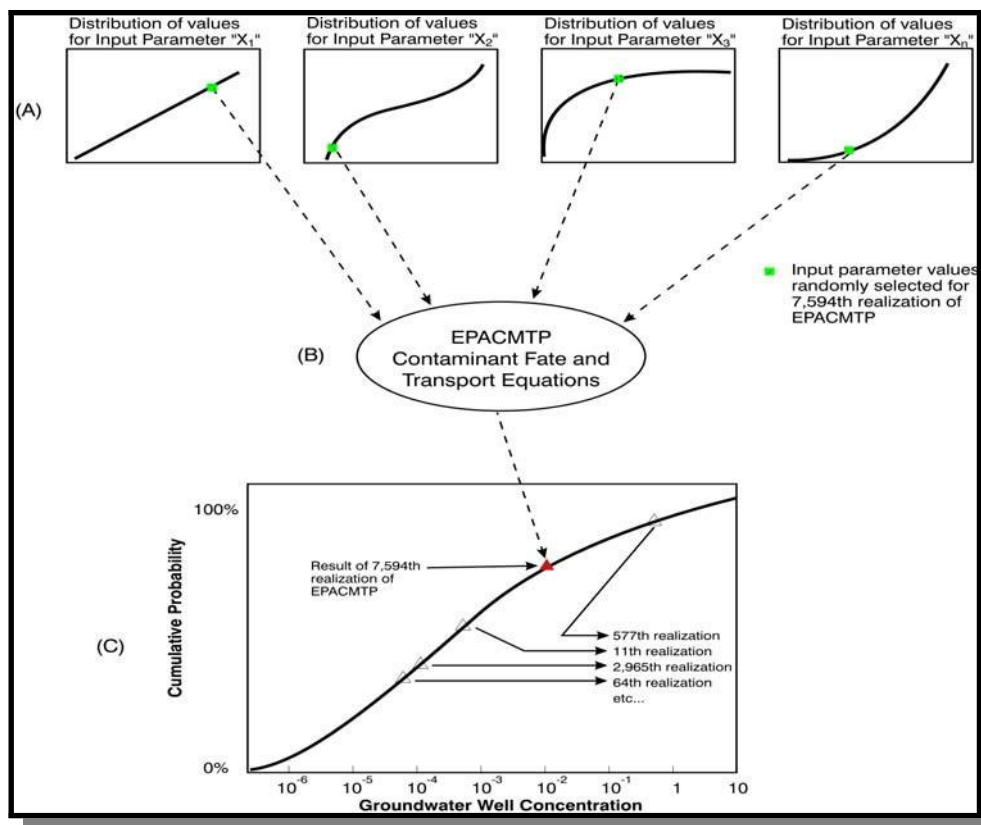


Figure 3.5 Graphical Representation of the EPACMTP Monte Carlo Process.

3.5 EPACMTP Assumptions and Limitations

EPA designed the EPACMTP fate and transport model to be used for regulatory assessments in a probabilistic framework. The simulation algorithms that are incorporated into the model are intended to meet the following requirements:

- # Account for the primary physical and chemical processes that affect constituent fate and transport in the unsaturated and saturated zone;
- # Be able to be used with relatively little site input data; and
- # Be computationally efficient for Monte Carlo analyses.

This section discusses the primary assumptions and limitations of EPACMTP that EPA made in developing the model to balance these competing requirements. EPACMTP

may not be suitable for all sites, and the user should understand the capabilities and limitations of the model to ensure it is used appropriately.

Source Module

The EPACMTP source module provides a relatively simple representation of different types of WMU's. WMU's are represented in terms of a source area, and a defined rate and duration of leaching. EPACMTP only accounts for the release of leachate through the base of the WMU, and assumes that the only mechanism of constituent release is through dissolution of waste constituents in the water that percolates through the WMU. In the case of SIs, EPACMTP assumes that the leachate concentration is the same as the constituent concentration in the waste water in the SI. EPACMTP does not account for the presence of non-aqueous free-phase liquids, such as an oily phase that might provide an additional release mechanism into the subsurface. EPACMTP does not account for releases from the WMU via other environmental pathways, such as volatilization or surface run-off. EPACMTP assumes that the rate of infiltration through the WMU is constant, representing long-term average conditions. EPACMTP does not account for fluctuations in rainfall rate, or degradation of liner systems that may cause the rate of infiltration and release of leachate to vary over time.

Unsaturated Zone and Saturated Zone Modules

Uniform Soil and Aquifer Assumption

EPACMTP simulates the unsaturated zone and saturated zone as separate domains that are connected at the water table. Both the unsaturated zone and saturated zone are assumed to be uniform porous media. EPACMTP does not explicitly account for the presence of macro-pores, fractures, solution features, faults or other heterogeneities in the soil or aquifer that may provide pathways for rapid movement of constituents. A certain amount of heterogeneity always exists at actual sites and it is not uncommon in ground-water modeling to use average parameter values. This means that parameters such as hydraulic conductivity and dispersivity represent effective site-wide average values. However, EPACMTP may not be appropriate for sites overlying fractured or very heterogeneous aquifers.

Steady-State Flow Assumption

Flow in the unsaturated zone and saturated zone is assumed to be driven by long-term average infiltration and recharge; EPACMTP treats flow in the unsaturated zone as steady state and does not account for fluctuations in the infiltration or recharge rate, either in time or areally. The use of EPACMTP may not be appropriate at sites with large seasonal fluctuations in rainfall conditions, or at sites where the recharge rate varies locally. Examples of the latter include the presence of surface water bodies such as rivers and lakes or ponds and man-made recharge sources near the WMU.

EPACMTP models ground-water flow based on the assumption that the contribution of recharge and infiltration from the unsaturated zone are small relative to the regional ground-water flow, and that the saturated aquifer thickness is large relative to the head difference that establishes the regional gradient. The implication is that the saturated zone can be modeled as having a uniform thickness, with mounding underneath the WMU represented by an increased head distribution along the water table. The mathematical ground-water flow solutions incorporated in EPACMTP are based on confined aquifer conditions. While EPACMTP accounts for ground-water mounding underneath a WMU, the saturated zone module of EPACMTP only accounts for the effect of mounding on ground-water flow velocities; it does not simulate the actual physical increase in the thickness of the saturated zone. The assumption of constant and uniform saturated zone thickness means that EPACMTP may not be suitable at sites with a non-uniform thickness of the water-bearing zone, or sites with significant seasonal variations in water table elevation. EPACMTP is designed for relatively simple ground-water flow systems in which flow is dominated by a regional gradient. EPACMTP does not account for the presence of ground-water sources or sinks such as pumping or injection wells. The presence of such man-made or natural features may cause a more complicated flow field than EPACMTP can handle. EPACMTP does not account for free-phase flow conditions of an oily or non-aqueous phase liquid.

Constituent Fate and Transport Assumptions

The unsaturated zone and saturated zone modules of EPACMTP account for constituent fate and transport by advection, hydrodynamic dispersion, molecular diffusion, sorption and first-order transformation. Advection refers to transport along with ground-water flow. Hydrodynamic dispersion and molecular diffusion both act as mixing processes. Hydrodynamic dispersion is caused by local variations in ground-water flow rate and is usually a significant plume-spreading mechanism. Molecular diffusion, on the other hand, is usually a very minor mechanism, except when ground-water flow rates are very low. EPACMTP does not account for matrix-diffusion processes, which may occur when the aquifer formation is comprised of zones with large contrast in permeability. In these situations, transport occurs primarily in the more

permeable zones, but constituents can move into and out of the low permeability zones by diffusion.

Leachate constituents can be subject to complex geochemical interactions in soil and ground water. EPACMTP treats these interactions as equilibrium sorption processes. The equilibrium assumption means that the sorption process occurs instantaneously, or at least very quickly relative to the time-scale of constituent transport. Although sorption, or the attachment of leachate constituents to solid soil or aquifer particles, may result from multiple chemical processes, EPACMTP lumps these processes together into an effective soil-water partition coefficient.

For organic constituents, EPACMTP assumes that the partition coefficient is constant, and equal to the product of the mass fraction of organic carbon in the soil or aquifer, and a constituent-specific organic carbon partition coefficient. In the case of metals, EPACMTP allows the partition coefficient to vary as a function of a number of primary geochemical parameters, including pH, leachate organic matter, soil organic matter, and the fraction of iron-oxide in the soil or aquifer.

For metals, EPACMTP uses a set of effective sorption isotherms which were developed by EPA by running the MINTEQA2 geochemical speciation model for each metal and each combination of geochemical parameters. In modeling metals transport in the unsaturated zone, EPACMTP uses the complete, nonlinear sorption isotherms. In modeling metals transport in the saturated zone, EPACMTP uses linearized MINTEQA2 isotherms, based on the assumption that after dilution of the leachate plume in ground-water, concentration values of metals will typically be in a range where the isotherm is approximately linear. This assumption may not be valid when metals concentrations in the leachate are high. Although EPACMTP is able to account for the effect of the geochemical environment at a site on the mobility of metals, the model assumes that the geochemical environment at a site is constant and not affected by the presence of the leachate plume. In reality, the presence of a leachate plume may alter the ambient geochemical environment.

EPACMTP does not account for colloidal transport or other forms of facilitated transport. For metals and other constituents that tend to strongly sorb to soil particles, and which EPACMTP will simulate as relatively immobile, movement as colloidal particles can be a significant transport mechanism. It is possible to approximate the effect of these transport processes by using a lower value of the partition coefficient as a user-input. In the IWEM application of EPACMTP, the model uses the same partition coefficient for the unsaturated and saturated zone if this parameter is provided as a user-input in Tier 2 evaluations.

EPACMTP accounts for biological and chemical transformation processes as first-order degradation reactions. That is, it assumes that the transformation process can be described in terms of a constituent-specific half-life. EPACMTP allows the degradation rate to have different values in the unsaturated zone and the saturated zone, but the model assumes that the value is uniform throughout the unsaturated zone and uniform throughout the saturated zone for each constituent. EPA's ground-water modeling database includes constituent-specific hydrolysis rate coefficients for constituents that are subject to hydrolysis transformation reactions; for these constituents, EPACMTP simulates transformation reactions subject to site-specific values of pH and soil and ground-water temperature, but other types of transformation processes are not explicitly simulated in EPACMTP.

For many organic constituents, biodegradation can be an important fate mechanism, but EPACMTP has only limited ability to account for this process. The user must provide an appropriate value for the effective first-order degradation rate. In the IWEM application of EPACMTP, the model uses the same degradation rate coefficient for the unsaturated and saturated zone if this parameter is provided as a user-input in Tier 2 evaluations. In an actual leachate plume, biodegradation rates may be different in different regions in the plume; for instance in portions of the plume that are anaerobic some constituents may biodegrade more readily, while other constituents will biodegrade only in the aerobic fringe of the plume. EPACMTP does not account for these or other processes that may cause a constituent's rate of transformation to vary in space and time.

Monte Carlo Module

The Monte Carlo module of EPACMTP allows you to take into account the effect of parameter variability on predicted ground-water concentrations. The resulting probability distribution of outcomes is valid only to the extent that EPACMTP can accurately simulate actual constituent fate and transport processes; it does not account for the uncertainty that results from processes that are not included in EPACMTP, or are modeled in EPACMTP in a simplified manner. For instance, the Monte Carlo modeling process can account for the site-to-site variability in the average hydraulic conductivity in the aquifer, but it does not account for the uncertainty that results from treating each site as uniform and ignoring aquifer heterogeneity.

4.0 How EPA Developed the Tier 1 and Tier 2 IWEM Evaluations

This chapter describes how EPA developed the Tier 1 and Tier 2 IWEM evaluations using EPACMTP. Section 4.1 provides an overview of the selected EPACMTP modeling options and parameters to develop the Tier 1 and Tier 2 analyses. Section 4.2 provides a detailed discussion of the input data for Tier 1 and Tier 2.

4.1 Overview

To develop the Tier 1 and Tier 2 evaluations, we linked the EPACMTP model described in the previous chapter to a series of databases that describe WMU characteristics, hydrogeological characteristics, and constituent fate and transport data. We used EPACMTP in a Monte Carlo mode to obtain a probability distribution of model outcomes, that is, predicted concentration levels at a ground-water well located downgradient from a WMU.

In Tier 1, the Monte Carlo process reflects the nationwide variations in WMU and site conditions that might affect the impact of leachate on ground water. In Tier 2, the user is required to input a few site-specific parameters; the user may also set several more parameters to site-specific values if these data are available. If site-specific data are not available, and for the additional parameters which cannot be modified by the user, values are drawn randomly from national or regional distributions. The underlying assumption in Tier 2 is that if a site-specific parameter value is not available, the uncertainty in the value of the parameter is captured by the nationwide range in values of that parameter. The Tier 2 evaluation also has the capability to reduce the uncertainty in some of the modeling parameters by using supporting site characterization data even if the actual value of a parameter is not known. For instance, if the actual value of hydraulic conductivity in the saturated zone is unknown, but information is available about the type of subsurface environment at the site (for example, alluvial versus sedimentary rock), the Tier 2 evaluation will use this information to reduce the uncertainty in the hydraulic conductivity by selecting only hydraulic conductivity values in the Monte Carlo process that are representative of alluvial aquifers. This methodology is discussed in detail in Section 4.2.3.1.

In using a Monte Carlo modeling approach, a higher number of realizations usually leads to a more stable and more accurate result. The desire to use the most accurate result possible, however is balanced by the computational demands of running Monte Carlo simulations with a large number of realizations. Based on the results of a bootstrap analysis (see Section 3.4), we determined that performing 10,000 Monte Carlo realizations would achieve the goals for the Tier 1 and Tier 2 analysis. The Tier 1 LCTV

tables which are presented in Appendix F and incorporated into the IWEM software, are based on 10,000 Monte Carlo realizations. Likewise, in a Tier 2 analysis, the IWEM software evaluation will execute 10,000 realizations of EPACMTP. We used the 90th percentile of the CDF of predicted ground-water concentrations to determine LCTVs for the Tier 1 analyses and to compare directly with RGCs in Tier 2 analyses.

For each realization, EPACMTP computes a maximum average constituent exposure concentration at a well (see Section 3.0). We used the same averaging period as the exposure period upon which the corresponding RGC is based. For instance, MCLs are compared against the peak ground-water well concentration; HBNs based on carcinogenic effects are compared against the maximum 30-year well concentration, and non-cancer HBNs are compared against the maximum 7-year well concentration. For the Tier 1 and Tier 2 analyses, EPACMTP used a 10,000 year maximum time horizon to calculate ground-water well concentrations. This means that EPACMTP determined the maximum ground-water concentration occurring within a period of 10,000 years after leaching begins. This does not mean that we ran all EPACMTP simulations out to 10,000 years; in most cases the leachate plume reaches the ground-water well much sooner. However in certain cases (e.g., low infiltration rate, deep unsaturated zone, strongly sorbing constituents) it is possible that EPACMTP would predict it takes more than 10,000 years to reach the well. In these cases the concentration value returned by the model is the concentration at 10,000 years (or more exact, the average concentration up to the 10,000 year time horizon for the RGC of concern, for example, the average concentration between years 9,970 - 10,000 in the case of carcinogenic HBNs).

To enable the IWEM Tier 2 evaluation to perform the Monte Carlo analyses on common desktop computer systems, we implemented EPACMTP using a computationally efficient pseudo-3-D approximation for modeling saturated zone plume transport (see Section 3.3 of the document). The resulting computer time requirements for a Tier 2 evaluation, involving all three liner designs (no-liner, single liner, and composite liner) is approximately 3 hours per waste constituent.⁴

4.1.1 EPACMTP Modeling Options and Parameters

In Tier 1, the only required IWEM inputs are the type of WMU to be evaluated, the waste constituents present in the leachate, and the leachate concentration value for each constituent. In Tier 2, there are a small number of additional required site-specific user input parameters, as well as a number of optional site-specific user-input parameters. The required additional site-specific Tier 2 parameters are:

⁴ This estimate is for a 500 MHz, Pentium-III or equivalent personal computer.

- # WMU Area
- # WMU Depth (for LF and SIs)
- # WMU location (to select the appropriate climate parameters)

Optional site-specific Tier 2 inputs are:

- # Distance to the nearest surface waterbody (for SIs)
- # Depth of the base of the WMU below ground surface (LFs, WPs, and SIs)
- # Operational Life of the WMU (for SIs, WPs, and LAUs)
- # Sludge thickness (SI)
- # Waste type (WP)
- # Leakage (infiltration) rate from the WMU
- # Distance to the nearest down-gradient well
- # Unsaturated zone soil type
- # Subsurface environment type, and/or individual values of;
 - # Depth from ground surface to the water table
 - # Saturated thickness of the upper aquifer
 - # Hydraulic conductivity in the saturated zone
 - # Regional hydraulic gradient in the saturated zone
 - # Ground water pH
- # Constituent-specific sorption coefficient (K_d)
- # Constituent-specific (bio-)degradation rate
- # Constituent-specific RGC and corresponding exposure duration

Table 4.1 summarizes the modeling options and parameters we used to developed the Tier 1 and Tier 2 analyses. Parameters that are used differently in Tier 1 versus Tier 2 are flagged as such; usually this is the case for Tier 2 parameters that the user may input as site-specific values.

IWEM parameters can be grouped into five categories: WMU infiltration and recharge, well location, soil and hydrogeology, and constituent-specific. The required site-specific parameters are underlined in Table 4.1. The third column in Table 4.1 indicates where you can find a detailed discussion of each parameter in this section. The IWEM User's Guide provides additional guidance in selecting site-specific values for these parameters.

Table 4.1 Summary of EPACMTP Options and Parameters

Modeling Element	Description or Value	Section Reference
WMU Parameters		
Waste Management Scenario	LF SI WP LAU	4.2.1
WMU Location (Nearest Climate Station)	Tier 1: Monte Carlo from nationwide distribution Tier 2: <u>Required</u> site-specific user input	4.2.1.3
Leachate concentration (mg/L)	Tier 1: <u>Required</u> constituent-specific user input Tier 2: <u>Required</u> constituent-specific user input	4.2.1.3
Operational Life (Leaching Duration) (yrs)	LF: Calculated inside EPACMTP; leaching continues until all waste depleted. SI, WP & LAU: Tier 1: SI = Distribution from SI survey WP = 20 yrs LAU = 40 yrs Tier 2: Optional user input; defaults same as Tier 1	4.2.1.3
WMU Area (m ²)	Tier 1: Nationwide distribution from industrial WMU surveys; Tier 2: <u>Required</u> site-specific user input	4.2.1.3
Depth of Waste in WMU (m)	Used for LFs and SIs; not applicable in case of WP or LAU. Equivalent to ponding depth for SIs. Tier 1: Nationwide distribution from industrial WMU surveys; Tier 2: <u>Required</u> site-specific user input for LF and SI	4.2.1.3
WMU Base Elevation below Ground Surface (m)	Tier 1: Distribution for SI. For all other units set to 0.0 (unit base at ground surface) Tier 2: Optional user input; default = 0.0	4.2.1.3
Distance to Nearest Surface Water Body (m)	Used to evaluate water table mounding for SI units Tier 1: 360 m Tier 2: Optional user input; default = 360 m	4.2.1.3
SI sediment layer thickness (m)	Thickness of accumulated sediment (sludge) layer in SI Tier 1: 0.2 m Tier 2: Optional user input; default = 0.2 m	4.2.1.3
Waste type permeability (cm/sec)	Used for WPs only; not applicable to other WMUs Tier 1: Nationwide, uniform distribution of three waste types (low-medium-high permeability) Tier 2: Optional user input; default same as Tier 1	4.2.2.2

Table 4.1 Summary of EPACMTP Options and Parameters (continued)

Modeling Element	Description or Value	Section Reference
Infiltration and Recharge Parameters		
No Liner Infiltration (m/yr)	LF:	4.2.2.2
	Tier 1: Nationwide distribution derived using HELP model based on survey of industrial landfill locations	
	Tier 2: Optional user input; default generated using HELP model based on site location	
	SI:	4.2.2.2
	Tier 1: Calculated by EPACMTP based on distribution of SI ponding depths	
	Tier 2: Optional user input; default calculated by EPACMTP based on site-specific ponding depth	
	WP:	4.2.2.2
	Tier 1: Nationwide distribution derived using HELP model based on survey of industrial waste pile locations	
Single Liner Infiltration (m/yr)	Tier 2: Optional user input; default generated using HELP model based on site location	
	LAU:	4.2.2.2
	Tier 1: Nationwide distribution derived using HELP model based on survey of industrial LAU locations	
	Tier 2: Optional user input; default generated using HELP model based on site location	
	LF:	4.2.2.3
	Tier 1: Nationwide distribution derived using HELP model with 3 ft. clay liner and survey of industrial landfill locations	
	Tier 2: Optional user input; default generated using HELP model based on site location and 3 ft. clay liner	
	SI:	4.2.2.3
	Tier 1: Calculated by EPACMTP based on SI ponding depth distribution and 3 ft clay liner	
	Tier 2: Optional user input; default calculated by EPACMTP based on site-specific ponding depth and 3 ft clay liner	
	WP:	4.2.2.3
	Tier 1: Nationwide distribution derived using HELP model with 3 ft. clay liner and survey of industrial waste pile locations	
	Tier 2: Optional user input; default generated using HELP model based on site location and 3 ft. clay liner	
	LAU:	
	Not Applicable	

Table 4.1 Summary of EPACMTP Options and Parameters (continued)

Modeling Element	Description or Value	Section Reference
Composite Liner Infiltration (m/yr)	LF:	4.2.2.4
	Tier 1: Nationwide distribution of reported leak detection system flow rates for composite lined units	
	Tier 2: Optional user input; default same as Tier 1.	
	SI:	4.2.2.4
	Tier 1: Calculated using Bonaparte (1989) equation for geomembrane liner using nationwide distribution of leak densities and unit-specific ponding depths;	
	Tier 2: Optional user input; default same as Tier 1	
	WP:	4.2.2.4
	Tier 1: Nationwide distribution of reported leak detection system flow rates for composite lined units;	
	Tier 2: Optional user input; default same as Tier 1	
	LAU: Not Applicable	
Recharge Rate (m/yr)	<u>All WMU types:</u> Tier 1: Monte Carlo based on nationwide distribution of WMU locations and regional soil types Tier 2: Monte Carlo based on distribution of soil types and location-specific climate conditions	4.2.2.5
Soil and Hydrogeologic Parameters		
Subsurface environment	Tier 1: Nationwide distribution of 13 major aquifer types associated with the locations of WMUs. Tier 2: Optional user input; default is unknown subsurface environment	4.2.3.1
Depth to ground water (m)	Tier 1: Nationwide distribution, correlated with subsurface environment Tier 2: Optional user input; default derived from subsurface environment if known, otherwise national average value (5.18 m)	4.2.3.1
Soil Hydraulic Parameters: (Hydraulic conductivity; saturated water content; residual water content; moisture retention curve parameters)	Distribution of values corresponding to three major soil types (sandy loam, silt loam, and silty clay loam). Probability of occurrence of each soil type based on nationwide distribution	4.2.3.2
Soil Temperature (°C)	Assigned based on WMU location	4.2.3.2
Bulk density (kg/L)	Assigned based on selected soil type (sandy loam, silt loam, or silty clay loam)	4.2.3.2

Table 4.1 Summary of EPACMTP Options and Parameters (continued)

Modeling Element	Description or Value	Section Reference
Unsaturated Zone Percent Organic Matter	Distribution of values corresponding to three major soil types (sandy loam, silt loam, and silty clay loam). Probability of occurrence of each soil type based on nationwide distribution	4.2.3.2
Unsaturated Zone pH	Assumed to be same as saturated zone pH; nationwide distribution derived from STORET ground-water quality database	4.2.3.2
Saturated Zone Hydraulic Conductivity (m/yr)	Tier 1: Nationwide distribution, correlated with subsurface environment Tier 2: Optional user input; default derived from subsurface environment if known, otherwise national average (1890 m/y)	4.2.3.3
Regional Ground water Hydraulic Gradient	Tier 1: Nationwide distribution, correlated with subsurface environment Tier 2: Optional user input; default derived from subsurface environment if known, otherwise national average (0.0057 m/m)	4.2.3.1
Saturated Zone Thickness (m)	Tier 1: Nationwide distribution, correlated with subsurface environment Tier 2: Optional user input; default derived from subsurface environment if known, otherwise national average (10.1 m)	4.2.3.1
Saturated Zone Porosity	Derived from nationwide distribution of mean aquifer particle diameter	4.2.3.3
Saturated Zone Bulk Density (kg/L)	Derived from saturated zone porosity	4.2.3.3
Saturated Zone pH	Nationwide distribution derived from STORET water quality database	4.2.3.3
Saturated Zone Fraction Organic Carbon	Nationwide distribution derived from STORET water quality database	4.2.3.3
Saturated Zone Temperature (°C)	Assigned based on WMU location	4.2.3.3
Constituent Fate and Transport Parameters		
Molecular Diffusion Coefficient (m ² /yr)	Accounts for constituent transport via diffusion in soil and ground water. Calculated from constituent-specific free-water diffusion coefficients	3.2, 3.3

Table 4.1 Summary of EPACMTP Options and Parameters (continued)

Modeling Element	Description or Value	Section Reference
Transformation Parameters - Hydrolysis Rate (yr^{-1}) (Bio-)degradation (yr^{-1})	Tier 1 and Tier 2 account for hydrolysis transformation reactions using constituent-specific hydrolysis rate constants. Other types of (bio-)degradation processes can be entered as optional Tier 2 constituent specific parameters	4.2.4.1
Sorption Parameters - Organic Carbon Partition Coefficient (kg/L) - Soil-Water Partition Coefficient (kg/L)	For organic constituents, equilibrium sorption is taken into account via constituent-specific organic carbon partition coefficients; for metals, effective equilibrium partition coefficients are generated using the MINTEQA2 geochemical speciation model	4.2.4.3
Well Location Parameters		
Downgradient Distance from WMU (m)	Tier 1: Set to 150 meters Tier 2: Optional user input (limited to 1600 meters); default same as Tier 1	4.2.5
Transverse Distance from Plume Centerline (m)	Well always on centerline of plume, transverse distance is 0.0	4.2.5
Depth of Well Intake (m)	Uniform distribution from 0 - 10 m below water table	4.2.5

4.2 EPACMTP Input Parameters Used to Develop Tier 1 and Tier 2 Tools

This section describes the parameters we used to develop the Tier 1 and Tier 2 tools, including their data sources, methodologies, and values. Appendix C provides detailed tables of Tier 1 parameter values. Section 4.2.1 describes WMU parameters. Section 4.2.2 describes the infiltration and recharge parameters. Section 4.2.3 describes the unsaturated zone and saturated zone parameters. Section 4.2.4 describes constituent-specific chemical fate parameters. Section 4.2.5 describes the well location parameters, and Section 4.2.6 describes the screening procedures we implemented in the Monte Carlo analysis to eliminate physically unrealistic parameter combinations.

4.2.1 WMU Parameters

4.2.1.1 WMU Types

IWEM simulates four different types of WMUs. Each of the four IWEM units reflects waste management practices that are likely to occur at industrial Subtitle D facilities. The WMU can be a LF, a WP, a SI, or a LAU. The latter is also sometimes called a land treatment unit. The four WMU types are represented graphically in Figure 4.1. In developing the IWEM tools, we assumed all units contained only one type of waste so that the entire capacity of the WMU is devoted to a single waste.

- # Landfill (LF). IWEM only considers closed LFs. A closed LF is assumed to have an 2-foot soil cover and one of three liner types: no-liner; a single clay liner; or a composite liner. The LF is filled with waste during the unit's operational life. Upon closure of the LF, the waste is left in place, and a final soil cover is installed. The starting point for the simulation is at the time when the LF is closed, i.e., the unit is at maximum capacity. The release of waste constituents into the soil and ground water underneath the LF is caused by dissolution and leaching of the constituents due to precipitation which percolates through the unit. The type of liner that is present controls, to a large extent, the amount of leachate which is released from the unit. We modeled LFs as a permanent WMU, with a rectangular footprint and a uniform depth. We did not simulate any loss process that may occur during the unit's active life (for example, due to leaching, volatilization, runoff or erosion, or biochemical degradation. We modeled the leaching of waste constituents from LFs as a depleting source scenario. In the depleting source scenario, the WMU is considered permanent and leaching continues until all waste that is originally present has been depleted. In IWEM Tier 1 and Tier 2, the magnitude of the initial leachate concentration is a model input; the rate of depletion is calculated internally in EPACMTP (see EPACMTP Technical Background Document).⁵ The leachate concentration value which is used an IWEM input is the expected initial leachate concentration, when the waste is 'fresh'.

⁵ In EPACMTP's finite source module for LFs, the rate of depletion is a function of the ratio between the waste concentration (C_w) and the leachate concentration (C_L). In IWEM, we set this ratio to a constant, protective value of $C_w/C_L = 10,000$.

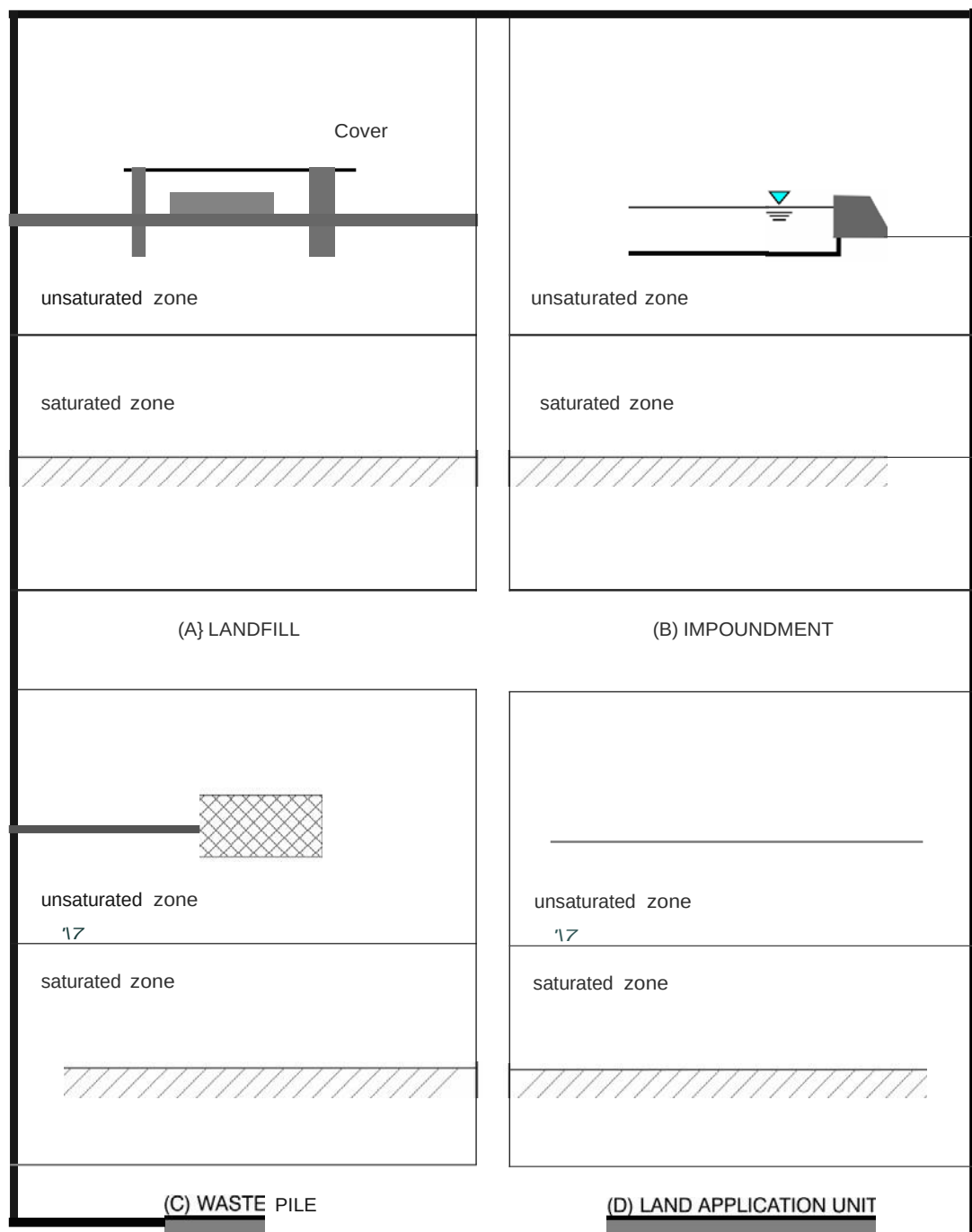


Figure 4.1 WMU Types Modeled in IWEM.

- # Waste Pile (WP). IWEM models WPs as temporary sources used for storage of solid wastes. Due to their temporary nature, they typically will not be covered. IWEM allows liners to be present, similar to LFs. In Tier 1 analyses, IWEM assumes that WPs have a finite operational life after which the WP is removed. In IWEM, we modeled WPs as a pulse-type source, with pulse duration equal to the unit's operating life.
- # Surface Impoundment (SI). In IWEM, SIs are ground level or below-ground level, flow-through units, which may be unlined, have a single clay liner, or have a composite clay-geomembrane liner. Release of leachate is driven by the ponding of water in the impoundment, which creates a hydraulic head gradient with the ground water underneath the unit. At the end of the unit's operational life, we assume there is no further release of waste constituents to the ground water (that is, clean closure from the SI). We modeled SIs as pulse-type sources; leaching occurs at a constant leachate concentration over a fixed period of time which is equal to the unit's operating life. We also assume a constant ponding depth (depth of waste water in SI) during the operational life.
- # Land Application Unit (LAU). LAU (or land treatment units) are areas of land which receive regular applications of waste that can be either tilled or sprayed directly onto the soil and subsequently mixed with the soil. IWEM models the leaching of wastes after tilling with soil. IWEM does not account for the losses due to volatilization during or after waste application. LAUs are modeled in IWEM as a constant pulse-type leachate source, with a leaching duration equal to the unit's operational life. We evaluated only the no-liner scenario for LAUs because liners are not typically used at this type of unit.

4.2.1.2 WMU Data Sources

In order to develop WMU parameters for IWEM, we used data from two nationwide EPA surveys of industrial Subtitle D WMUs. Data for LFs, WPs, and LAUs were obtained from an EPA survey of industrial D facilities conducted in 1986 (U.S. EPA, 1986). The survey provides a statistical sample design based set of observations of site specific areas, volumes and locations for industrial Subtitle D facilities in the United States. In the following description of WMU data, we will refer to this survey as the "1986 Subtitle D survey." Data for SIs were obtained from a recent Agency survey of industrial SIs (U.S. EPA, 2001). We will refer to this survey as the "Surface Impoundment Study."

Landfills

The 1986 Subtitle D survey provided LF data consisting of 824 observations of facility locations, area, number of units in the facility, facility design capacity, total remaining facility capacity, and the relative weight of each facility. The relative weight was assigned based on the total number of employees working at the facility and reflects the quantity of the waste managed in that facility.

We screened the LF data by placing constraints on the WMU depth and volume to eliminate unrealistic observations. The WMU depth, calculated by dividing the unit capacity by its area, was constrained to be either greater than or equal to 2 feet (0.67m), or less than or equal to 33 feet (10m). In addition, the LF volume was constrained to be greater than the remaining capacity. Ten area observations were reported missing and none were screened. Ninety-one volume observations were reported missing and 232 additional volume observations were screened.

In cases where the WMU depth or remaining capacity constraints were violated, we replaced the observed unit volume by generating a random realization from the volume probability distribution conditioned on area assuming that the unit area value was more likely to be correctly reported. The joint distribution was derived from the non-missing unit area/volume pairs that met the unit depth and remaining capacity constraints and was assumed to be lognormal. Missing values were generated from the joint area/volume probability if both the area and volume were missing, and from the corresponding conditional distribution if only one of the two values was missing. Final depth values were calculated by dividing the unit volume by the area.

Figure 4.2 shows the geographic locations of LF WMUs used in developing the Tier 1 and Tier 2 tools. A summary of the descriptive statistics of the LF parameters is provided in Appendix C; additional detailed data is provided in the EPACMTP Parameters/Data Background Document (U.S. EPA, 2002b).

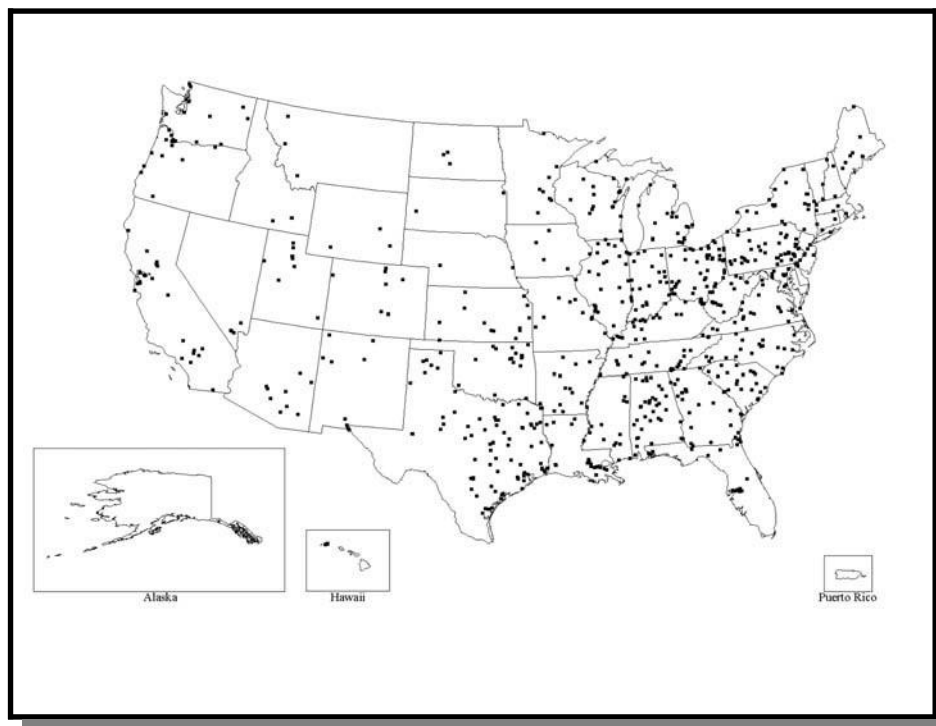


Figure 4.2 Geographic Locations of Landfill WMUs.

Surface Impoundments

The IWEM tools incorporate SI parameters from EPA's recent 5-year study of nonhazardous (Subtitle D) industrial SIs (U.S. EPA, 2001) in the United States. The Surface Impoundment Study is the product of a national survey of facilities that operate non-hazardous industrial waste SIs. We used information in the Surface Impoundment Study to create a database of SI characteristics comprising 503 SI units located at 143 facilities throughout the United States.

The Surface Impoundment Study provided data on impoundment locations, area, operating depths (depth of ponding in the impoundment), depth of the SI base below the ground surface, operational life of the impoundment, and proximity of the impoundment to a surface water body.

Figure 4.3 shows the geographic locations of the 143 SI facilities used from the Surface Impoundment Study. Due to the scale of this map, the individual units at each facility are not shown. A summary of the descriptive statistics of the SI unit parameters is provided in Appendix C; additional detailed data are provided in the EPACMTP Parameters/Data Background Document (U.S. EPA, 2002b).

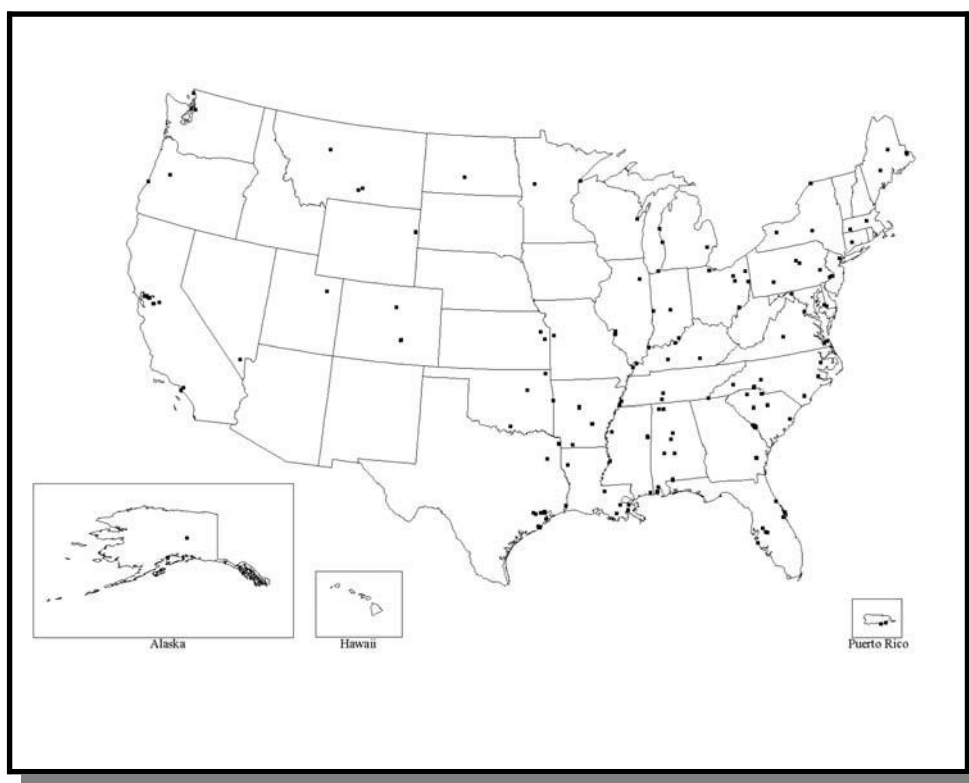


Figure 4.3 Geographic Locations of Surface Impoundment WMUs.

Waste Piles

The 1986 Subtitle D survey included 847 WP facilities with data on facility area, number of units, and the total amount of waste placed in the facility (waste volume) in 1985. We obtained unit values by dividing the facility values by the number of units in the facility. No screening constraints were placed on the WP data other than setting the 114 facility areas and the 30 facility waste volumes reporting zero values to 0.005 acres (20 m²) and 0.005 mega-tons (Mton), respectively.

Thirty waste volume observations were reported missing. No area observations were reported missing. We replaced missing volume values by random realizations from

the probability distribution of volume conditioned on area. The conditional distribution was assumed to be lognormal and was derived from the non-missing unit area/volume pairs.

Figure 4.4 shows the geographic locations of WP WMUs used in developing the Tier 1 and Tier 2 tools. A summary of the descriptive statistics of the WP parameters is provided in Appendix C; additional detailed data is provided in the EPACMTP Parameters/Data Background Document (U.S. EPA, 2002b).

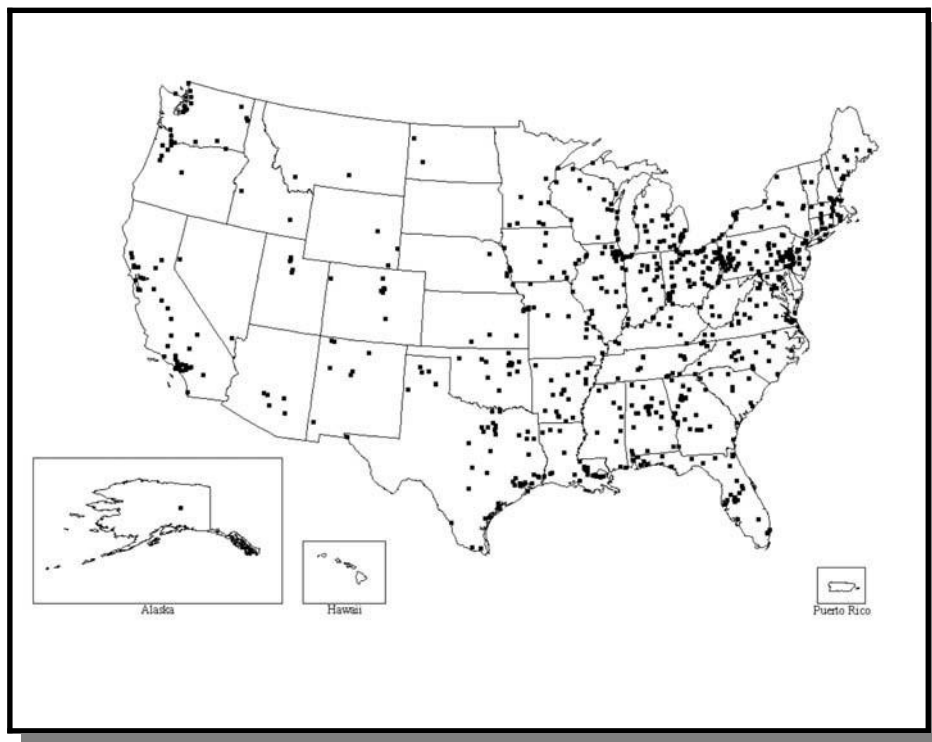


Figure 4.4 Geographic Locations of Waste Pile WMUs.

Land Application Units

The 1986 Subtitle D survey included 352 LAU facilities, with data on location, area, number of units in each facility, and the total amount of waste managed (waste volume) in 1985. We obtained unit values obtained by dividing the facility values by the number of units in the facility. We screened the LAU data by constraining waste application rates to be less than 10,000 tons/acre/year to eliminate unrealistic values. The application rate was calculated by dividing the waste managed in 1985 by the site acreage. (The upper bound was derived by assuming a maximum application rate of 200 dry tons/acre/year with a 2% solids content).

Eight waste volume observations were reported missing; twelve were screened out due to the application rate constraint. No area observations were reported missing and none were screened. As in the case of WPs, areas and volumes reported as zero were replaced with lower bounds. Three reported zero areas and nine reported zero waste volumes were set to 0.005 acres (20 m²) and 0.005 Mton, respectively.

We replaced missing and screened values by random realizations from the joint area/volume probability distribution or the corresponding marginal distributions depending on whether both or only one of either the waste volume or area values were missing or screened. The joint distribution was assumed to be lognormal and was derived from the non-missing unit area/volume pairs that met the unit depth constraint.

Figure 4.5 shows the geographic locations of LAU WMUs used in developing the Tier 1 and Tier 2 tools. A summary of the descriptive statistics of the LAU parameters is provided in Appendix C; additional detailed data are provided in the EPACMTP Parameters/Data Background Document (U.S. EPA, 2002b).



Figure 4.5 Geographic Locations of Land Application Unit WMUs.

4.2.1.3 WMU Parameters Used in Developing the Tier 1 and Tier 2 Tools

This section discusses the individual WMU-related parameters used in the IWEM modeling for Tier 1 and Tier 2. In most cases, the Tier 1 parameters are described by nationwide probability distributions. Appendix C provides a summary of the parameter distributions for each WMU type. With the exceptions noted in the following sections, these same distributions are used as the defaults in Tier 2.

Waste Leachate Concentration (mg/L)

Values of leachate concentration for all constituents of concern are required Tier 1 and Tier 2 input parameters. This parameter can be an actual measured value, or it can be an expected or estimated value. The user-provided leachate concentration values are the basis for IWEM's determination of the minimum protective liner design.

The Tier 1 software compares user-supplied leachate concentration values against each constituent's aqueous solubility. If the user input value exceeds the aqueous solubility of that constituent in the IWEM data base, IWEM will display a warning message. A leachate concentration value above the aqueous solubility value may indicate a number of conditions: (1) a measurement error, or (2) a case outside the validity of the EPACMTP fate and transport model. The model is designed to simulate transport of dissolved aqueous phase constituents, and therefore, the solubility is the theoretical maximum concentration value that may occur. However, IWEM will not reject user supplied leachate concentration values.

WMU Location

We obtained WMU locations from the 1986 subtitle D survey and the 2001 Surface Impoundment Study, respectively. The WMU locations are shown in Figures 4.2 - 4.5. In developing the Tier 1 and Tier 2 evaluations, we used information on WMU locations to assign appropriate site-based climate and hydrogeological parameter values to each location in the WMU database. Location-specific climate data from 102 climate stations were used to develop infiltration and recharge rates using the HELP model for unlined and single-lined WMUs (see Section 4.2.2), and to determine soil and aquifer temperature in order to calculate hydrolysis transformation rates (see Section 4.2.4). We also used information on WMU locations to assign location-specific soil and aquifer hydrogeological parameter values (see Section 4.2.3). In Tier 2, the WMU location is a required site-specific user input value that is needed by IWEM to assign the appropriate climate-related parameter values.

WMU Area (m²)

This parameter reflects the footprint area of the WMU (that is, length by width). Tier 1 values were obtained from EPA's 1986 Subtitle D Survey and the Surface Impoundment Study. The WMU footprint area is a required site-specific user-input value for a Tier 2 evaluation. This parameter represents the total surface area over which infiltration and leachate enter the subsurface.

WMU Waste Depth (m)

The WMU waste depth is used for LF and SI simulations. This parameter is not used for WPs or LAUs. In the case of LFs, this parameter represents the average waste thickness in the LF at closure. EPACMTP uses the waste depth as one of the parameters to calculate the LF source depletion rate (see EPACMTP Technical Background Document; U.S. EPA, 2002a). The Tier 1 evaluation is based on a nationwide distribution of LF depths obtained from the 1986 Subtitle D survey. In Tier 2, the user is required to provide a site-specific value.

For SIs, the waste depth is equal to the ponding depth, or average depth of free liquid in the impoundment. The SI ponding depth represents the hydraulic head that drives leakage of water from the SI; EPACMTP uses this parameter in order to calculate SI infiltration rates (see Section 3.1.2). The Tier 1 evaluation is based on a nationwide distribution of SI ponding depths obtained from the 2001 Surface Impoundment Study. In Tier 2, this is a required site-specific user input parameter.

Surface Impoundment Sediment (Sludge) Layer Thickness (m)

This parameter is applicable to SIs only and represents the average thickness of accumulated sediment (sludge) deposits on the bottom of the impoundment. This layer of accumulated sediment is different from an engineered liner underneath the impoundment, but its presence will serve to restrict the leakage of water from an impoundment, especially in unlined units. EPACMTP uses this parameter to calculate the rate of infiltration from unlined and single lined SIs. The EPACMTP SI infiltration module is described in Section 3.1, with a detailed description in the EPACMTP Technical Background Document (U.S. EPA, 2002a).

To model SIs, we assumed that the accumulated sediment consists of two equally thick layers, an upper unconsolidated layer and a lower consolidated layer ('filter cake') that has been compacted due to the weight of the sediment above it, and therefore has a reduced porosity and permeability. In Tier 1, we used a total (unconsolidated + consolidated) sediment layer thickness of 0.2 meters. In Tier 2, this is an optional site-specific user input parameter, with a default value of 0.2 m.

Depth of the WMU Base Below Ground Surface (m)

This parameter represents the depth of the base of the unit below the ground surface, as schematically depicted in Figure 4.6. The depth of the unit below the ground surface reduces the travel distance through the unsaturated zone before leachate constituents reach ground water. The SI characterization data from the EPA's 2001 Surface Impoundment Study provided unit-specific data for SIs that we used in the Tier 1 modeling. This parameter was not included in the EPA's 1986 Industrial Subtitle D Survey of LFs, WPs, and LAUs. For the Tier 1 analyses of these types of WMUs, we set this parameter to zero, which is equivalent to assuming the base of the unit is level with the ground surface.

In Tier 2, this parameter is an optional site-specific user input parameter, with a default value of zero. If a non-zero value is entered at Tier 2, IWEM will verify that the entered value, in combination with the depth to the water table, and magnitude of the unit's infiltration rate, does not lead to a physically infeasible condition (e.g., water table mound height above the ground surface or above the level of the waste liquid in an impoundment) in accordance with the infiltration screening methodology presented in Section 4.2.6.

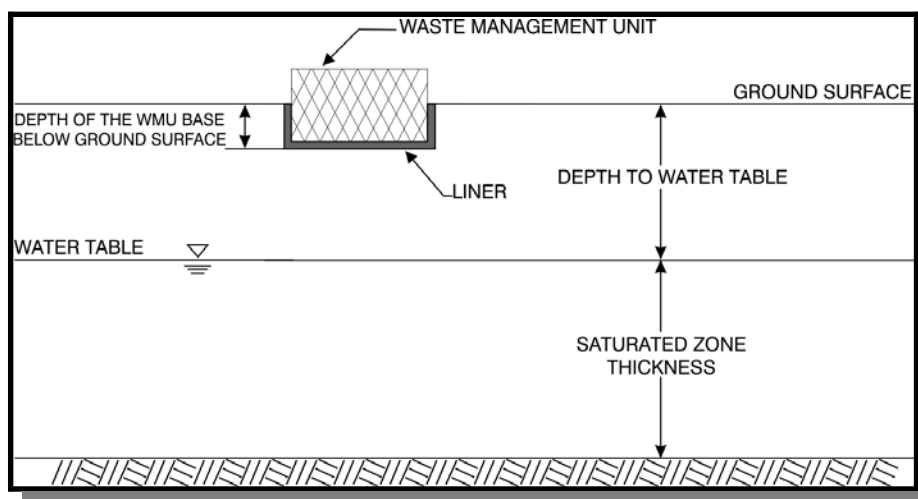


Figure 4.6 WMU with Base Elevation below Ground Surface.

Operational Life (Duration of Leaching Period) (yr)

For LFs, IWEM determines the duration of the leaching period internally, as a function of the amount of waste in the unit at closure and IWEM does not use an operational life. Because WPs, SIs and LAUs are modeled as finite duration pulse sources, we assumed the duration of the leaching period is equal to the unit's operational life.

In Tier 1, we determined unit-specific operational lives for SI, from information in the Surface Impoundment Study on present age of the unit and the planned closing date. If this information was missing, we assigned an operational life of 50 years. For WPs and LAUs, the 1986 Industrial Subtitle D Survey did not provide information on operational life. We assigned a life of 20 years for WPs and 40 years for LAUs.

In Tier 2, the operational life is an optional site-specific user input parameter for SIs, WPs, and LAUs. Tier 2 default values for this parameter are as follows:

#	LAU	=	40 years
#	WP	=	20 years
#	SI	=	50 years

Distance to Nearest Surface Water Body (m)

For SIs, IWEM uses information on the distance to the nearest permanent surface water, (that is, a river, pond or lake), in the infiltration screening procedure presented in Section 4.2.6. In Tier 1, we used reported data from the EPA's Surface Impoundment Study to assign a distance value to each SI unit in the national database. The data from the Surface Impoundment Study indicated a distribution of values with a range of 30 to 5,000 meters (3.1 miles), and a median value of 360 meters (see Appendix C).

In Tier 2, this parameter is an optional site-specific user input. Because the exact distance may not be known in many cases, the input is in terms of whether or not there is surface water body within 2,000 meters of the unit. If a surface water body is present within 2,000 meters, IWEM uses the median value of 360 meters as a default. If there is no water body within 2,000 meters, IWEM will use a value of 5,000 meters in its calculations.

IWEM requires the input of the rate of downward percolation of water and leachate through the unsaturated zone to the water table. The model distinguishes between two types of percolation, infiltration and recharge:

- # Infiltration (WMU leakage rate) is defined as water percolating through the WMU – including a liner if present – to the underlying soil.
- # Recharge is water percolating through the soil to the aquifer outside the WMU.

Infiltration is one of the key parameters affecting the leaching of waste constituents into the subsurface. For a given leachate concentration, the mass of constituents leached is directly proportional to the infiltration rate. In the IWEM Tier 1 and Tier 2 analyses, selecting different liner designs directly correlates to changing the infiltration rate; more protective liner designs reduce leaching by decreasing the rate of infiltration.

In contrast, recharge introduces pristine water into the aquifer. Increasing recharge therefore tends to result in a greater degree of plume dilution and lower constituent concentrations. High recharge rates may also affect the extent of ground-water mounding and ground-water velocity. The recharge rate is independent of the type and design of the WMU; rather it is a function of the climatic and hydrogeological conditions at the WMU location, such as precipitation, evapotranspiration, surface runoff, and regional soil type.

We used several methodologies to estimate infiltration and recharge. We used the HELP model (Schroeder et al, 1994) to compute recharge rates for all units, as well as infiltration rates for LAUs, and for LFs and WPs with no-liner and single-liner designs. For LFs and WPs, composite liner infiltration rates were compiled from leak-detection-system flow rates reported for actual composite-lined waste units (TetraTech, 2001).

For unlined and single-lined SIs, infiltration through the bottom of the impoundment is calculated internally by EPACMTP, as described in Section 3.1 of this document. For composite-lined SIs, we used the Bonaparte (1989) equation to calculate the infiltration rate assuming circular (pin-hole) leaks with a uniform leak size of 6 mm², and using the distribution of leak densities (number of leaks per hectare) assembled from the survey of composite-lined units (TetraTech, 2001).

Tables 4.2 through 4.5 summarize the liner assumptions and infiltration rate calculations for LFs, WPs, SIs, and LAUs. The remainder of Section 4.2.2 provides

background information and used the HELP model in conjunction with data from climate stations across the United States to develop nationwide recharge and infiltration rate distributions and provides detailed discussion of how we developed infiltration rates for different liner designs for each type of WMU.

4.2.2.1 Using the HELP Model to Develop Recharge and Infiltration Rates

The HELP model is a quasi-two-dimensional hydrologic model for computing water balances of LFs, cover systems, and other solid waste management facilities (Schroeder et al., 1994). The primary purpose of the model is to assist in the comparison of design alternatives. The HELP model uses weather, soil and design data to compute a water balance for LF systems accounting for the effects of surface storage, snowmelt, runoff, infiltration, evapotranspiration, vegetative growth, soil moisture storage, lateral subsurface drainage, leachate recirculation, unsaturated vertical drainage, and leakage through soil, geomembrane or composite liners. The HELP model can simulate LF systems consisting of various combinations of vegetation, cover soils, waste cells, lateral drain layers, low permeability barrier soils, and synthetic geomembrane liners.

For the IWEM Tier 1 and Tier 2 evaluations, HELP Versions 3.03 and 3.07 were used. We started with an existing database of no-liner infiltration for LFs, WPs and LAUs, and recharge rates for 97 climate stations in the lower 48 contiguous states (ABB, 1995), representing 25 climatic regions, that was developed with HELP version 3.03. To develop the Tier 1 and Tier 2 evaluations, we added five climate stations (located in Alaska, Hawaii, and Puerto Rico) to ensure coverage throughout all of the United States. Figure 4.7 shows the locations of the 102 climate stations.

The current version of HELP (version 3.07) was used for the additional modeling for the no-liner scenario. We compared the results of Version 3.07 against Version 3.03 and found that the differences in calculated infiltration rates were insignificant. We also used this comparison to verify a number of counter-intuitive infiltration rates that were generated with HELP Version 3.03. We had observed that for some climate stations located in areas of the country with low precipitation rates, the net infiltration for unlined LFs did not always correlate with the relative permeability of the LF cover. We found some cases in which a less permeable cover resulted in a higher modeled infiltration rate as compared to a more permeable cover. Examples can be seen in the detailed listing of infiltration data in Appendix D. Table D-1 shows that for a number of climate stations, including Albuquerque, Denver, and Las Vegas, the modeled infiltration rate for LFs with a silty clay loam (SCL) cover is higher than the values corresponding to silt loam (SLT) and sandy loam (SNL) soil covers. We determined that in all these cases, the HELP modeling results for unlined LFs were correct and could be explained in terms of other water balance components, including surface run-off and evapotranspiration.

	No Liner	Single Liner	Composite Liner
Method	HELP model simulations to compute an empirical distribution of infiltration rates for a 2 ft. thick cover of three native soil cover types using nationwide coverage of climate stations. Soil-type specific infiltration rates for a specific site are assigned by using the infiltration rates for respective soil types at the nearest climate station.	HELP model simulations to compute an empirical distribution of infiltration rates through a single clay liner using nationwide coverage of climate stations. Infiltration rates for a specific site were obtained by using the infiltration rate for the nearest climate station.	Compiled from literature sources (TetraTech, 2001) for composite liners
Final Cover	Monte Carlo selection from distribution of soil cover types. 2 ft thick native soil (1 of 3 soil types: silty clay loam, silt loam, and sandy loam) with a range of mean hydraulic conductivities (4.2×10^{-5} cm/s to 7.2×10^{-4} cm/s).	3 ft thick clay cover with a hydraulic conductivity of 1×10^{-7} cm/sec and a 10 ft thick waste layer. On top of the cover, a 1 ft layer of loam to support vegetation and drainage and a 1 ft percolation layer.	No cover modeled; the composite liner is the limiting factor in determining infiltration
Liner Design	No liner	3 ft thick clay liner with a hydraulic conductivity of 1×10^{-7} cm/sec. No leachate collection system. Assumes constant infiltration rate (assumes no increase in hydraulic conductivity of liner) over modeling period.	60 mil HDPE layer with either an underlying geosynthetic clay liner with maximum hydraulic conductivity of 5×10^{-9} cm/sec, or a 3-foot compacted clay liner with maximum hydraulic conductivity of 1×10^{-7} cm/sec. Assumes same infiltration rate (i.e., no increase in hydraulic conductivity of liner) over modeling period.
IWEM Infiltration Rate	Monte Carlo selection from HELP generated location-specific values.	Monte Carlo selection from HELP generated location-specific values.	Monte Carlo selection from distribution of leak detection system flow rates.

Table 4.3 Methodology Used to Compute Infiltration for SLEs

	No Liner	Single Liner	Composite Liner
Method	EPACMTP SI module for infiltration through consolidated sludge and native soil layers with a unit-specific ponding depth from EPA's SI Study (EPA, 2001).	EPACMTP module for infiltration through a layer of consolidated sludge and a single clay liner with unit-specific ponding depth from EPA's SI study.	Bonaparte equation (1989) for pin-hole leaks using distribution of leak densities for units installed with formal CQA programs
Ponding Depth	Unit-specific based on EPA's SI study.	Unit-specific based on EPA's SI study.	Unit-specific based on EPA's SI study.
Liner Design	None. However, barrier to infiltration is provided by layer of consolidated sludge at the bottom of the impoundment, and a layer of clogged native soil below the consolidated sludge. The sludge thickness is assumed to be constant over the modeling period. The hydraulic conductivity of the consolidated sludge is between 1.3×10^{-7} and 1.8×10^{-7} cm/sec. The hydraulic conductivity of the clogged native material is assumed to be 0.1 of the unaffected native material in the vadose zone.	3 ft thick clay liner with a hydraulic conductivity of 1×10^{-7} cm/sec. No leachate collection system. Assumes no increase in hydraulic conductivity of liner over modeling period. Additional barrier is provided by a layer of consolidated sludge at the bottom of the impoundment, see no-liner column.	60 mil HDPE layer with either an underlying geosynthetic clay liner with maximum hydraulic conductivity of 5×10^{-9} cm/sec, or a 3-foot compacted clay liner with maximum hydraulic conductivity of 1×10^{-7} cm/sec. Assumptions: 1) constant infiltration rate (i.e., no increase in hydraulic conductivity of liner) over modeling period; 2) geomembrane liner is limiting factor that determines infiltration rate.
IWEM Infiltration Rate	Calculated by EPACMTP based on Monte Carlo selection of unit-specific ponding depth.	Calculated based on Monte Carlo selection of unit-specific ponding depth	Calculated based on Monte Carlo selection of unit-specific ponding depth and distribution of leak densities

	No Liner	Single Liner	Composite Liner
Method	HELP model simulations to compute distribution of infiltration rates for a 10 ft. thick layer of waste, using three waste permeabilities (copper slag, coal bottom ash, coal fly ash) and nationwide coverage of climate stations. Waste-type-specific infiltration rates for a specific site are obtained by using the infiltration rates for respective waste types at the nearest climate station.	HELP model simulations to compute distribution of infiltration rates through 10 ft. waste layer using three waste permeabilities and nationwide coverage of climate stations. Infiltration rates for a specific site were obtained by using the infiltration rate for the nearest climate station.	Compiled from literature sources (TetraTech, 2001) for composite liners
Cover	None	None	None
Liner Design	No liner.	3 ft thick clay liner with a hydraulic conductivity of 1×10^{-7} cm/sec, no leachate collection system, and a 10 ft thick waste layer. Assumes no increase in hydraulic conductivity of liner over unit's operational life.	60 mil HDPE layer with either an underlying geosynthetic clay liner with maximum hydraulic conductivity of 5×10^{-9} cm/sec, or a 3-foot compacted clay liner with maximum hydraulic conductivity of 1×10^{-7} cm/sec. 1) same infiltration rate (i.e., no increase in hydraulic conductivity of liner) over unit's operational life; 2) geomembrane is limiting factor in determining infiltration rate.
IWEM Infiltration Rate	Monte Carlo selection from HELP generated location-specific values.	Monte Carlo selection from HELP generated location-specific values.	Monte Carlo selection from distribution of leak detection system flow rates

Table 4.4 Methodology Used to Compute Infiltration for WAFs

	No Liner	Single Liner	Composite Liner
Method	HELP model simulations to compute an empirical distribution of infiltration rates for a 0.5 ft thick sludge layer, underlain by a 3 ft layer of three types of native soil using nationwide coverage of climate stations. Soil-type specific infiltration rates for a specific site are assigned by using the infiltration rates for respective soil types at the nearest climate station.	N/A	N/A
Liner Design	No liner	N/A	N/A
IWEM Infiltration Rate	Monte Carlo selection from HELP generated location specific values.	N/A	N/A



Figure 4.7 Locations of HELP Climate Stations

The first 97 climate stations were grouped into 25 climate regions based on ranges of average annual precipitation and pan evaporation, as shown in Table 4.6. For each modeled climate station, HELP provides a database of five years of climatic data. We used this climatic data, along with data on the regional soil type and WMU design characteristics, to calculate a water balance for each applicable liner design as a function of the amount of precipitation that reaches the top surface of the unit, minus the amount of runoff and evapotranspiration. The HELP model then computed the net amount of water that infiltrates through the surface, waste, and liner layers, based on the initial moisture content and the hydraulic conductivity of each layer.

In addition to climate factors and liner designs, the infiltration rates calculated by HELP are affected by LF cover design, permeability of the waste material in WP, and LAU soil type. For every climate station and WMU type, we calculated three HELP infiltration rates. In Tier 1, for a selected WMU type and liner design, we used the EPACMTP Monte Carlo modeling process to select randomly from among the HELP-derived infiltration and recharge data, to capture both the nationwide variation in climate conditions, as well as variations in LF soil cover type and WP waste permeability. In Tier 2, the WMU location is a required user input, and the climate factors used in HELP are therefore also fixed; however, Tier 2 still accounts for local variability in LF soil cover type and WP waste permeability.

The factors related to soil type that affect the HELP-generated infiltration and recharge rates are the permeability of the soil used in the LF cover, and – in the case of recharge or for LAU units – the permeability of the soil type in the vicinity of the WMU. We used a consistent set of soil properties in the infiltration and recharge rate calculations as we did in the unsaturated zone fate and transport simulations (see Section 4.2.3). We used HELP to calculate infiltration and recharge for sandy loam, silty loam, and silty clay loam soils.

In the case of WPs, which do not have a cover, the permeability of the waste material itself plays a role similar to that of a LF cover in regulating infiltration rate. We modeled WPs with three different waste types, having different waste permeabilities, and each having equal likelihood of occurrence. The data for the different waste types are presented in Section 4.2.2.2.

Table 4.6 Grouping of Climate Stations by Average Annual Precipitation and Pan Evaporation (ABB, 1995)

City	State	Climate Region		City	State	Climate Region	
		Precipitation (in/yr)	Evaporation (in/yr)			Precipitation (in/yr)	Evaporation (in/yr)
Boise	ID	< 16	< 30	Columbia	MO	32 - 40	30 - 40
Fresno	CA			Put-in-Bay	OH		
				Madison	WI		
Bismarck	ND	< 16	30 - 40	Columbus	OH		
Denver	CO			Cleveland	OH		
Grand Junction	CO			Des Moines	IA		
Pocatello	ID			E. St. Louis	IL		
Glasgow	MT						
Pullman	WA			Topeka	KS	32 - 40	40 - 50
Yakima	WA						
Cheyenne	WY			Tampa	FL	32 - 40	50 - 60
Lander	WY			San Antonio	TX		
Rapid City	SD	< 16	40 - 50	Portland	ME	40 - 48	< 30
Los Angeles	CA			Hartford	CT		
Sacramento	CA			Syracuse	NY		
San Diego	CA			Worcester	MA		
Santa Maria	CA			Augusta	ME		
Ely	NV			Providence	RI		
Cedar City	UT			Nashua	NH		
				Ithaca	NY		
Albuquerque	NM	< 16	50 - 60	Boston	MA		
				Schenectady	NY		
Las Vegas	NV	< 16	> 60				
Phoenix	AZ			NY City	NY	40 - 48	30 - 40
Tucson	AZ			Lynchburg	VA		
El Paso	TX			Philadelphia	PA		
				Seabrook	NJ		
Medford	OR	16 - 24	30 - 40	Indianapolis	IN		
Great Falls	MT			Cincinnati	OH		
Salt Lake City	UT			Bridgeport	CT		

Table 4.6 Grouping of Climate Stations by Average Annual Precipitation and Pan Evaporation (ABB, 1995) (continued)

City	State	Climate Region		City	State	Climate Region	
		Precipitation (in/yr)	Evaporation (in/yr)			Precipitation (in/yr)	Evaporation (in/yr)
Grand Island	NE	16 - 24	40 - 50	Jacksonville	FL	40 - 48	40 - 50
				Orlando	FL		
Flagstaff	AZ	16 - 24	50 - 60	Greensboro	NC		
				Watkinsville	GA		
Dodge City	KS	16 - 24	> 60	Norfolk	VA		
Midland	TX			Shreveport	LA		
St. Cloud	MN	24 - 32	< 30	Astoria	OR	> 48	< 30
				New Haven	CT		
E. Lansing	MI	24 - 32	30 - 40	Plainfield	MA		
North Omaha	NE	24 - 32	40 - 50	Nashville	TN	> 48	30 - 40
				Knoxville	TN		
Dallas	TX	24 - 32	50 - 60	Central Park	NY		
Tulsa	OK			Lexington	KY		
Brownsville	TX			Edison	NJ		
Oklahoma City	OK	24 - 32	>60	Atlanta	GA	> 48	40 - 50
				Little Rock	AK		
Bangor	ME	32 - 40	< 30	Tallahassee	FL		
Concord	NH			New Orleans	LA		
Pittsburgh	PA			Charleston	SC		
Portland	OR			W. Palm Beach	FL		
Caribou	ME						
Chicago	IL			Lake Charles	LA	> 48	50 - 60
Burlington	VT			Miami	FL		
Rutland	VT						
Seattle	WA						
Montpelier	VT						
Sault St. Marie	MI						

4.2.2.2 Infiltration Rates for Unlined Units

Landfill

We used the HELP model to simulate infiltration through closed LFs for each of the 102 climate station locations shown in Figure 4.7. A 2-foot cover was included as the minimum Subtitle D requirement. Three different soil cover types were modeled: sandy loam, silty loam, and silty clay loam soils. Table 4.7 presents the hydraulic parameters for these three soil types.

Table 4.7 Hydraulic Parameters for the Modeled Soils

Soil Type	HELP Soil Number	Total Porosity (vol/vol)	Field Capacity (vol/vol)	Wilting Point (vol/vol)	Saturated Hydraulic Conductivity (cm/sec)
Sandy Loam	6	0.453	0.190	0.085	0.000720
Silt Loam	9	0.501	0.284	0.135	0.000190
Silty Clay Loam	12	0.471	0.342	0.210	0.000042

Other LF design criteria included:

- # A cover crop of “fair” grass — this is the quality of grass cover suggested by the HELP model for LFs where limitations to root zone penetration and poor irrigation techniques may limit grass quality.
- # The evaporation zone thickness selected for each location was generally the depth suggested by the model for that location for a fair grass crop; however, the evaporation zone thickness was not allowed to exceed the soil thickness (24 inches).
- # The leaf area index (LAI) selected for each location was that of fair grass (2.0) unless the model indicated a lower maximum for that location.
- # The LF configuration was based on a one-acre facility with a 2% top slope and a drainage length of 200 feet (one side of a square acre). Runoff was assumed to be possible from 100% of the cover.

Appendix D, Table D-1, presents the infiltration rate data for the 102 climate stations. The unlined LF infiltration rate for each soil type at each of the 102 climate

centers was used as the ambient regional recharge rate for that climatic center and soil type.

Surface Impoundment

We calculated SI infiltration rates using the built-in SI module in EPACMTP (see Section 3.1). This means that for EPACMTP, the SI infiltration rate is not really an input parameter, rather the model calculates infiltration rates “on the fly” during the simulation, as a function of impoundment ponding depth and other SI characteristics. For unlined SIs, the primary parameters that control the infiltration rate are the ponding depth in the impoundment, the thickness and permeability of any accumulated sediment layer at the base of the impoundment, and the presence of a ‘clogged’ (i.e., reduced permeability) layer of native soil underneath the impoundment caused by the migration of solids from the impoundment. In addition, IWEM checks that the calculated infiltration rate does not result in an unrealistic degree of ground-water mounding (see Section 4.2.6).

For IWEM, we used unit-specific data on SI ponding depths from EPA’s Surface Impoundment Study (U.S. EPA, 2001). We assumed a fixed sediment layer thickness of 20 cm at the base of the impoundment. The resulting sediment layer permeability has a relatively narrow range of variation between 1.26×10^{-7} and 1.77×10^{-7} cm/s. We assumed that the depth of clogging underneath the impoundment was 0.5 m in all cases, and that saturated hydraulic conductivity of the clogged layer is 10% of that of the native soil underlying the impoundment. The parameters used to calculate SI infiltration rates are tabulated as part of the Tier 1 parameter tables in Appendix C.

In the event that the SI is reported to have its base below the water table, we calculated the infiltration using Darcy’s law based on the hydraulic gradient across and the hydraulic conductivity of the consolidated sediment at the bottom of the impoundment unit.

Waste Pile

For the purpose of estimating leaching rates, we considered WPs to be similar to non-covered LFs with a total waste thickness of 10 feet. The infiltration rates for unlined WPs were, therefore, generated with the HELP model using the same general procedures as for LFs, but with the following modifications:

- # No cover
We modeled the leachate flux through active, uncovered piles. We modeled the WP surface as having no vegetation. The evaporative zone depth was taken as the suggested HELP model value for the “bare”

condition at each climate center. The LAI was set to zero to eliminate transpiration.

- # Variable waste permeability
For uncovered WPs, we found that the infiltration rates predicted by HELP model are sensitive to the permeability of the waste material itself. Based on these results, we simulated WP infiltration rates for three different WP materials: relatively high permeability, moderate permeability, and relatively low permeability. Parameters for the three waste types are presented in Table 4.8.

Table 4.8 Moisture Retention Parameters for the Modeled WP Materials

Waste Type	HELP Soil Number	Total Porosity (vol/vol)	Field Capacity (vol/vol)	Wilting Point (vol/vol)	Saturated Hydraulic Conductivity (cm/sec)
Low Permeability	30	0.541	0.187	0.047	0.00005
Moderate Permeability	31	0.578	0.076	0.025	0.00410
High Permeability	33	0.375	0.055	0.020	0.04100

We calculated WP infiltration rates for all 102 climate stations and waste material permeabilities. Appendix D, Table D-2, presents the WP infiltration rate values for all climate stations and waste types.

Land Application Unit

LAUs were modeled with HELP using two soil layers. The top layer was taken as six inches in thickness and represented the layer into which the waste was applied. The bottom layer was of the same material type as the top layer and was set at a thickness of 36 inches. Both of these layers were modeled as vertical percolation layers. The same three soil types for LFs were also used for LAUs.

We assumed the waste applied to the LAU to be a sludge-type material with a high water content. We also assumed a waste application rate of 7.25 inches per year (in/yr) with the waste having a solids content of 20% and a unit weight of 75 lb/ft³. Assuming that 100% of the water in the waste was available as free water, an excess water amount of 5.8 in/yr, in addition to precipitation, would be available for percolation. HELP model analyses showed that the additional water available for percolation generally would have little effect on the simulated water balance and net infiltration, except for sites located in arid regions of the United States with very little natural

precipitation. For more representative waste application rates, the effect disappeared because introducing additional moisture in the simulated water balance results in a commensurate increase in runoff and removal by evapotranspiration. The LAU infiltration values are presented in Appendix D, Table D-3.

4.2.2.3 Single-Lined Waste Units

IWEM includes infiltration rates for lined LFs, WPs, and SIs. In the case of LAUs, only unlined units are considered.

Landfill

We calculated infiltration rates for single-lined LFs using the HELP model. We modeled the LF as a four-layer system, consisting, from top to bottom of:

- # 1-foot percolation cover layer;
- # 3-foot compacted clay cover with hydraulic conductivity of 1×10^{-7} cm/s ;
- # 10-foot thick waste layer; and
- # 3-foot thick compacted clay liner with a hydraulic conductivity of 1×10^{-7} cm/sec.

We simulated the cover layer as a loam drainage layer supporting a “fair” cover crop with an evaporative zone depth equal to that associated with a fair cover crop at the climate center. The remaining conditions were identical to those described in Section 4.2.2.2 for unlined LFs.

In developing infiltration rates for Tier 1, we used the grouping of climate stations into 25 regions of similar climatic conditions depicted in Table 4.6 in order to reduce the number of required HELP simulations. Rather than calculating infiltration rates for each of the 102 individual climate stations, we calculated infiltration rates for the 25 climate regions, and then assigned the same value to each climate station in one group. To ensure a protective result, we chose the climate center with the highest average precipitation in each climate region as representative of that region. Appendix D, Table D-4, shows the infiltration rate values for clay-lined LFs that we used in developing the Tier 1 LCTVs. The actual climate stations that were used in the HELP simulations for each climate region are shown in bold face in the table. We calculated individual infiltration rates for the five climate centers in Alaska, Hawaii, and Puerto Rico that were not assigned to a climate region.

We used the database of HELP-generated infiltration rates to provide estimates of LF infiltration rates in Tier 2 when a user does not have site-specific data. During the process of assembling the HELP infiltration values for the IWEM software tool, we

realized that the grouping of climate centers into regions for clay-lined units, resulted in a number of apparent anomalies in which the suggested infiltration rate for a lined unit would be higher than the unlined infiltration rate at the same climate station. This resulted from the fact that we used the infiltration rate for the climate center with the highest annual precipitation in each region for clay-lined units, but then compared it with a location-specific infiltration value for unlined units. The occurrence of these anomalies was restricted to climate stations in arid parts of the United States, and was noticeable only when the absolute magnitude of infiltration was low. In order to remove these counter-intuitive results, we re-calculated location-specific HELP infiltration rates for clay-lined units at 17 climate stations (Glasgow, MT; Yakima, WA; Lander, WY; Cheyenne, WY; Pullman, WA; Pocatello, ID; Grand Junction, CO; Denver, CO; Great Falls, MT; Salt Lake City, UT; Cedar City, UT; El Paso, TX; Ely, NV; Las Vegas, NV; Rapid City, SD; Phoenix, AZ; and Tucson, AZ). We then incorporated location-specific infiltration rates for these 17 climate stations into the Tier 2 IWEM software, to replace the regional values used for these stations in Tier 1.

As a result of the additional HELP model simulations for clay-lined units that we performed after the Tier 1 LCTVs had been generated, the database of infiltration rates that is incorporate into the IWEM software is slightly different from the data used in Tier 1. We performed a sensitivity analysis to assess what would have been the impact on Tier 1 LCTVs had we used location-specific infiltration values, rather than regional values, for the 17 climate stations involved. We used three constituents in the sensitivity analysis: a weakly sorbing constituent (benzene, $K_{oc} = 63$ mL/g); a moderately sorbing constituent (carbon tetrachloride, $K_{oc} = 257$ mL/g); and a strongly sorbing constituent (heptachlor, $K_{oc} = 162,000$ mL/g). Table 4.9 summarizes the results of this sensitivity analysis. This table follows the format of the Tier 1 LCTV tables presented in Appendix F of this report.

For each of the three constituents, Table 4.9 compares the actual Tier 1 LCTVs to values calculated using location-specific infiltration rates for the 17 climate stations. The updated values are shaded and shown in bold-face. The table indicates that if we had used these data in the Tier 1 evaluations, it would have resulted in slightly higher LCTVs for some constituents, notably weakly to moderately sorbing constituents. Constituents that are strongly sorbing (as represented by heptachlor), and/or that rapidly degrade, would be less affected because the LCTVs for these constituents are often controlled by various imposed caps (see Section 6). Even for the constituents that are affected, the change in LCTV would have been very slight. The largest LCTV impact in Table 4.9 is 0.004 mg/L for the MCL-based LCTV of carbon tetrachloride. The sensitivity analysis shows that the use of regional infiltration rates for clay-lined LFs in Tier 1 resulted in slightly more protective LCTVs than if we had used location-specific values. This confirms the intent of Tier 1 to provide protective screening values.

Table 4.9 Sensitivity Analysis of Tier 1 LCTVs for Clay-lined LFs to Regional Versus Location-specific Infiltration Rates for 17 Climate Stations

Constituent	LCTV based on MCL (mg/L)	Non-Carc. Effect		Carc. Effect	
		LCTV based on Ingestion	LCTV based on Inhalation	LCTV based on Ingestion	LCTV based on Inhalation
Benzene TIER 1	0.030		0.50 ^a	0.011	0.010
Benzene REVISED INFIL.DATA	0.033		0.50 ^a	0.012	0.010
Carbon tetrachloride TIER 1	0.055	0.2	0.23	8.2E-03	8.4E-03
Carbon tetrachloride REVISED INFIL.DATA	0.059	0.2	0.25	8.7E-03	8.9E-03
Heptachlor TIER 1	8.0E-03 ^a	8.0E-03 ^a		8.0E-03 ^a	8.0E-03 ^a
Heptachlor REVISED INFIL.DATA	8.0E-03 ^a	8.0E-03 ^a		8.0E-03 ^a	8.0E-03 ^a

^a TC Rule exit level cap

Waste Pile

We calculated infiltration rates for single-lined WPs using the HELP model. We modeled the WP as a two-layer system, consisting, from top to bottom, of:

- # 10-foot thick, uncovered, waste layer; and
- # 3-foot thick compacted clay liner with a hydraulic conductivity of 1×10^{-7} cm/sec.

Other parameters were set to the same values as in the unlined WP case. The same three waste material types were used as in Tier 1. We also modeled a bare surface for the evaporative zone depth.

In developing WP infiltration rates for Tier 1, we used the same grouping of climate stations in 25 climate regions as previously discussed for LFs. Appendix D, Table D-4, shows the infiltration rate values for clay-lined WPs that we used in developing the Tier 1 LCTVs. The actual climate centers that were used in the HELP simulations for each climate region are shown in bold face in the table. We calculated individual infiltration rates for the five climate centers in Alaska, Hawaii, and Puerto Rico that were not assigned to a climate region.

Analogous to the situation encountered for LFs, we found a number of apparent anomalies between WP infiltration rates for unlined as compared to clay-lined WPs, resulting from the use of regional infiltration values for clay-lined units. The occurrence

of these anomalies for WPs was also restricted to climate centers in arid parts of the United States, for which the absolute magnitude of infiltration was low. In order to remove these counter-intuitive results, we re-calculated location-specific HELP infiltration rates for clay-lined WP units at 17 climate stations (Glasgow, MT; Yakima, WA; Lander, WY; Cheyenne, WY; Pullman, WA; Pocatello, ID; Grand Junction, CO; Denver, CO; Great Falls, MT; Salt Lake City, UT; Cedar City, UT; El Paso, TX; Ely, NV; Las Vegas, NV; Rapid City, SD; Phoenix, AZ; and Tucson, AZ). We then incorporated location-specific infiltration rates for these 17 climate stations into the Tier 2 IWEM software to replace the regional values used for these stations in Tier 1.

We also assessed the impact on Tier 1 LCTVs had we used location-specific infiltration values, rather than regional values, for the 17 climate stations. Table 4.10 summarizes the results of this sensitivity analysis for WP units. This table follows the format of the Tier 1 LCTV tables presented in Appendix F of this report. For each of the three constituents, the table compares the actual Tier 1 LCTVs to values calculated using location-specific infiltration rates for the 17 climate stations given above. The updated values are shaded and shown in bold-face. The results of the sensitivity analysis for WPs are consistent with, and of similar magnitude, as the results we found for LFs.

Table 4.10 indicates that if we had used the additional location-specific infiltration data in the Tier 1 evaluations, it would have resulted in slightly higher LCTVs for some constituents, notably weakly to moderately sorbing constituents. Constituents that are strongly sorbing (as represented by heptachlor), and/or that rapidly degrade, would be less affected because the LCTVs for these constituents are often controlled by various imposed caps (see Section 6). Even for the constituents that are affected, the change in LCTV would have been very slight. The largest LCTV impact in Table 4.10 is 0.03 mg/L for the MCL-based LCTV of carbon tetrachloride. The sensitivity analysis shows that the use of regional infiltration rates for clay-lined WPs in Tier 1 resulted in slightly more protective LCTVs than if we had used location-specific values. This confirms the intent of Tier 1 to provide protective screening values.

During the process of verifying the HELP-generated infiltration rates for clay-lined units we also replaced incorrect values for clay-lined WPs assigned to the Lake Charles, LA and Miami, FL climate stations. These two climate stations have high precipitation (Table 4.6), but were assigned low infiltration rates in the Tier 1 analyses (see Appendix D, Table D-4). We re-ran the HELP model for the clay-lined WP scenario for the three clay-lined WP scenarios, that is low, medium, and high waste permeability.

Table 4.10 Sensitivity Analysis of Tier 1 LCTVs for Clay-lined WPs to Regional Versus Location-specific Infiltration Rates for 17 Climate Stations

Constituent	LCTV based on MCL (mg/L)	Non-Carc. Effect		Carc. Effect	
		LCTV based on Ingestion	LCTV based on Inhalation	LCTV based on Ingestion	LCTV based on Inhalation
Benzene TIER 1	0.13		0.50 ^a	0.06	0.056
Benzene REVISED INFIL.DATA	0.15		0.50 ^a	0.07	0.064
Carbon tetrachloride TIER 1	0.21	0.50 ^a	0.50 ^a	0.043	0.044
Carbon tetrachloride REVISED INFIL.DATA	0.24	0.50 ^a	0.50 ^a	0.048	0.049
Heptachlor TIER 1	8.0E-03 ^a	8.0E-03 ^a		8.0E-03 ^a	8.0E-03 ^a
Heptachlor REVISED INFIL.DATA	8.0E-03 ^a	8.0E-03 ^a		8.0E-03 ^a	8.0E-03 ^a

^a TC Rule exit level cap

The re-calculated infiltration rate values averaged 0.066 m/yr, as compared to 0.019 m/yr in Tier 1. We incorporated the re-calculated values in the IWEM software tool for Tier 2. Note that the underestimation of infiltration rates for Lake Charles and Miami will have had the effect of partially compensating for overestimating infiltration rates at other locations in the national Tier 1 screening analysis.

Surface Impoundment

For single-lined SIs, infiltration rates were calculated inside of EPACMTP in the same manner as described in the previous section for unlined units, with the exception that we added a 3-foot compacted clay liner with a hydraulic conductivity of 1×10^{-7} cm/s at the bottom of the WMU and we did not include the effect of clogged native material due to the filtering effects of the liner.

4.2.2.4 Infiltration Rates for Composite-Lined Units

We conducted an information collection effort that involved searching the available literature for data that quantify liner integrity and leachate infiltration through composite liners (TetraTech, 2001). We assembled these data and applied them to develop the Tier 1 and Tier 2 analyses as follows:

Landfill and Waste Pile

We treated composite-lined LFs and WPs as being the same for the purpose of determining infiltration rates. For these WMU's, we developed an infiltration rate

distribution from actual leak detection system (LDS) flow rates reported for clay composite-lined LF cells.

We based the distribution of composite-lined LF and WP infiltration rates on available monthly average LDS flow rates from 27 LF cells reported by TetraTech (2001). The data and additional detail for the 27 LF cells are provided in Appendix D, Table D-5. The data included monthly average LDS flow rates for 22 operating LF cells and 5 closed LF cells. The 27 LF cells are located in eastern United States: 23 in the northeastern region, 1 in the mid-Atlantic region, and 3 in the southeastern region. Each of the LF cells is underlain by a geomembrane/ geosynthetic clay liner which consists of a geomembrane of thickness between 1 and 1.5 mm (with the majority, 22 of 27, being 1.5 mm thick), overlying a geosynthetic clay layer of reported thickness of 6 mm. The geomembrane is a flexible membrane layer made from HDPE. The geosynthetic clay liner is a composite barrier consisting of two geotextile outer layers with a uniform core of bentonite clay to form a hydraulic barrier. The liner system is underlain by a LDS.

We decided in this case to use a subset of the reported flow rates compiled by TetraTech (2001) in developing the composite liner infiltration rates for IWEM. We did not include LDS flow rates for geomembrane/compacted clay composite-lined LF cells in our distribution. For compacted clay liners (including composite geomembrane/compacted clay liners), there is the potential for water to be released during the consolidation of the clay liner and yield an unknown contribution of water to LDS flow, such that it is very difficult to determine how much of the LDS flow is due to liner leakage, versus how much is due to clay consolidation. We also decided in this case to not use LDS flow rates from three geomembrane/geosynthetic clay lined-cells. For one cell, flow rate data were available for the cell's operating period and the cell's post- closure period. The average flow rate for the cell was 26 liters/hectare/day when the cell was operating and 59 liters/hectare/day when the cell was closed. We believe these flow rates, which were among the highest reported, are difficult to interpret because the flow rate from the closed cell was over twice the flow rate from the open cell, a pattern inconsistent with the other open cell/closed cell data pairs we reviewed. For the two other cells, additional verification of the data may be needed in order to fully understand the reported flow rates.

The resulting cumulative probability distribution of infiltration rates for composite-lined LFs and WPs for use in this application is based on the 27 remaining data points is presented in Table 4.11. Note that over 50% of the values are zero, that is, they have no measurable infiltration.

Table 4.11 Cumulative Frequency Distribution of Infiltration Rate for Composite-Lined LFs and WPs

Percentile	0	10	25	50	75	90	100
Infiltration Rate (m/yr)	0.0	0.0	0.0	0.0	7.30×10^{-5}	1.78×10^{-4}	4.01×10^{-4}

Surface Impoundment

We calculated leakage through circular defects (pin holes) in a composite liner using the following equation developed by Bonaparte et al. (1989):

$$Q = 0.21a^{0.1} h^{0.9} K_s^{0.74}$$

where:

- Q = steady-state rate of leakage through a single hole in the liner (m³/s)
- a = area of hole in the geomembrane (m²)
- h = head of liquid on top of geomembrane (m)
- K_s = hydraulic conductivity of the low-permeability soil underlying the geomembrane (m/s)

This equation is applicable to cases where there is good contact between the geomembrane and the underlying compacted clay liner. For each SI unit, we determined its infiltration rate using the above equation. We used the unit-specific ponding depth data (corresponding to h in the above equation) from the recent Surface Impoundment Study (U.S. EPA, 2001) in combination with a distribution of leak densities (expressed as number of leaks per hectare) compiled from 26 leak density values reported in TetraTech (2001). The leak densities are based on liners installed with formal Construction Quality Assurance (CQA) programs.

The 26 sites with leak density data are mostly located outside the United States: 3 in Canada, 7 in France, 14 in United Kingdom, and 2 with unknown locations. The WMUs at these sites (8 LFs, 4 SIs, and 14 unknown) are underlain by a layer of geomembrane of thickness varying from 1.14 to 3 mm. The majority of the geomembranes are made from HDPE (23 of 26) with the remaining 3 made from prefabricated bituminous geomembrane or polypropylene. One of the sites has a layer of compacted clay liner beneath the geomembrane, however, for the majority of the sites (25 of 26) material types below the geomembrane layer are not reported. The leak density data above were used for SIs. The leak density distribution is shown in Table 4.12. Table D-6, Appendix D, provides additional detail.

To use the Bonaparte equation, we assumed a uniform leak size of 6 millimeters squared (mm^2). The leak size is the middle of a range of hole sizes reported by Rollin et al. (1999), who found that 25 percent of holes were less than 2 mm^2 , 50 percent of holes were 2 to 10 mm^2 , and 25 percent of holes were greater than 10 mm^2 . We assumed that the geomembrane is underlain by a compacted clay liner whose hydraulic conductivity is $1 \times 10^{-7} \text{ cm/s}$.

In order to ascertain the plausibility of the leak density data, we conducted an infiltration rate calculation to estimate the range of infiltration resulting from the leaks in geomembrane. Because of the absence of documented infiltration data for SIs, we used the infiltration data for LFs, described previously under the LF and WP section, as a surrogate infiltration data set for comparison purposes. Because the comparison was made on the basis of LF data, we set the head of liquid above the geomembrane to 0.3 m (1 foot) which is a typical maximum design head for LFs. Calculation results are shown in Table D-6, Appendix D. The results indicate that the calculated leakage rates, based on the assumptions of above-geomembrane head, hole dimension, hydraulic conductivity of the barrier underneath the geomembrane, and good contact between the geomembrane and the barrier, agree favorably with the observed LF flow rates reported in Table D-5, Appendix D. This result provided confidence that the leak density data could be used as a reasonable basis for calculating infiltration rates using actual SI ponding depths.

The resulting frequency distribution of calculated infiltration rates for composite-lined SIs used in Tier 1 is presented in Table 4.13. For Tier 2, the user is required to specify the unit's ponding depth. IWEM will then determine the unit's infiltration distribution using the Bonaparte equation and the leak density distribution in Table 4.12.

Table 4.12 Cumulative Frequency Distribution of Leak Density for Composite-Lined SIs

Percentile	0	10	20	30	40	50	60	70	80	90	100
Leak density (No. Leaks/ha)	0	0	0	0	0.7	0.915	1.36	2.65	4.02	4.77	12.5

Table 4.13 Cumulative Frequency Distribution of Infiltration Rate for Composite-Lined SIs

Percentile	0	10	25	50	75	90	100
Infiltration Rate (m/yr)	0.0	0.0	0.0	1.34×10^{-5}	1.34×10^{-4}	3.08×10^{-4}	4.01×10^{-3}

4.2.2.5 Determination of Recharge Rates

We estimated recharge rates for the three primary soil types across the United States (SNL, SLT, and SCL) and ambient climate conditions at 102 climate stations through the use of the HELP water-balance model as summarized in 4.2.2.1. We assumed the ambient regional recharge rate for a given climate center and soil type (for all four WMU types) is the same as the corresponding unlined LF infiltration rate.

4.2.3 Parameters Used to Describe the Unsaturated and Saturated Zones

We used a number of data sources to obtain parameter values for the unsaturated and saturated zone modeling in Tier 1 and Tier 2. A primary data source was the Hydrogeologic Database for Ground-Water Modeling (HGDB), assembled by Rice University on behalf of the American Petroleum Institute (API) (Newell et al, 1989). This database provides probability distributions of a number of key ground-water modeling parameters for various types of subsurface environments.

For unsaturated zone modeling, we used a database of soil hydraulic properties for various soil types, assembled by Carsel and Parrish (1988), in combination with information from the Soil Conservation Service (SCS) on the nationwide prevalence of different soil types across the United States.

4.2.3.1 Subsurface Parameters

The HGDB database provides site-specific data on four key subsurface parameters⁶:

- # Depth to ground water;
- # Saturated zone thickness;
- # Saturated zone hydraulic conductivity; and
- # Saturated zone hydraulic gradient;

The data in this hydrogeological database were collected by independent investigators for approximately 400 hazardous waste sites throughout the United States. In the HGDB, the data are grouped into twelve subsurface environments, which are based on EPA's DRASTIC classification of hydrogeologic settings (U.S. EPA, 1985). Table 4.14 lists the subsurface environments. The table includes a total of 13 categories; 12 are distinct subsurface environments, while the 13th category, which is labeled "other" or

⁶ The database also provides data on ground-water seepage velocity and on "vertical penetration depth" of a waste plume below the water table. We did not use these data. EPACMTP calculates the ground-water velocity directly and the vertical penetration depth is not used in EPACMTP.

“unknown”, was used for waste sites that could not be classified into one of the first 12 environments. The subsurface parameter values in this 13th category are simply averages of the parameter values in the 12 actual subsurface environments. Details on the individual parameter distributions for each subsurface environment are provided in the EPACMTP Parameters/Data Background Document (U.S. EPA, 2002b).

Table 4.14 HGDB Subsurface Environments (from Newell et al, 1989)

Region	Description
1	Metamorphic and Igneous
2	Bedded Sedimentary Rock
3	Till Over Sedimentary Rock
4	Sand and Gravel
5	Alluvial Basins Valleys and Fans
6	River Valleys and Floodplains with Overbank Deposit
7	River Valleys and Floodplains without Overbank Deposits
8	Outwash
9	Till and Till Over Outwash
10	Unconsolidated and Semi-consolidated Shallow Aquifers
11	Coastal Beaches
12	Solution Limestone
13	Other (Not classifiable)

The key feature of this database is that it provides a set of correlated values of the four parameters for each of the 400 sites in the database. That is, the value of each parameter is associated with the three other subsurface parameters reported for the same site. We preserved these correlations because having information on some parameters allows us to develop more accurate estimates for missing parameter values.

In Tier 1 we used the HGDB in conjunction with a geographical classification of aquifers developed by the United States Geological Survey (Heath, 1984) to assign each waste site in our nationwide database of Subtitle D WMU's (see Section 4.2.1) to one of the 13 subsurface environments. For each type of WMU, we used information on its location (see Figures 4.2 - 4.5), in combination with USGS state-by-state aquifer maps to determine the type of subsurface environment at that site. Sites that could not be classified into one of the 12 categories were assigned as “other” (that is, they were assigned to environment number 13). Using the subsurface parameters in the HGDB for each of the 13 environments, we could then assign a probability distribution of parameter values to each WMU location. This methodology is consistent with how we assigned HELP-derived infiltration and recharge rates to each WMU in the IWEM modeling database.

In Tier 2, the type of subsurface environment, as well as each of the four individual subsurface parameters (depth to ground water, saturated thickness, saturated hydraulic conductivity, and hydraulic gradient) are optional, site-specific user inputs. Depending on the extent of available site data, IWEM will use statistical correlations developed from the HGDB to estimate missing or unknown parameters. If site-specific values for all four parameters are known, then Tier 2 will use these values and in this case, information on the type of subsurface environment is not needed. If one or more of the four subsurface parameters are unknown, but the type of subsurface environment at the site is known, Tier 2 will use the known parameters to generate a probability distribution for the unknown parameters, using the statistical correlations that correspond to the type of environment at the site. If no site-specific hydrogeologic information is known, IWEM will treat the site as being in subsurface environment number 13 and assign values that are national averages.

4.2.3.2 Unsaturated Zone Parameters

To model flow of infiltration water through the unsaturated zone, we used data on unsaturated hydraulic properties assembled by Carsel and Parrish (1988) in conjunction with information from the SCS on the nationwide prevalence of different soil types across the United States. First, we used SCS soil mapping data to estimate the relative prevalence of light- (sandy loam), medium- (silt loam), and heavy-textured (silty clay loam) soils across the United States. The estimated percentages are shown in Table 4.15. The soil types used in the unsaturated zone modeling were also used in the HELP model to derive infiltration and recharge rates (See Section 4.2.2) in order to have a consistent set of soil modeling parameters. We then used the soil property data reported by Carsel and Parrish to determine the probability distributions of individual soil parameters for each soil type, and used these distributions in the Monte Carlo modeling for Tier 1 and Tier 2. Table 4.16 presents the unsaturated zone parameter values used in the Tier 1 and Tier 2 development.

Table 4.15 Nationwide Distribution of Soil Types Represented in IWEM

Texture Category	SCS Soil Type	Relative Frequency (%)
Light textured	Sandy Loam	15.4
Medium textured	Silt Loam	56.6
Heavy textured	Silty Clay Loam	28.0

Table 4.16 Statistical Parameters for Soil Properties for Three Soil Types Used in IWEM Tier 1 and Tier 2 Development (Carsel and Parrish, 1988)

Parameter ¹	Distribution Type ²	Limits of Variation		Mean	Standard Deviation
		Minimum	Maximum		
Soil Type - Silty Clay Loam					
K _{sat} (cm/hr)	SB	0	3.5	0.017	2.921
2 _r	NO	0	0.115	0.089	0.0094
" (cm ⁻¹)	SB	0	0.15	.009	.097
\$	NO	1.0	1.5	1.236	0.061
% OM	SB	0	8.35	0.11	5.91
D _b	Constant	-	-	1.67	-
2 _s	Constant	-	-	0.43	-
Soil Type - Silt Loam					
K _{sat} (cm/hr)	LN	0	15.0	.343	.989
2 _r	SB	0	0.11	.068	0.071
" (cm ⁻¹)	LN	0	0.15	.019	0.012
\$	SB	1.0	2.0	1.409	1.629
% OM	SB	0	8.51	0.105	5.88
D _b	Constant	-	-	1.65	-
2 _s	Constant	-	-	0.45	-
Soil Type - Sandy Loam					
K _{sat} (cm/hr)	SB	0	30.0	2.296	24.65
2 _r	SB	0	0.11	0.065	0.074
" (cm ⁻¹)	SB	0	0.25	0.070	0.171
\$	LN	1.35	3.00	1.891	0.155
% OM	SB	0	11.0	0.074	7.86
D _b	Constant	-	-	1.60	-
2 _s	Constant	-	-	0.41	-

¹ K_{sat} is saturated hydraulic conductivity; 2_r is residual water content; ", \$ are retention curve parameters; % OM is percent Organic Matter, D_b is bulk density; 2_s is saturated water content.

² NO is Normal (Gaussian) distribution; SB is Log ratio distribution where $Y = \ln [(x-A)/(B-x)]$, $A < x < B$; LN is Log normal distribution, $Y = \ln [x]$, where Y = normal distributed parameter

The parameters ", \$, and 2_r in Table 4.16 are specific to the Mualem-Van Genuchten model that is employed in the EPACMTP unsaturated zone flow module described in Section 3.2 (see the EPACMTP Technical Background Document for details).

In addition to the soil hydraulic parameters listed in Table 4.16, IWEM also requires certain soil transport parameters. These are the soil bulk density and percent organic matter, which are used to calculate the constituent-specific retardation coefficients, the unsaturated zone dispersivity, and the soil pH and temperature. The

latter two parameters are used to calculate hydrolysis transformation rates; pH is also a key parameter for modeling transport of metals. Soil bulk density and percent organic matter were obtained from the Carsel and Parrish (1988) database and are presented in Table 4.16. These parameters are used to calculate the retardation factor in the constituent transport equation (Section 3.2). We used the data on the percent organic matter to calculate the fraction organic carbon according to:

$$foc = \frac{\% OM}{174}$$

where:

foc	=	Mass fraction organic carbon in the soil (kg/kg)
% OM	=	Percent organic matter
174	=	Conversion constant

We calculated dispersivity in the unsaturated zone, α_{uz} as a function of the travel distance (D_u , m) between the base of the WMU and the water table, according to the following relationship:

$$\alpha_{uz} = 0.02 + (0.022 \times D_u)$$

where:

α_{uz}	=	longitudinal dispersivity in the unsaturated zone (m)
D_u	=	Depth of the unsaturated zone, from the base of the WMU to the water table (m)

This relationship is based on a regression analysis of field scale transport data presented by Gelhar et al. (1985). We capped the maximum allowed value of dispersivity at one meter in IWEM.

Soil temperature and pH were obtained from nationwide distributions. For these parameters we used the same distributions for the entire aquifer, that is, both for the unsaturated zone and for the saturated zone. In both the Tier 1 and Tier 2 evaluations, we used a nationwide aquifer pH distribution, derived from EPA's STORET database. The pH distribution is an empirical distribution with a median value of 6.8 and lower and upper bounds of 3.2 and 9.7, respectively, as shown in Table 4.17.

Table 4.17 Probability Distribution of Soil and Aquifer pH

Percentile	0	1	5	10	25	50	75	90	95	99	100
pH Value	3.20	3.60	4.50	5.20	6.07	6.80	7.40	7.90	8.2	8.95	9.7

As modeled in IWEM, soil and aquifer temperature affects the transformation rate of constituents that are subject to hydrolysis, through the effect of temperature on reaction rates (see Section 4.2.4.1). In the IWEM development, we used information on average annual temperatures in shallow ground-water systems (Todd, 1980) to assign a temperature value to each WMU in the modeling database, based on the unit's geographical location. For each WMU site, the assigned temperature was an average of the upper and lower values for that temperature region, as shown in Figure 4.8. In other words, all WMU's located in the band between 10° and 15° were assigned a temperature value of 12.5 degrees C.

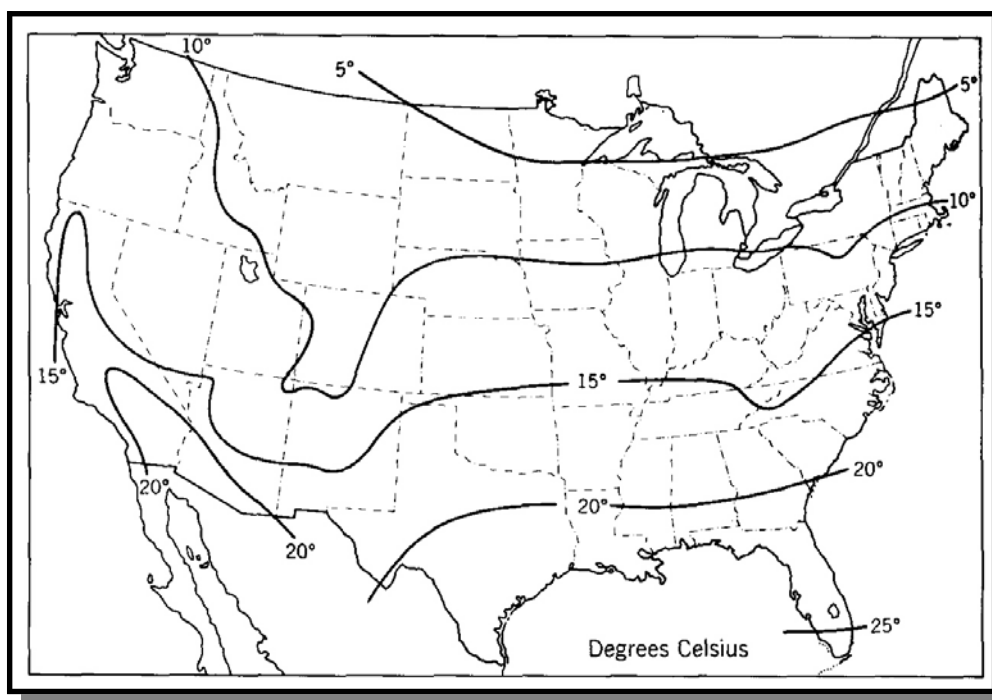


Figure 4.8 Ground-water Temperature Distribution for Shallow Aquifers in the United States (from Todd, 1980).

IWEM Monte Carlo Methodology for Soil Parameters

In both Tier 1 and Tier 2, we assumed that soil properties are uniform at each site. That is, while we selected a new set of soil parameters for each realization in the Tier 1 and Tier 2 modeling process, the soil properties were assumed uniform for a given realization. However, the methodology for assigning soil types differed. In Tier 1, we randomly selected one of the three soil types shown in Table 4.15 for each realization, with a probability given by each soil type's frequency of occurrence, i.e., we would select silt loam soils in 56.6% of the realizations, sandy loam soils in 15.4% of the cases, and silty clay loam soils in 28% of the cases. The selection of the soil type also determines the distribution of recharge and – for unlined and single-lined LF, WP, and LAUs – the infiltration rate through the unit (see Section 4.2.2). Based on the selected soil type, values for each of the unsaturated zone modeling parameters were generated using the distributions presented in Table 4.16.

In Tier 2, the soil type is a optional site-specific user input parameter. Because the site location must always be entered by the user, the selection of the soil type determines the recharge rate, as well as the HELP-derived infiltration rates which the IWEM tool will use in the evaluation. Based on the selected soil type, the IWEM tool will randomly select values for the parameters in Table 4.16 from the probability distributions corresponding to the soil type. If the soil type in Tier 2 is entered as “unknown”, the Tier 2 Monte Carlo process for the unsaturated zone parameters will default to that used in Tier 1, that is, IWEM will randomly select one of the three possible soil types in accordance with their nationwide frequency of occurrence.

4.2.3.3 Saturated Zone Parameters

In addition to the four site-related subsurface parameters discussed in Section 4.2.3.1, IWEM requires a number of additional saturated zone transport parameters. They are: saturated zone porosity; saturated zone bulk density; longitudinal, transverse and vertical dispersivities; fraction organic carbon; aquifer temperature; and aquifer pH.

Saturated zone porosity is used in the calculation of the ground-water seepage velocity; saturated zone porosity and bulk density are used in the calculation of constituent-specific retardation coefficients. In IWEM, we used default, nationwide distributions for aquifer porosity and bulk density, that is, they are not user inputs. Both were derived from a distribution of aquifer particle diameter presented by Shea (1974). This distribution is presented in Table 4.18. Using the data in Table 4.18 as an input distribution, IWEM calculates porosity, N , from particle diameter using an empirical relationship based on data reported by Davis (1969) as:

$$N = 0.261 - 0.0385 \ln (d)$$

where

- N = Porosity (dimensionless)
- d = Mean particle diameter (cm)
- ln = Natural logarithm

Additionally, we used relationships presented in McWorther and Sunada (1977), to establish relationships between total (N) and effective porosity (N_e) as a function of mean particle diameter, see Table 4.19.

Table 4.18 Empirical Distribution of Mean Aquifer Particle Diameter
(from Shea, 1974)

Percentile	0.0	3.8	10.4	17.1	26.2	37.1	56.0	79.2	90.4	94.4	97.6	100
Particle Diameter (cm)	3.9×10^{-4}	7.8×10^{-4}	0.0016	0.0031	0.0063	0.0125	0.025	0.05	0.1	0.2	0.4	0.8

Table 4.19 Ratio Between Effective and Total Porosity as a Function of Particle Diameter (after McWorther and Sunada, 1977)

Mean Particle Diameter (cm)	N_e/N Range
# 6.25×10^{-3}	0.03 - 0.77
6.25×10^{-3} - 2.5×10^{-2}	0.04 - 0.87
2.5×10^{-2} - 5.0×10^{-2}	0.31 - 0.91
5.0×10^{-2} - 10^{-1}	0.58 - 0.94
$> 10^{-1}$	0.52 - 0.95

IWEM calculates apparent saturated zone dispersivities as a function of the distance between the waste unit and the modeled ground-water well, using regression relationships based on a compilation of field-scale dispersivity data in Gelhar et al. (1985). These relationships are:

$$\begin{aligned} \alpha_L(x) &= \alpha_L^{REF} \times (x/152.4)^{0.5} \\ \alpha_T &= \alpha_L/8 \\ \alpha_V &= \alpha_L/160 \end{aligned}$$

where

x	=	downgradient ground-water travel distance (m)
α_L	=	longitudinal dispersivity (m)
α_T	=	horizontal transverse dispersivity (m)
α_V	=	vertical transverse dispersivity (m)
α_L^{REF}	=	reference dispersivity value (m)

We used the longitudinal dispersivity corresponding to a distance of 152.4 m (500 feet) as a reference to calculate dispersivity at different well distances, according to the probability distribution presented in Table 4.20.

Table 4.20 Cumulative Probability Distribution of Longitudinal Dispersivity at Reference Distance of 152.4 m (500 ft)

Percentile	0.0	1.00	70.0	100.0
Dispersivity, α_L^{REF} (m)	0.1	1.0	10.0	100.0

We used data as the fraction organic carbon in the aquifer (f_{oc}) to model sorption of organic constituents, as discussed in Section 3.2. In the development of the IWEM Tier 1 and Tier 2 evaluations, we used a nationwide distribution obtained from values of dissolved organic carbon in EPA's STORET water quality database. The distribution was modeled as a Johnson SB frequency distribution (see EPACMTP Parameters/Data Background Document) with a mean of 4.32×10^{-4} , a standard deviation of 0.0456, and lower and upper limits of 0.0 and 0.064, respectively.

We determined values of the ground-water temperature and pH in the same manner as we did for soil pH and temperature (see Section 4.2.3.2).

4.2.4 Parameters Used to Characterize the Chemical Fate of Constituents

For the Tier 1 and Tier 2 evaluations the chemical fate of constituents as they are transported through the subsurface is presented in terms of an overall first-order decay coefficient, a retardation coefficient which reflects equilibrium sorption reactions, and for transformation daughter-products, a production term that represents the formation of daughter compounds due to the transformation of parent constituents.

This section describes how we developed constituent-specific parameter values for these chemical fate processes. Section 4.2.4.1 describes constituent transformation processes, while Section 4.2.4.2 discusses all constituent degradation processes. Section 4.2.4.3 describes how we modeled sorption processes. Section 4.2.4.4 describes the

criteria we applied to determine whether constituents could be treated as being effectively non-reactive (i.e., zero transformation and sorption) in developing the Tier 1 evaluation.

4.2.4.1 Constituent Transformation

For organic constituents, IWEM accounts for chemical and biological transformations by considering a first-order overall degradation coefficient in the transport analysis (see Section 3.2). In Tier 1, we considered only hydrolysis reactions. In Tier 2, the default hydrolysis rate coefficients in the IWEM constituent database can be replaced with a user-specified overall degradation rate that can account for any type of transformation process, including biodegradation.

Hydrolysis

Hydrolysis refers to the transformation of chemical constituents through reactions with water. For organic constituents, hydrolysis can be one of the main degradation processes that occur in soil and ground water and is represented in the EPACMTP model by means of an overall first-order chemical decay coefficient. For modeling hydrolysis in the Tier 1 and Tier 2 evaluations, we used constituent-specific hydrolysis rate constants compiled at the EPA's Environmental Research Laboratory in Athens, GA (Kollig et al., 1993). These are listed in Appendix B.

The hydrolysis process as modeled in IWEM is affected by both aquifer pH, aquifer temperature and constituent sorption, through the following equations. The tendency of each constituent to hydrolyze is expressed through constituent-specific acid-catalyzed (K_a^T), neutral (K_n^T) and base-catalyzed (K_b^T) rate constants. The superscript T_r indicates that the values are measured at a specified reference temperature, T_r . First, the values of the rate constants are modified to account for the effect of aquifer temperature through the Arrhenius equation:

$$K_J^T = K_J^{T_r} \exp \left[E_a / R_g \left(\frac{1}{T_r + 273} - \frac{1}{T + 273} \right) \right]$$

where:

K_J^T	=	Hydrolysis rate constant for reaction process J and temperature T
J	=	a for acid, b for base, and n for neutral
T	=	Temperature of the subsurface (°C)
T_r	=	Reference temperature (°C)
R_g	=	Universal gas constant (1.987E-3 Kcal/deg-mole)
E_a	=	Arrhenius activation energy (Kcal/mole)

Next, the effect of pH on hydrolysis rates is incorporated via:

$$\lambda_1 = K_a^T [H^+] + K_n^T + K_b^T [OH^-]$$

where

- δ_1 = First-order decay rate for dissolved phase (1/yr)
- K_a^T, K_n^T, K_b^T = Hydrolysis rate constants
- $[H^+]$ = Hydrogen ion concentration (mole/L)
- $[OH^-]$ = Hydroxyl ion concentration (mole/L)

$[H^+]$ and $[OH^-]$ are computed from the pH of the soil or aquifer using

$$[H^+] = 10^{-pH}$$

$$[OH^-] = 10^{-(14-pH)}$$

The sorbed phase hydrolysis rate is calculated as:

$$\lambda_2 = 10K_a^T [H^+] + K_n^T$$

where:

- δ_2 = First-order hydrolysis rate for sorbed phase (1/yr)
- K_a^T = Acid-catalyzed hydrolysis rate constant (1/mole/yr)
- K_n^T = Neutral hydrolysis rate constant (1/yr)
- 10 = Acid-catalyzed hydrolysis enhancement factor

Finally, the overall first-order transformation rate for hydrolysis is calculated as:

$$\lambda = \frac{\lambda_1 \phi + \lambda_2 \rho_b k_d}{\phi + \rho_b k_d}$$

where:

θ	=	Overall first-order hydrolysis transformation rate (1/yr)
θ_1	=	Dissolved phase hydrolysis transformation rate (1/yr)
θ_2	=	Sorbed phase hydrolysis transformation rate (1/yr)
N	=	Porosity (water content in the unsaturated zone) (dimensionless)
D_b	=	Bulk density (kg/L)
K_d	=	Partition coefficient (L/kg)

We used the information on hydrolysis transformation pathways presented in Kollig et al. (1993) to identify toxic hydrolysis daughter products; Section 6 of this document describe how we incorporated this information into the determination of Tier 1 and Tier 2 LCTVs.

4.2.4.2 Other Constituent Degradation Processes

Many organic constituents may be subject to biodegradation in the subsurface, and in Tier 2, the IWEM tool allows the user to provide a constituent-specific overall degradation coefficient, which can include both aerobic or anaerobic biodegradation. IWEM does not specifically simulate biodegradation reactions, and therefore, the IWEM user must ensure that the value entered is representative of actual site conditions, and that the transformation reactions can be adequately characterized as a first-order rate process, (that, is a process that can be represented in terms of a characteristic half-life). The overall degradation rate parameter that is used as a Tier 2 input is related to the constituent's subsurface half-life and is expressed as:

$$\lambda = 0.693/t_{1/2}$$

where

θ	=	IWEM degradation rate input value (1/yr)
$t_{1/2}$	=	Constituent half-life (yr)

4.2.4.3 Constituent Sorption

In addition to physical and biological transformation processes, the transport of constituents can be affected by a wide range of complex geochemical reactions. From a practical view, the important aspect of these reactions is the removal of solute from solution, irrespective of the process. For this reason IWEM lumps the cumulative effects of the geochemical processes into a single term (i.e., solid-water partition coefficient)

which is one of several parameters needed to describe the degree to which a constituents mobility is retarded relative to ground water. In the EPACMTP fate and transport model upon which IWEM is based, this process is defined by the retardation factor defined in Section 3.2. The remainder of this section describes the procedures we used to model sorption for organic constituents and inorganic constituents, specifically, metals.

4.2.4.3.1 Sorption Modeling for Organic Constituents

For organic constituents we determined k_d values as the product of the constituent-specific K_{oc} and the fraction organic carbon in the soil or ground water:

$$k_d = K_{oc} \times f_{oc}$$

where

- k_d = partition coefficient (L/kg),
- K_{oc} = normalized organic carbon distribution coefficient (kg/L), and
- f_{oc} = fractional organic carbon content (dimensionless)

K_{oc} values for IWEM constituents are listed in Appendix B. For IWEM, we calculated the fraction organic carbon in the unsaturated zone from the percent organic matter in the soil (see section 4.2.3.2) as:

$$f_{oc} = \frac{\%OM}{174}$$

where

- f_{oc} = fractional organic carbon content (kg/kg),
- $\%OM$ = percent organic matter in the soil, and
- 174 = conversion factor.

In the saturated zone modeling we used the nation-wide data on the fraction organic carbon on ground water to provide direct values for f_{oc} (see Section 4.2.3.3)

4.2.4.3.2 Sorption Modeling for Inorganic Constituents (Metals)

Partition coefficients (k_d) for metals in the IWEM tool modeling are selected from non-linear sorption isotherms estimated using the geochemical speciation model, MINTEQA2. For a particular metal, k_d values in a soil or aquifer are dependent upon the metal concentration and various geochemical characteristics of the soil or aquifer and the associated porewater.

Geochemical parameters that have the greatest influence on the magnitude of k_d include the pH of the system and the nature and concentration of sorbents associated with the soil or aquifer matrix. In the subsurface beneath a disposal facility, the concentration of leachate constituents may also influence k_d . Although the dependence of metal partitioning on the total metal concentration and on pH and other geochemical characteristics is apparent from partitioning studies reported in the scientific literature, the reported k_d values for individual metals do not cover the range of metal concentrations or geochemical conditions relevant in the IWEM scenarios. For this reason, we chose to use an equilibrium speciation model, MINTEQA2, to estimate metals partition coefficients for the IWEM development. We used the speciation model to estimate k_d values for a range of total metal concentrations in various model systems designed to depict natural variability in those geochemical characteristics that most influence metal partitioning.

From input data consisting of total concentrations of inorganic chemicals, MINTEQA2 calculates the fraction of a constituent metal that is dissolved, adsorbed, and precipitated at equilibrium. The ratio of the adsorbed fraction to the dissolved fraction is the dimensionless partition coefficient. We converted the dimensionless partition coefficient to k_d with units of liters per kilogram (L/kg) by normalizing the mass of soil (in kg) with one liter of porewater in which it is equilibrated (the phase ratio).

We used MINTEQA2 to develop isotherms for Antimony (Sb-5+), Arsenic (As-3+ and As-5+), Barium (Ba), Beryllium (Be), Cadmium (Cd), Chromium (Cr-3+ and Cr-6+), Cobalt (Co), Copper (Cu), Fluoride (F), Manganese (Mn-2+), Mercury (Hg), Lead (Pb), Molybdenum (Mo-5+), Nickel (Ni), Selenium (Se-4+ and Se-6+), Silver (Ag), Thallium (Tl-1+), Vanadium (V-5+), and Zinc (Zn).

MINTEQA2 Input Parameters

We accounted for the expected natural variability in k_d for a particular metal in the MINTEQA2 modeling by including variability in important input parameters upon which k_d depends. The input parameters for which variability was incorporated include ground-water compositional type, pH, concentration of sorbents, and concentration of metal. In addition, we varied the concentration of representative anthropogenic organic acids that may be present in leachate from a waste site.

We modeled two ground-water compositional types – one with composition representative of a carbonate-terrain system and one representative of a non-carbonate system. The two ground-water compositional types are correlated with the subsurface environment (see Section 4.2.3.1, Table 4.14). The carbonate type corresponds to the “solution limestone” subsurface environment setting. The other eleven subsurface environments in IWEM are represented by the non-carbonate ground-water type. If the

subsurface environment is “unknown”, then IWEM will also assume it is a non-carbonate type. For both ground-water types, a representative, charge-balanced ground-water chemistry specified in terms of major ion concentrations and natural pH was selected from the literature. The carbonate system was represented by a sample reported in a limestone aquifer. This ground water had a natural pH of 7.5 and was saturated with respect to calcite. The non-carbonate system was represented by a sample reported from an unconsolidated sand and gravel aquifer with a natural pH of 7.4. We selected an unconsolidated sand and gravel aquifer to represent the non-carbonate compositional type because it is the most frequently occurring of the twelve subsurface environments in HGDB database.

We included two types of adsorbents in modeling the k_d values: ferric oxide (FeOx) and particulate organic matter (POM). Mineralogically, the ferric oxide was assumed to be goethite (FeOOH). We used a database of sorption reactions for goethite reported by Mathur (1995) with the diffuse-layer sorption model in MINTEQA2 to represent the interactions of protons and metals with the goethite surface. The concentration of sorption sites used in the model runs was based on a measurement of ferric iron extractable from soil samples using hydroxylamine hydrochloride as reported in EPRI (1986). This method of Fe extraction is intended to provide a measure of the exposed amorphous hydrous oxide of Fe present as mineral coatings and discrete particles and available for surface reaction with pore water. The variability in FeOx content represented by the variability in extractable Fe from these samples was included in the modeling by selecting low, medium and high FeOx concentrations corresponding to the 17th, 50th and 83rd percentiles of the sample measurements. The specific surface area and site density used in the diffuse-layer model were as prescribed by Mathur. Although we used the same distribution of extractable ferric oxide sorbent in the saturated and unsaturated zones, the actual concentration of sorbing sites corresponding to the low, medium, and high FeOx settings in MINTEQA2 was different in the two zones because the phase ratio was different (4.57 kg/L in the unsaturated zone; 3.56 kg/L in the saturated zone.)

We obtained the concentration of the second adsorbent, POM, from organic matter distributions already present in the IWEM modeling database. In the unsaturated zone, low, medium, and high concentrations for components representing POM in the MINTEQA2 model runs were based on the distribution of solid organic matter for the silt loam soil type. (The silt loam soil type is intermediate in weight percent organic matter in comparison with the sandy loam and silty clay loam soil types and is also the most frequently occurring soil type among the three.) The low, medium, and high POM concentrations used in the saturated zone MINTEQA2 model runs were obtained from the organic matter distribution for the saturated zone. For both the FeOx and POM adsorbents, the amount of sorbent included in the MINTEQA2 modeling was scaled to correspond with the phase ratio in the unsaturated and saturated zones.

We obtained a dissolved organic matter (DOM) distribution for the saturated zone from the EPA's STORET database. This distribution was used to provide low, medium, and high DOM concentrations for the MINTEQA2 model runs. The low, medium, and high DOM values were used exclusively with the low, medium, and high values, respectively, of POM. In the unsaturated zone, there was no direct measurement of DOM available. The ratio of POM to DOM for the three concentration levels (low, medium, high) in the unsaturated zone was assumed to be the same as for the saturated zone. In MINTEQA2, the POM and DOM components were modeled using the Gaussian distribution model. This model includes a database of metal-DOM reactions (Susetyo et al., 1991). Metal reactions with POM were assumed to be identical in their mean binding constants with the DOM reactions.

Leachate exiting a WMU may contain elevated concentrations of anthropogenic leachate organic acids (LOA). We included representative carboxylic acids for leachate from industrial WMUs in the MINTEQA2 modeling. An analysis of total organic carbon (TOC) in LF leachate by Gintautas et al. (1993) was used to select and quantify the organic acids. We assigned the low, medium, and high values for the representative acids in the modeling based on the lowest, the average, and the highest measured TOC among the six LF leachates analyzed. Because we expect leachate from industrial WMUs to be lower in organic matter than in municipal LFs, we included only the low and medium LOA values in IWEM.

MINTEQA2 Modeling and Results

We conducted the MINTEQA2 modeling separately for each metal in three steps for the unsaturated zone, and these were repeated for the saturated zone:

- # Sorbents were pre-equilibrated with ground waters: Each of nine possible combinations of the two FeOx and POM sorbent concentrations (low FeOx, low POM; low FeOx, medium POM; etc.) were equilibrated with each of the two ground-water types (carbonate and non-carbonate). Because the sorbents adsorb some ground-water constituents (calcium, magnesium, sulfate, fluoride), the input total concentrations of these constituents were adjusted so that their equilibrium dissolved concentrations in the model were equal to their original (reported) ground-water dissolved concentrations. This step was conducted at the natural pH of each ground water, and calcite was imposed as an equilibrium mineral for the carbonate ground-water type. Small additions of inert ions were added to maintain charge balance.
- # The pre-equilibrated systems were titrated to new target pH's: Each of the nine pre-equilibrated systems for each ground-water type were titrated

with NaOH to raise the pH or with HNO₃ to lower the pH. Nine target pH's spanning the range 4.5 to 8.2 were used for the non-carbonate ground water. Three target pH's spanning the range 7.0 to 8.0 were used for the carbonate ground water. Titration with acid or base to adjust the pH allowed charge balance to be maintained.

- # LOAs and the constituent metal were added: Each of the eighty-one pre-equilibrated, pH-adjusted systems of the non-carbonate ground water and the twenty-seven pre-equilibrated, pH-adjusted systems of the carbonate ground water were equilibrated with two concentrations (low and medium) of LOAs. The equilibrium pH was not imposed in MINTEQA2; pH was calculated and reflected the acid and metal additions. The constituent metal was added as a metal salt (e.g., PbNO₃) at a series of forty-four total concentrations spanning the range 0.001 mg/L to 10,000 mg/L of metal. Equilibrium composition and K_d were calculated at each of the forty-four total metal concentrations to produce an isotherm of sorbed metal versus metal concentration. The isotherm can also be expressed as k_d versus metal concentration.

This modeling resulted in eighty-one isotherms for the non-carbonate environment and twenty-seven isotherms for the carbonate environment for the unsaturated zone. A like number of isotherms for each environment was produced for the saturated zone. Each isotherm corresponds to a particular setting of FeOx sorbent concentration, POM sorbent (and associated DOM) concentration, leachate acid concentration, and pH. An example isotherm for Cr(VI) is shown in Figure 4.9. This isotherm corresponds to the following conditions: low LOAs, medium FeOX concentration, high POM concentration, for pH 6.3 in unsaturated zone, non-carbonate environment.

We computed isotherms for two environmentally relevant oxidation states of chromium, arsenic, and selenium. The different oxidation states of these metals have different geochemical behavior, and in the case of chromium also distinctly different toxicological behavior. Chromium-3+ exhibits behavior typical of a cation, but chromium-6+ behaves as an anion (chromate). Chromium-3+ and chromate are most strongly sorbed at opposite ends of the pH spectrum: sorption of chromium-3+ tends to increase with pH over the pH range 4 to 8, whereas sorption of chromate tends to decrease with pH over this range. In addition, separate health-based toxicity values have been established for chromium-3+ and chromate. The dissimilarity in sorption behavior and the availability of separate toxicity benchmarks warrants treating chromium-3+ and

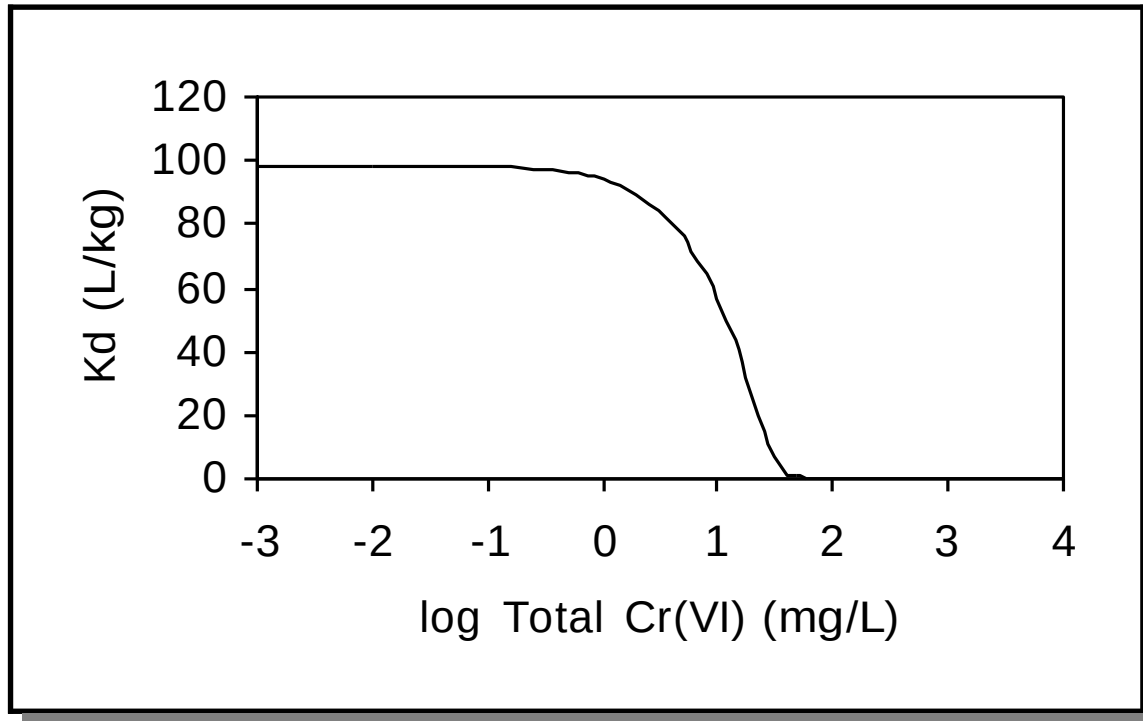


Figure 4.9 Example Unsaturated Zone Isotherm for Cr(VI) Corresponding to Low LOA, Medium FeOx, High POM, pH-6.3.

chromate as if they were separate metals. Thus, IWEM considers chromium-3+ and chromium-6+ as different constituents and we used both sets of Cr isotherms to produce Tier 1 LCTVs for both forms.

The two oxidation states of arsenic and selenium also exhibit differences in sorption behavior, but both metals tend always to behave as anions. Unlike chromium, separate toxicity values have not been established for the two forms of arsenic and selenium. We therefore incorporated the more mobile forms only of arsenic and selenium in IWEM as the more protective approach. We ran EPACMTP with both sets of isotherms for these metals to discover which oxidation state was more mobile. The results indicate that As and Se should be assumed to be present as As-5+ and Se-6+. Accordingly, these are the species used in producing the Tier 1 LCTVs, and partition coefficients for these are provided for use in Tier 2 modeling.

4.2.4.4 Partition Coefficient and Degradation Rate Threshold Criteria EPA Used to Define Conservative Constituents in Developing the Tier 1 Evaluation

In developing the Tier 1 LCTVs, we conducted a very large number of EPACMTP Monte Carlo runs to account for all constituents and combinations of WMU types and liner designs. We expedited these modeling analyses by treating all conservative organic constituents as a single group. This was permissible, because as modeled in EPACMTP, constituents that have the same fate characteristics will show the same subsurface transport behavior.

A conservative chemical is defined as a chemical that neither adsorbs to the soil matrix nor degrades as it is transported through the subsurface. Metals are not regarded as conservative chemicals because they tend to sorb strongly to the soil matrix. Organic chemicals, however, vary in degrees of sorptivity and susceptibility to degradation. Some of the organic chemicals may be approximated as equivalent to conservative chemicals due to their recalcitrance to degradation and low sorptivity. The sorptivity and degradation of organic chemicals are governed by two key parameters: the organic carbon distribution coefficient (K_{oc}) and the effective degradation rate constant (δ), respectively. For an organic to be considered conservative, it must have sufficiently small K_{oc} and δ .

We determined cutoff values for K_{oc} and δ by conducting a sensitivity analysis for selected waste management scenarios, each with several combinations of K_{oc} and δ . Based on the results of this analysis, we used threshold values of $K_{oc} = 100 \text{ L/kg}$, and $\delta = 1 \times 10^{-4} \text{ 1/year}$ to categorize constituents as conservative for the purpose of developing the IWEM Tier 1 LCTVs for unlined and single-lined WMUs only. In other words, we treated constituents with K_{oc} and δ values below these thresholds as conservative species. For all composite liner evaluations, we conducted individual Monte Carlo runs for each chemical. The reason is that at the low infiltration rates associated with composite liners, the DAF values predicted by EPACMTP become very sensitive to even small differences in K_{oc} and δ .

4.2.5 Well Location Parameters

In the IWEM Tier 1 and Tier 2 development, we modeled the ground-water exposure location as the intake point of a ground-water well located down gradient from the WMU. The location of the well in IWEM is described by three parameters:

- # Downgradient distance from the waste unit (x-location)
- # Transverse distance from the plume centerline (y-location)
- # Vertical distance below the water table (z-location)

The well location parameters are depicted schematically in Figure 4.10, which shows the location of the well relative to WMU in plan view and in cross-section view.

Downgradient Distance from WMU (m)

This parameter represents the distance between the downgradient edge of the WMU and the position of the well, measured along the direction of ground-water flow. This direction represents the x- coordinate as depicted in Figure 4.10. In Tier 1, we assigned this parameter a fixed value of 150 meters. In Tier 2, this parameter is an optional site-specific user input value, with a maximum allowed value of 1609 meters (1 mile). The default value in Tier 2 is 150 meters.

Well Transverse Distance from the Plume Centerline (m)

This parameter represents the horizontal distance between the well and the modeled centerline of the plume, see Figure 4.10. For the Tier 1 and Tier 2 evaluations, we always set this parameter to zero, that is, we modeled the ground-water well as always being located at the centerline of the plume. This is a protective assumption because the ground-water concentrations predicted by the model will be highest along the centerline of the plume, and decrease with distance away from the centerline.

Well Intake Depth Below the Water Table (m)

This parameter represents the vertical distance of the well intake point below the water table. In calculating the position of the well intake, the model uses the water table elevation before any mounding effects are taken into consideration. In both Tier 1 and Tier 2, we assigned the well depth parameter a uniform probability distribution with a range of 0 - 10 meters. This means that all depth values are between 0 to 10 meters below the water table are equally likely. For each Monte Carlo realization in which the modeled saturated zone thickness is less than 10 meters, the maximum well depth of 10 meters is replaced with the actual saturated zone thickness used in the realization.

4.2.6 Screening Procedures EPA Used to Eliminate Unrealistic Parameter Combinations in the Monte Carlo Process

Inherent to the Monte Carlo process is that parameter values are drawn from multiple data sources, and then combined in each realization of the modeling process. Because the parameter values are drawn randomly from their individual probability distributions, it is possible that parameters are combined in ways that are physically infeasible and that violate the validity of the EPACMTP flow and transport model. We

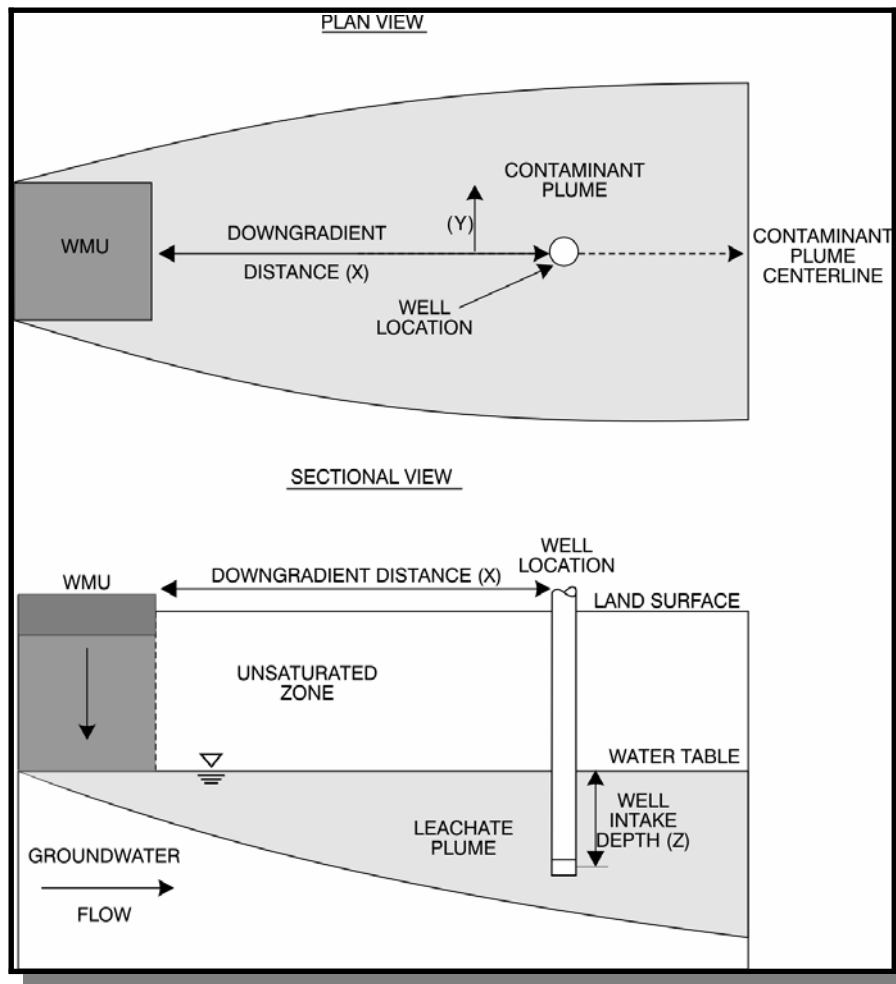


Figure 4.10 Position of the Modeled Ground-water Well Relative to the WMU.

implemented a number of checks to eliminate or reduce these occurrences as much as possible. As a relatively simple measure, upper and lower limits are specified on individual parameter values to ensure that their randomly generated values are within physically realistic limits. Where possible, we used data sources that contained multiple parameters, and implemented these in the Monte Carlo process in a way that preserved the existing correlations among the parameters. For example, we used the HGDB database of subsurface parameters (see Section 4.2.3) in combination with knowledge of the subsurface environments at each waste site location in our WMU parameter database to assign the most appropriate combinations of subsurface parameters to each site.

infiltration modeling database of 102 climate stations, as described in Section 4.2.2.

We also specified upper and lower limits on secondary parameters whose values are calculated (derived) internally in the Monte Carlo module as functions of the primary EPACMTP input parameters, see the EPACMTP Parameters/Data Background Document (U.S. EPA, 2002b), and implemented a set of screening procedures to ensure that infiltration rates and the resulting predicted ground-water mounding would remain physically plausible. Specifically, we screened the parameter values generated in each Monte Carlo realization for the following conditions:

- # Infiltration and recharge so high they cause the water table to rise above the ground surface;
- # Water level in a SI unit below the water table, causing flow into the SI; and
- # Infiltration rate from a SI exceeds the saturated hydraulic conductivity of the soil underneath.

These screening procedures are discussed in more detail below. Mathematical details of the screening algorithms are presented in the EPACMTP Technical Background Document (U.S. EPA, 2002a).

The logic diagram for the infiltration screening procedure is presented in Figure 4.11; Figure 4.12 provides a graphical illustration of the screening criteria. The numbered criteria checks in Figure 4.11 correspond to the numbered diagrams in Figure 4.12. Note that high infiltration rates are most likely with (unlined) SIs. Therefore, the screening procedure is the most involved for SI WMUs.

Figure 4.11(a) depicts the screening procedures for LFS, WPs, and LAUs. For these units, after the four correlated subsurface parameters (depth to water table, aquifer saturated thickness, aquifer hydraulic conductivity, and regional gradient), as well as recharge associated with the selected soil type and the nearest climate center, and source infiltration have been generated for each Monte Carlo realization, the IWEM tool calculates the estimated water table mounding that would result from the selected combination of parameter values. The combination of parameters is accepted if the calculated maximum water table elevation (the ground-water ‘mound’) remains below the ground surface elevation at the site. If the criterion is not satisfied, the selected parameters for the realization is rejected and a new data set is selected.

Likewise, we classified and added additional screening steps, as depicted in Figure 4.11(b). At each Monte Carlo realization, a SI unit is selected from the SI WMU database. The unit-specific parameter, including ponding depth, and base depth below ground surface are retrieved from the database. The four correlated subsurface parameters are then selected from the hydrogeologic database, based on the subsurface environment at that WMU location. Using the information on the base depth and water table elevations, we can determine whether the SI unit is hydraulically connected to the water table. If the base of the SI is below the water table, the SI unit is said to be hydraulically connected to the water table (see Figure 4.12, Criterion 1). The realization is rejected and a new set of hydrogeologic parameters is generated if the hydraulically connected SI is an inseeping type, that is, the water surface in the SI is below the water table (see Figure 4.12, Criterion 1(b)). As long as the elevation of the waste water surface in the impoundment is above the watertable, the first criterion is passed (Figure 4.12, Criterion 1(a)).

If the base of the unit is located above the ambient water table, that is, before any adjustment to the water table elevation to account for mounding is made, the unit is said to be hydraulically separated from the water table (see Figure 4.12, Criterion 2). However, in this case, it is necessary to ensure that the calculated infiltration rate does not exceed the maximum feasible infiltration rate. The maximum feasible infiltration rate is the maximum infiltration that allows the water table to be hydraulically separated from the SI. In other words, it is the rate that does not allow the crest of the local ground-water mound to be higher than the base of the SI. This limitation allows us to determine a conservative infiltration rate that is based on the free-drainage condition at the base of the SI. The infiltration rate is no longer conservative if the water table is allowed to be in hydraulic contact with the base of the SI. If the maximum feasible infiltration rate ($I_{\max}$) is exceeded, IWEM will set the infiltration rate to this maximum value.

IWEM handles the screening in this order to accommodate the internal software logic in EPACMTP. If the SI is a hydraulically connected type based on the user-supplied information on the WMU and water table positions, EPACMTP will simulate this system by by-passing the unsaturated zone module. On the other hand, if the hydraulic connection results from water table mounding, i.e., the original water table elevation is below the WMU, EPACMTP cannot easily handle this situation, and the realization is therefore rejected.

Once the infiltration limit has been imposed, the third criterion is checked to ensure that any ground-water mounding does not result in a rise of the water table mound above the ground surface, in the same manner as done for other types of WMU.

In the IWEM software, the parameter constraints are checked after all Tier 2 inputs have been specified, but before the actual EPACMTP Monte Carlo simulations are initiated. The first check applies when the user provides all Tier 2 input parameters as

site-specific values. In this case, the software checks that the combination of input values does not violate the infiltration and water table elevation constraints. The second check applies when some Tier 2 inputs are set to site-specific values, while default probability distributions are used for other Tier 2 inputs. In this case, it is possible that the combination of fixed, site-specific values with national or regional distributions, results in a high frequency of rejections in the EPACMTP simulations. An example would be simulating an unlined SI at a site where the depth to ground-water is set to a very small value. This combination is likely to lead to a large number of rejections in the EPACMTP Monte Carlo simulation due to violation of the ground-water mounding constraint. This, in turn, may result in very long EPACMTP run times. It also indicates that IWEM may not be appropriate for that site.

IWEM therefore checks the Tier 2 user inputs through a probabilistic screening routine which generates random combinations of EPACMTP parameter values in accordance with the specified Tier 2 inputs and measures the number of rejections. This routine will check that 20,000 acceptable parameter combinations can be generated in 100,000 or less random realizations. If the inputs fail this test, the software will report the most frequently violated constraint and suggest potential remedies in the user inputs.

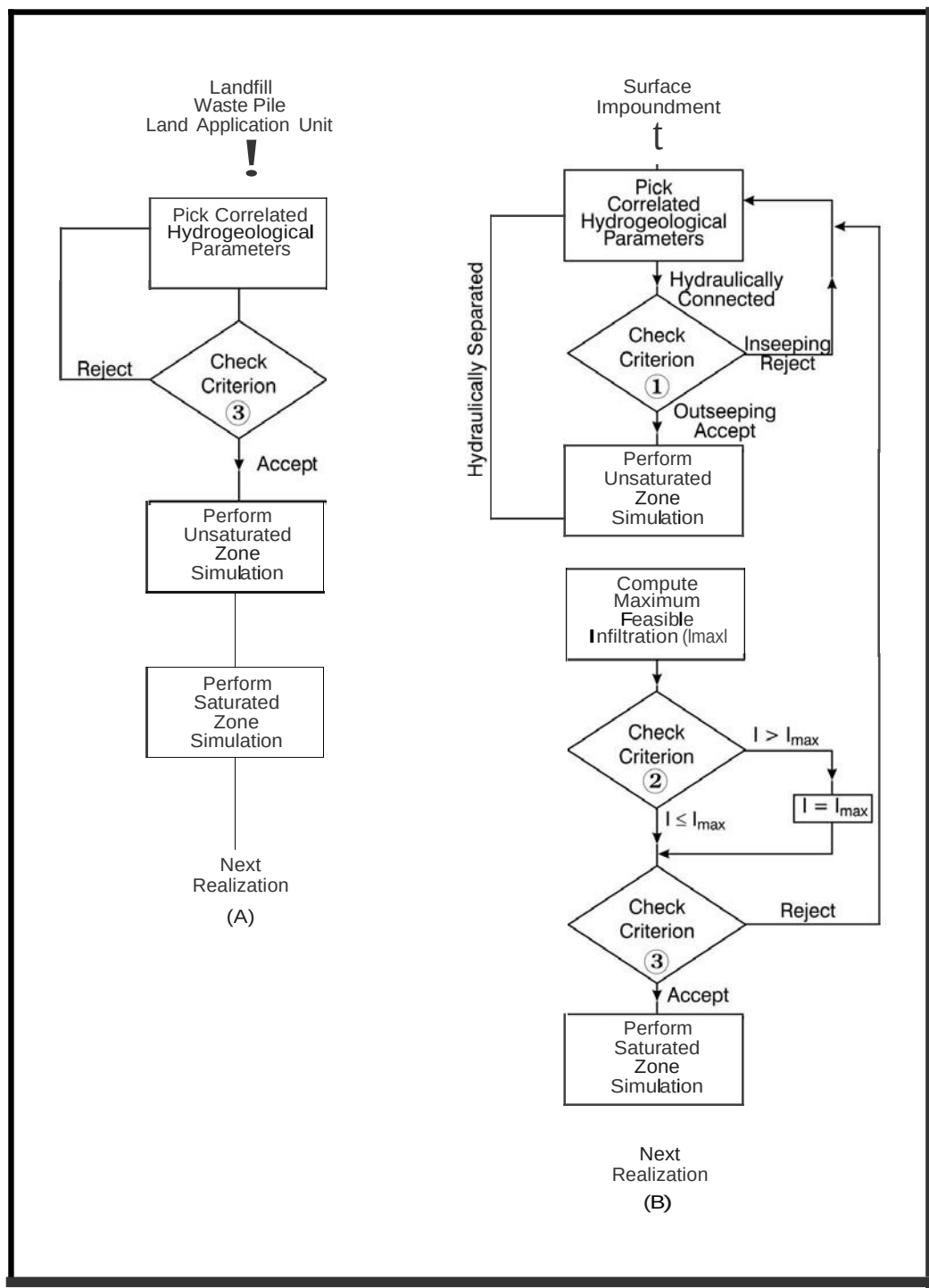


Figure 4.11 Flowchart Describing the Infiltration Screening Procedure.

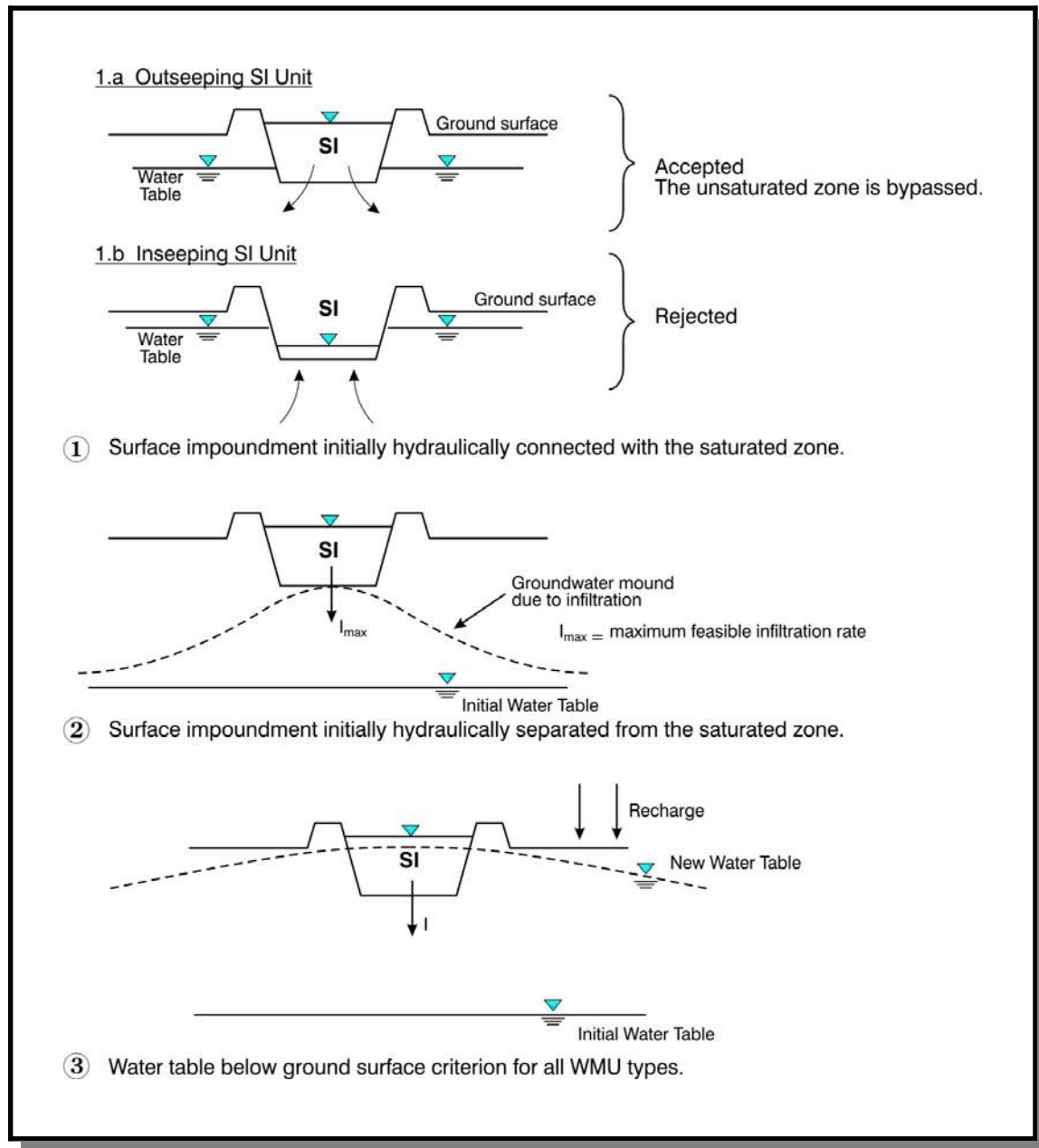


Figure 4.12 Infiltration Screening Criteria.

5.0 Establishing Reference Ground-water Concentrations

This section presents the RGCs that we used to establish protective constituent concentrations in the modeled well. The constituent-specific MCL and HBN values we used in IWEM are provided in Table 5.4 at the end of this chapter. Appendix E of this background document provides detailed background information on the methodology and human health benchmarks used in developing the HBNs.

The IWEM Tier 1 and Tier 2 evaluations incorporate two types of RGCs:

- # Maximum Contaminant Levels (MCLs). MCLs are available for some constituents in IWEM. MCLs are maximum constituent concentrations allowed in public drinking water and are established under the SDWA. In developing MCLs, EPA considers not only a constituent's health effects, but also additional factors, such as the cost of treatment.
- # Health-based numbers (HBNs). HBNs (for ingestion and/or inhalation route(s) of exposure) are available for all constituents. To calculate HBNs, we only consider parameters that describe a constituent's toxicity and a receptor's exposure to the constituent. For the purposes of developing the Tier 1 and Tier 2 evaluations, HBNs are the maximum constituent concentrations in ground water that we expect generally will not cause adverse noncancer health effects in the general population (including sensitive subgroups), or that will not result in an additional incidence of cancer in more than approximately one in one million individuals exposed to the constituent.

The sections below provide our methodology for calculating the cancer and noncancer HBNs for ingestion and inhalation of the constituents included in the IWEM software. We calculated the HBNs by "rearranging" standard risk equations (see EPA's Risk Assessment Guidance for Superfund: Volume 1 – Human Health Evaluation Manual [U.S. EPA, 1991a]) so that we could calculate constituent concentration, rather than cancer risk or noncancer hazard. The standard equations for cancer risk and noncancer hazard are comprised of two sets of variables: variables that describe an individual's exposure to a constituent and a variable that describes the toxicity of the constituent.

Exposure is the condition that occurs when a constituent comes into contact with the outer boundary of the body, such as the mouth and nostrils. Once EPA establishes the concentrations of constituents at the points of exposure, we can estimate the magnitude of each individual's exposure, or the potential dose of constituent. The dose is

the amount of the constituent that crosses the outer boundary of the body and is available for absorption at internal exchange boundaries (lungs, gut, skin) (U.S. EPA, 1992). For example, if an exposure to a carcinogen through ingestion of contaminated drinking water occur, the dose is a function of the concentration of the constituent in drinking water (assumed to be the concentration of the constituent at the receptor well), as well as certain “exposure factors,” such as how much drinking water the individual consumes each day (the intake rate), the period of time over which the individual is exposed to the contaminated drinking water (the exposure duration), how often the individual is exposed to contaminated drinking water during the exposure duration (the exposure frequency), and the body weight of the individual. For effects such as cancer, where we usually describe the biological response in terms of lifetime probabilities even though exposure does not occur over the entire lifetime, we average doses over an individual’s lifetime, which we call the “averaging time.”

Constituent toxicity is described through the use of “human health benchmarks.” Human health benchmarks are quantitative expressions of dose-response relationships. Human health benchmarks include:

- # Oral cancer slope factors (CSFo) for oral exposure to carcinogenic (cancer-causing) constituents;
- # Reference doses (RfD) for oral exposure to constituents that cause noncancer health effects;
- # Inhalation cancer slope factors (CSFi), that are derived from Unit Risk Factors (URFs), for inhalation exposure to carcinogenic constituents; and
- # Reference concentrations (RfC) for inhalation exposure to constituents that cause noncancer health effects.

EPA defines the cancer slope factor (CSF) as “an upper bound, approximating a 95% confidence limit, on the increased cancer risk from a lifetime exposure to an agent [constituent].” Because the CSF is an upper bound estimate of increased risk, EPA is reasonably confident that the “true risk” will not exceed the risk estimate derived using the CSF and that the “true risk” is likely to be less than predicted. CSFs are expressed in units of proportion (of a population) affected per milligram/kilogram/day (mg/kg/day). For non-cancer health effects, we use the RfD and the RfC as health benchmarks for ingestion and inhalation exposures, respectively. RfDs and RfCs are estimates of daily oral exposure (in the case of an RfD) or a continuous inhalation exposure (in the case of an RfC) that is likely to be without an appreciable risk of adverse effects in the general population, including sensitive individuals, over a lifetime. The methodology used to

develop RfDs and RfCs is expected to have an uncertainty spanning an order of magnitude.

We combined estimates of constituent dose and estimates of constituent toxicity (the health benchmarks) to calculate estimates of excess lifetime cancer risk for individuals who may be exposed to carcinogenic constituents and HQs for those constituents that produce noncancer health effects. Excess lifetime cancer risk is the incremental probability (chance) of an individual developing cancer over a lifetime as a result of exposure to a carcinogen. We estimate cancer risk resulting from exposure to a carcinogenic constituent by multiplying the constituent's CSF by our estimate of constituent dose. We calculate a receptor's ingestion HQ resulting from exposure to a noncarcinogenic constituent by dividing our estimate of daily constituent dose by the RfD (the HQ is the ratio of an individual's chronic daily constituent dose to the RfD for chronic exposures to the constituent). We calculated a receptor's inhalation HQ by dividing the concentration of the constituent in air by the RfC.

We developed the IWEM HBNs to correspond to a "target risk" and a "target HQ." The target risk we use to calculate the HBNs for carcinogens is 1×10^{-6} (one in one million). The target HQ we use to calculate the HBNs for noncarcinogens is 1 (unitless). A HQ of 1 indicates that the estimated dose is equal to the RfD and, therefore, an HQ of 1 is frequently EPA's threshold of concern for noncancer effects. These targets are used to calculate separate HBNs for each constituent of concern, and separate HBNs for each exposure route of concern (ingestion or inhalation). The Tier 1 and Tier 2 evaluations do not consider combined exposure from ground-water ingestion (from drinking water) and ground-water inhalation (from showering), nor do they consider the potential for additive exposure to multiple constituents.

Usually, doses less than the RfD (HQ=1) are not likely to be associated with adverse health effects and, therefore, are less likely to be of regulatory concern. As the frequency and/or magnitude of the exposures exceeding the RfD increase (HQ>1), the probability of adverse effects in a human population increases. However, it should not be categorically concluded that all doses below the RfD are "acceptable" (or will be risk-free) and that all doses in excess of the RfD are "unacceptable" (or will result in adverse effects).

5.1 Ingestion HBNs

Section 5.1.1 describes how we calculated ingestion HBNs for constituents that cause cancer, and Section 5.1.2 describes how we calculated ingestion HBNs for constituents that cause adverse health effects other than cancer.

5.1.1 Ingestion HBNs for Constituents That Cause Cancer

To calculate ingestion HBNs for carcinogens, we rearranged the standard equation for estimating risk so that instead of solving for risk, we solve for constituent concentration in water. The constituent concentration in water that corresponds to the target cancer risk is the cancer HBN for ingestion exposures, as follows:

$$C_{INGEST\_HBN} = \frac{Risk\_target \cdot AT \cdot 365}{CSFo \cdot EF \cdot ED \cdot CRw}$$

where

C_{INGEST_HBN}	=	cancer HBN for ingestion of water (mg/L)
$Risk\_target$	=	target risk for carcinogens = 1×10^{-6}
$CSFo$	=	constituent -specific oral cancer slope factor (mg/kg-d) ⁻¹
AT	=	averaging time = 70 years [yrs]
EF	=	exposure frequency = 350 d/yr
CRw	=	intake rate of water = 0.0252 L/kg/d
ED	=	exposure duration = 30 yr
365	=	conversion factor (d/yr).

In this equation, the CSFo quantifies the toxicity of the constituent. The averaging time, exposure frequency, intake rate of water (which is expressed as the amount of water an individual consumes each day per kilogram of their body weight), and exposure duration quantify aspects of an individual's potential exposure. In our calculation of cancer and noncancer ingestion HBNs, we use data that combine the factors for intake rate and body weight. That is, we express intake in terms of the amount of water an individual consumes per kilogram of their body weight. For example, if an individual consumes 2 liters (L) of water per day (d), and that individual weighs 65 kg, then their intake would be 2 L/d per 65 kg, or 0.03 L/kg/d. Table 5.1 summarizes the basis for the exposure parameter values that we used in this equation.

Inspection of the equation above shows that the HBN value is directly proportional to the target risk. That is, if the target risk were set to 10^{-5} instead of 10^{-6} , we would obtain a 10 times higher HBN value.

Table 5.1 Exposure Parameter Values for Ingestion HBNs – Carcinogens

Exposure Parameter	Value	Units	Source
Drinking Water Intake Rate	25.2	mL/kg/d	The value is a time-weighted average of mean drinking water intake rates (per kilogram body weight) for individuals aged 0 to 29 years. Table 3-7 of the Exposure Factors Handbook (U.S. EPA, 1997a)
Exposure Frequency	350	d/yr	The exposure frequency is the number of days per year that an individual is exposed. A value of 350 days per year considers that an individual is away from home for 2 weeks per year. Risk Assessment Guidance for Superfund: Volume 1—Human Health Evaluation Manual (U.S. EPA, 1991a)
Exposure Duration	30	yr	The exposure duration is the number of years that an individual is exposed. Thirty years is the 95 th percentile value for population mobility (exposure duration). Table 15-176 of the Exposure Factors Handbook (U.S. EPA, 1997b)
Averaging Time	70	yr	Averaging time is the period of time over which a receptor's dose is averaged. When evaluating carcinogens, dose is averaged over the lifetime of the individual, assumed to be 70 years. Risk Assessment Guidance for Superfund: Volume 1—Human Health Evaluation Manual (U.S. EPA, 1991a)

5.1.2 Ingestion HBNs for Constituents that Cause Noncancer Health Effects

To calculate ingestion HBNs for constituents that cause health effects other than cancer, we rearranged the standard equation for estimating HQ so that instead of solving for the HQ, we solve for constituent concentration in water. The constituent concentration in water that corresponds to the target HQ is the cancer HBN for ingestion exposures, as follows:

$$NC\_INGEST\_HBN = \frac{HQ\_target \cdot RfD \cdot 365}{EF \cdot CR_w}$$

where

NC_INGEST_HBN	=	noncancer HBN for ingestion of water (mg/L)
HQ_target	=	target HQ for noncarcinogens = 1
RfD	=	constituent-specific reference dose (mg/kg-d)
EF	=	exposure frequency = 350 d/yr
CR _w	=	intake rate of water = 0.0426 L/kg/d
365	=	conversion factor (d/yr).

In this equation, the exposure frequency and intake rate of water (expressed as the amount of water an individual consumes each day per kilogram of body weight) quantify aspects of an individual's exposure. To develop noncancer ingestion HBNs that are protective of children, the intake rate in this equation assumes that the individual who is drinking water from the modeled well is a child who is exposed from age 0 to 6 years. Children in this age range typically ingest greater amounts of water per unit body weight (that is, have greater exposure) than do adults.

The RfD in the equation quantifies the toxicity of the constituent. Even though the RfDs that we use in this analysis are defined to pertain to exposures that occur over a lifetime, these "chronic" RfDs commonly are used to evaluate potential noncancer effects associated with exposures that occur over a significant portion of a lifetime (generally assumed to be between seven years and a lifetime). We do not average the dose for noncarcinogens over the lifetime of an individual (the "averaging time") as we do for carcinogens, rather, we average dose over only the period of exposure. Consequently, the values for exposure duration and averaging time are the same, and cancel each other out (that is why they are not included in the above equation). Table 5.2 summarizes the basis for the exposure parameter values that we used in this equation.

Inspection of the equation above shows that the HBN value is directly proportional to the target HQ. That is, if the target risk were set to 0.1 instead of 1, we would obtain a 10 times lower HBN value.

Table 5.2 Exposure Parameter Values for Ingestion HBNs – Noncarcinogens

Exposure Parameter	Value	Units	Source
Drinking Water Intake Rate	42.6	mL/kg/d	The value is a time-weighted average of mean drinking water intake rates (per kilogram body weight) for children aged 0 to 6 years. Table 3-7 of the Exposure Factors Handbook (U.S. EPA, 1997a)
Exposure Frequency	350	d/yr	The exposure frequency is the number of days per year that an individual is exposed. A value of 350 days per year considers that an individual is away from home for 2 weeks per year. Risk Assessment Guidance for Superfund: Volume 1—Human Health Evaluation Manual (U.S. EPA, 1991a)

5.2 Inhalation HBNs

In the IWEM tool, the inhalation HBN is the maximum concentration of a constituent in ground water that is not expected to cause adverse health effects in most adults who inhale the constituent as a result of activities associated with showering. We did not evaluate children's shower-related exposure in developing inhalation HBNs because we assume that children take baths. Because we have not yet developed a "bath model" for evaluating children, we do not have inhalation HBNs that consider children's exposure. We calculated inhalation HBNs only for constituents that (1) volatilize (that is, mercury and organic constituents) and (2) have an inhalation health benchmark available (that is, a RfC, inhalation URF, and/or CSFi).

We developed the inhalation HBNs as follows:

First, we used a shower model to calculate, on a per unit ground-water concentration basis, the average concentration of each constituent in indoor air that an adult will be exposed to daily as a result of activities associated with showering. In this analysis, we assume that the shower water is ground water from the well. However, in this step of the analysis we only have to model a "unit" ground-water concentration. This is because the average concentration of a constituent in indoor air is directly proportional to the concentration of the constituent in the water coming into the shower. As a result, we can back-calculate the ground-water concentration that would result in any given constituent concentration in indoor air by simple scaling. Section 5.2.1 describes how we use the shower model to calculate the average concentration of a constituent in indoor air to which an adult is exposed during the day.

Second, we used the unit average constituent concentration in indoor air, determined above, to calculate the HBN. We first calculated the risk or HQ associated with the unit air concentration from the shower model, and then scaled this result to determine the ground-water concentration associated with the target risk level or target HQ. The ground-water concentration that generates the air concentration associated with a risk of 1×10^{-6} or a HQ of 1 is the inhalation HBN.

5.2.1 Calculation of Exposure Concentrations from Showering

Individuals may be exposed to constituents through inhalation of air-phase emissions from ground water. Such exposure may occur during the time spent in the shower while showering, in the shower stall after showering, and in the bathroom after showering. To evaluate these exposures, EPA uses a shower model to estimate constituent concentrations in a shower stall and in bathroom air.

A primary assumption of our evaluation is that constituents are released into household air only as the result of showering activity, and that exposure to air-phase constituents only occurs in the shower stall and in the bathroom. Some investigators evaluate constituent emissions resulting from other household uses of water (for example, use of water in sinks, toilets, washing machines, and dishwashers) and the associated inhalation exposure that occurs during the time spent in the non-bathroom portions of the house (that is, “the remainder of the house”). The model we used only focuses on exposure in the shower stall and bathroom, and the exposure that results from showering. The shower model is based on the mathematical formulation presented in McKone (1987) and Little (1992a). A detailed description of the shower model, its assumptions and limitations, and the parameter values we used to develop inhalation HBNs is provided in Appendix E.

5.2.2 Calculating Inhalation HBNs

To calculate HBNs, we used a unit ground-water concentration (usually 1 mg/L) within the solubility limits of each constituent and implemented the shower model using that concentration. The result of the shower model was the average concentration of a constituent in air to which an individual is exposed on a daily basis. We used this “unit” air concentration to calculate a corresponding “unit” risk (for cancer-causing chemicals) or “unit” HQ (for constituents that cause noncancer health effects). Because ground-water concentration and inhalation risk or hazard are directly proportional, we used simple ratios to adjust the unit ground-water concentration to the ground-water concentration corresponding to the target risk or target HQ (that is, to calculate the inhalation HBNs). Section 5.2.2.1 describes our application of this methodology to carcinogens and Section 5.2.2.2 describes our application of this methodology to noncarcinogens.

5.2.2.1 Inhalation HBNs for Constituents that Cause Cancer

Using the shower model, we estimated the average concentration of a constituent in air to which an individual is exposed on a daily basis. To calculate the inhalation HBN for carcinogens, we first calculate the inhalation risk that corresponds to this modeled constituent concentration:

$$Risk\_modeled = \frac{(Cair\_modeled \cdot IR \cdot ED \cdot EF)}{(BW \cdot AT \cdot 365)} \cdot CSFi$$

where

Risk_modeled	=	inhalation risk resulting from the modeled constituent concentration in air
Cair_modeled	=	average constituent concentration in air to which an individual is exposed during a day (mg/m ³) (calculated from the unit ground-water concentration using the shower model)
IR	=	inhalation rate = 13.25 m ³ /d
ED	=	exposure duration = 30 yr
EF	=	exposure frequency = 350 d/yr
BW	=	body weight (kg) = 71.8 kg
AT	=	averaging time = 70 yr
CSFi	=	constituent-specific inhalation cancer slope factor (mg/kg-d) ⁻¹
365	=	conversion factor (d/yr).

In this equation, the CSFi quantifies the toxicity of the constituent. We use the average constituent concentration in air, inhalation rate, exposure duration, exposure frequency, body weight, and averaging time to quantify the individual's exposure, or dose. Table 5.3 summarizes the basis for the exposure parameter values used in this equation.

Table 5.3 Exposure Parameter Values for Inhalation HBNs

Exposure Parameter	Value	Units	Source
Inhalation Rate	13.25	m ³ /d	The value corresponds to the mean inhalation rates for adults (ages 19 to 65+). The value was calculated by averaging the daily mean inhalation rates for females (11.3 m ³ /d) and males (15.2 m ³ /d). Table 5-23 of the Exposure Factors Handbook (U.S. EPA, 1997a)
Body Weight	71.8	kg	The value corresponds to the mean body weight of 18- to 75-year-old men and women. Tables 7-2 and 7-11 of the Exposure Factors Handbook (U.S. EPA, 1997a)
Exposure Frequency	350	d/yr	The exposure frequency is the number of days per year that an individual is exposed. A value of 350 days per year considers that an individual is away from home for 2 weeks per year. Risk Assessment Guidance for Superfund: Volume 1—Human Health Evaluation Manual (U.S. EPA, 1991a)
Exposure Duration	30	yr	The exposure duration is the number of years that an individual is exposed. Thirty years is the 95 th percentile value for population mobility (exposure duration). Table 15-176 of the Exposure Factors Handbook (U.S. EPA, 1997b)
Averaging Time	70	yr	Risk Assessment Guidance for Superfund: Volume 1—Human Health Evaluation Manual (U.S. EPA, 1991a)

The modeled constituent concentration in air was based on evaluating a unit constituent concentration in ground water (a constituent concentration in ground water that we selected somewhat arbitrarily). To calculate the ground-water concentration that corresponds to the target inhalation risk (that is, the inhalation HBN) we adjusted the modeled unit ground-water concentration using a simple ratio of target risk and modeled risk:

$$C_{\_INHALE\_HBN} = \frac{Risk\_target}{Risk\_modeled} \cdot C_{\_GW\_modeled}$$

where

C_INHALE_HBN	=	concentration in ground water resulting in target risk (:g/L) (cancer HBN for inhalation)
$C\_GW\_modeled$	=	unit concentration in ground water used in shower model (:g/L)
$Risk\_target$	=	target risk for carcinogens = 1×10^{-6}
$Risk\_modeled$	=	risk resulting from ground-water concentration modeled.

This equation assumes that ground-water concentration and inhalation risk are directly proportional, which we confirmed by running the shower model using the target ground-water concentration (the inhalation HBN) for several constituents and comparing the results to the target risk level.

Inspection of the equation above shows that the HBN value is directly proportional to the target risk. That is, if the target risk were set to 10^{-5} instead of 10^{-6} , we would obtain a 10 times higher HBN value.

5.2.2.2 Inhalation HBNs for Constituents that Causes Non-Cancer Health Effects

Calculating inhalation HBNs for noncarcinogens is simpler than calculating HBNs for carcinogens because the toxicity benchmark (RfC) is expressed as a concentration in air. To calculate the HBN, we first determine the HQ resulting from the unit air concentration output by the shower model:

$$HQ\_modeled = \frac{C_{air\_modeled}}{RfC}$$

where

$HQ\_modeled$	=	HQ resulting from the ground-water concentration modeled (unitless)
$C_{air\_modeled}$	=	average air concentration to which an individual is exposed during a day (mg/m^3) (calculated from the unit ground-water concentration using the shower model)
RfC	=	constituent-specific reference concentration (mg/m^3).

We then derive the target ground-water concentration (that is, the inhalation HBN) by adjusting the modeled unit ground-water concentration using the ratio of the target HQ to the modeled HQ:

$$NC\_INHALE\_HBN = \frac{HQ\_target}{HQ\_modeled} \cdot C\_GW\_modeled$$

where

NC_INHALE_HBN = concentration in ground water resulting in target HQ
(:g/L) (non-cancer HBN for inhalation)
C_GW_modeled = unit concentration in ground water used in shower model
(:g/L)
HQ_target = target HQ for noncarcinogens = 1
HQ_modeled = HQ resulting from ground-water concentration modeled.

Inspection of the equation above shows that the HBN value is directly proportional to the target HQ. That is, if the target risk were set to 0.1 instead of 1, we would obtain a 10 times lower HBN value.

Table 5.4 IWEM MCLs and HBNs

CAS Number	Chemical Name	MCL (mg/L)	Ingestion HBNs		Inhalation HBNs	
			Cancer HBN (mg/L)	Non-Cancer HBN (mg/L)	Cancer HBN (mg/L)	Non-cancer HBN (mg/L)
83-32-9	Acenaphthene			1.5E+00		
75-07-0	Acetaldehyde [Ethanal]				4.1E-02	2.2E-01
67-64-1	Acetone (2-propanone)			2.5E+00		1.5E+03
75-05-8	Acetonitrile (methyl cyanide)					3.1E+00
98-86-2	Acetophenone			2.5E+00		
107-02-8	Acrolein			4.9E-01		3.3E-04
79-06-1	Acrylamide		2.2E-05	4.9E-03	5.1E+00	
79-10-7	Acrylic acid [propenoic acid]			1.2E+01		1.5E+01
107-13-1	Acrylonitrile		1.8E-04	2.5E-02	1.0E-03	3.8E-02
309-00-2	Aldrin		5.7E-06	7.3E-04	1.0E-05	
107-18-6	Allyl alcohol			1.2E-01		
62-53-3	Aniline (benzeneamine)		1.7E-02		2.2E+00	9.3E-01
120-12-7	Anthracene			7.3E+00*		
7440-36-0	Antimony	6.0E-03		9.8E-03		
7440-38-2	Arsenic	5.0E-02	6.4E-05	7.3E-03		
7440-39-3	Barium	2.0E+00		1.7E+00		
56-55-3	Benz{a}anthracene		8.1E-05		1.8E-02*	
71-43-2	Benzene	5.0E-03	1.8E-03		1.6E-03	1.9E-01
92-87-5	Benzydine		4.2E-07	7.3E-02	2.6E+00	
50-32-8	Benzo{a}pyrene	2.0E-04	1.3E-05		5.4E-03*	
205-99-2	Benzo{b}fluoranthene		8.1E-05		6.3E-04	

Table 5.4 IWEM MCLs and HBNs (continued)

CAS Number	Chemical Name	MCL (mg/L)	Ingestion HBNs		Inhalation HBNs	
			Cancer HBN (mg/L)	Non-Cancer HBN (mg/L)	Cancer HBN (mg/L)	Non-cancer HBN (mg/L)
100-44-7	Benzyl chloride		5.7E-04		5.2E-04	
100-51-6	Benzyl alcohol			7.3E+00		
7440-41-7	Beryllium	4.0E-03		4.9E-02		
39638-32-9	Bis(2-chloroisopropyl)ether		1.4E-03	9.8E-01	5.9E-03	
111-44-4	Bis(2-chloroethyl)ether		8.8E-05		1.1E-03	
117-81-7	Bis(2-ethylhexyl)phthalate	6.0E-03	6.9E-03	4.9E-01*	2.8E+01*	1.8E+02*
75-27-4	Bromodichloromethane	8.0E-02	1.6E-03	4.9E-01	8.0E-04	
74-83-9	Bromomethane			3.4E-02		1.5E-02
106-99-0	Butadiene 1,3-				4.0E-05	6.0E-02
71-36-3	Butanol			2.5E+00		
88-85-7	Butyl-4,6-dinitrophenol,2-sec-(Dinoseb)	7.0E-03		2.5E-02		
85-68-7	Butyl benzyl phthalate			4.9E+00*		
7440-43-9	Cadmium	5.0E-03		1.2E-02		
56-23-5	Carbon tetrachloride	5.0E-03	7.4E-04	1.7E-02	7.6E-04	2.1E-02
75-15-0	Carbon disulfide			2.5E+00		1.9E+00
57-74-9	Chlordane	2.0E-03	2.8E-04	1.2E-02	1.5E-03	2.8E-02
126-99-8	Chloro-1,3-butadiene 2-(Chloroprene)			4.9E-01		2.2E-02
106-47-8	Chloroaniline p-			9.8E-02		
108-90-7	Chlorobenzene	1.0E-01		4.9E-01		2.0E-01
510-15-6	Chlorobenzilate		3.6E-04	4.9E-01	1.2E+00	
124-48-1	Chlorodibromomethane	8.0E-02	1.2E-03	4.9E-01	7.5E-04	
75-00-3	Chloroethane [Ethyl chloride]					3.0E+01
67-66-3	Chloroform	8.0E-02		2.5E-01		3.3E-01
74-87-3	Chloromethane		7.4E-03		5.9E-03	2.6E-01
95-57-8	Chlorophenol 2-			1.2E-01		9.7E-03
107-05-1	Chloropropene 3- (Allyl Chloride)				1.9E-03	3.0E-03
16065-83-1	Chromium (III) (Chromic Ion)	1.0E-01		3.7E+01		
18540-29-9	Chromium (VI)	1.0E-01		7.3E-02		
218-01-9	Chrysene		8.1E-04		7.3E-03*	
7440-48-4	Cobalt			4.9E-01		
7440-50-8	Copper	1.3E+00**				
106-44-5	Cresol p-			1.2E-01		1.3E+03

Table 5.4 IWEM MCLs and HBNs (continued)

CAS Number	Chemical Name	MCL (mg/L)	Ingestion HBNs		Inhalation HBNs	
			Cancer HBN (mg/L)	Non-Cancer HBN (mg/L)	Cancer HBN (mg/L)	Non-cancer HBN (mg/L)
108-39-4	Cresol M-			1.2E+00		1.2E+03
95-48-7	Cresol o-			1.2E+00		8.8E+02
1319-77-3	Cresols			1.2E+00		1.1E+03
98-82-8	Cumene			2.5E+00		1.3E+00
108-93-0	Cyclohexanol			4.2E-04		3.9E-04
108-94-1	Cyclohexanone			1.2E+02		
72-54-8	DDD		4.0E-04			
72-55-9	DDE		2.8E-04			
50-29-3	DDT p,p'-		2.8E-04	1.2E-02	8.8E-03	
117-84-0	Di-n-octyl phthalate			4.9E-01*		
84-74-2	Di-n-butyl phthalate			2.5E+00		
2303-16-4	Diallate		1.6E-03			
53-70-3	Dibenz{a,h}anthracene		1.3E-05		3.8E-01	
96-12-8	Dibromo-3-chloropropane 1,2-	2.0E-04	6.9E-05		7.9E-02	2.9E-03
106-46-7	Dichlorobenzene 1,4-	7.5E-02	4.0E-03		1.3E-03	3.0E+00
95-50-1	Dichlorobenzene 1,2-	6.0E-01		2.2E+00		7.7E-01
91-94-1	Dichlorobenzidine 3,3'-		2.2E-04		4.9E+00*	
75-71-8	Dichlorodifluoromethane (Freon 12)			4.9E+00		5.8E-01
107-06-2	Dichloroethane 1,2-	5.0E-03	1.1E-03		6.3E-04	1.0E+01
75-34-3	Dichloroethane 1,1-			2.5E+00	7.4E-03	1.6E+00
156-59-2	Dichloroethylene cis-1,2-	7.0E-02		2.5E-01		
156-60-5	Dichloroethylene trans-1,2-	1.0E-01		4.9E-01		
75-35-4	Dichloroethylene 1,1-	7.0E-03	1.6E-04	2.2E-01	2.2E-04	2.1E-01
120-83-2	Dichlorophenol 2,4-			7.3E-02		
94-75-7	Dichlorophenoxyacetic acid 2,4-(2,4-D)	7.0E-02		2.5E-01		
78-87-5	Dichloropropane 1,2-	5.0E-03	1.4E-03	2.2E+00		1.4E-02
542-75-6	Dichloropropene 1,3-(mixture of isomers)		9.7E-04	7.3E-01	2.9E-03	6.1E-02
10061-02-6	Dichloropropene trans-1,3-		9.7E-04	7.3E-01	3.5E-03	7.5E-02
10061-01-5	Dichloropropene cis-1,3-		9.7E-04	7.3E-01	3.3E-03	7.0E-02
60-57-1	Dieldrin		6.0E-06	1.2E-03	1.0E-04	
84-66-2	Diethyl phthalate			2.0E+01		

Table 5.4 IWEM MCLs and HBNs (continued)

CAS Number	Chemical Name	MCL (mg/L)	Ingestion HBNs		Inhalation HBNs	
			Cancer HBN (mg/L)	Non-Cancer HBN (mg/L)	Cancer HBN (mg/L)	Non-cancer HBN (mg/L)
56-53-1	Diethylstilbestrol		2.1E-08			
60-51-5	Dimethoate			4.9E-03		
119-90-4	Dimethoxybenzidine 3,3'-		6.9E-03			
68-12-2	Dimethyl formamide N,N- [DMF]			2.5E+00		7.1E+02
57-97-6	Dimethylbenz{a}anthracene 7,12-				3.0E-03	
119-93-7	Dimethylbenzidine 3,3'-		1.1E-05			
105-67-9	Dimethylphenol 2,4-			4.9E-01		
99-65-0	Dinitrobenzene 1,3-			2.5E-03		
51-28-5	Dinitrophenol 2,4-			4.9E-02		
121-14-2	Dinitrotoluene 2,4-		1.4E-04	4.9E-02	8.1E-01	
606-20-2	Dinitrotoluene 2,6-		1.4E-04	2.5E-02		
123-91-1	Dioxane 1,4-		8.8E-03		1.8E-01	1.1E+03
122-39-4	Diphenylamine			6.1E-01		
122-66-7	Diphenylhydrazine 1,2-		1.2E-04		2.0E-02	
298-04-4	Disulfoton			9.8E-04		
115-29-7	Endosulfan (Endosulfan I and II, mixture)			1.5E-01		
72-20-8	Endrin	2.0E-03		7.3E-03		
106-89-8	Epichlorohydrin		9.8E-03	4.9E-02	1.9E-01	6.0E-02
106-88-7	Epoxybutane 1,2-					2.4E-01
110-80-5	Ethoxyethanol 2-			9.8E+00		2.9E+03
111-15-9	Ethoxyethanol acetate 2-			7.3E+00		3.0E+02
62-50-0	Ethyl methanesulfonate		3.3E-07			
97-63-2	Ethyl methacrylate			2.2E+00		
141-78-6	Ethyl acetate			2.2E+01		
60-29-7	Ethyl ether			4.9E+00		
100-41-4	Ethylbenzene	7.0E-01		2.5E+00	1.1E-02	3.3E+00
96-45-7	Ethylene thiourea		8.8E-04	2.0E-03	1.6E+03	
107-21-1	Ethylene glycol			4.9E+01		1.2E+04
75-21-8	Ethylene oxide		9.5E-05		5.2E-04	4.1E-01
106-93-4	Ethylene dibromide (1,2-Dibromoethane)	5.0E-05	1.1E-06		8.4E-05	9.8E-04
206-44-0	Fluoranthene			9.8E-01*		

Table 5.4 IWEM MCLs and HBNs (continued)

CAS Number	Chemical Name	MCL (mg/L)	Ingestion HBNs		Inhalation HBNs	
			Cancer HBN (mg/L)	Non-Cancer HBN (mg/L)	Cancer HBN (mg/L)	Non-cancer HBN (mg/L)
16984-48-8	Fluoride	4.0E+00		2.9E+00		
50-00-0	Formaldehyde			4.9E+00	1.5E+00	5.1E+01
64-18-6	Formic acid			4.9E+01		
98-01-1	Furfural			7.3E-02		2.2E+01
319-84-6	HCH alpha-		1.5E-05	2.0E-01	3.6E-04	
58-89-9	HCH (Lindane) gamma-	2.0E-04	7.4E-05	7.3E-03	1.6E-03	
319-85-7	HCH beta-		5.4E-05		1.7E-02	
1024-57-3	Heptachlor epoxide	2.0E-04	1.1E-05	3.2E-04	2.8E-04	
76-44-8	Heptachlor	4.0E-04	2.2E-05	1.2E-02	1.5E-05	
87-68-3	Hexachloro-1,3-butadiene		1.2E-03	7.3E-03	6.1E-04	
118-74-1	Hexachlorobenzene	1.0E-03	6.0E-05	2.0E-02*	3.6E-05	
77-47-4	Hexachlorocyclopentadiene	5.0E-02		1.5E-01		6.9E-04
34465-46-8	Hexachlorodibenzo-p-dioxins [HxCDDs]		6.2E-09		1.4E-07	
55684-94-1	Hexachlorodibenzofurans [HxCDFs]		6.2E-09		1.4E-07	
67-72-1	Hexachloroethane		6.9E-03	2.5E-02	3.3E-03	
70-30-4	Hexachlorophene			7.3E-03		
110-54-3	Hexane N-			2.7E+02*		6.6E-01
7783-06-4	Hydrogen Sulfide			7.3E-02		
193-39-5	Indeno{1,2,3-cd}pyrene		8.1E-05*		3.8E-02*	
78-83-1	Isobutyl alcohol			7.3E+00		
78-59-1	Isophorone		1.0E-01	4.9E+00		5.3E+02
143-50-0	Kepone			1.2E-02		
7439-92-1	Lead	1.5E-02**				
7439-96-5	Manganese			1.2E+00		
7439-97-6	Mercury	2.0E-03		2.5E-03		7.0E-04
126-98-7	Methacrylonitrile			2.5E-03		6.5E-03
67-56-1	Methanol			1.2E+01		1.5E+03
72-43-5	Methoxychlor	4.0E-02		1.2E-01*		
110-49-6	Methoxyethanol acetate 2-			4.9E-02		5.1E+02
109-86-4	Methoxyethanol 2-			2.5E-02		4.4E+02
80-62-6	Methyl methacrylate			3.4E+01		5.3E+00
78-93-3	Methyl ethyl ketone			1.5E+01		3.3E+01

Table 5.4 IWEM MCLs and HBNs (continued)

CAS Number	Chemical Name	MCL (mg/L)	Ingestion HBNs		Inhalation HBNs	
			Cancer HBN (mg/L)	Non-Cancer HBN (mg/L)	Cancer HBN (mg/L)	Non-cancer HBN (mg/L)
298-00-0	Methyl parathion			6.1E-03		
108-10-1	Methyl isobutyl ketone			2.0E+00		1.2E+00
1634-04-4	Methyl tert-butyl ether [MTBE]					1.7E+01
56-49-5	Methylcholanthrene 3-				1.2E-03	
75-09-2	Methylene chloride (Dichloromethane)	5.0E-03	1.3E-02	1.5E+00	2.8E-02	1.0E+01
74-95-3	Methylene bromide (Dibromomethane)			2.5E-01		
7439-98-7	Molybdenum			1.2E-01		
91-20-3	Naphthalene			4.9E-01		1.9E-02
7440-02-0	Nickel			4.9E-01		
98-95-3	Nitrobenzene			1.2E-02		1.5E-01
79-46-9	Nitropropane 2-				2.3E-05	3.3E-01
924-16-3	Nitroso-di-n-butylamine N-		1.8E-05		2.0E-05	
621-64-7	Nitroso-di-n-propylamine N-		1.4E-05		1.5E-03	
55-18-5	Nitrosodiethylamine N-		6.4E-07		4.3E-05	
62-75-9	Nitrosodimethylamine N-		1.9E-06	2.0E-04	4.0E-04	
86-30-6	Nitrosodiphenylamine N-		2.0E-02	4.9E-01	5.2E-01	
10595-95-6	Nitrosomethylethylamine N-		4.4E-06		4.5E-03	
100-75-4	Nitrosopiperidine N-				8.7E-03	
930-55-2	Nitrosopyrrolidine N-		4.6E-05		9.2E-01	
152-16-9	Octamethyl pyrophosphoramidate			4.9E-02		
56-38-2	Parathion (ethyl)			1.5E-01		
608-93-5	Pentachlorobenzene			2.0E-02		
36088-22-9	Pentachlorodibenzo-p-dioxins [PeCDDs]		6.2E-10		6.0E-08	
30402-15-4	Pentachlorodibenzofurans [PeCDFs]		1.2E-09		6.3E-08	
82-68-8	Pentachloronitrobenzene (PCNB)		3.7E-04	7.3E-02		
87-86-5	Pentachlorophenol	1.0E-03	8.1E-04	7.3E-01	5.4E+01	
108-95-2	Phenol			1.5E+01		9.0E+02
62-38-4	Phenyl mercuric acetate			2.0E-03		
108-45-2	Phenylenediamine 1,3-			1.5E-01		
298-02-2	Phorate			4.9E-03		
85-44-9	Phthalic anhydride			4.9E+01		1.3E+04*

Table 5.4 IWEM MCLs and HBNs (continued)

CAS Number	Chemical Name	MCL (mg/L)	Ingestion HBNs		Inhalation HBNs	
			Cancer HBN (mg/L)	Non-Cancer HBN (mg/L)	Cancer HBN (mg/L)	Non-cancer HBN (mg/L)
1336-36-3	Polychlorinated biphenyls (Aroclors)	5.0E-04	2.4E-04	4.9E-04	1.4E-04	
23950-58-5	Pronamide			1.8E+00		
75-56-9	Propylene oxide [1,2-Epoxypropane]		4.0E-04		1.7E-02	4.9E-01
129-00-0	Pyrene			7.3E-01*		
110-86-1	Pyridine			2.5E-02		1.4E+00
94-59-7	Safrole		5.4E-04			
7782-49-2	Selenium	5.0E-02		1.2E-01		
7440-22-4	Silver			1.2E-01		
57-24-9	Strychnine and salts			7.3E-03		
100-42-5	Styrene	1.0E-01		4.9E+00		3.6E+00
95-94-3	Tetrachlorobenzene 1,2,4,5-			7.3E-03		
1746-01-6	Tetrachlorodibenzo-p-dioxin 2,3,7,8-	3.0E-08	6.2E-10	2.5E-08	2.2E-09	
51207-31-9	Tetrachlorodibenzofuran 2,3,7,8-		6.2E-09		1.0E-07	
630-20-6	Tetrachloroethane 1,1,1,2-		3.7E-03	7.3E-01	1.9E-03	
79-34-5	Tetrachloroethane 1,1,2,2-		4.8E-04	1.5E+00	5.0E-04	
127-18-4	Tetrachloroethylene	5.0E-03	1.9E-03	2.5E-01	2.1E-02	9.4E-01
58-90-2	Tetrachlorophenol 2,3,4,6-			7.3E-01		
3689-24-5	Tetraethyl dithiopyrophosphate (Sulfotep)			1.2E-02		
7440-28-0	Thallium	2.0E-03		2.0E-03		
137-26-8	Thiram [Thiuram]			1.2E-01		
108-88-3	Toluene	1.0E+00		4.9E+00		1.3E+00
95-80-7	Toluenediamine 2,4-		3.0E-05		7.5E+00	
106-49-0	Toluidine p-		5.1E-04			
95-53-4	Toluidine o-		4.0E-04		3.6E-02	
8001-35-2	Toxaphene (chlorinated camphenes)	3.0E-03	8.8E-05		3.6E-03	
75-25-2	Tribromomethane (Bromoform)	8.0E-02	1.2E-02	4.9E-01	1.9E-02	
76-13-1	Trichloro-1,2,2-trifluoro-ethane 1,1,2-			7.3E+02*		9.5E+01
120-82-1	Trichlorobenzene 1,2,4-	7.0E-02		2.5E-01		8.3E-01
71-55-6	Trichloroethane 1,1,1-	2.0E-01		6.9E+00		6.9E+00
79-00-5	Trichloroethane 1,1,2-	5.0E-03	1.7E-03	9.8E-02	1.1E-03	
79-01-6	Trichloroethylene (Trichloroethylene 1,1,2-)	5.0E-03	8.8E-03		6.8E-03	1.9E+00

Table 5.4 IWEM MCLs and HBNs (continued)

CAS Number	Chemical Name	MCL (mg/L)	Ingestion HBNs		Inhalation HBNs	
			Cancer HBN (mg/L)	Non-Cancer HBN (mg/L)	Cancer HBN (mg/L)	Non-cancer HBN (mg/L)
75-69-4	Trichlorofluoromethane (Freon 11)			7.3E+00		2.1E+00
95-95-4	Trichlorophenol 2,4,5-			2.5E+00		
88-06-2	Trichlorophenol 2,4,6-		8.8E-03		2.8E-01	
93-72-1	Trichlorophenoxy)propionic acid 2-(2,4,5-(Silvex)	5.0E-02		2.0E-01		
93-76-5	Trichlorophenoxyacetic acid 2,4,5-			2.5E-01		
96-18-4	Trichloropropane 1,2,3-		1.4E-05	1.5E-01		3.4E-02
121-44-8	Triethylamine					1.1E-01
99-35-4	Trinitrobenzene (Trinitrobenzene 1,3,5-) sym-			7.3E-01		
126-72-7	Tris(2,3-dibromopropyl)phosphate		9.9E-06			
7440-62-2	Vanadium			1.7E-01		
108-05-4	Vinyl acetate			2.5E+01		1.2E+00
75-01-4	Vinyl chloride	2.0E-03	1.3E-04	7.3E-02	2.5E-03	2.9E-01
95-47-6	Xylene o-			4.9E+01		1.4E+00
108-38-3	Xylene m-			4.9E+01		1.3E+00
106-42-3	Xylene p-			4.9E+01		1.3E+00
1330-20-7	Xylenes (total)	1.0E+01		4.9E+01		1.4E+00
7440-66-6	Zinc			7.3E+00		

Key:

* = Value exceeds constituent's water solubility

** = Value exceeds drinking water action level as specified by 40 CFR 141.32(e)(13) and (14)

6.0 How Does IWEM Calculate LCTVs and Make Liner Recommendations?

The objective of the ground-water fate and transport model is to determine the amount of dilution and attenuation a constituent may undergo as it migrates from a WMU to a ground-water well and determine the constituent concentration at the well. For Tier 1, once the amount of dilution and attenuation is determined, that data are used in conjunction with RGCs (either drinking water MCLs or HBNs which reflect a constituent's toxicity) to establish the maximum allowable leachate constituent concentrations for wastes that can be protectively managed in a particular unit design. We refer to these maximum allowable leachate concentrations as LCTVs. For Tier 2, the amount of dilution and attenuation help determine an exposure concentration that can be compared to RGCs. The dilution and attenuation also may be used to estimate an LCTV in Tier 2. This section describes the methods we used to develop the basis for the liner recommendations for the Tier 1 and Tier 2 analysis in IWEM.

6.1 Determining Liner Recommendations Corresponding to a 90th Percentile Exposure Concentration

Every single realization of EPACMTP in the Monte Carlo process results in a predicted concentration at the modeled ground-water well. Because the predicted ground-water concentrations are compared against health-based RGC's which reflect specific exposure duration assumptions (see Section 5), the ground-water concentrations calculated in IWEM represent time-averaged values, as depicted conceptually in Figure 6.1.

Depending on the type of RGC, the IWEM tool uses different averaging times in calculating ground-water well concentrations, as follows:

- # MCL: Peak ground-water well concentration
- # Non-cancer HBN: Maximum 7-year average well concentration
- # Cancer HBN: Maximum 30-year average well concentration

At the conclusion of a Monte Carlo simulation consisting of 10,000 realizations, the 10,000 values of predicted ground-water concentration for each specific averaging time period are sorted from low to high into a CDF function, see Figure 6.2. In Tier 1, the CDF represents the range in expected ground-water concentrations due to nationwide variations in site hydrogeologic and other conditions; in Tier 2, the CDF represents the

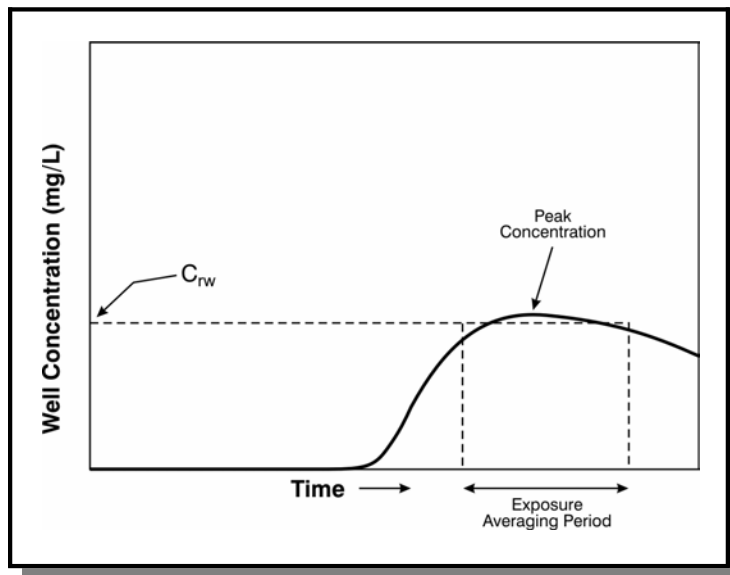


Figure 6.1 Determination of Time-Averaged Ground-Water Well Concentration.

range in the expected location-specific ground-water concentration due to uncertainty and variability in the local conditions.

For the development of the IWEM tool we selected the 90th percentile of the predicted ground-water concentration CDF as the basis for determining the Tier 1 LCTVs and as the point of comparison for the Tier 2 analysis. We based the selection of a 90th percentile protection level on: (1) the need to have a large degree of confidence that the results are adequately protective of human health and the environment given the degree of uncertainty inherent in the data and the analyses; and (2) the need to choose a level of protection that is consistent with EPA's Guidance for Risk Characterization (U.S. EPA, 1995b). The Tier 1 and Tier 2 evaluations are based on a high-end risk assessment which is used to describe the risk or hazard for individuals in small, but definable segments of the population. EPA's Guidance for Risk Characterization (U.S. EPA, 1995b) advises that "conceptually, high-end exposure means exposure above about the 90th percentile of the population distribution, but not higher than the individual in the population who has the highest exposure." Use of the 90th percentile protection level in IWEM implies that, of the modeled scenarios, 90% result in well concentrations that are lower than the specified RGC, and thus, are considered protective for at least 90% of the cases.

By definition, the LCTV is that value of leachate concentration for which the 90th percentile of the predicted ground-water well concentration is equal to the RGC. In the

case of organic constituents, the well concentration is linearly proportional to the leachate concentration input value. We used this relationship to facilitate the determination of LCTVs. For metals constituents that are subject to nonlinear sorption processes (see Section 4.2.4), we followed a slightly different process to determine LCTVs. The methodologies for organics and metals are discussed in the following sections.

6.1.1 Calculating LCTVs for Organic Constituents

For organic constituents, the fate and transport equations solved by EPACMTP are linear, which means that the magnitude of the predicted ground-water well concentration is linearly proportional to the value of the leachate concentration. In other words, a doubling of the EPACMTP input value of leachate concentration would result in a doubling of the predicted ground-water well concentration, as long as all other model parameters stay the same. This relationship can be expressed in terms of a Dilution and Attenuation Factor (DAF):

$$DAF = \frac{C_L}{C_{RW}}$$

where:

- C_{RW} = Ground-water well concentration (mg/L)
- C_L = Leachate concentration (mg/L)
- DAF = Dilution and attenuation factor (dimensionless)

Because both the leachate concentration and the well concentration can vary with time, the calculation of DAF uses the maximum value of a constituent's leachate concentration, that is, the initial concentration at the time when leaching from the WMU begins, and uses the maximum time-average well exposure concentration (see Figure 6.1 for C_{RW}).

The DAF accounts for the aggregate effects of all fate and transport processes simulated by EPACMTP. The value of the DAF is constituent-specific, as well as WMU- and liner design-specific, that is, more protective liner designs increase the value of the DAF for a given chemical constituent. Likewise, constituents which are subject to degradation and sorption in the subsurface will have higher DAFs than constituents which do not react in the subsurface.

For the purpose of determining IWEM LCTVs, the IWEM tool first converts the CDF of predicted ground-water well concentrations into an equivalent CDF of DAF values. This is depicted schematically in Figure 6.2. The 90th percentile DAF is the DAF value that corresponds to the 90th percentile value of the ground-water well concentration

for a fixed value of leachate concentration. Because the DAF is inversely related to the ground-water well concentration, a lower DAF value indicates that the concentration at the well is closer to the leachate concentration and this provides a higher degree of protection. As depicted in Figure 6.2, the CDF of DAF is ordered from high to low values, and the 90th percentile DAF is defined such that 90% of DAF values are higher than this threshold.

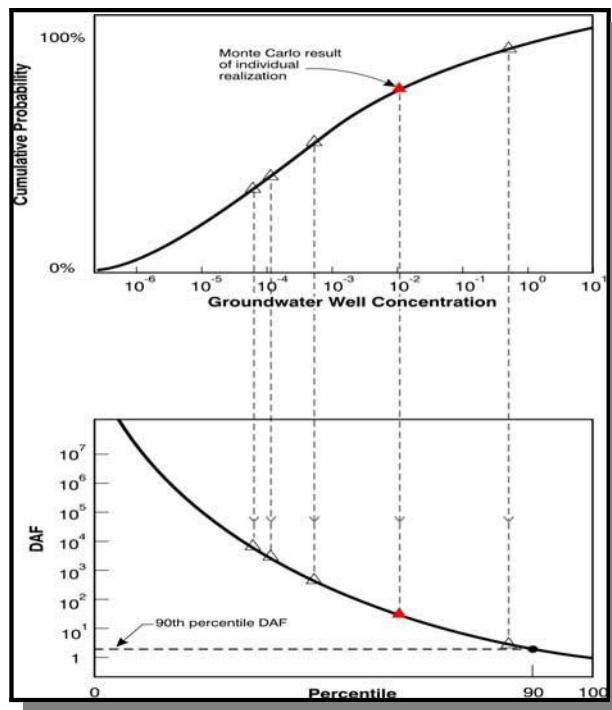


Figure 6.2 Relationship Between Cumulative Distribution Function (CDF) of Well Concentrations and Dilution and Attenuation Factors (DAFs).

Because the RGCs represent acceptable threshold values for the concentration of chemical constituents in ground water, the RGC can be substituted for C_{RW} in the equation above. In this case, C_L then represents the allowable concentration in the leachate, or the LCTV. Making these substitutions and rearranging to solve for the LCTV gives us:

$$\text{LCTV} = \text{DAF}_{90} \times \text{RGC}$$

where

- LCTV = Leachate Concentration Threshold Value (mg/L)
- DAF₉₀ = Dilution and attenuation factor at a 90th percentile protection level
- RGC = Reference ground-water concentration (mg/L)

For each organic constituent in Tier 1, we conducted one modeling run (consisting of 10,000 realizations) per WMU and liner scenario to determine the DAF₉₀, and then used the equation above to calculate the Tier 1 LCTV. As we will discuss in Section 6.2, these “raw” Tier 1 LCTVs were then subjected to several caps to determine the final Tier 1 LCTVs. The final LCTVs presented in the Tier 1 look-up tables were rounded to two significant digits. For organic constituents, the Tier 1 LCTV tables in Appendix F include the DAF values generated by EPACMTP.

In Tier 2, once all of the user-specified inputs have been entered, and the Monte Carlo simulations are complete, the IWEM software constructs the CDFs of the ground-water well concentration and the DAF, and then develops a liner recommendation by directly comparing expected exposure concentrations to RGCs. In addition, IWEM calculates Tier 2 LCTVs using the same equation and caps as used for Tier 1.

6.1.2 Determining LCTVs for Metals

In the case of metals constituent whose geochemical behavior is characterized by nonlinear sorption isotherms (see Section 4.2.4), the concept of a DAF is still applicable, but due to their nonlinear transport behavior, the metals do not have a DAF that is constant across all leachate concentrations. Therefore, for metals, we used a slightly different methodology to determine the Tier 1 LCTVs. For each metal constituent and WMU/liner scenario, we ran multiple EPACMTP Monte Carlo simulations using a number of different input values of leachate concentration. For each value of leachate concentration we compared the 90th percentile value of the predicted well concentration to each of the applicable RGCs until we found the leachate concentration that resulted in 10% of the simulations exceeding the given RGC – a protection level of 90%. In this way, we determined the Tier 1 LCTVs for metals directly, without the intermediate step of determining the DAF. For this reason, DAF values are not presented for the metals in the Tier 1 Look-up Tables (Appendix F) in the results of the IWEM software.

For each metal constituent and WMU/liner scenario, we continued the iterative process of running EPACMTP with different values of leachate concentration, until we found the leachate concentration value for which the predicted ground-water concentration would match the target RGC between 89.9 and 90.1 percentile probability, i.e., we used a convergence tolerance of ± 0.1 percentile point. We then rounded this convergent input leachate concentration to two significant digits and reported it as the

LCTV of the metal constituent for the specified liner scenario. As a quality control check on these calculations, we performed an independent Monte Carlo simulation for each metal LCTV, with the above value as input, and verified that the 90th percentile of the predicted ground-water well concentrations did indeed match the target RGC, up to the first two significant digits.

In Tier 2, the LCTV for metal constituents is an estimated value. Rather than performing time-consuming iterative EPACMTP Monte Carlo simulations to determine exact LCTVs, IWEM estimates values using an empirical adjustment factor of 0.85 in order to ensure adequate protection of ground water. Tier 2 LCTVs for metals are calculated as:

$$\text{LCTV} = \text{DAF} \times \text{RGC} \times 0.85$$

6.2 Capping the LCTVs

Once the raw LCTV was determined for each constituent, this value was then subjected to the following limits:

- # Toxic hydrolysis transformation products cap;
- # 1,000 (mg/L) cap; and
- # TC Rule cap.

6.2.1 Hydrolysis Transformation Products

For organic constituents with transformation products that are produced by chemical hydrolysis, the final LCTV values of the parent are modified if necessary to be protective for the daughter product(s). That is, we also calculated LCTVs for any transformation product(s) into which the parent might hydrolyze, assuming complete transformation. Then, if any of the daughter products was found to have a lower LCTV than the parent, the parent LCTV was set equal to (that is, capped at) the LCTV of the daughter. Details of the calculation procedure we used to develop the daughter product caps are presented in the text box which follows this page.

Table 6.1 presents the IWEM constituents that have toxic hydrolysis transformation products that are included in the IWEM Tier 1 and Tier 2 analyses. We assembled this table from information in Kollig et al. (1993) and Jeffers et al. (1989). The last column of Table 6.1 presents the ratio of the number of moles of the daughter product to the number of moles of the parent compound; for instance, a “1” in this column means that one mole of the daughter is produced by the hydrolysis of one mole of the parent, and a “2” in this column means that two moles of the daughter are produced by the hydrolysis of one mole of the parent compound.

In accounting for hydrolysis daughter products, we did not explicitly model the formation, fate, and transport of transformation products along with the parent constituent in the EPACMTP simulations, but rather made the adjustments by applying a cap to the parent LCTV if necessary. This methodology is relatively simple and protective because it is based on the assumption that the parent compounds are fully transformed. In reality, the rate of hydrolysis may be quite slow with half-lives on the order of several hundred years, and the formation of certain daughter products may also depend on pH and other factors. When we calculated the parent LCTVs for slowly hydrolyzing compounds we used the actual, constituent-specific hydrolysis parameters (see Appendix B). Only when we calculated the daughter LCTVs did we assume that 100% transformation would occur.

Calculation Procedure to Determine Daughter Product Caps

Suppose that we have a parent chemical (P) that hydrolyzes to form two daughter products (D1 and D2). The molecular weights of these chemicals are MW(P), MW(D1), and MW(D2). The EPACMTP-modeled DAFs are DAF(P), DAF(1), and DAF(2). The reference ground-water concentrations for these chemicals are RGC(P), RGC(D1), and RGC(D2). The “raw” LCTVs are calculated as the product of the modeled DAF and the given RGC; these values are denoted as LCTV(P), LCTV(D1) and LCTV(D2) and are referred to as “raw” LCTVs because they are the calculated values that have not yet been affected by the capping procedure. One mole of P hydrolyzes to form n(1) moles of D(1) and n(2) moles of D(2); n(1) and n(2) are referred to as the stoichiometric factors.

For a given RGC (reference ground-water concentration, e.g., MCL, HBN), the following steps are followed to calculate the final LCTV of the parent compound:

1. Determine the raw LCTV of the parent chemical, using the following equation:

$$\text{LCTV(P)} = \text{DAF(P)} \times \text{RGC(P)}$$

2. Determine the (raw) LCTV of each daughter, using the following equations:

$$\text{LCTV(D1)} = \text{DAF(D1)} \times \text{RGC(D1)}$$

$$\text{LCTV(D2)} = \text{DAF(D2)} \times \text{RGC(D2)}$$

3. Using the molecular weight and stoichiometric factor of each daughter, calculate the adjusted LCTV (denoted as LCTV(P(i)*) in the equations below) of the parent based on each daughter.

For D1:

$$\text{LCTV(P(D1)*)} = \text{LCTV(D1)} \times \text{MW(P)} / (\text{n(D1)} \times \text{MW(D1)})$$

For D2:

$$\text{LCTV(P(D2)*)} = \text{LCTV(D2)} \times \text{MW(P)} / (\text{n(D2)} \times \text{MW(D2)})$$

4. For each daughter, compare the adjusted LCTV of the parent based on that daughter to the uncapped LCTV of the parent; if the adjusted LCTV of the parent is less than the uncapped LCTV of the parent, replace the uncapped LCTV of the parent with the adjusted LCTV of the parent based on that daughter:

For D1:

$$\text{If } (\text{LCTV(P)} < \text{LCTV(D1)} \times \text{MW(P)} / (\text{n(D1)} \times \text{MW(D1)})) \\ \text{then } \text{LCTV(P(D1)*)} = \text{LCTV(D1)} \times \text{MW(P)} / (\text{n(D1)} \times \text{MW(D1)})$$

$$\text{Otherwise } \text{LCTV(P(D1)*)} = \text{LCTV(P)}$$

For D2:

$$\text{If } (\text{LCTV(P)} < \text{LCTV(D2)} \times \text{MW(P)} / (\text{n(D2)} \times \text{MW(D2)})) \\ \text{then } \text{LCTV(P(D2)*)} = \text{LCTV(D2)} \times \text{MW(P)} / (\text{n(D2)} \times \text{MW(D2)})$$

$$\text{Otherwise } \text{LCTV(P(D2)*)} = \text{LCTV(P)}$$

5. Compare all the adjusted LCTV of the parent, and pick the smallest value as the final LCTV of the parent:

$$\text{LCTV(P)} = \text{Min} (\text{LCTV(P(D1)*)}, \text{LCTV(P(D2)*)})$$

Table 6.1 IWEM Constituents with Toxic Hydrolysis Transformation Products

Parent Constituent CAS #	Common Name	Transformation Product(s) CAS #	Common Name	Molar Ratio
107-13-1	Acrylonitrile	79-06-1	Acrylamide	1
		79-10-7	Acrylic Acid	1
100-44-7	Benzyl chloride	100-51-6	Benzyl alcohol	1
74-83-9	Bromomethane	67-56-1	Methanol	1
50-29-3	DDT, p,p'-	72-55-9	DDE	1
80-62-6	Methyl methacrylate	67-56-1	Methanol	1
75-09-2	Methylene Chloride (Dichloromethane)	50-00-0	Formaldehyde	1
79-34-5	Tetrachloroethane 1,1,2,2-	79-01-6	Trichloroethylene	1
71-55-6	Trichloroethane 1,1,1-	75-35-4	Dichloroethylene 1,1-	1
79-00-5	Trichloroethane 1,1,2-	75-35-4	Dichloroethylene 1,1-	1
75-34-3	Dichloroethane 1,1-	75-07-0	Acetaldehyde	1
		75-01-4	Vinyl chloride	1
107-06-2	Dichloroethane 1,2-	75-01-4	Vinyl chloride	1
		75-21-8	Ethylene oxide	
		107-21-1	Ethylene Glycol	
111-44-4	Bis(2-chloroethyl)ether	123-91-1	Dioxane 1,4-	1
58-89-9	HCH (Lindane) gamma-	120-82-1	Trichlorobenzene 1,2,4-	1
319-84-6	HCH alpha-	120-82-1	Trichlorobenzene 1,2,4-	1
630-20-6	Tetrachloroethane 1,1,1,2-	79-01-6	Trichloroethylene	1
60-51-5	Dimethoate	7783-06-4	hydrogen sulfide	1
		67-56-1	Methanol	1
131-11-3	Dimethyl phthalate	67-56-1	Methanol	2
298-00-0	Methyl parathion	67-56-1	Methanol	2
		7783-06-4	hydrogen sulfide	1

A number of daughter products that are produced by hydrolysis of these parent compounds could not be included in the IWEM analyses due to a lack of toxicological benchmarks for the daughter compounds. Table 6.2 presents a list of these daughter products along with their IWEM parent constituents. Several parent constituents have the same hydrolysis end-products, and a number of the daughters in Table 6.2 therefore are listed with multiple parents. An example is hydrochloric acid which is a breakdown product of a several chlorinated components.

Table 6.2 IWEM Daughter Constituents Without RGC Values

Daughter Constituent		IWEM Parent Constituent	
CAS No.	Name	CAS No.	Name
64-19-7	Acetic acid	71-55-6	Trichloroethane, 1,1,1-
7664-41-7	Ammonia	107-13-1	Acrylonitrile
111-46-6	Bis(2-hydroxyethyl)ether	111-44-4	Bis(2-chloroethyl)ether
107-20-0	Chloroacetaldehyde	79-00-5	Trichloroethane, 1,1,2-
107-07-3	Chloroethanol, 2-	107-06-2	Dichloroethane
628-89-7	(2-chloroethoxy)ethanol,2-	111-44-4	Bis(2-chloroethyl)ether
7647-01-0	Hydrochloric acid	100-44-7	Benzyl chloride
		7647-01-0	DDT, p,p'-
		75-09-2	Dichloromethane
		79-34-5	Tetrachloroethane, 1,1,2,2-
		71-55-6	Trichloroethane, 1,1,1-
		79-00-5	Trichloroethane, 1,1,2-
		75-34-3	Dichloroethane, 1,1-
		107-06-2	Dichloroethane, 1,2-
		111-44-4	Bis(2-chloroethyl)ether
		58-89-9	HCH, gamma-
		319-84-6	HCH, alpha-
		630-20-6	Tetrachloroethane, 1,1,1,2-
7783-06-4	Hydrogen sulfide	630-20-6	Tetrachloroethane, 1,1,1,2-
		298-00-0	Methylparathion
		60-51-5	Dimethoate
79-14-1	Hydroxacetic acid	630-20-6	Tetrachloroethane, 1,1,1,2-
79-41-4	Methylacrylic acid	80-62-6	Methylmethacrylate
4376-18-5	Methylhydrogen phthalate	131-11-3	Dimethyl phthalate
100-02-7	Nitrophenol, 2-	298-00-0	Methylparathion
7664-38-2	Phosphoric acid	298-00-0	Methylparathion
88-99-3	Phthalic acid	131-11-3	Dimethylphthalate
87-61-6	Trichlorobenzene	58-89-9	HCH, gamma-
		319-84-6	HCH, alpha-

Table 6.3 1,000 mg/L Cap
 Table 6.3 Toxicity Characteristic Regulatory Levels (U.S. EPA, 1990)

The second cap we applied was to limit the calculated LCTV for any constituent at 1,000 mg/L. If the LCTV calculated from the ground-water modeling analysis is greater than 1,000 mg/L, the LCTV will be set to 1,000 mg/L. The basis for this cap is that leachate concentrations from nonhazardous wastes are not expected to exceed this value. The calculated “raw” LCTVs exceeded the 1,000 mg/L cap in a significant number of cases for composite liner designs. Review of the LCTV tables in Appendix F shows that many of the composite liner LCTVs are capped at this value.

6.2.3 TC Rule Cap

Finally, we capped the LCTVs for the 39 constituents that are identified in the Toxicity Characteristic Rule (TC Rule) (40 CFR 261.24; U.S. EPA, 1990) at their regulatory TC level (see Table 6.3). The basis for applying this cap is that any waste with leachate concentrations equal to or greater than the TC Rule regulatory level is a characteristically hazardous waste under RCRA and state statutes.

6.3 Making Liner Recommendations

The IWEM tool allows the user to enter chemical and facility information and automatically analyzes the results of the database query (Tier 1) or the modeling analysis (Tier 2) to determine an appropriate WMU design that is protective of ground water. The use and interpretation of the Tier 1 and Tier 2 evaluations are described in this section.

When interpreting the Tier 1 and 2 liner recommendations, the following key risk assessment issues should be kept in mind:

- # The IWEM HBNs correspond to a target risk of 1×10^{-6} for carcinogens and a target HQ of 1 for noncarcinogens. These targets are used to calculate separate HBNs for each constituent of concern, and separate HBNs for each exposure route of concern (ingestion or inhalation). The Tier 1 and Tier 2 evaluations do not consider combined exposure from ground-water ingestion (from drinking water) and ground-water inhalation (from showering), nor do they consider the potential for additive exposure to multiple constituents. Therefore, use caution when evaluating multiple constituents that have similar fate and transport characteristics (e.g., similar k_d s and hydrolysis rates), as well as constituents with non-cancer health effects associated with the same target organ.

Constituent	TC Rule Leachate Concentration Limit (mg/L)	Constituent	TC Rule Leachate Concentration Limit (mg/L)
Arsenic	5.0	Hexachlorobenzene	0.13
Barium	100	Hexachloro-1,3-butadiene	0.5
Benzene	0.5	Hexachloroethane	3.0
Cadmium	1.0	Lead	5.0
Carbon tetrachloride	0.5	Lindane	0.4
Chlordane	0.03	Mercury	0.2
Chlorobenzene	100	Methoxychlor	10.0
Chloroform	6.0	Methyl ethyl ketone	200.0
Chromium	5.0	Nitrobenzene	2.0
o-Cresol	200	Pentachlorophenol	100.0
m-Cresol	200	Pyridine	5.0
p-Cresol	200	Selenium	1.0
Cresol	200	Silver	5.0
2,4-D	10.0	Tetrachloroethylene	0.7
1,4-Dichlorobenzene	7.5	Toxaphene	0.5
1,2-Dichloroethane	0.5	Trichloroethylene	0.5
1,1-Dichloroethylene	0.7	2,4,5-Trichlorophenol	400
2,4-Dinitrotoluene	0.13	2,4,6-Trichlorophenol	2.0
Endrin	0.02	2,4,5-TP Acid (Silvex)	1.0
Heptachlor	0.008	Vinyl chloride	0.2

- # Usually, doses less than the RfD (HQ=1) are not likely to be associated with adverse health effects and, therefore, are less likely to be of regulatory concern. As the frequency and/or magnitude of the exposures exceeding the RfD increase (HQ>1), the probability of adverse effects in a human population increases. However, it should not be categorically concluded that all doses below the RfD are “acceptable” (or will be risk-free) and that all doses in excess of the RfD are “unacceptable” (or will result in adverse effects).

6.3.1 Use and Interpretation of Tier 1 Evaluation

The Tier 1 evaluation is intended to provide a rapid, national-scale screening assessment to determine if a proposed WMU design will be protective of human health and the environment.

Table 6.3 is a Tier 1 analysis characteristic Regulatory Level (U.S. EPA, 1990) ground-water resources is characterized by comparing the expected constituent leachate concentration (based on the TCLP or another appropriate leachate test method) to the calculated LCTV in the appropriate look-up table. That is, the Tier 1 user only needs to know the type of WMU to be evaluated, the chemical constituents expected in the waste (these constituents are chosen from a list provided in the IWEM software), and their expected leachate concentrations. EPA has performed the Tier 1 Monte Carlo simulations for each of the IWEM constituents and assembled the results into Tier 1 LCTV look-up tables. An electronic version of these look-up tables is included in the IWEM software as the Tier 1 Evaluation, and a printed copy of the tables are included in Appendix F of this document. This appendix presents LCTV values corresponding to each of the available RCGs for each constituent, that is LCTVs based on MCLs as well as on ingestion and inhalation cancer and non-cancer HBNs. Where a RGC is not available, for instance, a constituent does not have an inhalation HBN, the LCTV entry in the table is left blank. The IWEM Tier 1 evaluation automatically performs the required comparisons of leachate concentration to all of the LCTVs for each waste constituent and liner scenario. The result of this comparison determines the recommended liner system for the WMU or determines whether land application of this waste is appropriate (that is, determines whether the waste constituent concentrations will not exceed HBNs at a well if a particular WMU design is implemented). In Tier 1, the results of the evaluation are presented in terms of a MCL summary and a HBN summary. The HBNs summary reflects the liner recommendation based on the most protective, that is the lowest, HBN available for each constituent.

If the user-identified leachate concentrations for all constituents are lower than the corresponding no-liner LCTVs in the look-up table, then no liner is recommended as being sufficiently protective of ground water. If any leachate concentration is higher than the corresponding no-liner LCTV, then a minimum of a single clay liner is recommended. If any leachate concentration is higher than the corresponding single-liner LCTV, then a minimum of a composite liner is recommended. If any concentration is higher than the composite liner, consider pollution prevention, treatment, or additional controls. For waste streams with multiple constituents, the most protective minimum recommended liner that is specified for any one constituent is the recommended liner design.

After conducting a Tier 1 analysis, the user can choose to implement the Tier 1 recommendation by designing the unit based on the liner recommendations given by the IWEM software. If the user chooses to implement the Tier 1 recommendation, consultation with state authorities is recommended to ensure compliance with state regulations, which may require more protective measures than the Tier 1 lookup tables recommend. Alternatively, if the waste has one or very few "problem" constituents that call for a more stringent and costly liner system (or which make land application

inappropriate), evaluate pollution prevention, recycling, and treatment efforts for those constituents.

If, after conducting the Tier 1 analysis, the user is not satisfied with the resulting recommendations or if site-specific conditions seem likely to support the use of a liner design different from the one recommended (or suggest a different conclusion regarding the appropriateness of land application of a waste), then the user can proceed to the Tier 2 analysis or conduct a site-specific ground-water fate and transport analysis (Tier 3).

6.3.2 Use and Interpretation of Tier 2 Evaluation

The Tier 2 analysis is designed to provide user-friendly software that allows users to input location-specific data for a number of EPACMTP input parameters and quickly determine if a proposed WMU design will be protective of human health and the environment.

As with Tier 1, the IWEM software provides the Tier 2 user with a list of constituents commonly encountered when managing industrial waste, along with the opportunity to input constituent-specific data that are necessary for a Tier 2 analysis (for examples parameters such as decay rate and sorption coefficients, as well as HBNs and/or MCLs). The IWEM Tier 2 evaluation also allows the user to define new chemicals and enter the required chemical property data, including user-specified RGCs. Once the list of constituents and their chemical data have been specified, the user is requested to input location-specific data, where available, and to document the source of these data. In Tier 2, the user also selects the type of RGC to be used in the evaluation. This can be MCL, HBN, or all available. If the user selects one type of RGC, IWEM performs the evaluation only for that RGC. If all available RGCs are selected, then all are considered in the evaluation and the final liner recommendation will be based on the most protective, that is the lowest, RGC for each constituent.

After entering the available data, the EPACMTP model is automatically launched by the IWEM software. In Tier 2, EPACMTP will perform Monte Carlo simulations, comprising 10,000 model realizations for each waste constituent and liner design, in order to determine the minimum recommended liner design at a 90th percentile protection level. The Monte Carlo simulations can be computationally demanding, and an evaluation of multiple liner designs for a single waste constituent can take several hours. In order to optimize the computational process, IWEM will first perform the liner evaluations from least protective (no-liner) to most protective (composite liner). If during this process, IWEM identifies a liner design that is protective for all constituents (for instance, a single clay liner), it will stop the evaluation process, and not evaluate more protective designs (in the example case, it would skip the composite liner evaluation). Once the modeling analyses are complete, the user is provided with

recommendations regarding whether or not a specific liner type for a WMU is protective based on the modeled 90th percentile exposure concentrations using the location-specific data and the RGCs for the chemicals of concern.

After conducting the Tier 2 Evaluation, you can choose to implement the Tier 2 recommendation by designing the unit based on the liner recommendations given by the IWEM software or continue to a Tier 3 analysis. If the user chooses to implement the Tier 2 recommendation, consultation with state authorities is recommended to ensure compliance with state regulations, which may require more protective measures than the Tier 2 results recommend. Alternatively, if the waste has one or very few “problem” constituents that call for a more stringent and costly liner system (or which make land application inappropriate), evaluate pollution prevention, recycling, and treatment efforts for those constituents. If you are not satisfied with the resulting recommendations or if site-specific conditions seem likely to support the use of a liner design different from the one recommended (or suggest a different conclusion regarding the appropriateness of land application of a waste), then you may wish to consider a fully site-specific ground- water fate and transport analysis (Tier 3).

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APPENDIX A
GLOSSARY

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GLOSSARY

Adsorption - Adherence of molecules in solution to the surface of solids.

Adsorption isotherm - The relationship between the concentration of constituent in solution and the amount adsorbed at constant temperature.

Advection - The process whereby solutes are transported by the bulk mass of flowing fluid.

Alluvium - The general name for all sediments, including clay, silt, sand, gravel or similar unconsolidated material deposited in a sorted or semi-sorted condition by a stream or other body of running water, in a stream bed, floodplain, delta or at the base of a mountain slope as a fan.

Anisotropy - The condition of having different properties in different directions.

Aquifer - A geologic formation, group of formations, or part of a formation that contains sufficient saturated permeable material to yield significant quantities of water to wells and springs.

Aquifer system - A body of permeable material that functions regionally as a water-yielding unit; it comprises two or more permeable beds separated at least locally by confining beds that impede ground-water movement but do not greatly affect the regional hydraulic continuity of the system; includes both saturated and unsaturated parts of permeable material.

Area of influence of a well - The area surrounding a pumping or recharging well within which the potentiometric surface has been changed.

Breakthrough curve - A graph of concentration versus time at a fixed location.

Cancer slope factor (CFS) - An upper bound estimate, approximating a 95% confidence limit, on the increased cancer risk from a lifetime exposure to an agent. This estimate, usually expressed in units of proportion (of a population) affected per mg/kg/day, is generally reserved for use in the low-dose region of the dose-response relationship, that is, for exposures corresponding to risks less than 1 in 100.

Cation exchange capacity - The sum total of exchangeable cations that a porous medium can absorb. Expressed in moles of ion charge per kilogram of soil.

Chronic daily intake (CDI) - Exposure expressed as mass of a substance contacted per unit body weight per unit time, averaged over a long period of time.

Confined - A modifier that describes a condition in which the potentiometric surface is above the top of the aquifer.

Confined aquifer - An aquifer bounded above and below by impermeable beds or by beds of distinctly lower permeability than that of the aquifer itself; an aquifer containing confined ground water.

Confining unit - A body of impermeable or distinctly less permeable material which separates water-bearing layers.

Darcian velocity - The rate of ground-water flow per unit area of porous or fractured media measured perpendicular to the direction of flow. See specific discharge.

Darcy's law - An empirical law which states that the velocity of flow through porous medium is directly proportional to the hydraulic gradient.

Desorption - Removal of a substance adsorbed to the surface of an adsorbent. Also, the reverse process of sorption.

Diffusion - Spreading of solutes from regions of higher concentration to regions of lower concentration caused by the concentration gradient. In slow-moving ground water, this can be a significant mixing process.

Diffusion coefficient - The rate at which solutes are transported at the microscopic level due to variations in the solute concentrations within the fluid phases.

Dispersion coefficient - A measure of the tendency of a plume of dissolved constituents in ground water to spread. Equal to the sum of the coefficients of mechanical dispersion and molecular diffusion in a porous medium.

Dispersion, longitudinal - Process whereby some of the water molecules and solute molecules travel more rapidly than the average linear velocity and some travel more slowly. Results in the spreading of the solute in the direction of the bulk flow.

Dispersion, transverse - Process whereby some of the water molecules and solute molecules spread in directions perpendicular to the bulk flow.

Dispersivity - A geometric property of a porous medium that determines the dispersion characteristics of the medium by relating the components of pore velocity to the dispersion coefficient.

Distribution coefficient - The quantity of a constituent sorbed by a solid per unit weight of solid divided by the quantity dissolved in water per unit volume of water.

Dose-response relationship - The relationship between a quantified exposure (dose), and the proportion of subjects demonstrating specific, biological changes (response).

Evapotranspiration - The combined loss of water from a given area by evaporation from the land and transpiration from plants.

Exposure pathway - The course a chemical or physical agent takes from a source to an exposed organism. An exposure pathway describes a unique mechanism by which an individual or population is exposed to chemicals or physical agents at, or originating from, a site. Each exposure pathway includes a source or release from a source, an exposure point, and an exposure route. If the exposure point differs from the source, transport/exposure medium (e.g., water) or media (in case of intermedia transfer) also is included.

Exposure point - A location of potential contact between an organism and a chemical or physical agent.

Exposure point concentration - an estimate of the of the arithmetic average concentration of a contaminant at a exposure point.

Flow, steady - A characteristic of a flow system where the magnitude and direction of specific discharge are constant in time at any point. See also flow, unsteady.

Flow, uniform - A characteristic of a flow system where specific discharge has the same magnitude and direction at any point.

Flow, unsteady - A characteristic of a flow system where the magnitude and/or direction of the flow rate changes with time.

Flow velocity - The rate of ground-water flow per unit area of porous or fractured media measured perpendicular to the direction of flow. See specific discharge.

Flux - The rate of ground-water flow per unit area of porous or fractured media measured perpendicular to the direction of flow. See specific discharge.

Fracture - A break or crack in the bedrock.

Geohydrologic system - The geohydrologic units within a geologic setting, including any recharge, discharge, interconnections between units, and any natural or human-induced processes or events that could affect ground-water flow within or among those units. See ground-water system.

Geohydrologic unit - An aquifer, a confining unit, or a combination of aquifers and confining units comprising a framework for a reasonably distinct geohydrologic system. See hydrogeologic unit.

Ground water - Water present below the land surface in a zone of saturation. Ground water is the water contained within an aquifer.

Ground water, confined - Ground water under pressure significantly greater than atmospheric and whose upper limit is the bottom of a confining unit.

Ground-water discharge - Flow of water out of the zone of saturation.

Ground-water flow - The movement of water in the zone of saturation.

Ground-water flux - The rate of ground-water flow per unit area of porous or fractured media measured perpendicular to the direction of flow. See specific discharge.

Ground-water mound - A raised area in a water table or potentiometric surface created by ground-water recharge.

Ground-water recharge - The process of water addition to the saturated zone or the volume of water added by this process.

Ground-water system - A ground-water reservoir and its contained water. Also, the collective hydrodynamic and geochemical processes at work in the reservoir.

Ground-water table - That surface below which rock, gravel, sand or other material is saturated. It is the surface of a body of unconfined ground water at which the pressure is atmospheric. Also called water table; synonymous with phreatic surface.

Ground-water travel time - The time required for a unit volume of ground water or solute to travel between two locations. The travel time is the length of the flow path divided by the pore water velocity. If discrete segments of the flow path have different hydrologic properties, the total travel time will be the sum of the travel times for each discrete segment.

Ground water, unconfined - Water in an aquifer that has a water table. See also ground water, confined.

Hazard quotient - The ratio of a single contaminant exposure level over a specified time period to a reference dose for that contaminant derived from a similar period.

Health-based number (HBN) - The maximum constituent concentration in ground water that is expected to not usually cause adverse noncancer health effects in the general population (including sensitive subgroups), or that will not result in an additional incidence of cancer in more than approximately one in one million individuals exposed to the contaminant.

Heterogeneity - A characteristic of a medium in which material properties vary throughout the medium.

Homogeneity - A characteristic of a medium in which material properties are identical throughout the medium.

Hydraulic conductivity - A coefficient of proportionality describing the rate at which water can move through an aquifer or other permeable medium. Synonymous with permeability.

Hydraulic gradient - Slope of the water table or potentiometric surface.

Hydraulic head - The level to which water rises in a well with reference to a datum such as sea level.

Hydrodynamic dispersion - The spreading of the solute front during ground-water plume transport resulting from both mechanical dispersion and molecular diffusion. Synonymous with mechanical dispersion.

Hydrogeologic unit - Any soil or rock unit or zone that by virtue of its porosity or permeability, or lack thereof, has a distinct influence on the storage or movement of ground water.

Hydrologic properties - Those properties of a rock that govern the entrance of water and the capacity to hold, transmit, and deliver water. Hydrologic properties include porosity, effective porosity, and permeability.

Hydrolysis - The splitting (lysis) of a compound by a reaction with water. Example are the reaction of salts with water to produce solutions that are not neutral, and the reaction of an ester with water.

Hydrostratigraphic unit - See hydrogeologic unit.

Igneous rocks - Rocks that solidified from molten or partly molten materials, that is from a magma or lava.

Immiscible - The chemical property of two or more phases that, at mutual equilibrium, cannot dissolve completely in one another, for example, oil and water.

Impermeable - A characteristic of some geologic material that limits its ability to transmit significant quantities of water under the head differences ordinarily found in the subsurface.

Infiltration - The downward entry of water into the soil or rock, specifically from a waste management unit.

Isotropy - The condition in which the property or properties of interest are the same in all directions.

Leachate - A liquid that has percolated through waste and has extracted dissolved or suspended materials.

Leaching - Separation or dissolving out of soluble constituents from a waste by percolation of water.

Matrix - The solid particles in a porous system and their spatial arrangement. Often used in contrast to the pore space in a porous system.

Matrix diffusion - The tendency of solutes to diffuse from the larger pores in the system into small pores inside the solid matrix from where they can be removed only very slowly.

Maximum Contaminant Level (MCL) - Legally enforceable standards regulating the maximum allowed amount of certain chemicals in drinking water.

Mechanical dispersion - The process whereby solutes are mechanically mixed during advective transport caused by the velocity variations at the microscopic level.

Synonymous with hydrodynamic dispersion.

Metamorphic rocks - Any rock derived from pre-existing rocks by mineralogical, chemical, and/or structural changes, essentially in the solid state, in response to marked changes in temperature, pressure, shearing stress, and chemical environment, generally at depth in the Earth's crust.

Miscible - The chemical property of two or more fluid phases that, when brought together, have the ability to mix and form one phase.

Model - A simplified representation of a physical system obeying certain specified conditions, whose behavior is used to understand the real world system. Often, the model is a mathematical representation, programmed into a computer.

Moisture content - The ratio of either (a) the weight of water to the weight of solid particles expressed as moisture weight percentage or (b) the volume of water to the volume of solid particles expressed as moisture volume percentage in a given volume of porous medium. See water content.

Molecular diffusion - The process in which solutes are transported at the microscopic level due to variations in the solute concentrations within the fluid phases. See diffusion.

Monte Carlo simulation - A method that produces a statistical estimate of a quantity by taking many random samples from an assumed probability distribution, such as a normal distribution. The method is typically used when experimentation is infeasible or when the actual input values are difficult or impossible to obtain.

Mounding - Commonly, an outward and upward expansion of the free water table caused by surface infiltration or recharge.

Outwash deposits - Stratified drift deposited by meltwater streams flowing away from melting ice.

Overburden - The layer of fragmental and unconsolidated material including loose soil, silt, sand and gravel overlying bedrock, which has been either transported from elsewhere or formed in place.

Permeability - The property of a porous medium to transmit fluids under an hydraulic gradient.

Permeable - The property of a porous medium to allow the easy passage of a fluid through it.

pH - A numerical measure of the acidity or alkalinity of water ranging from 0 to 14. Neutral waters have pH near 7. Acidic waters have pH less than 7 and alkaline waters have pH greater than 7.

Pore-water velocity - Average velocity of water particles. Equals the Darcian velocity divided by the effective porosity. Synonymous with seepage velocity.

Porosity - The ratio, usually expressed as a percentage, of the total volume of voids (or pores) of a given porous medium to the total volume of the porous medium.

Porosity, effective - The ratio, usually expressed as a percentage, of the total volume of voids (or pores) available for fluid transmission to the total volume of the porous medium.

Receptor - The potentially exposed individual for the exposure pathway considered.

Recharge - The process of addition of water to the saturated zone; also the water added. In IWEM, recharge is the result of natural precipitation around a waste management unit.

Reference concentration (RfC) - An estimate (with uncertainty spanning perhaps an order of magnitude) of a continuous inhalation exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime. It can be derived from a NOAEL, LOAEL, or benchmark concentration, with uncertainty factors generally applied to reflect limitations of the data used. Generally used in EPA's noncancer health assessments.

Reference Dose (RfD) - An estimate (with uncertainty spanning perhaps an order of magnitude) of a daily oral or dermal exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime.

Retardation factor - The ratio of the average linear velocity of ground water to the velocity of a dissolved constituent. A value greater than one indicates that the constituent moves more slowly than water, usually caused by sorption.

Risk - The probability that a constituent will cause an adverse effect in exposed humans or to the environment.

Risk assessment - The process used to determine the risk posed by contaminants released into the environment. Elements include identification of the contaminants present in the environmental media, assessment of exposure and exposure pathways, assessment of the toxicity of the contaminants present at the site, characterization of human health risks, and characterization of the impacts or risks to the environment.

Saturated Zone - The part of the water bearing layer of rock or soil in which all spaces, large or small, are filled with water.

Sedimentary rocks - Rocks formed from consolidation of loose sediments such as clay, silt, sand, and gravel.

Seepage velocity - See pore-water velocity.

Soil bulk density - The mass of dry soil per unit bulk soil.

Soil moisture - Subsurface liquid water in the unsaturated zone expressed as a fraction of the total porous medium volume occupied by water. It is less than or equal to the porosity.

Solubility - The total amount of solute species that will remain indefinitely in a solution maintained at constant temperature and pressure in contact with the solid crystals from which the solutes were derived.

Solute transport - The net flux of solute (dissolved constituent) through a hydrogeologic unit controlled by the flow of subsurface water and transport mechanisms.

Sorption - A general term used to encompass the process of adsorption.

Source term - The kinds and amounts of constituents that make up the source of a potential release.

Specific discharge - The rate of discharge of ground water per unit area of a porous medium measured at right angle to the direction of flow. Synonymous with Darcian velocity, or (specific) flux.

Till - Till consists of a generally unconsolidated, unsorted, unstratified heterogeneous mixture of clay, silt, sand, gravel and boulders of different sizes and shapes. Till is deposited directly by and underneath glacial ice without subsequent reworking by meltwater.

Toxicity - The degree to which a chemical substance elicits a deleterious or adverse effect on a biological system of an organism exposed to the substance over a designated time period.

Transient flow - See flow, unsteady.

Transmissivity - The rate at which water is transmitted through a unit width of the aquifer under a unit hydraulic gradient. It is equal to an integration of the hydraulic conductivities across the saturated part of the aquifer perpendicular to the flow paths.

Transport - Conveyance of dissolved constituents and particulates in flow systems. See also solute transport.

Unconfined - A condition in which the upper surface of the zone of saturation forms a water table under atmospheric pressure.

Unconfined aquifer - An aquifer that has a water table.

Unconsolidated deposits - Deposits overlying bedrock and consisting of soil, silt, sand, gravel and other material which have either been formed in place or have been transported in from elsewhere.

Unsaturated flow - The movement of water in a porous medium in which the pore spaces are not filled to capacity with water.

Unsaturated zone - The subsurface zone between the water table and the land surface where some of the spaces between the soil particles are filled with air.

Vadose zone - See unsaturated zone.

Volatiles - Substances with relatively large vapor pressures that easily volatilize when in contact with air.

Water content - The amount of water lost from the soil after drying it to constant weight at 105 °C, expressed either as the weight of water per unit weight of dry soil or as the volume of water per unit bulk volume of soil. See also moisture content.

Water table - The upper surface of a zone of saturation except where that surface is formed by a confining unit. The water pressure at the water table equals atmospheric pressure.

Water table aquifer - See unconfined aquifer.

Well - A bored, drilled or driven shaft, or a dug hole extending from the ground surface into the ground water, that is used to inject (injection well) or extract ground water. Well screen - A cylindrical filter used to prevent sediment from entering a water well. There are several types of well screens, which can be ordered in various slot widths, selected on the basis of the grain size of the aquifer material where the well screen is to be located. In very fine grained aquifers, a zone of fine gravel or coarse sand may be required to act as a filter between the screen and the aquifer.

APPENDIX B

LIST OF IWEM WASTE CONSTITUENTS AND DEFAULT CHEMICAL PROPERTY DATA

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Table B-1: Constituent Chemical Properties

CAS	Constituent Name	Molecular Weight (g/mol) (a)	Solubility (mg/L) (b)	Log K _{oc} (log[mL/g]) (c)	Hydrolysis Rate Constants (c)			Diffusion Coefficient in Water (D _w) (m ² /yr) (d)
					Acid Catalyzed (K _a) (1/mol/yr)	Neutral (K _n) (1/yr)	Base Catalyzed (K _b) (1/mol/yr)	
83-32-9	Acenaphthene	154.2	4.24	3.75	0	0	0	
75-07-0	Acetaldehyde [Ethanal]	44.1	1.0E+06 (e)	-0.21 (h)	0	0	0	0.0426
67-64-1	Acetone (2-propanone)	58.1	1.0E+06 (e)	-0.59	0	0	0	0.0363
75-05-8	Acetonitrile (methyl cyanide)	41.1	1.0E+06 (e)	-0.71	0	0	45	0.0445
98-86-2	Acetophenone	120.2	6.13E+03	1.26	0	0	0	
107-02-8	Acrolein	56.1	2.13E+05	-0.22		6.7E+08		0.0385
79-06-1	Acrylamide	71.1	6.4E+05	-0.99	31.5	0.018	0	0.0397
79-10-7	Acrylic acid [propenoic acid]	72.1	1.0E+06 (e)	-1.84	0	0	0	0.0378
107-13-1	Acrylonitrile	53.1	7.4E+04	-0.09	500	0	5.2E+03	0.0388
309-00-2	Aldrin	364.9	0.18	6.18	0	0	0	0.0184
107-18-6	Allyl alcohol	58.1	1.0E+06 (e)	1.47 (e)	0	0	0	
62-53-3	Aniline (benzenamine)	93.1	3.6E+04	0.60	0	0	0	0.0319
120-12-7	Anthracene	178.2	4.3E-02	4.21	0	0	0	
7440-36-0	Antimony	121.8						
7440-38-2	Arsenic	74.9						
7440-39-3	Barium	137.3						
56-55-3	Benz(a)anthracene	228.3	9.4E-03	5.34	0	0	0	0.0186 (i)
71-43-2	Benzene	78.1	1.75E+03	1.80	0	0	0	0.0325
92-87-5	Benzidine	184.2	500.0	1.26	0	0	0	0.0239
50-32-8	Benzo(a)pyrene	252.3	1.62E-03	5.80	0	0	0	0.0208
205-99-2	Benzo(b)fluoranthene	252.3	1.5E-03	5.80	0	0	0	0.0174 (i)
100-51-6	Benzyl alcohol	108.1	4.0E+04	0.78	0	0	0	
100-44-7	Benzyl chloride	126.6	525.00	2.84	0	410	0	0.0278
7440-41-7	Beryllium	9.0						
111-44-4	Bis(2-chloroethyl)ether	143.0	1.72E+04	0.80	0	0.23	0	0.0275
39638-32-9	Bis(2-chloroisopropyl)ether	171.1	1.31E+03	2.39	0		0	0.0233
117-81-7	Bis(2-ethylhexyl)phthalate	390.6	0.34	7.13	0	0	1.4E+03	0.0132
75-27-4	Bromodichloromethane	163.8	6.74E+03	1.77			5.0E+04	0.0337
74-83-9	Bromomethane	94.9	1.52E+04	0.76	0	9.46	0	0.0426
106-99-0	Butadiene 1,3-	54.1	735.00	2.06 (e)				0.0325
71-36-3	Butanol n-	74.1	7.4E+04	0.50	0	0	0	
85-68-7	Butyl benzyl phthalate	312.4	2.69	4.23	0	0	1.2E+05	
88-85-7	Butyl-4,6-dinitrophenol,2-sec-(Dinoseb)	240.2	52.00	2.02	0	0	0	
7440-43-9	Cadmium	112.4						
75-15-0	Carbon disulfide	76.1	1.19E+03	1.84	0	0	31500	0.041
56-23-5	Carbon tetrachloride	153.8	793.00	2.41	0	0.017	0	0.0308
57-74-9	Chlordane	409.8	0.06	5.89	0	0	37.7	0.0172
126-99-8	Chloro-1,3-butadiene 2-(Chloroprene)	88.5	1.74E+03	1.74	0	0	0	0.0315
106-47-8	Chloroaniline p-	127.6	5.3E+03	1.61	0	0	0	
108-90-7	Chlorobenzene	112.6	472.00	2.58	0	0	0	0.0299
510-15-6	Chlorobenzilate	325.2	11.10	4.04	0	0	2.8E+06	0.0173
124-48-1	Chlorodibromomethane	208.3	2.6E+03	1.91			2.5E+04	0.0334
75-00-3	Chloroethane [Ethyl chloride]	64.5	5.68E+03	0.51	0	0	0	0.0366
67-66-3	Chloroform	119.4	7.92E+03	1.58	0	1.0E-04	2740	0.0344
74-87-3	Chloromethane	50.5	5.33E+03	0.91				0.0429
95-57-8	Chlorophenol 2-	128.6	2.2E+04	1.82	0	0	0	0.0299
107-05-1	Chloropropene 3- (Allyl Chloride)	76.5	3.37E+03	1.13	0	40	0	0.0341
16065-83-1	Chromium (III) (Chromic Ion)	52.0						
18540-29-9	Chromium (VI)	52.0						
218-01-9	Chrysene	228.3	1.6E-03	5.34	0	0	0	0.0213
7440-48-4	Cobalt	58.9						
7440-50-8	Copper	63.5						
108-39-4	Cresol m-	108.1	2.27E+04	1.76	0	0	0	0.0294
95-48-7	Cresol o-	108.1	2.6E+04	1.76	0	0	0	0.0311
106-44-5	Cresol p-	108.1	2.15E+04	1.76	0	0	0	0.0291
1319-77-3	Cresols	324.4	2.34E+04	2.12	0	0	0	0.0299
98-82-8	Cumene	120.2	61.30	3.40	0	0	0	0.0248
108-93-0	Cyclohexanol	100.2	4.3E+04 (e)	1.11 (g)	0	0	0	0.0295
108-94-1	Cyclohexanone	98.1	5.0E+03	1.82	0	0	0	
72-54-8	DDD	320.0	0.09	5.89	0	0.025	2.2E+04	
72-55-9	DDE	318.0	0.12	6.64	0	0	0	
50-29-3	DDT p,p'-	354.5	0.03	6.59	0	0.06	3.1E+05	0.014
2303-16-4	Diallate	270.2	40.00	4.17	0	0.1	8.0E+03	
53-70-3	Dibenz(a,h)anthracene	278.4	0.00	6.52	0	0	0	0.019
96-12-8	Dibromo-3-chloropropane 1,2-	236.3	1.23E+03	1.94	0	4.0E-03	1.2E+05	0.0281
95-50-1	Dichlorobenzene 1,2-	147.0	156.00	3.08	0	0	0	0.0281
106-46-7	Dichlorobenzene 1,4-	147.0	73.80	3.05	0	0	0	0.0274
91-94-1	Dichlorobenzidine 3,3'-	253.1	3.11	3.32	0	0	0	0.0173 (i)

Table B-1: Constituent Chemical Properties

CAS	Constituent Name	Molecular Weight (g/mol) (a)	Solubility (mg/L) (b)	Log K _{oc} (log[mL/g]) (c)	Hydrolysis Rate Constants (c)			Diffusion Coefficient in Water (D _w) (m ² /yr) (d)
					Acid Catalyzed (K _a) (1/mol/yr)	Neutral (K _n) (1/yr)	Base Catalyzed (K _b) (1/mol/yr)	
75-71-8	Dichlorodifluoromethane (Freon 12)	120.9	280.00	2.16				0.0341
75-34-3	Dichloroethane 1,1-	99.0	5.06E+03	1.46	0	1.13E-02	0.378	0.0334
107-06-2	Dichloroethane 1,2-	99.0	8.52E+03	1.13	0	9.61E-03	54.7	0.0344
75-35-4	Dichloroethylene 1,1-	96.9	2.25E+03	1.79	0	0	0	0.0347
156-59-2	Dichloroethylene cis-1,2-	96.9	3.5E+03	1.70	0	0	0	
156-60-5	Dichloroethylene trans-1,2-	96.9	6.3E+03	1.60	0	0	0	
120-83-2	Dichlorophenol 2,4-	163.0	4.5E+03	2.49	0	0	0	
94-75-7	Dichlorophenoxyacetic acid 2,4-(2,4-D)	221.0	677.00	0.68	0	0	0	
78-87-5	Dichloropropane 1,2-	113.0	2.8E+03	1.67	0	0	0	0.0307
542-75-6	Dichloropropene 1,3-(mixture of isomers)	111.0	2.8E+03	1.43				0.0319
10061-01-5	Dichloropropene cis-1,3-	111.0	2.72E+03	1.80	0	40	0	0.0322
10061-02-6	Dichloropropene trans-1,3-	111.0	2.72E+03	1.80	0	40	0	0.0319
60-57-1	Dieldrin	380.9	0.20	5.08	0	6.30E-02	0	0.019
84-66-2	Diethyl phthalate	222.2	1.08E+03	1.99	0	0	3.1E+05	
56-53-1	Diethylstilbestrol	268.4	0.10	4.09	0	0	0	
60-51-5	Dimethoate	229.2	2.5E+04	0.13	0	1.68	4.48E+06	
119-90-4	Dimethoxybenzidine 3,3'-	0.0	60.00	1.49	0	0	0	
68-12-2	Dimethyl formamide N,N- [DMF]	73.1	1.0E+06 (g)	-0.99 (h)	0	0	0	0.0353
57-97-6	Dimethylbenz[a]anthracene 7,12-	256.3	2.50E-02	6.64	0	0	0	0.0172 (i)
119-93-7	Dimethylbenzidine 3,3'-	212.3	1.3E+03	2.55	0	0	0	
105-67-9	Dimethylphenol 2,4-	122.2	7.87E+03	2.29	0	0	0	
84-74-2	Di-n-butyl phthalate	278.3	11.20	4.37	0	0	1.8E+06	
99-65-0	Dinitrobenzene 1,3-	168.1	861.00	1.31	0	0	0	
51-28-5	Dinitrophenol 2,4-	184.1	2.79E+03	-0.09	0	0	0	
121-14-2	Dinitrotoluene 2,4-	182.1	270.00	1.68	0	0	0	0.0249
606-20-2	Dinitrotoluene 2,6-	182.1	182.00	1.40	0	0	0	
117-84-0	Di-n-octyl phthalate	390.6	0.02	7.60	0	0	5.2E+05	
123-91-1	Dioxane 1,4-	88.1	1.0E+06 (e)	-0.81	0	0	0	0.0331
122-39-4	Diphenylamine	169.2	35.70	3.30	0	0	0	
122-66-7	Diphenylhydrazine 1,2-	184.2	68.00	2.82	0	0	0	0.0229
298-04-4	Disulfoton	274.4	16.30	2.94	0	2.3	5.4E+04	
115-29-7	Endosulfan (Endosulfan I and II,mixture)	406.9	0.51	3.55				
72-20-8	Endrin	380.9	0.25	4.60	0	0.055	0	
106-89-8	Epichlorohydrin	92.5	6.59E+04	-0.53	2.5E+04	30.9	0	0.035
106-88-7	Epoxybutane 1,2-	72.1	9.5E+04 (e)	0.90 (e)				0.0331
110-80-5	Ethoxyethanol 2-	90.1	1.0E+06 (e)	-0.54	0	0	0	0.0308
111-15-9	Ethoxyethanol acetate 2-	132.2	2.29E+05 (g)	0.70 (g)	0	0	0	0.0252
141-78-6	Ethyl acetate	88.1	8.03E+04	0.35	3.5E+03	4.8E-03	3.4E+06	
60-29-7	Ethyl ether	74.1	5.68E+04	0.55	0	0	0	
97-63-2	Ethyl methacrylate	114.1	3.67E+03	1.27	0	0	1.1E+06	
62-50-0	Ethyl methanesulfonate	124.2	6.3E+03	-0.27	0	1.25E+03	0	
100-41-4	Ethylbenzene	106.2	169.00	3.00	0	0	0	0.0267
106-93-4	Ethylene dibromide (1,2-Dibromoethane)	187.9	4.18E+03	1.42	0	0.63	0	0.0331
107-21-1	Ethylene glycol	62.1	1.0E+06 (e)	-1.50	0	0	0	0.0429
75-21-8	Ethylene oxide	44.1	1.0E+06 (e)	-1.10	2.9E+05	21	0	0.046
96-45-7	Ethylene thiourea	102.2	6.2E+04	0.00	0	0	0	0.0319 (i)
206-44-0	Fluoranthene	202.3	0.21	4.63	0	0	0	
16984-48-8	Fluoride	19.0						
50-00-0	Formaldehyde	30.0	5.5E+05	-1.30	0	0	0	0.0549
64-18-6	Formic acid	46.0	1.0E+06 (e)	-2.70	0	0	0	
98-01-1	Furfural	96.1	1.1E+05	0.80 (j)	0	0	0	0.0337
319-85-7	HCH beta-	290.8	0.24	3.43	0	0	0	0.0233
58-89-9	HCH (Lindane) gamma-	290.8	6.80	3.40	0	1.05	1.7E+06	0.023
319-84-6	HCH alpha-	290.8	2.00	3.43	0	0	0	0.0232
76-44-8	Heptachlor	373.3	0.18	5.21	0	61	0	0.018
1024-57-3	Heptachlor epoxide	389.3	0.20	4.90	0	0.063	0	0.0176
87-68-3	Hexachloro-1,3-butadiene	260.8	3.23	4.46	0	0	0	0.0222
118-74-1	Hexachlorobenzene	284.8	0.01	5.41	0	0	0	0.0248
77-47-4	Hexachlorocyclopentadiene	272.8	1.80	4.72	0	24.8	0	0.0228
55684-94-1	Hexachlorodibenzofurans [HxCDFs]	374.9	8.25E-06 (f)	7.00	0	0	0	0.0133 (i)
34465-46-8	Hexachlorodibenzo-p-dioxins [HxCDDs]	390.9	4.0E-06 (f)	6.38 (g)	0	0	0	0.013 (i)
67-72-1	Hexachloroethane	236.7	50.00	3.61	0	0	0	0.028
70-30-4	Hexachlorophene	406.9	140.00	5.00	0	0	0	
110-54-3	Hexane n-	86.2	12.40	2.95 (k)	0	0	0	0.0256
7783-06-4	Hydrogen Sulfide	34.1	437.00		0	0	0	
193-39-5	Indeno{1,2,3-cd}pyrene	276.3	2.2E-05	6.26	0	0	0	0.0164 (i)
78-83-1	Isobutyl alcohol	74.1	8.5E+04	0.44	0	0	0	
78-59-1	Isophorone	138.2	1.2E+04	1.90	0	0	0	0.0238

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CAS	Constituent Name	Molecular Weight (g/mol) (a)	Solubility (mg/L) (b)	Log K _{oc} (log[mL/g]) (c)	Hydrolysis Rate Constants (c)			Diffusion Coefficient in Water (D _w) (m ² /yr) (d)
					Acid Catalyzed (K _a) (1/mol/yr)	Neutral (K _n) (1/yr)	Base Catalyzed (K _b) (1/mol/yr)	
143-50-0	Kepon	490.6	7.60	4.15	0	0	0	
7439-92-1	Lead	207.2						
7439-96-5	Manganese	54.9						
7439-97-6	Mercury	200.6	0.06					0.0949
126-98-7	Methacrylonitrile	67.1	25400.00	0.22	500	0	5.2E+03	0.0334
67-56-1	Methanol	32.0	1.0E+06 (e)	-1.08	0	0	0	0.052
72-43-5	Methoxychlor	345.7	0.05	4.90	0	0.69	1.2E+04	
109-86-4	Methoxyethanol 2-	76.1	1.0E+06 (e)	0.95 (e)	0	0	0	0.0347
110-49-6	Methoxyethanol acetate 2-	118.1	1.0E+06 (m)		0	0	0	0.0275
78-93-3	Methyl ethyl ketone	72.1	2.23E+05	-0.03	0	0	0	0.0322
108-10-1	Methyl isobutyl ketone	100.2	1.9E+04	0.87	0	0	0	0.0264
80-62-6	Methyl methacrylate	100.1	1.5E+04	0.74	0	0	0	0.0292
298-00-0	Methyl parathion	263.2	55.00	2.47		2.8		
1634-04-4	Methyl tert-butyl ether [MTBE]	88.1	5.13E+04 (e)	1.05 (e)	0	0	0	0.0272
56-49-5	Methylcholanthrene 3-	268.4	0.00	7.00	0	1.7E-02	0	0.0194
74-95-3	Methylene bromide (Dibromomethane)	173.8	1.19E+04	1.21	0	0	0	
75-09-2	Methylene Chloride (Dichloromethane)	84.9	1.3E+04	0.93	0	1.0E-03	0.6	0.0394
7439-98-7	Molybdenum	95.9						
91-20-3	Naphthalene	128.2	31.00	3.11	0	0	0	0.0264
7440-02-0	Nickel	58.7						
98-95-3	Nitrobenzene	123.1	2.09E+03	1.51	0	0	0	0.0298
79-46-9	Nitropropane 2-	89.1	1.7E+04	0.23	0	0	0	0.0322
55-18-5	Nitrosodiethylamine N-	102.1	9.3E+04	-0.03	0	0	0	0.0288
62-75-9	Nitrosodimethylamine N-	74.1	1.0E+06 (e)	0.45	0	0	0	0.0363
924-16-3	Nitroso-di-n-butylamine N-	158.2	1.27E+03	2.09	0	0	0	0.0215
621-64-7	Nitroso-di-n-propylamine N-	130.2	9.89E+03	1.03	0	0	0	0.0245
86-30-6	Nitrosodiphenylamine N-	198.2	35.10	2.84	0	0	0	0.0227
10595-95-6	Nitrosomethylethylamine N-	88.1	1.97E+04	1.03	0	0	0	0.0315
100-75-4	Nitrosopiperidine N-	114.1	7.65E+04	-0.02	0	0	0	0.029
930-55-2	Nitrosopyrrolidine N-	100.1	1.0E+06 (e)	-0.57	0	0	0	0.0319
152-16-9	Octamethyl pyrophosphoramide	286.3	1.0E+06 (m)	-0.51	1.9E+03			
56-38-2	Parathion (ethyl)	291.3	6.54	3.15	0	2.4	3.7E+06	
608-93-5	Pentachlorobenzene	250.3	1.33	5.39	0	0	0	
30402-15-4	Pentachlorodibenzofurans [PeCDFs]	340.4	2.40E-04 (f)	4.93 (g)	0	0	0	0.0142 (i)
36088-22-9	Pentachlorodibenzo-p-dioxins [PeCDDs]	356.4	1.18E-04 (f)	6.3 (g)	0	0	0	0.0138 (i)
82-68-8	Pentachloronitrobenzene (PCNB)	295.3	0.55	4.57	0	0	0	
87-86-5	Pentachlorophenol	266.3	1.95E+03	3.06	0	0	0	0.0253
108-95-2	Phenol	94.1	8.28E+04	1.23	0	0	0	0.0325
62-38-4	Phenyl mercuric acetate	336.7	2.0E+03	0.00	0	0	0	
108-45-2	Phenylenediamine 1,3-	108.1	2.55E+06	-0.30	0	0	0	
298-02-2	Phorate	260.4	50.00	2.64	0	62	0	
85-44-9	Phthalic anhydride	148.1	6.2E+03	1.56 (e)	0	4.9E+05	0	0.0308
1336-36-3	Polychlorinated biphenyls (Aroclors)		0.07	6.19	0	0	0	0.0189
23950-58-5	Pronamide	256.1	32.80	2.63	59	0	610	
75-56-9	Propylene oxide [1,2-Epoxypropane]	58.1	4.05E+05 (e)	1.40 (e)	0	0	0	0.0382
129-00-0	Pyrene	202.3	0.14	4.92	0	0	0	
110-86-1	Pyridine	79.1	1.0E+06 (e)	0.34	0	0	0	0.0344
94-59-7	Safrole	162.2	810.67	2.34	0	0	0	
7782-49-2	Selenium	79.0						
7440-22-4	Silver	107.9						
57-24-9	Strychnine and salts	334.4	160.00	1.90	0	0	0	
100-42-5	Styrene	104.2	310.00	2.84	0	0	0	0.0278
95-94-3	Tetrachlorobenzene 1,2,4,5-	215.9	0.60	4.28	0	0	0	
51207-31-9	Tetrachlorodibenzofuran 2,3,7,8-	306.0	6.92E-04 (f)	6.62	0	0	0	0.0153 (i)
1746-01-6	Tetrachlorodibenzo-p-dioxin 2,3,7,8-	322.0	7.91E-06 (f)	6.10	0	0	0	0.0148 (i)
630-20-6	Tetrachloroethane 1,1,1,2-	167.8	1.1E+03	2.71	0	0.0137	1.13E+04	0.0287
79-34-5	Tetrachloroethane 1,1,2,2-	167.8	2.97E+03	2.07	0	5.1E-03	1.59E+07	0.0293
127-18-4	Tetrachloroethylene	165.8	200.00	2.21	0	0	0	0.0298
58-90-2	Tetrachlorophenol 2,3,4,6-	231.9	100.00	2.32	0	0	0	
3689-24-5	Tetraethyl dithiopyrophosphate (Sulfotep)	322.3	25.00	3.51	0	84	9.0E+06	
7440-28-0	Thallium	204.4						
137-26-8	Thiram [Thiuram]	240.4	30.00	2.83 (e)	0	0	0	
108-88-3	Toluene	92.1	526.00	2.43	0	0	0	0.0291
95-80-7	Toluenediamine 2,4-	122.2	3.37E+04	0.02	0	0	0	0.0282 (i)
95-53-4	Toluidine o-	107.2	1.66E+04	1.24	0	0	0	0.029
106-49-0	Toluidine p-	107.2	782.00	1.24	0	0	0	
8001-35-2	Toxaphene (chlorinated camphenes)		0.74	4.31	0	0.07	2.8E+04	0.0173
75-25-2	Tribromomethane (Bromofom)	252.7	3.1E+03	2.05			1.0E+04	0.0328

Table B-1: Constituent Chemical Properties

CAS	Constituent Name	Molecular Weight (g/mol) (a)	Solubility (mg/L) (b)	Log K _{oc} (log[mL/g]) (c)	Hydrolysis Rate Constants (c)			Diffusion Coefficient in Water (D _w) (m ² /yr) (d)
					Acid Catalyzed (K _a) (1/mol/yr)	Neutral (K _n) (1/yr)	Base Catalyzed (K _b) (1/mol/yr)	
76-13-1	Trichloro-1,2,2-trifluoro-ethane 1,1,2-	187.4	170.00	2.97	0	0	0	0.0271
120-82-1	Trichlorobenzene 1,2,4-	181.4	34.60	3.96	0	0	0	0.0265
71-55-6	Trichloroethane 1,1,1-	133.4	1.33E+03	2.16	0	0.64	2.4E+06	0.0303
79-00-5	Trichloroethane 1,1,2-	133.4	4.42E+03	1.73	0	2.73E-05	4.95E+04	0.0315
79-01-6	Trichloroethylene (Trichloroethylene 1,1,2-)	131.4	1.1E+03	2.10	0	0	0	0.0322
75-69-4	Trichlorofluoromethane (Freon 11)	137.4	1.1E+03	2.11	0	0	0	0.0319
95-95-4	Trichlorophenol 2,4,5-	197.4	1.2E+03	2.93	0	0	0	
88-06-2	Trichlorophenol 2,4,6-	197.4	800.00	2.25	0	0	0	0.0255
93-72-1	Trichlorophenoxypropionic acid 2-(2,4,5-	269.5	140.00	1.74	0	0	0	
93-76-5	Trichlorophenoxyacetic acid 2,4,5-	255.5	268.30	1.43	0	0	0	
96-18-4	Trichloropropane 1,2,3-	147.4	1.75E+03	1.66	0	1.7E-02	3.6E+03	0.0291
121-44-8	Triethylamine	101.2	5.5E+04 (e)	1.31 (l)	0	0	0	0.0247
99-35-4	Trinitrobenzene (Trinitrobenzene 1,3,5-)	213.1	350.00	1.05	0	0	0	
126-72-7	Tris(2,3-dibromopropyl)phosphate	697.6	8.00	3.19	0	8.8E-02	3.0E+05	
7440-62-2	Vanadium	50.9						
108-05-4	Vinyl acetate	86.1	2.0E+04	0.45	0	0	0	0.0315
75-01-4	Vinyl chloride	62.5	2.76E+03	1.04	0	0	0	0.0378
108-38-3	Xylene m-	106.2	161.00	3.09	0	0	0	0.0267
95-47-6	Xylene o-	106.2	178.00	3.02	0	0	0	0.027
106-42-3	Xylene p-	106.2	185.00	3.12	0	0	0	0.0267
1330-20-7	Xylenes (total)	318.5	175.00	3.08	0	0	0	0.0268
7440-66-6	Zinc	65.4						

Note: Data sources for chemical property values are indicated in the column headings; exceptions are noted in parentheses for individual chemical values.

Data sources:

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- U.S. EPA, 1997b. Superfund Chemical Data Matrix (SCDM). SCDMWIN 1.0 (SCDM Windows User's Version), Version 1. Office of Solid Waste and Emergency Response Washington DC: GPO. <http://www.epa.gov/superfund/resources/scdm/index.htm>. Accessed July 2001
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- Calculated based on Water 9. U.S. EPA, 2001. Office of Air Quality Planning and Standards, Research Triangle Park, NC. <http://www.epa.gov/ttn/chief/software/water/ind> Accessed July 2001
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- Lyman, W.J., W.F. Reehl, and D.H. Rosenblatt, 1990. Handbook of Chemical Property Estimation Methods: Environmental Behavior of Organic Compounds. Washington, DC: American Chemical Society.

APPENDIX C
TIER 1 INPUT PARAMETERS

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Table C-1: IWEM Tier 1 Input Parameters for Landfill, No Liner Scenario

Input Type	Input No.	Parameter	Input Distribution Type	Units (output)	Percentiles ²						References	
					0	10	25	50	75	90		100
Source	SS1	Area	Regional Site-Based	m	40.5	486	2,430	12,100	52,600	142,000	3,120,000	USEPA, 1986 and 1997b
	SS2/3	Length/Width	Derived	m	6.36	22.0	49.3	110	229	376	1,770	Derived
	SS5	Recharge Rate	Regional Site-Based	m/yr	1.00E-05	0.0135	0.0686	0.122	0.308	0.438	1.15	ABB, 1995 and USEPA, 1997b
	SS6	Infiltration Rate	Regional Site-Based	m/yr	1.00E-05	0.0135	0.0658	0.109	0.274	0.411	1.08	ABB, 1995 and USEPA, 1997b
	SS10	Duration of Leaching	Derived	yr	9,340	48,200	94,500	199,000	521,000	1,810,000	1.20E+10	Derived
	SS11	Fraction of Landfill Occupied by Waste of Concern	Constant	unitless	1.00						Policy for Tier 1	
	SS12	Depth of Waste Disposal Facility	Regional Site-Based	m	0.510	0.880	1.32	2.57	4.09	6.13	10.1	USEPA, 1986 and 1997b
	SS13	Density of Hazardous Waste	Empirical	g/cm ³	0.700	0.737	0.794	0.889	1.33	1.45	2.10	Schanz and Salhotra, 1992
	FS1	Ratio of Waste Concentration to Leachate Concentration	Constant	L/kg	10000						Policy for Tier 1	
	SS15	Base Depth Below Grade	Constant	m	0.00						No data available	
Unsaturated Zone	US1	Saturated Hydraulic Conductivity	Lognormal ¹	m/yr	0.00377	0.594	2.04	7.80	35.0	169	2,450	Carsel and Parrish, 1988
	US2	Moisture Retention Parameter (alpha)	Johnson SB ¹	1/m	0.129	0.596	0.935	1.52	2.71	5.90	21.8	Carsel and Parrish, 1988
	US3	Moisture Retention Parameter (beta)	Johnson SB ¹	unitless	1.03	1.20	1.27	1.37	1.53	1.82	2.50	Carsel and Parrish, 1988
	US4	Residual Water Content	Johnson SB ¹	unitless	0.0106	0.0489	0.0609	0.0746	0.0857	0.0937	0.115	Carsel and Parrish, 1988
	US5	Saturated Water Content	Constant	unitless	0.410	0.410	0.430	0.450	0.450	0.450	0.450	Carsel and Parrish, 1988
	US6	Thickness of Unsaturated Zone	Regional Site-Based	m	0.305	1.68	3.96	6.10	15.2	42.7	610	API, 1989
	US7	Dispersivity	Derived	m	0.0267	0.0570	0.107	0.154	0.354	0.959	1.00	Gelhar, 1986; EPRI, 1985; USEPA, 1997a
	US8	Percent Organic Matter	Johnson SB ¹	unitless	0.00358	0.0341	0.0567	0.1020	0.177	0.289	1.69	Carsel and others, 1988
	US9	Bulk Density	Constant	g/cm ³	1.60	1.60	1.65	1.65	1.67	1.67	1.67	Carsel and others, 1988
	US10	Soil/Water Distribution Coefficient	Derived	cm ³ /g	chemical-specific value						Derived	
	US11	Freundlich Adsorption Isotherm Exponent	Constant	unitless	1.00						Assumption	
	US12	Chemical Degradation Rate Coefficient	Derived	1/yr	chemical-specific value						Derived	
	US13	Biodegradation Rate Coefficient	Constant	1/yr	0.00						Policy for Tier 1	
Saturated Zone	AS1	Average Particle Diameter	Empirical	cm	0.0004	0.0015	0.00557	0.0191	0.0409	0.0762	0.211	Sahe, 1974
	AS2	Aquifer Effective Porosity	Derived	unitless	0.0501	0.107	0.164	0.236	0.296	0.334	0.426	Davis, 1969; McWorter and Sunada 1977
	AS3	Aquifer Bulk Density	Derived	g/cm ³	1.16	1.30	1.43	1.56	1.63	1.70	1.80	Freeze and Cherry, 1979
	AS4	Aquifer Saturated Thickness	Regional Site-Based	m	0.305	4.27	7.62	14.3	32.4	91.4	914	API, 1989
	AS5	Longitudinal Hydraulic Conductivity	Regional Site-Based	m/yr	3.15	174	804	1,890	11,000	31,500	4,290,000	API, 1989
	AS6	Anisotropy Ratio	Constant	unitless	1.00						Assumption	
	AS7	Hydraulic Gradient	Regional Site-Based	unitless	0.000002	0.0009	0.002	0.0057	0.0151	0.0310	0.491	API, 1989
	AS8	Seepage Velocity	Derived	m/yr	0.100	3.15	16.3	55.0	321	1,320	11,000	Derived
	AS9	Retardation Factor	Derived	unitless	chemical-specific value						Derived	
	AS10	Longitudinal Dispersivity	Gelhar Empirical	m	0.109	0.928	2.72	6.18	9.76	14.5	40.0	EPRI, 1985; Gelhar, 1986; Gelhar, 1992
	AS11	Transverse Dispersivity	Gelhar Empirical	m	0.0136	0.116	0.340	0.773	1.22	1.81	4.99	EPRI, 1985; Gelhar, 1986; Gelhar, 1992
	AS12	Vertical Dispersivity	Gelhar Empirical	m	0.00500	0.00580	0.0170	0.0387	0.0610	0.0903	0.250	EPRI, 1985; Gelhar, 1986; Gelhar, 1992
	AS13	Temperature of Ambient Aquifer Water	Regional Site-Based	degrees C	7.50	7.50	12.5	12.5	17.5	22.5	22.5	Collins, 1925
	AS14	Ambient Groundwater pH	Empirical	standard units	3.21	5.17	6.05	6.81	7.41	7.92	9.70	USEPA STORET database
	AS15	Fraction of Organic Carbon	Johnson SB	unitless	0.0000164	0.000132	0.000234	0.000433	0.000810	0.00139	0.00984	USEPA STORET database
	AS16	Radial Distance of Observation Well from Downgradient Edge of Waste Unit	Constant	m	150						Policy for Tier 1	
	AS17	Angle Off-Center of Observation Well	Constant	degrees	0.00						Policy for Tier 1	
	AS20	Depth of Well Below Water Table	Uniform	m	0.00321	0.945	2.52	6.42	16.4	47.0	897	API, 1989
	AS21	Leading Coefficient of Freundlich Adsorption Isotherm	Derived	cm ³ /g	chemical-specific value						Derived	
	AS22	Freundlich Adsorption Isotherm Exponent	Constant	unitless	1.00						Assumption	
	AS23	Hydrolysis Degradation Rate Coefficient	Derived	1/yr	chemical-specific value						Derived	
	AS24	Biodegradation Rate Coefficient	Derived	1/yr	0.00						Policy for Tier 1	

¹ The actual distribution type depends upon the soil type; the distribution types given here correspond to the silty loam soil (the most common type). In the Tier 1 modeling runs, soil type is automatically varied among the three soil types; each soil type has its own values/distributions of values for the soil parameters. The values presented in this table include all three soil types.

² Values were generated using a Monte Carlo simulation with 10,000 iterations.

Table C-2: IWEM Tier 1 Input Parameters for Surface Impoundment, No Liner Scenario

Input Type	Input No.	Parameter	Input Distribution Type	Units (output)	Percentiles ²							References
					0	10	25	50	75	90	100	
Source	SS1	Area	Regional Site-Based	m	9.30	174	401	1,770	6,970	28,300	4,860,000	USEPA, 2001
	SS2/3	Length/Width	Derived	m	3.05	13.2	20.0	42.1	83.5	168	2,200	Derived
	SS5	Recharge Rate	Regional Site-Based	m/yr	0.0000100	0.00990	0.0465	0.144	0.269	0.377	1.84	ABB 1995 and USEPA, 1997b
	SS6	Infiltration Rate	Regional Site-Based	m/yr	3.78E-15	0.270	0.521	1.14	2.27	3.51	22.3	Derived
	SS10	Operational Life (Duration of Leaching)	Constant	yr	4.00	15.0	50.0	50.0	50.0	50.0	95.0	USEPA, 2001
	SS15	Base Depth Below Grade	DBGS	m	0.00	0.00	0.00	1.22	3.05	4.57	33.5	USEPA, 2001
	SS7	Waste Water Ponding Depth	HZERO	m	0.0100	0.460	0.993	1.81	2.95	4.24	18.2	USEPA, 2001
	SS16	Sediment Thickness (Thickness of Sludge)	DSLUDGE	m				0.20				Assumption
	SS22	Distance to Nearest Surface Water Body	DISSW	m	0.00	90.0	240	360	800	5,000	5,000	USEPA, 2001
Unsaturated Zone	US1	Saturated Hydraulic Conductivity	Lognormal ¹	m/yr	0.00224	0.318	1.08	4.94	43.8	301	2,420	Carsel and Parrish, 1988
	US2	Moisture Retention Parameter (alpha)	Johnson SB ¹	1/m	0.104	0.516	0.801	1.36	3.19	7.88	22.3	Carsel and Parrish, 1988
	US3	Moisture Retention Parameter (beta)	Johnson SB ¹	unitless	1.03	1.18	1.23	1.31	1.61	1.91	2.43	Carsel and Parrish, 1988
	US4	Residual Water Content	Johnson SB ¹	unitless	0.00997	0.0525	0.0674	0.0812	0.0905	0.0976	0.115	Carsel and Parrish, 1988
	US5	Saturated Water Content	Constant	unitless	0.410	0.410	0.430	0.430	0.430	0.450	0.450	Carsel and Parrish, 1988
	US6	Thickness of Unsaturated Zone	Regional Site-Based	m	0.305	2.74	4.27	9.14	15.2	35.4	610	API, 1989
	US7	Dispersivity	Derived	m	0.0267	0.0803	0.114	0.22	0.354	0.799	1.00	Gelhar, 1986; EPRI, 1985;
	US8	Percent Organic Matter	Johnson SB ¹	unitless	0.00285	0.0316	0.0552	0.100	0.181	0.302	1.98	Carsel and others, 1988
	US9	Bulk Density	Constant	g/cm ³	1.60	1.60	1.65	1.6700	1.67	1.67	1.67	Carsel and others, 1988
	US10	Soil/Water Distribution Coefficient	Derived	cm ³ /g				chemical-specific value				Derived
	US11	Freundlich Adsorption Isotherm Exponent	Constant	unitless				1.00				Assumption
	US12	Chemical Degradation Rate Coefficient	Derived	1/yr				chemical-specific value				Derived
	US13	Biodegradation Rate Coefficient	Constant	1/yr				0.00				Policy for Tier 1
Saturated Zone	AS1	Average Particle Diameter	Empirical	cm	0.000400	0.00145	0.00546	0.0196	0.0418	0.0777	0.211	Sahe, 1974
	AS2	Aquifer Effective Porosity	Derived	unitless	0.0500	0.108	0.162	0.233	0.294	0.333	0.430	Davis, 1969; McWorter and Sunada 1977
	AS3	Aquifer Bulk Density	Derived	g/cm ³	1.16	1.29	1.43	1.56	1.63	1.70	1.80	Freeze and Cherry, 1979
	AS4	Aquifer Saturated Thickness	Regional Site-Based	m	0.305	4.57	7.62	15.2	30.5	79.3	914	API, 1989
	AS5	Longitudinal Hydraulic Conductivity	Regional Site-Based	m/yr	3.15	126	315	2,210	9,780	24,800	7,660,000	API, 1989
	AS6	Anisotropy Ratio	Constant	unitless				1.00				Assumption
	AS7	Hydraulic Gradient	Regional Site-Based	unitless	5.00E-07	0.000508	0.00200	0.00670	0.0141	0.0330	0.538	API, 1989
	AS8	Seepage Velocity	Derived	m/yr	0.100	2.48	11.1	43.4	227	814	10,800	Derived
	AS9	Retardation Factor	Derived	unitless				chemical-specific value				Derived
	AS10	Longitudinal Dispersivity	Gelhar Empirical	m	0.104	0.802	2.44	5.71	9.01	15.6	40.0	EPRI, 1985; Gelhar, 1986; Gelhar, 1992
	AS11	Transverse Dispersivity	Gelhar Empirical	m	0.0130	0.100	0.305	0.714	1.13	1.95	5.00	EPRI, 1985; Gelhar, 1986; Gelhar, 1992
Saturated Zone (cont'd)	AS12	Vertical Dispersivity	Gelhar Empirical	m	0.00500	0.00501	0.0152	0.0357	0.0563	0.0976	0.250	EPRI, 1985; Gelhar, 1986; Gelhar, 1992
	AS13	Temperature of Ambient Aquifer Water	Regional Site-Based	degrees C	7.5	7.5	12.5	17.5	17.5	17.5	27.5	Collins, 1925
	AS14	Ambient Groundwater pH	Empirical	standard units	3.20	5.21	6.06	6.81	7.42	7.91	9.69	USEPA'STORET database
	AS15	Fraction of Organic Carbon	Johnson SB	unitless	0.0000128	0.000135	0.000235	0.000430	0.000790	0.00137	0.0120	USEPA STORET data ase
	AS16	Radial Distance of Observation Well from Downgradient Edge of Waste Unit	Constant	m				150				Policy for Tier 1
	AS17	Angle Off-Center of Observation Well	Constant	degrees				0.00				Policy for Tier 1
	AS20	Depth of Well Below Water Table	Uniform	m	0.000126	0.953	2.49	6.04	15.2	39.4	904	API, 1989
	AS21	Leading Coefficient of Freundlich Adsorption Isotherm	Derived	cm ³ /g				chemical-specific value				Derived
	AS22	Freundlich Adsorption Isotherm Exponent	Constant	unitless				1.00				Assumption
	AS23	Hydrolysis Degradation Rate Coefficient	Derived	1/yr				chemical-specific value				Derived
	AS24	Biodegradation Rate Coefficient	Derived	1/yr				0.00				Policy for Tier 1

¹ The actual distribution type depends upon the soil type; the distribution types given here correspond to the silty loam soil (the most common type). In the Tier 1 modeling runs, soil type is automatically varied among the three soil types; each soil type has its own values/distributions of values for the soil parameters. The values presented in this table include all three soil types.

² Values were generated using a Monte Carlo simulation with 10,000 iterations.

Table C-3: IWEM Tier 1 Input Parameters for Waste Pile, No Liner Scenario

Input Type	Input No.	Parameter	Input Distribution Type	Units (output)	Percentiles ²						References	
					0	10	25	50	75	90		100
Source	SS1	Area	Regional Site-Based	m	5.06	20.2	20.2	121	1,210	4,170	1,940,000	USEPA, 1986 and 1997b
	SS2/3	Length/Width	Derived	m	2.25	4.49	4.49	11.0	34.8	64.6	1,390	Derived
	SS5	Recharge Rate	Regional Site-Based	m/yr	0.00001	0.0508	0.0787	0.145	0.282	0.417	1.84	ABB, 1995 and USEPA, 1997b
	SS6	Infiltration Rate	Regional Site-Based	m/yr	0.0003	0.0602	0.128	0.255	0.391	0.538	1.82	ABB, 1995 and USEPA, 1997b
	SS10	Operational Life (Duration of Leaching)	Constant	yr	20.0						US EPA, 1996	
	SS15	Base Depth Below Land Surface		m	0.00						Assumption of waste pile design	
Unsaturated Zone	US1	Saturated Hydraulic Conductivity	Lognormal ¹	m/yr	0.00347	0.617	2.10	8.32	36.2	165	2,400	Carsel and Parrish, 1988
	US2	Moisture Retention Parameter (alpha)	Johnson SB ¹	l/m	0.120	0.624	0.946	1.55	2.71	5.76	20.2	Carsel and Parrish, 1988
	US3	Moisture Retention Parameter (beta)	Johnson SB ¹	unitless	1.02	1.20	1.26	1.38	1.53	1.82	2.52	Carsel and Parrish, 1988
	US4	Residual Water Content	Johnson SB ¹	unitless	0.0114	0.0487	0.0608	0.0742	0.0854	0.0934	0.114	Carsel and Parrish, 1988
	US5	Saturated Water Content	Constant	unitless	0.410	0.410	0.430	0.450	0.450	0.450	0.450	Carsel and Parrish, 1988
	US6	Thickness of Unsaturated Zone	Regional Site-Based	m	0.305	1.83	3.96	7.01	15.2	36.6	610	API, 1989
	US7	Dispersivity	Derived	m	0.0267	0.0603	0.107	0.174	0.354	0.825	1.00	Gelhar, 1986; EPRI, 1985; USEPA, 1997a
	US8	Percent Organic Matter	Johnson SB ¹	unitless	0.00421	0.0339	0.0569	0.100	0.175	0.294	3.56	Carsel and others, 1988
	US9	Bulk Density	Constant	g/cm ³	1.60	1.60	1.65	1.65	1.67	1.67	1.67	Carsel and others, 1988
	US10	Soil/Water Distribution Coefficient	Derived	cm ³ /g	chemical-specific value						Derived	
	US11	Freundlich Adsorption Isotherm Exponent	Constant	unitless	1.00						Assumption	
	US12	Chemical Degradation Rate Coefficient	Derived	1/yr	chemical-specific value						Derived	
	US13	Biodegradation Rate Coefficient	Constant	1/yr	0.00						Policy for Tier 1	
Saturated Zone	AS1	Average Particle Diameter	Empirical	cm	0.000401	0.00153	0.00549	0.0193	0.0408	0.0740	0.212	Sahe, 1974
	AS2	Aquifer Effective Porosity	Derived	unitless	0.0501	0.105	0.161	0.235	0.297	0.335	0.421	Davis, 1969; McWorter and Sunada 1977
	AS3	Aquifer Bulk Density	Derived	g/cm ³	1.16	1.30	1.43	1.56	1.63	1.69	1.80	Freeze and Cherry, 1979
	AS4	Aquifer Saturated Thickness	Regional Site-Based	m	0.305	3.60	7.38	15.2	33.5	91.4	914	API, 1989
	AS5	Longitudinal Hydraulic Conductivity	Regional Site-Based	m/yr	3.15	126	317	1,890	11,000	31,500	6,750,000	API, 1989
	AS6	Anisotropy Ratio	Constant	unitless	1.00						Assumption	
	AS7	Hydraulic Gradient	Regional Site-Based	unitless	0.000002	0.0009	0.00200	0.00570	0.0170	0.0330	0.301	API, 1989
	AS8	Seepage Velocity	Derived	m/yr	0.101	2.69	10.8	46.8	272	1,260	10,900	Derived
	AS9	Retardation Factor	Derived	unitless	chemical-specific value						Derived	
	AS10	Longitudinal Dispersivity	Gelhar Empirical	m	0.101	0.848	2.50	5.59	8.71	14.7	40.0	EPRI, 1985; Gelhar, 1986; Gelhar, 1992
	AS11	Transverse Dispersivity	Gelhar Empirical	m	0.0126	0.106	0.313	0.699	1.09	1.83	5.00	EPRI, 1985; Gelhar, 1986; Gelhar, 1992
	AS12	Vertical Dispersivity	Gelhar Empirical	m	0.00500	0.00530	0.0156	0.0350	0.0544	0.0916	0.250	EPRI, 1985; Gelhar, 1986; Gelhar, 1992
	AS13	Temperature of Ambient Aquifer Water	Regional Site-Based	degrees C	7.50	7.50	12.5	12.5	17.5	22.5	22.5	Collins, 1925
	AS14	Ambient Groundwater pH	Empirical	standard units	3.21	5.20	6.07	6.81	7.41	7.90	9.69	USEPA STORET database
	AS15	Fraction of Organic Carbon	Johnson SB	unitless	0.0000128	0.000132	0.000237	0.000437	0.000794	0.00137	0.00998	USEPA STORET database
	AS16	Radial Distance of Observation Well from Downgradient Edge of Waste Unit	Constant	m	150						Policy for Tier 1	
	AS17	Angle Off-Center of Observation Well	Constant	degrees	0.00						Policy for Tier 1	
	AS20	Depth of Well Below Water Table	Uniform	m	0.000308	0.868	2.44	6.27	16.9	47.7	892	API, 1989
	AS21	Leading Coefficient of Freundlich Adsorption Isotherm (soil/water distribution coeff)	Derived	cm ³ /g	chemical-specific value						Derived	
	AS22	Freundlich Adsorption Isotherm Exponent	Constant	unitless	1.00						Assumption	
	AS23	Hydrolysis Degradation Rate Coefficient	Derived	1/yr	chemical-specific value						Derived	
	AS24	Biodegradation Rate Coefficient	Derived	1/yr	0.00						Policy for Tier 1	

¹ The actual distribution type depends upon the soil type; the distribution types given here correspond to the silty loam soil (the most common type). In the Tier 1 modeling runs, soil type is automatically varied among the three soil types; each soil type has its own values/distributions of values for the soil parameters. The values presented in this table include all three soil types.

² Values were generated using a Monte Carlo simulation with 10,000 iterations.

Table C-4: IWEM Tier 1 Input Parameters for Land Application Unit Scenario

Input Type	Input No.	Parameter	Input Distribution Type	Units (output)	Percentiles ²							References
					0	10	25	50	75	90	100	
Source	SS1	Area	Regional Site-Based	m	20.2	40.5	4,050	40,500	182,000	648,000	80,900,000	USEPA, 1986 and 1997b
	SS2/3	Length/Width	Derived	m	4.49	6.36	63.6	201	427	805	8,990	Derived
	SS5	Recharge Rate	Regional Site-Based	m/yr	0.00001	0.0104	0.0686	0.110	0.212	0.326	0.745	ABB, 1995 and USEPA, 1997b
	SS6	Infiltration Rate	Regional Site-Based	m/yr	0.00001	0.0130	0.0704	0.110	0.201	0.326	0.745	ABB, 1995 and USEPA, 1997b
	SS10	Operational Life (Duration of Leaching)	Constant	yr	40.0							US EPA, 1996
	SS15	Base Depth Below Grade		m	0.00							Assumption of LAU Design
Unsaturated Zone	US1	Saturated Hydraulic Conductivity	Lognormal ¹	m/yr	0.00224	0.586	2.01	7.80	33.8	147	2,510	Carsel and Parrish, 1988
	US2	Moisture Retention Parameter (alpha)	Johnson SB ¹	l/m	0.0926	0.605	0.929	1.51	2.59	5.41	20.8	Carsel and Parrish, 1988
	US3	Moisture Retention Parameter (beta)	Johnson SB ¹	unitless	1.04	1.20	1.26	1.37	1.51	1.78	2.55	Carsel and Parrish, 1988
	US4	Residual Water Content	Johnson SB ¹	unitless	0.0126	0.0498	0.0613	0.0749	0.0862	0.0942	0.115	Carsel and Parrish, 1988
	US5	Saturated Water Content	Constant	unitless	0.410	0.410	0.430	0.450	0.450	0.450	0.450	Carsel and Parrish, 1988
	US6	Thickness of Unsaturated Zone	Regional Site-Based	m	0.305	2.13	4.57	8.53	18.3	45.7	610	API, 1989
	US7	Dispersivity	Derived	m	0.0267	0.0669	0.121	0.208	0.423	1.00	1.00	Gelhar, 1986; EPRI, 1985; USEPA, 1997a
	US8	Percent Organic Matter	Johnson SB ¹	unitless	0.00418	0.0346	0.0578	0.102	0.175	0.291	1.96	Carsel and others, 1988
	US9	Bulk Density	Constant	g/cm ³	1.60	1.60	1.65	1.65	1.67	1.67	1.67	Carsel and others, 1988
	US10	Soil/Water Distribution Coefficient	Derived	cm ³ /g	chemical-specific value							Derived
	US11	Freundlich Adsorption Isotherm Exponent	Constant	unitless	1.00							Assumption
	US12	Chemical Degradation Rate Coefficient	Derived	1/yr	chemical-specific value							Derived
	US13	Biodegradation Rate Coefficient	Constant	1/yr	0.00							Policy for Tier 1
Saturated Zone	AS1	Average Particle Diameter	Empirical	cm	0.000402	0.00143	0.00545	0.0195	0.0408	0.0778	0.212	Sahe, 1974
	AS2	Aquifer Effective Porosity	Derived	unitless	0.0501	0.105	0.162	0.235	0.295	0.334	0.427	Davis, 1969; McWorter and Sunada, 1977
	AS3	Aquifer Bulk Density	Derived	g/cm ³	1.16	1.29	1.43	1.56	1.63	1.70	1.80	Freeze and Cherry, 1979
	AS4	Aquifer Saturated Thickness	Regional Site-Based	m	0.305	3.96	7.62	19.5	53.3	144	914	API, 1989
	AS5	Longitudinal Hydraulic Conductivity	Regional Site-Based	m/yr	3.15	94.6	315	2,190	11,000	31,500	6,310,000	API, 1989
	AS6	Anisotropy Ratio	Constant	unitless	1.00							Assumption
	AS7	Hydraulic Gradient	Regional Site-Based	unitless	0.000002	0.000556	0.00200	0.00800	0.0223	0.0430	0.430	API, 1989
	AS8	Seepage Velocity	Derived	m/yr	0.100	2.34	9.93	50.2	316	1,210	10,900	Derived
	AS9	Retardation Factor	Derived	unitless	chemical-specific value							Derived
	AS10	Longitudinal Dispersivity	Gelhar Empirical	m	0.108	1.02	2.99	6.70	10.7	16.1	40.0	EPRI 1985; Gelhar, 1986; Gelhar, 1992
	AS11	Transverse Dispersivity	Gelhar Empirical	m	0.0134	0.128	0.374	0.838	1.34	2.02	5.00	EPRI 1985; Gelhar, 1986; Gelhar, 1992
	AS12	Vertical Dispersivity	Gelhar Empirical	m	0.00500	0.00639	0.0187	0.0419	0.0669	0.101	0.250	EPRI 1985; Gelhar, 1986; Gelhar, 1992
	AS13	Temperature of Ambient Aquifer Water	Regional Site-Based	degrees C	7.50	7.50	12.5	12.5	17.5	17.5	22.5	Collins, 1925
	AS14	Ambient Groundwater pH	Empirical	standard units	3.21	5.20	6.07	6.82	7.42	7.89	9.69	USEPA's STORET database
	AS15	Fraction of Organic Carbon	Johnson SB	unitless	0.0000149	0.000130	0.000229	0.000421	0.000781	0.00133	0.0120	USEPA STORET database
	AS16	Radial Distance of Observation Well from Downgradient Edge of Waste Unit	Constant	m	150							Policy for Tier 1
	AS17	Angle Off-Center of Observation Well	Constant	degrees	0.00							Policy for Tier 1
	AS20	Depth of Well Below Water Table	Uniform	m	0.0000963	1.03	2.83	7.95	21.7	60.1	882	API, 1989
	AS21	Leading Coefficient of Freundlich Adsorption Isotherm	Derived	cm ³ /g	chemical-specific value							Derived
	AS22	Freundlich Adsorption Isotherm Exponent	Constant	unitless	1.00							Assumption
	AS23	Hydrolysis Degradation Rate Coefficient	Derived	1/yr	chemical-specific value							Derived
	AS24	Biodegradation Rate Coefficient	Derived	1/yr	0.00							Policy for Tier 1

¹ The actual distribution type depends upon the soil type; the distribution types given here correspond to the silty loam soil (the most common type). In the Tier 1 modeling runs, soil type is automatically varied among the three soil types; each soil type has its own values/distributions of values for the soil parameters. The values presented in this table include all three soil types.

² Values were generated using a Monte Carlo simulation with 6,557 iterations.

Table C-5: IWEM Tier 1 Input Parameters for Landfill, Single Liner Scenario

Input Type	Input No.	Parameter	Input Distribution Type	Units (output)	Percentiles ²							References
					0	10	25	50	75	90	100	
Source	SS1	Area	Regional Site-Based	m	40.5	567	2,480	12,100	54,600	149,000	3,120,000	USEPA, 1986 and 1997b
	SS2/3	Length/Width	Derived	m	6.36	23.8	49.8	110	234	386	1,770	Derived
	SS5	Recharge Rate	Regional Site-Based	m/yr	0.00001	0.0135	0.0686	0.130	0.312	0.446	1.15	ABB, 1995 and USEPA, 1997b
	SS6	Infiltration Rate	Regional Site-Based	m/yr	0.00001	0.00944	0.0253	0.0432	0.0445	0.0486	0.0526	USEPA, 1999
	SS10	Duration of Leaching	Derived	yr	81,100	228,000	376,000	728,000	1,370,000	2,930,000	1.63E+10	USEPA, 2001
	SS11	Fraction of Landfill Occupied by Waste of Concern	Constant	unitless	1.00							Policy for Tier 1
	SS12	Depth of Waste Disposal Facility	Regional Site-Based	m	0.510	0.883	1.32	2.58	4.09	6.14	10.1	USEPA, 1986 and 1997b
	SS13	Density of Hazardous Waste	Empirical	g/cm ³	0.700	0.737	0.794	0.889	1.33	1.45	2.10	Schanz and Salhotra, 1992
	FS1	Ratio of Waste Concentration to Leachate Concentration	Constant	L/kg	10000							Policy for Tier 1
	SS15	Base Depth Below Grade	m		0.00							No data available
Unsaturated Zone	US1	Saturated Hydraulic Conductivity	Lognormal ¹	m/yr	0.00377	0.598	2.06	7.79	35.0	169	2,450	Carsel and Parrish, 1988
	US2	Moisture Retention Parameter (alpha)	Johnson SB ¹	l/m	0.129	0.595	0.935	1.52	2.72	5.92	21.8	Carsel and Parrish, 1988
	US3	Moisture Retention Parameter (beta)	Johnson SB ¹	unitless	1.04	1.20	1.27	1.37	1.53	1.82	2.50	Carsel and Parrish, 1988
	US4	Residual Water Content	Johnson SB ¹	unitless	0.0106	0.0489	0.0611	0.0746	0.0857	0.0937	0.115	Carsel and Parrish, 1988
	US5	Saturated Water Content	Constant	unitless	0.410	0.410	0.430	0.450	0.450	0.450	0.450	Carsel and Parrish, 1988
	US6	Thickness of Unsaturated Zone	Regional Site-Based	m	0.305	1.68	3.96	6.10	15.2	36.6	610	API, 1989
	US7	Dispersivity	Derived	m	0.0267	0.0570	0.107	0.154	0.354	0.825	1.00	Gelhar, 1986; EPRI, 1985; USEPA, 1997a
	US8	Percent Organic Matter	Johnson SB ¹	unitless	0.00358	0.0340	0.0568	0.101	0.177	0.288	1.69	Carsel and others, 1988
	US9	Bulk Density	Constant	g/cm ³	1.60	1.60	1.65	1.65	1.67	1.67	1.67	Carsel and others, 1988
	US10	Soil/Water Distribution Coefficient	Derived	cm ³ /g	chemical-specific value							Derived
	US11	Freundlich Adsorption Isotherm Exponent	Constant	unitless	1.00							Assumption
	US12	Chemical Degradation Rate Coefficient	Derived	1/yr	chemical-specific value							Derived
	US13	Biodegradation Rate Coefficient	Constant	1/yr	0.00							Policy for Tier 1
Saturated Zone	AS1	Average Particle Diameter	Empirical	cm	0.000400	0.00151	0.00558	0.0192	0.0411	0.0765	0.211	Sahe, 1974
	AS2	Aquifer Effective Porosity	Derived	unitless	0.0501	0.107	0.164	0.236	0.295	0.334	0.426	Davis, 1969; McWorter and Sunada 1977
	AS3	Aquifer Bulk Density	Derived	g/cm ³	1.16	1.30	1.43	1.56	1.63	1.70	1.80	Freeze and Cherry, 1979
	AS4	Aquifer Saturated Thickness	Regional Site-Based	m	0.305	4.03	7.62	12.2	32.0	91.4	914	API, 1989
	AS5	Longitudinal Hydraulic Conductivity	Regional Site-Based	m/yr	3.15	141	631	1,890	11,000	31,500	4,290,000	API, 1989
	AS6	Anisotropy Ratio	Constant	unitless	1.00							Assumption
	AS7	Hydraulic Gradient	Regional Site-Based	unitless	0.000002	0.0009	0.002	0.00570	0.0153	0.0310	0.491	API, 1989
	AS8	Seepage Velocity	Derived	m/yr	0.100	2.97	14.5	52.2	297	1,280	11,000	Derived
	AS9	Retardation Factor	Derived	unitless	chemical-specific value							Derived
	AS10	Longitudinal Dispersivity	Gelhar Empirical	m	0.109	0.916	2.71	6.15	9.72	14.4	40.0	EPRI, 1985; Gelhar, 1986; Gelhar, 1992
	AS11	Transverse Dispersivity	Gelhar Empirical	m	0.0136	0.114	0.338	0.769	1.22	1.80	4.99	EPRI, 1985; Gelhar, 1986; Gelhar, 1992
	AS12	Vertical Dispersivity	Gelhar Empirical	m	0.005	0.00572	0.0169	0.0385	0.0608	0.0899	0.250	EPRI, 1985; Gelhar, 1986; Gelhar, 1992
	AS13	Temperature of Ambient Aquifer Water	Regional Site-Based	degrees C	7.50	7.50	12.5	12.5	17.5	22.5	22.5	Collins, 1925
	AS14	Ambient Groundwater pH	Empirical	standard units	3.21	5.18	6.05	6.82	7.41	7.93	9.70	USEPA STORET database
	AS15	Fraction of Organic Carbon	Johnson SB	unitless	0.0000164	0.000131	0.000234	0.000434	0.000810	0.00139	0.00984	USEPA STORET database
	AS16	Radial Distance of Observation Well from Downgradient Edge of Waste Unit	Constant	m	150							Policy for Tier 1
	AS17	Angle Off-Center of Observation Well	Constant	degrees	0.00							Policy for Tier 1
	AS20	Depth of Well Below Water Table	Uniform	m	0.00321	0.944	2.49	6.27	16.1	46.3	897	API, 1989
	AS21	Leading Coefficient of Freundlich Adsorption Isotherm	Derived	cm ³ /g	chemical-specific value							Derived
	AS22	Freundlich Adsorption Isotherm Exponent	Constant	unitless	1.00							Assumption
	AS23	Hydrolysis Degradation Rate Coefficient	Derived	1/yr	chemical-specific value							Derived
	AS24	Biodegradation Rate Coefficient	Derived	1/yr	0.00							Policy for Tier 1

¹ The actual distribution type depends upon the soil type; the distribution types given here correspond to the silty loam soil (the most common type). In the Tier 1 modeling runs, soil type is automatically varied among the three soil types; each soil type has its own values/distributions of values for the soil parameters. The values presented in this table include all three soil types.

² Values were generated using a Monte Carlo simulation with 10,000 iterations.

Table C-6: IWEM Tier 1 Input Parameters for Surface Impoundment, Single Liner Scenario

Input Type	Input No.	Parameter	Input Distribution Type	Units (output)	Percentiles ²							References
					0	10	25	50	75	90	100	
Source	SS1	Area	Regional Site-Based	m	9.30	192	581	1,860	7,810	29,800	4,860,000	USEPA, 2001
	SS2/3	Length/Width	Derived	m	3.05	13.8	24.1	43.1	88.4	173	2,200	Derived
	SS5	Recharge Rate	Regional Site-Based	m/yr	1.00E-05	0.00990	0.0465	0.147	0.269	0.377	1.84	ABB 1995 and USEPA, 1997b
	SS6	Infiltration Rate	Regional Site-Based	m/yr	3.78E-15	0.042	0.0629	0.108	0.163	0.217	0.798	Derived
	SS10	Operational Life (Duration of Leaching)	Constant	yr	4.00	15.0	50.0	50.0	50.0	50.0	95.0	USEPA, 2001
	SS15	Base Depth Below Grade	DBGS	m	0.00	0.00	0.00	1.52	3.05	4.57	33.5	USEPA, 2001
	SS7	Waste Water Ponding Depth	HZERO	m	0.0100	0.460	1.06	1.83	3.09	4.27	18.2	USEPA, 2001
		Total Impoundment Operating Depth	DEPTH	m	4.63							Derived
	SS16	Sediment Thickness (Thickness of Sludge)	DSLUDGE	m	0.20							Assumption
SS22	Distance to Nearest Surface Water Body	DISSW	m	0.00	90.0	240	360	850	1,800	5,000	USEPA, 2001	
Unsaturated Zone	US1	Saturated Hydraulic Conductivity	Lognormal ¹	m/yr	0.00224	0.347	1.20	5.56	49.6	308	2,420	Carsel and Parrish, 1988
	US2	Moisture Retention Parameter (alpha)	Johnson SB ¹	1/m	0.0983	0.524	0.815	1.39	3.31	7.97	22.3	Carsel and Parrish, 1988
	US3	Moisture Retention Parameter (beta)	Johnson SB ¹	unitless	1.02	1.18	1.23	1.31	1.63	1.92	2.43	Carsel and Parrish, 1988
	US4	Residual Water Content	Johnson SB ¹	unitless	0.00997	0.0522	0.0669	0.0809	0.0904	0.0976	0.115	Carsel and Parrish, 1988
	US5	Saturated Water Content	Constant	unitless	0.410	0.410	0.430	0.430	0.430	0.450	0.450	Carsel and Parrish, 1988
	US6	Thickness of Unsaturated Zone	Regional Site-Based	m	0.305	2.44	3.70	7.62	15.2	30.5	610	API, 1989
	US7	Dispersivity	Derived	m	0.0267	0.0737	0.101	0.188	0.354	0.691	1.00	Gelhar, 1986; EPRI, 1985; USEPA, 1997a
	US8	Percent Organic Matter	Johnson SB ¹	unitless	0.00254	0.0314	0.0550	0.0994	0.180	0.299	1.98	Carsel and others, 1988
	US9	Bulk Density	Constant	g/cm ³	1.60	1.60	1.65	1.67	1.67	1.67	1.67	Carsel and others, 1988
	US10	Soil/Water Distribution Coefficient	Derived	cm ³ /g	chemical-specific value							Derived
	US11	Freundlich Adsorption Isotherm Exponent	Constant	unitless	1.00							Assumption
	US12	Chemical Degradation Rate Coefficient	Derived	1/yr	chemical-specific value							Derived
	US13	Biodegradation Rate Coefficient	Constant	1/yr	0.00							Policy for Tier 1
Saturated Zone	AS1	Average Particle Diameter	Empirical	cm	0.000400	0.00145	0.00540	0.0195	0.0415	0.0780	0.211	Sahe, 1974
	AS2	Aquifer Effective Porosity	Derived	unitless	0.0500	0.107	0.162	0.232	0.294	0.334	0.430	Davis, 1969; McWorter and Sunada 1977
	AS3	Aquifer Bulk Density	Derived	g/cm ³	1.16	1.29	1.43	1.56	1.63	1.70	1.80	Freeze and Cherry, 1979
	AS4	Aquifer Saturated Thickness	Regional Site-Based	m	0.305	3.66	7.32	13.7	30.0	76.2	914	API, 1989
	AS5	Longitudinal Hydraulic Conductivity	Regional Site-Based	m/yr	3.15	108	315	2,210	6,940	22,100	7,660,000	API, 1989
	AS6	Anisotropy Ratio	Constant	unitless	1.00							Assumption
	AS7	Hydraulic Gradient	Regional Site-Based	unitless	5.00E-07	0.000700	0.00200	0.00700	0.0150	0.0330	0.538	API, 1989
	AS8	Seepage Velocity	Derived	m/yr	0.100	2.11	9.36	34.1	193	723	10,800	Derived
	AS9	Retardation Factor	Derived	unitless	chemical-specific value							Derived
	AS10	Longitudinal Dispersivity	Gelhar Empirical	m	0.107	0.808	2.49	5.78	9.06	15.5	40.0	EPRI, 1985; Gelhar, 1986; Gelhar, 1992
	AS11	Transverse Dispersivity	Gelhar Empirical	m	0.0134	0.101	0.311	0.723	1.13	1.94	5.00	EPRI, 1985; Gelhar, 1986; Gelhar, 1992
	AS12	Vertical Dispersivity	Gelhar Empirical	m	0.00500	0.00505	0.0156	0.0361	0.0566	0.0969	0.250	EPRI, 1985; Gelhar, 1986; Gelhar, 1992
	AS13	Temperature of Ambient Aquifer Water	Regional Site-Based	degrees C	7.5	7.5	12.5	17.5	17.5	17.5	27.5	Collins, 1925
	AS14	Ambient Groundwater pH	Empirical	standard units	3.20	5.20	6.07	6.82	7.43	7.91	9.68	USEPA's STORET database
	AS15	Fraction of Organic Carbon	Johnson SB	unitless	0.0000128	0.000136	0.000236	0.000433	0.000794	0.00137	0.0103	USEPA STORET database
	AS16	Radial Distance of Observation Well from Downgradient Edge of Waste Unit	Constant	m	150							Policy for Tier 1
	AS17	Angle Off-Center of Observation Well	Constant	degrees	0.00							Policy for Tier 1
	AS20	Depth of Well Below Water Table	Uniform	m	0.000126	0.884	2.37	5.70	14.0	35.8	794	API, 1989
		Leading Coefficient of Freundlich Adsorption Isotherm	Derived	cm ³ /g	chemical-specific value							Derived
	AS22	Freundlich Adsorption Isotherm Exponent	Constant	unitless	1.00							Assumption
	AS23	Hydrolysis Degradation Rate Coefficient	Derived	1/yr	chemical-specific value							Derived
	AS24	Biodegradation Rate Coefficient	Derived	1/yr	0.00							Policy for Tier 1

¹ The actual distribution type depends upon the soil type; the distribution types given here correspond to the silty loam soil (the most common type). In the Tier 1 modeling runs, soil type is automatically varied among the three soil types; each soil type has its own values/distributions of values for the soil parameters. The values presented in this table include all three soil types.

² Values were generated using a Monte Carlo simulation with 10,000 iterations.

Table C-7: IWEM Tier 1 Input Parameters for Waste Pile, Single Liner Scenario

Input Type	Input No.	Parameter	Input Distribution Type	Units (output)	Percentiles ²						References	
					0	10	25	50	75	90		100
Source	SS1	Area	Regional Site-Based	m	5.06	20.2	20.2	121	1,210	4,170	1,940,000	USEPA, 1986 and 1997b
	SS2/3	Length/Width	Derived	m	2.25	4.49	4.49	11.0	34.8	64.6	1,390	Derived
	SS5	Recharge Rate	Regional Site-Based	m/yr	0.00001	0.0508	0.0787	0.145	0.282	0.417	1.84	ABB, 1995 and USEPA, 1997b
	SS6	Infiltration Rate	Regional Site-Based	m/yr	0.00001	0.0264	0.0950	0.127	0.133	0.135	0.136	USEPA, 1999
	SS10	Duration of Leaching	Constant	yr	20.0						US EPA, 1996	
	SS15	Base Depth Below Grade		m	0.00						Assumption of waste pile design	
Unsaturated Zone	US1	Saturated Hydraulic Conductivity	Lognormal ¹	m/yr	0.00347	0.617	2.09	8.26	35.8	163	2,400	Carsel and Parrish, 1988
	US2	Moisture Retention Parameter (alpha)	Johnson SB ¹	l/m	0.120	0.620	0.942	1.54	2.70	5.76	20.2	Carsel and Parrish, 1988
	US3	Moisture Retention Parameter (beta)	Johnson SB ¹	unitless	1.02	1.20	1.26	1.38	1.53	1.82	2.52	Carsel and Parrish, 1988
	US4	Residual Water Content	Johnson SB ¹	unitless	0.0114	0.0487	0.0608	0.0743	0.0855	0.0935	0.114	Carsel and Parrish, 1988
	US5	Saturated Water Content	Constant	unitless	0.410	0.410	0.430	0.450	0.450	0.450	0.450	Carsel and Parrish, 1988
	US6	Thickness of Unsaturated Zone	Regional Site-Based	m	0.305	1.83	3.96	7.01	15.2	36.6	610	API, 1989
	US7	Dispersivity	Derived	m	0.0267	0.0603	0.107	0.174	0.354	0.825	1.00	Gelhar, 1986; EPRI, 1985; USEPA, 1997a
	US8	Percent Organic Matter	Johnson SB ¹	unitless	0.00421	0.0339	0.0566	0.100	0.175	0.294	3.56	Carsel and others, 1988
	US9	Bulk Density	Constant	g/cm ³	1.60	1.60	1.65	1.65	1.67	1.67	1.67	Carsel and others, 1988
	US10	Soil/Water Distribution Coefficient	Derived	cm ³ /g	chemical-specific value						Derived	
	US11	Freundlich Adsorption Isotherm Exponent	Constant	unitless	1.00						Assumption	
	US12	Chemical Degradation Rate Coefficient	Derived	1/yr	chemical-specific value						Derived	
	US13	Biodegradation Rate Coefficient	Constant	1/yr	0.00						Policy for Tier 1	
Saturated Zone	AS1	Average Particle Diameter	Empirical	cm	0.000401	0.00153	0.00547	0.0192	0.0408	0.0738	0.212	Sahe, 1974
	AS2	Aquifer Effective Porosity	Derived	unitless	0.0501	0.105	0.161	0.235	0.298	0.336	0.421	Davis, 1969; McWorter and Sunada 1977
	AS3	Aquifer Bulk Density	Derived	g/cm ³	1.16	1.30	1.43	1.56	1.63	1.69	1.80	Freeze and Cherry, 1979
	AS4	Aquifer Saturated Thickness	Regional Site-Based	m	0.305	3.60	7.32	15.2	33.2	91.4	914	API, 1989
	AS5	Longitudinal Hydraulic Conductivity	Regional Site-Based	m/yr	3.15	126	315	1,890	11,000	31,500	6,750,000	API, 1989
	AS6	Anisotropy Ratio	Constant	unitless	1.00						Assumption	
	AS7	Hydraulic Gradient	Regional Site-Based	unitless	0.000002	0.0009	0.002	0.00570	0.0170	0.0330	0.301	API, 1989
	AS8	Seepage Velocity	Derived	m/yr	0.101	2.64	10.5	45.7	263	1,240	10,900	Derived
	AS9	Retardation Factor	Derived	unitless	chemical-specific value						Derived	
	AS10	Longitudinal Dispersivity	Gelhar Empirical	m	0.101	0.845	2.50	5.60	8.73	14.8	40.0	EPRI, 1985; Gelhar, 1986; Gelhar, 1992
	AS11	Transverse Dispersivity	Gelhar Empirical	m	0.0126	0.106	0.312	0.700	1.09	1.85	5.00	EPRI, 1985; Gelhar, 1986; Gelhar, 1992
	AS12	Vertical Dispersivity	Gelhar Empirical	m	0.00500	0.00528	0.0156	0.0350	0.0546	0.0925	0.250	EPRI, 1985; Gelhar, 1986; Gelhar, 1992
	AS13	Temperature of Ambient Aquifer Water	Regional Site-Based	degrees C	7.50	7.50	12.5	12.5	17.5	22.5	22.5	Collins, 1925
	AS14	Ambient Groundwater pH	Empirical	standard units	3.21	5.19	6.06	6.80	7.41	7.90	9.69	USEPA STORET database
	AS15	Fraction of Organic Carbon	Johnson SB	unitless	0.0000128	0.000132	0.000237	0.000437	0.000793	0.00137	0.00998	USEPA STORET database
	AS16	Radial Distance of Observation Well from Downgradient Edge of Waste Unit	Constant	m	150						Policy for Tier 1	
	AS17	Angle Off-Center of Observation Well	Constant	degrees	0.00						Policy for Tier 1	
	AS20	Depth of Well Below Water Table	Uniform	m	0.000308	0.868	2.43	6.24	16.9	47.4	892	API, 1989
	AS21	Leading Coefficient of Freundlich Adsorption Isotherm	Derived	cm ³ /g	chemical-specific value						Derived	
	AS22	Freundlich Adsorption Isotherm Exponent	Constant	unitless	1.00						Assumption	
	AS23	Hydrolysis Degradation Rate Coefficient	Derived	1/yr	chemical-specific value						Derived	
	AS24	Biodegradation Rate Coefficient	Derived	1/yr	0.00						Policy for Tier 1	

¹ The actual distribution type depends upon the soil type; the distribution types given here correspond to the silty loam soil (the most common type). In the Tier 1 modeling runs, soil type is automatically varied among the three soil types; each soil type has its own values/distributions of values for the soil parameters. The values presented in this table include all three soil types.

² Values were generated using a Monte Carlo simulation with 10,000 iterations.

Table C-8: IWEM Tier 1 Input Parameters for Landfill, Composite Liner Scenario

Input Type	Input No.	Parameter	Input Distribution Type	Units (output)	Percentiles ²							References
					0	10	25	50	75	90	100	
Source	SS1	Area	Regional Site-Based	m	40.5	445	2,480	12,100	54,600	134,000	3,120,000	USEPA, 1986 and 1997b
	SS2/3	Length/Width	Derived	m	6.36	21.1	49.8	110	234	365	1,770	Derived
	SS5	Recharge Rate	Regional Site-Based	m/yr	0.00001	0.0226	0.0780	0.143	0.326	0.450	1.15	ABB, 1995 and USEPA, 1997b
	SS6	Infiltration Rate	Regional Site-Based	m/yr	0.00	0.00	0.00	0.00	0.0000730	0.000169	0.000401	TetraTech, 2001
	SS10	Duration of Leaching	Derived	yr	0.00	0.00	0.00	0.00	301,000,000	1.09E+10	8.33E+12	USEPA, 2001
	SS11	Fraction of Landfill Occupied by Waste of Concern	Constant	unitless	1.00							Policy for Tier 1
	SS12	Depth of Waste Disposal Facility	Regional Site-Based	m	0.510	0.879	1.31	2.51	4.09	6.41	10.1	USEPA, 1986 and 1997b
	SS13	Density of Hazardous Waste	Empirical	g/cm ³	0.700	0.738	0.794	0.888	1.33	1.46	2.10	Schanz and Salhotra, 1992
	FS1	Ratio of Waste Concentration to Leachate Concentration	Constant	L/kg	10000							Policy for Tier 1
	SS15	Base Depth Below Grade		m	0.00							No data available
Unsaturated Zone	US1	Saturated Hydraulic Conductivity	Lognormal ¹	m/yr	0.00463	0.608	2.06	8.35	36.7	180	2,390	Carsel and Parrish, 1988
	US2	Moisture Retention Parameter (alpha)	Johnson SB ¹	1/m	0.130	0.614	0.930	1.54	2.73	6.15	20.3	Carsel and Parrish, 1988
	US3	Moisture Retention Parameter (beta)	Johnson SB ¹	unitless	1.01	1.20	1.27	1.38	1.54	1.83	2.47	Carsel and Parrish, 1988
	US4	Residual Water Content	Johnson SB ¹	unitless	0.0118	0.0490	0.0613	0.0747	0.0857	0.0937	0.115	Carsel and Parrish, 1988
	US5	Saturated Water Content	Constant	unitless	0.410	0.410	0.430	0.450	0.450	0.450	0.450	Carsel and Parrish, 1988
	US6	Thickness of Unsaturated Zone	Regional Site-Based	m	0.305	1.68	3.96	6.10	15.2	36.6	610	API, 1989
	US7	Dispersivity	Derived	m	0.0267	0.0570	0.107	0.154	0.354	0.825	1.00	Gelhar, 1986; EPRI, 1985; USEPA, 1997a
	US8	Percent Organic Matter	Johnson SB ¹	unitless	0.00347	0.0337	0.0566	0.102	0.179	0.294	1.60	Carsel and others, 1988
	US9	Bulk Density	Constant	g/cm ³	1.60	1.60	1.65	1.65	1.67	1.67	1.67	Carsel and others, 1988
	US10	Soil/Water Distribution Coefficient	Derived	cm ³ /g	chemical-specific value							Derived
	US11	Freundlich Adsorption Isotherm Exponent	Constant	unitless	1.00							Assumption
	US12	Chemical Degradation Rate Coefficient	Derived	1/yr	chemical-specific value							Derived
	US13	Biodegradation Rate Coefficient	Constant	1/yr	0.00							Policy for Tier 1
Saturated Zone	AS1	Average Particle Diameter	Empirical	cm	0.000401	0.00151	0.00538	0.0188	0.0413	0.0762	0.211	Sahe, 1974
	AS2	Aquifer Effective Porosity	Derived	unitless	0.0502	0.105	0.163	0.236	0.296	0.335	0.424	Davis, 1969; McWorter and Sunada 1977
	AS3	Aquifer Bulk Density	Derived	g/cm ³	1.16	1.30	1.43	1.55	1.63	1.70	1.80	Freeze and Cherry, 1979
	AS4	Aquifer Saturated Thickness	Regional Site-Based	m	0.305	3.96	7.62	12.2	30.5	91.4	914	API, 1989
	AS5	Longitudinal Hydraulic Conductivity	Regional Site-Based	m/yr	3.15	94.6	315	1,890	11,000	31,500	8,480,000	API, 1989
	AS6	Anisotropy Ratio	Constant	unitless	1.00							Assumption
	AS7	Hydraulic Gradient	Regional Site-Based	unitless	0.000002	0.001	0.002	0.00570	0.0180	0.0330	0.483	API, 1989
	AS8	Seepage Velocity	Derived	m/yr	0.100	2.51	10.5	45.6	250	1,200	10,800	Derived
	AS9	Retardation Factor	Derived	unitless	chemical-specific value							Derived
	AS10	Longitudinal Dispersivity	Gelhar Empirical	m	0.111	0.958	2.91	6.38	9.87	14.7	40.0	EPRI, 1985; Gelhar, 1986; Gelhar, 1992
	AS11	Transverse Dispersivity	Gelhar Empirical	m	0.0139	0.120	0.364	0.797	1.23	1.84	4.99	EPRI, 1985; Gelhar, 1986; Gelhar, 1992
	AS12	Vertical Dispersivity	Gelhar Empirical	m	0.00500	0.00599	0.0182	0.0399	0.0617	0.0921	0.250	EPRI, 1985; Gelhar, 1986; Gelhar, 1992
	AS13	Temperature of Ambient Aquifer Water	Regional Site-Based	degrees C	7.50	7.50	12.5	12.5	17.5	22.5	22.5	Collins, 1925
	AS14	Ambient Groundwater pH	Empirical	standard unit	3.20	5.20	6.06	6.79	7.39	7.89	9.70	USEPA STORET database
	AS15	Fraction of Organic Carbon	Johnson SB	unitless	0.00000858	0.000135	0.000238	0.000443	0.000814	0.00140	0.0159	USEPA STORET database
	AS16	Radial Distance of Observation Well from Downgradient Edge of Waste Unit	Constant	m	150							Policy for Tier 1
	AS17	Angle Off-Center of Observation Well	Constant	degrees	0.00							Policy for Tier 1
	AS20	Depth of Well Below Water Table	Uniform	m	0.000936	0.974	2.48	6.07	15.6	44.4	867	API, 1989
	AS21	Leading Coefficient of Freundlich Adsorption Isotherm	Derived	cm ³ /g	chemical-specific value							Derived
	AS22	Freundlich Adsorption Isotherm Exponent	Constant	unitless	1.00							Assumption
	AS23	Hydrolysis Degradation Rate Coefficient	Derived	1/yr	chemical-specific value							Derived
	AS24	Biodegradation Rate Coefficient	Derived	1/yr	0.00							Policy for Tier 1

¹ The actual distribution type depends upon the soil type; the distribution types given here correspond to the silty loam soil (the most common type). In the Tier 1 modeling runs, soil type is automatically varied among the three soil types; each soil type has its own values/distributions of values for the soil parameters. The values presented in this table include all three soil types.

² Values were generated using a Monte Carlo simulation with 10,000 iterations.

Table C-9: IWEM Tier 1 Input Parameters for Surface Impoundment, Composite Liner Scenario

Input Type	Input No.	Parameter	Input Distribution Type	Units (output)	Percentiles ²							References
					0	10	25	50	75	90	100	
Source	SS1	Area	Regional Site-Based	m	9.30	206	609	2,020	8,760	35,200	4,860,000	USEPA, 2001
	SS2/3	Length/Width	Derived	m	3.05	14.4	24.7	45.0	93.6	188	2,200	Derived
	SS5	Recharge Rate	Regional Site-Based	m/yr	1.00E-05	0.00990	0.0465	0.168	0.271	0.450	1.84	ABB 1995 and USEPA, 1997b
	SS6	Infiltration Rate	Regional Site-Based	m/yr	0.00	0.00	0.00	0.0000488	0.000202	0.000498	0.00369	Derived
	SS10	Duration of Leaching	Constant	yr	4.00	15.0	50.0	50.0	50.0	50.0	95.0	USEPA, 2001
	SS15	Base Depth Below Grade	DBGS	m	0.00	0.00	0.00	1.52	3.38	4.57	33.5	USEPA, 2001
	SS7	Waste Water Ponding Depth	HZERO	m	0.0100	0.460	1.07	1.83	3.15	4.27	18.2	USEPA, 2001
		Total Impoundment Operating Depth	DEPTH	m	4.63							Derived
	SS16	Sediment Thickness	DSLUDGE	m	0.20							Assumption
SS22	Distance to Nearest Surface Water Body	DISSW	m	0.00	105	240	360	1,000	2,000	5,000	USEPA, 2001	
Unsaturated Zone	US1	Saturated Hydraulic Conductivity	Lognormal ¹	m/yr	0.00437	0.375	1.28	6.19	52.3	305	2,520	Carsel and Parrish, 1988
	US2	Moisture Retention Parameter (alpha)	Johnson SB ¹	1/m	0.109	0.534	0.817	1.42	3.31	8.06	19.8	Carsel and Parrish, 1988
	US3	Moisture Retention Parameter (beta)	Johnson SB ¹	unitless	1.02	1.18	1.23	1.31	1.64	1.93	2.49	Carsel and Parrish, 1988
	US4	Residual Water Content	Johnson SB ¹	unitless	0.00851	0.0521	0.0668	0.0809	0.0902	0.0973	0.115	Carsel and Parrish, 1988
	US5	Saturated Water Content	Constant	unitless	0.410	0.410	0.410	0.430	0.430	0.450	0.450	Carsel and Parrish, 1988
	US6	Thickness of Unsaturated Zone	Regional Site-Based	m	0.305	1.83	3.35	6.10	15.2	30.5	610	API, 1989
	US7	Dispersivity	Derived	m	0.0267	0.0603	0.0937	0.154	0.354	0.691	1.00	Gelhar, 1986; EPRI, 1985; USEPA, 1997a
	US8	Percent Organic Matter	Johnson SB ¹	unitless	0.00366	0.0319	0.0552	0.0993	0.180	0.304	2.75	Carsel and others, 1988
	US9	Bulk Density	Constant	g/cm ³	1.60	1.60	1.60	1.67	1.67	1.67	1.67	Carsel and others, 1988
	US10	Soil/Water Distribution Coefficient	Derived	cm ³ /g	chemical-specific value							Derived
	US11	Freundlich Adsorption Isotherm Exponent	Constant	unitless	1.00							Assumption
	US12	Chemical Degradation Rate Coefficient	Derived	1/yr	chemical-specific value							Derived
	US13	Biodegradation Rate Coefficient	Constant	1/yr	0.00							Policy for Tier 1
Saturated Zone	AS1	Average Particle Diameter	Empirical	cm	0.000401	0.00143	0.00538	0.0195	0.0407	0.0768	0.212	Sahe, 1974
	AS2	Aquifer Effective Porosity	Derived	unitless	0.0501	0.100	0.160	0.235	0.296	0.334	0.429	Davis, 1969; McWorter and Sunada 1977
	AS3	Aquifer Bulk Density	Derived	g/cm ³	1.16	1.29	1.43	1.56	1.63	1.70	1.80	Freeze and Cherry, 1979
	AS4	Aquifer Saturated Thickness	Regional Site-Based	m	0.305	3.53	6.10	12.2	24.4	61.0	914	API, 1989
	AS5	Longitudinal Hydraulic Conductivity	Regional Site-Based	m/yr	3.15	63.1	284	1,890	5,990	21,300	7,740,000	API, 1989
	AS6	Anisotropy Ratio	Constant	unitless	1.00							Assumption
	AS7	Hydraulic Gradient	Regional Site-Based	unitless	5.00E-07	0.000700	0.00200	0.00700	0.0151	0.0330	0.650	API, 1989
	AS8	Seepage Velocity	Derived	m/yr	0.100	1.53	7.44	28.2	183	680	11,000	Derived
	AS9	Retardation Factor	Derived	unitless	chemical-specific value							Derived
	AS10	Longitudinal Dispersivity	Gelhar Empirical	m	0.101	0.873	2.54	5.84	9.11	13.7	40.0	EPRI, 1985; Gelhar, 1986; Gelhar, 1992
	AS11	Transverse Dispersivity	Gelhar Empirical	m	0.0126	0.109	0.317	0.731	1.14	1.72	5.00	EPRI, 1985; Gelhar, 1986; Gelhar, 1992
	AS12	Vertical Dispersivity	Gelhar Empirical	m	0.00500	0.00546	0.0159	0.0365	0.0569	0.0859	0.250	EPRI, 1985; Gelhar, 1986; Gelhar, 1992
	AS13	Temperature of Ambient Aquifer Water	Regional Site-Based	degrees C	7.5	7.5	12.5	17.5	17.5	22.5	27.5	Collins, 1925
	AS14	Ambient Groundwater pH	Empirical	standard units	3.20	5.22	6.08	6.80	7.40	7.89	9.69	USEPA STORET database
	AS15	Fraction of Organic Carbon	Johnson SB	unitless	0.0000103	0.000136	0.000237	0.000429	0.000796	0.00135	0.00823	USEPA STORET database
	AS16	Radial Distance of Observation Well from Downgradient Edge of Waste Unit	Constant	m	150							Policy for Tier 1
	AS17	Angle Off-Center of Observation Well	Constant	degrees	0.00							Policy for Tier 1
	AS20	Depth of Well Below Water Table	Uniform	m	0.000118	0.803	2.18	5.38	13.1	31.9	908	API, 1989
		Leading Coefficient of Freundlich Adsorption Isotherm	Derived	cm ³ /g	chemical-specific value							Derived
	AS22	Freundlich Adsorption Isotherm Exponent	Constant	unitless	1.00							Assumption
	AS23	Hydrolysis Degradation Rate Coefficient	Derived	1/yr	chemical-specific value							Derived
	AS24	Biodegradation Rate Coefficient	Derived	1/yr	0.00							Policy for Tier 1

¹ The actual distribution type depends upon the soil type; the distribution types given here correspond to the silty loam soil (the most common type). In the Tier 1 modeling runs, soil type is automatically varied among the three soil types; each soil type has its own values/distributions of values for the soil parameters. The values presented in this table include all three soil types.

² Values were generated using a Monte Carlo simulation with 10,000 iterations.

Table C-10: IWEM Tier 1 Input Parameters for Waste Pile, Composite Liner Scenario

Input Type	Input No.	Parameter	Input Distribution Type	Units (output)	Percentiles ²							References
					0	10	25	50	75	90	100	
Source	SS1	Area	Regional Site-Based	m	5.06	20.2	20.2	121	1,210	4,170	2,020,000	USEPA, 1986 and 1997b
	SS2/3	Length/Width	Derived	m	2.25	4.49	4.49	11.0	34.8	64.6	1,420	Derived
	SS5	Recharge Rate	Regional Site-Based	m/yr	0.00001	0.0495	0.0787	0.147	0.286	0.419	1.68	ABB, 1995 and USEPA, 1997b
	SS6	Infiltration Rate	Regional Site-Based	m/yr	0.00	0.00	0.00	0.00	0.0000730	0.000167	0.000401	Tetra Tech, 2001
	SS10	Duration of Leaching	Constant	yr	20.0							US EPA, 1996
	SS15	Base Depth Below Grade		m	0.00							Assumption of waste pile design
Unsaturated Zone	US1	Saturated Hydraulic Conductivity	Lognormal ¹	m/yr	0.00684	0.611	2.04	8.26	35.5	159	2,520	Carsel and Parrish, 1988
	US2	Moisture Retention Parameter (alpha)	Johnson SB ¹	1/m	0.100	0.616	0.939	1.53	2.74	6.00	20.2	Carsel and Parrish, 1988
	US3	Moisture Retention Parameter (beta)	Johnson SB ¹	unitless	1.02	1.20	1.26	1.37	1.53	1.82	2.45	Carsel and Parrish, 1988
	US4	Residual Water Content	Johnson SB ¹	unitless	0.0156	0.0492	0.0610	0.0745	0.0857	0.0937	0.115	Carsel and Parrish, 1988
	US5	Saturated Water Content	Constant	unitless	0.410	0.410	0.430	0.450	0.450	0.450	0.450	Carsel and Parrish, 1988
	US6	Thickness of Unsaturated Zone	Regional Site-Based	m	0.305	1.68	3.96	6.10	15.2	34.1	610	API, 1989
	US7	Dispersivity	Derived	m	0.0267	0.0570	0.107	0.154	0.354	0.770	1.00	Gelhar, 1986; EPRI, 1985; USEPA, 1997a
	US8	Percent Organic Matter	Johnson SB ¹	unitless	0.00250	0.0336	0.0570	0.101	0.176	0.291	2.11	Carsel and others, 1988
	US9	Bulk Density	Constant	g/cm ³	1.60	1.60	1.65	1.65	1.67	1.67	1.67	Carsel and others, 1988
	US10	Soil/Water Distribution Coefficient	Derived	cm ³ /g	chemical-specific value							Derived
	US11	Freundlich Adsorption Isotherm Exponent	Constant	unitless	1.00							Assumption
	US12	Chemical Degradation Rate Coefficient	Derived	1/yr	chemical-specific value							Derived
	US13	Biodegradation Rate Coefficient	Constant	1/yr	0.00							Policy for Tier 1
Saturated Zone	AS1	Average Particle Diameter	Empirical	cm	0.000402	0.00149	0.00563	0.0200	0.0422	0.0781	0.211	Sahe, 1974
	AS2	Aquifer Effective Porosity	Derived	unitless	0.0501	0.106	0.168	0.238	0.298	0.335	0.423	Davis, 1969; McWorter and Sunada 1977
	AS3	Aquifer Bulk Density	Derived	g/cm ³	1.16	1.29	1.43	1.56	1.64	1.70	1.80	Freeze and Cherry, 1979
	AS4	Aquifer Saturated Thickness	Regional Site-Based	m	0.305	3.73	7.32	15.2	32.0	91.4	914	API, 1989
	AS5	Longitudinal Hydraulic Conductivity	Regional Site-Based	m/yr	3.15	94.6	315	1,890	11,000	31,500	4,440,000	API, 1989
	AS6	Anisotropy Ratio	Constant	unitless	1.00							Assumption
	AS7	Hydraulic Gradient	Regional Site-Based	unitless	0.000002	0.000903	0.00200	0.00570	0.0180	0.0330	0.390	API, 1989
	AS8	Seepage Velocity	Derived	m/yr	0.100	2.08	8.68	42.2	245	1,210	10,900	Derived
	AS9	Retardation Factor	Derived	unitless	chemical-specific value							Derived
	AS10	Longitudinal Dispersivity	Gelhar Empirical	m	0.101	0.864	2.58	5.60	8.72	15.2	40.0	EPRI, 1985; Gelhar, 1986; Gelhar, 1992
	AS11	Transverse Dispersivity	Gelhar Empirical	m	0.0126	0.108	0.322	0.701	1.09	1.90	5.00	EPRI, 1985; Gelhar, 1986; Gelhar, 1992
	AS12	Vertical Dispersivity	Gelhar Empirical	m	0.00500	0.00540	0.0161	0.0350	0.0545	0.0948	.250	EPRI, 1985; Gelhar, 1986; Gelhar, 1992
	AS13	Temperature of Ambient Aquifer Water	Regional Site-Based	degrees C	7.50	7.50	12.5	12.5	17.5	22.5	22.5	Collins, 1925
	AS14	Ambient Groundwater pH	Empirical	standard units	3.21	5.23	6.08	6.82	7.42	7.93	9.68	USEPA STORET
	AS15	Fraction of Organic Carbon	Johnson SB	unitless	0.0000116	0.000133	0.000236	0.000435	0.000809	0.00142	0.0116	USEPA STORET
	AS16	Radial Distance of Observation Well from Downgradient Edge of Waste Unit	Constant	m	150							Policy for Tier 1
	AS17	Angle Off-Center of Observation Well	Constant	degrees	0.00							Policy for Tier 1
	AS20	Depth of Well Below Water Table	Uniform	m	0.00270	0.947	2.45	6.08	16.2	46.0	914	API, 1989
	AS21	Leading Coefficient of Freundlich Adsorption Isotherm	Derived	cm ³ /g	chemical-specific value							Derived
	AS22	Freundlich Adsorption Isotherm Exponent	Constant	unitless	1.00							Assumption
	AS23	Hydrolysis Degradation Rate Coefficient	Derived	1/yr	chemical-specific value							Derived
	AS24	Biodegradation Rate Coefficient	Derived	1/yr	0.00							Policy for Tier 1

¹ The actual distribution type depends upon the soil type; the distribution types given here correspond to the silty loam soil (the most common type). In the Tier 1 modeling runs, soil type is automatically varied among the three soil types; each soil type has its own values/distributions of values for the soil parameters. The values presented in this table include all three soil types.

² Values were generated using a Monte Carlo simulation with 10,000 iterations.

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APPENDIX D
INFILTRATION RATE DATA

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Table D-1: Tier 2 HELP-derived Infiltration Rates for Landfills (m/yr)

ID	City	State	No Liner			Clay Liner
			SLT	SNL	SCL	
19	Albuquerque	NM	0.00E+00	0.00E+00	3.00E-04	0.00E+00
98	Annette	AK	1.68E+00	1.84E+00	1.46E+00	3.38E-02
82	Astoria	OR	1.08E+00	1.15E+00	9.65E-01	5.26E-02
95	Atlanta	GA	3.42E-01	3.99E-01	2.82E-01	4.77E-02
62	Augusta	ME	2.12E-01	2.70E-01	1.67E-01	4.45E-02
44	Bangor	ME	1.47E-01	2.05E-01	1.23E-01	4.32E-02
99	Bethel	AK	5.64E-02	7.21E-02	5.54E-02	2.95E-02
7	Bismarck	ND	2.39E-02	3.00E-02	1.96E-02	1.88E-02
2	Boise	ID	8.00E-04	9.40E-03	3.80E-03	4.61E-03
67	Boston	MA	2.33E-01	2.38E-01	1.54E-01	4.45E-02
75	Bridgeport	CT	1.95E-01	2.46E-01	1.62E-01	4.44E-02
35	Brownsville	TX	5.49E-02	1.05E-01	3.84E-02	2.41E-02
43	Burlington	VT	1.36E-01	1.78E-01	1.17E-01	4.32E-02
41	Caribou	ME	1.08E-01	1.49E-01	8.86E-02	4.32E-02
18	Cedar City	UT	0.00E+00	8.00E-04	0.00E+00	6.69E-05
86	Central Park	NY	3.36E-01	4.17E-01	2.74E-01	4.86E-02
93	Charleston	SC	2.61E-01	3.29E-01	2.12E-01	4.77E-02
10	Cheyenne	WY	5.00E-04	1.30E-03	8.60E-03	2.38E-05
42	Chicago	IL	7.98E-02	1.14E-01	6.20E-02	4.32E-02
74	Cincinnati	OH	1.55E-01	2.21E-01	1.54E-01	4.44E-02
52	Cleveland	OH	7.80E-02	1.21E-01	8.23E-02	4.09E-02
55	Columbia	MO	1.53E-01	1.99E-01	1.22E-01	4.09E-02
51	Columbus	OH	7.65E-02	1.16E-01	6.63E-02	4.09E-02
38	Concord	NH	1.59E-01	2.06E-01	1.37E-01	4.32E-02
36	Dallas	TX	5.99E-02	1.07E-01	5.31E-02	2.41E-02
3	Denver	CO	8.00E-04	8.00E-04	3.60E-03	1.83E-05
53	Des Moines	IA	1.14E-01	1.64E-01	1.16E-01	4.09E-02
29	Dodge City	KS	1.35E-02	3.45E-02	2.26E-02	9.44E-03
32	E. Lansing	MI	1.09E-01	1.45E-01	1.10E-01	3.74E-02
54	E. St. Louis	IL	1.44E-01	1.68E-01	7.04E-02	4.09E-02
88	Edison	NJ	3.12E-01	3.91E-01	2.49E-01	4.86E-02
23	El Paso	TX	7.60E-03	1.30E-02	8.10E-03	1.03E-04
16	Ely	NV	0.00E+00	0.00E+00	3.00E-04	3.54E-05
100	Fairbanks	AK	1.04E-02	2.34E-02	1.17E-02	9.40E-03
28	Flagstaff	AZ	2.39E-02	6.30E-02	2.26E-02	2.41E-02
1	Fresno	CA	3.07E-02	3.68E-02	3.81E-02	4.61E-03
6	Glasgow	MT	9.90E-03	7.40E-03	9.90E-03	6.69E-05
27	Grand Island	NE	4.42E-02	6.27E-02	3.23E-02	1.96E-02
4	Grand Junction	CO	0.00E+00	0.00E+00	3.00E-04	2.70E-05
25	Great Falls	MT	3.60E-03	6.90E-03	7.40E-03	1.02E-04
77	Greensboro	NC	3.26E-01	3.90E-01	2.71E-01	3.62E-02
59	Hartford	CT	1.71E-01	2.23E-01	1.41E-01	4.45E-02
101	Honolulu	HI	5.23E-02	9.45E-02	3.66E-02	4.83E-03
73	Indianapolis	IN	1.30E-01	1.86E-01	1.06E-01	4.44E-02
66	Ithaca	NY	1.68E-01	2.14E-01	1.39E-01	4.45E-02
78	Jacksonville	FL	1.51E-01	2.11E-01	1.10E-01	3.62E-02
85	Knoxville	TN	4.11E-01	4.46E-01	3.54E-01	4.86E-02
96	Lake Charles	LA	3.65E-01	4.64E-01	2.82E-01	4.92E-02
11	Lander	WY	3.30E-03	5.30E-03	9.40E-03	1.28E-04
20	Las Vegas	NV	0.00E+00	0.00E+00	1.80E-03	6.89E-05
87	Lexington	KY	3.29E-01	3.97E-01	2.70E-01	4.86E-02
90	Little Rock	AK	3.53E-01	4.34E-01	2.82E-01	4.77E-02
12	Los Angeles	CA	7.87E-02	9.50E-02	6.99E-02	1.26E-03
69	Lynchburg	VA	3.08E-01	3.61E-01	2.57E-01	4.44E-02
50	Madison	WI	9.12E-02	1.40E-01	6.86E-02	4.09E-02
24	Medford	OR	2.07E-01	2.31E-01	2.10E-01	4.32E-02

Table D-1: Tier 2 HELP-derived Infiltration Rates for Landfills (m/yr)

ID	City	State	No Liner			Clay Liner
			SLT	SNL	SCL	
97	Miami	FL	1.45E-01	2.20E-01	1.02E-01	4.92E-02
30	Midland	TX	1.80E-02	2.54E-02	1.35E-02	9.44E-03
47	Montpelier	VT	1.06E-01	1.48E-01	8.79E-02	4.32E-02
65	Nashua	NH	2.27E-01	2.81E-01	1.94E-01	4.45E-02
89	Nashville	TN	4.67E-01	5.40E-01	3.77E-01	4.86E-02
83	New Haven	CT	3.52E-01	4.63E-01	2.86E-01	5.26E-02
92	New Orleans	LA	5.89E-01	7.45E-01	4.50E-01	4.77E-02
70	New York City	NY	2.44E-01	2.94E-01	1.97E-01	4.44E-02
80	Norfolk	VA	3.12E-01	0.00E+00	2.69E-01	3.62E-02
33	North Omaha	NE	6.71E-02	7.95E-02	5.36E-02	2.91E-02
37	Oklahoma City	OK	6.12E-02	9.42E-02	3.89E-02	2.46E-02
76	Orlando	FL	1.02E-01	1.70E-01	8.05E-02	3.62E-02
71	Philadelphia	PA	2.01E-01	2.61E-01	1.64E-01	4.44E-02
21	Phoenix	AZ	0.00E+00	3.00E-04	3.00E-04	1.69E-05
39	Pittsburg	PA	8.94E-02	1.31E-01	7.92E-02	4.32E-02
84	Plainfield	MA	1.90E-01	2.54E-01	1.52E-01	5.26E-02
5	Pocatello	ID	0.00E+00	0.00E+00	0.00E+00	5.50E-04
40	Portland	OR	4.17E-01	4.39E-01	3.93E-01	4.32E-02
64	Portland	ME	2.29E-01	2.84E-01	1.87E-01	4.45E-02
63	Providence	RI	2.13E-01	2.86E-01	1.75E-01	4.45E-02
8	Pullman	WA	6.90E-03	1.32E-02	8.40E-03	2.27E-04
49	Put-in-Bay	OH	5.08E-02	1.00E-01	4.95E-02	4.09E-02
17	Rapid City	SD	5.00E-04	7.10E-03	3.30E-03	6.40E-05
45	Rutland	VT	1.21E-01	1.60E-01	1.01E-01	4.32E-02
13	Sacramento	CA	1.02E-01	8.76E-02	9.45E-02	1.26E-03
26	Salt Lake City	UT	1.30E-02	2.69E-02	1.85E-02	5.10E-04
58	San Antonio	TX	1.10E-01	1.65E-01	8.20E-02	2.53E-02
14	San Diego	CA	2.21E-02	3.40E-02	2.41E-02	1.26E-03
102	San Juan	PR	1.27E-01	1.92E-01	9.45E-02	1.93E-02
15	Santa Maria	CA	9.47E-02	1.15E-01	8.41E-02	1.26E-03
48	Sault St. Marie	MI	1.65E-01	2.10E-01	1.44E-01	4.32E-02
68	Schenectady	NY	1.47E-01	1.93E-01	1.22E-01	4.45E-02
72	Seabrook	NJ	1.81E-01	2.43E-01	1.43E-01	4.44E-02
46	Seattle	WA	4.38E-01	4.58E-01	4.08E-01	4.32E-02
81	Shreveport	LA	2.30E-01	2.94E-01	1.84E-01	3.62E-02
31	St. Cloud	MN	6.02E-02	8.31E-02	5.54E-02	3.42E-02
60	Syracuse	NY	2.55E-01	3.25E-01	2.12E-01	4.45E-02
91	Tallahassee	FL	5.91E-01	7.31E-01	4.56E-01	4.77E-02
57	Tampa	FL	6.58E-02	1.03E-01	4.75E-02	2.53E-02
56	Topeka	KS	1.05E-01	1.48E-01	7.62E-02	3.50E-02
22	Tucson	AZ	0.00E+00	3.00E-04	5.00E-04	2.23E-05
34	Tulsa	OK	6.86E-02	1.01E-01	4.65E-02	2.41E-02
94	W. Palm Beach	FL	2.61E-01	3.49E-01	1.78E-01	4.77E-02
79	Watkinsville	GA	2.89E-01	3.56E-01	2.33E-01	3.62E-02
61	Worcester	MA	2.02E-01	2.59E-01	1.70E-01	4.45E-02
9	Yakima	WA	0.00E+00	2.30E-03	3.00E-04	1.15E-04

Notes:

SLT = Silt Loam cover SNL =

Sandy Loam cover SCL =

Silty Clay Loam cover

Table D-2: Tier 2 HELP-derived Infiltration Rates for Waste Piles (m/yr)

ID	City	State	No Liner			Clay Liner		
			Low Permeability Waste	Medium Permeability Waste	High Permeability Waste	Low Permeability Waste	Medium Permeability Waste	High Permeability Waste
19	Albuquerque	NM	2.54E-04	2.54E-04	2.54E-04	1.60E-03	1.51E-02	7.43E-03
98	Annette	AK	1.54E+00	1.81E+00	1.88E+00	1.35E-01	1.36E-01	1.35E-01
82	Astoria	OR	1.21E+00	1.21E+00	1.21E+00	1.32E-01	1.35E-01	1.35E-01
95	Atlanta	GA	5.16E-01	5.16E-01	5.16E-01	1.18E-01	1.35E-01	1.35E-01
62	Augusta	ME	3.14E-01	3.14E-01	3.14E-01	1.19E-01	1.29E-01	1.28E-01
44	Bangor	ME	2.57E-01	2.57E-01	2.57E-01	1.13E-01	1.27E-01	1.27E-01
99	Bethel	AK	5.02E-02	7.25E-02	1.23E-01	3.52E-02	3.64E-02	6.60E-02
7	Bismarck	ND	2.59E-02	2.59E-02	2.59E-02	1.24E-02	6.89E-02	9.50E-02
2	Boise	ID	2.54E-04	2.54E-04	2.54E-04	1.36E-02	4.34E-02	6.06E-02
67	Boston	MA	3.22E-01	3.22E-01	3.22E-01	1.19E-01	1.29E-01	1.28E-01
75	Bridgeport	CT	3.69E-01	3.69E-01	3.69E-01	1.06E-01	1.34E-01	1.33E-01
35	Brownsville	TX	2.27E-01	2.27E-01	2.27E-01	4.97E-03	1.33E-01	1.32E-01
43	Burlington	VT	2.13E-01	2.13E-01	2.13E-01	1.13E-01	1.27E-01	1.27E-01
41	Caribou	ME	1.88E-01	1.88E-01	1.88E-01	1.13E-01	1.27E-01	1.27E-01
18	Cedar City	UT	2.54E-04	2.54E-04	2.54E-04	4.82E-03	8.26E-04	5.32E-03
86	Central Park	NY	5.23E-01	5.23E-01	5.23E-01	1.26E-01	1.35E-01	1.35E-01
93	Charleston	SC	4.83E-01	4.83E-01	4.83E-01	1.18E-01	1.35E-01	1.35E-01
10	Cheyenne	WY	4.32E-03	4.32E-03	4.32E-03	1.37E-03	2.92E-04	7.07E-03
42	Chicago	IL	1.68E-01	1.68E-01	1.68E-01	1.13E-01	1.27E-01	1.27E-01
74	Cincinnati	OH	3.10E-01	3.10E-01	3.10E-01	1.06E-01	1.34E-01	1.33E-01
52	Cleveland	OH	1.82E-01	1.82E-01	1.82E-01	6.88E-02	1.32E-01	1.32E-01
55	Columbia	MO	3.10E-01	3.10E-01	3.10E-01	6.88E-02	1.32E-01	1.32E-01
51	Columbus	OH	1.72E-01	1.72E-01	1.72E-01	6.88E-02	1.32E-01	1.32E-01
38	Concord	NH	2.35E-01	2.35E-01	2.35E-01	1.13E-01	1.27E-01	1.27E-01
36	Dallas	TX	2.58E-01	2.58E-01	2.58E-01	4.97E-03	1.33E-01	1.32E-01
3	Denver	CO	7.62E-04	7.62E-04	7.62E-04	1.97E-03	1.28E-03	3.66E-03
53	Des Moines	IA	2.51E-01	2.51E-01	2.51E-01	6.88E-02	1.32E-01	1.32E-01
29	Dodge City	KS	1.01E-01	1.01E-01	1.01E-01	3.26E-03	1.06E-01	1.19E-01
32	E. Lansing	MI	1.36E-01	1.36E-01	1.36E-01	4.81E-02	1.15E-01	1.11E-01
54	E. St. Louis	IL	2.63E-01	2.63E-01	2.63E-01	6.88E-02	1.32E-01	1.32E-01
88	Edison	NJ	4.90E-01	4.90E-01	4.90E-01	1.26E-01	1.35E-01	1.35E-01
23	El Paso	TX	2.31E-02	2.31E-02	2.31E-02	5.81E-03	2.63E-03	6.74E-03
16	Ely	NV	2.54E-04	2.54E-04	2.54E-04	5.89E-03	1.12E-03	3.61E-03
100	Fairbanks	AK	7.67E-03	1.67E-02	7.77E-02	9.80E-03	1.18E-02	4.07E-02
28	Flagstaff	AZ	4.04E-02	4.04E-02	4.04E-02	1.05E-02	1.23E-01	1.23E-01
1	Fresno	CA	4.22E-02	4.22E-02	4.22E-02	1.36E-02	4.34E-02	6.06E-02
6	Glasgow	MT	3.66E-02	3.66E-02	3.66E-02	5.35E-04	2.25E-04	2.34E-02
27	Grand Island	NE	9.63E-02	9.63E-02	9.63E-02	4.22E-02	1.35E-01	1.34E-01
4	Grand Junction	CO	2.54E-04	2.54E-04	2.54E-04	4.59E-03	1.66E-03	1.98E-03
25	Great Falls	MT	2.59E-02	2.59E-02	2.59E-02	1.94E-03	4.66E-03	3.34E-02
77	Greensboro	NC	4.84E-01	4.84E-01	4.84E-01	8.04E-02	1.27E-01	1.27E-01
59	Hartford	CT	2.79E-01	2.79E-01	2.79E-01	1.19E-01	1.29E-01	1.28E-01
101	Honolulu	HI	5.01E-02	1.08E-01	1.98E-01	3.23E-02	4.94E-02	8.71E-02
73	Indianapolis	IN	2.69E-01	2.69E-01	2.69E-01	1.06E-01	1.34E-01	1.33E-01
66	Ithaca	NY	2.61E-01	2.61E-01	2.61E-01	1.19E-01	1.29E-01	1.28E-01
78	Jacksonville	FL	4.09E-01	4.09E-01	4.09E-01	8.04E-02	1.27E-01	1.27E-01
85	Knoxville	TN	5.42E-01	5.42E-01	5.42E-01	1.26E-01	1.35E-01	1.35E-01
96	Lake Charles	LA	6.07E-01	6.07E-01	6.07E-01	4.89E-02	5.58E-02	9.27E-02
11	Lander	WY	2.03E-03	2.03E-03	2.03E-03	4.19E-03	1.25E-03	2.00E-02
20	Las Vegas	NV	2.54E-04	2.54E-04	2.54E-04	5.15E-03	1.79E-03	7.97E-03
87	Lexington	KY	4.52E-01	4.52E-01	4.52E-01	1.26E-01	1.35E-01	1.35E-01
90	Little Rock	AK	5.38E-01	5.38E-01	5.38E-01	1.18E-01	1.35E-01	1.35E-01
12	Los Angeles	CA	1.33E-01	1.33E-01	1.33E-01	0.00E+00	5.56E-02	7.18E-02
69	Lynchburg	VA	2.69E-01	2.69E-01	2.69E-01	1.06E-01	1.34E-01	1.33E-01
50	Madison	WI	2.02E-01	2.02E-01	2.02E-01	6.88E-02	1.32E-01	1.32E-01

Table D-2: Tier 2 HELP-derived Infiltration Rates for Waste Piles (m/yr)

ID	City	State	No Liner			Clay Liner		
			Low Permeability Waste	Medium Permeability Waste	High Permeability Waste	Low Permeability Waste	Medium Permeability Waste	High Permeability Waste
24	Medford	OR	2.50E-01	2.50E-01	2.50E-01	1.26E-01	1.33E-01	1.31E-01
97	Miami	FL	4.23E-01	4.23E-01	4.23E-01	4.89E-02	5.58E-02	9.27E-02
30	Midland	TX	7.57E-02	7.57E-02	7.57E-02	3.26E-03	1.06E-01	1.19E-01
47	Montpelier	VT	1.76E-01	1.76E-01	1.76E-01	1.13E-01	1.27E-01	1.27E-01
65	Nashua	NH	3.34E-01	3.34E-01	3.34E-01	1.19E-01	1.29E-01	1.28E-01
89	Nashville	TN	6.14E-01	6.14E-01	6.14E-01	1.26E-01	1.35E-01	1.35E-01
83	New Haven	CT	5.42E-01	5.42E-01	5.42E-01	1.32E-01	1.35E-01	1.35E-01
92	New Orleans	LA	8.49E-01	8.49E-01	8.49E-01	1.18E-01	1.35E-01	1.35E-01
70	New York City	NY	3.99E-01	3.99E-01	3.99E-01	1.06E-01	1.34E-01	1.33E-01
80	Norfolk	VA	4.54E-01	4.54E-01	4.54E-01	8.04E-02	1.27E-01	1.27E-01
33	North Omaha	NE	1.62E-01	1.62E-01	1.62E-01	2.02E-02	1.26E-01	1.27E-01
37	Oklahoma City	OK	2.42E-01	2.42E-01	2.42E-01	7.47E-03	1.31E-01	1.30E-01
76	Orlando	FL	3.84E-01	3.84E-01	3.84E-01	8.04E-02	1.27E-01	1.27E-01
71	Philadelphia	PA	3.53E-01	3.53E-01	3.53E-01	1.06E-01	1.34E-01	1.33E-01
21	Phoenix	AZ	2.54E-04	2.54E-04	2.54E-04	4.73E-03	2.01E-03	7.62E-04
39	Pittsburg	PA	1.72E-01	1.72E-01	1.72E-01	1.13E-01	1.27E-01	1.27E-01
84	Plainfield	MA	3.03E-01	3.03E-01	3.03E-01	1.32E-01	1.35E-01	1.35E-01
5	Pocatello	ID	2.54E-04	2.54E-04	2.54E-04	5.86E-03	1.50E-03	3.19E-02
40	Portland	OR	5.06E-01	5.06E-01	5.06E-01	1.13E-01	1.27E-01	1.27E-01
64	Portland	ME	3.25E-01	3.25E-01	3.25E-01	1.19E-01	1.29E-01	1.28E-01
63	Providence	RI	3.48E-01	3.48E-01	3.48E-01	1.19E-01	1.29E-01	1.28E-01
8	Pullman	WA	2.54E-04	2.54E-04	2.54E-04	9.27E-03	1.43E-02	3.44E-02
49	Put-in-Bay	OH	1.48E-01	1.48E-01	1.48E-01	6.88E-02	1.32E-01	1.32E-01
17	Rapid City	SD	1.35E-02	1.35E-02	1.35E-02	9.92E-04	1.14E-03	1.92E-02
45	Rutland	VT	2.13E-01	2.13E-01	2.13E-01	1.13E-01	1.27E-01	1.27E-01
13	Sacramento	CA	1.23E-01	1.23E-01	1.23E-01	0.00E+00	5.56E-02	7.18E-02
26	Salt Lake City	UT	1.93E-02	1.93E-02	1.93E-02	9.11E-03	1.05E-02	3.68E-02
58	San Antonio	TX	2.95E-01	2.95E-01	2.95E-01	2.00E-02	1.34E-01	1.33E-01
14	San Diego	CA	6.58E-02	6.58E-02	6.58E-02	0.00E+00	5.56E-02	7.18E-02
102	San Juan	PR	1.50E-01	2.88E-01	4.44E-01	6.37E-02	7.93E-02	1.11E-01
15	Santa Maria	CA	1.51E-01	1.51E-01	1.51E-01	0.00E+00	5.56E-02	7.18E-02
48	Sault St. Marie	MI	2.37E-01	2.37E-01	2.37E-01	1.13E-01	1.27E-01	1.27E-01
68	Schenectady	NY	2.75E-01	2.75E-01	2.75E-01	1.19E-01	1.29E-01	1.28E-01
72	Seabrook	NJ	3.41E-01	3.41E-01	3.41E-01	1.06E-01	1.34E-01	1.33E-01
46	Seattle	WA	5.31E-01	5.31E-01	5.31E-01	1.13E-01	1.27E-01	1.27E-01
81	Shreveport	LA	4.46E-01	4.46E-01	4.46E-01	8.04E-02	1.27E-01	1.27E-01
31	St. Cloud	MN	1.52E-01	1.52E-01	1.52E-01	2.64E-02	1.26E-01	1.26E-01
60	Syracuse	NY	4.10E-01	4.10E-01	4.10E-01	1.19E-01	1.29E-01	1.28E-01
91	Tallahassee	FL	8.22E-01	8.22E-01	8.22E-01	1.18E-01	1.35E-01	1.35E-01
57	Tampa	FL	2.72E-01	2.72E-01	2.72E-01	2.00E-02	1.34E-01	1.33E-01
56	Topeka	KS	2.47E-01	2.47E-01	2.47E-01	1.74E-02	1.31E-01	1.30E-01
22	Tucson	AZ	2.54E-04	2.54E-04	2.54E-04	6.41E-03	7.53E-03	1.69E-03
34	Tulsa	OK	2.49E-01	2.49E-01	2.49E-01	4.97E-03	1.33E-01	1.32E-01
94	W. Palm Beach	FL	5.64E-01	5.64E-01	5.64E-01	1.18E-01	1.35E-01	1.35E-01
79	Watkinsville	GA	4.67E-01	4.67E-01	4.67E-01	8.04E-02	1.27E-01	1.27E-01
61	Worcester	MA	3.31E-01	3.31E-01	3.31E-01	1.19E-01	1.29E-01	1.28E-01
9	Yakima	WA	2.54E-04	2.54E-04	2.54E-04	4.86E-03	4.74E-03	2.84E-02

Notes:

Low, Medium, and High denote representative waste types with different hydraulic conductivities:

Low = Fine-grained waste (e.g., fly ash), Hydraulic conductivity is 5×10^{-5} cm/sec

Medium = Medium-grained waste (e.g., bottom ash), Hydraulic conductivity is 0.0041 cm/sec

High = Coarse-grained waste (e.g., slag), Hydraulic conductivity is 0.041 cm/sec

Table D-3: Tier 2 HELP-derived Infiltration Rates for Land Application Units (m/yr)

ID	City	State	No Liner		
			SLT	SNL	SCL
19	Albuquerque	NM	0.00E+00	0.00E+00	3.00E-04
98	Annette	AK	1.80E+00	1.98E+00	1.52E+00
82	Astoria	OR	1.08E+00	1.15E+00	9.65E-01
95	Atlanta	GA	3.42E-01	3.99E-01	2.82E-01
62	Augusta	ME	2.12E-01	2.70E-01	1.67E-01
44	Bangor	ME	1.47E-01	2.05E-01	1.23E-01
99	Bethel	AK	1.85E-01	1.98E-01	1.78E-01
7	Bismarck	ND	2.39E-02	3.00E-02	1.96E-02
2	Boise	ID	8.00E-04	9.40E-03	3.80E-03
67	Boston	MA	2.33E-01	2.38E-01	1.54E-01
75	Bridgeport	CT	1.95E-01	2.46E-01	1.62E-01
35	Brownsville	TX	5.49E-02	1.05E-01	3.84E-02
43	Burlington	VT	1.36E-01	1.78E-01	1.17E-01
41	Caribou	ME	1.08E-01	1.49E-01	8.86E-02
18	Cedar City	UT	0.00E+00	8.00E-04	0.00E+00
86	Central Park	NY	3.36E-01	4.17E-01	2.74E-01
93	Charleston	SC	2.61E-01	3.29E-01	2.12E-01
10	Cheyenne	WY	5.00E-04	1.30E-03	8.60E-03
42	Chicago	IL	7.98E-02	1.14E-01	6.20E-02
74	Cincinnati	OH	1.55E-01	2.21E-01	1.54E-01
52	Cleveland	OH	7.80E-02	1.21E-01	8.23E-02
55	Columbia	MO	1.53E-01	1.99E-01	1.22E-01
51	Columbus	OH	7.65E-02	1.16E-01	6.63E-02
38	Concord	NH	1.59E-01	2.06E-01	1.37E-01
36	Dallas	TX	5.99E-02	1.07E-01	5.31E-02
3	Denver	CO	8.00E-04	8.00E-04	3.60E-03
53	Des Moines	IA	1.14E-01	1.64E-01	1.16E-01
29	Dodge City	KS	1.35E-02	3.45E-02	2.26E-02
32	E. Lansing	MI	1.09E-01	1.45E-01	1.10E-01
54	E. St. Louis	IL	1.44E-01	1.68E-01	7.04E-02
88	Edison	NJ	3.12E-01	3.91E-01	2.49E-01
23	El Paso	TX	7.60E-03	1.30E-02	8.10E-03
16	Ely	NV	0.00E+00	0.00E+00	3.00E-04
100	Fairbanks	AK	1.46E-01	1.48E-01	1.45E-01
28	Flagstaff	AZ	2.39E-02	6.30E-02	2.26E-02
1	Fresno	CA	3.07E-02	3.68E-02	3.81E-02
6	Glasgow	MT	9.90E-03	7.40E-03	9.90E-03
27	Grand Island	NE	4.42E-02	6.27E-02	3.23E-02
4	Grand Junction	CO	0.00E+00	0.00E+00	3.00E-04
25	Great Falls	MT	3.60E-03	6.90E-03	7.40E-03
77	Greensboro	NC	3.26E-01	3.90E-01	2.71E-01
59	Hartford	CT	1.71E-01	2.23E-01	1.41E-01
101	Honolulu	HI	5.41E-02	9.83E-02	3.63E-02
73	Indianapolis	IN	1.30E-01	1.86E-01	1.06E-01
66	Ithaca	NY	1.68E-01	2.14E-01	1.39E-01
78	Jacksonville	FL	1.51E-01	2.11E-01	1.10E-01
85	Knoxville	TN	4.11E-01	4.46E-01	3.54E-01
96	Lake Charles	LA	3.65E-01	4.64E-01	2.82E-01
11	Lander	WY	3.30E-03	5.30E-03	9.40E-03
20	Las Vegas	NV	0.00E+00	0.00E+00	1.80E-03
87	Lexington	KY	3.29E-01	3.97E-01	2.70E-01
90	Little Rock	AK	3.53E-01	4.34E-01	2.82E-01
12	Los Angeles	CA	7.87E-02	9.50E-02	6.99E-02
69	Lynchburg	VA	3.08E-01	3.61E-01	2.57E-01
50	Madison	WI	9.12E-02	1.40E-01	6.86E-02
24	Medford	OR	2.07E-01	2.31E-01	2.10E-01

Table D-3: Tier 2 HELP-derived Infiltration Rates for Land Application Units (m/yr)

ID	City	State	No Liner		
			SLT	SNL	SCL
97	Miami	FL	1.45E-01	2.20E-01	1.02E-01
30	Midland	TX	1.80E-02	2.54E-02	1.35E-02
47	Montpelier	VT	1.06E-01	1.48E-01	8.79E-02
65	Nashua	NH	2.27E-01	2.81E-01	1.94E-01
89	Nashville	TN	4.67E-01	5.40E-01	3.77E-01
83	New Haven	CT	3.52E-01	4.63E-01	2.86E-01
92	New Orleans	LA	5.89E-01	7.45E-01	4.50E-01
70	New York City	NY	2.44E-01	2.94E-01	1.97E-01
80	Norfolk	VA	3.12E-01	0.00E+00	2.69E-01
33	North Omaha	NE	6.71E-02	7.95E-02	5.36E-02
37	Oklahoma City	OK	6.12E-02	9.42E-02	3.89E-02
76	Orlando	FL	1.02E-01	1.70E-01	8.05E-02
71	Philadelphia	PA	2.01E-01	2.61E-01	1.64E-01
21	Phoenix	AZ	0.00E+00	3.00E-04	3.00E-04
39	Pittsburg	PA	8.94E-02	1.31E-01	7.92E-02
84	Plainfield	MA	1.90E-01	2.54E-01	1.52E-01
5	Pocatello	ID	0.00E+00	0.00E+00	0.00E+00
40	Portland	OR	4.17E-01	4.39E-01	3.93E-01
64	Portland	ME	2.29E-01	2.84E-01	1.87E-01
63	Providence	RI	2.13E-01	2.86E-01	1.75E-01
8	Pullman	WA	6.90E-03	1.32E-02	8.40E-03
49	Put-in-Bay	OH	5.08E-02	1.00E-01	4.95E-02
17	Rapid City	SD	5.00E-04	7.10E-03	3.30E-03
45	Rutland	VT	1.21E-01	1.60E-01	1.01E-01
13	Sacramento	CA	1.02E-01	8.76E-02	9.45E-02
26	Salt Lake City	UT	1.30E-02	2.69E-02	1.85E-02
58	San Antonio	TX	1.10E-01	1.65E-01	8.20E-02
14	San Diego	CA	2.21E-02	3.40E-02	2.41E-02
102	San Juan	PR	1.49E-01	2.16E-01	1.05E-01
15	Santa Maria	CA	9.47E-02	1.15E-01	8.41E-02
48	Sault St. Marie	MI	1.65E-01	2.10E-01	1.44E-01
68	Schenectady	NY	1.47E-01	1.93E-01	1.22E-01
72	Seabrook	NJ	1.81E-01	2.43E-01	1.43E-01
46	Seattle	WA	4.38E-01	4.58E-01	4.08E-01
81	Shreveport	LA	2.30E-01	2.94E-01	1.84E-01
31	St. Cloud	MN	6.02E-02	8.31E-02	5.54E-02
60	Syracuse	NY	2.55E-01	3.25E-01	2.12E-01
91	Tallahassee	FL	5.91E-01	7.31E-01	4.56E-01
57	Tampa	FL	6.58E-02	1.03E-01	4.75E-02
56	Topeka	KS	1.05E-01	1.48E-01	7.62E-02
22	Tucson	AZ	0.00E+00	3.00E-04	5.00E-04
34	Tulsa	OK	6.86E-02	1.01E-01	4.65E-02
94	W. Palm Beach	FL	2.61E-01	3.49E-01	1.78E-01
79	Watkinsville	GA	2.89E-01	3.56E-01	2.33E-01
61	Worcester	MA	2.02E-01	2.59E-01	1.70E-01
9	Yakima	WA	0.00E+00	2.30E-03	3.00E-04

Notes:

SLT = Silt Loam soil SNL =

Sandy Loam soil SCL =

Silty Clay Loam soil

Table D-4: Tier 1 HELP-derived Infiltration Rates for Clay Liner Scenarios (m/yr)

City	State	Tier 1 Clay Lined Landfill Infiltration Rate (m/yr)	Tier 1 Clay Lined Waste Pile Infiltration Rate (m/yr)		
			Low Permeability Waste	Medium Permeability Waste	High Permeability Waste
Boise ¹⁾	ID	4.61E-03	1.36E-02	4.34E-02	6.06E-02
Fresno	CA	4.61E-03	1.36E-02	4.34E-02	6.06E-02
Bismarck	ND	1.88E-02	1.24E-02	6.89E-02	9.50E-02
Denver	CO	1.88E-02	1.24E-02	6.89E-02	9.50E-02
Grand Junction	CO	1.88E-02	1.24E-02	6.89E-02	9.50E-02
Pocatello	ID	1.88E-02	1.24E-02	6.89E-02	9.50E-02
Glasgow	MT	1.88E-02	1.24E-02	6.89E-02	9.50E-02
Pullman	WA	1.88E-02	1.24E-02	6.89E-02	9.50E-02
Yakima	WA	1.88E-02	1.24E-02	6.89E-02	9.50E-02
Cheyenne	WY	1.88E-02	1.24E-02	6.89E-02	9.50E-02
Lander	WY	1.88E-02	1.24E-02	6.89E-02	9.50E-02
Rapid City	SD	1.26E-03	0.00E+00	5.56E-02	7.18E-02
Los Angeles	CA	1.26E-03	0.00E+00	5.56E-02	7.18E-02
Sacramento	CA	1.26E-03	0.00E+00	5.56E-02	7.18E-02
San Diego	CA	1.26E-03	0.00E+00	5.56E-02	7.18E-02
Santa Maria	CA	1.26E-03	0.00E+00	5.56E-02	7.18E-02
Ely	NV	1.26E-03	0.00E+00	5.56E-02	7.18E-02
Cedar City	UT	1.26E-03	0.00E+00	5.56E-02	7.18E-02
Albuquerque	NM	0.00E+00	1.60E-03	1.51E-02	7.43E-03
Las Vegas	NV	0.00E+00	9.68E-02	1.35E-01	1.34E-01
Phoenix	AZ	0.00E+00	9.68E-02	1.35E-01	1.34E-01
Tucson	AZ	0.00E+00	9.68E-02	1.35E-01	1.34E-01
El Paso	TX	0.00E+00	9.68E-02	1.35E-01	1.34E-01
Medford	OR	4.32E-02	1.26E-01	1.33E-01	1.31E-01
Great Falls	MT	4.32E-02	1.26E-01	1.33E-01	1.31E-01
Salt Lake City	UT	4.32E-02	1.26E-01	1.33E-01	1.31E-01
Grand Island	NE	1.96E-02	4.22E-02	1.35E-01	1.34E-01
Flagstaff	AZ	2.41E-02	1.05E-02	1.23E-01	1.23E-01
Dodge City	KS	9.44E-03	3.26E-03	1.06E-01	1.19E-01
Midland	TX	9.44E-03	3.26E-03	1.06E-01	1.19E-01
St. Cloud	MN	3.42E-02	2.64E-02	1.26E-01	1.26E-01
E. Lansing	MI	3.74E-02	4.81E-02	1.15E-01	1.11E-01
North Omaha	NE	2.91E-02	2.02E-02	1.26E-01	1.27E-01
Dallas	TX	2.41E-02	4.97E-03	1.33E-01	1.32E-01
Tulsa	OK	2.41E-02	4.97E-03	1.33E-01	1.32E-01
Brownsville	TX	2.41E-02	4.97E-03	1.33E-01	1.32E-01
Oklahoma City	OK	2.46E-02	7.47E-03	1.31E-01	1.30E-01
Bangor	ME	4.32E-02	1.13E-01	1.27E-01	1.27E-01
Concord	NH	4.32E-02	1.13E-01	1.27E-01	1.27E-01
Pittsburg	PA	4.32E-02	1.13E-01	1.27E-01	1.27E-01
Portland	OR	4.32E-02	1.13E-01	1.27E-01	1.27E-01
Caribou	ME	4.32E-02	1.13E-01	1.27E-01	1.27E-01
Chicago	IL	4.32E-02	1.13E-01	1.27E-01	1.27E-01
Burlington	VT	4.32E-02	1.13E-01	1.27E-01	1.27E-01
Rutland	VT	4.32E-02	1.13E-01	1.27E-01	1.27E-01
Seattle	WA	4.32E-02	1.13E-01	1.27E-01	1.27E-01
Montpelier	VT	4.32E-02	1.13E-01	1.27E-01	1.27E-01
Sault St. Marie	MI	4.32E-02	1.13E-01	1.27E-01	1.27E-01
Columbia	MO	4.09E-02	6.88E-02	1.32E-01	1.32E-01
Put-in-Bay	OH	4.09E-02	6.88E-02	1.32E-01	1.32E-01
Madison	WI	4.09E-02	6.88E-02	1.32E-01	1.32E-01
Columbus	OH	4.09E-02	6.88E-02	1.32E-01	1.32E-01

Table D-4: Tier 1 HELP-derived Infiltration Rates for Clay Liner Scenarios (m/yr)

City	State	Tier 1 Clay Lined Landfill Infiltration Rate (m/yr)	Tier 1 Clay Lined Waste Pile Infiltration Rate (m/yr)		
			Low Permeability Waste	Medium Permeability Waste	High Permeability Waste
Cleveland	OH	4.09E-02	6.88E-02	1.32E-01	1.32E-01
Des Moines	IA	4.09E-02	6.88E-02	1.32E-01	1.32E-01
E. St. Louis	IL	4.09E-02	6.88E-02	1.32E-01	1.32E-01
Topeka	KS	3.50E-02	1.74E-02	1.31E-01	1.30E-01
Tampa	FL	2.53E-02	2.00E-02	1.34E-01	1.33E-01
San Antonio	TX	2.53E-02	2.00E-02	1.34E-01	1.33E-01
Portland	ME	4.45E-02	1.19E-01	1.29E-01	1.28E-01
Hartford	CT	4.45E-02	1.19E-01	1.29E-01	1.28E-01
Syracuse	NY	4.45E-02	1.19E-01	1.29E-01	1.28E-01
Worcester	MA	4.45E-02	1.19E-01	1.29E-01	1.28E-01
Augusta	ME	4.45E-02	1.19E-01	1.29E-01	1.28E-01
Providence	RI	4.45E-02	1.19E-01	1.29E-01	1.28E-01
Nashua	NH	4.45E-02	1.19E-01	1.29E-01	1.28E-01
Ithaca	NY	4.45E-02	1.19E-01	1.29E-01	1.28E-01
Boston	MA	4.45E-02	1.19E-01	1.29E-01	1.28E-01
Schenectady	NY	4.45E-02	1.19E-01	1.29E-01	1.28E-01
New York City	NY	4.44E-02	1.06E-01	1.34E-01	1.33E-01
Lynchburg	VA	4.44E-02	1.06E-01	1.34E-01	1.33E-01
Philadelphia	PA	4.44E-02	1.06E-01	1.34E-01	1.33E-01
Seabrook	NJ	4.44E-02	1.06E-01	1.34E-01	1.33E-01
Indianapolis	IN	4.44E-02	1.06E-01	1.34E-01	1.33E-01
Cincinnati	OH	4.44E-02	1.06E-01	1.34E-01	1.33E-01
Bridgeport	CT	4.44E-02	1.06E-01	1.34E-01	1.33E-01
Jacksonville	FL	3.62E-02	8.04E-02	1.27E-01	1.27E-01
Orlando	FL	3.62E-02	8.04E-02	1.27E-01	1.27E-01
Greensboro	NC	3.62E-02	8.04E-02	1.27E-01	1.27E-01
Watkinsville	GA	3.62E-02	8.04E-02	1.27E-01	1.27E-01
Norfolk	VA	3.62E-02	8.04E-02	1.27E-01	1.27E-01
Shreveport	LA	3.62E-02	8.04E-02	1.27E-01	1.27E-01
Astoria	OR	5.26E-02	1.32E-01	1.35E-01	1.35E-01
New Haven	CT	5.26E-02	1.32E-01	1.35E-01	1.35E-01
Plainfield	MA	5.26E-02	1.32E-01	1.35E-01	1.35E-01
Nashville	TN	4.86E-02	1.26E-01	1.35E-01	1.35E-01
Knoxville	TN	4.86E-02	1.26E-01	1.35E-01	1.35E-01
Central Park	NY	4.86E-02	1.26E-01	1.35E-01	1.35E-01
Lexington	KY	4.86E-02	1.26E-01	1.35E-01	1.35E-01
Edison	NJ	4.86E-02	1.26E-01	1.35E-01	1.35E-01
Atlanta	GA	4.77E-02	1.18E-01	1.35E-01	1.35E-01
Little Rock	AK	4.77E-02	1.18E-01	1.35E-01	1.35E-01
Tallahassee	FL	4.77E-02	1.18E-01	1.35E-01	1.35E-01
New Orleans	LA	4.77E-02	1.18E-01	1.35E-01	1.35E-01
Charleston	SC	4.77E-02	1.18E-01	1.35E-01	1.35E-01
W. Palm Beach	FL	4.77E-02	1.18E-01	1.35E-01	1.35E-01
Lake Charles	LA	4.92E-02	3.84E-03	2.36E-02	2.97E-02
Miami	FL	4.92E-02	3.84E-03	2.36E-02	2.97E-02
Annette	AK	3.38E-02	1.35E-01	1.36E-01	1.35E-01
Bethel	AK	2.95E-02	3.52E-02	3.64E-02	6.60E-02
Fairbanks	AK	9.40E-03	9.80E-03	1.18E-02	4.07E-02
Honolulu	HI	4.83E-03	3.23E-02	4.94E-02	8.71E-02
San Juan	PR	1.93E-02	6.37E-02	7.93E-02	1.11E-01

¹⁾ City names in bold face are climate stations selected as representative of that region

Table D-5: Flow rate data used to develop landfill and waste pile composite liner infiltration rates (from TetraTech, 2001)

Landfill Cell ID ¹	Cell Type	Average Monthly LDS Flow Rate		Liner Type ²	Type of Waste ³	Site Parameters			Landfill Cell Construction/Operation Information									Source of Data
		(L/ha/d)	(m/y)			Location	Average Annual Rainfall (mm)	Subsurface Soil Type	Cell Area (ha)	GM Liner Material ⁴	GM Liner Thickness (mm)	GCL or CCL Thickness (mm)	Maximum Height of Waste (m)	End Construction Date	Waste Placement Start Date	Final Closure Date		
G228	Open	5.85	2.14E-04	GM/GCL	MSW	Mid-Atlantic	NA	NA	51	HDPE	1.5	NA	NA	1988	1989	NA	Eith & Koerner (1997)	
G232	Open	11	4.02E-04	GM/GCL	MSW	Northeast	990	Silty Clay	4.7	HDPE	1.5	6	NA	May-92	May-92	Jul-94	EPA (1998)	
G233	Open	0	0.00E+00	GM/GCL	MSW	Northeast	1040	Sand & Gravel	2	HDPE	1.5	6	24	Jun-88	Jul-88	Feb-91	EPA (1998)	
G234	Open	2	7.30E-05	GM/GCL	MSW	Northeast	1040	Sand & Gravel	2	HDPE	1.5	6	24	Jun-88	Jul-88	Feb-91	EPA (1998)	
G235	Open	4	1.46E-04	GM/GCL	MSW	Northeast	1040	Sand & Gravel	1.7	HDPE	1.5	6	24	Aug-88	Sep-88	Apr-93	EPA (1998)	
G236	Open	1	3.65E-05	GM/GCL	MSW	Northeast	1040	Sand & Gravel	1.7	HDPE	1.5	6	24	Aug-88	Sep-88	Apr-93	EPA (1998)	
G237	Open	2	7.30E-05	GM/GCL	MSW	Northeast	1040	Sand & Gravel	2.8	HDPE	1.5	6	24	Sep-88	Oct-88	-	EPA (1998)	
G238	Open	0	0.00E+00	GM/GCL	MSW	Northeast	1040	Sand & Gravel	3.9	HDPE	1.5	6	24	Dec-88	Dec-88	-	EPA (1998)	
G239	Open	2	7.30E-05	GM/GCL	MSW	Northeast	1040	Sand & Gravel	2.6	HDPE	1.5	6	24	Jan-89	Feb-89	-	EPA (1998)	
G240	Open	0	0.00E+00	GM/GCL	MSW	Northeast	1040	Sand & Gravel	3.8	HDPE	1.5	6	24	Jul-89	Jul-89	-	EPA (1998)	
G241	Open	0	0.00E+00	GM/GCL	MSW	Northeast	1040	Sand & Gravel	3.3	HDPE	1.5	6	24	Dec-89	Dec-89	-	EPA (1998)	
G242	Open	0	0.00E+00	GM/GCL	MSW	Northeast	1040	Sand & Gravel	3.9	HDPE	1.5	6	24	Feb-90	Jul-90	-	EPA (1998)	
G243	Open	0	0.00E+00	GM/GCL	MSW	Northeast	1040	Sand & Gravel	3	HDPE	1.5	6	24	Feb-90	Feb-90	-	EPA (1998)	
G244	Open	0	0.00E+00	GM/GCL	MSW	Northeast	1040	Sand & Gravel	4	HDPE	1.5	6	24	Oct-90	Oct-90	-	EPA (1998)	
G245	Open	0	0.00E+00	GM/GCL	MSW	Northeast	1040	Sand & Gravel	3	HDPE	1.5	6	24	Jan-91	Jan-91	-	EPA (1998)	
G246	Open	0	0.00E+00	GM/GCL	MSW	Northeast	1040	Sand & Gravel	2.8	HDPE	1.5	6	24	Apr-92	Apr-92	-	EPA (1998)	
G247	Open	0	0.00E+00	GM/GCL	MSW	Northeast	1040	Sand & Gravel	2.8	HDPE	1.5	6	24	May-92	May-92	-	EPA (1998)	
G248	Open	0	0.00E+00	GM/GCL	MSW	Northeast	1040	Sand & Gravel	4.5	HDPE	1.5	6	24	Jan-93	Jan-93	-	EPA (1998)	
G249	Open	2	7.30E-05	GM/GCL	MSW	Northeast	760	Sand	3.8	HDPE	1.5	250	41	Sep-92	Dec-92	-	EPA (1998)	
G250	Open	6	2.19E-04	GM/GCL	MSW	Southeast	1090	NA	4	HDPE	1.5	6	28	Dec-90	Feb-91	-	EPA (1998)	
G251	Open	0	0.00E+00	GM/GCL	MSW	Southeast	1090	NA	2.4	HDPE	1.5	6	30	Jan-93	Jan-93	-	EPA (1998)	
G252	Open	0	0.00E+00	GM/GCL	MSW	Southeast	1090	NA	2.8	HDPE	1.5	6	30	Jan-93	Jan-93	-	EPA (1998)	
G232	closed	2	7.30E-05	GM/GCL	MSW	Northeast	990	Silty Clay	4.7	HDPE	1	6	NA	May-92	May-92	Jul-94	EPA (1998)	
G233	closed	0	0.00E+00	GM/GCL	MSW	Northeast	1040	Sand & Gravel	2	HDPE	1	6	24	Jun-88	Jul-88	Feb-91	EPA (1998)	
G234	closed	0	0.00E+00	GM/GCL	MSW	Northeast	1040	Sand & Gravel	2	HDPE	1	6	24	Jun-88	Jul-88	Feb-91	EPA (1998)	
G235	closed	1	3.65E-05	GM/GCL	MSW	Northeast	1040	Sand & Gravel	1.7	HDPE	1	6	24	Aug-88	Sep-88	Apr-93	EPA (1998)	
G236	closed	0	0.00E+00	GM/GCL	MSW	Northeast	1040	Sand & Gravel	1.7	HDPE	1	6	24	Aug-88	Sep-88	Apr-93	EPA (1998)	

Notes:

1. Cell ID as reported by Tetra Tech (2001)
 2. GM = geomembrane; GCL = geosynthetic clay liner
 3. MSW = municipal solid waste
 4. HDPE = high density polyethylene
- NA = not available
 - = not applicable

Data Sources:

Eith, A. W., and G.R. Koerner, 1997. Assessment of HDPE geomembrane performance in municipal waste landfill double liner system after eight years of service. Geotextiles and geomembranes, Vol. 15, pp. 277 - 287.

EPA, 1998. Assessment and Recommendations for Optimal Performance of Waste Containment Systems. Office of Research and Development, Cincinnati, Ohio.

Table D-6: Leak Density Data Used to Develop Surface Impound composite liner infiltration rates (from TetraTech, 2001)

Site ID ¹	Date	Area (m ²)	Location	Waste Type	WMU type	Type of GM Liner ²	Thickness of GM (mm)	Quality of Material Beneath GM	Holes	Knife Cuts/Tears	Seam or Weld Defects	Total Leaks	Range of Hole Size (mm)	Leak Density (leaks/ha)	Source
L1	1995	18500	France	domestic	landfill	HDPE	2	high	0	0	5	5	NA	2.7	Rollin et al. (1999)
L2	1996	14926	France	domestic	landfill	HDPE	2	high	4	0	2	6	NA	4.02	Rollin et al. (1999)
L3	1994	13480	France	HW	landfill	HDPE	2	high	1	1	1	3	NA	2.23	Rollin et al. (1999)
L4	1995	11652	France	HW	landfill	HDPE	2	high	1	2	2	5	NA	4.29	Rollin et al. (1999)
L5	1997	8200	France	HW	landfill	HDPE	2	high	0	0	0	0	NA	0	Rollin et al. (1999)
L6	1998	9284	France	HW	landfill	HDPE	2	high	0	1	0	1	NA	1.08	Rollin et al. (1999)
L7	1995	67100	Canada	waste water treatment	pond	PBGM	3	high	3	0	2	5	NA	0.75	Rollin et al. (1999)
L8	1995	66150	Canada	waste water treatment	pond	PBGM	3	high	1	1	7	9	NA	1.36	Rollin et al. (1999)
L9	1997	11460	Canada	black liqueur	pond	PP	1.14	high	2	2	2	6	NA	5.24	Rollin et al. (1999)
L10	1998	18135	France	domestic	landfill	HDPE	2	high	0	3	3	6	NA	3.31	Rollin et al. (1999)
L86	Apr-96	9416	United Kingdom	NA	NA	HDPE	NA	NA	0	0	0	0	-	0	McQuade and Needham (1999)
L103	Oct-96	4980	United Kingdom	NA	NA	HDPE	NA	NA	0	0	0	0	-	0	McQuade and Needham (1999)
L110	Jan-97	11720	United Kingdom	NA	NA	HDPE	NA	NA	0	2	1	3	-	2.6	McQuade and Needham (1999)
L114	Jan-97	7000	United Kingdom	NA	NA	HDPE	NA	NA	0	3	1	4	-	5.7	McQuade and Needham (1999)
L136	Oct-97	13526	United Kingdom	NA	NA	HDPE	NA	NA	0	1	0	1	30x50	0.7	McQuade and Needham (1999)
L144	May-98	5608	United Kingdom	NA	NA	HDPE	NA	NA	0	0	0	0	-	0	McQuade and Needham (1999)
L152	Aug-98	3742	United Kingdom	NA	NA	HDPE	NA	NA	0	0	0	0	-	0	McQuade and Needham (1999)
L159	NA	15000	United Kingdom	NA	NA	HDPE	NA	NA	0	0	0	0	-	0	McQuade and Needham (1999)
L160	NA	10000	United Kingdom	NA	NA	HDPE	NA	NA	0	0	0	0	-	0	McQuade and Needham (1999)
L176	May-98	13500	United Kingdom	NA	NA	HDPE	NA	NA	1	0	0	1	NA	0.7	McQuade and Needham (1999)
L177	Sep-96	15000	United Kingdom	NA	NA	HDPE	NA	NA	0	0	0	0	-	0	McQuade and Needham (1999)
L178	Apr-97	7500	United Kingdom	NA	NA	HDPE	NA	NA	0	1	0	1	-	1.3	McQuade and Needham (1999)
L179	Sep-98	5000	United Kingdom	NA	NA	HDPE	NA	NA	0	0	0	0	-	0	McQuade and Needham (1999)
L180	Sep-98	13200	United Kingdom	NA	NA	HDPE	NA	NA	0	0	0	0	-	0	McQuade and Needham (1999)
L181	NA	48600	NA	waste water containment	pond	HDPE	1.5	NA	NA	NA	NA	21	NA	4.3	Laine (1991)
L182	NA	8000	NA	HW	landfill	HDPE/CCL	2	NA	NA	NA	NA	10	NA	12.5	Laine (1991)

Notes:

1. Cell ID as reported by Tetra Tech (2001)

2. HDPE = high density polyethylene; PBGM = pre-fabricated bituminous geomembrane; PP = polypropylene; CCL = compacted clay liner

NA = not available; - = not applicable

Data Sources:

Rollin, A.L., M. Marcotte, T. Jacquelein, and L. Chaput. 1999. Leak location in exposed geomembrane liners using an electrical leak detection technique. Geosynthetics '99, Vol. 2, pp. 615-626

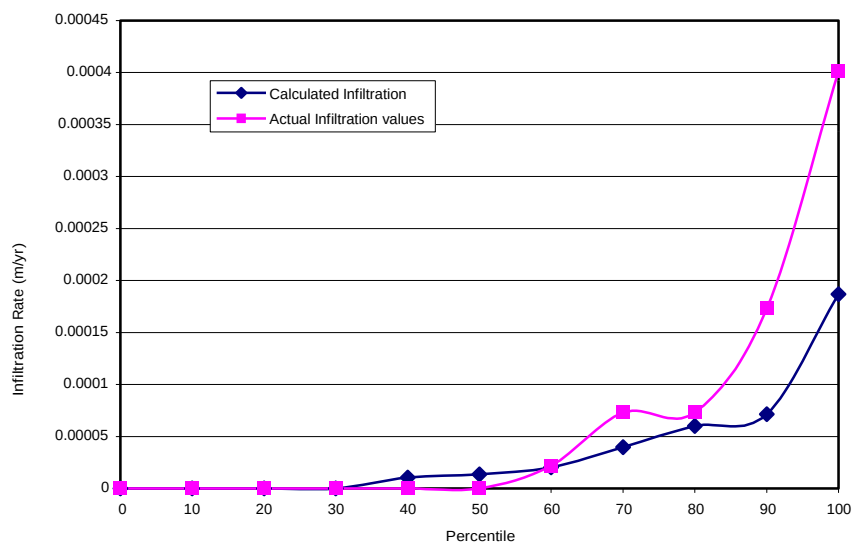
McQuade, S.J., and A.D. Needham, 1999. Geomembrane liner defects - causes, frequency and avoidance. Geotechnical Engineering, Vol., 137. No. 4, pp. 203-213

Laine, D.L., 1991. Analysis of pinhole seam leaks located in geomembrane liners using the electrical leak location method. Proceedings, Geosynthetics '91, pp.239-253

Table D-7: Comparison of composite liner infiltration rates
Calculated using Bonaparte Equation and Infiltration
Rates for composite-lined landfill cells

Percentile	Calculated Infiltration (m/yr)	Observed Infiltration (m/yr)
0	0.00E+00	0.00E+00
10	0.00E+00	0.00E+00
20	0.00E+00	0.00E+00
30	0.00E+00	0.00E+00
40	1.05E-05	0.00E+00
50	1.37E-05	0.00E+00
60	2.03E-05	2.19E-05
70	3.96E-05	7.30E-05
80	6.01E-05	7.30E-05
90	7.13E-05	1.73E-04
100	1.87E-04	4.02E-04

Figure D-1: Infiltration Rate Comparison (Head = 0.3m, Hole Area = 6mm²)



APPENDIX E

BACKGROUND INFORMATION FOR THE DEVELOPMENT OF REFERENCE GROUND-WATER CONCENTRATION VALUES

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BACKGROUND INFORMATION FOR THE DEVELOPMENT OF REFERENCE GROUND-WATER CONCENTRATION VALUES

E-1 Shower Model

E-1.1 Shower Model

The shower model calculates the incremental change in the concentration of a constituent in air that results from the transfer of constituent mass from the water phase (the shower water) to the vapor phase (the air in the shower stall) over time. The model then estimates the concentration of the constituent in a bathroom that results from air exchange within the bathroom and between the bathroom and the rest of the house over time. After the model calculates the predicted air-phase constituent concentration in the shower stall and bathroom, we use those concentrations to estimate the average air-phase constituent concentration to which an individual is exposed over the course of an entire day. We use this average daily concentration to calculate inhalation HBNs.

The shower model is based on differential equations presented in McKone (1987) and Little (1992a). We solved the differential equations using a mathematical technique called “finite difference numerical integration,” to produce the equations that we use in our analysis, Equations E-1 to E-11 in this Appendix. In reviewing the equations and reading the following sections, it will help to keep in mind the following two concepts:

We calculate air-phase constituent concentrations for different “compartments.” The shower model is based on the understanding that there are two compartments in the bathroom: 1) the shower stall and 2) the rest of the bathroom (outside of the shower stall). We assume that an adult spends time: in the shower stall when the shower is running; in the shower stall after the shower is turned off; and in the rest of the bathroom after the shower is turned off (see Equations E-1 and E-2).

We calculate air-phase constituent concentrations for different time steps. We implement the shower model in time steps. That is, we estimate the air-phase constituent concentration in each of the two compartments in 0.2-minute increments or time steps. The air-phase constituent concentration at the beginning of the 0.2-minute time step differs from the concentration at the end of the 0.2-minute time step because of volatilization of constituent mass from the shower water (which adds constituent mass) and the exchange of air between the compartments in the bathroom and the rest of the house (which disperses the mass). At the beginning of a time step, the air-phase concentration in each

bathroom compartment is equal to the air-phase concentration that was estimated for the compartment at the end of the previous time step.

The following is our basic procedure for implementing the shower model:

- # Calculate a mass transfer coefficient for each constituent;
- # Estimate the air-phase constituent concentration in the shower stall for sequential 0.2-minute time steps;
- # Estimate the air-phase constituent concentration in the bathroom (other than in the shower stall) for sequential 0.2-minute time steps;
- # Use the air-phase constituent concentrations calculated for the shower stall, and the air-phase constituent concentrations calculated for the bathroom, to calculate the average constituent concentration to which an adult is exposed during the course of a day.

This procedure is explained in greater detail below. Table E-2 provides the values for the constituent-specific properties used in the model. Table E-1 provides the values we used for the parameters in the model.

Calculating a Mass Transfer Coefficient

The first step in estimating the concentration of a constituent in air is to quantify the constituent's "resistance" to movement between the water phase and the air phase. We quantify this resistance using the mass transfer coefficient presented in Equation E-4, which incorporates variables calculated in Equations E-3 and E-5. The mass transfer coefficient depends on properties specific to each constituent evaluated, as well as physical properties of the water droplet. Specifically, the mass transfer coefficient depends on:

- # The constituent's diffusivity in water (the molecular diffusion coefficient for the constituent in water), which determines how readily the constituent mass in the center of the water droplet will diffuse to the surface of the water droplet. If a constituent's diffusivity in water is low, then as the constituent is emitted from the surface of the water droplet, the rate at which the surface of the droplet is "supplied" with constituent from the center of the water droplet will be slow, resulting in less constituent being emitted from the droplet. Diffusivity influences the concentration gradient across the droplet.

- # The Henry's law constant for the constituent, which establishes how the constituent will partition between the water phase and the air phase to achieve equilibrium. Henry's law states that, at equilibrium, the amount of a constituent dissolved in water is proportional to the amount of the constituent in the air phase that is in contact with the water. This proportion is constituent-specific (each constituent has a different Henry's law constant). The Henry's law constant influences the magnitude of the air-phase constituent concentrations more than any other constituent-specific parameter.
- # The constituent's diffusivity in air (the molecular diffusion coefficient for the constituent in air), which determines how readily the constituent will migrate away from the droplet once it is released into the air surrounding the droplet. Constituents with lower diffusivities in air will have comparatively higher concentrations around the water droplet than in the surrounding air. Therefore, because of Henry's law, less constituent would need to come out of solution into the air phase in order to achieve equilibrium.
- # The amount of time that the droplet is in contact with the air, which we assume is equivalent to the time it takes for the droplet to fall to the floor of the shower. We determine the time it takes the droplet to fall by dividing distance that the droplet has to fall (which we assume is equal to the height of the shower nozzle) by the velocity at which the water droplet falls (which we assume is the terminal velocity of the droplet). For this analysis, we set the nozzle height and the terminal velocity of the droplet at fixed values, as presented in Table E-1.
- # The ratio of the water droplet's surface area to its volume. Because we assume that the droplet is a sphere, its surface area to volume ratio is equal to a value of 6 divided by the diameter of the droplet. For this analysis, the diameter of the droplet, therefore its surface area to volume ratio, is a fixed value (see Table E-1).

Table E-2 presents the constituent-specific diffusivities and Henry's law constants that we used in our analysis.

Table E-1. Shower Model Input Parameters

Input Parameter	Description	Value	Units	Reference	Comment
Bathroom Properties					
Vb	Volume of the bathroom	10	m ³	McKone, 1987	
Exchange Rate					
Qbh	Volumetric exchange rate between the bathroom and the house	300	L/min	derived value	Estimated from the volume and flow rate in McKone (1987) such that the exchange rate equals the volume divided by the residence time (e.g., 10,000L/30 min).
Qsb	Volumetric exchange rate between the shower and the bathroom	100	L/min	derived value	Estimated from the volume and flow rate in McKone (1987) such that the exchange rate equals the volume divided by the residence time (e.g., 2000L/20 min).
Exposure Time					
ShowerStallTime	Time in shower stall after showering	5	min	U.S. EPA, 1997c	Table 15-23. 50th percentile overall
T_bathroom	Time spent in bathroom, not in shower	5	min	U.S. EPA, 1997c	Table 15-32. 50th percentile overall
ShowerTime	Shower time, 50th percentile	15	min	U.S. EPA, 1997c	Table 15-21. 50th percentile overall
Shower Properties					
Vs	Volume of shower	2	m ³	McKone, 1987	
NozHeight	Height of shower head	1.8	m	Little, 1992a	Selected based on the maximum height reported in Table 1 of Little (1992a), a summary of five studies.
ShowerRate	Rate of water flow from shower head	10	L/min	derived value	Value obtained by averaging the flow rates reported in five studies in Table 1 of Little (1992a) (QL) = 10.08 L/min.
DropVel	Terminal velocity of water drop	400	cm/s	derived value	Selected value by correlating to existing data.
DropDiam	Diameter of shower water drop	0.098	cm	derived value	Estimated as a function of terminal velocity <= 600 cm/sec (Coburn, 1996).
Groundwater					

Cin	Constituent concentration in incoming water	0.001	mg/L	NA	Unit concentration selected.

Calculating the Air-Phase Constituent Concentration in the Shower

Calculating the air-phase constituent concentration in the shower at the end of each time step involves:

1. Calculating the fraction of constituent that can be emitted into the air from each water droplet (Equation E-7);
2. Translating the fraction of constituent that can be emitted from each water droplet (from step 1) into the mass of constituent that is emitted from the entire volume of water that is coming into the shower during each time step (Equation E-6); and
3. Determining the constituent concentration at the end of the time step by: calculating the concentration added to the shower air during the time step (dividing the constituent mass emitted from the water in step 2 by the volume of the shower); adding this concentration to the concentration of the constituent that was already in the shower air at the beginning of the time step; and subtracting the concentration lost from the shower air due to the exchange of air with the rest of the bathroom (Equation E-9).

An important element of this analysis is the difference between the time in the shower stall that is spent showering (15 minutes, Table E.1) and the time in the shower stall that occurs after showering (5 minutes, Table E.1). The difference in these two time periods involves how we handle the value for mass of constituent emitted from the shower water (step 2, above). When we switch the model over from the time period where the shower nozzle is turned on (the time spent showering), to the time period where the shower nozzle is turned off (the time spent in the shower stall after showering), we set the mass emitted from the water to zero. This means that during the 5-minute period when the individual is in the shower after the shower is turned off, the air-phase concentration of the constituent is only a function of the concentration of the constituent in the air at the beginning of the time step and the air exchange between the shower stall and the rest of the bathroom. The following paragraphs describe steps 1 and 2 in more detail.

The fraction of the constituent mass that potentially can be emitted from a droplet at any given time during the droplet's fall through the air (Equation E-7) is a function of the mass transfer coefficient (the constituent's resistance to movement from the water phase to the air phase, described previously) and the "fraction of gas phase saturation" in the shower (calculated using Equation E-8). Inherent in this calculation is an assumption that the concentration of the constituent in the air is constant over the time it takes the droplet to fall. The fraction of gas phase saturation is an expression of how close the air-phase constituent concentration is to the maximum possible (equilibrium) air-phase

concentration. Stated another way, Henry's law dictates that for a certain constituent concentration in water, we can predict the maximum concentration of constituent in the air that is in contact with the water (assuming the air and water are in equilibrium). Consequently, if there is already constituent in the air, then, to maintain equilibrium, there is a limit to how much additional constituent can be emitted from the water to the air (the less constituent already present in the air, the more constituent that theoretically may be emitted). The fraction of gas phase saturation is an expression of how close the air concentration is to that limit at the beginning of each time step. However, as suggested at the beginning of this paragraph, even though Henry's law influences the maximum fraction of mass that could be emitted from the droplet, the mass transfer coefficient also influences how much of the constituent will "free itself" from the water. Factors such as the constituent's dispersivity (in water and air) and the surface area of the droplet also influence the fraction of constituent mass that can be emitted from the droplet.

In most cases, for each 0.2-minute time step we evaluate, the mass of a constituent emitted from the shower water to the air is the product of: the concentration of the constituent in the shower water; the volume of water emitted from the shower during the time step; and the fraction of the constituent mass in the water that potentially could be emitted from the water (discussed above). However, in certain cases (typically rare), the mass transfer coefficient is of a magnitude that the concentration calculated in this way exceeds the mass that possibly could be emitted when the water and the air phases are at equilibrium. In this case, we "cap" the constituent mass that can be emitted from the shower water during the time step. The cap is the maximum constituent mass that could be emitted from the water at equilibrium (based on Henry's law) minus the constituent mass already in the shower stall at the beginning of the time step

Calculating the Air-Phase Constituent Concentration in the Bathroom (other than in the Shower Stall)

The air-phase constituent concentration in the bathroom (Equation E-10) is a function of the air-phase constituent concentration calculated for the shower, and the exchange of air 1) between the shower and the bathroom and 2) between the bathroom and the rest of the house. Specifically, for each time step, the air-phase constituent concentration in the bathroom is equal to: the air-phase constituent concentration in the bathroom at the beginning of the time step, plus the constituent concentration added as a result of the exchange of air with the shower, minus the constituent concentration lost as a result of the exchange of air with the rest of the house. Table E-1 presents the values we used for the volumetric exchange rate between the shower and the bathroom; the volumetric exchange rate between the bathroom and the house; and the volume of the bathroom.

Calculating the Average Daily Constituent Concentration to which an Individual is Exposed

To calculate the average concentration of a constituent to which an individual is exposed on a daily basis (24 hours per day) (Equation E-11), we:

1. Calculate the average constituent concentration in the shower air across all time steps and multiply this concentration by the amount of time an individual spends in the shower stall (Equation E-2);
2. Calculate the average constituent concentration in the bathroom air (not including the shower air) across all time steps and multiply this concentration by the amount of time an individual spends in the bathroom (not including the time spent in the shower stall);
3. Sum the values calculated in steps 1 and 2, and divide the sum by the length of a day. This calculation carries with it an assumption that an individual only is exposed to the constituent in the shower, and in the bathroom after showering (that is, that the concentration of the constituent in the rest of the house is zero).

E-1.2 Shower Model Uncertainties and Limitations

The primary limitations and uncertainties of the shower model are as follows:

- # The model is constructed such that air-phase concentration of a constituent in household air results solely from showering activity. Individuals are exposed to emissions via inhalation for time spent in the shower while showering, in the shower stall after showering, and in the bathroom after showering. Other models calculate indoor air concentrations resulting from emissions from household use of tap water and/or calculate inhalation exposures for time spent in the remainder of the house. However, McKone (1987) found that the risk from inhalation exposures in the remainder of the house was considerably lower than the risk from inhalation exposures in the bathroom and during showering. In addition, there are few data available to estimate the input parameters needed to calculate exposure concentrations from other household activities, including variables such as house volume, air exchange rate between the house and outside air, and exposure time in the house. Given the expected lower risk due to exposure in the remainder of the house, and the lack of available data to estimate house constituent concentrations, we focused on showering as the greatest source of inhalation exposure and risk due to use of contaminated water.

- # The model currently only considers exposures to adults who shower, and does not consider exposures to children who bathe in bathtubs. This limitation of the model may be significant. A recent report by EPA's National Center for Environmental Assessment states that: "Because of the longer exposure times, chemical emissions during the use of bathtubs may be as, or more, significant than during showers, in terms of human inhalation. This is particularly important given that small children are typically washed in bathtubs rather than showers and are generally more sensitive to chemical exposure than are healthy adults" (U.S. EPA, 2000).
- # Our analysis does not consider an individual's dermal exposure to water or an individual's incidental ingestion of water while showering.
- # The model only considers emissions that result from falling droplets of water in the shower. The model does not include algorithms that account for emissions from water films on shower walls or puddles on the floor of the shower. Use of the model also assumes that a droplet falls directly from the shower nozzle to the shower stall floor, and is not intercepted by the body of the individual who is showering.
- # The input parameter values are a source of uncertainty for the shower model. To select values for the shower properties (shower and bathroom volume, nozzle height, and flow rate), we generally used central tendency values that were reported in the literature. Although fixing shower model input parameters as constant does not capture variability in the results, the results still compare favorably to experimental data for numerous organic compounds of varying volatility (Coburn, 1996). The values for droplet properties (diameter and velocity) are also constants, and are based on correlation to existing data. The largest uncertainty is likely in the volumetric exchange rates used between the shower and bathroom and the bathroom and the rest of house. We derived these values, 300 L/min for the exchange rate between the bathroom and house, and 100 L/min for the exchange rate between the shower and bathroom, from McKone (1987). However, values reported in a five-study summary by Little (1992a) ranged from 35 to 460 L/min for the exchange between the shower and bathroom, and 38 to 480 L/min for the exchange between the bathroom and the rest of the house. Such a large range of volumetric exchange rates imparts uncertainty to the shower model's estimation of constituent concentrations.
- # A constituent's solubility in water depends on a number of factors including the temperature of the water and the other chemicals (for

example, other solvents) that are in the water. When the concentration of a constituent in water exceeds the constituent's solubility in that water, we expect that at least some of the constituent will exist in the water as a non-aqueous (free) phase. Henry's law, a basic principle of the shower model, only applies to constituents dissolved in water, it does not apply to non-aqueous phase constituents (U.S. EPA, 1996). As a result, it would not be appropriate to use the HBNs we developed for the inhalation pathway if the shower water (which we assume is from a ground-water well) contained non-aqueous phase constituent. More importantly, however, EPACMTP, the ground-water fate and transport model that we use to estimate constituent concentrations in the modeled ground water, cannot be used to model non-aqueous phase liquids. Consequently, the IWEM tool should not be used in cases where non-aqueous phase constituents are present in leachate. In these situations, another tool must be used that is capable of evaluating non-aqueous phase liquids.

Equation E-1. Total time spent in shower and bathroom

$$\text{BSResTime} = \text{ShowerTime} + \text{ShowerStallTime} + \text{T\_bathroom}$$

Name	Description	Value
BSResTime	Total time spent in shower and bathroom (min)	Calculated above
ShowerTime	Duration of shower (min)	Provided in Table E-1
ShowerStallTime	Time in shower stall after showering (min)	Provided in Table E-1
T_bathroom	Time spent in bathroom, not in shower (min)	Provided in Table E-1

This equation calculates the total time that a receptor is exposed to vapors.

Equation E-2. Total time spent in shower stall

$$\text{ShowerResTime} = \text{ShowerStallTime} + \text{ShowerTime}$$

Name	Description	Value
ShowerResTime	Total time spent in shower stall (min)	Calculated above
ShowerStallTime	Time in shower stall after showering (min)	Provided in Table E-1
ShowerTime	Duration of shower (min)	Provided in Table E-1

This equation calculates the total time that a receptor is exposed to vapors in the shower stall.

Equation E-3. Dimensionless Henry's law constant

$$H_{\text{prime}} = HLC_{\text{coef}} \cdot HLC$$

$$HLC_{\text{coef}} = \frac{1}{R \cdot \text{Temp}}$$

Name	Description	Value
Hprime	Dimensionless Henry's law constant (dimensionless)	Calculated above
HLCcoef	Coefficient to Henry's law constant Mol/(atm·m ³)	Calculated above
HLC	Henry's law constant (atm·m ³ /Mol)	Chemical-specific
R	Ideal Gas constant (atm·m ³ /K·Mol)	0.00008206
Temp	Temperature (K)	298

This equation calculates the dimensionless form of Henry's law constant.

Equation E-4. Dimensionless overall mass transfer coefficient

$$N = K_{ol} \cdot AVR_{\text{Ratio}} \cdot \text{DropResTime}$$

$$AVR_{\text{Ratio}} = \frac{6}{\text{DropDiam}}$$

$$\text{DropResTime} = \frac{\text{NozHeight} \cdot 100}{\text{DropVel}}$$

Name	Description	Value
N	Dimensionless overall mass transfer coefficient (dimensionless)	Calculated above
AVRatio	Area-to-volume ratio for a sphere (cm ² /cm ³)	Calculated above
Kol	Overall mass transfer coefficient (cm/s)	Calculated in Equation E-5
DropResTime	Residence time for falling drops (s)	Calculated above
DropDiam	Drop diameter (cm)	Provided in Table E-1
NozHeight	Nozzle height (m)	Provided in Table E-1
DropVel	Drop terminal velocity (cm/s)	Provided in Table E-1
100	Conversion factor (cm/m)	Conversion factor

This equation calculates the dimensionless overall mass transfer coefficient. The above equation is based on Little (1992a; Equation 5), which provides the equation as $N = K_{ol} \times A/Q_1$ where A is the total surface area for mass transfer and Q1 is water flow in volume per time.

Equation E-5. Overall mass transfer coefficient		
$Kol = \beta \cdot \left(\frac{2.5}{D_w^{2/3}} + \frac{1}{D_a^{2/3} \cdot H_{prime}} \right)^{0.1}$		
Name	Description	Value
Kol	Overall mass transfer coefficient (cm/s)	Calculated above
beta	Proportionality constant (cm-s ^{-1/3})	216
Dw	Diffusion coefficient in water (cm ² /s)	Chemical-specific
Da	Diffusion coefficient in air (cm ² /s)	Chemical-specific
Hprime	Dimensionless Henry's law constant (dimensionless)	Calculated in Equation E-3

This equation calculates the overall mass transfer coefficient. The above equation corresponds to Equation 17 in McKone (1987) and was modified to use the dimensionless Henry's law constant. McKone (1987) noted that the proportionality constant, beta, was a dimensionless value. Little (1992b) indicated that beta is not dimensionless. The correct units are noted above. The value for beta was derived using data for benzene and verified for chemicals of varying volatility (Coburn, 1996).

Equation E-6. Constituent mass emitted in the shower for a given time step

For $E_t > E_{max}$,

$$E_s = E_{max}$$

For $E_t \leq E_{max}$,

$$E_s = E_t$$

Where,

$$E_t = C_{in} \cdot \text{ShowerRate} \cdot t_s \cdot f_{em}$$

$$E_{max} = (y_{eq} - y_{s,t}) \cdot V_s \cdot 1000$$

Name	Description	Value
E_s	Constituent mass emitted in the shower for a given time step (mg)	Calculated above
E_{max}	Maximum possible mass of constituent emitted from shower during time step (mg)	Calculated above
E_t	Potential mass of constituent emitted from shower during time step (mg)	Calculated above
y_{eq}	Gas-phase constituent concentration in equilibrium between water and air (mg/L)	$H_{prime} \times C_{in}$
$y_{s,t}$	Gas-phase constituent concentration in the shower at the beginning of time step (mg/L)	Calculated in Equation E-9 (As $y_{s,t+ts}$ for previous time step)
V_s	Volume of shower (m^3)	Provided in Table E-1
C_{in}	Liquid-phase constituent concentration in the incoming water (mg/L)	Provided in Table E-1
ShowerRate	Rate of flow from showerhead (L/min)	Provided in Table E-1
t_s	Time step (min)	0.2
f_{em}	Fraction of constituent emitted from a droplet (dimensionless)	Calculated in Equation E-7
H_{prime}	Dimensionless Henry's law constant (dimensionless)	Calculated in Equation E-3
1000	Conversion factor (L/m^3)	Conversion factor

The above equations are used to determine the mass of constituent emitted for a given time step. The equilibrium concentration in air (y_{eq}) is calculated from Equation 1 in Little (1992a). If the mass emitted based on the mass transfer coefficient (E_t) is greater than the amount emitted to reach equilibrium (E_{max}), the mass is set to the amount that results in the air concentration at equilibrium.

Equation E-7. Fraction of constituent emitted from a droplet		
$fem = (1 - F_{sat}) \cdot (1 - e^{-N})$		
Name	Description	Value
fem	Fraction of constituent emitted from a droplet (dimensionless)	Calculated above
Fsat	Fraction of gas-phase saturation (dimensionless)	Calculated in Equation E-8
N	Dimensionless overall mass transfer coefficient (dimensionless)	Calculated in Equation E-4

This equation is used to calculate the fraction of a given chemical emitted from a droplet of water in the shower. The equation is based on Equation 5 in Little (1992a). The above equation is obtained by rearranging the equation in Little given that $y_{s\_max}/m = C_{in}$ and $F_{sat} = y_s/y_{s\_max} = y_s/(m \times C_{in})$.

Equation E-8. Fraction of gas-phase saturation in shower		
$F_{sat} = \frac{y_{s,t}}{y_{eq}}$		
Name	Description	Value
Fsat	Fraction of gas-phase saturation in shower (dimensionless)	Calculated above
y _{eq}	Gas-phase constituent concentration in equilibrium between water and air (mg/L)	H _{prime} x C _{in}
y _{s, t}	Current gas-phase constituent concentration in air (mg/L)	Calculated in Equation E-9 (as y _{s, t} +t _s for previous time step)
H _{prime}	Dimensionless Henry's law constant (dimensionless)	Calculated in Equation E-3
C _{in}	Constituent concentration in incoming water (mg/L)	Provided in Table E-1

This equation is used to calculate the fraction of gas phase saturation in shower for each time step. The equilibrium concentration in air (y_{eq}) is calculated from Equation 1 in Little (1992a).

Equation E-9. Gas-phase constituent concentration in the shower at end of time step		
$y_{s,t+ts} = y_{s,t} + \frac{\left[E_s - (Q_{sb} \cdot (y_{s,t} - y_{b,t}) \cdot ts) \right]}{V_s \cdot 1000}$		
Name	Description	Value
$y_{s,t+ts}$	Gas-phase constituent concentration in the shower at end of time step (mg/L)	Calculated above
$y_{s,t}$	Gas-phase constituent concentration in the shower at the beginning of time step (mg/L)	Calculated in Equation E-10 (as $y_{b,t+ts}$ for previous time step)
$y_{b,t}$	Gas-phase constituent concentration in the bathroom at the beginning of time step (mg/L)	Calculated from last time step
E_s	Mass emitted in the shower for a given time step (mg)	Calculated in Equation E-6
Q_{sb}	Volumetric exchange rate between the shower and the bathroom (L/min)	Provided in Table E-1
V_s	Volume of shower (m^3)	Provided in Table E-1
ts	Time step (min)	0.2
1000	Conversion factor (L/m^3)	Conversion factor

This equation is used to calculate the gas-phase constituent concentration in the shower at end of time step. The equation is derived from Equation 9 in Little (1992a). E_s is set to 0 when the shower is turned off (i.e., at the end of showering) to estimate the reduction in shower stall air concentrations after emissions cease.

Equation E-10. Gas-phase constituent concentration in the bathroom at end of time step

$$y_{b, t+ts} = y_{b, t} + \frac{\left[(Q_{sb} \cdot (y_{s, t+ts} - y_{b, t}) - Q_{bh} \cdot (y_{b, t} - y_{h, t})) \right]}{V_b \cdot 1000} \cdot ts$$

Name	Description	Value
$y_{b, t+ts}$	Gas-phase constituent concentration in the bathroom at end of time step (mg/L)	Calculated above
$y_{b, t}$	Gas-phase constituent concentration in the bathroom at the beginning of time step (mg/L)	Calculated from last time step
$y_{s, t+ts}$	Gas-phase constituent concentration in the shower at the end of time step (mg/L)	Calculated in Equation E-9
$y_{h, t}$	Gas-phase constituent concentration in the house at the beginning of time step (mg/L)	Assumed de minimus, zero
Q_{sb}	Volumetric exchange rate between the shower and the bathroom (L/min)	Provided in Table E-1
Q_{bh}	Volumetric exchange rate between the bathroom and the house (L/min)	Provided in Table E-1
V_b	Volume of bathroom (m^3)	Provided in Table E-1
ts	Time step (min)	0.2
1000	Conversion factor (L/m^3)	Conversion factor

This equation is used to calculate the gas-phase constituent concentration in the bathroom at end of time step. The equation is derived from Equation 10 in Little (1992a).

Equation E-11. Average daily concentration in indoor air

$$C_{\text{air\_indoor}} = \frac{(C_{\text{air\_shower}} \cdot \text{ShowerResTime}) + (C_{\text{air\_bathroom}} \cdot T_{\text{bathroom}})}{1440}$$

$$C_{\text{air\_shower}} = \frac{\frac{1}{n_s} \left[(y_{s, t+ts} + y_{s, t}) / 2 \right] \cdot 1000}{n_s}$$

$$C_{\text{air\_bathroom}} = \frac{\frac{1}{n_b} \left[(y_{b, t+ts} + y_{b, t}) / 2 \right] \cdot 1000}{n_b}$$

Name	Description	Value
Cair_indoor	Average daily concentration in indoor air (mg/m ³)	Calculated above
Cair_shower	Average concentration in shower (mg/m ³)	Calculated above
Cair_bathroom	Average concentration in bathroom (mg/m ³)	Calculated above
ShowerResTime	Total time spent in shower stall (min)	Calculated in Equation E-2
T_bathroom	Time spent in bathroom, not in shower (min)	Provided in Table E-1
ys, t	Gas-phase constituent concentration in the shower at the beginning of time step (mg/L)	Calculated in Equation E-9 (as ys, t+ts for previous time step)
ys, t+ts	Gas-phase constituent concentration in the shower at the end of time step (mg/L)	Calculated in Equation E-9
yb, t	Gas-phase constituent concentration in the bathroom at the beginning of time step (mg/L)	Calculated in Equation E-10 (as yb, t+ts for previous time step)
yb, t+ts	Gas-phase constituent concentration in the bathroom at the end of time step (mg/L)	Calculated in Equation E-10
ns	Number of time steps corresponding to time spent in the shower (dimensionless)	Summed in model code
nb	Number of time steps corresponding to time spent in the bathroom (dimensionless)	Summed in model code
1440	Minutes per day (min)	Adjustment factor
1000	Conversion factor (L/m ³)	Conversion factor

The above equations are used to calculate the time-weighted average daily indoor air concentration to which a receptor is exposed. The equation assumes that receptors are only exposed to constituents in the shower and bathroom.

E-1.3 References for Section E-1

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E-2 Constituent-specific Chemical and Physical Properties for the Shower Model

To calculate inhalation HBNs, the shower model requires input of several chemical-specific properties, including solubility (Sol), Henry's law constant (HLC), and diffusion coefficients in air (D_a) and water (D_w). This attachment describes the data sources and methodologies used to collect and develop these properties. Table E.2 lists by constituent the chemical-specific properties used to calculate inhalation HBNs, along with the data source for each value.

E-2.1 Data Collection Procedure

To select data values available from multiple sources, we created a hierarchy of references based on the reliability and availability of data in such sources. Our first choice for data collection and calculations was EPA reports and software. When we could not find data or equations from EPA publications, we consulted highly recognized sources, including chemical information databases on the Internet. These on-line sources

are compilations of data that provide the primary references for data values. The specific hierarchy varied among properties as described in subsequent sections.

For dioxins, the preferred data source in all cases was the Exposure and Human Health Reassessment of 2,3,7,8-Tetrachlorodibenzo-p-Dioxin (TCDD) and Related Compounds, Part 1, Vol. 3 (Dioxin Reassessment) (U.S. EPA, 2000). We used the Mercury Study Report to Congress (U.S. EPA, 1997a) as the preferred source for mercury properties. If values were unavailable from these sources, we followed the same reference hierarchy that was used for other constituents.

All data entry for chemical and physical properties was checked by comparing each entry against the original online or hardcopy reference. All property calculation programs were checked using hand calculations to ensure that they were functioning correctly.

E-2.2 Solubility (Sol)

For solubility (Sol) values, we looked for data by searching the following sources in the following order:

1. Superfund Chemical Data Matrix (SCDM) (U.S. EPA, 1997b);
2. CHEMFATE Chemical Search (SRC, 1999);
3. Hazardous Substances Data Bank (HSDB) (U.S. NLM, 2001);
4. ChemFinder (CambridgeSoft Corporation, 2001).

For mercury, we obtained a solubility for elemental mercury from The Merck Index: An Encyclopedia of Chemicals, Drugs, and Biologicals (Budavari, 1996).

E-2.3 Henry's Law Constant (HLC)

Collection of Henry's law constant (HLC) data proceeded by searching sources in the following order:

1. SCDM;
2. CHEMFATE;
3. HSDB.

When we could not find data from these sources, we calculated HLC using equation 15-8 from Lyman, Reehl, and Rosenblatt (1990):

$$\text{HLC} = \frac{P_{vp}}{\text{Sol}}$$

where

HLC	=	Henry's law constant (atm-m ³ /mole)
P _{vp}	=	vapor pressure (atm)
Sol	=	solubility (mol/m ³).

E-2.4 Diffusion Coefficient in Water (D_w)

For all chemicals, we calculated the diffusion coefficient in water (D_w) by hand because few empirical data are available. The preferred calculation was equation 17-6 from the WATER9 model (U.S. EPA, 2001):

$$D_w = 0.0001 \left(\frac{T + 273.16}{298.16} \right)^{1.7} \left(\frac{1}{MW} \right)^{0.6}$$

where

D _w	=	diffusion coefficient in water (cm ² /s)
T	=	temperature (degrees C)
MW	=	molecular weight (g/g-mol)
D	=	density (g/cc).

When we did not know chemical density, we used equation 3.16 from Process Coefficients and Models for Simulating Toxic Organics and Heavy Metals in Surface Waters (Process Coefficients) (U.S. EPA, 1987), which only requires molecular weight:

$$D_w = 0.00022 \cdot MW^{-2/3}$$

where

D _w	=	diffusion coefficient in water (cm ² /s)
MW	=	molecular weight (g/mol).

E-2.5 Diffusion Coefficient in Air (D_a)

All diffusion coefficients in air (D_a) were calculated values because few empirical data are available. Similar to D_w , we first consulted WATER9 and then used U.S. EPA (1987). Equation 17-5 in WATER9 calculates diffusivity in air as follows:

$$D_a = \frac{0.0029(T + 273.16)^{1.5} \sqrt{0.034 + \frac{1}{MW} (1 - 0.000015 MW^2)}}{\left[\left(\frac{MW}{2.5} \right)^{0.333} + 1.8 \right]^2}$$

where

D_a	=	diffusion coefficient in air (cm^2/s)
T	=	temperature (degrees C)
MW	=	molecular weight (g/g-mol)
D	=	density (g/cc).

When density was not available, we used equation 3.17 from Process Coefficients (U.S. EPA, 1987):

$$Da = 1.9 \times MW^{-2/3}$$

where

D_a	=	diffusion coefficient in air (cm^2/s)
MW	=	molecular weight (g/mol).

For dioxins and furans, we used an equation from the Dioxin Reassessment (U.S. EPA, 2000) to estimate diffusion coefficients from diphenyl's diffusivity:

$$\frac{D_a}{D_b} = \left(\frac{MW_b}{MW_a} \right)^{0.5}$$

where

D_a	=	diffusion coefficient of constituent in air (cm^2/s)
D_b	=	diffusion coefficient of diphenyl at 25 degrees C (0.068 cm^2/s)
MW_a	=	molecular weight of constituent (g/mole)
MW_b	=	molecular weight of diphenyl (154 g/mole).

Table E-2. Constituent-specific Chemical and Physical Properties

Constituent	CASRN	D _a (cm ² /s) (a)	D _w (cm ² /s) (a)	HLC (atm- m ³ /mol) (c)	Sol (mg/L) (c)
Acetaldehyde (ethanal)	75-07-0	0.128	0	7.89e-05	1.00e+06
Acetone (2-propanone)	67-64-1	1.06E-01	1.15E-05	3.88e-05	1.00e+06
Acetonitrile (methyl cyanide)	75-05-8	1.34E-01	1.41E-05	3.46e-05	1.00e+06
Acrolein	107-02-8	1.12E-01	1.22E-05	1.22e-04	2.13e+05
Acrylamide	79-06-1	1.07E-01	1.26E-05	1.00e-09	6.40e+05
Acrylic acid (propenoic acid)	79-10-7	1.03E-01	1.20E-05	1.17e-07	1.00e+06
Acrylonitrile	107-13-1	1.14E-01	1.23E-05	1.03e-04	7.40e+04
Aldrin	309-00-2	2.28E-02	5.84E-06	1.70e-04	1.80e-01
Aniline (benzeneamine)	62-53-3	8.30E-02	1.01E-05	1.90e-06	3.60e+04
Benz(a)anthracene	56-55-3	5.09E-02 ^b	5.89E-06 ^b	3.35e-06	9.40e-03
Benzene	71-43-2	8.95E-02	1.03E-05	5.55e-03	1.75e+03
Benzidine	92-87-5	3.55E-02	7.59E-06	3.88e-11	5.00e+02
Benzo(a)pyrene	50-32-8	2.55E-02	6.58E-06	1.13e-06	1.62e-03
Benzo(b)fluoranthene	205-99-2	4.76E-02 ^b	5.51E-06 ^b	1.11e-04	1.50e-03
Benzyl chloride	100-44-7	6.34E-02	8.81E-06	4.15e-04	5.25e+02
Bis(2-ethylhexyl)phthalate	117-81-7	1.73E-02	4.18E-06	1.02e-07	3.40e-01
Bis(2-chloroethyl)ether	111-44-4	5.67E-02	8.71E-06	1.80e-05	1.72e+04
Bis(2-chloroisopropyl)ether	39638-32-9	4.01E-02	7.40E-06	1.34e-04 ^e	1.31e+03
Bromodichloromethane	75-27-4	5.63E-02	1.07E-05	1.60e-03	6.74e+03
Bromomethane (methyl bromide)	74-83-9	1.00E-01	1.35E-05	6.24e-03	1.52e+04
Butadiene, 1,3-	106-99-0	1.00E-01	1.03E-05	7.36e-02	7.35e+02
Carbon tetrachloride	56-23-5	5.71E-02	9.78E-06	3.04e-02	7.93e+02
Carbon disulfide	75-15-0	1.06E-01	1.30E-05	3.03e-02	1.19e+03
Chlordane	57-74-9	2.15E-02	0	4.86e-05	5.60e-02
Chloro-1,3-butadiene, 2- (Chloroprene)	126-99-8	8.41E-02	1.00E-05	1.19e-02 ^f	1.74e+03
Chlorobenzene	108-90-7	7.21E-02	9.48E-06	3.70e-03	4.72e+02
Chlorobenzilate	510-15-6	2.18E-02	5.48E-06	7.24e-08 ^f	1.11e+01
Chlorodibromomethane	124-48-1	3.66E-02	1.06E-05	7.83e-04	2.60e+03
Chloroethane (ethyl chloride)	75-00-3	1.04E-01	1.16E-05	8.82e-03	5.68e+03
Chloroform	67-66-3	7.70E-02	1.09E-05	3.67e-03	7.92e+03

Table E-2. Constituent-specific Chemical and Physical Properties (continued)

Constituent	CASRN	D _a (cm ² /s) (a)	D _w (cm ² /s) (a)	HLC (atm- m ³ /mol) (c)	Sol (mg/L) (c)
Chloromethane (methyl chloride)	74-87-3	0.124	1.36E-05	8.82e-03	5.33e+03
Chlorophenol, 2-	95-57-8	0.0661	0	3.91e-04	2.20e+04
Chloropropene, 3- (allyl chloride)	107-05-1	9.36E-02	1.08E-05	1.10e-02	3.37e+03
Chrysene	218-01-9	2.61E-02	6.75E-06	9.46e-05	1.60e-03
Cresol, o-	95-48-7	7.59E-02	9.86E-06	1.20e-06	2.60e+04
Cresol, —	108-39-4	0.0729	0	8.65e-07	2.27e+04
Cresol, p-	106-44-5	7.24E-02	9.24E-06	7.92e-07	2.15e+04
Cresols (total)	1319-77-3	7.37E-02	9.48E-06	9.52e-07	2.34e+04
Cumene	98-82-8	6.02E-02	7.85E-06	1.16e+00	6.13e+01
Cyclohexanol	108-93-0	7.59E-02	9.35E-06	1.02e-04 ^f	4.30e+04 ^f
DDT, p,p'-	50-29-3	1.83E-02	4.44E-06	8.10e-06	2.50e-02
Dibenz(a,h)anthracene	53-70-3	0.0236	6.02E-06	1.47e-08	2.49e-03
Dibromo-3-chloropropane, 1,2-	96-12-8	0.0321	8.90E-06	1.47e-04	1.23e+03
Dichlorobenzene, 1,2-	95-50-1	0.0562	8.92E-06	1.90e-03	1.56e+02
Dichlorobenzene, 1,4-	106-46-7	0.055	8.68E-06	2.40e-03	7.38e+01
Dichlorobenzidine, 3,3'-	91-94-1	4.75E-02 ^b	5.50E-06 ^b	4.00e-09	3.11e+00
Dichlorodifluoromethane (Freon 12)	75-71-8	7.60E-02	1.08E-05	3.43e-01	2.80e+02
Dichloroethane, 1,1-	75-34-3	8.36E-02	1.06E-05	5.62e-03	5.06e+03
Dichloroethane, 1,2-	107-06-2	8.54E-02	1.09E-05	9.79e-04	8.52e+03
Dichloroethylene, 1,1-	75-35-4	8.63E-02	1.10E-05	2.61e-02	2.25e+03
Dichloropropane, 1,2-	78-87-5	7.33E-02	9.73E-06	2.80e-03	2.80e+03
Dichloropropene, trans-1,3-	10061-02-6	7.63E-02	1.01E-05	1.80e-03 ⁱ	2.72e+03
Dichloropropene, 1,3- (isomer mixture)	542-75-6	7.63E-02	1.01E-05	1.77e-02	2.80e+03
Dichloropropene, cis-1,3-	10061-01-5	7.65E-02	1.02E-05	2.40e-03 ⁱ	2.72e+03
Dieldrin	60-57-1	2.33E-02	6.01E-06	1.51e-05	1.95e-01
Dimethyl formamide, N,N- (DMF)	68-12-2	9.72E-02	1.12E-05	7.39e-08 ⁱ	1.00e+06 ^f
Dimethylbenz(a)anthracene, 7,12-	57-97-6	4.71E-02 ^b	5.45E-06 ^b	3.11e-08	2.50e-02
Dinitrotoluene, 2,4-	121-14-2	3.75E-02	7.90E-06	9.26e-08	2.70e+02
Dioxane, 1,4-	123-91-1	8.74E-02	1.05E-05	4.80e-06	1.00e+06
Diphenylhydrazine, 1,2-	122-66-7	0.0343	7.25E-06	1.53e-06	6.80e+01
Epichlorohydrin	106-89-8	0.0888	1.11E-05	3.04e-05	6.59e+04

Table E-2. Constituent-specific Chemical and Physical Properties (continued)

Constituent	CASRN	D _a (cm ² /s) (a)	D _w (cm ² /s) (a)	HLC (atm- m ³ /mol) (c)	Sol (mg/L) (c)
Epoxybutane, 1,2-	106-88-7	9.32E-02	1.05E-05	1.80e-04 ^f	9.50e+04 ^f
Ethoxyethanol acetate, 2-	111-15-9	0.057	0	1.80e-06 ⁱ	2.29e+05 ⁱ
Ethoxyethanol, 2-	110-80-5	8.19E-02	9.76E-06	1.23e-07	1.00e+06
Ethylbenzene	100-41-4	6.86E-02	8.48E-06	7.88e-03	1.69e+02
Ethylene dibromide (1,2-dibromoethane)	106-93-4	4.31E-02	1.05E-05	7.43e-04	4.18e+03
Ethylene glycol	107-21-1	1.17E-01	1.36E-05	6.00e-08	1.00e+06
Ethylene thiourea	96-45-7	8.69E-02	1.01E-05	3.08e-10	6.20e+04
Ethylene oxide	75-21-8	1.34E-01	1.46E-05	1.48e-04	1.00e+06 ^g
Formaldehyde	50-00-0	1.67E-01	1.74E-05	3.36e-07	5.50e+05
Furfural	98-01-1	8.53E-02	1.07E-05	4.00e-06	1.10e+05
HCH, gamma- (Lindane)	58-89-9	2.74E-02	7.30E-06	1.40e-05	6.80e+00
HCH, beta-	319-85-7	0.0277	7.40E-06	7.43e-07	2.40e-01
HCH, alpha-	319-84-6	2.75E-02	7.35E-06	1.06e-05	2.00e+00
Heptachlor epoxide	1024-57-3	2.19E-02	5.58E-06	9.50e-06	2.00e-01
Heptachlor	76-44-8	2.23E-02	5.70E-06	1.10e-03	1.80e-01
Hexachloro-1,3-butadiene	87-68-3	2.67E-02	7.03E-06	8.15e-03	3.23e+00
Hexachlorobenzene	118-74-1	2.90E-02	7.85E-06	1.32e-03	5.00e-03
Hexachlorocyclopentadiene	77-47-4	2.72E-02	7.22E-06	2.70e-02	1.80e+00
Hexachlorodibenzo-p-dioxins (HxCDDs)	34465-46-8	4.27E-02 ^j	4.12E-06 ^b	1.10e-05 ^d	4.40e-06 ^d
Hexachlorodibenzofurans (HxCDFs)	55684-94-1	4.36E-02 ^j	4.23E-06 ^b	1.10e-05 ^d	1.30e-05 ^d
Hexachloroethane	67-72-1	3.21E-02	8.89E-06	3.89e-03	5.00e+01
Hexane	110-54-3	7.28E-02	8.12E-06	1.43e-02	1.24e+01
Indeno(1,2,3-cd)pyrene	193-39-5	4.48E-02	5.19E-06	1.60e-06	2.20e-05
Isophorone	78-59-1	5.25E-02	7.53E-06	6.64e-06	1.20e+04
Mercury	7439-97-6	7.15E-02	3.01E-05	7.10e-03 ^k	5.62e-02 ^h
Methacrylonitrile	126-98-7	9.64E-02	1.06E-05	2.47e-04	2.54e+04
Methanol	67-56-1	1.58E-01	1.65E-05	4.55e-06	1.00e+06
Methoxyethanol acetate, 2-	110-49-6	6.59E-02	8.71E-06	3.11e-07 ^e	1.00e+06 ⁱ
Methoxyethanol, 2-	109-86-4	0.0952	1.10E-05	8.10e-08 ^f	1.00e+06 ^g
Methyl methacrylate	80-62-6	7.53E-02	9.25E-06	3.37e-04	1.50e+04

Table E-2. Constituent-specific Chemical and Physical Properties (continued)

Constituent	CASRN	D _a (cm ² /s) (a)	D _w (cm ² /s) (a)	HLC (atm- m ³ /mol) (c)	Sol (mg/L) (c)
Methyl tert-butyl ether (MTBE)	1634-04-4	0.0755	0	5.87e-04 ^f	5.13e+04 ^f
Methyl isobutyl ketone	108-10-1	0.0698	0	1.38e-04	1.90e+04
Methyl ethyl ketone	78-93-3	0.0917	0	5.59e-05	2.23e+05
Methylcholanthrene, 3-	56-49-5	2.41E-02	6.14E-06	9.40e-07	3.23e-03
Methylene chloride (dichloromethane)	75-09-2	9.99E-02	1.25E-05	2.19e-03	1.30e+04
N-Nitrosomethylethylamine	10595-95-6	8.41E-02	9.99E-06	1.40e-06 ⁱ	1.97e+04
N-Nitrosodimethylamine	62-75-9	9.88E-02	1.15E-05	1.20e-06	1.00e+06
N-Nitrosopiperidine	100-75-4	6.99E-02	9.18E-06	2.80e-07	7.65e+04
N-Nitrosodiphenylamine	86-30-6	2.84E-02	7.19E-06	5.00e-06	3.51e+01
N-Nitrosodiethylamine	55-18-5	7.38E-02	9.13E-06	3.63e-06	9.30e+04
N-Nitroso-di-n-butylamine	924-16-3	4.22E-02	6.83E-06	3.16e-04	1.27e+03
N-Nitrosopyrrolidine	930-55-2	8.00E-02	1.01E-05	1.20e-08	1.00e+06
N-Nitroso-di-n-propylamine	621-64-7	5.64E-02	7.76E-06	2.25e-06	9.89e+03
Naphthalene	91-20-3	6.05E-02	8.38E-06	4.83e-04	3.10e+01
Nitrobenzene	98-95-3	6.81E-02	9.45E-06	2.40e-05	2.09e+03
Nitropropane, 2-	79-46-9	8.47E-02	1.02E-05	1.23e-04	1.70e+04
Pentachlorodibenzo-p-dioxins (PeCDDs)	36088-22-9	0.0447 ^j	4.38E-06 ^b	2.60e-06 ^d	1.18e-04 ^d
Pentachlorodibenzofurans (PeCDFs)	30402-15-4	4.57E-02 ^j	4.51E-06 ^b	5.00e-06 ^d	2.40e-04 ^d
Pentachlorophenol	87-86-5	2.95E-02	8.01E-06	2.44e-08	1.95e+03
Phenol	108-95-2	8.34E-02	1.03E-05	3.97e-07	8.28e+04
Phthalic anhydride	85-44-9	5.95E-02	9.75E-06	1.63e-08	6.20e+03
Polychlorinated biphenyls (Aroclors)	1336-36-3	2.33E-02	5.98E-06	2.60e-03	7.00e-02
Propylene oxide (1,2-epoxypropane)	75-56-9	1.10E-01	1.21E-05	1.23e-04 ^f	4.05e+05 ^f
Pyridine	110-86-1	9.31E-02	1.09E-05	8.88e-06	1.00e+06
Styrene	100-42-5	7.13E-02	8.81E-06	2.75e-03	3.10e+02
Tetrachlorodibenzo-p-dioxin, 2,3,7,8- (2,3,7,8-TCDD)	1746-01-6	4.70E-02 ^j	4.68E-06 ^b	3.29e-05 ^d	1.93e-05 ^d
Tetrachlorodibenzofurans (TCDFs)*	55722-27-5	4.82E-02 ^j	4.84E-06 ^b	1.40e-05 ^d	4.20e-04 ^d
Tetrachloroethane, 1,1,2,2-	79-34-5	4.89E-02	9.29E-06	3.45e-04	2.97e+03
Tetrachloroethane, 1,1,1,2-	630-20-6	4.82E-02	9.10E-06	2.42e-03	1.10e+03
Tetrachloroethylene	127-18-4	5.05E-02	9.45E-06	1.84e-02	2.00e+02

Table E-2. Constituent-specific Chemical and Physical Properties (continued)

Constituent	CASRN	D _a (cm ² /s) (a)	D _w (cm ² /s) (a)	HLC (atm- m ³ /mol) (c)	Sol (mg/L) (c)
Toluene	108-88-3	0.078	0	6.64e-03	5.26e+02
Toluenediamine 2,4-	95-80-7	7.72E-02 ^b	8.94E-06 ^b	7.92e-10	3.37e+04
Toluidine, o-	95-53-4	0.0724	0	2.72e-06	1.66e+04
Toxaphene (chlorinated camphenes)	8001-35-2	0.0216	0	6.00e-06	7.40e-01
Tribromomethane (bromoform)	75-25-2	3.58E-02	1.04E-05	5.35e-04	3.10e+03
Trichloro-1,2,2-trifluoro-ethane, 1,1,2-	76-13-1	3.76E-02	8.59E-06	4.81e-01	1.70e+02
Trichlorobenzene, 1,2,4-	120-82-1	3.96E-02	8.40E-06	1.42e-03	3.46e+01
Trichloroethane, 1,1,2-	79-00-5	6.69E-02	1.00E-05	9.13e-04	4.42e+03
Trichloroethane, 1,1,1-	71-55-6	6.48E-02	9.60E-06	1.72e-02	1.33e+03
Trichloroethylene (TCE)	79-01-6	6.87E-02	1.02E-05	1.03e-02	1.10e+03
Trichlorofluoromethane (Freon 11)	75-69-4	6.55E-02	1.01E-05	9.70e-02	1.10e+03
Trichlorophenol, 2,4,6-	88-06-2	3.14E-02	8.09E-06	7.79e-06	8.00e+02
Trichloropropane, 1,2,3-	96-18-4	5.75E-02	9.24E-06	4.09e-04	1.75e+03
Triethylamine	121-44-8	6.63E-02	7.84E-06	1.38e-04 ^f	5.50e+04 ^f
Vinyl acetate	108-05-4	8.51E-02	1.00E-05	5.11e-04	2.00e+04
Vinyl chloride	75-01-4	1.07E-01	1.20E-05	2.70e-02	2.76e+03
Xylene, p-	106-42-3	6.84E-02	8.45E-06	7.66e-03	1.85e+02
Xylene, o-	95-47-6	6.91E-02	8.56E-06	5.19e-03	1.78e+02
Xylene, m-	108-38-3	6.85E-02	8.47E-06	7.34e-03	1.61e+02
Xylenes (total)	1330-20-7	0.0687	0	6.73e-03	1.75e+02

D_a = air diffusivity; D_w = water diffusivity; HLC = Henry's law constant; Sol = aqueous solubility

CASRN = Chemical Abstract Service Registry Number

* Values used for 2,3,7,8-tetrachlorodibenzofuran (CAS #51207-31-9).

Data Sources:

^a Calculated based on WATER9 (U.S. EPA, 2001).

^b Calculated based on U.S. EPA, 1987.

^c SCDM (U.S. EPA, 1997b).

^d U.S. EPA, 2000.

^e Calculated based on Lyman, Reehl, and Rosenblatt, 1990.

^f CHEMFATE (SRC, 1999).

^g ChemFinder.com (CambridgeSoft Corporation, 2001).

^h The Merck Index (Budavari, 1996).

ⁱ HSDB (U.S. NLM, 2001).

^j Calculated based on U.S. EPA, 2000.

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E-26 Human Health Benchmarks used in the IWEM Tool

Human health benchmarks for chronic oral and inhalation exposures are an important component of the IWEM 1 tool. The EPA uses reference doses (RfDs) and reference concentrations (RfCs) to evaluate noncancer risk from oral and inhalation exposures, respectively. Oral cancer slope factors (CSFs), inhalation unit risk factors (URFs), and inhalation CSFs are used to evaluate risk for carcinogens.

This section provides the toxicity benchmarks we used to develop the HBNs that we will use in developing Reference Ground-Water Concentrations for IWEM. Section E-3.1 describes the data sources and general hierarchy used to collect these benchmarks. Section E-3.2 provides the benchmarks along with discussions of individual human health benchmarks extracted from a variety of sources.

E-3.1 Methodology and Data Sources

Several sources of health benchmarks are available. Human health benchmarks were obtained from these sources in the following order of preference:

- # Integrated Risk Information System (IRIS)
- # Superfund Technical Support Center Provisional Benchmarks
- # Health Effects Assessment Summary Tables (HEAST)
- # Agency for Toxic Substances and Disease Registry (ATSDR) minimal risk levels (MRLs)
- # California Environmental Protection Agency (CalEPA) chronic inhalation reference exposure levels (RELs) and cancer potency factors.
- # EPA health assessment documents
- # Various other EPA health benchmark sources.

For dioxins and dibenzofurans, World Health Organization (WHO) toxicity equivalency factors (TEFs) from Van den Berg et al. (1998) were applied to the oral and inhalation CSF for 2,3,7,8-TCDD to obtain CSFs for all other dioxins and furans (see Section E-3.2.4).

E-3.1.1 Integrated Risk Information System (IRIS)

Benchmarks in IRIS are prepared and maintained by EPA, and values from IRIS were used to develop HBNs for the IWEM tool whenever IRIS benchmarks were available. IRIS is EPA's electronic database containing information on human health effects (U.S. EPA, 2001a). Each chemical file contains descriptive and quantitative information on potential health effects. Health benchmarks for chronic noncarcinogenic health effects include RfDs and RfCs. Cancer classification, oral CSFs, and inhalation

URFs are included for carcinogenic effects. IRIS is the official repository of Agency-wide consensus of human health risk information.

Inhalation CSFs are not available from IRIS, so they were calculated from inhalation URFs (which are available from IRIS) using the following equation:

$$\text{inh CSF} = \text{inh URF} \times 70 \text{ kg} \div 20 \text{ m}^3/\text{d} \times 1000 \text{ } \mu\text{g}/\text{mg}$$

In this equation, 70 kg represents average body weight; 20 m³/d represents average inhalation rate; and 1000 μg/mg is a units conversion factor (U.S. EPA, 1997). These standard estimates of body weight and inhalation rate are used by EPA in the calculation of the URF, and, therefore, the values were used to calculate inhalation CSFs.

E-3.1.2 Superfund Provisional Benchmarks

The Superfund Technical Support Center (EPA's National Center for Environmental Assessment [NCEA]) derives provisional RfCs, RfDs, and CSFs for certain chemicals. These provisional health benchmarks can be found in Risk Assessment Issue Papers. Some of the provisional values have been externally peer reviewed, and some (e.g., trichloroethylene, tetrachloroethylene) come from previously published EPA Health Assessment Documents. These provisional values have not undergone EPA's formal review process for finalizing benchmarks and do not represent Agency-wide consensus information. Specific provisional values used in the IWEM tool are described in Section E-3.2.5.

E-3.1.3 Health Effects Summary Tables (HEAST)

HEAST is a listing of provisional noncarcinogenic and carcinogenic health toxicity values (RfDs, RfCs, URFs, and CSFs) derived by EPA (U.S. EPA, 1997). Although the health toxicity values in HEAST have undergone review and have the concurrence of individual EPA program offices, either they have not been reviewed as extensively as those in IRIS or their data set is not complete enough to be listed in IRIS. HEAST benchmarks have not been updated in several years and do not represent Agency-wide consensus information.

E-3.1.4 ATSDR Minimal Risk Levels

The ATSDR MRLs are substance-specific health guidance levels for noncarcinogenic endpoints (ATSDR, 2001). An MRL is an estimate of the daily human exposure to a hazardous substance that is likely to be without appreciable risk of adverse noncancer health effects over a specified duration of exposure. MRLs are based on noncancer health effects only and are not based on a consideration of cancer effects.

MRLs are derived for acute, intermediate, and chronic exposure durations for oral and inhalation routes of exposure. Inhalation and oral MRLs are derived in a manner similar to EPA's RfCs and RfDs, respectively (i.e., ATSDR uses the no-observed-adverse-effect-level/uncertainty factor (NOAEL/UF) approach); however, MRLs are intended to serve as screening levels and are exposure duration-specific. Also, ATSDR uses EPA's 1994 inhalation dosimetry methodology in the derivation of inhalation MRLs. A chronic inhalation MRL for mixed xylenes was used as a surrogate for each of the xylene isomers.

E-3.1.5 CalEPA Cancer Potency Factors and Reference Exposure Levels

CalEPA has developed cancer potency factors for chemicals regulated under California's Hot Spots Air Toxics Program (CalEPA, 1999a). The cancer potency factors are analogous to EPA's oral and inhalation CSFs. CalEPA has also developed chronic inhalation RELs, analogous to EPA's RfC, for 120 substances (CalEPA, 1999b, 2000). CalEPA used EPA's 1994 inhalation dosimetry methodology in the derivation of inhalation RELs. The cancer potency factors and inhalation RELs have undergone internal peer review by various California agencies and have been the subject of public comment. A chronic inhalation REL for mixed cresols was used as a surrogate for each of the cresol isomers.

E-3.1.6 Other EPA Health Benchmarks

EPA has also derived health benchmark values in other risk assessment documents, such as Health Assessment Documents (HADs), Health Effect Assessments (HEAs), Health and Environmental Effects Profiles (HEEPs), Health and Environmental Effects Documents (HEEDs), Drinking Water Criteria Documents, and Ambient Water Quality Criteria Documents. Evaluations of potential carcinogenicity of chemicals in support of reportable quantity adjustments were published by EPA's Carcinogen Assessment Group (CAG) and may include cancer potency factor estimates. Health toxicity values identified in these EPA documents are usually dated and are not recognized as Agency-wide consensus information or verified benchmarks, however, and as a result they are used in the hierarchy only when values are not available from IRIS, HEAST, Superfund provisional values, ATSDR, or CalEPA. Section E-3.2.6 describes the specific values from these alternative EPA sources that were used in the IWEM tool.

E-3.2 Human Health Benchmark Values

The chronic human health benchmarks used to calculate the HBNs in the IWEM tool are summarized in Table E-3, which provides the Chemical Abstract Service Registry Number (CASRN), constituent name, RfD (mg/kg-d), RfC (mg/m³), oral CSF (mg/kg-d⁻¹), inhalation URF [(μ g/m³)⁻¹], inhalation CSF (mg/kg-d⁻¹), and reference for each benchmark. A key to the references cited and abbreviations used is provided at the end of the table.

For a majority of the IWEM constituents, human health benchmarks were available from IRIS (U.S. EPA, 2001a), Superfund Provisional Benchmarks, or HEAST (U.S. EPA, 1997). Benchmarks also were obtained from ATSDR (2001) or CalEPA (1999a, 1999b, 2000). This section describes benchmarks obtained from other sources, along with the Superfund Provisional values and special uses (e.g., benzene, vinyl chloride) of IRIS benchmarks.

Table E-3. Human Health Benchmark Values

Constituent Name	CASRN	RfD (mg/kg-d)	RfD Ref	CSFo (per mg/kg-d)	CSFo Ref	RfC (mg/m3)	RfC Ref	URF (per g/m3)	URF Ref	CSFi (per mg/kg-d)	CSFi Ref
Acenaphthene	83-32-9	6.0E-02	I								
Acetaldehyde (ethanal)	75-07-0					9.0E-03	I	2.2E-06	I	7.7E-03	calc
Acetone (2-propanone)	67-64-1	1.0E-01	I			3.1E+01	A				
Acetonitrile (methyl cyanide)	75-05-8					6.0E-02	I				
Acetophenone	98-86-2	1.0E-01	I								
Acrolein	107-02-8	2.0E-02	H			2.0E-05	I				
Acrylamide	79-06-1	2.0E-04	I	4.5E+0	I			1.3E-03	I	4.6E+00	calc
Acrylic acid (propenoic acid)	79-10-7	5.0E-01	I			1.0E-03	I				
Acrylonitrile	107-13-1	1.0E-03	H	5.4E-1	I	2.0E-03	I	6.8E-05	I	2.4E-01	calc
Aldrin	309-00-2	3.0E-05	I	1.7E+01	I			4.9E-03	I	1.7E+01	calc
Allyl alcohol	107-18-6	5.0E-03	I								
Aniline (benzeneamine)	62-53-3			5.7E-3	I	1.0E-03	I	1.6E-06	C99a	5.6E-03	calc
Anthracene	120-12-7	3.0E-01	I								
Antimony	7440-36-0	4.0E-04	I								
Arsenic	7440-38-2	3.0E-04	I	1.5E+00	I						
Barium	7440-39-3	7.0E-02	I								
Benz{a}anthracene	56-55-3			1.2E+00	C99a			1.1E-04	C99a	3.9E-01	calc
Benzene	71-43-2			5.5E-02	I	6.0E-02	C00	7.8E-06	I	2.7E-02	calc
Benzidine	92-87-5	3.0E-03	I	2.3E+02	I			6.7E-02	I	2.3E+02	I
Benzo{a}pyrene	50-32-8			7.3E+00	I			1.1E-03	C99a	3.9E+00	calc
Benzo{b}fluoranthene	205-99-2			1.2E+00	C99a			1.1E-04	C99a	3.9E-01	calc
Benzyl chloride	100-44-7			1.7E-01	I			4.9E-05	C99a	1.7E-01	calc
Benzyl alcohol	100-51-6	3.0E-01	H								

Beryllium	7440-41-7	2.0E-03	I								
Bis(2-chloroethyl)ether	111-44-4			1.1E+00	I			3.3E-04	I	1.2E+00	calc

Table E-3. Human Health Benchmark Values (continued)

Constituent Name	CASRN	RfD (mg/kg-d)	RfD Ref	CSFo (per mg/kg-d)	CSFo Ref	RfC (mg/m3)	RfC Ref	URF (per g/m3)	URF Ref	CSFi (per mg/kg-d)	CSFi Ref
Bis(2-chloroisopropyl)ether	39638-32-9	4.0E-02	I	7.0E-02	H			1.0E-05	H	3.5E-02	calc
Bis(2-ethylhexyl)phthalate	117-81-7	2.0E-02	I	1.4E-02	I	1.0E-02	C99b	2.4E-06	C99a	8.4E-03	calc
Bromodichloromethane	75-27-4	2.0E-02	I	6.2E-02	I			1.8E-05	AC	6.2E-02	AC
Bromomethane (methyl bromide)	74-83-9	1.4E-03	I			5.0E-03	I				
Butadiene, 1,3-	106-99-0					2.0E-02	C00	2.8E-04	I	9.8E-01	calc
Butanol	71-36-3	1.0E-01	I								
Butyl benzyl phthalate	85-68-7	2.0E-01	I								
Butyl-4,6-dinitrophenol,2-sec- (Dinoseb)	88-85-7	1.0E-03	I								
Cadmium	7440-43-9	5.0E-04	I								
Carbon tetrachloride	56-23-5	7.0E-04	I	1.3E-01	I	7.0E-03	SF	1.5E-05	I	5.3E-02	calc
Carbon disulfide	75-15-0	1.0E-01	I			7.0E-01	I				
Chlordane	57-74-9	5.0E-04	I	3.5E-01	I	7.0E-04	I	1.0E-04	I	3.5E-01	calc
Chloro-1,3-butadiene, 2- (Chloroprene)	126-99-8	2.0E-02	H			7.0E-03	H				
Chloroaniline, p-	106-47-8	4.0E-03	I								
Chlorobenzene	108-90-7	2.0E-02	I			6.0E-02	SF				
Chlorobenzilate	510-15-6	2.0E-02	I	2.7E-01	H			7.8E-05	H	2.7E-01	calc
Chlorodibromomethane	124-48-1	2.0E-02	I	8.4E-02	I			2.4E-05	AC	8.4E-02	AC
Chloroethane (ethyl chloride)	75-00-3					1.0E+01	I				
Chloroform	67-66-3	1.0E-02	I			1.0E-01	A				
Chloromethane (methyl chloride)	74-87-3			1.3E-02	H	9.0E-02	I	1.8E-06	H	6.3E-03	calc
Chlorophenol, 2-	95-57-8	5.0E-03	I			1.4E-03	AC				

Table E-3. Human Health Benchmark Values (continued)

Constituent Name	CASRN	RfD (mg/kg-d)	RfD Ref	CSFo (per mg/kg-d)	CSFo Ref	RfC (mg/m3)	RfC Ref	URF (per g/m3)	URF Ref	CSFi (per mg/kg-d)	CSFi Ref
Chloropropene, 3- (allyl chloride)	107-05-1					1.0E-03	I	6.0E-06	C99a	2.1E-02	calc
Chromium (III)	16065-83-1	1.5E+00	I								
Chromium (VI)	18540-29-9	3.0E-03	I								
Chrysene	218-01-9			1.2E-01	C99a			1.1E-05	C99a	3.9E-02	calc
Cobalt	7440-48-4	2.0E-02	SF								
Copper	7440-50-8	(only a drinking water action level is available for this metal)									
Cresol, p-	106-44-5	5.0E-03	H			6.0E-01	surr (C00)				
Cresol, o-	95-48-7	5.0E-02	I			6.0E-01	surr (C00)				
Cresol, m-	108-39-4	5.0E-02	I			6.0E-01	surr (C00)				
Cresols (total)	1319-77-3	5.0E-02	surr (I)			6.0E-01	C00				
Cumene	98-82-8	1.0E-01	I			4.0E-01	I				
Cyclohexanol	108-93-0	1.7E-05	solv			2.0E-05	solv				
Cyclohexanone	108-94-1	5.0E+00	I								
DDD	72-54-8			2.4E-01	I						
DDE	72-55-9			3.4E-01	I						
DDT, p,p'-	50-29-3	5.0E-04	I	3.4E-01	I			9.7E-05	I	3.4E-01	calc
Di-n-butyl phthalate	84-74-2	1.0E-01	I								
Di-n-octyl phthalate	117-84-0	2.0E-02	H								
Diallylate	2303-16-4			6.1E-02	H						
Dibenz{a,h}anthracene	53-70-3			7.3E+00	TEF			1.2E-03	C99a	4.2E+00	calc
Dibromo-3-chloropropane, 1,2-	96-12-8			1.4E+0	H	2.0E-04	I	6.9E-07	H	2.4E-03	calc

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Table E-3. Human Health Benchmark Values (continued)

Constituent Name	CASRN	RfD (mg/kg-d)	RfD Ref	CSFo (per mg/kg-d)	CSFo Ref	RfC (mg/m3)	RfC Ref	URF (per g/m3)	URF Ref	CSFi (per mg/kg-d)	CSFi Ref
Dichlorobenzene, 1,2-	95-50-1	9.0E-02	I			2.0E-01	H				
Dichlorobenzene, 1,4-	106-46-7			2.4E-2	H	8.0E-01	I	1.1E-05	C99a	3.9E-02	calc
Dichlorobenzidine, 3,3'-	91-94-1			4.5E-01	I			3.4E-04	C99a	1.2E+00	calc
Dichlorodifluoromethane (Freon 12)	75-71-8	2.0E-01	I			2.0E-01	H				
Dichloroethane, 1,2-	107-06-2			9.1E-2	I	2.4E+00	A	2.6E-05	I	9.1E-02	calc
Dichloroethane, 1,1-	75-34-3	1.0E-01	H			5.0E-01	H	1.6E-06	C99a	5.6E-03	calc
Dichloroethylene, 1,1-	75-35-4	9.0E-03	I	6.0E-1	I	7.0E-02	C00	5.0E-05	I	1.8E-01	calc
Dichloroethylene, trans-1,2-	156-60-5	2.0E-02	I								
Dichloroethylene, cis-1,2-	156-59-2	1.0E-02	H								
Dichlorophenol, 2,4-	120-83-2	3.0E-03	I								
Dichlorophenoxyacetic acid, 2,4- (2,4-D)	94-75-7	1.0E-02	I								
Dichloropropane, 1,2-	78-87-5	9.0E-02	A	6.8E-2	H	4.0E-03	I				
Dichloropropene, trans-1,3-	10061-02-6	3.0E-02	I	1.0E-1	I	2.0E-02	surr (I)	4.0E-06	surr (I)	1.4E-02	calc
Dichloropropene, cis-1,3-	10061-01-5	3.0E-02	I	1.0E-1	I	2.0E-02	surr (I)	4.0E-06	surr (I)	1.4E-02	calc
Dichloropropene, 1,3- (mixture of isomers)	542-75-6	3.0E-02	I	1.0E-01	I	2.0E-02	I	4.0E-06	I	1.4E-02	calc
Dieldrin	60-57-1	5.0E-05	I	1.6E+01	I			4.6E-03	I	1.6E+01	calc
Diethyl phthalate	84-66-2	8.0E-01	I								
Diethylstilbestrol	56-53-1			4.7E+03	H						
Dimethoate	60-51-5	2.0E-04	I								
Dimethoxybenzidine, 3,3'-	119-90-4			1.4E-02	H						
Dimethyl formamide, N,N- (DMF)	68-12-2	1.0E-01	H			3.0E-02	I				
Dimethylbenz{a}anthracene, 7,12-	57-97-6							7.1E-02	C99a	2.5E+02	calc

Table E-3. Human Health Benchmark Values (continued)

Constituent Name	CASRN	RfD (mg/kg-d)	RfD Ref	CSFo (per mg/kg-d)	CSFo Ref	RfC (mg/m3)	RfC Ref	URF (per g/m3)	URF Ref	CSFi (per mg/kg-d)	CSFi Ref
Dimethylbenzidine, 3,3'-	119-93-7			9.2E+00	H						
Dimethylphenol, 2,4-	105-67-9	2.0E-02	I								
Dinitrobenzene, 1,3-	99-65-0	1.0E-04	I								
Dinitrophenol, 2,4-	51-28-5	2.0E-03	I								
Dinitrotoluene, 2,6-	606-20-2	1.0E-03	H	6.8E-01	surr (I)						
Dinitrotoluene, 2,4-	121-14-2	2.0E-03	I	6.8E-01	surr (I)			8.9E-05	C99a	3.1E-01	calc
Dioxane, 1,4-	123-91-1			1.1E-2	I	3.0E+00	C00	7.7E-06	C99a	2.7E-02	calc
Diphenylamine	122-39-4	2.5E-02	I								
Diphenylhydrazine, 1,2-	122-66-7			8.0E-1	I			2.2E-04	I	7.7E-01	calc
Disulfoton	298-04-4	4.0E-05	I								
Endosulfan (Endosulfan I and II,mixture)	115-29-7	6.0E-03	I								
Endrin	72-20-8	3.0E-04	I								
Epichlorohydrin	106-89-8	2.0E-03	H	9.9E-3	I	1.0E-03	I	1.2E-06	I	4.2E-03	calc
Epoxybutane, 1,2-	106-88-7					2.0E-02	I				
Ethoxyethanol acetate, 2-	111-15-9	3.0E-01	H			3.0E-01	C00				
Ethoxyethanol, 2-	110-80-5	4.0E-01	H			2.0E-01	I				
Ethyl acetate	141-78-6	9.0E-01	I								
Ethyl ether	60-29-7	2.0E-01	I								
Ethyl methacrylate	97-63-2	9.0E-02	H								
Ethyl methanesulfonate	62-50-0			2.9E+02	RQ						
Ethylbenzene	100-41-4	1.0E-01	I			1.0E+00	I	1.1E-06	SF	3.9E-03	calc
Ethylene oxide	75-21-8			1.0E+0	H	3.0E-02	C00	1.0E-04	H	3.5E-01	calc
Ethylene dibromide (1,2-dibromoethane)	106-93-4			8.5E+1	I	2.0E-04	H	2.2E-04	I	7.7E-01	calc
Ethylene glycol	107-21-1	2.0E+00	I			4.0E-01	C00				

Table E-3. Human Health Benchmark Values (continued)

Constituent Name	CASRN	RfD (mg/kg-d)	RfD Ref	CSFo (per mg/kg-d)	CSFo Ref	RfC (mg/m3)	RfC Ref	URF (per g/m3)	URF Ref	CSFi (per mg/kg-d)	CSFi Ref
Ethylene thiourea	96-45-7	8.0E-05	I	1.1E-01	H			1.3E-05	C99a	4.6E-02	calc
Fluoranthene	206-44-0	4.0E-02	I								
Fluoride	16984-48-8	0.12	surr (I)								
Formaldehyde	50-00-0	2.0E-01	I			9.8E-03	A	1.3E-05	I	4.6E-02	calc
Formic acid	64-18-6	2.0E+00	H								
Furfural	98-01-1	3.0E-03	I			5.0E-02	H				
HCH, beta-	319-85-7			1.8E+00	I			5.3E-04	I	1.9E+00	calc
HCH, gamma- (Lindane)	58-89-9	3.0E-04	I	1.3E+00	H			3.1E-04	C99a	1.1E+00	calc
HCH, alpha-	319-84-6	8.0E-03	A	6.3E+00	I			1.8E-03	I	6.3E+00	calc
Heptachlor	76-44-8	5.0E-04	I	4.5E+00	I			1.3E-03	I	4.6E+00	calc
Heptachlor epoxide	1024-57-3	1.3E-05	I	9.1E+00	I			2.6E-03	I	9.1E+00	calc
Hexachloro-1,3-butadiene	87-68-3	3.0E-04	SF	7.8E-2	I			2.2E-05	I	7.7E-02	calc
Hexachlorobenzene	118-74-1	8.0E-04	I	1.6E+0	I			4.6E-04	I	1.6E+00	calc
Hexachlorocyclopentadiene	77-47-4	6.0E-03	I			2.0E-04	I				
Hexachlorodibenzo-p-dioxins (HxCDDs)	34465-46-8			1.56E+04	WHO98			3.3E+00	WHO98	1.5E+04	WHO98
Hexachlorodibenzofurans (HxCDFs)	55684-94-1			1.56E+04	WHO98			3.3E+00	WHO98	1.5E+04	WHO98
Hexachloroethane	67-72-1	1.0E-03	I	1.4E-02	I			4.0E-06	I	1.4E-02	calc
Hexachlorophene	70-30-4	3.0E-04	I								
Hexane, n-	110-54-3	1.1E+01	SF			2.0E-01	I				
Hydrogen Sulfide	7783-06-4	3.0E-03	I								
Indeno{1,2,3-cd}pyrene	193-39-5			1.2E+00	C99a			1.1E-04	C99a	3.9E-01	calc
Isobutyl alcohol	78-83-1	3.0E-01	I								
Isophorone	78-59-1	2.0E-01	I	9.5E-04	I	2.0E+00	C99b				
Kepone	143-50-0	5.0E-04	A								

Table E-3. Human Health Benchmark Values (continued)

Constituent Name	CASRN	RfD (mg/kg-d)	RfD Ref	CSFo (per mg/kg-d)	CSFo Ref	RfC (mg/m3)	RfC Ref	URF (per g/m3)	URF Ref	CSFi (per mg/kg-d)	CSFi Ref
Lead	7439-92-1	(only a drinking water action level is available for this metal)									
Manganese	7439-96-5	4.7E-02	I								
Mercury	7439-97-6	1.0E-04	surr (I)			3.0E-04	I				
Methacrylonitrile	126-98-7	1.0E-04	I			7.0E-04	H				
Methanol	67-56-1	5.0E-01	I			4.0E+00	C00				
Methoxychlor	72-43-5	5.0E-03	I								
Methoxyethanol, 2-	109-86-4	1.0E-03	H			2.0E-02	I				
Methoxyethanol acetate, 2-	110-49-6	2.0E-03	H			9.0E-02	C00				
Methyl parathion	298-00-0	2.5E-04	I								
Methyl methacrylate	80-62-6	1.4E+00	I			7.0E-01	I				
Methyl isobutyl ketone	108-10-1	8.0E-02	H			8.0E-02	H				
Methyl ethyl ketone	78-93-3	6.0E-01	I			1.0E+00	I				
Methyl tert-butyl ether (MTBE)	1634-04-4					3.0E+00	I				
Methylcholanthrene, 3-	56-49-5							6.3E-03	C99a	2.2E+01	calc
Methylene bromide (dibromomethane)	74-95-3	1.0E-02	H								
Methylene Chloride (dichloromethane)	75-09-2	6.0E-02	I	7.5E-03	I	3.0E+00	H	4.7E-07	I	1.6E-03	calc
Molybdenum	7439-98-7	5.0E-03	I								
N-Nitroso-di-n-butylamine	924-16-3			5.4E+00	I			1.6E-03	I	5.6E+00	calc
N-Nitroso-di-n-propylamine	621-64-7			7.0E+00	I			2.0E-03	C99a	7.0E+00	calc
N-Nitrosodiethylamine	55-18-5			1.5E+02	I			4.3E-02	I	1.5E+02	calc
N-Nitrosodimethylamine	62-75-9	8.00E-06	SF	5.1E+01	I			1.4E-02	I	4.9E+01	calc
N-Nitrosodiphenylamine	86-30-6	2.00E-02	SF	4.9E-03	I			2.6E-06	C99a	9.1E-03	calc
N-Nitrosomethylethylamine	10595-95-6			2.2E+01	I			6.3E-03	C99a	3.7E+00	C99a

Table E-3. Human Health Benchmark Values (continued)

Constituent Name	CASRN	RfD (mg/kg-d)	RfD Ref	CSFo (per mg/kg-d)	CSFo Ref	RfC (mg/m3)	RfC Ref	URF (per g/m3)	URF Ref	CSFi (per mg/kg-d)	CSFi Ref
N-Nitrosopiperidine	100-75-4							2.7E-03	C99a	9.5E+00	calc
N-Nitrosopyrrolidine	930-55-2			2.1E+00	I			6.1E-04	I	2.1E+00	calc
Naphthalene	91-20-3	2.0E-02	I			3.0E-03	I				
Nickel	7440-02-0	2.0E-02	I								
Nitrobenzene	98-95-3	5.0E-04	I			2.0E-03	H				
Nitropropane, 2-	79-46-9					2.0E-02	I	2.7E-03	H	9.5E+00	calc
Octamethyl pyrophosphoramide	152-16-9	2.0E-03	H								
Parathion (ethyl)	56-38-2	6.0E-03	H								
Pentachlorobenzene	608-93-5	8.0E-04	I								
Pentachlorodibenzo-p-dioxins (PeCDDs)	36088-22-9			1.56E+05	WHO98			3.3E+01	WHO98	1.5E+05	WHO98
Pentachlorodibenzofurans (PeCDFs)	30402-15-4			7.8E+04	WHO98			1.7E+01	WHO98	7.5E+04	WHO98
Pentachloronitrobenzene (PCNB)	82-68-8	3.0E-03	I	2.6E-01	H						
Pentachlorophenol	87-86-5	3.0E-02	I	1.2E-01	I			5.1E-06	C99a	1.8E-02	calc
Phenol	108-95-2	6.0E-01	I			2.0E-01	C00				
Phenyl mercuric acetate	62-38-4	8.0E-05	I								
Phenylenediamine, 1,3-	108-45-2	6.0E-03	I								
Phorate	298-02-2	2.0E-04	H								
Phthalic anhydride	85-44-9	2.0E+00	I			1.2E-01	H				
Polychlorinated biphenyls (Aroclors)	1336-36-3	2.0E-05	surr (I)	4.0E-01	I			1.0E-04	I	4.0E-01	I
Pronamide	23950-58-5	7.5E-02	I								
Propylene oxide (1,2- epoxypropane)	75-56-9			2.4E-01	I	3.0E-02	I	3.7E-06	I	1.3E-02	calc

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Table E-3. Human Health Benchmark Values (continued)

Constituent Name	CASRN	RfD (mg/kg-d)	RfD Ref	CSFo (per mg/kg-d)	CSFo Ref	RfC (mg/m3)	RfC Ref	URF (per g/m3)	URF Ref	CSFi (per mg/kg-d)	CSFi Ref
Pyrene	129-00-0	3.0E-02	I								
Pyridine	110-86-1	1.0E-03	I			7.0E-03	EPA86				
Safrole	94-59-7			1.8E-01	RQ						
Selenium	7782-49-2	5.0E-03	I								
Silver	7440-22-4	5.0E-03	I								
Strychnine and salts	57-24-9	3.0E-04	I								
Styrene	100-42-5	2.0E-01	I			1.0E+00	I				
Tetrachlorobenzene, 1,2,4,5-	95-94-3	3.0E-04	I								
Tetrachlorodibenzo-p-dioxin, 2,3,7,8-(2,3,7,8-TCDD)	1746-01-6			1.56E+05	DA85			3.3E+01	H	1.5E+05	H
Tetrachlorodibenzofuran, 2,3,7,8- (2,3,7,8-TCDF)	51207-31-9			1.56E+04	WHO98			3.3E+00	WHO98	1.5E+04	WHO98
Tetrachloroethane, 1,1,2,2-	79-34-5	6.0E-02	SF	2.0E-01	I			5.8E-05	I	2.0E-01	calc
Tetrachloroethane, 1,1,1,2-	630-20-6	3.0E-02	I	2.6E-02	I			7.4E-06	I	2.6E-02	calc
Tetrachloroethylene	127-18-4	1.0E-02	I	5.2E-02	HAD	3.0E-01	A	5.8E-07	HAD	2.0E-03	HAD
Tetrachlorophenol, 2,3,4,6-	58-90-2	3.0E-02	I								
Tetraethyl dithiopyrophosphate (Sulfotep)	3689-24-5	5.0E-04	I								
Thallium	7440-28-0	8.0E-05	surr (I)								
Thiram (Thiuram)	137-26-8	5.0E-03	I								
Toluene	108-88-3	2.0E-01	I			4.0E-01	I				
Toluenediamine, 2,4-	95-80-7			3.2E+00	H			1.1E-03	C99a	3.9E+00	calc
Toluidine, o-	95-53-4			2.4E-01	H			6.9E-05	AC	2.4E-01	AC
Toluidine, p-	106-49-0			1.9E-01	H						
Toxaphene (chlorinated camphenes)	8001-35-2			1.1E+00	I			3.2E-04	I	1.1E+00	calc

Table E-3. Human Health Benchmark Values (continued)

Constituent Name	CASRN	RfD (mg/kg-d)	RfD Ref	CSFo (per mg/kg-d)	CSFo Ref	RfC (mg/m3)	RfC Ref	URF (per g/m3)	URF Ref	CSFi (per mg/kg-d)	CSFi Ref
Tribromomethane (bromoform)	75-25-2	2.0E-02	I	7.9E-03	I			1.1E-06	I	3.9E-03	calc
Trichloro-1,2,2- trifluoroethane, 1,1,2-	76-13-1	3.0E+01	I			3.0E+01	H				
Trichlorobenzene, 1,2,4-	120-82-1	1.0E-02	I			2.0E-01	H				
Trichloroethane, 1,1,1-	71-55-6	2.8E-01	SF			2.2E+00	SF				
Trichloroethane, 1,1,2-	79-00-5	4.0E-03	I	5.7E-02	I			1.6E-05	I	5.6E-02	calc
Trichloroethylene (1,1,2- trichloroethylene)	79-01-6			1.1E-02	HAD	6.0E-01	C00	1.7E-06	HAD	6.0E-03	HAD
Trichlorofluoromethane (Freon 11)	75-69-4	3.0E-01	I			7.0E-01	H				
Trichlorophenol, 2,4,5-	95-95-4	1.0E-01	I								
Trichlorophenol, 2,4,6-	88-06-2			1.1E-02	I			3.1E-06	I	1.1E-02	calc
Trichlorophenoxy)propionic acid, 2-(2,4,5- (Silvex)	93-72-1	8.0E-03	I								
Trichlorophenoxyacetic acid, 2,4,5-	93-76-5	1.0E-02	I								
Trichloropropane, 1,2,3-	96-18-4	6.0E-03	I	7.0E+00	H	5.0E-03	SF				
Triethylamine	121-44-8					7.0E-03	I				
Trinitrobenzene, sym- (1,3,5-Trinitrobenzene)	99-35-4	3.0E-02	I								
Tris(2,3- dibromopropyl)phosphate	126-72-7			9.8E+00	RQ						
Vanadium	7440-62-2	7.0E-03	H								
Vinyl acetate	108-05-4	1.0E+00	H			2.0E-01	I				
Vinyl chloride	75-01-4	3.0E-03	I	7.2E-01	I	1.0E-01	I	4.4E-06	I	1.5E-02	calc
Xylene, p-	106-42-3	2.0E+00	surr (H)			4.0E-01	surr (A)				

Table E-3. Human Health Benchmark Values (continued)

Constituent Name	CASRN	RfD (mg/kg-d)	RfD Ref	CSFo (per mg/kg-d)	CSFo Ref	RfC (mg/m3)	RfC Ref	URF (per g/m3)	URF Ref	CSFi (per mg/kg-d)	CSFi Ref
Xylene, m-	108-38-3	2.0E+00	H			4.0E-01	surr (A)				
Xylene, o-	95-47-6	2.0E+00	H			4.0E-01	surr (A)				
Xylenes (total)	1330-20-7	2.0E+00	I			4.0E-01	A				
Zinc	7440-66-6	3.0E-01	I								

Key:

CASRN = Chemical Abstract Service registry number.

CSFo = oral cancer slope factor.

CSFi = inhalation cancer slope factor.

RfD = reference dose.

RfC = reference concentration.

URF = unit risk factor.

^a Sources:

A = ATSDR MRLs (ATSDR, 2001)

AC = developed for the Air Characteristic Study (U.S. EPA, 1999g)

calc = calculated

H = HEAST (U.S. EPA, 1997)

I = IRIS (U.S. EPA, 2001a)

RQ = reportable quantity adjustments (U.S. EPA, 1998d,e,f)

SF = Superfund Risk Issue Paper (U.S. EPA, 1998a,b; 1999a,b,c,d,e,f; 2000, 2001b,c,d)

C99a = CalEPA cancer potency factor (CalEPA, 1999a)

C99b = CalEPA chronic REL (CalEPA, 1999b)

C00 = CalEPA chronic REL (CalEPA, 2000)

DA85 = Dioxin Assessment (U.S. EPA, 1985)

solv = 63 FR 64371-0402 (U.S. EPA, 1998c)

surr = surrogate (source in parentheses; see section C.2.8)

TEF = toxicity equivalency factor (U.S. EPA, 1993)

WHO98 = World Health Organization (WHO) 1998 toxicity equivalency factor scheme (Van den Berg et al., 1998)

EPA86 = Pyridine Health Effects Profile (U.S. EPA, 1986b)

HAD = Health Assessment Document (U.S. EPA, 1986a, 1987)

E-3.2.1 Benzene

The cancer risk estimates for benzene are provided as ranges in IRIS. The oral CSF for benzene is $1.5\text{E-}02$ to $5.5\text{E-}02$ (mg/kg/d)⁻¹ and the inhalation URF is $2.2\text{E-}06$ to $7.8\text{E-}06$ ($\mu\text{g/m}^3$)⁻¹ (U.S. EPA, 2001a). For IWEM, the upper range estimates were used (i.e., $5.5\text{E-}02$ (mg/kg/d)⁻¹ and $7.8\text{E-}06$ ($\mu\text{g/m}^3$)⁻¹ for the oral CSF and inhalation URF, respectively).

E-3.2.2 Vinyl Chloride

Based on use of the linearized multistage model, IRIS recommends an oral CSF of $7.2\text{E-}1$ per mg/kg-d for vinyl chloride to account for continuous lifetime exposure during adulthood; this value was used in the IWEM tool.¹ Based on use of the linearized multistage model, an inhalation URF of $4.4\text{E-}6$ per $\mu\text{g/m}^3$ to account for continuous, lifetime exposure during adulthood was recommended for vinyl chloride and was used for IWEM; an inhalation CSF of $1.5\text{E-}2$ per mg/kg-d was calculated from the URF.²

E-3.2.3 Polychlorinated Biphenyls

There are two inhalation CSFs available from IRIS for polychlorinated biphenyls (PCBs): 0.4 per mg/kg-d for evaporated congeners and 2.0 per mg/kg-d for dust or aerosol (high risk and persistence). The inhalation CSF for evaporated congeners was used for IWEM.

E-3.2.4 Dioxin-like Compounds

Certain polychlorinated dibenzodioxin, polychlorinated dibenzofuran, and polychlorinated biphenyl (PCB) congeners are said to have “dioxin-like” toxicity, meaning that they are understood to have toxicity similar to that of 2,3,7,8-tetrachlorodibenzo(p)dioxin (2,3,7,8-TCDD). Although EPA has not developed health benchmarks for each specific compound with dioxin-like toxicity, these compounds have been assigned individual “toxicity equivalency factors” (TEFs; Van den Berg et al., 1998). TEFs are estimates of the toxicity of dioxin-like compounds relative to the toxicity of 2,3,7,8-TCDD, which is assigned a TEF of 1.0. TEF estimates are based on a

¹A twofold increase of the oral CSF to 1.4 per mg/kg-d to account for continuous lifetime exposure from birth was also recommended but was not used for IWEM.

²A twofold increase to $8.8\text{E-}6$ per $\mu\text{g/m}^3$ for the inhalation URF, to account for continuous lifetime exposure from birth, was also recommended but was not used for IWEM.

knowledge of a constituent's mechanism of action, available experimental data, and other structure-activity information. We used the TEFs to calculate cancer slope factors for the dioxin and furan congeners (and congener groups) in the IWEM tool.

The dioxin-like congeners (and groups of congeners) included in IWEM are as follows:

- # 2,3,7,8-TCDD,
- # 2,3,7,8-Tetrachlorodibenzofuran (2,3,7,8-TCDF)
- # Pentachlorodibenzodioxins (PeCDDs)
- # Pentachlorodibenzofurans (PeCDFs)
- # Hexachlorodibenzodioxins (HxCDDs)
- # Hexachlorodibenzofurans (HxCDFs).

2,3,7,8-TCDF has a TEF of 0.1. The dioxin-like PeCDD congener is 1,2,3,7,8-PeCDD, which has a TEF of 1.0. The dioxin-like PeCDF congeners include 1,2,3,7,8-PeCDF and 2,3,4,7,8-PeCDF which have TEFs of 0.05 and 0.5, respectively. The dioxin-like HxCDD congeners include 1,2,3,7,8,9-HxCDD, 1,2,3,4,7,8-HxCDD, and 1,2,3,6,7,8-HxCDD, which have TEFs of 0.1. The dioxin-like HxCDF congeners include 1,2,3,7,8,9-HxCDF, 1,2,3,4,7,8-HxCDF, 1,2,3,6,7,8-HxCDF, and 2,3,4,6,7,8-HxCDF, which also have TEFs of 0.1. Table E-4 shows the TEFs that we used to calculate CSFs for the dioxin and furan congeners (and congener groups) for the purpose of developing HBNs for the Tier 1 tool.

Table E-4. TEFs Used for Dioxin and Furan Congeners

Constituent Name	TEF	CSFo (mkd) ⁻¹	CSFo Source	URF (:g/m ³) ⁻¹	URF Source	CSFi (mkd) ⁻¹	CSFi Source
Dioxins							
Pentachlorodibenzodioxins	1	1.56+05	WHO 1998	3.3E+01	WHO 1998	1.56+05	WHO 1998
2,3,7,8-TCDD	1	1.56+5	EPA, 1985	3.3E+01	EPA, 1997	1.56+5	EPA, 1985
Hexachlorodibenzodioxins	0.1	1.56+4	WHO 1998	3.3E+00	WHO 1998	1.56+4	WHO 1998
Furans							
Hexachlorodibenzofurans	0.1	1.56+4	WHO 1998	3.3E+00	WHO 1998	1.56+4	WHO 1998
Pentachlorodibenzofurans	0.5	7.8+4	WHO 1998	1.7E+01	WHO 1998	7.8+4	WHO 1998
2,3,7,8-TCDF	0.1	1.56+4	WHO 1998	3.3E+00	WHO 1998	1.56+4	WHO 1998

WHO 98 = TEFs presented in Van den Berg et al. (1998)

EPA, 1997 = HEAST (U.S. EPA, 1997).

The human health benchmarks calculated using the TEFs for 1,2,3,4,7,8-hexachlorodibenzo-p-dioxin and 1,2,3,4,7,8-hexachlorodibenzofuran were surrogates for hexachlorodibenzo-p-dioxins (HxCDDs) and hexachlorodibenzofurans (HxCDFs), respectively. The human health benchmarks for 1,2,3,7,8-pentachlorodibenzo-p-dioxin and 2,3,4,7,8-pentachlorodibenzofuran were used to represent pentachlorodibenzodioxins (PeCDDs) and pentachlorodibenzofurans (PeCDFs), respectively. The human health benchmarks for 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD) and 2,3,7,8-tetrachlorodibenzofuran were used to represent tetrachlorodibenzo-p-dioxins (TCDDs) and tetrachlorodibenzofurans (TCDFs), respectively. When TEFs varied within a class of dioxin-like compounds (i.e., pentachlorodibenzofurans), the TEF most protective of human health was used.

E-3.2.5 Superfund Technical Support Center Provisional Benchmarks

Table E-5 lists the provisional human health benchmarks from the Superfund Technical Support Center that were used for some of the IWEM constituents. A provisional subchronic RfC of $2.0\text{E-}2 \text{ mg/m}^3$ was developed by the Superfund Technical Support Center (U.S. EPA, 1999a) for carbon tetrachloride; a provisional chronic RfC of $7.0\text{E-}3 \text{ mg/m}^3$ was derived from this value by applying an uncertainty factor of 3 to account for the use of a subchronic study.

Table E-5. Provisional Human Health Benchmarks Developed by the Superfund Technical Support Center

CASRN	Chemical Name	Benchmark Type	Benchmark Value	Units	Reference
108-90-7	Chlorobenzene	RfC	$6.0\text{E-}02$	mg/m^3	U.S. EPA, 1998a
7440-48-4	Cobalt (and compounds)	RfD	$2.0\text{E-}02$	mg/kg-d	U.S. EPA, 2001b
100-41-4	Ethylbenzene	URF	$1.1\text{E-}06$	$(\text{:g/m}^3)^{-1}$	U.S. EPA, 1999b
87-68-3	Hexachlorobutadiene	RfD	$3.0\text{E-}04$	mg/kg-d	U.S. EPA, 1998b
110-54-3	Hexane	RfD	$1.1\text{E+}01$	mg/kg-d	U.S. EPA, 1999c
62-75-9	N-Nitrosodimethylamine (N-methyl-N-nitroso-methanamine)	RfD	$8.0\text{E-}06$	mg/kg-d	U.S. EPA, 2001c
86-30-6	N-Nitrosodiphenylamine	RfD	$2.0\text{E-}02$	mg/kg-d	U.S. EPA, 2001d
79-34-5	Tetrachloroethane, 1,1,2,2-	RfD	$6.0\text{E-}02$	mg/kg-d	U.S. EPA, 2000
71-55-6	Trichloroethane, 1,1,1-	RfD	$2.8\text{E-}01$	mg/kg-d	U.S. EPA, 1999d
71-55-6	Trichloroethane, 1,1,1-	RfC	$2.2\text{E+}00$	mg/m^3	U.S. EPA, 1999e
96-18-4	Trichloropropane, 1,2,3-	RfC	$5.0\text{E-}03$	mg/m^3	U.S. EPA, 1999f

E-3.2.6 Benchmarks From Other EPA Sources

For some IWEM constituents, human health benchmarks were not available from IRIS, the Superfund Technical Support Center, HEAST, ATSDR, or CalEPA, but were available from other EPA sources:

- # The provisional oral CSF of $5.2\text{E-}2$ per mg/kg-d, provisional inhalation URF of $5.8\text{E-}7$ per $\mu\text{g}/\text{m}^3$, and the provisional inhalation CSF of $2.0\text{E-}3$ per mg/kg-d developed for tetrachloroethylene by EPA in a Health Assessment Document (HAD) (U.S. EPA, 1986a) were used.
- # For trichloroethylene, provisional cancer benchmarks developed by EPA in a HAD (U.S. EPA, 1987) were used and include the oral CSF of $1.1\text{E-}2$ per mg/kg-d, inhalation URF of $1.7\text{E-}6$ per $\mu\text{g}/\text{m}^3$, and inhalation CSF of $6.0\text{E-}3$ per mg/kg-d.
- # A provisional RfD of $1.7\text{E-}5$ mg/kg-d and a provisional RfC of $2.0\text{E-}5$ mg/m^3 were derived for cyclohexanol in the final listing rule for solvents (63 FR 64371) and were used (U.S. EPA, 1998c).
- # An acceptable daily intake (ADI) of $2.0\text{E-}03$ mg/kg-d from inhalation ($7.0\text{E-}3$ mg/m^3) was identified for pyridine (U.S. EPA, 1986b).
- # EPA calculated an oral cancer potency factor of 293 per mg/kg-d for ethyl methanesulfonate in a reportable quantity adjustment evaluation (U.S. EPA, 1998d).
- # EPA calculated an oral cancer potency factor of 0.18 per mg/kg-d for safrole in a reportable quantity adjustment evaluation (U.S. EPA, 1998e).
- # EPA calculated an oral cancer potency factor of 9.8 per mg/kg-d for tris(2,3-dibromopropyl)phosphate in a reportable quantity adjustment evaluation (U.S. EPA, 1998f).
- # The cancer slope factor for dibenzo(a,h)anthracene was calculated using a TEF approach developed for polycyclic aromatic hydrocarbons (U.S. EPA, 1993). The TEF approach assigns dibenzo(a,h)anthracene a TEF of 1 relative to the toxicity of benzo(a)pyrene. The oral CSF for dibenzo(a,h)anthracene is therefore the same as the IRIS (U.S. EPA, 2001a) value for benzo(a)pyrene: $7.3\text{E+}00$ $(\text{mg}/\text{kg-d})^{-1}$.

E-3.2.7 Air Characteristic Study Provisional Benchmarks

Provisional inhalation health benchmarks were developed in the Air Characteristic Study (U.S. EPA, 1999g) for several constituents lacking IRIS, HEAST, alternative EPA, or ATSDR values. For 2-chlorophenol, a provisional RfC was developed using route-to-route extrapolation of the oral RfD. Using route-to-route extrapolations based on oral CSFs from IRIS and HEAST, the Air Characteristic Study developed provisional inhalation URFs and inhalation CSFs for bromodichloromethane, chlorodibromomethane, and o-Toluidine.

These provisional inhalation benchmark values are summarized in Table E-6 below. Additional details on the derivation of these inhalation benchmarks can be found in the Revised Risk Assessment for the Air Characteristic Study (U.S. EPA, 1999g).

Table E-6. Provisional Inhalation Benchmarks Developed in the Air Characteristic Study

CASRN	Chemical Name	RfC (mg/m ³)	RfC Target Effect	URF (:g/m ³) ⁻¹	CSFi (mg/kg-d) ⁻¹
75-27-4	Bromodichloromethane (dichlorobromomethane)			1.8E-05	6.2E-02
124-48-1	Chlorodibromomethane (dibromochloromethane)			2.4E-05	8.4E-02
95-57-8	2-Chlorophenol (o-)	1.4E-03	Reproductive, developmental		
95-53-4	o-Toluidine (2-methylaniline)			6.9E-05	2.4E-01

E-3.2.8 Surrogate Health Benchmarks

For several IWEM constituents, IRIS benchmarks for similar chemicals were used as surrogate data. The rationale for these recommendations is as follows:

- # cis-1,3-Dichloropropylene and trans-1,3-dichloropropylene were based on 1,3-dichloropropene. The studies cited in the IRIS file for 1,3-dichloropropene used a technical-grade chemical that contained about a 50/50 mixture of the cis- and trans-isomers. The RfD is 3E-02 mg/kg-d and the RfC is 2E-02 mg/m³. The oral CSF for 1,3-dichloropropene is 0.1 (mg/kg-d)⁻¹ and the inhalation URF is 4E-06 (µg/m³)⁻¹.

- # The IRIS oral CSF for the 2,4-/2,6-dinitrotoluene mixture (6.8E-01 per mg/kg-d) was used as the oral CSFs for 2,4-dinitrotoluene and 2,6-dinitrotoluene.
- # The RfDs for o- and m-cresol (both 5E-02 mg/kg/d) are cited on IRIS. The provisional RfD for p-cresol (5E-03 mg/kg/d) is from HEAST. Cresol mixtures contain all three cresol isomers. Based on the hierarchy described above (i.e., IRIS is preferred over HEAST because IRIS is EPA's official repository of Agency-wide consensus human health risk information), the RfD for m-cresol (5E-02 mg/kg-d) was used as a surrogate for cresol mixtures.
- # Fluoride was based on fluorine. The IRIS RfD for fluorine (0.12 mg/kg-d) is based on soluble fluoride and related to the endpoint of skeletal fluorosis.
- # The RfD for methyl mercury (1E-04 mg/kg-d) was used as a surrogate for elemental mercury.
- # The RfD for Arochlor 1254 (2E-05 mg/kg-d) was used as a surrogate for PCBs.
- # Thallium was based on thallium chloride. There are several thallium salts that have RfDs in IRIS. The lowest value among the thallium salts (8E-05 mg/kg-d) is routinely used to represent thallium in risk assessments.
- # p-Xylene was based on total xylenes. An RfD of 2 mg/kg-d is listed for total xylenes, m-xylene, and o-xylene in IRIS. Total xylenes contain a mixture of all three isomers; therefore, the RfD likely is appropriate for p-xylene.

E-3.2.9 Chloroform

EPA has classified chloroform as a Group B2, Probable Human Carcinogen, based on an increased incidence of several tumor types in rats and mice (U.S. EPA, 2001a). However, based on an evaluation initiated by EPA's Office of Water (OW), the Office of Solid Waste (OSW) now believes the weight of evidence for the carcinogenic mode of action for chloroform does not support a mutagenic mode of action; therefore, a nonlinear low-dose extrapolation is more appropriate for assessing risk from exposure to chloroform. EPA's Science Advisory Board (SAB), the World Health Organization (WHO), the Society of Toxicology, and EPA all strongly endorse the nonlinear approach for assessing risks from chloroform.

Although OW conducted its evaluation of chloroform carcinogenicity for oral exposure, a nonlinear approach for low-dose extrapolation would apply to inhalation exposure to chloroform as well, because chloroform's mode of action is understood to be the same for both ingestion and inhalation exposures. Specifically, tumorigenesis for both ingestion and inhalation exposures is induced through cytotoxicity (cell death) produced by the oxidative generation of highly reactive metabolites (phosgene and hydrochloric acid), followed by regenerative cell proliferation (U.S. EPA, 1998g). Chloroform-induced liver tumors in mice have only been seen after bolus corn oil dosing and have not been observed following administration by other routes (i.e., drinking water and inhalation). As explained in EPA OW's March 31, 1998, and December 16, 1998, Federal Register notices pertaining to chloroform (U.S. EPA, 1998g and 1998h, respectively), EPA now believes that "based on the current evidence for the mode of action by which chloroform may cause tumorigenesis, ...a nonlinear approach is more appropriate for extrapolating low-dose cancer risk rather than the low-dose linear approach..." (U.S. EPA, 1998g). OW determined that, given chloroform's mode of carcinogenic action, liver toxicity (a noncancer health effect) actually "is a more sensitive effect of chloroform than the induction of tumors" and that protecting against liver toxicity "should be protective against carcinogenicity given that the putative mode of action understanding for chloroform involves cytotoxicity as a key event preceding tumor development" (U.S. EPA, 1998g).

The recent evaluations conducted by OW concluded that protecting against chloroform's noncancer health effects protects against excess cancer risk. EPA now believes that the noncancer health effects resulting from inhalation of chloroform would precede the development of cancer and would occur at lower doses than would tumor development. Although EPA has not finalized a noncancer health benchmark for inhalation exposure (i.e., an RfC), ATSDR has developed an inhalation MRL for chloroform. Therefore, ATSDR's chronic inhalation MRL for chloroform (0.1 mg/m³) was used in IWEM.

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APPENDIX F

TIER 1 LCTV TABLES

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Common Name	CAS#	MCL (mg/L)	HBN (mg/L)				Peak DAF	LCTV based on MCL (mg/L)	No Liner/In-Situ Soil					
			Ingestion	Inhalation		Non-Carcinogenic Effect (NC)			Carcinogenic Effect (C)					
				NC	C	NC			C	7-yr Avg DAF	LCTV based on Ingestion	LCTV based on Inhalation	30-yr Avg DAF	LCTV based on Ingestion
Acenaphthene	83-32-9		1.47E+00				2.2		2.2	3.3		2.2		
Acetaldehyde [Ethanal]	75-07-0				2.20E-01	4.10E-02	2.2		2.2		0.49	2.2		0.091
Acetone (2-propanone)	67-64-1		2.45E+00		1.50E+03		2.2		2.2	5.4	1.0E+03 ^b	2.2		
Acetonitrile (methyl cyanide)	75-05-8				3.10E+00		2.2		2.2		6.9	2.2		
Acetophenone	98-86-2		2.45E+00				2.2		2.2	5.4		2.2		
Acrolein	107-02-8		4.90E-01		3.30E-04		1.0E+30		1.0E+30	1.0E+03 ^b	1.0E+03 ^b	1.0E+30		
Acrylamide	79-06-1		4.90E-03	2.15E-05		5.10E+00	2.6		2.6	0.013		2.6	5.5E-05	13
Acrylic acid [propenoic acid]	79-10-7		1.22E+01		1.50E+01		2.2		2.2	27	33	2.2		
Acrylonitrile	107-13-1		2.45E-02	1.79E-04	3.80E-02	1.00E-03	2.3		2.3	9.4E-03 ^d	0.088	2.3	4.1E-05 ^d	2.3E-03
Aldrin	309-00-2		7.34E-04	5.68E-06		1.00E-05	1.3E+05		1.3E+05	97 ^e		1.4E+05	0.77 ^c	1.4 ^c
Allyl alcohol	107-18-6		1.22E-01				2.2		2.2	0.27		2.2		
Aniline (benzeneamine)	62-53-3			1.69E-02	9.30E-01	2.20E+00	2.2		2.2		2.1	2.2	0.037	4.9
Anthracene	120-12-7		7.34E+00				2.3		2.3	17 ^e		2.3		
Antimony	7440-36-0	6.00E-03	9.79E-03					0.014		0.023				
Arsenic	7440-38-2	5.00E-02	7.34E-03	6.44E-05				0.11		0.016			1.9E-04	
Barium	7440-39-3	2.00E+00	1.71E+00					4.3		3.8				
Benz[a]anthracene	56-55-3			8.05E-05		1.80E-02	5.3		5.4			5.4	4.3E-04	0.097 ^c
Benzene	71-43-2	5.00E-03		1.76E-03	1.90E-01	1.60E-03	2.2	0.011	2.2		0.42	2.2	3.9E-03	3.6E-03
Benzidine	92-87-5		7.34E-02	4.20E-07		2.60E+00	2.2		2.2	0.2		2.2	9.3E-07	5.7
Benzo[a]pyrene	50-32-8	2.00E-04		1.32E-05		5.40E-03	58	0.012 ^c	59			59	7.8E-04	0.32 ^c
Benzo[b]fluoranthene	205-99-2			8.05E-05		6.30E-04	59		59			59	4.8E-03 ^c	0.037 ^c
Benzyl alcohol	100-51-6		7.34E+00				2.2		2.2	16		2.2		
Benzyl chloride	100-44-7			5.68E-04		5.20E-04	1.0E+30		1.0E+30	19 ^e		1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Beryllium	7440-41-7	4.00E-03	4.90E-02					0.026		0.14				
Bis(2-chloroethyl)ether	111-44-4			8.78E-05		1.10E-03	6.8		6.8		1.0E+03 ^e	6.8	6.00E-04	7.50E-03
Bis(2-chloroisopropyl)ether	39638-32-9		9.79E-01	1.38E-03		5.90E-03	2.2		2.2	2.2		2.2	3.10E-03	0.013
Bis(2-ethylhexyl)phthalate	117-81-7	6.00E-03	4.90E-01	6.90E-03	1.80E+02	2.80E+01	1.0E+30	1.0E+03 ^{b,c}	1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}	1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Bromodichloromethane	75-27-4	8.00E-02	4.90E-01	1.56E-03		8.00E-04	2.5	0.2	2.5	1.2		2.5	3.9E-03	2.0E-03
Bromomethane	74-83-9		3.43E-02		1.50E-02		2.1E+07		2.1E+07	80 ^e	1.0E+03 ^b	2.1E+07		
Butadiene 1, 3-	106-99-0				6.00E-02	4.00E-05	2.2		2.2		0.13	2.2		8.9E-05
Butanol n-	71-36-3		2.45E+00				2.2		2.2	5.4		2.2		
Butyl benzyl phthalate	85-68-7		4.90E+00				2.7		2.7	13 ^e		2.7		
Butyl-4,6-dinitrophenol,2-sec-(Dinoseb)	88-85-7	7.00E-03	2.45E-02				2.2	0.015	2.2	0.054		2.2		
Cadmium	7440-43-9	5.00E-03	1.22E-02					0.011		0.027				
Carbon disulfide	75-15-0		2.45E+00		1.90E+00		2.4		2.4	5.9	4.6	2.4		
Carbon tetrachloride	56-23-5	5.00E-03	0.0171	7.43E-04	0.021	7.60E-04	2.8	0.014	2.8	0.048	0.059	2.8	2.1E-03	2.2E-03
Chlordane	57-74-9	2.00E-03	0.0122	2.76E-04	2.80E-02	1.50E-03	160	0.030 ^a	160	0.030 ^a	0.030 ^a	160	0.030 ^a	0.030 ^a
Chloro-1,3-butadiene 2-(Chloroprene)	126-99-8		4.90E-01		2.20E-02		2.2		2.2	1.1	0.049	2.2		
Chloroaniline p-	106-47-8		9.79E-02				2.2		2.2	0.22		2.2		
Chlorobenzene	108-90-7	1.00E-01	4.90E-01		2.00E-01		2.2	0.22	2.2	1.1	0.44	2.2		
Chlorobenzilate	510-15-6		4.90E-01	3.58E-04		1.20E+00	5.8		5.8	2.8		5.8	2.1E-03	6.9
Chlorodibromomethane	124-48-1	8.00E-02	4.90E-01	1.15E-03		7.50E-04	2.4	0.19	2.4	1.2		2.4	2.7E-03	1.8E-03
Chloroethane [Ethyl chloride]	75-00-3				3.00E+01		2.2		2.2		66	2.2		
Chloroform	67-66-3	8.00E-02	2.45E-01		3.30E-01		2.3	0.18	2.3	0.55	0.74	2.3		
Chloromethane	74-87-3			7.43E-03	2.60E-01	5.90E-03	2.2		2.2		0.57	2.2	0.016	0.013
Chlorophenol 2-	95-57-8		1.22E-01		9.70E-03		2.2		2.2	0.27	0.022	2.2		
Chloropropene 3- (Allyl Chloride)	107-05-1				3.00E-03	1.90E-03	1.0E+30		1.0E+30		1.0E+03 ^b	1.0E+30		1.0E+03 ^b
Chromium (III) (Chromic Ion)	16065-83-1	1.00E-01	3.67E+01					0.31		81				
Chromium (VI)	18540-29-9	1.00E-01	7.34E-02					0.25		0.19				
Chrysene	218-01-9			8.05E-04		7.30E-03	5.3		5.4			5.4	4.3E-03 ^c	0.039 ^c

KEY:

- a - TC Rule cap
b - 1,000 mg/L cap
c - Exceeds solubility
d - Capped by daughter LCTV
e - Constituent has no RGC; LCTV from daughter

Table F-1: Landfill No-Liner LCTVs

Common Name	CAS#	MCL (mg/L)	HBN (mg/L)				Peak DAF	LCTV based on MCL (mg/L)	No Liner/In-Situ Soil					
			Ingestion		Inhalation				Non-Carcinogenic Effect (NC)			Carcinogenic Effect (C)		
			NC	C	NC	C			7-yr Avg DAF	LCTV based on Ingestion	LCTV based on Inhalation	30-yr Avg DAF	LCTV based on Ingestion	LCTV based on Inhalation
Cobalt	7440-48-4		4.90E-01						1.1					
Copper	7440-50-8	1.30E+00					3							
Cresol m-	108-39-4		1.22E+00		1.20E+03		2.2		2.2	2.7	200 ^a	2.2		
Cresol o-	95-48-7		1.22E+00		8.80E+02		2.2		2.2	2.7	200 ^a	2.2		
Cresol p-	106-44-5		1.22E-01		1.30E+03		2.2		2.2	0.27	200 ^a	2.2		
Cresols	1319-77-3		1.22E+00		1.10E+03		2.2		2.2	2.7	1.0E+03 ^b	2.2		
Cumene	98-82-8		2.45E+00		1.30E+00		2.2		2.2	5.5	2.9	2.2		
Cyclohexanol	108-93-0		4.16E-04		3.90E-04		2.2		2.2	9.2E-04	8.6E-04	2.2		
Cyclohexanone	108-94-1		1.22E+02				2.2		2.2	270		2.2		
DDD	72-54-8			4.02E-04			1.0E+30		1.0E+30			1.0E+30	1.0E+03 ^{b,c}	
DDE	72-55-9			2.84E-04			1.8E+13		1.8E+13			1.8E+13	1.0E+03 ^{b,c}	
DDT p,p'-	50-29-3		1.22E-02	2.84E-04		8.80E-03	1.0E+30		1.0E+30	1.0E+03 ^{b,c}		1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Diallate	2303-16-4			1.58E-03			8.0E+03		8.0E+03			8.0E+03	13	
Dibenz{a,h}anthracene	53-70-3			1.32E-05		3.80E-01	1.2E+10		1.2E+10			1.2E+10	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Dibromo-3-chloropropane 1,2-	96-12-8	2.00E-04		6.90E-05	2.90E-03	7.90E-02	2.8	5.5E-04	2.8		8.0E-03	2.8	1.9E-04	0.22
Dichlorobenzene 1,2-	95-50-1	6.00E-01	2.20E+00		7.70E-01		2.2	1.3	2.2	4.9	1.7	2.2		
Dichlorobenzene 1,4-	106-46-7	7.50E-02		4.02E-03	3.00E+00	1.30E-03	2.2	0.17	2.2		6.7	2.2	8.9E-03	2.9E-03
Dichlorobenzidine 3,3'-	91-94-1			2.15E-04		4.90E+00	2.2		2.2			2.2	4.8E-04	11 ^e
Dichlorodifluoromethane (Freon 12)	75-71-8		4.90E+00		5.80E-01		2.2		2.2	11	1.3	2.2		
Dichloroethane 1,1-	75-34-3		2.45		1.6	7.40E-03	2.5	9.9E-03 ^e	2.5	0.36 ^d	0.45 ^d	2.5	6.7E-04 ^e	0.012 ^d
Dichloroethane 1,2-	107-06-2	5.00E-03		1.06E-03	1.00E+01	6.30E-04	2.5	7.0E-03 ^d	2.5	0.26 ^e	0.32 ^d	2.5	4.7E-04 ^d	1.5E-03
Dichloroethylene cis-1,2-	156-59-2	7.00E-02	2.45E-01				2.2	0.15	2.2	0.54		2.2		
Dichloroethylene trans-1,2-	156-60-5	1.00E-01	4.90E-01				2.2	0.22	2.2	1.1		2.2		
Dichloroethylene 1,1-	75-35-4	7.00E-03	2.20E-01	1.61E-04	2.10E-01	2.20E-04	2.2	0.016	2.2	0.49	0.47	2.2	3.6E-04	4.9E-04
Dichlorophenol 2,4-	120-83-2		7.34E-02				2.2		2.2	0.16		2.2		
Dichlorophenoxyacetic acid 2,4-(2,4-D)	94-75-7	7.00E-02	2.45E-01				2.2	0.15	2.2	0.54		2.2		
Dichloropropane 1,2-	78-87-5	5.00E-03	2.20E+00	1.42E-03	1.40E-02		3.2	0.016	3.2	7	0.044	3.2	4.5E-03	
Dichloropropene 1,3-(mixture of isomers)	542-75-6		7.34E-01	9.66E-04	6.10E-02	2.90E-03	2.2		2.2	1.6	0.13	2.2	2.1E-03	6.4E-03
Dichloropropene cis-1,3-	10061-01-5		7.34E-01	9.66E-04	7.00E-02	3.30E-03	1.0E+30		1.0E+30	1.0E+03 ^b	1.0E+03 ^b	1.0E+30	1.0E+03 ^b	1.0E+03 ^b
Dichloropropene trans-1,3-	10061-02-6		7.34E-01	9.66E-04	7.50E-02	3.50E-03	1.0E+30		1.0E+30	1.0E+03 ^b	1.0E+03 ^b	1.0E+30	1.0E+03 ^b	1.0E+03 ^b
Dieldrin	60-57-1		1.22E-03	6.04E-06		1.00E-04	1.5E+15		1.5E+15	1.0E+03 ^{b,c}		1.5E+15	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Diethyl phthalate	84-66-2		1.96E+01				2.9		2.9	58		2.9		
Diethylstilbestrol	56-53-1			2.05E-08			2.3		2.3			2.3	4.7E-08	
Dimethoate	60-51-5		4.90E-03				550		550	0.55 ^d	1.0E+03 ^b	550		
Dimethoxybenzidine 3,3'-	119-90-4			6.90E-03			2.2		2.2			2.2	0.015	
Dimethyl formamide N,N- [DMF]	68-12-2		2.45E+00		7.10E+02		2.2		2.2	5.4	1.0E+03 ^b	2.2		
Dimethylbenz{a}anthracene 7,12-	57-97-6					3.00E-03	6.5E+12		6.6E+12			6.6E+12		1.0E+03 ^{b,c}
Dimethylbenzidine 3,3'-	119-93-7			1.05E-05			2.2		2.2			2.2	2.3E-05	
Dimethylphenol 2,4-	105-67-9		4.90E-01				2.2		2.2	1.1		2.2		
Di-n-butyl phthalate	84-74-2		2.45E+00				2.8		2.8	6.7		2.8		
Dinitrobenzene 1,3-	99-65-0		2.45E-03				2.2		2.2	5.4E-03		2.2		
Dinitrophenol 2,4-	51-28-5		4.90E-02				2.2		2.2	0.11		2.2		
Dinitrotoluene 2,4-	121-14-2		4.90E-02	1.42E-04		8.12E-01	2.2		2.2	0.11		2.2	3.1E-04	0.13 ^a
Dinitrotoluene 2,6-	606-20-2		2.45E-02	1.42E-04			2.2		2.2	0.054		2.2	3.1E-04	
Di-n-octyl phthalate	117-84-0		4.90E-01				1.0E+30		1.0E+30	1.0E+03 ^{b,c}		1.00E+30		
Dioxane 1,4-	123-91-1			8.78E-03	1.09E+03	1.80E-01	2.2		2.2		1.0E+03 ^b	2.2	0.019	0.4
Diphenylamine	122-39-4		6.12E-01				2.2		2.2	1.4		2.2		
Diphenylhydrazine 1, 2-	122-66-7			1.21E-04		2.00E-02	2.2		2.2			2.2	2.70E-04	0.044
Disulfoton	298-04-4		9.79E-04				2.1E+06		2.20E+06	1.0E+03 ^{b,c}		2.20E+06		

KEY:

a - TC Rule cap

b - 1,000 mg/L cap

c - Exceeds solubility

d - Capped by daughter LCTV

e - Constituent has no RGC; LCTV from daughter

Table F-1: Landfill No-Liner LCTVs

Common Name	CAS#	MCL (mg/L)	HBN (mg/L)				No Liner/In-Situ Soil							
		Ingestion	Ingestion		Inhalation		Peak DAF	LCTV based on MCL (mg/L)	Non-Carcinogenic Effect (NC)		Carcinogenic Effect (C)			
			NC	C	NC	C			7-yr Avg DAF	LCTV based on Ingestion	LCTV based on Inhalation	30-yr Avg DAF	LCTV based on Ingestion	LCTV based on Inhalation
Endosulfan (Endosulfan I and II,mixture)	115-29-7		1.47E-01				2.2		2.2	0.33		2.2		
Endrin	72-20-8	2.00E-03	7.34E-03				7.7E+04	0.02 ^a	7.7E+04	0.020 ^a		7.7E+04		
Epichlorohydrin	106-89-8		4.90E-02	9.75E-03	6.00E-02	1.90E-01	1.0E+30		1.0E+30	1.0E+03 ^b	1.0E+03 ^b	1.0E+30	1.0E+03 ^b	1.0E+03 ^b
Epoxybutane 1, 2-	106-88-7				2.40E-01		2.2		2.2		0.53	2.2		
Ethoxyethanol 2-	110-80-5		9.79E+00		2.90E+03		2.2		2.2	22	1.0E+03 ^b	2.2		
Ethoxyethanol acetate 2-	111-15-9		7.34E+00		3.00E+02		2.2		2.2	16	660	2.2		
Ethyl acetate	141-78-6		2.20E+01				7.4		7.4	160		7.4		
Ethyl ether	60-29-7		4.9				2.2		2.2	11		2.2		
Ethyl methacrylate	97-63-2		2.20E+00				3.9		3.9	8.5		3.9		
Ethyl methanesulfonate	62-50-0			3.30E-07			1.0E+30		1.0E+30			1.0E+30	1.0E+03 ^b	
Ethylbenzene	100-41-4	7.00E-01	2.45E+00		3.30E+00	1.10E-02	2.2	1.6	2.2	5.4	7.3	2.2		0.024
Ethylene dibromide (1,2-Dibromoethane)	106-93-4	5.00E-05		1.14E-06	9.80E-04	8.40E-05	25	1.3E-03	25		0.025	25	2.9E-05	2.1E-03
Ethylene glycol	107-21-1		4.90E+01		1.20E+04		2.2		2.2	110	1.0E+03 ^b	2.2		
Ethylene oxide	75-21-8			9.47E-05	4.10E-01	5.20E-04	1.0E+30		1.0E+30		1.0E+03 ^c	1.0E+30	1.0E+03 ^c	1.0E+03 ^c
Ethylene thiourea	96-45-7		1.96E-03	8.78E-04		1.60E+03	2.2		2.2	4.3E-03		2.2	1.9E-03	1.0E+03
Fluoranthene	206-44-0		9.79E-01				2.5		2.5	2.5 ^c		2.5		
Fluoride	16984-48-8	4.00E+00	2.90E+00					8.7		6.3				
Formaldehyde	50-00-0		4.90E+00		5.10E+01	1.5	2.2		2.2	11	110	2.2		3.3
Formic acid	64-18-6		4.90E+01				2.2		2.2	110		2.2		
Furfural	98-01-1		7.34E-02		2.20E+01		2.2		2.2	0.16	49	2.2		
HCH beta-	319-85-7			5.36E-05		1.70E-02	2.2		2.2			2.2	1.2E-04	0.038
HCH (Lindane) gamma-	58-89-9	2.00E-04	7.34E-03	7.43E-05		1.60E-03	4.2E+06	0.26 ^{a,b}	4.3E+06	0.4 ^{a,b,c,d}	0.4 ^{a,b}	4.3E+06	0.4 ^{a,b}	0.4 ^{a,b}
HCH alpha-	319-84-6		0.196	1.53E-05		3.60E-04	7.4E+06	0.25 ^a	7.6E+06	0.56 ^a	3.0 ^{a,c}	7.6E+06	120	1.0E+03 ^b
Heptachlor	76-44-8	4.00E-04	1.22E-02	2.15E-05		1.50E-05	1.0E+30	8.0E-03 ^a	1.0E+30	8.0E-03 ^a		1.0E+30	8.0E-03 ^c	8.0E-03 ^c
Heptachlor epoxide	1024-57-3	2.00E-04	3.18E-04	1.06E-05		2.80E-04	3.9E+08	1.0E+03 ^{a,c}	3.9E+08	1.0E+03 ^{a,c}		3.9E+08	1.0E+03 ^b	1.0E+03 ^b
Hexachloro-1,3-butadiene	87-68-3		7.34E-03	1.24E-03		6.10E-04	2.4		2.4	0.018		2.4	3.0E-03	1.5E-03
Hexachlorobenzene	118-74-1	1.00E-03	1.96E-02	6.04E-05		3.60E-05	6.3	6.3E-03 ^c	6.3	0.12 ^c		6.3	3.8E-04	2.3E-04
Hexachlorocyclopentadiene	77-47-4	5.00E-02	1.47E-01		6.90E-04		1.0E+30	1.0E+03 ^{b,c}	1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}	1.0E+30		
Hexachlorodibenzofurans [HxCDFs]	55684-94-1			6.19E-09		1.44E-07	1.0E+30		1.0E+30			1.0E+30	1.0E+03 ^b	1.0E+03 ^b
Hexachlorodibenzo-p-dioxins [HxCDDs]	34465-46-8			6.19E-09		1.43E-07	4.6E+07		4.6E+07			4.8E+07	0.30 ^c	6.9
Hexachloroethane	67-72-1		2.45E-02	6.90E-03		3.30E-03	2.2		2.2	0.055		2.2	0.015	7.4E-03
Hexachlorophene	70-30-4		7.34E-03				3.1		3.1	0.023		3.1		
Hexane n-	110-54-3		2.69E+02		6.60E-01		2.2		2.2	600 ^c	1.5	2.2		
Hydrogen Sulfide	7783-06-4		7.34E-02				2.2		2.2	0.16		2.2		
Indeno[1,2,3-cd]pyrene	193-39-5			8.05E-05		3.80E-02	1.3E+06		1.3E+06			1.3E+06	110 ^c	1.0E+03 ^{b,c}
Isobutyl alcohol	78-83-1		7.34E+00				2.2		2.2	16		2.2		
Isophorone	78-59-1		4.90E+00	1.02E-01	5.33E+02		2.2		2.2	11	1.0E+03 ^b	2.2	0.23	
Kepone	143-50-0		1.22E-02				2.3		2.3	0.028		2.3		
Lead	7439-92-1	1.50E-02						0.037						
Manganese	7439-96-5		1.15E+00							2.5				
Mercury	7439-97-6	2.00E-03	2.45E-03		7.00E-04			5.8E-03		7.2E-03	2.1E-03			
Methacrylonitrile	126-98-7		2.45E-03		6.50E-03		2.3		2.3	5.7E-03	0.015	2.3		
Methanol	67-56-1		1.22E+01		1.54E+03		2.2		2.2	27	1.0E+03 ^b	2.2		
Methoxychlor	72-43-5	4.00E-02	1.22E-01				1.0E+30	10 ^{a,c}	1.0E+30	10 ^{a,c}		1.0E+30		
Methoxyethanol 2-	109-86-4		2.45E-02		4.40E+02		2.2		2.2	0.054	970	2.2		
Methoxyethanol acetate 2-	110-49-6		4.90E-02		5.10E+02		2.2		2.2	0.11	1.0E+03 ^b	2.2		
Methyl ethyl ketone	78-93-3		1.47E+01		3.30E+01		2.2		2.2	32	73	2.2		
Methylisobutyl ketone	108-10-1		1.96E+00		1.20E+00		2.2		2.2	4.3	2.7	2.2		

KEY:

- a - TC Rule cap d - Capped by daughter LCTV
b - 1,000 mg/L cap e - Constituent has no RGC; LCTV from daughter
c - Exceeds solubility

Table F-1: Landfill No-Liner LCTVs

Common Name	CAS#	MCL (mg/L)	HBN (mg/L)				No Liner/In-Situ Soil							
		Ingestion	Ingestion		Inhalation		Peak DAF	LCTV based on MCL (mg/L)	Non-Carcinogenic Effect (NC)			Carcinogenic Effect (C)		
			NC	C	NC	C			7-yr Avg DAF	LCTV based on Ingestion	LCTV based on Inhalation	30-yr Avg DAF	LCTV based on Ingestion	LCTV based on Inhalation
Methyl methacrylate	80-62-6		3.43E+01		5.30E+00		4.6		4.6	84 ^d	24		4.6	
Methyl parathion	298-00-0		6.12E-03				8.1E+04		8.1E+04	1.3 ^{c,d}	1.0E+03 ^e	8.1E+04		
Methyl tert-butyl ether [MTBE]	1634-04-4				1.70E+01		2.2		2.2		38	2.2		
Methylcholanthrene 3-	56-49-5					1.20E-03	1.0E+30		1.0E+30			1.0E+30		1.0E+03 ^{b,c}
Methylene bromide (Dibromomethane)	74-95-3		2.45E-01				2.2		2.2	0.54		2.2		
Methylene Chloride (Dichloromethane)	75-09-2	5.00E-03	1.47E+00	1.29E-02	1.00E+01	2.80E-02	2.2	0.011	2.2	3.3	22	2.2	0.029	0.063
Molybdenum	7439-98-7		1.22E-01							0.28				
Naphthalene	91-20-3		4.90E-01		1.90E-02		2.2		2.2	1.1	0.042	2.2		
Nickel	7440-02-0		4.90E-01							1.1				
Nitrobenzene	98-95-3		1.22E-02		1.50E-01		2.2		2.2	0.027	0.33	2.2		
Nitropropane 2-	79-46-9				3.30E-01	2.30E-05	2.2		2.2		0.73	2.2		5.1E-05
Nitrosodiethylamine N-	55-18-5			6.44E-07		4.30E-05	2.2		2.2			2.2	1.4E-06	9.5E-05
Nitrosodimethylamine N-	62-75-9		1.96E-04	1.89E-06		4.00E-04	2.2		2.2	4.30E-04		2.2	4.2E-06	8.8E-04
Nitroso-di-n-butylamine N-	924-16-3			1.79E-05		2.00E-05	2.2		2.2			2.2	4.0E-05	4.4E-05
Nitroso-di-n-propylamine N-	621-64-7			1.38E-05		1.50E-03	2.2		2.2			2.2	3.0E-05	3.3E-03
Nitrosodiphenylamine N-	86-30-6		4.90E-01	1.97E-02		5.20E-01	2.2		2.2	1.1		2.2	0.044	1.2
Nitrosomethylethylamine N-	10595-95-6			4.39E-06		4.50E-03	2.2		2.2			2.2	9.7E-06	9.9E-03
Nitrosopiperidine N-	100-75-4					8.70E-03	2.2		2.2			2.2		0.019
Nitrosopyrrolidine N-	930-55-2			4.60E-05		9.20E-01	2.2		2.2			2.2	1.0E-04	2
Octamethyl pyrophosphoramidate	152-16-9		4.90E-02				2.3		2.3	0.11		2.3		
Parathion (ethyl)	56-38-2		0.147				1.1E+09		1.2E+09	1.0E+03 ^{b,c}		1.2E+09		
Pentachlorobenzene	608-93-5		1.96E-02				6.1		6.1	0.12		6.1		
Pentachlorodibenzofurans [PeCDFs]	30402-15-4			1.24E-09		6.29E-08	3		3			3	3.7E-09	1.9E-07
Pentachlorodibenzo-p-dioxins [PeCDDs]	36088-22-9			6.19E-10		6.00E-08	4.4E+06		4.5E+06			4.5E+06	2.8E-03 ^c	0.27 ^c
Pentachloronitrobenzene (PCNB)	82-68-8		7.34E-02	3.71E-04			2.5		2.5	0.18		2.5	9.2E-04	
Pentachlorophenol	87-86-5	1.00E-03	7.34E-01	8.05E-04		5.40E+01	2.2	2.2E-03	2.2	1.6		2.2	1.8E-03	100 ^a
Phenol	108-95-2		1.47E+01		9.00E+02		2.2		2.2	32	1.0E+03 ^b	2.2		
Phenyl mercuric acetate	62-38-4		1.96E-03				2.2		2.2	4.3E-03		2.2		
Phenylenediamine 1,3-	108-45-2		1.47E-01				2.2		2.2	0.32		2.2		
Phorate	298-02-2		4.90E-03				1.00E+30		1.0E+30	1.0E+03 ^{b,c}		1.0E+30		
Phthalic anhydride	85-44-9		4.90E+01		1.30E+04		1.00E+30		1.0E+30	1.0E+03 ^b	1.0E+03 ^b	1.0E+30		
Polychlorinated biphenyls (Aroclors)	1336-36-3	5.00E-04	4.90E-04	2.41E-04		1.40E-04	1.70E+05	83 ^c	1.7E+05	82 ^c		1.7E+05	40 ^c	23 ^c
Pronamide	23950-58-5		1.84E+00				2.3		2.3	4.2		2.3		
Propylene oxide [1,2-Epoxypropane]	75-56-9			4.02E-04	4.90E-01	1.70E-02	2.2		2.2		1.1	2.2	8.9E-04	0.038
Pyrene	129-00-0		7.34E-01				2.9		2.9	2.2 ^c		2.9		
Pyridine	110-86-1		2.45E-02		1.40E+00		2.2		2.2	0.054	3.1	2.2		
Safrole	94-59-7			5.36E-04			2.2		2.2			2.2	1.2E-03	
Selenium	7782-49-2	5.00E-02	1.22E-01					0.12		0.3				
Silver	7440-22-4		1.22E-01							0.37				
Strychnine and salts	57-24-9		7.34E-03				2.2		2.2	0.016		2.2		
Styrene	100-42-5	1.00E-01	4.90E+00		3.60E+00		2.2	0.22	2.2	11	8	2.2		
Tetrachlorobenzene 1,2,4,5-	95-94-3		7.34E-03				2.3		2.3	0.017		2.3		
Tetrachlorodibenzofuran, 2,3,7,8-	51207-31-9			6.19E-09		1.00E-07	2.2E+12		2.2E+12			2.2E+12	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Tetrachlorodibenzo-p-dioxin, 2,3,7,8-	1746-01-6	3.00E-08	2.45E-08	6.44E-10		2.20E-09	1.4E+04	4.1E-04 ^c	1.4E+04	3.4E-04 ^c		1.4E+04	9.0E-06	3.1E-05
Tetrachloroethane 1,1,1,2-	630-20-6		0.734	3.71E-03		1.90E-03	3	0.014 ^a	3	2.2		3	0.011	5.7E-03
Tetrachloroethane 1,1,2,2-	79-34-5		1.47E+00	4.83E-04		5.00E-04	17	0.014 ^a	17	24	0.64 ^a	17	8.0E-03	8.3E-03
Tetrachloroethylene	127-18-4	5.00E-03	2.45E-01	1.86E-03	9.40E-01	2.10E-02	2.2	0.011	2.2	0.54	0.70 ^a	2.2	4.10E-03	0.047
Tetrachlorophenol 2,3,4,6-	58-90-2		0.734				2.2		2.2	1.6		2.2		
Tetraethyl dithiopyrophosphate (Sulfotep)	3689-24-5		1.22E-02				1.0E+30		1.0E+30	1.0E+03 ^{b,c}		1.0E+30		

KEY:

- a - TC Rule cap d - Capped by daughter LCTV
b - 1,000 mg/L cap e - Constituent has no RGC; LCTV from daughter
c - Exceeds solubility

Table F-1: Landfill No-Liner LCTVs

Common Name	CAS#	MCL (mg/L)	HBN (mg/L)				No Liner/In-Situ Soil							
			Ingestion		Inhalation		Peak DAF	LCTV based on MCL (mg/L)	Non-Carcinogenic Effect (NC)			Carcinogenic Effect (C)		
		Ingestion	NC	C	NC	C			7-yr Avg DAF	LCTV based on Ingestion	LCTV based on Inhalation	30-yr Avg DAF	LCTV based on Ingestion	LCTV based on Inhalation
Thallium	7440-28-0	2.00E-03	1.96E-03					5.8E-03		5.8E-03				
Thiram [Thiuram]	137-26-8		1.22E-01				2.2			0.27		2.2		
Toluene	108-88-3	1.00E+00	4.90E+00		1.30E+00		2.2	2.2	2.2	11	2.9	2.2		
Toluenediamine 2,4-	95-80-7			3.02E-05		7.50E+00	2.2		2.2			2.2	6.7E-05	17
Toluidine o-	95-53-4			4.02E-04		3.60E-02	2.2		2.2			2.2	8.9E-04	0.08
Toluidine p-	106-49-0			5.08E-04			2.2		2.2			2.2	1.1E-03	
Toxaphene (chlorinated camphenes)	8001-35-2	3.00E-03		8.78E-05		3.60E-03	6.3E+03	0.50 ^a	6.3E+03			6.3E+03	0.50 ^a	0.50 ^a
Tribromomethane (Bromoform)	75-25-2	8.00E-02	4.90E-01	1.22E-02		1.90E-02	2.3	0.18	2.3	1.1		2.3	0.028	0.044
Trichloro-1,2,2-trifluoro-ethane 1,1,2-	76-13-1		7.34E+02		9.50E+01		2.2		2.2	1.0E+03 ^{b,c}	210 ^c	2.2		
Trichlorobenzene 1,2,4-	120-82-1	7.00E-02	2.45E-01		8.30E-01		2.3	0.16	2.3	0.56	1.9	2.3		
Trichloroethane 1,1,1-	71-55-6	2.00E-01	6.85E+00		6.90E+00		98	0.021 ^d	98	0.67 ^d	0.64 ^d	98	4.9E-04 ^e	6.72E-04 ^e
Trichloroethane 1,1,2-	79-00-5	5.00E-03	0.0979	1.69E-03		1.10E-03	2.5	0.012	2.5	0.24	0.64 ^e	2.5	4.9E-04 ^d	6.7E-04 ^d
Trichloroethylene (1,1,2-Trichloroethylene)	79-01-6	5.00E-03		8.78E-03	1.90E+00	6.80E-03	2.2	0.011	2.2		0.50 ^a	2.2	0.019	0.015
Trichlorofluoromethane (Freon 11)	75-69-4		7.34E+00		2.10E+00		2.2		2.2	16	4.7	2.2		
Trichlorophenol 2,4,5-	95-95-4		2.45E+00				2.2		2.2	5.4		2.2		
Trichlorophenol 2,4,6-	88-06-2			8.78E-03		2.80E-01	2.2		2.2			2.2	0.019	0.62
Trichlorophenoxypropionic acid 2-(2,4,5- (Silvex)	93-72-1	5.00E-02	1.96E-01				2.2	0.11	2.2	0.43		2.2		
Trichlorophenoxyacetic acid 2,4,5-	93-76-5		2.45E-01				2.2		2.2	0.54		2.2		
Trichloropropane 1,2,3-	96-18-4		1.47E-01	1.38E-05	3.40E-02		2.7		2.7	0.39	0.09	2.7	3.7E-05	
Triethylamine	121-44-8				1.10E-01		2.2		2.2		0.24	2.2		
Trinitrobenzene (1,3,5-Trinitrobenzene) sym-	99-35-4		7.34E-01				2.2		2.2	1.6		2.2		
Tris(2,3-dibromopropyl)phosphate	126-72-7			9.89E-06			21		21			21	2.0E-04	
Vanadium	7440-62-2		1.71E-01							0.5				
Vinyl acetate	108-05-4		2.45E+01		1.20E+00		2.2		2.2	54	2.7	2.2		
Vinyl chloride	75-01-4	2.00E-03	7.34E-02	1.34E-04	2.90E-01	2.50E-03	2.2	4.4E-03	2.2	0.16	0.20 ^a	2.2	3.0E-04	5.5E-03
Xylene m-	108-38-3		4.90E+01		1.30E+00		2.2		2.2	110	2.9	2.2		
Xylene o-	95-47-6		4.90E+01		1.40E+00		2.2		2.2	110	3.1	2.2		
Xylene p-	106-42-3		4.90E+01		1.30E+00		2.2		2.2	110	2.9	2.2		
Xylenes (total)	1330-20-7	1.00E+01	4.90E+01		1.40E+00		2.2	22	2.2	110	3.1	2.2		
Zinc	7440-66-6		7.34E+00							16				

KEY:

- a - TC Rule cap
b - 1,000 mg/L cap
c - Exceeds solubility
- d - Capped by daughter LCTV
e - Constituent has no RGC; LCTV from daughter

Table F-2: Landfill Single Clay Liner LCTVs

Common Name	CAS#	MCL (mg/L)	HBN (mg/L)				Peak DAF	LCTV based on MCL (mg/L)	Compacted Clay Liner					
		Ingestion	Ingestion		Inhalation				Non-Carcinogenic Effect (NC)			Carcinogenic Effect (C)		
			NC	C	NC	C			7-yr Avg DAF	LCTV based on Ingestion	LCTV based on Inhalation	30-yr Avg DAF	LCTV based on Ingestion	LCTV based on Inhalation
Acenaphthene	83-32-9		1.47E+00				6.4		6.4	9.4 ^c		6.4		
Acetaldehyde [Ethanal]	75-07-0				2.20E-01	4.10E-02	6.1		6.1		1.3	6.1		0.25
Acetone (2-propanone)	67-64-1		2.45E+00		1.50E+03		6.1		6.1	15	1.0E+03 ^b	6.1		
Acetonitrile (methyl cyanide)	75-05-8				3.10E+00		6.1		6.1		19	6.1		
Acetophenone	98-86-2		2.45E+00				6.1		6.1	15		6.1		
Acrolein	107-02-8		4.90E-01		3.30E-04		1.0E+30		1.0E+30	1.0E+03 ^b	1.0E+03 ^b	1.0E+30		
Acrylamide	79-06-1		4.90E-03	2.15E-05		5.10E+00	8.8		8.8	0.043		8.8	1.9E-04	45
Acrylic acid [propenoic acid]	79-10-7		1.22E+01		1.50E+01		6.1		6.1	74	91	6.1		
Acrylonitrile	107-13-1		2.45E-02	1.79E-04	3.80E-02	1.00E-03	6.6		6.6	0.032 ^d	0.25	6.6	1.4E-04 ^d	6.6E-03
Aldrin	309-00-2		7.34E-04	5.68E-06		1.00E-05	1.6E+15		1.6E+15	1.0E+03 ^{b,c}		1.6E+15	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Allyl alcohol	107-18-6		1.22E-01				6.1		6.1	0.74		6.1		
Aniline (benzeneamine)	62-53-3			1.69E-02	9.30E-01	2.20E+00	6.1		6.1		5.7	6.1	0.10	13
Anthracene	120-12-7		7.34E+00				7.2		7.2	53 ^c		7.2		
Antimony	7440-36-0	6.00E-03	9.79E-03					0.040		0.068				
Arsenic	7440-38-2	5.00E-02	7.34E-03	6.44E-05				0.33		0.050		1.3E-03		
Barium	7440-39-3	2.00E+00	1.71E+00					13		12				
Benz(a)anthracene	56-55-3			8.05E-05		1.80E-02	280		280			280	0.023 ^c	5.1 ^c
Benzene	71-43-2	5.00E-03		1.76E-03	1.90E-01	1.60E-03	6.1	0.030	6.1		0.50 ^a	6.1	0.011	0.010
Benzidine	92-87-5		7.34E-02	4.20E-07		2.60E+00	6.1		6.1	0.45		6.1	2.6E-06	16
Benzo(a)pyrene	50-32-8	2.00E-04		1.32E-05		5.40E-03	5.1E+06	1.0E+03 ^{b,c}	5.1E+06			5.2E+06	69 ^c	1.0E+03 ^{b,c}
Benzo(b)fluoranthene	205-99-2			8.05E-05		6.30E-04	6.2E+06		6.2E+06			6.4E+06	520 ^c	1.0E+03 ^{b,c}
Benzyl alcohol	100-51-6		7.34E+00				6.1		6.1	45		6.1		
Benzyl chloride	100-44-7			5.68E-04		5.20E-04	1.0E+30		1.0E+30	52 ^a		1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Beryllium	7440-41-7	4.00E-03	4.90E-02					0.13		0.45				
Bis(2-chloroethyl)ether	111-44-4			8.78E-05		1.10E-03	79		79		1.0E+03 ^e	79	7.0E-03	0.087
Bis(2-chloroisopropyl)ether	39638-32-9		9.79E-01	1.38E-03		5.90E-03	6.1		6.1	6.0		6.1	8.4E-03	0.036
Bis(2-ethylhexyl)phthalate	117-81-7	6.00E-03	4.90E-01	6.90E-03	1.80E+02	2.80E+01	1.0E+30	1.0E+03 ^{b,c}	1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}	1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Bromodichloromethane	75-27-4	8.00E-02	4.90E-01	1.56E-03		8.00E-04	7.5	0.60	7.5	3.7		7.5	0.012	6.0E-03
Bromomethane	74-83-9		3.43E-02		1.50E-02		1.0E+30		1.0E+30	220 ^d	1.0E+03 ^b	1.0E+30		
Butadiene 1, 3-	106-99-0				6.00E-02	4.00E-05	6.1		6.1		0.37	6.1		2.4E-04
Butanol n-	71-36-3		2.45E+00				6.1		6.1	15		6.1		
Butyl benzyl phthalate	85-68-7		4.90E+00				11		11	52 ^c		11		
Butyl-4,6-dinitrophenol,2-sec-(Dinoseb)	88-85-7	7.00E-03	2.45E-02				6.1	0.043	6.1	0.15		6.1		
Cadmium	7440-43-9	5.00E-03	1.22E-02					0.033		0.083				
Carbon disulfide	75-15-0		2.45E+00		1.90E+00		7.1		7.1	17	13	7.1		
Carbon tetrachloride	56-23-5	5.00E-03	0.0171	7.43E-04	0.021	7.60E-04	11.0	0.055	11	0.2	0.23	11	8.2E-03	8.4E-03
Chlordane	57-74-9	2.00E-03	0.0122	2.76E-04	2.80E-02	1.50E-03	8.2E+07	0.030 ^a	8.4E+07	0.030 ^a	0.030 ^a	8.5E+07	0.030 ^a	0.030 ^a
Chloro-1,3-butadiene 2-(Chloroprene)	126-99-8		4.90E-01		2.20E-02		6.1		6.1	3.0	0.13	6.1		
Chloroaniline p-	106-47-8		9.79E-02				6.1		6.1	0.6		6.1		
Chlorobenzene	108-90-7	1.00E-01	4.90E-01		2.00E-01		6.1	0.61	6.1	3.0	1.2	6.1		
Chlorobenzilate	510-15-6		4.90E-01	3.58E-04		1.20E+00	36		36	17 ^c		36	0.013	43 ^c
Chlorodibromomethane	124-48-1	8.00E-02	4.90E-01	1.15E-03		7.50E-04	6.9	0.55	6.9	3.4		6.9	7.9E-03	5.2E-03
Chloroethane [Ethyl chloride]	75-00-3				3.00E+01		6.1		6.1		180	6.1		
Chloroform	67-66-3	8.00E-02	2.45E-01		3.30E-01		6.3	0.50	6.3	1.5	2.1	6.3		
Chloromethane	74-87-3			7.43E-03	2.60E-01	5.90E-03	6.1		6.1		1.6	6.1	0.045	0.036
Chlorophenol 2-	95-57-8		1.22E-01		9.70E-03		6.1		6.1	0.74	0.059	6.1		
Chloropropene 3- (Allyl Chloride)	107-05-1				3.00E-03	1.90E-03	1.0E+30		1.0E+30		1.0E+03 ^b	1.0E+30		1.0E+03 ^b
Chromium (III) (Chromic Ion)	16065-83-1	1.00E-01	3.67E+01					1.3		260				
Chromium (VI)	18540-29-9	1.00E-01	7.34E-02					1.0		0.75				

KEY:

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Table F-2: Landfill Single Clay Liner LCTVs

Common Name	CAS#	MCL (mg/L)	HBN (mg/L)				Peak DAF	LCTV based on MCL (mg/L)	Compacted Clay Liner					
		Ingestion	Ingestion		Inhalation				Non-Carcinogenic Effect (NC)			Carcinogenic Effect (C)		
			NC	C	NC	C			7-yr Avg DAF	LCTV based on Ingestion	LCTV based on Inhalation	30-yr Avg DAF	LCTV based on Ingestion	LCTV based on Inhalation
Chrysene	218-01-9			8.05E-04		7.30E-03	280		280			280	0.23 ^c	2.0 ^c
Cobalt	7440-48-4		4.90E-01							3.1				
Copper	7440-50-8	1.30E+00						9.4						
Cresol m-	108-39-4		1.22E+00		1.20E+03		6.1		6.1	7.4	200 ^a	6.1		
Cresol o-	95-48-7		1.22E+00		8.80E+02		6.1		6.1	7.4	200 ^a	6.1		
Cresol p-	106-44-5		1.22E-01		1.30E+03		6.1		6.1	0.74	200 ^a	6.1		
Cresols	1319-77-3		1.22E+00		1.10E+03		6.1		6.1	7.4	1.0E+03 ^b	6.1		
Cumene	98-82-8		2.45E+00		1.30E+00		6.2		6.2	15	8.0	6.2		
Cyclohexanol	108-93-0		4.16E-04		3.90E-04		6.1		6.1	2.5E-03	2.4E-03	6.1		
Cyclohexanone	108-94-1		1.22E+02				6.1		6.1	740		6.1		
DDD	72-54-8			4.02E-04			1.0E+30		1.0E+30			1.0E+30	1.0E+03 ^{b,c}	
DDE	72-55-9			2.84E-04			1.0E+30		1.0E+30			1.0E+30	1.0E+03 ^{b,c}	
DDT p,p'-	50-29-3		1.22E-02	2.84E-04		8.80E-03	1.0E+30		1.0E+30	1.0E+03 ^{b,c}		1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Diallate	2303-16-4			1.58E-03			4.9E+08		4.9E+08			4.9E+08	1.0E+03 ^{b,c}	
Dibenz[a,h]anthracene	53-70-3			1.32E-05		3.80E-01	1.0E+30		1.0E+30			1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Dibromo-3-chloropropane 1,2-	96-12-8	2.00E-04		6.90E-05	2.90E-03	7.90E-02	9.8	2.0E-03	9.8		0.028	9.8	6.7E-04	0.77
Dichlorobenzene 1,2-	95-50-1	6.00E-01	2.20E+00		7.70E-01		6.1	3.7	6.1	13	4.7	6.1		
Dichlorobenzene 1,4-	106-46-7	7.50E-02		4.02E-03	3.00E+00	1.30E-03	6.1	0.46	6.1		7.5 ^a	6.1	0.025	7.9E-03
Dichlorobenzidine 3,3'-	91-94-1			2.15E-04		4.90E+00	6.1		6.1			6.1	1.3E-03	0.30 ^c
Dichlorodifluoromethane (Freon 12)	75-71-8		4.90E+00		5.80E-01		6.1		6.1	30	3.5	6.1		
Dichloroethane 1,1-	75-34-3		2.45		1.6	7.40E-03	7.8	0.027 ^e	7.8	0.45 ^d	0.45 ^d	7.8	1.8E-03 ^e	0.034 ^d
Dichloroethane 1,2-	107-06-2	5.00E-03		1.06E-03	1.00E+01	6.30E-04	7.6	0.019 ^d	7.6	0.32 ^e	0.32 ^d	7.6	1.3E-03 ^d	4.8E-03
Dichloroethylene cis-1,2-	156-59-2	7.00E-02	2.45E-01				6.1	0.43	6.1	1.5		6.1		
Dichloroethylene trans-1,2-	156-60-5	1.00E-01	4.90E-01				6.1	0.61	6.1	3.0		6.1		
Dichloroethylene 1,1-	75-35-4	7.00E-03	2.20E-01	1.61E-04	2.10E-01	2.20E-04	6.1	0.043	6.1	0.70 ^a	0.70 ^a	6.1	9.8E-04	1.3E-03
Dichlorophenol 2,4-	120-83-2		7.34E-02				6.1		6.1	0.45		6.1		
Dichlorophenoxyacetic acid 2,4-(2,4-D)	94-75-7	7.00E-02	2.45E-01				6.1	0.43	6.1	1.5		6.1		
Dichloropropane 1,2-	78-87-5	5.00E-03	2.20E+00	1.42E-03	1.40E-02		14.0	0.071	14.0	31	0.20	14.0	0.02	
Dichloropropene 1,3-(mixture of isomers)	542-75-6		7.34E-01	9.66E-04	6.10E-02	2.90E-03	6.1		6.1	4.5	0.37	6.1	5.9E-03	0.018
Dichloropropene cis-1,3-	10061-01-5		7.34E-01	9.66E-04	7.00E-02	3.30E-03	1.0E+30		1.0E+30	1.0E+03 ^b	1.0E+03 ^b	1.0E+30	1.0E+03 ^b	1.0E+03 ^b
Dichloropropene trans-1,3-	10061-02-6		7.34E-01	9.66E-04	7.50E-02	3.50E-03	1.0E+30		1.0E+30	1.0E+03 ^b	1.0E+03 ^b	1.0E+30	1.0E+03 ^b	1.0E+03 ^b
Dieldrin	60-57-1		1.22E-03	6.04E-06		1.00E-04	1.0E+30		1.0E+30	1.0E+03 ^{b,c}		1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Diethyl phthalate	84-66-2		1.96E+01				11		11	220		11		
Diethylstilbestrol	56-53-1			2.05E-08			6.8		6.8			6.8	1.4E-07	
Dimethoate	60-51-5		4.90E-03				1.1E+06		1.2E+06	1.5 ^d	1.0E+03 ^e	1.2E+06		
Dimethoxybenzidine 3,3'-	119-90-4			6.90E-03			6.1		6.1			6.1	0.042	
Dimethyl formamide N,N- [DMF]	68-12-2		2.45E+00		7.10E+02		6.1		6.1	15	1.0E+03 ^b	6.1		
Dimethylbenz[a]anthracene 7,12-	57-97-6					3.00E-03	1.0E+30		1.0E+30			1.0E+30		1.0E+03 ^{b,c}
Dimethylbenzidine 3,3'-	119-93-7			1.05E-05			6.1		6.1			6.1	6.4E-05	
Dimethylphenol 2,4-	105-67-9		4.90E-01				6.1		6.1	3.0		6.1		
Di-n-butyl phthalate	84-74-2		2.45E+00				12		12	28 ^c		12		
Dinitrobenzene 1,3-	99-65-0		2.45E-03				6.1		6.1	0.015		6.1		
Dinitrophenol 2,4-	51-28-5		4.90E-02				6.1		6.1	0.30		6.1		
Dinitrotoluene 2,4-	121-14-2		4.90E-02	1.42E-04		8.12E-01	6.1		6.1	0.13 ^a		6.1	8.6E-04	0.13 ^a
Dinitrotoluene 2,6-	606-20-2		2.45E-02	1.42E-04			6.1		6.1	0.15		6.1	8.6E-04	
Di-n-octyl phthalate	117-84-0		4.90E-01				1.0E+30		1.0E+30	1.0E+03 ^{b,c}		1.0E+30		
Dioxane 1,4-	123-91-1			8.78E-03	1.09E+03	1.80E-01	6.1		6.1		1.0E+03 ^b	6.1	0.053	1.1

KEY:

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b - 1,000 mg/L cap
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Table F-2: Landfill Single Clay Liner LCTVs

Common Name	CAS#	MCL (mg/L)	HBN (mg/L)				Compacted Clay Liner							
		Ingestion	Ingestion		Inhalation		Peak DAF	LCTV based on MCL (mg/L)	Non-Carcinogenic Effect (NC)			Carcinogenic Effect (C)		
			NC	C	NC	C			7-yr Avg DAF	LCTV based on Ingestion	LCTV based on Inhalation	30-yr Avg DAF	LCTV based on Ingestion	LCTV based on Inhalation
Diphenylamine	122-39-4		6.12E-01				6.1		6.1	3.8		6.1		
Diphenylhydrazine 1, 2-	122-66-7			1.21E-04		2.00E-02	6.1		6.1			6.1	7.4E-04	0.12
Disulfoton	298-04-4		9.79E-04				1.0E+30		1.0E+30	1.0E+03 ^{b,c}		1.0E+30		
Endosulfan (Endosulfan I and II,mixture)	115-29-7		1.47E-01				6.3		6.3	0.92 ^c		6.3		
Endrin	72-20-8	2.00E-03	7.34E-03				1.1E+22	0.020 ^a	1.1E+22	0.020 ^a		1.1E+22		
Epichlorohydrin	106-89-8		4.90E-02	9.75E-03	6.00E-02	1.90E-01	1.0E+30		1.0E+30	1.0E+03 ^b	1.0E+03 ^b	1.0E+30	1.0E+03 ^b	1.0E+03 ^b
Epoxybutane 1, 2-	106-88-7			2.40E-01			6.1		6.1		1.5	6.1		
Ethoxyethanol 2-	110-80-5		9.79E+00		2.90E+03		6.1		6.1	60	1.0E+03 ^b	6.1		
Ethoxyethanol acetate 2-	111-15-9		7.34E+00		3.00E+02		6.1		6.1	45	1.0E+03 ^b	6.1		
Ethyl acetate	141-78-6		2.20E+01				55		55	1.0E+03 ^b		55		
Ethyl ether	60-29-7		4.9				6.1		6.1	30		6.1		
Ethyl methacrylate	97-63-2		2.20E+00				17		17	37		17		
Ethyl methanesulfonate	62-50-0			3.30E-07			1.0E+30		1.0E+30			1.0E+30	1.0E+03 ^b	
Ethylbenzene	100-41-4	7.00E-01	2.45E+00		3.30E+00	1.10E-02	6.1	4.3	6.1	15	20	6.1		0.067
Ethylene dibromide (1,2-Dibromoethane)	106-93-4	5.00E-05		1.14E-06	9.80E-04	8.40E-05	1.3E+03	0.063	1.3E+03		1.2	1.3E+03	1.4E-03	0.11
Ethylene glycol	107-21-1		4.90E+01		1.20E+04		6.1		6.1	300	1.0E+03 ^b	6.1		
Ethylene oxide	75-21-8			9.47E-05	4.10E-01	5.20E-04	1.0E+30		1.0E+30		1.0E+03 ^b	1.0E+30	1.0E+03 ^b	1.0E+03 ^b
Ethylene thiourea	96-45-7		1.96E-03	8.78E-04		1.60E+03	6.1		6.1	0.012		6.1	5.3E-03	1.0E+03 ^b
Fluoranthene	206-44-0		9.79E-01				11		11	11 ^c		11		
Fluoride	16984-48-8	4.00E+00	2.90E+00					27		20				
Formaldehyde	50-00-0		4.90E+00		5.10E+01	1.5	6.1		6.1	30	310	6.1		9.1
Formic acid	64-18-6		4.90E+01				6.1		6.1	300		6.1		
Furfural	98-01-1		7.34E-02		2.20E+01		6.1		6.1	0.45	130	6.1		
HCH beta-	319-85-7			5.36E-05		1.70E-02	6.2		6.2			6.2	3.3E-04	0.10
HCH (Lindane) gamma-	58-89-9	2.00E-04	7.34E-03	7.43E-05		1.60E-03	1.0E+30	0.4 ^{a,d}	1.0E+30	0.4 ^{a,d}	0.4 ^{a,e}	1.0E+30	0.4 ^{a,b,c}	0.4 ^{a,b,c}
HCH alpha-	319-84-6		0.196	1.53E-05		3.60E-04	1.0E+30	0.74 ^e	1.0E+30	1.6 ^d	8.8 ^{c,e}	1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Heptachlor	76-44-8	4.00E-04	1.22E-02	2.15E-05		1.50E-05	1.0E+30	8.0E-03 ^a	1.0E+30	8.0E-03 ^a		1.0E+30	8.0E-03 ^a	8.0E-03 ^a
Heptachlor epoxide	1024-57-3	2.00E-04	3.18E-04	1.06E-05		2.80E-04	1.0E+30	1.0E+03 ^{b,c}	1.0E+30	1.0E+03 ^{b,c}		1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Hexachloro-1,3-butadiene	87-68-3		7.34E-03	1.24E-03		6.10E-04	8.8		8.8	0.065		8.8	0.011	5.4E-03
Hexachlorobenzene	118-74-1	1.00E-03	1.96E-02	6.04E-05		3.60E-05	570	0.13 ^{a,c}	580	0.13 ^{a,c}		580	0.035 ^c	0.021 ^c
Hexachlorocyclopentadiene	77-47-4	5.00E-02	1.47E-01		6.90E-04		1.0E+30	1.0E+03 ^{b,c}	1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}	1.0E+30		
Hexachlorodibenzofurans [HxCDFs]	55684-94-1			6.19E-09		1.44E-07	1.0E+30		1.0E+30			1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Hexachlorodibenzo-p-dioxins [HxCDDs]	34465-46-8			6.19E-09		1.43E-07	1.0E+30		1.0E+30			1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Hexachloroethane	67-72-1		2.45E-02	6.90E-03		3.30E-03	6.3		6.3	0.15		6.3	0.043	0.021
Hexachlorophene	70-30-4		7.34E-03				31		31	0.22		31		
Hexane n-	110-54-3		2.69E+02		6.60E-01		6.1		6.1	1.0E+03 ^{b,c}	4.0	6.1		
Hydrogen Sulfide	7783-06-4		7.34E-02				6.1		6.1	0.45		6.1		
Indeno{1,2,3-cd}pyrene	193-39-5			8.05E-05		3.80E-02	1.0E+30		1.0E+30			1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Isobutyl alcohol	78-83-1		7.34E+00				6.1		6.1	45		6.1		
Isophorone	78-59-1		4.90E+00	1.02E-01	5.33E+02		6.1		6.1	30	1.0E+03 ^b	6.1	0.62	
Kepone	143-50-0		1.22E-02				7.0		7.0	0.086		7.0		
Lead	7439-92-1	1.50E-02						0.15						
Manganese	7439-96-5		1.15E+00							8.0				
Mercury	7439-97-6	2.00E-03	2.45E-03		7.00E-04			0.019		0.20 ^{a,c}	9.4E-03			
Methacrylonitrile	126-98-7		2.45E-03		6.50E-03		6.6		6.6	0.016	0.043	6.6		
Methanol	67-56-1		1.22E+01		1.54E+03		6.1		6.1	74	1.0E+03 ^b	6.1		
Methoxychlor	72-43-5	4.00E-02	1.22E-01				1.0E+30	10 ^{a,c}	1.0E+30	10 ^{a,c}		1.0E+30		
Methoxyethanol 2-	109-86-4		2.45E-02		4.40E+02		6.1		6.1	0.15	1.0E+03 ^b	6.1		

KEY:

- a - TC Rule cap
b - 1,000 mg/L cap
c - Exceeds solubility
- d - Capped by daughter LCTV
e - Constituent has no RGC; LCTV from daughter

Table F-2: Landfill Single Clay Liner LCTVs

Common Name	CAS#	MCL (mg/L)	HBN (mg/L)				Peak DAF	LCTV based on MCL (mg/L)	Compacted Clay Liner					
		Ingestion	Ingestion		Inhalation				Non-Carcinogenic Effect (NC)			Carcinogenic Effect (C)		
			NC	C	NC	C			7-yr Avg DAF	LCTV based on Ingestion	LCTV based on Inhalation	30-yr Avg DAF	LCTV based on Ingestion	LCTV based on Inhalation
Methoxyethanol acetate 2-	110-49-6		4.90E-02		5.10E+02		6.1		6.1	0.30	1.0E+03 ^b	6.1		
Methyl ethyl ketone	78-93-3		1.47E+01		3.30E+01		6.1		6.1	90	200 ^a	6.1		
Methyl isobutyl ketone	108-10-1		1.96E+00		1.20E+00		6.1		6.1	12	7.3	6.1		
Methyl methacrylate	80-62-6		3.43E+01		5.30E+00		22		22	230 ^d	120	22		
Methyl parathion	298-00-0		6.12E-03				1.0E+30		1.0E+30	3.5 ^d	1.0E+03 ^e	1.0E+30		
Methyl tert-butyl ether [MTBE]	1634-04-4				1.70E+01		6.1		6.1		100	6.1		
Methylcholanthrene 3-	56-49-5					1.20E-03	1.0E+30		1.0E+30			1.0E+30		1.0E+03 ^{b,c}
Methylene bromide (Dibromomethane)	74-95-3		2.45E-01				6.1		6.1	1.5		6.1		
Methylene Chloride (Dichloromethane)	75-09-2	5.00E-03	1.47E+00	1.29E-02	1.00E+01	2.80E-02	6.2	0.031	6.2	9.2	62	6.2	0.080	0.17
Molybdenum	7439-98-7		1.22E-01							0.90				
Naphthalene	91-20-3		4.90E-01		1.90E-02		6.1		6.1	3.0	0.12	6.1		
Nickel	7440-02-0		4.90E-01							3.3				
Nitrobenzene	98-95-3		1.22E-02		1.50E-01		6.1		6.1	0.074	0.91	6.1		
Nitropropane 2-	79-46-9				3.30E-01	2.30E-05	6.1		6.1		2.0	6.1		1.4E-04
Nitrosodiethylamine N-	55-18-5			6.44E-07		4.30E-05	6.1		6.1			6.1	3.9E-06	2.6E-04
Nitrosodimethylamine N-	62-75-9		1.96E-04	1.89E-06		4.00E-04	6.1		6.1	1.2E-03		6.1	1.2E-05	2.4E-03
Nitroso-di-n-butylamine N-	924-16-3			1.79E-05		2.00E-05	6.1		6.1			6.1	1.1E-04	1.2E-04
Nitroso-di-n-propylamine N-	621-64-7			1.38E-05		1.50E-03	6.1		6.1			6.1	8.4E-05	9.1E-03
Nitrosodiphenylamine N-	86-30-6		4.90E-01	1.97E-02		5.20E-01	6.1		6.1	3.0		6.1	0.12	3.2
Nitrosomethylethylamine N-	10595-95-6			4.39E-06		4.50E-03	6.1		6.1			6.1	2.7E-05	0.027
Nitrosopiperidine N-	100-75-4					8.70E-03	6.1		6.1			6.1		0.053
Nitrosopyrrolidine N-	930-55-2			4.60E-05		9.20E-01	6.1		6.1			6.1	2.8E-04	5.6
Octamethyl pyrophosphoramidate	152-16-9		4.90E-02				6.6		6.6	0.32		6.6		
Parathion (ethyl)	56-38-2		0.147				1.0E+30		1.0E+30	1.0E+03 ^{b,c}		1.0E+30		
Pentachlorobenzene	608-93-5		1.96E-02				660		670	13 ^c		670		
Pentachlorodibenzofurans [PeCDFs]	30402-15-4			1.24E-09		6.29E-08	22		22			22	2.78E-08	1.4E-06
Pentachlorodibenzo-p-dioxins [PeCDDs]	36088-22-9			6.19E-10		6.00E-08	1.0E+30		1.0E+30			1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Pentachloronitrobenzene (PCNB)	82-68-8		7.34E-02	3.71E-04			10		10	0.73 ^c		10	3.7E-03	
Pentachlorophenol	87-86-5	1.00E-03	7.34E-01	8.05E-04		5.40E+01	6.1	6.E-03	6.1	4.5		6.1	4.9E-03	100 ^a
Phenol	108-95-2		1.47E+01		9.00E+02		6.1		6.1	90	1.0E+03 ^b	6.1		
Phenyl mercuric acetate	62-38-4		1.96E-03				6.1		6.1	0.012		6.1		
Phenylenediamine 1,3-	108-45-2		1.47E-01				6.1		6.1	0.90		6.1		
Phorate	298-02-2		4.90E-03				1.0E+30		1.0E+30	1.0E+03 ^{b,c}		1.0E+30		
Phthalic anhydride	85-44-9		4.90E+01		1.30E+04		1.0E+30		1.0E+30	1.0E+03 ^b	1.0E+03 ^b	1.0E+30		
Polychlorinated biphenyls (Aroclors)	1336-36-3	5.00E-04	4.90E-04	2.41E-04		1.40E-04	3.1E+15	1.0E+03 ^{b,c}	3.1E+15	1.0E+03 ^{b,c}		3.4E+15	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Pronamide	23950-58-5		1.84E+00				6.5		6.5	12		6.5		
Propylene oxide [1,2-Epoxypropane]	75-56-9			4.02E-04	4.90E-01	1.70E-02	6.1		6.1		3.0	6.1	2.4E-03	0.10
Pyrene	129-00-0		7.34E-01				22		22	16 ^c		22		
Pyridine	110-86-1		2.45E-02		1.40E+00		6.1		6.1	0.15	5.0 ^a	6.1		
Safrole	94-59-7			5.36E-04			6.1		6.1			6.1	3.3E-03	
Selenium	7782-49-2	5.00E-02	1.22E-01					0.50		1.0 ^a				
Silver	7440-22-4		1.22E-01							5.0 ^a				
Strychnine and salts	57-24-9		7.34E-03				6.1		6.1	0.045		6.1		
Styrene	100-42-5	1.00E-01	4.90E+00		3.60E+00		6.1	0.61	6.1	30	22	6.1		
Tetrachlorobenzene 1,2,4,5-	95-94-3		7.34E-03				7.5		7.5	0.055		7.5		
Tetrachlorodibenzofuran, 2,3,7,8-	51207-31-9			6.19E-09		1.00E-07	1.0E+30		1.0E+30			1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Tetrachlorodibenzo-p-dioxin, 2,3,7,8-	1746-01-6	3.00E-08	2.45E-08	6.44E-10		2.20E-09	1.2E+13	1.0E+03 ^{b,c}	1.2E+13	1.0E+03 ^{b,c}		1.2E+13	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Tetrachloroethane 1,1,1,2-	630-20-6		0.734	3.71E-03		1.90E-03	13	0.039 ^e	13	9.4		13	0.047	0.024
Tetrachloroethane 1,1,2,2-	79-34-5		1.47E+00	4.83E-04		5.00E-04	200	0.039 ^e	200	300	0.64 ^e	200	0.068 ^d	0.053 ^d

KEY:

- a - TC Rule cap
b - 1,000 mg/L cap
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d - Capped by daughter LCTV
e - Constituent has no RGC; LCTV from daughter

Table F-2: Landfill Single Clay Liner LCTVs

Common Name	CAS#	MCL (mg/L)	HBN (mg/L)				Compacted Clay Liner								
		Ingestion	Ingestion		Inhalation		Peak DAF	LCTV based on MCL (mg/L)	Non-Carcinogenic Effect (NC)			Carcinogenic Effect (C)			
			NC	C	NC	C			7-yr Avg DAF	LCTV based on Ingestion	LCTV based on Inhalation	30-yr Avg DAF	LCTV based on Ingestion	LCTV based on Inhalation	
Tetrachloroethylene	127-18-4	5.00E-03	2.45E-01	1.86E-03	9.40E-01	2.10E-02	6.1	0.030	6.1	0.70 ^a	0.70 ^a	6.1	0.011	0.13	
Tetrachlorophenol 2,3,4,6-	58-90-2		0.734				6.1		6.1	4.5		6.1			
Tetraethyl dithiopyrophosphate (Sulfotep)	3689-24-5		1.22E-02				1.0E+30		1.0E+30	1.0E+03 ^{b,c}		1.0E+30			
Thallium	7440-28-0	2.00E-03	1.96E-03					0.018		0.019					
Thiram [Thiuram]	137-26-8		1.22E-01				6.1		6.1	0.74		6.1			
Toluene	108-88-3	1.00E+00	4.90E+00		1.30E+00		6.1	6.1	6.1	30	7.9	6.1			
Toluenediamine 2,4-	95-80-7			3.02E-05		7.50E+00	6.1		6.1			6.1	1.8E-04	46	
Toluidine o-	95-53-4			4.02E-04		3.60E-02	6.1		6.1			6.1	2.4E-03	0.22	
Toluidine p-	106-49-0			5.08E-04			6.1		6.1			6.1	3.1E-03		
Toxaphene (chlorinated camphenes)	8001-35-2	3.00E-03		8.78E-05		3.60E-03	1.8E+08	0.50 ^a	1.8E+08			1.8E+08	0.50 ^a	0.50 ^a	
Tribromomethane (Bromoform)	75-25-2	8.00E-02	4.90E-01	1.22E-02		1.90E-02	6.5	0.52	6.5	3.2		6.5	0.080	0.12	
Trichloro-1,1,2,2-trifluoro-ethane 1,1,2-	76-13-1		7.34E+02		9.50E+01		6.1		6.1	1.0E+03 ^{b,c}	580 ^c	6.1			
Trichlorobenzene 1,2,4-	120-82-1	7.00E-02	2.45E-01		8.30E-01		6.6	0.46	6.6	1.6	5.5	6.6			
Trichloroethane 1,1,1-	71-55-6	2.00E-01	6.85E+00		6.90E+00		2.0E+04	0.059 ^d	2.0E+04	0.96 ^d	0.96 ^d	2.0E+04	1.4E-03 ^e	1.8E-03 ^e	
Trichloroethane 1,1,2-	79-00-5	5.00E-03	0.0979	1.69E-03		1.10E-03	7.5	0.037	7.5	0.73	0.96 ^e	7.5	1.4E-03 ^d	1.8E-03 ^d	
Trichloroethylene (1,1,2-Trichloroethylene)	79-01-6	5.00E-03		8.78E-03	1.90E+00	6.80E-03	6.1	0.030	6.1		0.50 ^a	6.1	0.053	0.041	
Trichlorofluoromethane (Freon 11)	75-69-4		7.34E+00		2.10E+00		6.1		6.1	45	13	6.1			
Trichlorophenol 2,4,5-	95-95-4		2.45E+00				6.1		6.1	15		6.1			
Trichlorophenol 2,4,6-	88-06-2			8.78E-03		2.80E-01	6.1		6.1			6.1	0.053	1.7	
Trichlorophenoxypropionic acid 2-(2,4,5- (Silvex)	93-72-1	5.00E-02	1.96E-01				6.1	0.30	6.1	1.0 ^a		6.1			
Trichlorophenoxyacetic acid 2,4,5-	93-76-5		2.45E-01				6.1		6.1	1.5		6.1			
Trichloropropane 1,2,3-	96-18-4		1.47E-01	1.38E-05	3.40E-02		9.3		9.3	1.4	0.32	9.3	1.3E-04		
Triethylamine	121-44-8				1.10E-01		6.1		6.1		0.67	6.1			
Trinitrobenzene (1,3,5-Trinitrobenzene) sym-	99-35-4		7.34E-01				6.1		6.1	4.5		6.1			
Tris(2,3-dibromopropyl)phosphate	126-72-7			9.89E-06			610		610			610	6.1E-03		
Vanadium	7440-62-2		1.71E-01							1.8					
Vinyl acetate	108-05-4		2.45E+01		1.20E+00		6.1		6.1	150	7.3	6.1			
Vinyl chloride	75-01-4	2.00E-03	7.34E-02	1.34E-04	2.90E-01	2.50E-03	6.1	0.012	6.1	0.20 ^a	0.20 ^a	6.1	8.2E-04	0.015	
Xylene m-	108-38-3		4.90E+01		1.30E+00		6.1		6.1	300 ^c	7.9	6.1			
Xylene o-	95-47-6		4.90E+01		1.40E+00		6.1		6.1	300 ^c	8.5	6.1			
Xylene p-	106-42-3		4.90E+01		1.30E+00		6.1		6.1	300 ^c	7.9	6.1			
Xylenes (total)	1330-20-7	1.00E+01	4.90E+01		1.40E+00		6.1	61	6.1	300 ^c	8.6	6.1			
Zinc	7440-66-6		7.34E+00							51					

KEY:

- a - TC Rule cap
 b - 1,000 mg/L cap
 c - Exceeds solubility
 d - Capped by daughter LCTV
 e - Constituent has no RGC; LCTV from daughter

Table F-3: Landfill Composite Liner LCTVs

Common Name	CAS#	MCL (mg/L)	HBN (mg/L)				Peak DAF	LCTV based on MCL (mg/L)	Composite Liner					
		Ingestion	Ingestion		Inhalation				Non-Carcinogenic Effect (NC)			Carcinogenic Effect (C)		
			NC	C	NC	C			7-yr Avg DAF	LCTV based on Ingestion	LCTV based on Inhalation	30-yr Avg DAF	LCTV based on Ingestion	LCTV based on Inhalation
Acenaphthene	83-32-9		1.47E+00				1.0E+30		1.0E+30	1.0E+03 ^{b,c}		1.0E+30		
Acetaldehyde [Ethanal]	75-07-0				2.20E-01	4.10E-02	1.5E+04		1.5E+04		1.0E+03 ^b	1.5E+04		620
Acetone (2-propanone)	67-64-1		2.45E+00		1.50E+03		1.5E+04		1.6E+04	1.0E+03 ^b	1.0E+03 ^b	1.6E+04		
Acetonitrile (methyl cyanide)	75-05-8				3.10E+00		1.6E+04		1.6E+04		1.0E+03 ^b	1.6E+04		
Acetophenone	98-86-2		2.45E+00				2.1E+05		2.1E+05	1.0E+03 ^b		2.1E+05		
Acrolein	107-02-8		4.90E-01		3.30E-04		1.0E+30		1.0E+30	1.0E+03 ^b	1.0E+03 ^b	1.0E+30		
Acrylamide	79-06-1		4.90E-03	2.15E-05		5.10E+00	1.0E+30		1.0E+30	1.0E+03 ^b		1.0E+30	1.0E+03 ^b	1.0E+03 ^b
Acrylic acid [propenoic acid]	79-10-7		1.22E+01		1.50E+01		1.5E+04		1.5E+04	1.0E+03 ^b	1.0E+03 ^b	1.5E+04		
Acrylonitrile	107-13-1		2.45E-02	1.79E-04	3.80E-02	1.00E-03	9.3E+05		9.3E+05	740 ^d	740 ^d	9.3E+05	170	750 ^d
Aldrin	309-00-2		7.34E-04	5.68E-06		1.00E-05	1.0E+30		1.0E+30	1.0E+03 ^{b,c}		1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Allyl alcohol	107-18-6		1.22E-01				2.7E+05		2.7E+05	1.0E+03 ^b		2.7E+05		
Aniline (benzenamine)	62-53-3			1.69E-02	9.30E-01	2.20E+00	1.6E+04		1.6E+04		1.0E+03 ^b	1.6E+04	270	1.0E+03 ^b
Anthracene	120-12-7		7.34E+00				1.0E+30		1.0E+30	1.0E+03 ^{b,c}		1.0E+30		
Antimony	7440-36-0	6.00E-03	9.79E-03					1.0E+03 ^b		1.0E+03 ^b				
Arsenic	7440-38-2	5.00E-02	7.34E-03	6.44E-05				5.0 ^a		5.0 ^a			5.0 ^a	
Barium	7440-39-3	2.00E+00	1.71E+00					100 ^a		100 ^a				
Benz{a}anthracene	56-55-3			8.05E-05		1.80E-02	1.0E+30		1.0E+30			1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Benzene	71-43-2	5.00E-03		1.76E-03	1.90E-01	1.60E-03	1.9E+04	0.50 ^a	1.9E+04		0.50 ^a	1.9E+04	0.50 ^a	0.50 ^a
Benidine	92-87-5		7.34E-02	4.20E-07		2.60E+00	1.8E+04		1.9E+04	1.0E+03 ^{b,c}		1.9E+04	7.8E-03	1.0E+03 ^{b,c}
Benzo{a}pyrene	50-32-8	2.00E-04		1.32E-05		5.40E-03	1.0E+30	1.0E+03 ^{b,c}	1.0E+30			1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Benzo{b}fluoranthene	205-99-2			8.05E-05		6.30E-04	1.0E+30		1.0E+30			1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Benzyl alcohol	100-51-6		7.34E+00				1.6E+05		1.6E+05	1.0E+03 ^b		1.6E+05		
Benzyl chloride	100-44-7			5.68E-04		5.20E-04	1.0E+30		1.0E+30	1.0E+03 ^e		1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Beryllium	7440-41-7	4.00E-03	4.90E-02					1.0E+03 ^b		1.0E+03 ^b				
Bis(2-chloroethyl)ether	111-44-4			8.78E-05		1.10E-03	1.0E+30		1.0E+30		1.0E+03 ^e	1.0E+30	1.0E+03 ^b	1.0E+03 ^b
Bis(2-chloroisopropyl)ether	39638-32-9		9.79E-01	1.38E-03		5.90E-03	3.1E+04		3.1E+04	1.0E+03 ^b		3.1E+04	43	190
Bis(2-ethylhexyl)phthalate	117-81-7	6.00E-03	4.90E-01	6.90E-03	1.80E+02	2.80E+01	1.0E+30	1.0E+03 ^{b,c}	1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}	1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Bromodichloromethane	75-27-4	8.00E-02	4.90E-01	1.56E-03		8.00E-04	1.2E+07	1.0E+03 ^b	1.2E+07	1.0E+03 ^b		1.2E+07	1.0E+03 ^b	1.0E+03 ^b
Bromomethane	74-83-9		3.43E-02		1.50E-02		1.0E+30		1.0E+30	1.0E+03 ^b	1.0E+03 ^b	1.0E+30		
Butadiene 1, 3-	106-99-0				6.00E-02	4.00E-05	2.2E+04		2.2E+04		1.0E+03 ^{b,c}	2.2E+04		0.88
Butanol n-	71-36-3		2.45E+00				1.6E+05		1.6E+05	1.0E+03 ^b		1.6E+05		
Butyl benzyl phthalate	85-68-7		4.90E+00				1.0E+30		1.0E+30	1.0E+03 ^{b,c}		1.0E+30		
Butyl-4,6-dinitrophenol,2-sec-(Dinoseb)	88-85-7	7.00E-03	2.45E-02				1.3E+06	1.0E+03 ^{b,c}	1.4E+06	1.0E+03 ^{b,c}		1.4E+06		
Cadmium	7440-43-9	5.00E-03	1.22E-02					1.0 ^a		1.0 ^a				
Carbon disulfide	75-15-0		2.45E+00		1.90E+00		2.4E+06		2.4E+06	1.0E+03 ^b	1.0E+03 ^b	2.4E+06		
Carbon tetrachloride	56-23-5	5.00E-03	0.0171	7.43E-04	0.021	7.60E-04	1.0E+30	0.50 ^a	1.0E+30	0.50 ^a	0.50 ^a	1.0E+30	0.50 ^a	0.50 ^a
Chlordane	57-74-9	2.00E-03	0.0122	2.76E-04	2.80E-02	1.50E-03	1.0E+30	0.030 ^a	1.0E+30	0.030 ^a	0.030 ^a	1.0E+30	0.030 ^a	0.030 ^a
Chloro-1,3-butadiene 2-(Chloroprene)	126-99-8		4.90E-01		2.20E-02		1.8E+04		1.9E+04	1.0E+03 ^b	410	1.9E+04		
Chloroaniline p-	106-47-8		9.79E-02				3.4E+05		3.4E+05	1.0E+03 ^b		3.4E+05		
Chlorobenzene	108-90-7	1.00E-01	4.90E-01		2.00E-01		3.3E+04	100 ^a	3.4E+04	100 ^a	100 ^a	3.4E+04		
Chlorobenzilate	510-15-6		4.90E-01	3.58E-04		1.20E+00	1.0E+30		1.0E+30	1.0E+03 ^{b,c}		1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Chlorodibromomethane	124-48-1	8.00E-02	4.90E-01	1.15E-03		7.50E-04	1.4E+06	1.0E+03 ^b	1.4E+06	1.0E+03 ^b		1.4E+06	1.0E+03 ^b	1.0E+03 ^b
Chloroethane [Ethyl chloride]	75-00-3				3.00E+01		1.5E+04		1.6E+04		1.0E+03 ^b	1.6E+04		
Chloroform	67-66-3	8.00E-02	2.45E-01		3.30E-01		9.7E+04	6.0 ^a	9.7E+04	6.0 ^a	6.0 ^a	9.7E+04		
Chloromethane	74-87-3			7.43E-03	2.60E-01	5.90E-03	1.5E+04		1.5E+04		1.0E+03 ^b	1.5E+04	110	90
Chlorophenol 2-	95-57-8		1.22E-01		9.70E-03		1.9E+04		1.9E+04	1.0E+03 ^b	190	2.0E+04		

KEY:

- a - TC Rule cap
b - 1,000 mg/L cap
c - Exceeds solubility
d - Capped by daughter LCTV
e - Constituent has no RGC; LCTV from daughter

Table F-3: Landfill Composite Liner LCTVs

Common Name	CAS#	MCL (mg/L)	HBN (mg/L)				Composite Liner							
		Ingestion	Ingestion		Inhalation		Peak DAF	LCTV based on MCL (mg/L)	Non-Carcinogenic Effect (NC)			Carcinogenic Effect (C)		
			NC	C	NC	C			7-yr Avg DAF	LCTV based on Ingestion	LCTV based on Inhalation	30-yr Avg DAF	LCTV based on Ingestion	LCTV based on Inhalation
Chloropropene 3- (Allyl Chloride)	107-05-1				3.00E-03	1.90E-03	1.0E+30		1.0E+30		1.0E+03 ^b	1.0E+30		1.0E+03 ^b
Chromium (III) (Chromic Ion)	16065-83-1	1.00E-01	3.67E+01					1.0E+03 ^b		1.0E+03 ^b				
Chromium (VI)	18540-29-9	1.00E-01	7.34E-02					5.0 ^a		5.0 ^a				
Chrysene	218-01-9			8.05E-04		7.30E-03	1.0E+30		1.0E+30			1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Cobalt	7440-48-4		4.90E-01							1.0E+03 ^b				
Copper	7440-50-8	1.30E+00						1.0E+03 ^b						
Cresol m-	108-39-4		1.22E+00		1.20E+03		1.9E+04		1.9E+04	200 ^a	200 ^a	1.9E+04		
Cresol o-	95-48-7		1.22E+00		8.80E+02		1.9E+04		1.9E+04	200 ^a	200 ^a	1.9E+04		
Cresol p-	106-44-5		1.22E-01		1.30E+03		1.9E+04		1.9E+04	200 ^a	200 ^a	1.9E+04		
Cresols	1319-77-3		1.22E+00		1.10E+03		2.3E+04		2.4E+04	1.0E+03 ^b	1.0E+03 ^b	2.4E+04		
Cumene	98-82-8		2.45E+00		1.30E+00		2.9E+05		3.0E+05	1.0E+03 ^{b,c}	1.00E+03 ^{b,c}	3.0E+05		
Cyclohexanol	108-93-0		4.16E-04		3.90E-04		1.7E+04		1.7E+04	7.0	6.6	1.7E+04		
Cyclohexanone	108-94-1		1.22E+02				6.1E+05		6.2E+05	1.0E+03 ^b		6.2E+05		
DDD	72-54-8			4.02E-04			1.0E+30		1.0E+30			1.0E+30	1.0E+03 ^{b,c}	
DDE	72-55-9			2.84E-04			1.0E+30		1.0E+30			1.0E+30	1.0E+03 ^{b,c}	
DDT p,p'-	50-29-3		1.22E-02	2.84E-04		8.80E-03	1.0E+30		1.0E+30	1.0E+03 ^{b,c}		1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Diallate	2303-16-4			1.58E-03			1.0E+30		1.0E+30			1.0E+30	1.0E+03 ^{b,c}	
Dibenz[a,h]anthracene	53-70-3			1.32E-05		3.80E-01	1.0E+30		1.0E+30			1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Dibromo-3-chloropropane 1,2-	96-12-8	2.00E-04		6.90E-05	2.90E-03	7.90E-02	1.0E+30	1.0E+03 ^b	1.0E+30		1.0E+03 ^b	1.0E+30	1.0E+03 ^b	1.0E+03 ^b
Dichlorobenzene 1,2-	95-50-1	6.00E-01	2.20E+00		7.70E-01		9.4E+04	1.0E+03 ^{b,c}	9.5E+04	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}	9.5E+04		
Dichlorobenzene 1,4-	106-46-7	7.50E-02		4.02E-03	3.00E+00	1.30E-03	9.0E+04	7.5 ^a	9.1E+04		7.5 ^a	9.1E+04	7.5 ^a	7.5
Dichlorobenzidine 3,3'-	91-94-1			2.15E-04		4.90E+00	3.7E+05		3.7E+05			3.8E+05	82	1.0E+03 ^b
Dichlorodifluoromethane (Freon 12)	75-71-8		4.90E+00		5.80E-01		2.3E+04		2.3E+04	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}	2.3E+04		
Dichloroethane 1,1-	75-34-3		2.45		1.6	7.40E-03	1.0E+30	0.45 ^b	1.0E+30	0.45 ^b	0.45 ^b	1.0E+30	0.45 ^b	0.45
Dichloroethane 1,2-	107-06-2	5.00E-03		1.06E-03	1.00E+01	6.30E-04	1.0E+30	0.32 ^b	1.0E+30	0.32 ^b	0.32 ^b	1.0E+30	0.32 ^b	0.32
Dichloroethylene cis-1,2-	156-59-2	7.00E-02	2.45E-01				4.0E+05	1.0E+03 ^b	4.1E+05	1.0E+03 ^b		4.1E+05		
Dichloroethylene trans-1,2-	156-60-5	1.00E-01	4.90E-01				3.5E+05	1.0E+03 ^b	3.5E+05	1.0E+03 ^b		3.5E+05		
Dichloroethylene 1,1-	75-35-4	7.00E-03	2.20E-01	1.61E-04	2.10E-01	2.20E-04	1.8E+04	0.70 ^a	1.8E+04	0.70 ^a	0.70 ^a	1.9E+04	0.70 ^a	070 ^a
Dichlorophenol 2,4-	120-83-2		7.34E-02				4.5E+07		4.6E+07	1.0E+03 ^b		5.0E+07		
Dichlorophenoxyacetic acid 2,4-(2,4-D)	94-75-7	7.00E-02	2.45E-01				1.6E+05	0.4	1.6E+05	0.4		1.6E+05		
Dichloropropane 1,2-	78-87-5	5.00E-03	2.20E+00	1.42E-03	1.40E-02		1.0E+30	1.0E+03 ^b	1.0E+30	1.0E+03 ^b	1.0E+03 ^b	1.0E+30	1.0E+03 ^b	
Dichloropropene 1,3-(mixture of isomers)	542-75-6		7.34E-01	9.66E-04	6.10E-02	2.90E-03	1.7E+04		1.7E+04	1.0E+03 ^b	1.0E+03 ^b	1.7E+04	17	50
Dichloropropene cis-1,3-	10061-01-5		7.34E-01	9.66E-04	7.00E-02	3.30E-03	1.0E+30		1.0E+30	1.0E+03 ^b	1.0E+03 ^b	1.0E+30	1.0E+03 ^b	1.0E+03
Dichloropropene trans-1,3-	10061-02-6		7.34E-01	9.66E-04	7.50E-02	3.50E-03	1.0E+30		1.0E+30	1.0E+03 ^b	1.0E+03 ^b	1.0E+30	1.0E+03 ^b	1.0E+03
Dieldrin	60-57-1		1.22E-03	6.04E-06		1.00E-04	1.0E+30		1.0E+30	1.0E+03 ^{b,c}		1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^b
Diethyl phthalate	84-66-2		1.96E+01				1.0E+30		1.0E+30	1.0E+03 ^b		1.0E+30		
Diethylstilbestrol	56-53-1			2.05E-08			1.0E+30		1.0E+30			1.0E+30	1.0E+03 ^{b,c}	
Dimethoate	60-51-5		4.90E-03				1.0E+30		1.0E+30	1.0E+03 ^b	1.00E+03 ^a	1.0E+30		
Dimethoxybenzidine 3,3'-	119-90-4			6.90E-03			2.7E+05		2.7E+05			2.7E+05	1.0E+03 ^{b,c}	
Dimethyl formamide N,N- [DMF]	68-12-2		2.45E+00		7.10E+02		1.6E+04		1.6E+04	1.0E+03 ^b	1.0E+03 ^b	1.6E+04		
Dimethylbenz[a]anthracene 7,12-	57-97-6					3.00E-03	1.0E+30		1.0E+30			1.0E+30		1.0E+03 ^{b,c}
Dimethylbenzidine 3,3'-	119-93-7			1.05E-05			8.8E+07		9.1E+07			9.5E+07	1.0E+03	
Dimethylphenol 2,4-	105-67-9		4.90E-01				8.7E+06		9.0E+06	1.0E+03 ^b		9.4E+06		
Di-n-butyl phthalate	84-74-2		2.45E+00				1.0E+30		1.0E+30	1.0E+03 ^{b,c}		1.0E+30		
Dinitrobenzene 1,3-	99-65-0		2.45E-03				2.2E+05		2.2E+05	540		2.2E+05		
Dinitrophenol 2,4-	51-28-5		4.90E-02				1.5E+05		1.5E+05	1.0E+03 ^b		1.5E+05		

KEY:

- a - TC Rule cap
b - 1,000 mg/L cap
c - Exceeds solubility
- d - Capped by daughter LCTV
e - Constituent has no RGC; LCTV from daughter

Table F-3: Landfill Composite Liner LCTVs

Common Name	CAS#	MCL (mg/L)	HBN (mg/L)				Peak DAF	LCTV based on MCL (mg/L)	Composite Liner					
			Ingestion		Inhalation				Non-Carcinogenic Effect (NC)		Carcinogenic Effect (C)			
			NC	C	NC	C			7-yr Avg DAF	LCTV based on Ingestion	LCTV based on Inhalation	30-yr Avg DAF	LCTV based on Ingestion	LCTV based on Inhalation
Dinitrotoluene 2,4-	121-14-2		4.90E-02	1.42E-04		8.12E-01	2.0E+04		2.0E+04	0.13 ^a		2.0E+04	0.13 ^a	0.13 ^a
Dinitrotoluene 2,6-	606-20-2		2.45E-02	1.42E-04			2.4E+05		2.4E+05	1.0E+03 ^{b,c}		2.4E+05	35	
Di-n-octyl phthalate	117-84-0		4.90E-01				1.0E+30		1.0E+30	1.0E+03 ^{b,c}		1.0E+30		
Dioxane 1,4-	123-91-1			8.78E-03	1.09E+03	1.80E-01	1.6E+04		1.6E+04		1.0E+03 ^b	1.6E+04	140	1.0E+03 ^b
Diphenylamine	122-39-4		6.12E-01				1.0E+30		1.0E+30	1.0E+03 ^{b,c}		1.0E+30		
Diphenylhydrazine 1, 2-	122-66-7			1.21E-04		2.00E-02	6.1E+04		6.1E+04			6.1E+04	7.4	1.0E+03 ^{b,c}
Disulfoton	298-04-4		9.79E-04				1.0E+30		1.0E+30	1.0E+03 ^{b,c}		1.0E+30		
Endosulfan (Endosulfan I and II,mixture)	115-29-7		1.47E-01				1.0E+30		1.0E+30	1.0E+03 ^{b,c}		1.0E+30		
Endrin	72-20-8	2.00E-03	7.34E-03				1.0E+30	0.020 ^a	1.0E+30	0.020 ^a		1.0E+30		
Epichlorohydrin	106-89-8		4.90E-02	9.75E-03	6.00E-02	1.90E-01	1.0E+30		1.0E+30	1.0E+03 ^b	1.0E+03 ^b	1.0E+30	1.0E+03 ^b	1.0E+03 ^b
Epoxybutane 1, 2-	106-88-7				2.40E-01		1.6E+04		1.6E+04		1.0E+03 ^b	1.6E+04		
Ethoxyethanol 2-	110-80-5		9.79E+00		2.90E+03		1.6E+04		1.6E+04	1.0E+03 ^b	1.0E+03 ^b	1.6E+04		
Ethoxyethanol acetate 2-	111-15-9		7.34E+00		3.00E+02		1.7E+04		1.7E+04	1.0E+03 ^b	1.0E+03 ^b	1.7E+04		
Ethyl acetate	141-78-6		2.20E+01				1.0E+30		1.0E+30	1.0E+03 ^b		1.0E+30		
Ethyl ether	60-29-7		4.9				1.6E+05		1.6E+05	1.0E+03 ^b		1.6E+05		
Ethyl methacrylate	97-63-2		2.20E+00				1.0E+30		1.0E+30	1.0E+03 ^b		1.0E+30		
Ethyl methanesulfonate	62-50-0			3.30E-07			1.0E+30		1.0E+30			1.0E+30	1.0E+03 ^b	
Ethylbenzene	100-41-4	7.00E-01	2.45E+00		3.30E+00	1.10E-02	8.0E+04	1.0E+03 ^{b, c}	8.1E+04	1.0E+03 ^{b, c}	1.0E+03 ^{b, c}	8.1E+04		890 ^c
Ethylene dibromide (1,2-Dibromoethane)	106-93-4	5.00E-05		1.14E-06	9.80E-04	8.40E-05	1.0E+30	1.0E+03 ^b	1.0E+30		1.0E+03 ^b	1.0E+30	1.0E+03 ^b	1.0E+03 ^b
Ethylene glycol	107-21-1		4.90E+01		1.20E+04		1.5E+04		1.5E+04	1.0E+03 ^b	1.0E+03 ^b	1.5E+04		
Ethylene oxide	75-21-8			9.47E-05	4.10E-01	5.20E-04	1.0E+30		1.0E+30		1.0E+03 ^b	1.0E+30	1.0E+03 ^b	1.0E+03 ^b
Ethylene thiourea	96-45-7		1.96E-03	8.78E-04		1.60E+03	1.6E+04		1.6E+04	32		1.6E+04	14	1.0E+03 ^b
Fluoranthene	206-44-0		9.79E-01				1.0E+30		1.0E+30	1.0E+03 ^{b, c}		1.0E+30		
Fluoride	16984-48-8	4.00E+00	2.90E+00					1.0E+03 ^b		1.0E+03 ^b				
Formaldehyde	50-00-0		4.90E+00		5.10E+01	1.5	1.4E+04		1.4E+04	1.0E+03 ^b	1.0E+03 ^b	1.4E+04		1.0E+03 ^b
Formic acid	64-18-6		4.90E+01				1.4E+05		1.5E+05	1.0E+03 ^b		1.5E+05		
Furfural	98-01-1		7.34E-02		2.20E+01		1.6E+04		1.6E+04	1.0E+03 ^b	1.0E+03 ^b	1.6E+04		
HCH beta-	319-85-7			5.36E-05		1.70E-02	3.5E+05		3.6E+05			3.6E+05	19 ^c	1.0E+03 ^{b, c}
HCH (Lindane) gamma-	58-89-9	2.00E-04	7.34E-03	7.43E-05		1.60E-03	1.0E+30	0.4 ^{a, b, c}	1.0E+30	0.4 ^{a, b, c}	0.4 ^{a, e}	1.0E+30	0.4 ^{a, b, c}	0.4 ^{a, b, c}
HCH alpha-	319-84-6		0.196	1.53E-05		3.60E-04	1.0E+30	1.0E+03 ^{b, e}	1.0E+30	1.0E+03 ^{b, c}	1.00E+03 ^e	1.0E+30	1.0E+03 ^{b, c}	1.0E+03 ^{b, c}
Heptachlor	76-44-8	4.00E-04	1.22E-02	2.15E-05		1.50E-05	1.0E+30	8.0E-03 ^a	1.0E+30	8.0E-03 ^a		1.0E+30	8.0E-03 ^a	8.0E-03 ^a
Heptachlor epoxide	1024-57-3	2.00E-04	3.18E-04	1.06E-05		2.80E-04	1.0E+30	1.0E+03 ^{b, c}	1.0E+30	1.0E+03 ^{b, c}		1.0E+30	1.0E+03 ^{b, c}	1.0E+03 ^{b, c}
Hexachloro-1,3-butadiene	87-68-3		7.34E-03	1.24E-03		6.10E-04	2.5E+11		2.6E+11	0.50 ^a		2.6E+11	0.50 ^a	0.50 ^a
Hexachlorobenzene	118-74-1	1.00E-03	1.96E-02	6.04E-05		3.60E-05	1.0E+30	0.13 ^{a, c}	1.0E+30	0.13 ^{a, c}		1.0E+30	0.13 ^{a, c}	0.13 ^{a, c}
Hexachlorocyclopentadiene	77-47-4	5.00E-02	1.47E-01		6.90E-04		1.0E+30	1.00E+03 ^{b, c}	1.0E+30	1.0E+03 ^{b, c}	1.0E+03 ^{b, c}	1.0E+30		
Hexachlorodibenzofurans [HxCDFs]	55684-94-1			6.19E-09		1.44E-07	1.0E+30		1.0E+30			1.0E+30	1.0E+03 ^{b, c}	1.0E+03 ^{b, c}
Hexachlorodibenzo-p-dioxins [HxCDDs]	34465-46-8			6.19E-09		1.43E-07	1.0E+30		1.0E+30			1.0E+30	1.0E+03 ^{b, c}	1.0E+03 ^{b, c}
Hexachloroethane	67-72-1		2.45E-02	6.90E-03		3.30E-03	6.0E+05		6.0E+05	3.0 ^a		6.0E+05	3.0 ^a	3.0 ^a
Hexachlorophene	70-30-4		7.34E-03				1.0E+30		1.0E+30	1.0E+03 ^{b, c}		1.0E+30		
Hexane n-	110-54-3		2.69E+02		6.60E-01		7.2E+04		7.3E+04	1.0E+03 ^{b, c}	1.0E+03 ^{b, c}	7.3E+04		
Hydrogen Sulfide	7783-06-4		7.34E-02				1.4E+05		1.5E+05	1.0E+03 ^b		1.5E+05		
Indeno{1,2,3-cd}pyrene	193-39-5			8.05E-05		3.80E-02	1.0E+30		1.0E+30			1.0E+30	1.0E+03 ^{b, c}	1.0E+03 ^{b, c}
Isobutyl alcohol	78-83-1		7.34E+00				1.5E+05		1.5E+05	1.0E+03 ^b		1.5E+05		
Isophorone	78-59-1		4.90E+00	1.02E-01	5.33E+02		2.1E+04		2.2E+04	1.0E+03 ^b	1.0E+03 ^b	2.2E+04	1.0E+03 ^b	
Kepone	143-50-0		1.22E-02				1.0E+30		1.0E+30	1.0E+03 ^{b, c}		1.0E+30		
Lead	7439-92-1	1.50E-02						5.0 ^a						

KEY:

a - TC Rule cap

b - 1,000 mg/L cap

c - Exceeds solubility

d - Capped by daughter LCTV

e - Constituent has no RGC; LCTV from daughter

Table F-3: Landfill Composite Liner LCTVs

Common Name	CAS#	MCL (mg/L)	HBN (mg/L)				Peak DAF	LCTV based on MCL (mg/L)	Composite Liner				
		Ingestion	Ingestion		Inhalation				Non-Carcinogenic Effect (NC)			Carcinogenic Effect (C)	
			NC	C	NC	C			7-yr Avg DAF	LCTV based on Ingestion	LCTV based on Inhalation	30-yr Avg DAF	LCTV based on Ingestion
Manganese	7439-96-5		1.15E+00						1.0E+03 ^b				
Mercury	7439-97-6	2.00E-03	2.45E-03		7.00E-04			0.20 ^{a,c}	0.20 ^{a,c}	0.20 ^{a,c}			
Methacrylonitrile	126-98-7		2.45E-03		6.50E-03		9.8E+05		9.8E+05	1.0E+03 ^b	1.0E+03 ^b	9.8E+05	
Methanol	67-56-1		1.22E+01		1.54E+03		1.4E+04		1.4E+04	1.0E+03 ^b	1.0E+03 ^b	1.4E+04	
Methoxychlor	72-43-5	4.00E-02	1.22E-01				1.0E+30	10 ^{a,c}	1.0E+30	10 ^{a,c}		1.0E+30	
Methoxyethanol 2-	109-86-4		2.45E-02		4.40E+02		1.6E+04		1.6E+04	390	1.0E+03 ^b	1.6E+04	
Methoxyethanol acetate 2-	110-49-6		4.90E-02		5.10E+02		1.6E+04		1.7E+04	810	1.0E+03 ^b	1.7E+04	
Methyl ethyl ketone	78-93-3		1.47E+01		3.30E+01		1.6E+04		1.6E+04	200 ^a	200 ^a	1.6E+04	
Methyl isobutyl ketone	108-10-1		1.96E+00		1.20E+00		1.7E+04		1.7E+04	1.0E+03 ^b	1.0E+03 ^b	1.7E+04	
Methyl methacrylate	80-62-6		3.43E+01		5.30E+00		1.0E+30		1.0E+30	1.0E+03 ^{b,d}	1.0E+03 ^b	1.0E+30	
Methyl parathion	298-00-0		6.12E-03				1.0E+30		1.0E+30	1.0E+03 ^{b,c}	1.00E+03 ^e	1.0E+30	
Methyl tert-butyl ether [MTBE]	1634-04-4				1.70E+01		1.7E+04		1.7E+04		1.0E+03 ^b	1.7E+04	
Methylcholanthrene 3-	56-49-5					1.20E-03	1.0E+30		1.0E+30			1.0E+30	1.0E+03 ^{b,c}
Methylene bromide (Dibromomethane)	74-95-3		2.45E-01				2.0E+05		2.0E+05	1.0E+03 ^b		2.0E+05	
Methylene Chloride (Dichloromethane)	75-09-2	5.00E-03	1.47E+00	1.29E-02	1.00E+01	2.80E-02	6.2E+05	1.0E+03 ^b	6.3E+05	1.0E+03 ^b	1.0E+03 ^b	6.3E+05	1.0E+03 ^b 1.0E+03 ^b
Molybdenum	7439-98-7		1.22E-01							1.0E+03 ^b			
Naphthalene	91-20-3		4.90E-01		1.90E-02		1.1E+05		1.1E+05	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}	1.1E+05	
Nickel	7440-02-0		4.90E-01							1.0E+03 ^b			
Nitrobenzene	98-95-3		1.22E-02		1.50E-01		1.7E+04		1.8E+04	2.0 ^a	2.0 ^a	1.8E+04	
Nitropropane 2-	79-46-9				3.30E-01 2.30E-05	1.6E+04		1.6E+04			1.0E+03 ^b	1.6E+04	0.37
Nitrosodiethylamine N-	55-18-5			6.44E-07		4.30E-05	1.6E+04		1.6E+04			1.6E+04	0.010 0.70
Nitrosodimethylamine N-	62-75-9		1.96E-04	1.89E-06		4.00E-04	1.6E+04		1.6E+04	3.1		1.6E+04	0.030 6.4
Nitroso-di-n-butylamine N-	924-16-3			1.79E-05		2.00E-05	2.6E+04		2.6E+04			2.6E+04	0.47 0.52
Nitroso-di-n-propylamine N-	621-64-7			1.38E-05		1.50E-03	1.7E+04		1.8E+04			1.8E+04	0.25 27
Nitrosodiphenylamine N-	86-30-6		4.90E-01	1.97E-02		5.20E-01	6.4E+04		6.5E+04	1.0E+03 ^{b,c}		6.6E+04	1.0E+03 ^{b,c} 1.0E+03 ^{b,c}
Nitrosomethylethylamine N-	10595-95-6			4.39E-06		4.50E-03	1.6E+04		1.6E+04			1.6E+04	0.072 74
Nitrosopiperidine N-	100-75-4					8.70E-03	1.6E+04		1.6E+04			1.6E+04	140
Nitrosopyrrolidine N-	930-55-2			4.60E-05		9.20E-01	1.6E+04		1.6E+04			1.6E+04	0.74 1.0E+03 ^b
Octamethyl pyrophosphoramide	152-16-9		4.90E-02				4.0E+06		4.0E+06	1.0E+03 ^b		4.0E+06	
Parathion (ethyl)	56-38-2		0.147				1.0E+30		1.0E+30	1.0E+03 ^{b,c}		1.0E+30	
Pentachlorobenzene	608-93-5		1.96E-02				1.0E+30		1.0E+30	1.0E+03 ^{b,c}		1.0E+30	
Pentachlorodibenzofurans [PeCDFs]	30402-15-4			1.24E-09		6.29E-08	1.0E+30		1.0E+30			1.0E+30	1.0E+03 ^{b,c} 1.0E+03 ^{b,c}
Pentachlorodibenzo-p-dioxins [PeCDDs]	36088-22-9			6.19E-10		6.00E-08	1.0E+30		1.0E+30			1.0E+30	1.0E+03 ^{b,c} 1.0E+03 ^{b,c}
Pentachloronitrobenzene (PCNB)	82-68-8		7.34E-02	3.71E-04			1.0E+30		1.0E+30	1.0E+03 ^{b,c}		1.0E+30	1.0E+03 ^{b,c}
Pentachlorophenol	87-86-5	1.00E-03	7.34E-01	8.05E-04		5.40E+01	9.7E+04	97	9.8E+04	100 ^a		9.9E+04	80 100 ^a
Phenol	108-95-2		1.47E+01		9.00E+02		1.6E+04		1.7E+04	1.0E+03 ^b	1.0E+03 ^b	1.7E+04	
Phenyl mercuric acetate	62-38-4		1.96E-03				1.5E+05		1.5E+05	290		1.5E+05	
Phenylenediamine 1,3-	108-45-2		1.47E-01				1.5E+05		1.5E+05	1.0E+03 ^b		1.5E+05	
Phorate	298-02-2		4.90E-03				1.0E+30		1.0E+30	1.0E+03 ^{b,c}		1.0E+30	
Phthalic anhydride	85-44-9		4.90E+01		1.30E+04		1.0E+30		1.0E+30	1.0E+03 ^b	1.0E+03 ^b	1.0E+30	
Polychlorinated biphenyls (Aroclors)	1336-36-3	5.00E-04	4.90E-04	2.41E-04		1.40E-04	1.0E+30	1.0E+03 ^{b,c}	1.0E+30	1.0E+03 ^{b,c}		1.0E+30	1.0E+03 ^{b,c} 1.0E+03 ^{b,c}
Pronamide	23950-58-5		1.84E+00				4.5E+09		4.6E+09	1.0E+03 ^{b,c}		4.7E+09	
Propylene oxide [1,2-Epoxypropane]	75-56-9			4.02E-04	4.90E-01	1.70E-02	1.6E+04		1.7E+04		1.0E+03 ^b	1.7E+04	6.6 280
Pyrene	129-00-0		7.34E-01				1.0E+30		1.0E+30	1.0E+03 ^{b,c}		1.0E+30	
Pyridine	110-86-1		2.45E-02		1.40E+00		1.6E+04		1.6E+04	5.0 ^a	5.0 ^a	1.6E+04	
Safrole	94-59-7			5.36E-04			1.3E+07		1.3E+07			1.4E+07	1.0E+03 ^{b,c}

KEY:

- a - TC Rule cap
b - 1,000 mg/L cap
c - Exceeds solubility
d - Capped by daughter LCTV
e - Constituent has no RGC; LCTV from daughter

Table F-3: Landfill Composite Liner LCTVs

Common Name	CAS#	MCL (mg/L)	HBN (mg/L)				Peak DAF	LCTV based on MCL (mg/L)	Composite Liner					
		Ingestion	Ingestion		Inhalation				Non-Carcinogenic Effect (NC)		Carcinogenic Effect (C)			
			NC	C	NC	C			7-yr Avg DAF	LCTV based on Ingestion	LCTV based on Inhalation	30-yr Avg DAF	LCTV based on Ingestion	LCTV based on Inhalation
Selenium	7782-49-2	5.00E-02	1.22E-01					1.0 ^a		1.0 ^a				
Silver	7440-22-4		1.22E-01							5.0 ^a				
Strychnine and salts	57-24-9		7.34E-03				7.7E+05		7.8E+05	1.0E+03 ^{b,c}		7.8E+05		
Styrene	100-42-5	1.00E-01	4.90E+00		3.60E+00		5.4E+04	1.0E+03 ^{b,c}	5.5E+04	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}	5.5E+04		
Tetrachlorobenzene 1,2,4,5-	95-94-3		7.34E-03				1.0E+30		1.0E+30	1.0E+03 ^{b,c}		1.0E+30		
Tetrachlorodibenzofuran, 2,3,7,8-	51207-31-9			6.19E-09		1.00E-07	1.0E+30		1.0E+30			1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Tetrachlorodibenzo-p-dioxin, 2,3,7,8-	1746-01-6	3.00E-08	2.45E-08	6.44E-10		2.20E-09	1.0E+30	1.0E+03 ^{b,c}	1.0E+30	1.0E+03 ^{b,c}		1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Tetrachloroethane 1,1,1,2-	630-20-6		0.734	3.71E-03		1.90E-03	1.0E+30	0.64 ^e	1.0E+30	1.0E+03 ^b		1.0E+30	0.64 ^d	0.64 ^d
Tetrachloroethane 1,1,2,2-	79-34-5		1.47E+00	4.83E-04		5.00E-04	1.0E+30	0.64 ^e	1.0E+30	1.0E+03 ^b	0.64 ^e	1.0E+30	0.64 ^d	0.64 ^d
Tetrachloroethylene	127-18-4	5.00E-03	2.45E-01	1.86E-03	9.40E-01	2.10E-02	2.5E+04	0.70 ^a	2.5E+04	0.70 ^a	0.70 ^a	2.5E+04	0.70 ^a	0.70 ^a
Tetrachlorophenol 2,3,4,6-	58-90-2		0.734				1.1E+07		1.1E+07	1.0E+03 ^{b,c}		1.2E+07		
Tetraethyl dithiopyrophosphate (Sulfotep)	3689-24-5		1.22E-02				1.0E+30		1.0E+30	1.0E+03 ^{b,c}		1.0E+30		
Thallium	7440-28-0	2.00E-03	1.96E-03					1.0E+03 ^b		1.0E+03 ^b				
Thiram [Thiuram]	137-26-8		1.22E-01				3.0E+09		3.2E+09	1.0E+03 ^{b,c}		3.5E+09		
Toluene	108-88-3	1.00E+00	4.90E+00		1.30E+00		2.9E+04	1.0E+03 ^{b,c}	2.9E+04	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}	2.9E+04		
Toluenediamine 2,4-	95-80-7			3.02E-05		7.50E+00	1.6E+04		1.6E+04			1.6E+04	0.50	1.0E+03 ^b
Toluidine o-	95-53-4			4.02E-04		3.60E-02	1.7E+04		1.7E+04			1.7E+04	6.9	620
Toluidine p-	106-49-0			5.08E-04			2.0E+05		2.1E+05			2.1E+05	100	
Toxaphene (chlorinated camphenes)	8001-35-2	3.00E-03		8.78E-05		3.60E-03	1.0E+30	0.50 ^a	1.0E+30			1.0E+30	0.50 ^a	0.50 ^a
Tribromomethane (Bromoform)	75-25-2	8.00E-02	4.90E-01	1.22E-02		1.90E-02	3.1E+05	1.0E+03 ^b	3.1E+05	1.0E+03 ^b		3.2E+05	1.0E+03 ^b	1.0E+03 ^b
Trichloro-1,2,2-trifluoro-ethane 1,1,2-	76-13-1		7.34E+02		9.50E+01		7.4E+04		7.4E+04	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}	7.5E+04		
Trichlorobenzene 1,2,4-	120-82-1	7.00E-02	2.45E-01		8.30E-01		6.8E+06	1.0E+03 ^{b,c}	6.8E+06	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}	6.9E+06		
Trichloroethane 1,1,1-	71-55-6	2.00E-01	6.85E+00		6.90E+00		1.0E+30	0.96 ^d	1.0E+30	0.96 ^d	0.96 ^d	1.0E+30	0.96 ^e	0.96 ^e
Trichloroethane 1,1,2-	79-00-5	5.00E-03	0.0979	1.69E-03		1.10E-03	1.4E+07	0.96 ^d	1.4E+07	0.96 ^d	0.96 ^e	1.4E+07	0.96 ^d	0.96 ^d
Trichloroethylene (1,1,2-Trichloroethylene)	79-01-6	5.00E-03		8.78E-03	1.90E+00	6.80E-03	2.3E+04	0.50 ^a	2.3E+04		0.50 ^a	2.3E+04	0.50 ^a	0.50 ^a
Trichlorofluoromethane (Freon 11)	75-69-4		7.34E+00		2.10E+00		2.3E+04		2.3E+04	1.0E+03 ^b	1.0E+03 ^b	2.3E+04		
Trichlorophenol 2,4,5-	95-95-4		2.45E+00				3.8E+10		4.2E+10	400 ^a		4.2E+10		
Trichlorophenol 2,4,6-	88-06-2			8.78E-03		2.80E-01	2.7E+04		2.7E+04			2.7E+04	2.0 ^a	2.0 ^a
Trichlorophenoxy)propionic acid 2-(2,4,5- (Silvex)	93-72-1	5.00E-02	1.96E-01				4.3E+05	1.0 ^a	4.4E+05	1.0 ^a		4.4E+05		
Trichlorophenoxyacetic acid 2,4,5-	93-76-5		2.45E-01				2.5E+05		2.5E+05	1.0E+03 ^{b,c}		2.5E+05		
Trichloropropane 1,2,3-	96-18-4		1.47E-01	1.38E-05	3.40E-02		1.0E+30		1.0E+30	1.0E+03 ^b	1.0E+03 ^b	1.0E+30	1.0E+03 ^b	
Triethylamine	121-44-8				1.10E-01		1.8E+04		1.8E+04		1.0E+03 ^b	1.8E+04		
Trinitrobenzene (1,3,5-Trinitrobenzene) sym-	99-35-4		7.34E-01				1.7E+05		1.8E+05	1.0E+03 ^{b,c}		1.8E+05		
Tris(2,3-dibromopropyl)phosphate	126-72-7			9.89E-06			1.0E+30		1.0E+30			1.0E+30	1.0E+03 ^{b,c}	
Vanadium	7440-62-2		1.71E-01							1.0E+03 ^b				
Vinyl acetate	108-05-4		2.45E+01		1.20E+00		1.6E+04		1.6E+04	1.0E+03 ^b	1.0E+03 ^b	1.6E+04		
Vinyl chloride	75-01-4	2.00E-03	7.34E-02	1.34E-04	2.90E-01	2.50E-03	1.6E+04	0.20 ^a	1.6E+04	0.20 ^a	0.20 ^a	1.6E+04	0.20 ^a	0.20 ^a
Xylene m-	108-38-3		4.90E+01		1.30E+00		1.0E+05		1.0E+05	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}	1.1E+05		
Xylene o-	95-47-6		4.90E+01		1.40E+00		8.4E+04		8.4E+04	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}	8.5E+04		
Xylene p-	106-42-3		4.90E+01		1.30E+00		1.1E+05		1.1E+05	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}	1.1E+05		
Xylenes (total)	1330-20-7	1.00E+01	4.90E+01		1.40E+00		9.7E+04	1.0E+03 ^{b,c}	9.8E+04	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}	9.9E+04		
Zinc	7440-66-6		7.34E+00							1.0E+03 ^b				

KEY:

- a - TC Rule cap
b - 1,000 mg/L cap
c - Exceeds solubility
d - Capped by daughter LCTV
e - Constituent has no RGC; LCTV from daughter

Table F-4: Surface Impoundment No-Liner LCTVs

Common Name	CAS#	MCL (mg/L)	HBN (mg/L)				No Liner/In-Situ Soil								
			Ingestion	Ingestion		Inhalation		Peak DAF	LCTV based on MCL (mg/L)	Non-Carcinogenic Effect (NC)			Carcinogenic Effect (C)		
				NC	C	NC	C			7-yr Avg DAF	LCTV based on Ingestion	LCTV based on Inhalation	30-yr Avg DAF	LCTV based on Ingestion	LCTV based on Inhalation
Acenaphthene	83-32-9		1.47E+00				2.2		2.2	3.2		2.3			
Acetaldehyde [Ethanal]	75-07-0				2.20E-01	4.10E-02	1.3		1.3		0.29	1.5		6.2E-02	
Acetone (2-propanone)	67-64-1		2.45E+00		1.50E+03		1.3		1.3	3.2	1.0E+03 ^b	1.5			
Acetonitrile (methyl cyanide)	75-05-8				3.10E+00		1.3		1.3		4.1	1.5			
Acetophenone	98-86-2		2.45E+00				1.3		1.3	3.2		1.5			
Acrolein	107-02-8		4.90E-01		3.30E-04		1.0E+30		1.0E+30	1.0E+03 ^b	1.0E+03 ^b	1.0E+30			
Acrylamide	79-06-1		4.90E-03	2.15E-05		5.10E+00	1.3		1.4	6.9E-03		1.7	3.5E-05	8.4E+00	
Acrylic acid [propenoic acid]	79-10-7		1.22E+01		1.50E+01		1.3		1.3	16	20	1.5			
Acrylonitrile	107-13-1		2.45E-02	1.79E-04	3.80E-02	1.00E-03	1.3		1.4	5.2E-03 ^d	0.051	1.6	2.7E-05 ^d	1.6E-03	
Aldrin	309-00-2		7.34E-04	5.68E-06		1.00E-05	380		380	0.28 ^c		380	2.1E-03	3.8E-03	
Allyl alcohol	107-18-6		1.22E-01				1.3		1.3	0.16		1.5			
Aniline (benzenamine)	62-53-3			1.69E-02	9.30E-01	2.20E+00	1.3		1.3		1.2	1.5	0.026	3.3E+00	
Anthracene	120-12-7		7.34E+00				3.6		3.6	27 ^c		3.8			
Antimony	7440-36-0	6.00E-03	9.79E-03					8.5E-03		0.014					
Arsenic	7440-38-2	5.00E-02	7.34E-03	6.44E-05				0.080		0.013			1.4E-04		
Barium	7440-39-3	2.00E+00	1.71E+00					2.7		2.4					
Benz[a]anthracene	56-55-3			8.05E-05		1.80E-02	36		37			37	2.9E-03	0.66 ^c	
Benzene	71-43-2	5.00E-03		1.76E-03	1.90E-01	1.60E-03	1.3	6.4E-03	1.3		0.25	1.6	2.7E-03	2.5E-03	
Benzidine	92-87-5		7.34E-02	4.20E-07		2.60E+00	1.3		1.3	0.097		1.5	6.4E-07	4.0	
Benzo[a]pyrene	50-32-8	2.00E-04		1.32E-05		5.40E-03	110	0.021 ^c	110			110	1.4E-03	0.57 ^c	
Benzo[b]fluoranthene	205-99-2			8.05E-05		6.30E-04	110		110			110	8.6E-03 ^c	0.067 ^c	
Benzyl alcohol	100-51-6		7.34E+00				1.3		1.3	9.7		1.5			
Benzyl chloride	100-44-7			5.68E-04		5.20E-04	1.0E+30		1.0E+30	11 ^e		1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}	
Beryllium	7440-41-7	4.00E-03	4.90E-02					0.28		0.53					
Bis(2-chloroethyl)ether	111-44-4			8.78E-05		1.10E-03	2.1		2.2		1.0E+03 ^e	2.6	2.2E-04	2.8E-03	
Bis(2-chloroisopropyl)ether	39638-32-9		9.79E-01	1.38E-03		5.90E-03	1.3		1.4	1.3		1.6	2.2E-03	9.3E-03	
Bis(2-ethylhexyl)phthalate	117-81-7	6.00E-03	4.90E-01	6.90E-03	1.80E+02	2.80E+01	7.4E+10	1.0E+03 ^{b,c}	7.5E+10	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}	7.5E+10	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}	
Bromodichloromethane	75-27-4	8.00E-02	4.90E-01	1.56E-03		8.00E-04	1.3	0.11	1.4	0.68		1.6	2.6E-03	1.3E-03	
Bromomethane	74-83-9		3.43E-02		1.50E-02		190		230	7.7	3.4	230			
Butadiene 1, 3-	106-99-0			6.00E-02	4.00E-05		1.3		1.3		0.080	1.6		6.2E-05	
Butanol n-	71-36-3		2.45E+00				1.3		1.3	3.2		1.5			
Butyl benzyl phthalate	85-68-7		4.90E+00				4.0		4.1	20 ^c		4.2			
Butyl-4,6-dinitrophenol,2-sec-(Dinoseb)	88-85-7	7.00E-03	2.45E-02				1.3	8.9E-03	1.3	0.033		1.6			
Cadmium	7440-43-9	5.00E-03	1.22E-02					8.3E-03		0.021					
Carbon disulfide	75-15-0		2.45E+00		1.90E+00		1.3		1.4	3.4	2.6	1.6			
Carbon tetrachloride	56-23-5	5.00E-03	0.0171	7.43E-04	0.021	7.60E-04	1.5	7.3E-03	1.5	0.025	0.031	1.7	1.3E-03	1.3E-03	
Chlordane	57-74-9	2.00E-03	0.0122	2.76E-04	2.80E-02	1.50E-03	130	0.030 ^a	140	0.030 ^a	0.030 ^a	140	0.030 ^a	0.030 ^a	
Chloro-1,3-butadiene 2-(Chloroprene)	126-99-8		4.90E-01		2.20E-02		1.3		1.3	0.65	0.029	1.6			
Chloroaniline p-	106-47-8		9.79E-02				1.3		1.3	0.13		1.5			
Chlorobenzene	108-90-7	1.00E-01	4.90E-01		2.00E-01		1.3	0.13	1.4	0.67	0.27	1.6			
Chlorobenzilate	510-15-6		4.90E-01	3.58E-04		1.20E+00	4.4		4.4	2.2		4.7	1.7E-03	5.6	
Chlorodibromomethane	124-48-1	8.00E-02	4.90E-01	1.15E-03		7.50E-04	1.3	0.10	1.4	0.67		1.6	1.8E-03	1.2E-03	
Chloroethane [Ethyl chloride]	75-00-3			3.00E+01			1.3		1.3		40	1.5			
Chloroform	67-66-3	8.00E-02	2.45E-01		3.30E-01		1.3	0.10	1.3	0.33	0.44	1.6			
Chloromethane	74-87-3			7.43E-03	2.60E-01	5.90E-03	1.3		1.3		0.34	1.5	1.1E-02	9.0E-03	
Chlorophenol 2-	95-57-8		1.22E-01		9.70E-03		1.3		1.3	0.16	0.013	1.6			
Chloropropene 3- (Allyl Chloride)	107-05-1			3.00E-03	1.90E-03		9.7E+05		9.8E+05		1.0E+03 ^b	2.2E+06		1.0E+03 ^b	
Chromium (III) (Chromic Ion)	16065-83-1	1.00E-01	3.67E+01					2.6		100					
Chromium (VI)	18540-29-9	1.00E-01	7.34E-02					0.69		0.55					
Chrysene	218-01-9			8.05E-04		7.30E-03	36		37			37	0.029 ^c	0.27 ^c	

KEY:

- a - TC Rule cap d - Capped by daughter LCTV
b - 1,000 mg/L cap e - Constituent has no RGC; LCTV from daughter
c - Exceeds solubility

Table F-4: Surface Impoundment No-Liner LCTVs

Common Name	CAS#	MCL (mg/L)	HBN (mg/L)				No Liner/In-Situ Soil							
		Ingestion	Ingestion		Inhalation		Peak DAF	LCTV based on MCL (mg/L)	Non-Carcinogenic Effect (NC)		Carcinogenic Effect (C)			
			NC	C	NC	C			7-yr Avg DAF	LCTV based on Ingestion	LCTV based on Inhalation	30-yr Avg DAF	LCTV based on Ingestion	LCTV based on Inhalation
Cobalt	7440-48-4		4.90E-01						1.2					
Copper	7440-50-8	1.30E+00						5.5						
Cresol m-	108-39-4		1.22E+00		1.20E+03		1.3		1.3	1.6	200 ^a	1.5		
Cresol o-	95-48-7		1.22E+00		8.80E+02		1.3		1.3	1.6	200 ^a	1.5		
Cresol p-	106-44-5		1.22E-01		1.30E+03		1.3		1.3	0.16	200 ^a	1.5		
Cresols	1319-77-3		1.22E+00		1.10E+03		1.3		1.3	1.6	1.0E+03 ^b	1.6		
Cumene	98-82-8		2.45E+00		1.30E+00		1.7		1.7	4.2	2.2	1.9		
Cyclohexanol	108-93-0		4.16E-04		3.90E-04		1.3		1.3	5.5E-04	5.1E-04	1.5		
Cyclohexanone	108-94-1		1.22E+02				1.3		1.3	160		1.5		
DDD	72-54-8			4.02E-04			4.4E+08		4.4E+08			4.4E+08	1.0E+03 ^{b,c}	
DDE	72-55-9			2.84E-04			3.2E+04		3.2E+04			3.2E+04	9.0 ^c	
DDT p,p'	50-29-3		1.22E-02	2.84E-04	8.80E-03	1.0E+30	1.0E+30	1.0E+03 ^{b,c}				1.0E+30	10 ^c	1.0E+03 ^{b,c}
Diallate	2303-16-4			1.58E-03			38		38			42	0.066	
Dibenz[a,h]anthracene	53-70-3			1.32E-05	3.80E-01	4.8E+03		4.9E+03				4.9E+03	0.064 ^c	1.0E+03 ^{b,c}
Dibromo-3-chloropropane 1,2-	96-12-8	2.00E-04		6.90E-05	2.90E-03	7.90E-02	1.4	2.8E-04	1.5		4.2E-03	1.7	1.2E-04	0.14
Dichlorobenzene 1,2-	95-50-1	6.00E-01	2.20E+00		7.70E-01		1.5	0.88	1.5	3.3	1.1	1.7		
Dichlorobenzene 1,4-	106-46-7	7.50E-02		4.02E-03	3.00E+00	1.30E-03	1.5	0.11	1.5		4.4	1.7	6.7E-03	2.2E-03
Dichlorobenzidine 3,3'-	91-94-1			2.15E-04		4.90E+00	1.6		1.6			1.8	3.9E-04	8.9 ^c
Dichlorodifluoromethane (Freon 12)	75-71-8		4.90E+00		5.80E-01		1.3		1.3	6.6	0.78	1.6		
Dichloroethane 1,1-	75-34-3		2.45		1.6	7.40E-03	1.3	5.6E-03 ^e	1.4	0.22 ^d	0.45 ^d	1.6	4.6E-04 ^e	8.5E-03 ^d
Dichloroethane 1,2-	107-06-2	5.00E-03		1.06E-03	1.00E+01	6.30E-04	1.3	4.0E-03 ^d	1.4	0.15 ^e	0.32 ^d	1.6	3.2E-04 ^d	1.0E-03
Dichloroethylene cis-1,2-	156-59-2	7.00E-02	2.45E-01				1.3	0.088	1.3	0.33		1.5		
Dichloroethylene trans-1,2-	156-60-5	1.00E-01	4.90E-01				1.3	0.13	1.3	0.65		1.5		
Dichloroethylene 1,1-	75-35-4	7.00E-03	2.20E-01	1.61E-04	2.10E-01	2.20E-04	1.3	8.9E-03	1.3	0.29	0.28	1.6	2.5E-04	3.4E-04
Dichlorophenol 2,4-	120-83-2		7.34E-02				1.3		1.4	0.10		1.6		
Dichlorophenoxyacetic acid 2,4-(2,4-D)	94-75-7	7.00E-02	2.45E-01				1.3	0.088	1.3	0.3		1.5		
Dichloropropane 1,2-	78-87-5	5.00E-03	2.20E+00	1.42E-03	1.40E-02		1.5	7.5E-03	1.6	3.4	0.022	1.9	2.6E-03	
Dichloropropene 1,3-(mixture of isomers)	542-75-6		7.34E-01	9.66E-04	6.10E-02	2.90E-03	1.3		1.3	1.0	0.081	1.5	1.5E-03	4.4E-03
Dichloropropene cis-1,3-	10061-01-5		7.34E-01	9.66E-04	7.00E-02	3.30E-03	5.3E+06		5.9E+06	1.0E+03 ^b	1.0E+03 ^b	1.3E+07	1.0E+03 ^b	1.0E+03 ^b
Dichloropropene trans-1,3-	10061-02-6		7.34E-01	9.66E-04	7.50E-02	3.50E-03	5.3E+06		5.9E+06	1.0E+03 ^b	1.0E+03 ^b	1.3E+07	1.0E+03 ^b	1.0E+03 ^b
Dieldrin	60-57-1		1.22E-03	6.04E-06		1.00E-04	3.3E+04		3.3E+04	40 ^c		3.3E+04	0.20 ^c	3.3 ^c
Diethyl phthalate	84-66-2		1.96E+01				1.5		1.5	30		1.8		
Diethylstilbestrol	56-53-1			2.05E-08			3.1		3.1			3.2	6.6E-08	
Dimethoate	60-51-5		4.90E-03				10		11	0.054	1.0E+03 ^e	12		
Dimethoxybenzidine 3,3'-	119-90-4			6.90E-03			1.3		1.3			1.5	0.010	
Dimethyl formamide N,N- [DMF]	68-12-2		2.45E+00		7.10E+02		1.3		1.3	3.2	940	1.5		
Dimethylbenz[a]anthracene 7,12-	57-97-6					3.00E-03	3.1E+04		3.1E+04			3.1E+04		94 ^c
Dimethylbenzidine 3,3'-	119-93-7			1.05E-05			1.3		1.4			1.6	1.6E-05	
Dimethylphenol 2,4-	105-67-9		4.90E-01				1.3		1.3	0.66		1.6		
Di-n-butyl phthalate	84-74-2		2.45E+00				5.0		5.1	12 ^c		5.2		
Dinitrobenzene 1,3-	99-65-0		2.45E-03				1.3		1.3	3.2E-03		1.5		
Dinitrophenol 2,4-	51-28-5		4.90E-02				1.3		1.3	0.065		1.5		
Dinitrotoluene 2,4-	121-14-2		4.90E-02	1.42E-04		8.12E-01	1.3		1.3	0.065		1.5	2.2E-04	0.13 ^a
Dinitrotoluene 2,6-	606-20-2		2.45E-02	1.42E-04			1.3		1.3	0.032		1.5	2.2E-04	
Di-n-octyl phthalate	117-84-0		4.90E-01				1.0E+30		1.0E+30	1.0E+03 ^{b,c}		1.0E+30		
Dioxane 1,4-	123-91-1			8.78E-03	1.09E+03	1.80E-01	1.3		1.3		1.0E+03 ^b	1.5	0.013	0.27
Diphenylamine	122-39-4		6.12E-01				1.6		1.6	1.0		1.8		
Diphenylhydrazine 1, 2-	122-66-7			1.21E-04		2.00E-02	1.4		1.4			1.6	1.9E-04	0.032
Disulfoton	298-04-4		9.79E-04				150		160	0.15		200		

KEY:

a - TC Rule cap

d - Capped by daughter LCTV

b - 1,000 mg/L cap

e - Constituent has no RGC; LCTV from daughter

c - Exceeds solubility

Table F-4: Surface Impoundment No-Liner LCTVs

Common Name	CAS#	MCL (mg/L)	HBN (mg/L)				No Liner/In-Situ Soil							
			Ingestion	Inhalation		Peak DAF	LCTV based on MCL (mg/L)	Non-Carcinogenic Effect (NC)			Carcinogenic Effect (C)			
				NC	C			NC	C	7-yr Avg DAF	LCTV based on Ingestion	LCTV based on Inhalation	30-yr Avg DAF	LCTV based on Ingestion
Endosulfan (Endosulfan I and II,mixture)	115-29-7		1.47E-01				1.8		1.9	0.27		2.1		
Endrin	72-20-8	2.00E-03	7.34E-03				150	0.020 ^a	150	0.020 ^a		150		
Epichlorohydrin	106-89-8		4.90E-02	9.75E-03	6.00E-02	1.90E-01	7.6E+04		8.3E+04	1.0E+03 ^b	1.0E+03 ^b	8.8E+04	860	1.0E+03 ^b
Epoxybutane 1, 2-	106-88-7				2.40E-01		1.3		1.3		0.32	1.5		
Ethoxyethanol 2-	110-80-5		9.79E+00		2.90E+03		1.3		1.3	13	1.0E+03 ^b	1.5		
Ethoxyethanol acetate 2-	111-15-9		7.34E+00		3.00E+02		1.3		1.3	9.7	400	1.5		
Ethyl acetate	141-78-6		2.20E+01				2.1		2.2	49		2.6		
Ethyl ether	60-29-7		4.9				1.3		1.3	6.5		1.5		
Ethyl methacrylate	97-63-2		2.20E+00				1.6		1.7	3.8		2.0		
Ethyl methanesulfonate	62-50-0			3.30E-07			1.0E+30		1.0E+30			1.0E+30	1.0E+03 ^b	
Ethylbenzene	100-41-4	7.00E-01	2.45E+00		3.30E+00	1.10E-02	1.4	1.0	1.5	3.6	4.82	1.6		0.018
Ethylene dibromide (1,2-Dibromoethane)	106-93-4	5.00E-05		1.14E-06	9.80E-04	8.40E-05	3.5	1.7E-04	3.8		3.7E-03	4.3	4.9E-06	3.6E-04
Ethylene glycol	107-21-1		4.90E+01		1.20E+04		1.3		1.3	65	1.0E+03 ^b	1.5		
Ethylene oxide	75-21-8			9.47E-05	4.10E-01	5.20E-04	7.3E+03		8.3E+03		1.0E+03 ^b	8.6E+03	0.81	4.5
Ethylene thiourea	96-45-7		1.96E-03	8.78E-04		1.60E+03	1.3		1.3	2.6E-03		1.5	1.3E-03	1.0E+03 ^b
Fluoranthene	206-44-0		9.79E-01				7.7		7.7	7.5 ^c		7.8		
Fluoride	16984-48-8	4.00E+00	2.90E+00					4.9		3.8				
Formaldehyde	50-00-0		4.90E+00		5.10E+01	1.5	1.3		1.3	6.5	67	1.5		2.3
Formic acid	64-18-6		4.90E+01				1.3		1.3	65		1.5		
Furfural	98-01-1		7.34E-02		2.20E+01		1.3		1.3	0.097	29	1.5		
HCH beta-	319-85-7			5.36E-05		1.70E-02	1.7		1.7			1.9	1.0E-04	0.0
HCH (Lindane) gamma-	58-89-9	2.00E-04	7.34E-03	7.43E-05		1.60E-03	220	0.044	230	0.4 ^{a,d}	0.4 ^{a,e}	290	0.021	0.4 ^a
HCH alpha-	319-84-6		0.196	1.53E-05		3.60E-04	280	0.29 ^e	280	0.64 ^d	3.5 ^e	350	5.3E-03	0.13
Heptachlor	76-44-8	4.00E-04	1.22E-02	2.15E-05		1.50E-05	1.0E+30	8.0E-03 ^a	1.0E+30	8.0E-03 ^a		1.0E+30	8.0E-03 ^a	8.0E-03 ^a
Heptachlor epoxide	1024-57-3	2.00E-04	3.18E-04	1.06E-05		2.80E-04	3.3E+03	0.66 ^c	3.3E+03	1.1 ^c		3.4E+03	0.036	9.6E-01 ^c
Hexachloro-1,3-butadiene	87-68-3		7.34E-03	1.24E-03		6.10E-04	5.6		5.6	0.041		5.7	7.1E-03	3.5E-03
Hexachlorobenzene	118-74-1	1.00E-03	1.96E-02	6.04E-05		3.60E-05	43	0.043 ^c	43	0.13 ^{a,c}		43	2.6E-03	1.5E-03
Hexachlorocyclopentadiene	77-47-4	5.00E-02	1.47E-01		6.90E-04		1.0E+30	1.0E+03 ^{b, c}	1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}	1.0E+30		
Hexachlorodibenzofurans [HxCDFs]	55684-94-1			6.19E-09		1.44E-07	4.9E+08		4.9E+08			5.0E+08	3.1 ^c	71 ^c
Hexachlorodibenzo-p-dioxins [HxCDDs]	34465-46-8			6.19E-09		1.43E-07	1.8E+03		1.8E+03			1.8E+03	1.1E-05 ^c	2.6E-04 ^c
Hexachloroethane	67-72-1		2.45E-02	6.90E-03		3.30E-03	1.9		1.9	0.047		2.2	0.015	7.1E-03
Hexachlorophene	70-30-4		7.34E-03				17		17	0.13		17		
Hexane n-	110-54-3		2.69E+02		6.60E-01		1.4		1.4	390 ^c	0.95	1.6		
Hydrogen Sulfide	7783-06-4		7.34E-02				1.3		1.3	0.097		1.5		
Indeno[1,2,3-cd]pyrene	193-39-5			8.05E-05		3.80E-02	550		550			550	0.044 ^c	2.1E+01 ^c
Isobutyl alcohol	78-83-1		7.34E+00				1.3		1.3	9.7		1.5		
Isophorone	78-59-1		4.90E+00	1.02E-01	5.33E+02		1.3		1.3	6.5	710	1.6	0.16	
Kepone	143-50-0		1.22E-02				3.4		3.4	0.041		3.5		
Lead	7439-92-1	1.50E-02						0.078						
Manganese	7439-96-5		1.15E+00							1.6				
Mercury	7439-97-6	2.00E-03	2.45E-03		7.00E-04			2.5E-03		3.3E-03	9.4E-04			
Methacrylonitrile	126-98-7		2.45E-03		6.50E-03		1.3		1.4	3.3E-03	8.8E-03	1.6		
Methanol	67-56-1		1.22E+01		1.54E+03		1.3		1.3	16	1.0E+03 ^b	1.5		
Methoxychlor	72-43-5	4.00E-02	1.22E-01				1.1E+20	10 ^{a, c}	1.8E+20	1.0E+01 ^{a,c}		1.8E+20		
Methoxyethanol acetate 2-	110-49-6		4.90E-02		5.10E+02		1.3		1.3	0.065	670	1.5		
Methoxyethanol 2-	109-86-4		2.45E-02		4.40E+02		1.3		1.3	0.032	580	1.5		
Methyl ethyl ketone	78-93-3		1.47E+01		3.30E+01		1.3		1.3	19	44	1.5		
Methyl isobutyl ketone	108-10-1		1.96E+00		1.20E+00		1.3		1.3	2.6	1.6	1.5		
Methyl methacrylate	80-62-6		3.43E+01		5.30E+00		1.7		1.8	50 ^c	9.8	2.1		

KEY:

- a - TC Rule cap
b - 1,000 mg/L cap
c - Exceeds solubility
d - Capped by daughter LCTV
e - Constituent has no RGC; LCTV from daughter

Table F-4: Surface Impoundment No-Liner LCTVs

Common Name	CAS#	MCL (mg/L)	HBN (mg/L)				No Liner/In-Situ Soil							
			Ingestion	Ingestion		Inhalation		Peak DAF	LCTV based on MCL (mg/L)	Non-Carcinogenic Effect (NC)		Carcinogenic Effect (C)		
				NC	C	NC	C			7-yr Avg DAF	LCTV based on Ingestion	LCTV based on Inhalation	30-yr Avg DAF	LCTV based on Ingestion
Methyl parathion	298-00-0		6.12E-03				68		75	0.46	1.0E+03 ^a	83		
Methyl tert-butyl ether [MTBE]	1634-04-4				1.70E+01		1.3		1.3		22	1.5		
Methylcholanthrene 3-	56-49-5					1.20E-03	4.9E+08		4.9E+08			5.0E+08		1.0E+03 ^{b,c}
Methylene bromide (Dibromomethane)	74-95-3		2.45E-01				1.3		1.3	0.32		1.5		
Methylene Chloride (Dichloromethane)	75-09-2	5.00E-03	1.47E+00	1.29E-02	1.00E+01	2.80E-02	1.3	6.3E-03	1.3	2.0	13	1.5	0.020	0.043
Molybdenum	7439-98-7		1.22E-01							0.16				
Naphthalene	91-20-3		4.90E-01		1.90E-02		1.5		1.5	0.74	0.029	1.7		
Nickel	7440-02-0		4.90E-01							0.77				
Nitrobenzene	98-95-3		1.22E-02		1.50E-01		1.3		1.3	0.016	0.20	1.5		
Nitropropane 2-	79-46-9				3.30E-01	2.30E-05	1.3		1.3		0.44	1.5		3.5E-05
Nitrosodiethylamine N-	55-18-5			6.44E-07		4.30E-05	1.3		1.3			1.5	9.8E-07	6.5E-05
Nitrosodimethylamine N-	62-75-9		1.96E-04	1.89E-06		4.00E-04	1.3		1.3	2.6E-04		1.5	2.9E-06	6.1E-04
Nitroso-di-n-butylamine N-	924-16-3			1.79E-05		2.00E-05	1.3		1.3			1.6	2.8E-05	3.1E-05
Nitroso-di-n-propylamine N-	621-64-7			1.38E-05		1.50E-03	1.3		1.3			1.5	2.1E-05	2.3E-03
Nitrosodiphenylamine N-	86-30-6		4.90E-01	1.97E-02		5.20E-01	1.4		1.4	0.69		1.6	0.032	0.84
Nitrosomethylethylamine N-	10595-95-6			4.39E-06		4.50E-03	1.3		1.3			1.5	6.7E-06	6.8E-03
Nitrosopiperidine N-	100-75-4					8.70E-03	1.3		1.3			1.5		0.013
Nitrosopyrrolidine N-	930-55-2			4.60E-05		9.20E-01	1.3		1.3			1.5	7.0E-05	1.4
Octamethyl pyrophosphoramidate	152-16-9		4.90E-02				1.3		1.4	0.066		1.6		
Parathion (ethyl)	56-38-2		0.147				930		960	140 ^c		1.2E+03		
Pentachlorobenzene	608-93-5		1.96E-02				41		41	0.80		41		
Pentachlorodibenzofurans [PeCDFs]	30402-15-4			1.24E-09		6.29E-08	15		15			15	1.8E-08	9.2E-07
Pentachlorodibenzo-p-dioxins [PeCDDs]	36088-22-9			6.19E-10		6.00E-08	680		680			680	4.3E-07	4.1E-05
Pentachloronitrobenzene (PCNB)	82-68-8		7.34E-02	3.71E-04			6.8		6.8	0.50		7.0	2.6E-03	
Pentachlorophenol	87-86-5	1.00E-03	7.34E-01	8.05E-04		5.40E+01	1.5	1.5E-03	1.5	1.1		1.7	1.3E-03	90
Phenol	108-95-2		1.47E+01		9.00E+02		1.3		1.3	19	1.0E+03 ^b	1.5		
Phenyl mercuric acetate	62-38-4		1.96E-03				1.3		1.3	2.6E-03		1.5		
Phenylenediamine 1,3-	108-45-2		1.47E-01				1.3		1.3	0.19		1.5		
Phorate	298-02-2		4.90E-03				6.7E+19		1.2E+20	1.0E+03 ^{b,c}		1.6E+20		
Phthalic anhydride	85-44-9		4.90E+01		1.30E+04		1.0E+30		1.0E+30	1.0E+03 ^b	1.0E+03 ^b	1.0E+30		
Polychlorinated biphenyls (Aroclors)	1336-36-3	5.00E-04	4.90E-04	2.41E-04		1.40E-04	390	0.20 ^c	390	0.19 ^c		390	0.095 ^c	0.055
Pronamide	23950-58-5		1.84E+00				1.4		1.4	2.6		1.6		
Propylene oxide [1,2-Epoxypropane]	75-56-9			4.02E-04	4.90E-01	1.70E-02	1.3		1.3		0.65	1.5	6.1E-04	0.026
Pyrene	129-00-0		7.34E-01				14		14	11 ^c		14		
Pyridine	110-86-1		2.45E-02		1.40E+00		1.3		1.3	0.032	1.8	1.5		
Safrole	94-59-7			5.36E-04			1.3		1.3			1.6	8.4E-04	
Selenium	7782-49-2	5.00E-02	1.22E-01					0.063		0.16				
Silver	7440-22-4		1.22E-01							0.17				
Strychnine and salts	57-24-9		7.34E-03				1.3		1.3	0.010		1.6		
Styrene	100-42-5	1.00E-01	4.90E+00		3.60E+00		1.4	0.14	1.4	6.9	5.1	1.6		
Tetrachlorobenzene 1,2,4,5-	95-94-3		7.34E-03				4.1		4.1	0.030		4.3		
Tetrachlorodibenzofuran 2,3,7,8-	51207-31-9			6.19E-09		1.00E-07	2.0E+04		2.0E+04			2.0E+04	1.3E-04	2.0E-03 ^c
Tetrachlorodibenzo-p-dioxin 2,3,7,8-	1746-01-6	3.00E-08	2.45E-08	6.44E-10		2.20E-09	2.7E+02	8.1E-06 ^c	2.7E+02	6.6E-06		2.7E+02	1.7E-07	6.0E-07
Tetrachloroethane 1,1,1,2-	630-20-6		0.734	3.71E-03		1.90E-03	1.5	8.2E-03 ^e	1.6	1.1		1.8	6.7E-03	3.4E-03
Tetrachloroethane 1,1,2,2-	79-34-5		1.47E+00	4.83E-04		5.00E-04	3.0	8.2E-03 ^e	3.2	4.7	0.64 ^e	3.8	1.8E-03	1.9E-03
Tetrachloroethylene	127-18-4	5.00E-03	2.45E-01	1.86E-03	9.40E-01	2.10E-02	1.3	6.4E-03	1.3	0.33	0.70 ^a	1.6	2.9E-03	0.033
Tetrachlorophenol 2,3,4,6-	58-90-2		0.734				1.3		1.3	0.98		1.6		
Tetraethyl dithiopyrophosphate (Sulfotep)	3689-24-5		1.22E-02				1.0E+30		1.0E+30	1.0E+03 ^{b,c}		1.0E+30		
Thallium	7440-28-0	2.00E-03	1.96E-03					2.5E-03		2.6E-03				
Thiram [Thiuram]	137-26-8		1.22E-01				1.4		1.4	0.17		1.6		

KEY:

- a - TC Rule cap d - Capped by daughter LCTV
b - 1,000 mg/L cap e - Constituent has no RGC; LCTV from daughter
c - Exceeds solubility

Table F-4: Surface Impoundment No-Liner LCTVs

Common Name	CAS#	MCL (mg/L)	HBN (mg/L)				No Liner/In-Situ Soil							
				Ingestion		Inhalation		Peak DAF	LCTV based on MCL (mg/L)	Non-Carcinogenic Effect (NC)		Carcinogenic Effect (C)		
				NC	C	NC	C			7-yr Avg DAF	LCTV based on Ingestion	LCTV based on Inhalation	30-yr Avg DAF	LCTV based on Ingestion
Toluene	108-88-3	1.00E+00	4.90E+00		1.30E+00		1.3	1.3	1.4	6.6	1.8	1.6		
Toluenediamine 2,4-	95-80-7			3.02E-05		7.50E+00	1.3		1.3			1.5	4.6E-05	11
Toluidine o-	95-53-4			4.02E-04		3.60E-02	1.3		1.3			1.5	6.1E-04	0.055
Toluidine p-	106-49-0			5.08E-04			1.3		1.3			1.5	7.7E-04	
Toxaphene (chlorinated camphenes)	8001-35-2	3.00E-03		8.78E-05		3.60E-03	42	0.13	42			44	3.9E-03	0.16
Tribromomethane (Bromoform)	75-25-2	8.00E-02	4.90E-01	1.22E-02		1.90E-02	1.3	0.10	1.4	0.66		1.6	0.019	0.030
Trichloro-1,2,2-trifluoro-ethane 1,1,2-	76-13-1		7.34E+02		9.50E+01		1.4		1.5	1.0E+03 ^{b,c}	140	1.6		
Trichlorobenzene 1,2,4-	120-82-1	7.00E-02	2.45E-01		8.30E-01		2.6	0.18	2.6	0.64	2.2	2.8		
Trichloroethane 1,1,1-	71-55-6	2.00E-01	6.85E+00		6.90E+00		5.9	0.012 ^d	6.4	0.40 ^d	0.38 ^d	7.4	3.4E-04 ^e	4.7E-04 ^e
Trichloroethane 1,1,2-	79-00-5	5.00E-03	0.0979	1.69E-03		1.10E-03	1.3	6.7E-03	1.4	0.14	0.38 ^e	1.6	3.4E-04 ^d	4.7E-04 ^d
Trichloroethylene (1,1,2-Trichloroethylene)	79-01-6	5.00E-03		8.78E-03	1.90E+00	6.80E-03	1.3	6.4E-03	1.3		0.50 ^a	1.6	0.014	0.011
Trichlorofluoromethane (Freon 11)	75-69-4		7.34E+00		2.10E+00		1.3		1.3	9.8	2.8	1.6		
Trichlorophenol 2,4,5-	95-95-4		2.45E+00				1.4		1.4	3.5		1.6		
Trichlorophenol 2,4,6-	88-06-2			8.78E-03		2.80E-01	1.3		1.3			1.6	0.014	0.44
Trichlorophenoxy)propionic acid 2-(2,4,5- (Silvex)	93-72-1	5.00E-02	1.96E-01				1.3	0.063	1.3	0.26		1.5		
Trichlorophenoxyacetic acid 2,4,5-	93-76-5		2.45E-01				1.3		1.3	0.32		1.5		
Trichloropropane 1,2,3-	96-18-4		1.47E-01	1.38E-05	3.40E-02		1.4		1.4	0.21	0.048	1.7	2.3E-05	
Triethylamine	121-44-8				1.10E-01		1.3		1.3		0.15	1.5		
Trinitrobenzene (1,3,5-Trinitrobenzene) sym-	99-35-4		7.34E-01				1.3		1.3	1.0		1.5		
Tris(2,3-dibromopropyl)phosphate	126-72-7			9.89E-06			3.5		3.5			4.2	4.1E-05	
Vanadium	7440-62-2		1.71E-01							2.6				
Vinyl acetate	108-05-4		2.45E+01		1.20E+00		1.3		1.3	32	1.6	1.5		
Vinyl chloride	75-01-4	2.00E-03	7.34E-02	1.34E-04	2.90E-01	2.50E-03	1.3	2.5E-03	1.3	0.10	0.20 ^a	1.5	2.0E-04	3.8E-03
Xylene m-	108-38-3		4.90E+01		1.30E+00		1.5		1.5	74	2.0	1.7		
Xylene o-	95-47-6		4.90E+01		1.40E+00		1.4		1.5	72	2.1	1.7		
Xylene p-	106-42-3		4.90E+01		1.30E+00		1.5		1.5	74	2.0	1.7		
Xylenes (total)	1330-20-7	1.00E+01	4.90E+01		1.40E+00		1.5	15	1.5	73	2.1	1.7		
Zinc	7440-66-6		7.34E+00							13				

KEY:

- a - TC Rule cap
 b - 1,000 mg/L cap
 c - Exceeds solubility
 d - Capped by daughter LCTV
 e - Constituent has no RGC; LCTV from daughter

Table F-5: Surface Impoundment Single Clay Liner LCTVs

Common Name	CAS#	MCL (mg/L)	HBN (mg/L)				Peak DAF	LCTV based on MCL (mg/L)	Compacted Clay Liner					
			Ingestion		Inhalation				Non-Carcinogenic Effect (NC)			Carcinogenic Effect (C)		
			NC	C	NC	C			7-yr Avg DAF	LCTV based on Ingestion	LCTV based on Inhalation	30-yr Avg DAF	LCTV based on Ingestion	LCTV based on Inhalation
Acenaphthene	83-32-9		1.47E+00				17		17	25 ^a		17		
Acetaldehyde [Ethanal]	75-07-0				2.20E-01	4.10E-02	3.9		4.0		0.87	4.5		0.18
Acetone (2-propanone)	67-64-1		2.45E+00		1.50E+03		3.9		4.0	9.7	1.0E+03 ^b	4.5		
Acetonitrile (methyl cyanide)	75-05-8				3.10E+00		4.0		4.0		12	4.5		
Acetophenone	98-86-2		2.45E+00				3.9		4.0	9.7		4.5		
Acrolein	107-02-8		4.90E-01		3.30E-04		1.0E+30		1.0E+30	1.0E+03 ^b	1.0E+03 ^b	1.0E+30		
Acrylamide	79-06-1		4.90E-03	2.15E-05		5.10E+00	4.8		4.8	0.024		5.6	1.2E-04	29
Acrylic acid [propenoic acid]	79-10-7		1.22E+01		1.50E+01		3.9		4.0	48	59	4.5		
Acrylonitrile	107-13-1		2.45E-02	1.79E-04	3.80E-02	1.00E-03	4.1		4.2	0.018 ^d	0.16	4.8	9.0E-05 ^d	4.8E-03
Aldrin	309-00-2		7.34E-04	5.68E-06		1.00E-05	3.7E+08		3.7E+08	1.0E+03 ^{b,c}		3.7E+08	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Allyl alcohol	107-18-6		1.22E-01				3.9		4.0	0.48		4.5		
Aniline (benzenamine)	62-53-3			1.69E-02	9.30E-01	2.20E+00	3.9		4.0		3.7	4.5	7.6E-02	9.9
Anthracene	120-12-7		7.34E+00				42.4		43	310 ^c		43		
Antimony	7440-36-0	6.00E-03	9.79E-03					0.026		0.047				
Arsenic	7440-38-2	5.00E-02	7.34E-03	6.44E-05				0.26		0.048			1.1E-03	
Barium	7440-39-3	2.00E+00	1.71E+00					7.3		7.0				
Benz(a)anthracene	56-55-3			8.05E-05		1.80E-02	910		910			910	0.073 ^c	16 ^c
Benzene	71-43-2	5.00E-03		1.76E-03	1.90E-01	1.60E-03	4.1	0.020	4.1		0.50 ^a	4.7	8.2E-03	7.5E-03
Benzidine	92-87-5		7.34E-02	4.20E-07		2.60E+00	3.9		4.0	0.29		4.5	1.9E-06	12
Benzo(a)pyrene	50-32-8	2.00E-04		1.32E-05		5.40E-03	2.6E+04	5.2 ^c	2.7E+04			2.7E+04	0.35 ^c	140 ^c
Benzo(b)fluoranthene	205-99-2			8.05E-05		6.30E-04	2.6E+04		2.6E+04			2.6E+04	2.1 ^c	17 ^c
Benzyl alcohol	100-51-6		7.34E+00				3.9		4.0	29		4.5		
Benzyl chloride	100-44-7			5.68E-04		5.20E-04	1.0E+30		1.0E+30	34 ^a		1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Beryllium	7440-41-7	4.00E-03	4.90E-02					4.5		8.7				
Bis(2-chloroethyl)ether	111-44-4			8.78E-05		1.10E-03	17		17		1.0E+03 ^e	21	1.9E-03	0.023
Bis(2-chloroisopropyl)ether	39638-32-9		9.79E-01	1.38E-03		5.90E-03	4.5		4.5	4.4		5.0	6.9E-03	0.030
Bis(2-ethylhexyl)phthalate	117-81-7	6.00E-03	4.90E-01	6.90E-03	1.80E+02	2.80E+01	1.0E+30	1.0E+03 ^{b,c}	1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}	1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Bromodichloromethane	75-27-4	8.00E-02	4.90E-01	1.56E-03		8.00E-04	4.6	0.37	4.7	2.3		5.3	8.2E-03	4.2E-03
Bromomethane	74-83-9		3.43E-02		1.50E-02		1.5E+08		1.5E+08	140 ^d	1.0E+03 ^b	2.6E+08		
Butadiene 1, 3-	106-99-0				6.00E-02	4.00E-05	4.2		4.3		0.26	4.8		1.9E-04
Butanol n-	71-36-3		2.45E+00				3.9		4.0	9.7		4.5		
Butyl benzyl phthalate	85-68-7		4.90E+00				55		55	270 ^c		55		
Butyl 4,6-dinitrophenol,2-sec-(Dinoseb)	88-85-7	7.00E-03	2.45E-02				4.2	0.029	4.2	0.10		4.7		
Cadmium	7440-43-9	5.00E-03	1.22E-02					0.029		0.069				
Carbon disulfide	75-15-0		2.45E+00		1.90E+00		4.5		4.5	11	8.5	5.1		
Carbon tetrachloride	56-23-5	5.00E-03	0.0171	7.43E-04	0.021	7.60E-04	6.0	0.030	6.1	0.10	0.13	6.8	5.0E-03	5.2E-03
Chlordane	57-74-9	2.00E-03	0.0122	2.76E-04	2.80E-02	1.50E-03	1.1E+05	0.030 ^a	1.1E+05	0.030 ^a	0.030 ^a	1.1E+05	0.030 ^a	0.030 ^a
Chloro-1,3-butadiene 2-(Chloroprene)	126-99-8		4.90E-01		2.20E-02		4.1		4.1	2.0	0.090	4.6		
Chloroaniline p-	106-47-8		9.79E-02				3.9		4.0	0.39		4.5		
Chlorobenzene	108-90-7	1.00E-01	4.90E-01		2.00E-01		4.8	0.48	4.9	2.4	1.0	5.3		
Chlorobenzilate	510-15-6		4.90E-01	3.58E-04		1.20E+00	87		87	43 ^f		87	3.1E-02	100 ^c
Chlorodibromomethane	124-48-1	8.00E-02	4.90E-01	1.15E-03		7.50E-04	4.4	0.35	4.5	2.2		5.1	5.8E-03	3.8E-03
Chloroethane [Ethyl chloride]	75-00-3				3.00E+01		3.9		4.0		120	4.5		
Chloroform	67-66-3	8.00E-02	2.45E-01		3.30E-01		4.1	0.32	4.1	1.0	1.3	4.7		
Chloromethane	74-87-3			7.43E-03	2.60E-01	5.90E-03	3.9		4.0		1.0	4.5	3.3E-02	0.027
Chlorophenol 2-	95-57-8		1.22E-01		9.70E-03		4.1		4.1	0.50	0.040	4.7		
Chloropropene 3- (Allyl Chloride)	107-05-1				3.00E-03	1.90E-03	1.0E+30		1.0E+30		1.0E+03 ^b	1.0E+30		1.0E+03 ^b
Chromium (III) (Chromic Ion)	16065-83-1	1.00E-01	3.67E+01					57		450				
Chromium (VI)	18540-29-9	1.00E-01	7.34E-02					5.0 ^a		5.0 ^a				

KEY:

- a - TC Rule cap
b - 1,000 mg/L cap
c - Exceeds solubility
- d - Capped by daughter LCTV
e - Constituent has no RGC; LCTV from daughter

Table F-5: Surface Impoundment Single Clay Liner LCTVs

Common Name	CAS#	MCL (mg/L)	HBN (mg/L)				Compacted Clay Liner							
			Ingestion	Inhalation		Peak DAF	LCTV based on MCL (mg/L)	Non-Carcinogenic Effect (NC)			Carcinogenic Effect (C)			
				NC	C			NC	C	7-yr Avg DAF	LCTV based on Ingestion	LCTV based on Inhalation	30-yr Avg DAF	LCTV based on Ingestion
Chrysene	218-01-9			8.05E-04		7.30E-03	910		910			910	0.73 ^c	6.6 ^c
Cobalt	7440-48-4		4.90E-01							8.0				
Copper	7440-50-8	1.30E+00						61						
Cresol m-	108-39-4		1.22E+00		1.20E+03		4.0		4.1	5.0	200 ^a	4.6		
Cresol o-	95-48-7		1.22E+00		8.80E+02		4.1		4.1	5.0	200 ^a	4.6		
Cresol p-	106-44-5		1.22E-01		1.30E+03		4.0		4.1	0.50	200 ^a	4.6		
Cresols	1319-77-3		1.22E+00		1.10E+03		4.3		4.3	5.2	1.0E+03 ^b	4.8		
Cumene	98-82-8		2.45E+00		1.30E+00		9.8		9.8	24	13	10		
Cyclohexanol	108-93-0		4.16E-04		3.90E-04		3.9		4.0	1.6E-03	1.5E-03	4.5		
Cyclohexanone	108-94-1		1.22E+02				4.1		4.1	500		4.6		
DDD	72-54-8			4.02E-04			1.0E+30		1.0E+30			1.0E+30	1.0E+03 ^{b,c}	
DDE	72-55-9			2.84E-04			1.0E+30		1.0E+30			1.0E+30	1.0E+03 ^{b,c}	
DDT p,p'-	50-29-3		1.22E-02	2.84E-04		8.80E-03	1.0E+30		1.0E+30	1.0E+03 ^{b,c}		1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Diallate	2303-16-4			1.58E-03			1.9E+05		1.9E+05			1.9E+05	310 ^c	
Dibenz{a,h}anthracene	53-70-3			1.32E-05		3.80E-01	1.0E+30		1.0E+30			1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Dibromo-3-chloropropane 1,2-	96-12-8	2.00E-04		6.90E-05	2.90E-03	7.90E-02	5.5	1.1E-03	5.5		0.016	6.4	4.4E-04	0.50
Dichlorobenzene 1,2-	95-50-1	6.00E-01	2.20E+00		7.70E-01		6.7	4.0	6.8	15	5.2	7.2		
Dichlorobenzene 1,4-	106-46-7	7.50E-02		4.02E-03	3.00E+00	1.30E-03	6.6	0.49	6.6		7.5 ^a	7.0	2.8E-02	9.1E-03
Dichlorobenzidine 3,3'-	91-94-1			2.15E-04		4.90E+00	8.7		8.7			9.1	2.0E-03	45 ^d
Dichlorodifluoromethane (Freon 12)	75-71-8		4.90E+00		5.80E-01		4.3		4.3	21	2.5	4.9		
Dichloroethane 1,1-	75-34-3		2.45		1.6	7.40E-03	4.5	0.018 ^e	4.6	0.45 ^d	0.45 ^d	5.3	1.4E-03 ^e	0.025 ^d
Dichloroethane 1,2-	107-06-2	5.00E-03		1.06E-03	1.00E+01	6.30E-04	4.4	0.012 ^d	4.5	0.32 ^e	0.32 ^d	5.2	9.6E-04 ^d	3.3E-03
Dichloroethylene cis-1,2-	156-59-2	7.00E-02	2.45E-01				4.0	0.28	4.1	1.0		4.6		
Dichloroethylene trans-1,2-	156-60-5	1.00E-01	4.90E-01				3.9	0.39	4.0	1.9		4.5		
Dichloroethylene 1,1-	75-35-4	7.00E-03	2.20E-01	1.61E-04	2.10E-01	2.20E-04	4.1	0.028	4.1	0.70 ^a	0.70 ^a	4.7	7.5E-04	1.0E-03
Dichlorophenol 2,4-	120-83-2		7.34E-02				4.6		4.7	0.34		5.1		
Dichlorophenoxyacetic acid 2,4-(2,4-D)	94-75-7	7.00E-02	2.45E-01				3.9	0.27	4.0	1.0		4.5		
Dichloropropane 1,2-	78-87-5	5.00E-03	2.20E+00	1.42E-03	1.40E-02		6.5	0.033	6.6	14	0.092	7.6	0.011	
Dichloropropene 1,3-(mixture of isomers)	542-75-6		7.34E-01	9.66E-04	6.10E-02	2.90E-03	3.9		4.0	2.9	0.24	4.5	4.3E-03	0.013
Dichloropropene cis-1,3-	10061-01-5		7.34E-01	9.66E-04	7.00E-02	3.30E-03	1.0E+30		1.0E+30	1.0E+03 ^b	1.0E+03 ^b	1.0E+30	1.0E+03 ^b	1.0E+03 ^b
Dichloropropene trans-1,3-	10061-02-6		7.34E-01	9.66E-04	7.50E-02	3.50E-03	1.0E+30		1.0E+30	1.0E+03 ^b	1.0E+03 ^b	1.0E+30	1.0E+03 ^b	1.0E+03 ^b
Dieldrin	60-57-1		1.22E-03	6.04E-06		1.00E-04	1.0E+30		1.0E+30	1.0E+03 ^{b,c}		1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Diethyl phthalate	84-66-2		1.96E+01				6.1		6.2	120		7.0		
Diethylstilbestrol	56-53-1			2.05E-08			33		33			34	6.9E-07	
Dimethoate	60-51-5		4.90E-03				2.8E+03		2.9E+03	0.98 ^d	1.0E+03 ^e	3.7E+03		
Dimethoxybenzidine 3,3'-	119-90-4			6.90E-03			3.9		4.0			4.5	3.1E-02	
Dimethyl formamide N,N- [DMF]	68-12-2	2.45E+00			7.10E+02		3.9		4.0	9.7	1.0E+03 ^b	4.5		
Dimethylbenz{a}anthracene 7,12-	57-97-6					3.00E-03	1.0E+30		1.0E+30			1.0E+30		1.0E+03 ^{b,c}
Dimethylbenzidine 3,3'-	119-93-7			1.05E-05			4.7		4.8			5.2	5.5E-05	
Dimethylphenol 2,4-	105-67-9		4.90E-01				4.4		4.4	2.2		4.9		
Di-n-butyl phthalate	84-74-2		2.45E+00				75		75	180 ^c		75		
Dinitrobenzene 1,3-	99-65-0		2.45E-03				3.9		4.0	9.7E-03		4.5		
Dinitrophenol 2,4-	51-28-5		4.90E-02				3.9		4.0	0.19		4.5		
Dinitrotoluene 2,4-	121-14-2		4.90E-02	1.42E-04		8.12E-01	3.9		4.0	0.13 ^a		4.5	6.4E-04	0.13 ^a
Dinitrotoluene 2,6-	606-20-2		2.45E-02	1.42E-04			3.9		4.0	0.10		4.5	6.4E-04	
Di-n-octyl phthalate	117-84-0		4.90E-01				1.0E+30		1.0E+30	1.0E+03 ^{b,c}		1.0E+30		
Dioxane 1,4-	123-91-1			8.78E-03	1.09E+03	1.80E-01	3.9		4.0		1.0E+03 ^b	4.5	4.0E-02	0.81
Diphenylamine	122-39-4		6.12E-01				8.4		8.5	5.2		8.8		

KEY:

a - TC Rule cap

d - Capped by daughter LCTV

b - 1,000 mg/L cap

e - Constituent has no RGC; LCTV from daughter

c - Exceeds solubility

Table F-5: Surface Impoundment Single Clay Liner LCTVs

Common Name	CAS#	MCL (mg/L)	HBN (mg/L)				Compacted Clay Liner							
			Ingestion	Inhalation		Peak DAF	LCTV based on MCL (mg/L)	Non-Carcinogenic Effect (NC)			Carcinogenic Effect (C)			
				NC	C			NC	C	7-yr Avg DAF	LCTV based on Ingestion	LCTV based on Inhalation	30-yr Avg DAF	LCTV based on Ingestion
Diphenylhydrazine 1, 2-	122-66-7			1.21E-04		2.00E-02	5.5		5.5			5.9	7.2E-04	0.12
Disulfoton	298-04-4		9.79E-04				4.0E+07		4.0E+07	1.0E+03 ^{b,c}		4.6E+07		
Endosulfan (Endosulfan I and II,mixture)	115-29-7		1.47E-01				12		12	1.8 ^c		12		
Endrin	72-20-8	2.00E-03	7.34E-03				6.5E+06	0.020 ^a	6.6E+06	0.020 ^a		6.6E+06		
Epichlorohydrin	106-89-8		4.90E-02	9.75E-03	6.00E-02	1.90E-01	1.0E+30		1.0E+30	1.0E+03 ^b	1.0E+03 ^b	1.0E+30	1.0E+03 ^b	1.0E+03 ^b
Epoxybutane 1, 2-	106-88-7			2.40E-01			3.9		4.0		1.0	4.5		
Ethoxyethanol 2-	110-80-5		9.79E+00		2.90E+03		3.9		4.0	39	1.0E+03 ^b	4.5		
Ethoxyethanol acetate 2-	111-15-9		7.34E+00		3.00E+02		3.9		4.0	29	1.0E+03 ^b	4.5		
Ethyl acetate	141-78-6		2.20E+01				18		18	400		22		
Ethyl ether	60-29-7		4.9				3.9		4.0	19		4.5		
Ethyl methacrylate	97-63-2		2.20E+00				7.7		7.9	17		9.1		
Ethyl methanesulfonate	62-50-0			3.30E-07			1.0E+30		1.0E+30			1.0E+30	1.0E+03 ^b	
Ethylbenzene	100-41-4	7.00E-01	2.45E+00		3.30E+00	1.10E-02	6.3	4.4	6.4	16	21	6.8		0.074
Ethylene dibromide (1,2-Dibromoethane)	106-93-4	5.00E-05		1.14E-06	9.80E-04	8.40E-05	79	4.0E-03	82		0.080	100	1.1E-04	8.4E-03
Ethylene glycol	107-21-1		4.90E+01		1.20E+04		3.9		4.0	190	1.0E+03 ^b	4.5		
Ethylene oxide	75-21-8			9.47E-05	4.10E-01	5.20E-04	1.0E+30		1.0E+30		1.0E+03 ^b	1.0E+30	1.0E+03 ^b	1.0E+03 ^b
Ethylene thiourea	96-45-7		1.96E-03	8.78E-04		1.60E+03	3.9		4.0	7.8E-03		4.5	4.0E-03	1.0E+03 ^b
Fluoranthene	206-44-0		9.79E-01				110		110	110 ^c		110		
Fluoride	16984-48-8	4.00E+00	2.90E+00					14		11				
Formaldehyde	50-00-0		4.90E+00		5.10E+01	1.5	3.9		4.0	19	200	4.5		6.8
Formic acid	64-18-6		4.90E+01				3.9		4.0	190		4.5		
Furfural	98-01-1		7.34E-02		2.20E+01		3.9		4.0	0.29	87	4.5		
HCH beta-	319-85-7			5.36E-05		1.70E-02	10		10			11	5.6E-04	0.18
HCH (Lindane) gamma-	58-89-9	2.00E-04	7.34E-03	7.43E-05		1.60E-03	5.8E+07	0.4 ^{a,d}	5.8E+07	0.4 ^{a,d}	0.4 ^{a,e}	6.4E+07	0.4 ^{a,b,c}	0.4 ^{a,b,c}
HCH alpha-	319-84-6		0.196	1.53E-05		3.60E-04	1.2E+08	2.9 ^e	1.2E+08	6.4 ^{c,d}	35 ^{c,e}	1.3E+08	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Heptachlor	76-44-8	4.00E-04	1.22E-02	2.15E-05		1.50E-05	1.0E+30	8.0E-03 ^a	1.0E+30	8.0E-03 ^a		1.0E+30	8.0E-03 ^a	8.0E-03 ^a
Heptachlor epoxide	1024-57-3	2.00E-04	3.18E-04	1.06E-05		2.80E-04	4.2E+15	1.0E+03 ^{b,c}	4.2E+15	1.0E+03 ^{b,c}		4.2E+15	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Hexachloro-1,3-butadiene	87-68-3		7.34E-03	1.24E-03		6.10E-04	76		76	0.50 ^a		76	0.095	0.047
Hexachlorobenzene	118-74-1	1.00E-03	1.96E-02	6.04E-05		3.60E-05	1.2E+03	0.13 ^{a,c}	1.2E+03	0.13 ^{a,c}		1.2E+03	0.073 ^c	0.043 ^c
Hexachlorocyclopentadiene	77-47-4	5.00E-02	1.47E-01		6.90E-04		1.0E+30	1.0E+03 ^{b,c}	1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}	1.0E+30		
Hexachlorodibenzofurans [HxCDFs]	55684-94-1			6.19E-09		1.44E-07	1.0E+30		1.0E+30			1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Hexachlorodibenzo-p-dioxins [HxCDDs]	34465-46-8			6.19E-09		1.43E-07	5.2E+14		5.2E+14			5.2E+14	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Hexachloroethane	67-72-1		2.45E-02	6.90E-03		3.30E-03	14		14	0.34		14	0.097	0.046
Hexachlorophene	70-30-4		7.34E-03				270		270	2.0		270		
Hexane n-	110-54-3		2.69E+02		6.60E-01		6.1		6.1	1.0E+03 ^{b,c}	4.0	6.5		
Hydrogen Sulfide	7783-06-4		7.34E-02				3.9		4.0	0.29		4.5		
Indeno{1,2,3-cd}pyrene	193-39-5			8.05E-05		3.80E-02	2.3E+10		2.3E+10			2.3E+10	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Isobutyl alcohol	78-83-1		7.34E+00				3.9		4.0	29		4.5		
Isophorone	78-59-1		4.90E+00	1.02E-01	5.33E+02		4.1		4.2	20	1.0E+03 ^b	4.7	0.477	
Kepone	143-50-0		1.22E-02				38		38	0.46		38		
Lead	7439-92-1	1.50E-02						0.78						
Manganese	7439-96-5		1.15E+00							4.9				
Mercury	7439-97-6	2.00E-03	2.45E-03		7.00E-04			6.9E-03		9.4E-03	2.7E-03			
Methacrylonitrile	126-98-7		2.45E-03		6.50E-03		4.1		4.2	0.010	0.027	4.8		
Methanol	67-56-1		1.22E+01		1.54E+03		3.9		4.0	48	1.0E+03 ^b	4.5		
Methoxychlor	72-43-5	4.00E-02	1.22E-01				1.0E+30	10 ^{a,c}	1.0E+30	10 ^{a,c}		1.0E+30		
Methoxyethanol acetate 2-	110-49-6		4.90E-02		5.10E+02		3.9		4.0	0.19	1.0E+03 ^b	4.5		
Methoxyethanol 2-	109-86-4		2.45E-02		4.40E+02		3.9		4.0	0.10	1.0E+03 ^b	4.5		

KEY:

- a - TC Rule cap
b - 1,000 mg/L cap
c - Exceeds solubility
d - Capped by daughter LCTV
e - Constituent has no RGC; LCTV from daughter

Table F-5: Surface Impoundment Single Clay Liner LCTVs

Common Name	CAS#	MCL (mg/L)	HBN (mg/L)				Peak DAF	LCTV based on MCL (mg/L)	Compacted Clay Liner					
		Ingestion	Ingestion		Inhalation				Non-Carcinogenic Effect (NC)			Carcinogenic Effect (C)		
			NC	C	NC	C			7-yr Avg DAF	LCTV based on Ingestion	LCTV based on Inhalation	30-yr Avg DAF	LCTV based on Ingestion	LCTV based on Inhalation
Methyl ethyl ketone	78-93-3		1.47E+01		3.30E+01		3.9		4.0	58	130	4.5		
Methyl isobutyl ketone	108-10-1		1.96E+00		1.20E+00		3.9		4.0	7.8	4.8	4.5		
Methyl methacrylate	80-62-6		3.43E+01		5.30E+00		9.3		9.4	150 ^d	50	11		
Methyl parathion	298-00-0		6.12E-03				7.7E+06		7.9E+06	2.3 ^d	1.0E+03 ^e	9.0E+06		
Methyl tert-butyl ether [MTBE]	1634-04-4				1.70E+01		3.9		4.0		67	4.5		
Methylcholanthrene 3-	56-49-5					1.20E-03	1.0E+30		1.0E+30			1.0E+30		1.0E+03 ^{b,c}
Methylene bromide (Dibromomethane)	74-95-3		2.45E-01				3.9		4.0	1.0		4.5		
Methylene Chloride (Dichloromethane)	75-09-2	5.00E-03	1.47E+00	1.29E-02	1.00E+01	2.80E-02	4.0	0.020	4.1	6.0	41	4.6	0.059	0.13
Molybdenum	7439-98-7		1.22E-01							0.44				
Naphthalene	91-20-3		4.90E-01		1.90E-02		7.0		7.0	3.4	0.13	7.3		
Nickel	7440-02-0		4.90E-01							2.5				
Nitrobenzene	98-95-3		1.22E-02		1.50E-01		3.9		4.0	0.048	0.59	4.5		
Nitropropane 2-	79-46-9				3.30E-01	2.30E-05	3.9		4.0		1.3	4.5		1.0E-04
Nitrosodiethylamine N-	55-18-5			6.44E-07		4.30E-05	3.9		4.0			4.5	2.9E-06	1.9E-04
Nitrosodimethylamine N-	62-75-9		1.96E-04	1.89E-06		4.00E-04	3.9		4.0	7.8E-04		4.5	8.5E-06	1.8E-03
Nitroso-di-n-butylamine N-	924-16-3			1.79E-05		2.00E-05	4.2		4.3			4.8	8.5E-05	9.5E-05
Nitroso-di-n-propylamine N-	621-64-7			1.38E-05		1.50E-03	3.9		4.0			4.5	6.2E-05	6.8E-03
Nitrosodiphenylamine N-	86-30-6		4.90E-01	1.97E-02		5.20E-01	5.6		5.6	2.7		6.0	0.12	3.1
Nitrosomethylethylamine N-	10595-95-6			4.39E-06		4.50E-03	3.9		4.0			4.5	2.0E-05	0.020
Nitrosopiperidine N-	100-75-4					8.70E-03	3.9		4.0			4.5		0.039
Nitrosopyrrolidine N-	930-55-2			4.60E-05		9.20E-01	3.9		4.0			4.5	2.1E-04	4.1
Octamethyl pyrophosphoramide	152-16-9		4.90E-02				4.2		4.2	0.21		4.8		
Parathion (ethyl)	56-38-2		0.147				1.7E+14		1.7E+14	1.0E+03 ^{b,c}		1.8E+14		
Pentachlorobenzene	608-93-5		1.96E-02				1.1E+03		1.1E+03	21 ^c		1.1E+03		
Pentachlorodibenzofurans [PeCDFs]	30402-15-4			1.24E-09		6.29E-08	230		230			230	2.9E-07	1.5E-05
Pentachlorodibenzo-p-dioxins [PeCDDs]	36088-22-9			6.19E-10		6.00E-08	3.9E+11		3.9E+11			3.9E+11	240 ^c	1.0E+03 ^{b,c}
Pentachloronitrobenzene (PCNB)	82-68-8		7.34E-02	3.71E-04			95		96	7.0 ^c		96	0.036	
Pentachlorophenol	87-86-5	1.00E-03	7.34E-01	8.05E-04		5.40E+01	6.6	6.6E-03	6.7	4.9		7.0	5.7E-03	100 ^a
Phenol	108-95-2		1.47E+01		9.00E+02		3.9		4.0	58	1.0E+03 ^b	4.5		
Phenyl mercuric acetate	62-38-4		1.96E-03				3.9		4.0	7.8E-03		4.5		
Phenylenediamine 1,3-	108-45-2		1.47E-01				3.9		4.0	0.58		4.5		
Phorate	298-02-2		4.90E-03				1.0E+30		1.0E+30	1.0E+03 ^{b,c}		1.0E+30		
Phthalic anhydride	85-44-9		4.90E+01		1.30E+04		1.0E+30		1.0E+30	1.0E+03 ^b	1.0E+03 ^b	1.0E+30		
Polychlorinated biphenyls (Aroclors)	1336-36-3	5.00E-04	4.90E-04	2.41E-04		1.40E-04	5.5E+08	1.0E+03 ^{b,c}	5.5E+08	1.0E+03 ^{b,c}		5.6E+08	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Pronamide	23950-58-5		1.84E+00				5.1		5.1	9.4		5.6		
Propylene oxide [1,2-Epoxypropane]	75-56-9			4.02E-04	4.90E-01	1.70E-02	3.9		4.0		1.9	4.5	1.8E-03	0.077
Pyrene	129-00-0		7.34E-01				220		220	160 ^c		220		
Pyridine	110-86-1		2.45E-02		1.40E+00		3.9		4.0	0.10	5.0 ^a	4.5		
Safrole	94-59-7			5.36E-04			4.4		4.4			5.0	2.7E-03	
Selenium	7782-49-2	5.00E-02	1.22E-01					0.17		0.43				
Silver	7440-22-4		1.22E-01							0.61				
Strychnine and salts	57-24-9		7.34E-03				4.1		4.1	0.030		4.7		
Styrene	100-42-5	1.00E-01	4.90E+00		3.60E+00		5.6	0.56	5.6	27	20	6.0		
Tetrachlorobenzene 1,2,4,5-	95-94-3		7.34E-03				50		51	0.37		51		
Tetrachlorodibenzofuran 2,3,7,8-	51207-31-9			6.19E-09		1.00E-07	1.0E+30		1.0E+30			1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Tetrachlorodibenzo-p-dioxin 2,3,7,8-	1746-01-6	3.00E-08	2.45E-08	6.44E-10		2.20E-09	2.9E+07	0.86 ^c	2.9E+07	0.71 ^c		2.9E+07	0.019 ^c	0.064 ^c
Tetrachloroethane 1,1,1,2-	630-20-6		0.734	3.71E-03		1.90E-03	7.3	0.027 ^e	7.3	5.4		8.0	0.030	0.015
Tetrachloroethane 1,1,2,2-	79-34-5		1.47E+00	4.83E-04		5.00E-04	46	0.027 ^e	46	68	0.64 ^e	54	0.026	0.027
Tetrachloroethylene	127-18-4	5.00E-03	2.45E-01	1.86E-03	9.40E-01	2.10E-02	4.3	0.022	4.4	0.70 ^a	0.70 ^a	4.9	9.1E-03	0.10

KEY:

a - TC Rule cap

d - Capped by daughter LCTV

b - 1,000 mg/L cap

e - Constituent has no RGC; LCTV from daughter

c - Exceeds solubility

Table F-5: Surface Impoundment Single Clay Liner LCTVs

Common Name	CAS#	MCL (mg/L)	HBN (mg/L)				Compacted Clay Liner							
		Ingestion	Ingestion		Inhalation		Peak DAF	LCTV based on MCL (mg/L)	Non-Carcinogenic Effect (NC)		Carcinogenic Effect (C)			
			NC	C	NC	C			7-yr Avg DAF	LCTV based on Ingestion	LCTV based on Inhalation	30-yr Avg DAF	LCTV based on Ingestion	LCTV based on Inhalation
Tetrachlorophenol 2,3,4,6-	58-90-2		0.734				4.4		4.4	3.3		4.9		
Tetraethyl dithiopyrophosphate (Sulfotep)	3689-24-5		1.22E-02				1.0E+30		1.0E+30	1.0E+03 ^{b,c}		1.0E+30		
Thallium	7440-28-0	2.00E-03	1.96E-03					6.6E-03		7.4E-03				
Thiram [Thiuram]	137-26-8		1.22E-01				5.5		5.5	0.67		5.9		
Toluene	108-88-3	1.00E+00	4.90E+00		1.30E+00		4.6	4.6	4.6	23	6.0	5.1		
Toluenediamine 2,4-	95-80-7			3.02E-05		7.50E+00	3.9		4.0			4.5	1.4E-04	34
Toluidine o-	95-53-4			4.02E-04		3.60E-02	3.9		4.0			4.5	1.8E-03	0.16
Toluidine p-	106-49-0			5.08E-04			3.9		4.0			4.5	2.3E-03	
Toxaphene (chlorinated camphenes)	8001-35-2	3.00E-03		8.78E-05		3.60E-03	1.7E+05	0.50 ^a	1.7E+05			1.7E+05	0.50 ^a	0.50 ^a
Tribromomethane (Bromoform)	75-25-2	8.00E-02	4.90E-01	1.22E-02		1.90E-02	4.4	0.35	4.4	2.1		4.9	0.060	0.094
Trichloro-1,2,2-trifluoro- ethane 1,1,2-	76-13-1		7.34E+02		9.50E+01		6.2		6.2	1.0E+03 ^{b,c}	590 ^c	6.6		
Trichlorobenzene 1,2,4-	120-82-1	7.00E-02	2.45E-01		8.30E-01		26	1.8	26	6.4	22	26		
Trichloroethane 1,1,1-	71-55-6	2.00E-01	6.85E+00		6.90E+00		390	0.039 ^d	400	0.96 ^d	0.96 ^d	490	1.0E-03 ^e	1.4E-03 ^e
Trichloroethane 1,1,2-	79-00-5	5.00E-03	0.0979	1.69E-03		1.10E-03	4.6	0.023	4.6	0.45	0.96 ^e	5.3	1.0E-03 ^d	1.4E-03 ^d
Trichloroethylene (1,1,2-Trichloroethylene)	79-01-6	5.00E-03		8.78E-03	1.90E+00	6.80E-03	4.2	0.021	4.3		0.50 ^a	4.8	0.042	0.033
Trichlorofluoromethane (Freon 11)	75-69-4		7.34E+00		2.10E+00		4.3		4.3	32	9.0	4.8		
Trichlorophenol 2,4,5-	95-95-4		2.45E+00				5.9		5.9	14		6.3		
Trichlorophenol 2,4,6-	88-06-2			8.78E-03		2.80E-01	4.4		4.4			4.9	0.043	1.4
Trichlorophenoxy)propionic acid 2-(2,4,5- (Silvex)	93-72-1	5.00E-02	1.96E-01				4.0	0.20	4.1	0.80		4.6		
Trichlorophenoxyacetic acid 2,4,5-	93-76-5		2.45E-01				3.9		4.0	1.0		4.5		
Trichloropropane 1,2,3-	96-18-4		1.47E-01	1.38E-05	3.40E-02		5.0		5.1	0.75	0.17	5.9	8.1E-05	
Triethylamine	121-44-8				1.10E-01		3.9		4.0		0.44	4.5		
Trinitrobenzene (1,3,5-Trinitrobenzene) sym-	99-35-4		7.34E-01				3.9		4.0	2.9		4.5		
Tris(2,3-dibromopropyl)phosphate	126-72-7			9.89E-06			83		84			89	8.8E-04	
Vanadium	7440-62-2		1.71E-01							41				
Vinyl acetate	108-05-4		2.45E+01		1.20E+00		3.9		4.0	97	4.8	4.5		
Vinyl chloride	75-01-4	2.00E-03	7.34E-02	1.34E-04	2.90E-01	2.50E-03	3.9	7.8E-03	4.0	0.20 ^a	0.20 ^a	4.5	6.0E-04	0.011
Xylene m-	108-38-3		4.90E+01		1.30E+00		6.8		6.8	340 ^c	8.9	7.2		
Xylene o-	95-47-6		4.90E+01		1.40E+00		6.4		6.5	320 ^c	9.0	6.9		
Xylene p-	106-42-3		4.90E+01		1.30E+00		7.1		7.1	350 ^c	9.2	7.4		
Xylenes (total)	1330-20-7	1.00E+01	4.90E+01		1.40E+00		6.7	67	6.8	330 ^c	9.5	7.2		
Zinc	7440-66-6		7.34E+00							68				

KEY:

a - TC Rule cap

b - 1,000 mg/L cap

c - Exceeds solubility

d - Capped by daughter LCTV

e - Constituent has no RGC; LCTV from daughter

Table F-6: Surface Impoundment Composite Liners LCTVs

Common Name	CAS#	MCL (mg/L)	HBN (mg/L)				Peak DAF	LCTV based on MCL (mg/L)	Composite Liner					
		Ingestion	Ingestion		Inhalation				Non-Carcinogenic Effect (NC)			Carcinogenic Effect (C)		
			NC	C	NC	C			7-yr Avg DAF	LCTV based on Ingestion	LCTV based on Inhalation	30-yr Avg DAF	LCTV based on Ingestion	LCTV based on Inhalation
Acenaphthene	83-32-9		1.47E+00				1.0E+30		1.0E+30	1.0E+03 ^{b,c}		1.0E+30		
Acetaldehyde [Ethanal]	75-07-0				2.20E-01	4.10E-02	2.7E+05		2.7E+05		1.0E+03 ^b	2.9E+05		1.0E+03 ^b
Acetone (2-propanone)	67-64-1		2.45E+00		1.50E+03		2.7E+05		2.7E+05	1.0E+03 ^b	1.0E+03 ^b	2.8E+05		
Acetonitrile (methyl cyanide)	75-05-8				3.10E+00		2.8E+05		2.8E+05		1.0E+03 ^b	3.0E+05		
Acetophenone	98-86-2		2.45E+00				2.4E+05		2.4E+05	1.0E+03 ^b		2.4E+05		
Acrolein	107-02-8		4.90E-01		3.30E-04		1.0E+30		1.0E+30	1.0E+03 ^b	1.0E+03 ^b	1.0E+30		
Acrylamide	79-06-1		4.90E-03	2.15E-05		5.10E+00	2.9E+08		2.9E+08	1.0E+03 ^b		3.2E+08	1.0E+03 ^b	1.0E+03 ^b
Acrylic acid [propenoic acid]	79-10-7		1.22E+01		1.50E+01		2.7E+05		2.7E+05	1.0E+03 ^b	1.0E+03 ^b	2.8E+05		
Acrylonitrile	107-13-1		2.45E-02	1.79E-04	3.80E-02	1.00E-03	9.2E+05		9.3E+05	740 ^d	740 ^d	9.7E+05	170	750 ^d
Aldrin	309-00-2		7.34E-04	5.68E-06		1.00E-05	1.0E+30		1.0E+30	1.0E+03 ^{b,c}		1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Allyl alcohol	107-18-6		1.22E-01				2.6E+05		2.6E+05	1.0E+03 ^b		2.6E+05		
Aniline (benzenamine)	62-53-3			1.69E-02	9.30E-01	2.20E+00	2.7E+05		2.8E+05		1.0E+03 ^b	2.8E+05	1.0E+03 ^b	1.0E+03 ^b
Anthracene	120-12-7		7.34E+00				1.0E+30		1.0E+30	1.0E+03 ^{b,c}		1.0E+30		
Antimony	7440-36-0	6.00E-03	9.79E-03					1.0E+03 ^b		1.0E+03 ^b				
Arsenic	7440-38-2	5.00E-02	7.34E-03	6.44E-05				5.0 ^a		5.0 ^a			5.0 ^a	
Barium	7440-39-3	2.00E+00	1.71E+00					100 ^a		100 ^a				
Benz(a)anthracene	56-55-3			8.05E-05		1.80E-02	1.0E+30		1.0E+30			1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Benzene	71-43-2	5.00E-03		1.76E-03	1.90E-01	1.60E-03	3.4E+05	0.50 ^a	3.5E+05		0.50 ^a	3.6E+05	0.501 ^a	0.50 ^a
Benzidine	92-87-5		7.34E-02	4.20E-07		2.60E+00	2.9E+05		2.9E+05	1.0E+03 ^{b,c}		3.0E+05	0.13	1.0E+03 ^{b,c}
Benzo(a)pyrene	50-32-8	2.00E-04		1.32E-05		5.40E-03	1.0E+30	1.0E+03 ^{b,c}	1.0E+30			1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Benzo(b)fluoranthene	205-99-2			8.05E-05		6.30E-04	1.0E+30		1.0E+30			1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Benzyl alcohol	100-51-6		7.34E+00				2.3E+05		2.3E+05	1.0E+03 ^b		2.3E+05		
Benzyl chloride	100-44-7			5.68E-04		5.20E-04	1.0E+30		1.0E+30	1.0E+03 ^e		1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Beryllium	7440-41-7	4.00E-03	4.90E-02					1.0E+03 ^b		1.0E+03 ^b				
Bis(2-chloroethyl)ether	111-44-4			8.78E-05		1.10E-03	1.0E+30		1.0E+30		1.0E+03 ^e	1.0E+30	1.0E+03 ^b	1.0E+03 ^b
Bis(2-chloroisopropyl)ether	39638-32-9		9.79E-01	1.38E-03		5.90E-03	5.4E+05		5.5E+05	1.0E+03 ^b		5.6E+05	780	1.0E+03 ^b
Bis(2-ethylhexyl)phthalate	117-81-7	6.00E-03	4.90E-01	6.90E-03	1.80E+02	2.80E+01	1.0E+30	1.0E+03 ^{b,c}	1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}	1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Bromodichloromethane	75-27-4	8.00E-02	4.90E-01	1.56E-03		8.00E-04	2.5E+06	1.0E+03 ^b	2.6E+06	1.0E+03 ^b		2.6E+06	1.0E+03 ^b	1.0E+03 ^b
Bromomethane	74-83-9		3.43E-02		1.50E-02		1.0E+30		1.0E+30	1.0E+03 ^b	1.0E+03 ^b	1.0E+30		
Butadiene 1, 3-	106-99-0				6.00E-02	4.00E-05	3.9E+05		3.94E+05		1.0E+03 ^{b,c}	4.1E+05		16.4
Butanol n-	71-36-3		2.45E+00				2.2E+05		2.2E+05	1.0E+03 ^b		2.2E+05		
Butyl benzyl phthalate	85-68-7		4.90E+00				1.0E+30		1.0E+30	1.0E+03 ^{b,c}		1.0E+30		
Butyl-4,6-dinitrophenol,2-sec-(Dinoseb)	88-85-7	7.00E-03	2.45E-02				3.8E+05	1.0E+03 ^{b,c}	3.8E+05	1.0E+03 ^{b,c}		3.8E+05		
Cadmium	7440-43-9	5.00E-03	1.22E-02					1.0 ^a		1.0 ^a				
Carbon disulfide	75-15-0		2.45E+00		1.90E+00		1.7E+06		1.7E+06	1.0E+03 ^b	1.0E+03 ^b	1.8E+06		
Carbon tetrachloride	56-23-5	5.00E-03	0.0171	7.43E-04	0.021	7.60E-04	9.1E+11	0.50 ^a	9.4E+11	0.50 ^a	0.50 ^a	9.4E+11	0.50 ^a	0.50 ^a
Chlordane	57-74-9	2.00E-03	0.0122	2.76E-04	2.80E-02	1.50E-03	1.0E+30	0.030 ^a	1.0E+30	0.030 ^a	0.030 ^a	1.0E+30	0.030 ^a	0.030 ^a
Chloro-1,3-butadiene 2-(Chloroprene)	126-99-8		4.90E-01		2.20E-02		3.4E+05		3.5E+05	1.0E+03 ^b	1.0E+03 ^b	3.6E+05		
Chloroaniline p-	106-47-8		9.79E-02				2.8E+05		2.8E+05	1.0E+03 ^b		2.8E+05		
Chlorobenzene	108-90-7	1.00E-01	4.90E-01		2.00E-01		6.6E+05	100 ^a	6.7E+05	100 ^a	100 ^a	6.9E+05		
Chlorobenzilate	510-15-6		4.90E-01	3.58E-04		1.20E+00	1.0E+30		1.0E+30	1.0E+03 ^{b,c}		1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Chlorodibromomethane	124-48-1	8.00E-02	4.90E-01	1.15E-03		7.50E-04	1.5E+06	1.0E+03 ^b	1.5E+06	1.0E+03 ^b		1.5E+06	1.0E+03 ^b	1.0E+03 ^b
Chloroethane [Ethyl chloride]	75-00-3				3.00E+01		2.7E+05		2.8E+05		1.0E+03 ^b	2.9E+05		
Chloroform	67-66-3	8.00E-02	2.45E-01		3.30E-01		5.5E+05	6.0 ^a	5.5E+05	6.0 ^a	6.0 ^a	5.7E+05		
Chloromethane	74-87-3			7.43E-03	2.60E-01	5.90E-03	2.8E+05		2.9E+05		1.0E+03 ^b	3.0E+05	1.0E+03 ^b	1.0E+03 ^b
Chlorophenol 2-	95-57-8		1.22E-01		9.70E-03		3.5E+05		3.5E+05	1.0E+03 ^b	1.0E+03 ^b	3.7E+05		

KEY:

- a - TC Rule cap
b - 1,000 mg/L cap
c - Exceeds solubility
d - Capped by daughter LCTV
e - Constituent has no RGC; LCTV from daughter

Table F-6: Surface Impoundment Composite Liners LCTVs

Common Name	CAS#	MCL (mg/L)	HBN (mg/L)				Peak DAF	LCTV based on MCL (mg/L)	Composite Liner					
			Ingestion		Inhalation				Non-Carcinogenic Effect (NC)			Carcinogenic Effect (C)		
									7-yr Avg DAF	LCTV based on Ingestion	LCTV based on Inhalation	30-yr Avg DAF	LCTV based on Ingestion	LCTV based on Inhalation
Chloropropene 3- (Allyl Chloride)	107-05-1				3.00E-03	1.90E-03	1.0E+30		1.0E+30		1.0E+03 ^b	1.0E+30		1.0E+03 ^b
Chromium (III) (Chromic Ion)	16065-83-1	1.00E-01	3.67E+01					1.0E+03 ^b		1.0E+03 ^b				
Chromium (VI)	18540-29-9	1.00E-01	7.34E-02					5.0 ^a		5.0 ^a				
Chrysene	218-01-9			8.05E-04		7.30E-03	1.0E+30		1.0E+30			1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Cobalt	7440-48-4		4.90E-01						1.0E+03 ^b					
Copper	7440-50-8	1.30E+00						1.0E+03 ^b						
Cresol m-	108-39-4		1.22E+00		1.20E+03		3.3E+05		3.3E+05	200 ^a	200 ^a	3.6E+05		
Cresol o-	95-48-7		1.22E+00		8.80E+02		3.4E+05		3.4E+05	200 ^a	200 ^a	3.6E+05		
Cresol p-	106-44-5		1.22E-01		1.30E+03		3.3E+05		3.3E+05	200 ^a	200 ^a	3.6E+05		
Cresols	1319-77-3		1.22E+00		1.10E+03		4.1E+05		4.1E+05	1.0E+03 ^b	1.0E+03 ^b	4.2E+05		
Cumene	98-82-8		2.45E+00		1.30E+00		4.0E+06		4.0E+06	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}	4.1E+06		
Cyclohexanol	108-93-0		4.16E-04		3.90E-04		2.8E+05		2.8E+05	120	110.37	3.0E+05		
Cyclohexanone	108-94-1		1.22E+02				3.3E+05		3.3E+05	1.0E+03 ^b		3.3E+05		
DDD	72-54-8			4.02E-04			1.0E+30		1.0E+30			1.0E+30	1.0E+03 ^{b,c}	
DDE	72-55-9			2.84E-04			1.0E+30		1.0E+30			1.0E+30	1.0E+03 ^{b,c}	
DDT p,p'-	50-29-3		1.22E-02	2.84E-04		8.80E-03	1.0E+30		1.0E+30	1.0E+03 ^{b,c}		1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Diallate	2303-16-4			1.58E-03			1.0E+30		1.0E+30			1.0E+30	1.0E+03 ^{b,c}	
Dibenz[a,h]anthracene	53-70-3			1.32E-05		3.80E-01	1.0E+30		1.0E+30			1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Dibromo-3-chloropropane 1,2-	96-12-8	2.00E-04		6.90E-05	2.90E-03	7.90E-02	2.2E+08	1.0E+03 ^b	2.2E+08		1.0E+03 ^b	2.3E+08	1.0E+03 ^b	1.0E+03 ^b
Dichlorobenzene 1,2-	95-50-1	6.00E-01	2.20E+00		7.70E-01		1.7E+06	1.0E+03 ^{b,c}	1.7E+06	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}	1.7E+06		
Dichlorobenzene 1,4-	106-46-7	7.50E-02		4.02E-03	3.00E+00	1.30E-03	1.6E+06	7.5 ^a	1.6E+06		7.5 ^a	1.6E+06	7.5 ^a	7.5 ^a
Dichlorobenzidine 3,3'-	91-94-1			2.15E-04		4.90E+00	3.6E+06		3.7E+06			3.8E+06	810 ^c	1.0E+03 ^{b,c}
Dichlorodifluoromethane (Freon 12)	75-71-8		4.90E+00		5.80E-01		4.3E+05		4.4E+05	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}	4.4E+05		
Dichloroethane 1,1-	75-34-3		2.45		1.6	7.40E-03	6.4E+07	0.45 ^e	6.4E+07	0.45 ^d	0.45 ^d	6.7E+07	0.45 ^e	0.45 ^d
Dichloroethane 1,2-	107-06-2	5.00E-03		1.06E-03	1.00E+01	6.30E-04	3.8E+07	0.32 ^d	3.9E+07	0.32 ^e	0.32 ^d	4.0E+07	0.32 ^d	0.32 ^d
Dichloroethylene cis-1,2-	156-59-2	7.00E-02	2.45E-01				3.0E+05	1.0E+03 ^b	3.0E+05	1.0E+03 ^b		3.0E+05		
Dichloroethylene trans-1,2-	156-60-5	1.00E-01	4.90E-01				2.8E+05	1.0E+03 ^b	2.8E+05	1.0E+03 ^b		2.8E+05		
Dichloroethylene 1,1-	75-35-4	7.00E-03	2.20E-01	1.61E-04	2.10E-01	2.20E-04	3.4E+05	0.70 ^a	3.4E+05	0.70 ^a	0.70 ^a	3.6E+05	0.70 ^a	0.70 ^a
Dichlorophenol 2,4-	120-83-2		7.34E-02				8.7E+05		8.7E+05	1.0E+03 ^b		8.7E+05		
Dichlorophenoxyacetic acid 2,4-(2,4-D)	94-75-7	7.00E-02	2.45E-01				2.3E+05	10 ^a	2.3E+05	10:00 AM		2.3E+05		
Dichloropropane 1,2-	78-87-5	5.00E-03	2.20E+00	1.42E-03	1.40E-02		1.0E+30	1.0E+03 ^b	1.0E+30	1.0E+03 ^b	1.0E+03 ^b	1.0E+30	1.0E+03 ^b	
Dichloropropene 1,3-(mixture of isomers)	542-75-6		7.34E-01	9.66E-04	6.10E-02	2.90E-03	3.0E+05		3.0E+05	1.0E+03 ^b	1.0E+03 ^b	3.1E+05	300	900
Dichloropropene cis-1,3-	10061-01-5		7.34E-01	9.66E-04	7.00E-02	3.30E-03	1.0E+30		1.0E+30	1.0E+03 ^b	1.0E+03 ^b	1.0E+30	1.0E+03 ^b	1.0E+03 ^b
Dichloropropene trans-1,3-	10061-02-6		7.34E-01	9.66E-04	7.50E-02	3.50E-03	1.0E+30		1.0E+30	1.0E+03 ^b	1.0E+03 ^b	1.0E+30	1.0E+03 ^b	1.0E+03 ^b
Dieldrin	60-57-1		1.22E-03	6.04E-06		1.00E-04	1.0E+30		1.0E+30	1.0E+03 ^{b,c}		1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Diethyl phthalate	84-66-2		1.96E+01				4.1E+09		4.1E+09	1.0E+03 ^b		4.1E+09		
Diethylstilbestrol	56-53-1			2.05E-08			1.0E+30		1.0E+30			1.0E+30	1.0E+03 ^{b,c}	
Dimethoate	60-51-5		4.90E-03				1.0E+30		1.0E+30	1.0E+03 ^b	1.0E+03 ^e	1.0E+30		
Dimethoxybenzidine 3,3'-	119-90-4			6.90E-03			2.6E+05		2.7E+05			2.7E+05	1.0E+03 ^{b,c}	
Dimethyl formamide N,N- [DMF]	68-12-2		2.45E+00		7.10E+02		2.7E+05		2.7E+05	1.0E+03 ^b	1.0E+03 ^b	2.8E+05		
Dimethylbenz[a]anthracene 7,12-	57-97-6					3.00E-03	1.0E+30		1.0E+30			1.0E+30		1.0E+03 ^{b,c}
Dimethylbenzidine 3,3'-	119-93-7			1.05E-05			1.0E+06		1.0E+06			1.0E+06	11	
Dimethylphenol 2,4-	105-67-9		4.90E-01				5.6E+05		5.7E+05	1.0E+03 ^b		5.7E+05		
Di-n-butyl phthalate	84-74-2		2.45E+00				1.0E+30		1.0E+30	1.0E+03 ^{b,c}		1.0E+30		
Dinitrobenzene 1,3-	99-65-0		2.45E-03				2.4E+05		2.5E+05	610		2.5E+05		
Dinitrophenol 2,4-	51-28-5		4.90E-02				2.2E+05		2.2E+05	1.0E+03 ^b		2.2E+05		

KEY:

- a - TC Rule cap
b - 1,000 mg/L cap
c - Exceeds solubility
d - Capped by daughter LCTV
e - Constituent has no RGC; LCTV from daughter

Table F-6: Surface Impoundment Composite Liners LCTVs

Common Name	CAS#	MCL (mg/L)	HBN (mg/L)				Composite Liner							
		Ingestion	Ingestion		Inhalation		Peak DAF	LCTV based on MCL (mg/L)	Non-Carcinogenic Effect (NC)		Carcinogenic Effect (C)			
			NC	C	NC	C			7-yr Avg DAF	LCTV based on Ingestion	LCTV based on Inhalation	30-yr Avg DAF	LCTV based on Ingestion	LCTV based on Inhalation
Dinitrotoluene 2,4-	121-14-2		4.90E-02	1.42E-04	8.12E-01		3.2E+05		3.3E+05	0.13 ^a		3.4E+05	0.13 ^a	0.13 ^a
Dinitrotoluene 2,6-	606-20-2		2.45E-02	1.42E-04			2.6E+05		2.6E+05	1.0E+03 ^{b,c}		2.6E+05	36	
Di-n-octyl phthalate	117-84-0		4.90E-01				1.0E+30		1.0E+30	1.0E+03 ^{b,c}		1.0E+30		
Dioxane 1,4-	123-91-1			8.78E-03	1.09E+03	1.80E-01	2.7E+05		2.7E+05		1.0E+03 ^b	2.8E+05	1.0E+03 ^b	1.0E+03 ^b
Diphenylamine	122-39-4		6.12E-01				2.4E+09		2.5E+09	1.0E+03 ^{b,c}		2.7E+09		
Diphenylhydrazine 1, 2-	122-66-7			1.21E-04		2.00E-02	1.0E+06		1.0E+06			1.1E+06	130 ^c	1.0E+03 ^{b,c}
Disulfoton	298-04-4		9.79E-04				1.0E+30		1.0E+30	1.0E+03 ^{b,c}		1.0E+30		
Endosulfan (Endosulfan I and II,mixture)	115-29-7		1.47E-01				1.0E+30		1.0E+30	1.0E+03 ^{b,c}		1.0E+30		
Endrin	72-20-8	2.00E-03	7.34E-03				1.0E+30	0.02 ^a	1.0E+30	0.020 ^a		1.0E+30		
Epichlorohydrin	106-89-8		4.90E-02	9.75E-03	6.00E-02	1.90E-01	1.0E+30		1.0E+30	1.0E+03 ^b	1.0E+03 ^b	1.0E+30	1.0E+03 ^b	1.0E+03 ^b
Epoxybutane 1, 2-	106-88-7				2.40E-01		2.8E+05		2.78E+05		1.0E+03 ^b	2.9E+05		
Ethoxyethanol 2-	110-80-5		9.79E+00		2.90E+03		2.7E+05		2.7E+05	1.0E+03 ^b	1.0E+03 ^b	2.7E+05		
Ethoxyethanol acetate 2-	111-15-9		7.34E+00		3.00E+02		2.7E+05		2.7E+05	1.0E+03 ^b	1.0E+03 ^b	2.8E+05		
Ethyl acetate	141-78-6		2.20E+01				1.0E+30		1.0E+30	1.0E+03 ^b		1.0E+30		
Ethyl ether	60-29-7		4.9				2.2E+05		2.2E+05	1.0E+03 ^b		2.2E+05		
Ethyl methacrylate	97-63-2		2.20E+00				1.0E+30		1.0E+30	1.0E+03 ^b		1.0E+30		
Ethyl methanesulfonate	62-50-0			3.30E-07			1.0E+30		1.0E+30			1.0E+30	1.0E+03 ^b	
Ethylbenzene	100-41-4	7.00E-01	2.45E+00		3.30E+00	1.10E-02	1.4E+06	1.0E+03 ^{b,c}	1.4E+06	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}	1.5E+06		1.0E+03 ^b
Ethylene dibromide (1,2-Dibromoethane)	106-93-4	5.00E-05		1.14E-06	9.80E-04	8.40E-05	1.0E+30	1.0E+03 ^b	1.0E+30		1.0E+03 ^b	1.0E+30	1.0E+03 ^b	1.0E+03 ^b
Ethylene glycol	107-21-1		4.90E+01		1.20E+04		2.7E+05		2.7E+05	1.0E+03 ^b	1.0E+03 ^b	2.9E+05		
Ethylene oxide	75-21-8			9.47E-05	4.10E-01	5.20E-04	1.0E+30		1.0E+30		1.0E+03 ^b	1.0E+30	1.0E+03 ^b	1.0E+03 ^b
Ethylene thiourea	96-45-7		1.96E-03	8.78E-04		1.60E+03	2.7E+05		2.7E+05	540		2.8E+05	240	1.0E+03 ^b
Fluoranthene	206-44-0		9.79E-01				1.0E+30		1.0E+30	1.0E+03 ^{b,c}		1.0E+30		
Fluoride	16984-48-8	4.00E+00	2.90E+00					1.0E+03 ^b		1.0E+03 ^b				
Formaldehyde	50-00-0		4.90E+00		5.10E+01	1.5	2.8E+05		2.8E+05	1.0E+03 ^b	1.0E+03 ^b	3.0E+05		1.0E+03 ^b
Formic acid	64-18-6		4.90E+01				2.2E+05		2.2E+05	1.0E+03 ^b		2.2E+05		
Furfural	98-01-1		7.34E-02		2.20E+01		2.7E+05		2.8E+05	1.0E+03 ^b	1.0E+03 ^b	2.9E+05		
HCH beta-	319-85-7			5.36E-05		1.70E-02	4.5E+06		4.7E+06			4.7E+06	250	1.0E+03 ^b
HCH (Lindane) gamma-	58-89-9	2.00E-04	7.34E-03	7.43E-05		1.60E-03	1.0E+30	0.4 ^{a,b,c}	1.0E+30	0.4 ^{a,b,c}	0.4 ^{a,b,c}	1.0E+30	0.4 ^{a,b,c}	0.4 ^{a,b,c}
HCH alpha-	319-84-6		0.196	1.53E-05		3.60E-04	1.0E+30	1.0E+03 ^{b,c}	1.0E+30	1.0E+03 ^{b,c}	1.0E+03	1.0E+30	1.0E+03 ^b	1.0E+03 ^b
Heptachlor	76-44-8	4.00E-04	1.22E-02	2.15E-05		1.50E-05	1.0E+30	8.0E-03 ^a	1.0E+30	8.0E-03 ^a		1.0E+30	8.0E-03 ^a	8.0E-03 ^a
Heptachlor epoxide	1024-57-3	2.00E-04	3.18E-04	1.06E-05		2.80E-04	1.0E+30	1.0E+03 ^{b,c}	1.0E+30	1.0E+03 ^{b,c}		1.0E+30	1.0E+03 ^b	1.0E+03 ^b
Hexachloro-1,3-butadiene	87-68-3		7.34E-03	1.24E-03		6.10E-04	4.7E+09		4.7E+09	0.50 ^a		4.8E+09	0.50 ^a	0.50
Hexachlorobenzene	118-74-1	1.00E-03	1.96E-02	6.04E-05		3.60E-05	1.0E+30	0.13 ^{a,c}	1.0E+30	0.13 ^{a,c}		1.0E+30	0.13 ^{a,c}	0.13 ^{a,c}
Hexachlorocyclopentadiene	77-47-4	5.00E-02	1.47E-01		6.90E-04		1.0E+30	1.0E+03 ^{b,c}	1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}	1.0E+30		
Hexachlorodibenzofurans [HxCDFs]	55684-94-1			6.19E-09		1.44E-07	1.0E+30		1.0E+30			1.0E+30	1.0E+03 ^b	1.0E+03 ^b
Hexachlorodibenzo-p-dioxins [HxCDDs]	34465-46-8			6.19E-09		1.43E-07	1.0E+30		1.0E+30			1.0E+30	1.0E+03 ^b	1.0E+03 ^b
Hexachloroethane	67-72-1		2.45E-02	6.90E-03		3.30E-03	7.4E+06		7.4E+06	3.0 ^a		7.5E+06	3.0	3.0
Hexachlorophene	70-30-4		7.34E-03				1.0E+30		1.0E+30	1.0E+03 ^{b,c}		1.0E+30		
Hexane n-	110-54-3		2.69E+02		6.60E-01		1.3E+06		1.3E+06	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}	1.4E+06		
Hydrogen Sulfide	7783-06-4		7.34E-02				2.2E+05		2.2E+05	1.0E+03 ^b		2.2E+05		
Indeno{1,2,3-cd}pyrene	193-39-5			8.05E-05		3.80E-02	1.0E+30		1.0E+30			1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Isobutyl alcohol	78-83-1		7.34E+00				2.2E+05		2.2E+05	1.0E+03 ^b		2.2E+05		
Isophorone	78-59-1		4.90E+00	1.02E-01	5.33E+02		3.5E+05		3.5E+05	1.0E+03 ^b	1.0E+03 ^b	3.7E+05	1.0E+03 ^b	
Kepone	143-50-0		1.22E-02				1.0E+30		1.0E+30	1.0E+03 ^{b,c}		1.0E+30		
Lead	7439-92-1	1.50E-02						5.0 ^a						

KEY:

- a - TC Rule cap
b - 1,000 mg/L cap
c - Exceeds solubility
d - Capped by daughter LCTV
e - Constituent has no RGC; LCTV from daughter

Table F-6: Surface Impoundment Composite Liners LCTVs

Common Name	CAS#	MCL (mg/L)	HBN (mg/L)				Peak DAF	LCTV based on MCL (mg/L)	Composite Liner					
			Ingestion		Inhalation				Non-Carcinogenic Effect (NC)			Carcinogenic Effect (C)		
									7-yr Avg DAF	LCTV based on Ingestion	LCTV based on Inhalation	30-yr Avg DAF	LCTV based on Ingestion	LCTV based on Inhalation
Manganese	7439-96-5		1.15E+00						1.0E+03 ^b					
Mercury	7439-97-6	2.00E-03	2.45E-03		7.00E-04			0.20 ^{a,c}		0.20 ^{a,c}	0.20 ^{a,c}			
Methacrylonitrile	126-98-7		2.45E-03		6.50E-03		9.2E+05		9.2E+05	1.0E+03 ^b	1.0E+03 ^b	9.7E+05		
Methanol	67-56-1		1.22E+01		1.54E+03		2.8E+05		2.8E+05	1.0E+03 ^b	1.0E+03 ^b	2.9E+05		
Methoxychlor	72-43-5	4.00E-02	1.22E-01				1.0E+30	10 ^{a,c}	1.0E+30	10 ^{a,c}		1.0E+30		
Methoxyethanol acetate 2-	110-49-6		4.90E-02		5.10E+02		2.7E+05		2.7E+05	1.0E+03 ^b	1.0E+03 ^b	2.8E+05		
Methoxyethanol 2-	109-86-4		2.45E-02		4.40E+02		2.8E+05		2.9E+05	1.0E+03 ^b	1.0E+03 ^b	2.9E+05		
Methyl ethyl ketone	78-93-3		1.47E+01		3.30E+01		2.7E+05		2.7E+05	200 ^a	200 ^a	2.8E+05		
Methyl isobutyl ketone	108-10-1		1.96E+00		1.20E+00		2.7E+05		2.7E+05	1.0E+03 ^b	1.0E+03 ^b	2.8E+05		
Methyl methacrylate	80-62-6		3.43E+01		5.30E+00		6.8E+10		7.0E+10	1.0E+03 ^{b,d}	1.0E+03 ^b	7.5E+10		
Methyl parathion	298-00-0		6.12E-03				1.0E+30		1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^e	1.0E+30		
Methyl tert-butyl ether [MTBE]	1634-04-4				1.70E+01		2.7E+05		2.8E+05		1.0E+03 ^b	2.9E+05		
Methylcholanthrene 3-	56-49-5					1.20E-03	1.0E+30		1.0E+30			1.0E+30		1.0E+03 ^{b,c}
Methylene bromide (Dibromomethane)	74-95-3		2.45E-01				2.4E+05		2.4E+05	1.0E+03 ^b		2.4E+05		
Methylene Chloride (Dichloromethane)	75-09-2	5.00E-03	1.47E+00	1.29E-02	1.00E+01	2.80E-02	6.8E+05	1.0E+03 ^b	6.8E+05	1.0E+03 ^b	1.0E+03 ^b	7.0E+05	1.0E+03 ^b	1.0E+03 ^b
Molybdenum	7439-98-7		1.22E-01							1.0E+03 ^b				
Naphthalene	91-20-3		4.90E-01		1.90E-02		1.8E+06		1.8E+06	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}	1.9E+06		
Nickel	7440-02-0		4.90E-01							1.0E+03 ^b				
Nitrobenzene	98-95-3		1.22E-02		1.50E-01		3.0E+05		3.0E+05	2.0 ^a	2.0 ^a	3.2E+05		
Nitropropane 2-	79-46-9				3.30E-01	2.30E-05	2.7E+05		2.7E+05		1.0E+03 ^b	2.8E+05		6.463
Nitrosodiethylamine N-	55-18-5			6.44E-07		4.30E-05	2.7E+05		2.7E+05			2.8E+05	0.18	12.04
Nitrosodimethylamine N-	62-75-9		1.96E-04	1.89E-06		4.00E-04	2.7E+05		2.7E+05	53		2.9E+05	0.54	110
Nitroso-di-n-butylamine N-	924-16-3			1.79E-05		2.00E-05	4.0E+05		4.1E+05			4.2E+05	7.5	8.4
Nitroso-di-n-propylamine N-	621-64-7			1.38E-05		1.50E-03	2.7E+05		2.7E+05			2.9E+05	3.9	430
Nitrosodiphenylamine N-	86-30-6		4.90E-01	1.97E-02		5.20E-01	1.1E+06		1.1E+06	1.0E+03 ^{b,c}		1.1E+06	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Nitrosomethylethylamine N-	10595-95-6			4.39E-06		4.50E-03	2.8E+05		2.8E+05			2.9E+05	1.3	1.0E+03 ^b
Nitrosopiperidine N-	100-75-4					8.70E-03	2.7E+05		2.7E+05			2.8E+05		1.0E+03 ^b
Nitrosopyrrolidine N-	930-55-2			4.60E-05		9.20E-01	2.7E+05		2.7E+05			2.8E+05	13	1.0E+03 ^b
Octamethyl pyrophosphoramidate	152-16-9		4.90E-02				7.0E+05		7.0E+05	1.0E+03 ^b		7.0E+05		
Parathion (ethyl)	56-38-2		0.147				1.0E+30		1.0E+30	1.0E+03 ^{b,c}		1.0E+30		
Pentachlorobenzene	608-93-5		1.96E-02				1.0E+30		1.0E+30	1.0E+03 ^{b,c}		1.0E+30		
Pentachlorodibenzofurans [PeCDFs]	30402-15-4			1.24E-09		6.29E-08	1.0E+30		1.0E+30			1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Pentachlorodibenzo-p-dioxins [PeCDDs]	36088-22-9			6.19E-10		6.00E-08	1.0E+30		1.0E+30			1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Pentachloronitrobenzene (PCNB)	82-68-8		7.34E-02	3.71E-04			1.0E+30		1.0E+30	1.0E+03 ^{b,c}		1.0E+30	1.0E+03 ^{b,c}	
Pentachlorophenol	87-86-5	1.00E-03	7.34E-01	8.05E-04		5.40E+01	1.6E+06	100 ^a	1.6E+06	100 ^a		1.7E+06	100 ^a	100 ^a
Phenol	108-95-2		1.47E+01		9.00E+02		2.9E+05		2.9E+05	1.0E+03 ^b	1.0E+03 ^b	3.0E+05		
Phenyl mercuric acetate	62-38-4		1.96E-03				2.2E+05		2.2E+05	430		2.2E+05		
Phenylenediamine 1,3-	108-45-2		1.47E-01				2.2E+05		2.2E+05	1.0E+03 ^b		2.2E+05		
Phorate	298-02-2		4.90E-03				1.0E+30		1.0E+30	1.0E+03 ^{b,c}		1.0E+30		
Phthalic anhydride	85-44-9		4.90E+01		1.30E+04		1.0E+30		1.0E+30	1.0E+03 ^b	1.0E+03 ^b	1.0E+30		
Polychlorinated biphenyls (Aroclors)	1336-36-3	5.00E-04	4.90E-04	2.41E-04		1.40E-04	1.0E+30	1.0E+03 ^{b,c}	1.0E+30	1.0E+03 ^{b,c}		1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Pronamide	23950-58-5		1.84E+00				4.4E+06		4.4E+06	1.0E+03 ^{b,c}		4.4E+06		
Propylene oxide [1,2-Epoxypropane]	75-56-9			4.02E-04	4.90E-01	1.70E-02	3.0E+05		3.1E+05		1.0E+03 ^b	3.1E+05	120	1.0E+03 ^b
Pyrene	129-00-0		7.34E-01				1.0E+30		1.0E+30	1.0E+03 ^{b,c}		1.0E+30		
Pyridine	110-86-1		2.45E-02		1.40E+00		2.7E+05		2.8E+05	5.0 ^a	5.0 ^a	2.9E+05		
Safrole	94-59-7			5.36E-04			6.2E+05		6.3E+05			6.3E+05	340	

KEY:

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Table F-6: Surface Impoundment Composite Liners LCTVs

Common Name	CAS#	MCL (mg/L)	HBN (mg/L)				Peak DAF	LCTV based on MCL (mg/L)	Composite Liner					
			Ingestion		Inhalation				Non-Carcinogenic Effect (NC)			Carcinogenic Effect (C)		
									7-yr Avg DAF	LCTV based on Ingestion	LCTV based on Inhalation	30-yr Avg DAF	LCTV based on Ingestion	LCTV based on Inhalation
Selenium	7782-49-2	5.00E-02	1.22E-01					1.0 ^a		1.0 ^a				
Silver	7440-22-4		1.22E-01							5.0 ^a				
Strychnine and salts	57-24-9		7.34E-03				3.4E+05		3.5E+05	1.0E+03 ^{b,c}		3.5E+05		
Styrene	100-42-5	1.00E-01	4.90E+00		3.60E+00		1.0E+06	1.0E+03 ^{b,c}	1.0E+06	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}	1.1E+06		
Tetrachlorobenzene 1,2,4,5-	95-94-3		7.34E-03				1.0E+30		1.0E+30	1.0E+03 ^{b,c}		1.0E+30		
Tetrachlorodibenzofuran 2,3,7,8-	51207-31-9			6.19E-09		1.00E-07	1.0E+30		1.00E+30			1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Tetrachlorodibenzo-p-dioxin 2,3,7,8-	1746-01-6	3.00E-08	2.45E-08	6.44E-10		2.20E-09	1.0E+30	1.0E+03 ^{b,c}	1.0E+30	1.0E+03 ^{b,c}		1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Tetrachloroethane 1,1,1,2-	630-20-6		0.734	3.71E-03		1.90E-03	1.0E+30	0.64 ^e	1.0E+30	1.0E+03 ^b		1.0E+30	0.64 ^d	0.64 ^d
Tetrachloroethane 1,1,2,2-	79-34-5		1.47E+00	4.83E-04		5.00E-04	1.0E+30	0.64 ^e	1.0E+30	1.0E+03 ^b	0.64 ^e	1.0E+30	0.64 ^d	0.64 ^d
Tetrachloroethylene	127-18-4	5.00E-03	2.45E-01	1.86E-03	9.40E-01	2.10E-02	4.5E+05	0.70 ^a	4.5E+05	0.70 ^a	0.70 ^a	4.5E+05	0.70 ^a	0.70 ^a
Tetrachlorophenol 2,3,4,6-	58-90-2		0.734				5.9E+05		6.0E+05	1.0E+03 ^{b,c}		6.0E+05		
Tetraethyl dithiopyrophosphate (Sulfotep)	3689-24-5		1.22E-02				1.0E+30		1.0E+30	1.0E+03 ^{b,c}		1.0E+30		
Thallium	7440-28-0	2.00E-03	1.96E-03					380		570				
Thiram [Thiuram]	137-26-8		1.22E-01				3.6E+06		3.6E+06	1.0E+03 ^{b,c}		3.6E+06		
Toluene	108-88-3	1.00E+00	4.90E+00		1.30E+00		5.5E+05	1.0E+03 ^{b,c}	5.6E+05	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}	5.7E+05		
Toluenediamine 2,4-	95-80-7			3.02E-05		7.50E+00	2.6E+05		2.7E+05			2.8E+05	8.4	1.0E+03 ^b
Toluidine o-	95-53-4			4.02E-04		3.60E-02	2.8E+05		2.9E+05			3.0E+05	120	1.0E+03 ^b
Toluidine p-	106-49-0			5.08E-04			2.4E+05		2.5E+05			2.5E+05	120	
Toxaphene (chlorinated camphenes)	8001-35-2	3.00E-03		8.78E-05		3.60E-03	1.0E+30	0.50 ^a	1.0E+30			1.0E+30	0.50 ^a	0.50 ^a
Tribromomethane (Bromoform)	75-25-2	8.00E-02	4.90E-01	1.22E-02		1.90E-02	9.3E+05	1.0E+03 ^b	9.5E+05	1.0E+03 ^b		9.9E+05	1.0E+03 ^b	1.0E+03 ^b
Trichloro-1,2,2-trifluoro-ethane 1,1,2-	76-13-1		7.34E+02		9.50E+01		1.3E+06		1.3E+06	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}	1.4E+06		
Trichlorobenzene 1,2,4-	120-82-1	7.00E-02	2.45E-01		8.30E-01		3.2E+07	1.0E+03 ^{b,c}	3.2E+07	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}	3.3E+07		
Trichloroethane 1,1,1-	71-55-6	2.00E-01	6.85E+00		6.90E+00		1.0E+30	0.96 ^d	1.0E+30	0.96 ^d	0.96 ^d	1.0E+30	0.96 ^e	0.96 ^e
Trichloroethane 1,1,2-	79-00-5	5.00E-03	0.0979	1.69E-03		1.10E-03	3.0E+06	0.96 ^d	3.0E+06	0.96 ^d	0.96 ^d	3.1E+06	0.96 ^d	0.96 ^d
Trichloroethylene (1,1,2-Trichloroethylene)	79-01-6	5.00E-03		8.78E-03	1.90E+00	6.80E-03	4.0E+05	0.50 ^a	4.1E+05		0.50 ^a	4.2E+05	0.50 ^a	0.50 ^a
Trichlorofluoromethane (Freon 11)	75-69-4		7.34E+00		2.10E+00		4.1E+05		4.1E+05	1.0E+03 ^b	1.0E+03 ^b	4.3E+05		
Trichlorophenol 2,4,5-	95-95-4		2.45E+00				7.3E+06		7.3E+06	400 ^a		7.3E+06		
Trichlorophenol 2,4,6-	88-06-2			8.78E-03		2.80E-01	4.6E+05		4.6E+05			4.9E+05	2.0 ^a	2.0 ^a
Trichlorophenoxy)propionic acid 2-(2,4,5- (Silvex)	93-72-1	5.00E-02	1.96E-01				3.1E+05	1.0 ^a	3.1E+05	1.0 ^a		3.1E+05		
Trichlorophenoxyacetic acid 2,4,5-	93-76-5		2.45E-01				2.6E+05		2.6E+05	1.0E+03 ^{b,c}		2.6E+05		
Trichloropropane 1,2,3-	96-18-4		1.47E-01	1.38E-05	3.40E-02		1.3E+09		1.3E+09	1.0E+03 ^b	1.0E+03 ^b	1.5E+09	1.0E+03 ^b	
Triethylamine	121-44-8				1.10E-01		2.9E+05		2.9E+05		1.0E+03 ^b	3.0E+05		
Trinitrobenzene (1,3,5-Trinitrobenzene) sym-	99-35-4		7.34E-01				2.3E+05		2.4E+05	1.0E+03 ^{b,c}		2.4E+05		
Tris(2,3-dibromopropyl)phosphate	126-72-7			9.89E-06			1.0E+30		1.0E+30			1.0E+30	1.0E+03 ^{b,c}	
Vanadium	7440-62-2		1.71E-01							1.0E+03 ^b				
Vinyl acetate	108-05-4		2.45E+01		1.20E+00		2.6E+05		2.7E+05	1.0E+03 ^b	1.0E+03 ^b	2.8E+05		
Vinyl chloride	75-01-4	2.00E-03	7.34E-02	1.34E-04	2.90E-01	2.50E-03	2.8E+05	0.20 ^a	2.8E+05	0.20 ^a	0.20 ^a	3.0E+05	0.20 ^a	0.20 ^a
Xylene m-	108-38-3		4.90E+01		1.30E+00		1.7E+06		1.7E+06	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}	1.8E+06		
Xylene o-	95-47-6		4.90E+01		1.40E+00		1.5E+06		1.5E+06	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}	1.6E+06		
Xylene p-	106-42-3		4.90E+01		1.30E+00		1.9E+06		1.9E+06	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}	1.9E+06		
Xylenes (total)	1330-20-7	1.00E+01	4.90E+01		1.40E+00		1.6E+06	1.0E+03 ^{b,c}	1.6E+06	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}	1.7E+06		
Zinc	7440-66-6		7.34E+00							1.0E+03 ^b				

KEY:

- a - TC Rule cap
b - 1,000 mg/L cap
c - Exceeds solubility
d - Capped by daughter LCTV
e - Constituent has no RGC; LCTV from daughter

Table F-7: Waste Pile No-Liner LCTVs

Common Name	CAS#	MCL (mg/L)	HBN (mg/L)				Peak DAF	LCTV based on MCL (mg/L)	No Liner/In-Situ Soil					
		Ingestion	Ingestion		Inhalation				Non-Carcinogenic Effect (NC)			Carcinogenic Effect (C)		
			NC	C	NC	C			7-yr Avg DAF	LCTV based on Ingestion	LCTV based on Inhalation	30-yr Avg DAF	LCTV based on Ingestion	LCTV based on Inhalation
Acenaphthene	83-32-9		1.47E+00				65		66	97 ^a		70		
Acetaldehyde [Ethanal]	75-07-0				2.20E-01	4.10E-02	10		11		2.4	15		0.62
Acetone (2-propanone)	67-64-1		2.45E+00		1.50E+03		10		11	27	1.0E+03 ^b	15		
Acetonitrile (methyl cyanide)	75-05-8				3.10E+00		10		11		34	15		
Acetophenone	98-86-2		2.45E+00				10		11	27		15		
Acrolein	107-02-8		4.90E-01		3.30E-04		1.0E+30		1.0E+30	1.0E+03 ^b	1.0E+03 ^b	1.0E+30		
Acrylamide	79-06-1		4.90E-03	2.15E-05		5.10E+00	12		12	0.061		17	3.7E-04	88
Acrylic acid [propenoic acid]	79-10-7		1.22E+01		1.50E+01		10		11	130	170	15		
Acrylonitrile	107-13-1		2.45E-02	1.79E-04	3.80E-02	1.00E-03	11		12	0.045 ^d	0.44	16	2.8E-04 ^d	0.016
Aldrin	309-00-2		7.34E-04	5.68E-06		1.00E-05	1.1E+07		1.1E+07	1.0E+03 ^{b,c}		1.1E+07	63 ^d	110 ^c
Allyl alcohol	107-18-6		1.22E-01				10		11	1.3		15		
Aniline (benzeneamine)	62-53-3			1.69E-02	9.30E-01	2.20E+00	10		11		10	15	0.26	33
Anthracene	120-12-7		7.34E+00				170		170	1.0E+03 ^{b,c}		174		
Antimony	7440-36-0	6.00E-03	9.79E-03					0.087		0.16				
Arsenic	7440-38-2	5.00E-02	7.34E-03	6.44E-05				1.0		0.2			5.5E-04	
Barium	7440-39-3	2.00E+00	1.71E+00					24		24				
Benzo(a)anthracene	56-55-3			8.05E-05		1.80E-02	3.3E+03		3.3E+03			3.3E+03	0.26 ^c	59 ^d
Benzene	71-43-2	5.00E-03		1.76E-03	1.90E-01	1.60E-03	11	0.055	12		0.50 ^a	16	0.03	0.025
Benzidine	92-87-5		7.34E-02	4.20E-07		2.60E+00	10		11	0.81		15	6.3E-06	39
Benzo(a)pyrene	50-32-8	2.00E-04		1.32E-05		5.40E-03	4.6E+04	9.1 ^c	4.6E+04			4.6E+04	0.61 ^c	250 ^c
Benzo(b)fluoranthene	205-99-2			8.05E-05		6.30E-04	4.6E+04		4.6E+04			4.6E+04	3.7 ^c	29 ^d
Benzyl alcohol	100-51-6		7.34E+00				10		11	81		15		
Benzyl chloride	100-44-7			5.68E-04		5.20E-04	1.0E+30		1.0E+30	95 ^d		1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Beryllium	7440-41-7	4.00E-03	4.90E-02					8.1		16				
Bis(2-chloroethyl)ether	111-44-4			8.78E-05		1.10E-03	33		35		1.0E+03 ^e	49	4.3E-03	0.054
Bis(2-chloroisopropyl)ether	39638-32-9		9.79E-01	1.38E-03		5.90E-03	12		13	12		17	0.024	0.10
Bis(2-ethylhexyl)phthalate	117-81-7	6.00E-03	4.90E-01	6.90E-03	1.80E+02	2.80E+01	1.0E+30	1.0E+03 ^{b,c}	1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}	1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Bromodichloromethane	75-27-4	8.00E-02	4.90E-01	1.56E-03		8.00E-04	12	0.95	12	6.1		17	0.027	0.014
Bromomethane	74-83-9		3.43E-02		1.50E-02		8.6E+06		8.9E+06	400 ^d	1.0E+03 ^b	2.7E+07		
Butadiene 1, 3-	106-99-0				6.00E-02	4.00E-05	11		12		0.71	16		6.5E-04
Butanol n-	71-36-3		2.45E+00				10		11	27		15		
Butyl benzyl phthalate	85-68-7		4.90E+00				210		210	1.0E+03 ^{b,c}		210		
Butyl-4,6-dinitrophenol,2-sec-(Dinoseb)	88-85-7	7.00E-03	2.45E-02				11	0.078	12	0.29		16		
Cadmium	7440-43-9	5.00E-03	1.22E-02					0.10		0.26				
Carbon disulfide	75-15-0		2.45E+00		1.90E+00		12		12	30	23	17		
Carbon tetrachloride	56-23-5	5.00E-03	1.71E-02	7.43E-04	2.10E-02	7.60E-04	15	0.077	16	0.27	0.33	21	0.016	0.016
Chlordane	57-74-9	2.00E-03	1.22E-02	2.76E-04	2.80E-02	1.50E-03	1.1E+05	0.030 ^a	1.1E+05	0.030 ^a	0.030 ^a	1.1E+05	0.030 ^a	0.030 ^a
Chloro-1,3-butadiene 2-(Chloroprene)	126-99-8		4.90E-01		2.20E-02		11		11	5.6	0.25	16		
Chloroaniline p-	106-47-8		9.79E-02				10		11	1.1		15		
Chlorobenzene	108-90-7	1.00E-01	4.90E-01		2.00E-01		14	1.4	14	6.9	2.8	19		
Chlorobenzilate	510-15-6		4.90E-01	3.58E-04		1.20E+00	330		330	160 ^c		340	0.12	400 ^c
Chlorodibromomethane	124-48-1	8.00E-02	4.90E-01	1.15E-03		7.50E-04	12	0.94	12	6		17	0.020	0.013
Chloroethane [Ethyl chloride]	75-00-3				3.00E+01		10		11		330	15		
Chloroform	67-66-3	8.00E-02	2.45E-01		3.30E-01		11	0.86	11	2.8	3.7	16		
Chloromethane	74-87-3			7.43E-03	2.60E-01	5.90E-03	10		11		2.9	15	0.11	0.089
Chlorophenol 2-	95-57-8		1.22E-01		9.70E-03		11		12	1.4	0.11	16		
Chloropropene 3- (Allyl Chloride)	107-05-1				3.00E-03	1.90E-03	1.0E+30		1.0E+30		1.0E+03 ^b	1.0E+30		1.0E+03 ^b
Chromium (III) (Chromic Ion)	16065-83-1	1.00E-01	3.67E+01					67		1.0E+03 ^b				

KEY:

a - TC Rule cap

d - Capped by daughter LCTV

b - 1,000 mg/L cap

e - Constituent has no RGC; LCTV from daughter

c - Exceeds solubility

Table F-7: Waste Pile No-Liner LCTVs

Common Name	CAS#	MCL (mg/L)	HBN (mg/L)				No Liner/In-Situ Soil							
		Ingestion	Ingestion		Inhalation		Peak DAF	LCTV based on MCL (mg/L)	Non-Carcinogenic Effect (NC)		Carcinogenic Effect (C)			
			NC	C	NC	C			7-yr Avg DAF	LCTV based on Ingestion	LCTV based on Inhalation	30-yr Avg DAF	LCTV based on Ingestion	LCTV based on Inhalation
Chromium (VI)	18540-29-9	1.00E-01	7.34E-02				5.0 ^a	5.0 ^a						
Chrysene	218-01-9			8.05E-04		7.30E-03	3.3E+03		3.3E+03			3.3E+03	2.6 ^c	24 ^c
Cobalt	7440-48-4		4.90E-01							27				
Copper	7440-50-8	1.30E+00						150						
Cresol m-	108-39-4		1.22E+00		1.20E+03		11		11	14	200 ^a	16		
Cresol o-	95-48-7		1.22E+00		8.80E+02		11		11	14	200 ^a	16		
Cresol p-	106-44-5		1.22E-01		1.30E+03		11		11	1.4	200 ^a	16		
Cresols	1319-77-3		1.22E+00		1.10E+03		12		12	15	1.0E+03 ^u	17		
Cumene	98-82-8		2.45E+00		1.30E+00		35		35	85 ^c	45	39		
Cyclohexanol	108-93-0		4.16E-04		3.90E-04		10		11	4.60E-03	0.0043	15		
Cyclohexanone	108-94-1		1.22E+02				11		12	1.0E+03 ^u		16		
DDD	72-54-8			4.02E-04			1.0E+30		1.0E+30			1.0E+30	1.0E+03 ^{b,c}	
DDE	72-55-9			2.84E-04			6.7E+17		6.7E+17			6.7E+17	1.0E+03 ^{b,c}	
DDT p,p'-	50-29-3		1.22E-02	2.84E-04		8.80E-03	1.0E+30		1.0E+30	1.0E+03 ^{b,c}		1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Diallate	2303-16-4			1.58E-03			1.5E+05		1.5E+05			1.5E+05	240 ^c	
Dibenz[a,h]anthracene	53-70-3			1.32E-05		3.80E-01	1.8E+12		1.8E+12			1.8E+12	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Dibromo-3-chloropropane 1,2-	96-12-8	2.00E-04		6.90E-05	2.90E-03	7.90E-02	13	2.7E-03	14		0.040	19	1.3E-03	1.5
Dichlorobenzene 1,2-	95-50-1	6.00E-01	2.20E+00		7.70E-01		22	13	22	48	17	27		
Dichlorobenzene 1,4-	106-46-7	7.50E-02		4.02E-03	3.00E+00	1.30E-03	21	1.6	21		7.5 ^a	26	0.10	0.034
Dichlorobenzidine 3,3'-	91-94-1			2.15E-04		4.90E+00	30		31			35	7.5E-03	170 ^c
Dichlorodifluoromethane (Freon 12)	75-71-8		4.90E+00		5.80E-01		12		12	59	7.0	17		
Dichloroethane 1,1-	75-34-3		2.45E+00		1.60E+00	7.40E-03	12	0.046 ^u	12	0.45 ^u	0.45 ^u	17	4.6E-03 ^u	0.085 ^u
Dichloroethane 1,2-	107-06-2	5.00E-03		1.06E-03	1.00E+01	6.30E-04	11	0.033 ^u	12	0.32 ^u	0.32 ^u	16	3.2E-03 ^u	0.010
Dichloroethylene cis-1,2-	156-59-2	7.00E-02	2.45E-01				11	0.76	11	2.8		16		
Dichloroethylene trans-1,2-	156-60-5	1.00E-01	4.90E-01				10	1.0	11	5.4		15		
Dichloroethylene 1,1-	75-35-4	7.00E-03	2.20E-01	1.61E-04	2.10E-01	2.20E-04	11	0.076	11	0.70 ^a	0.70 ^a	16	2.5E-03	3.5E-03
Dichlorophenol 2,4-	120-83-2		7.34E-02				13		13	1		18		
Dichlorophenoxyacetic acid 2,4-(2,4-D)	94-75-7	7.00E-02	2.45E-01				10	0.72	11	2.7		15		
Dichloropropane 1,2-	78-87-5	5.00E-03	2.20E+00	1.42E-03	1.40E-02		15	0.075	16	35	0.022	22	0.031	
Dichloropropene 1,3-(mixture of isomers)	542-75-6		7.34E-01	9.66E-04	6.10E-02	2.90E-03	10		11	8.1	0.67	15	0.015	0.044
Dichloropropene cis-1,3-	10061-01-5		7.34E-01	9.66E-04	7.00E-02	3.30E-03	1.0E+30		1.0E+30	1.0E+03 ^u	1.0E+03 ^u	1.0E+30	1.0E+03 ^u	1.0E+03
Dichloropropene trans-1,3-	10061-02-6		7.34E-01	9.66E-04	7.50E-02	3.50E-03	1.0E+30		1.0E+30	1.0E+03 ^u	1.0E+03 ^u	1.0E+30	1.0E+03 ^u	1.0E+03
Dieldrin	60-57-1		1.22E-03	6.04E-06		1.00E-04	6.5E+13		6.5E+13	1.0E+03 ^{b,c}		6.5E+13	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Diethyl phthalate	84-66-2		1.96E+01				15		15	300		22		
Diethylstilbestrol	56-53-1			2.05E-08			130		130			137	2.8E-06	
Dimethoate	60-51-5		4.90E-03				3.1E+03		3.4E+03	2.7 ^u	1.0E+03 ^u	4.7E+03		
Dimethoxybenzidine 3,3'-	119-90-4			6.90E-03			10		11			15	0.10	
Dimethyl formamide N,N- [DMF]	68-12-2		2.45E+00		7.10E+02		10		11	27	1.0E+03 ^u	15		
Dimethylbenz[a]anthracene 7,12-	57-97-6					3.00E-03	6.0E+16		6.1E+16			6.1E+16		1.0E+03 ^{b,c}
Dimethylbenzidine 3,3'-	119-93-7			1.05E-05			13		14			18	1.9E-04	
Dimethylphenol 2,4-	105-67-9		4.90E-01				12		12	6.1		17		
Di-n-butyl phthalate	84-74-2		2.45E+00				290		290	700 ^c		290		
Dinitrobenzene 1,3-	99-65-0		2.45E-03				10		11	0.027		15		
Dinitrophenol 2,4-	51-28-5		4.90E-02				10		11	0.54		15		
Dinitrotoluene 2,4-	121-14-2		4.90E-02	1.42E-04		8.12E-01	10		11	0.13 ^a		15	2.1E-03	0.13 ^a
Dinitrotoluene 2,6-	606-20-2		2.45E-02	1.42E-04			10		11	0.27		15	2.1E-03	
Di-n-octyl phthalate	117-84-0		4.90E-01				1.0E+30		1.0E+30	1.0E+03 ^{b,c}		1.0E+30		
Dioxane 1,4-	123-91-1			8.78E-03	1.09E+03	1.80E-01	10		11		1.0E+03 ^b	15	0.13	2.72

KEY:

a - TC Rule cap

b - 1,000 mg/L cap

c - Exceeds solubility

d - Capped by daughter LCTV

e - Constituent has no RGC; LCTV from daughter

Table F-7: Waste Pile No-Liner LCTVs

Common Name	CAS#	MCL (mg/L)	HBN (mg/L)				No Liner/In-Situ Soil							
		Ingestion	Ingestion		Inhalation		Peak DAF	LCTV based on MCL (mg/L)	Non-Carcinogenic Effect (NC)			Carcinogenic Effect (C)		
			NC	C	NC	C			7-yr Avg DAF	LCTV based on Ingestion	LCTV based on Inhalation	30-yr Avg DAF	LCTV based on Ingestion	LCTV based on Inhalation
Diphenylamine	122-39-4		6.12E-01				29		29	18		33		
Diphenylhydrazine 1, 2-	122-66-7			1.21E-04		2.00E-02	16		17			21	2.5E-03	0.42
Disulfoton	298-04-4		9.79E-04				2.8E+06		2.8E+06	1.0E+03 ^{b,c}		4.7E+06		
Endosulfan (Endosulfan I and II,mixture)	115-29-7		1.47E-01				45		45	6.6 ^c		49		
Endrin	72-20-8	2.00E-03	7.34E-03				2.4E+06	0.020 ^a	2.4E+06	0.020 ^a		2.4E+06		
Epichlorohydrin	106-89-8		4.90E-02	9.75E-03	6.00E-02	1.90E-01	1.0E+30		1.0E+30	1.0E+03 ^b	1.0E+03 ^b	1.0E+30	1.0E+03 ^b	1.0E+03 ^b
Epoxybutane 1, 2-	106-88-7				2.40E-01		10		11		2.6	15		
Ethoxyethanol 2-	110-80-5		9.79E+00		2.90E+03		10		11	110	1.0E+03 ^b	15		
Ethoxyethanol acetate 2-	111-15-9		7.34E+00		3.00E+02		10		11	81	1.0E+03 ^b	15		
Ethyl acetate	141-78-6		2.20E+01				43		45	990		64		
Ethyl ether	60-29-7		4.90E+00				10		11	54		15		
Ethyl methacrylate	97-63-2		2.20E+00				20		21	47		30		
Ethyl methanesulfonate	62-50-0			3.30E-07			1.0E+30		1.0E+30			1.0E+30	1.0E+03 ^b	
Ethylbenzene	100-41-4	7.00E-01	2.45E+00		3.30E+00	1.10E-02	20	14	20	49	66	25		0.27
Ethylene dibromide (1,2-Dibromoethane)	106-93-4	5.00E-05		1.14E-06	9.80E-04	8.40E-05	150	7.4E-03	150		0.15	220	2.5E-04	0.019
Ethylene glycol	107-21-1		4.90E+01		1.20E+04		10		11	540	1.0E+03 ^b	15		
Ethylene oxide	75-21-8			9.47E-05	4.10E-01	5.20E-04	1.2E+12		1.4E+12		1.0E+03 ^a	3.4E+12	1.0E+03 ^a	1.0E+03
Ethylene thiourea	96-45-7		1.96E-03	8.78E-04		1.60E+03	10		11	0.022		15	0.013	1.0E+03
Fluoranthene	206-44-0		9.79E-01				450		450	440 ^c		450		
Fluoride	16984-48-8	4.00E+00	2.90E+00					38		32				
Formaldehyde	50-00-0		4.90E+00		5.10E+01	1.50E+00	10		11	54	560	15		23
Formic acid	64-18-6		4.90E+01				10		11	540		15		
Furfural	98-01-1		7.34E-02		2.20E+01		10		11	0.81	240	15		
HCH beta-	319-85-7			5.36E-05		1.70E-02	37		37			41	2.2E-03	0.69
HCH (Lindane) gamma-	58-89-9	2.00E-04	7.34E-03	7.43E-05		1.60E-03	5.9E+06	0.4 ^{a,b}	6.0E+06	0.4 ^{a,b}	0.4 ^{a,b}	8.6E+06	0.4 ^{a,b}	0.4 ^{a,b}
HCH alpha-	319-84-6		1.96E-01	1.53E-05		3.60E-04	9.2E+06	11 ^a	9.4E+06	25 ^{a,b}	140 ^b	1.3E+07	210	1.0E+03 ^b
Heptachlor	76-44-8	4.00E-04	1.22E-02	2.15E-05		1.50E-05	1.0E+30	8.0E-03 ^a	1.0E+30	8.0E-03 ^a		1.0E+30	8.0E-03 ^a	8.0E-03
Heptachlor epoxide	1024-57-3	2.00E-04	3.18E-04	1.06E-05		2.80E-04	4.2E+09	1.0E+03 ^{b,c}	4.3E+09	1.0E+03 ^{b,c}		4.3E+09	1.0E+03 ^b	1.0E+03 ^b
Hexachloro-1,3-butadiene	87-68-3		7.34E-03	1.24E-03		6.10E-04	310		310	0.50 ^a		310	0.38	0.19
Hexachlorobenzene	118-74-1	1.00E-03	1.96E-02	6.04E-05		3.60E-05	4.3E+03	0.13 ^{a,c}	4.3E+03	0.13 ^{a,c}		4.3E+03	0.13 ^{a,c}	0.13 ^{a,c}
Hexachlorocyclopentadiene	77-47-4	5.00E-02	1.47E-01		6.90E-04		1.0E+30	1.0E+03 ^{b,c}	1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}	1.0E+30		
Hexachlorodibenzofurans [HxCDFs]	55684-94-1			6.19E-09		1.44E-07	1.0E+30		1.0E+30			1.0E+30	1.0E+03 ^b	1.0E+03 ^b
Hexachlorodibenzo-p-dioxins [HxCDDs]	34465-46-8			6.19E-09		1.43E-07	4.6E+09		4.7E+09			4.7E+09	29	670
Hexachloroethane	67-72-1		2.45E-02	6.90E-03		3.30E-03	51		51	1.3		55	0.38	0.18
Hexachlorophene	70-30-4		7.34E-03				1.1E+03		1.1E+03	8.2		1.1E+03		
Hexane n-	110-54-3		2.69E+02		6.60E-01		19		19	1.0E+03 ^{b,c}	13 ^c	24		
Hydrogen Sulfide	7783-06-4		7.34E-02				10		11	0.81		15		
Indeno[1,2,3-cd]pyrene	193-39-5			8.05E-05		3.80E-02	9.9E+07		1.0E+08			1.0E+08	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Isobutyl alcohol	78-83-1		7.34E+00				10		11	81		15		
Isophorone	78-59-1		4.90E+00	1.02E-01	5.33E+02		11		12	56	1.0E+03 ^b	16	1.6	
Kepone	143-50-0		1.22E-02				150		150	1.8		160		
Lead	7439-92-1	1.50E-02						3.9						
Manganese	7439-96-5		1.15E+00							17				
Mercury	7439-97-6	2.00E-03	2.45E-03		7.00E-04			0.020		0.027	0.0084			
Methacrylonitrile	126-98-7		2.45E-03		6.50E-03		11		12	0.028	0.075	16		
Methanol	67-56-1		1.22E+01		1.54E+03		10		11	130	1.0E+03 ^b	15		
Methoxychlor	72-43-5	4.00E-02	1.22E-01				1.0E+30	10 ^{a,c}	1.0E+30	10 ^{a,c}		1.0E+30		
Methoxyethanol acetate 2-	110-49-6		4.90E-02		5.10E+02		10		11	0.54	1.0E+03 ^b	15		

KEY:

- a - TC Rule cap
b - 1,000 mg/L cap
c - Exceeds solubility
d - Capped by daughter LCTV
e - Constituent has no RGC; LCTV from daughter

Table F-7: Waste Pile No-Liner LCTVs

Common Name	CAS#	MCL (mg/L)	HBN (mg/L)				Peak DAF	LCTV based on MCL (mg/L)	No Liner/In-Situ Soil					
		Ingestion	Ingestion		Inhalation				Non-Carcinogenic Effect (NC)			Carcinogenic Effect (C)		
			NC	C	NC	C			7-yr Avg DAF	LCTV based on Ingestion	LCTV based on Inhalation	30-yr Avg DAF	LCTV based on Ingestion	LCTV based on Inhalation
Methoxyethanol 2-	109-86-4		2.45E-02		4.40E+02		10		11	0.27	1.0E+03 ^b	15		
Methyl ethyl ketone	78-93-3		1.47E+01		3.30E+01		10		11	160	200 ^a	15		
Methyl isobutyl ketone	108-10-1		1.96E+00		1.20E+00		10		11	22	13	15		
Methyl methacrylate	80-62-6		3.43E+01		5.30E+00		26		26	420 ^d	140	36		
Methyl parathion	298-00-0		6.12E-03				2.0E+05		2.1E+05	6.2 ^d	1.0E+03 ^e	3.1E+05		
Methyl tert-butyl ether [MTBE]	1634-04-4				1.70E+01		10		11		190	15		
Methylcholanthrene 3-	56-49-5					1.20E-03	1.0E+30		1.0E+30			1.0E+30		1.0E+03 ^{b,c}
Methylene bromide (Dibromomethane)	74-95-3		2.45E-01				10		11	2.7		15		
Methylene Chloride (Dichloromethane)	75-09-2	5.00E-03	1.47E+00	1.29E-02	1.00E+01	2.80E-02	10	0.052	11	16	110	15	0.20	0.43
Molybdenum	7439-98-7		1.22E-01							1.2				
Naphthalene	91-20-3		4.90E-01		1.90E-02		22		23	11	0.43	27		
Nickel	7440-02-0		4.90E-01							9.9				
Nitrobenzene	98-95-3		1.22E-02		1.50E-01		10		11	0.13	1.7	15		
Nitropropane 2-	79-46-9				3.30E-01	2.30E-05	10		11		3.6	15		3.5E-04
Nitrosodiethylamine N-	55-18-5			6.44E-07		4.30E-05	10		11			15	9.7E-06	6.5E-04
Nitrosodimethylamine N-	62-75-9		1.96E-04	1.89E-06		4.00E-04	10		11	2.2E-03		15	2.9E-05	6.0E-03
Nitroso-di-n-butylamine N-	924-16-3			1.79E-05		2.00E-05	11		12			16	2.9E-04	3.3E-04
Nitroso-di-n-propylamine N-	621-64-7			1.38E-05		1.50E-03	10		11			15	2.1E-04	0.023
Nitrosodiphenylamine N-	86-30-6		4.90E-01	1.97E-02		5.20E-01	17		17	8.3		21	0.42	11
Nitrosomethylethylamine N-	10595-95-6			4.39E-06		4.50E-03	10		11			15	6.6E-05	0.068
Nitrosopiperidine N-	100-75-4					8.70E-03	10		11			15		0.13
Nitrosopyrrolidine N-	930-55-2			4.60E-05		9.20E-01	10		11			15	6.9E-04	14
Octamethyl pyrophosphoramidate	152-16-9		4.90E-02				11		12	0.57		16		
Parathion (ethyl)	56-38-2		1.47E-01				2.1E+08		2.1E+08	1.0E+03 ^{b,c}		3.4E+08		
Pentachlorobenzene	608-93-5		1.96E-02				3.9E+03		3.9E+03	76 ^d		3.9E+03		
Pentachlorodibenzofurans [PeCDFs]	30402-15-4			1.24E-09		6.29E-08	940		940			940	1.2E-06	5.9E-05
Pentachlorodibenzo-p-dioxins [PeCDDs]	36088-22-9			6.19E-10		6.00E-08	3.2E+08		3.3E+08			3.3E+08	0.21 ^c	20 ^g
Pentachloronitrobenzene (PCNB)	82-68-8		7.34E-02	3.71E-04			390		390	29 ^e		390	0.14	
Pentachlorophenol	87-86-5	1.00E-03	7.34E-01	8.05E-04		5.40E+01	21	0.021	21	16		26	0.021	100 ^a
Phenol	108-95-2		1.47E+01		9.00E+02		10		11	160	1.0E+03 ^b	15		
Phenyl mercuric acetate	62-38-4		1.96E-03				10		11	0.022		15		
Phenylenediamine 1,3-	108-45-2		1.47E-01				10		11	1.6		15		
Phorate	298-02-2		4.90E-03				1.0E+30		1.0E+30	1.0E+03 ^{b,c}		1.0E+30		
Phthalic anhydride	85-44-9		4.90E+01		1.30E+04		1.0E+30		1.0E+30	1.0E+03 ^b	1.0E+03 ^b	1.0E+30		
Polychlorinated biphenyls (Aroclors)	1336-36-3	5.00E-04	4.90E-04	2.41E-04		1.40E-04	1.4E+07	1.0E+03 ^{b,c}	1.4E+07	1.0E+03 ^{b,c}		1.4E+07	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Pronamide	23950-58-5		1.84E+00				14		15	27		19		
Propylene oxide [1,2-Epoxypropane]	75-56-9			4.02E-04	4.90E-01	1.70E-02	10		11		5.4	15	6.1E-03	0.26
Pyrene	129-00-0		7.34E-01				910		910	670 ^c		910		
Pyridine	110-86-1		2.45E-02		1.40E+00		10		11	0.27	5.0 ^a	15		
Safrrole	94-59-7			5.36E-04			12		13			17	9.1E-03	
Selenium	7782-49-2	5.00E-02	1.22E-01					0.46		1.0 ^a				
Silver	7440-22-4		1.22E-01							2				
Strychnine and salts	57-24-9		7.34E-03				11		12	0.085		16		
Styrene	100-42-5	1.00E-01	4.90E+00		3.60E+00		17	1.7	17	83	61	21		
Tetrachlorobenzene 1,2,4,5-	95-94-3		7.34E-03				200		200	1.5 ^c		210		
Tetrachlorodibenzofuran 2,3,7,8-	51207-31-9			6.19E-09		1.00E-07	2.3E+15		2.3E+15			2.3E+15	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Tetrachlorodibenzo-p-dioxin 2,3,7,8-	1746-01-6	3.00E-08	2.45E-08	6.44E-10		2.20E-09	2.0E+06	0.059 ^c	2.0E+06	0.049 ^c		2.0E+06	1.3E-03 ^c	4.4E-03 ^c
Tetrachloroethane 1,1,1,2-	630-20-6		7.34E-01	3.71E-03		1.90E-03	19	0.073 ^e	20	14		26	0.095	0.048
Tetrachloroethane 1,1,2,2-	79-34-5		1.47E+00	4.83E-04		5.00E-04	120	0.073 ^e	130	190	0.64 ^e	180	0.085	0.088

KEY:

- a - TC Rule cap d - Capped by daughter LCTV
b - 1,000 mg/L cap e - Constituent has no RGC; LCTV from daughter
c - Exceeds solubility

Table F-7: Waste Pile No-Liner LCTVs

Common Name	CAS#	MCL (mg/L)	HBN (mg/L)				No Liner/In-Situ Soil							
		Ingestion	Ingestion		Inhalation		Peak DAF	LCTV based on MCL (mg/L)	Non-Carcinogenic Effect (NC)		Carcinogenic Effect (C)			
			NC	C	NC	C			7-yr Avg DAF	LCTV based on Ingestion	LCTV based on Inhalation	30-yr Avg DAF	LCTV based on Ingestion	LCTV based on Inhalation
Tetrachloroethylene	127-18-4	5.00E-03	2.45E-01	1.86E-03	9.40E-01	2.10E-02	12	0.059	12	0.70 ^a	0.70 ^a	17	0.031	0.35
Tetrachlorophenol 2,3,4,6-	58-90-2		7.34E-01				12		13	9.2		17		
Tetraethyl dithiopyrophosphate (Sulfotep)	3689-24-5		1.22E-02				1.0E+30		1.0E+30	1.0E+03 ^{b,c}		1.0E+30		
Thallium	7440-28-0	2.00E-03	1.96E-03					0.019		0.021				
Thiram [Thiuram]	137-26-8		1.22E-01				16		17	2		21		
Toluene	108-88-3	1.00E+00	4.90E+00		1.30E+00		13	13	13	64	17	18		
Toluenediamine 2,4-	95-80-7			3.02E-05	7.50E+00		10		11			15	4.6E-04	110
Toluidine o-	95-53-4			4.02E-04	3.60E-02		10		11			15	6.1E-03	0.54
Toluidine p-	106-49-0			5.08E-04			10		11			15	7.7E-03	
Toxaphene (chlorinated camphenes)	8001-35-2	3.00E-03		8.78E-05	3.60E-03		1.6E+05	0.50 ^a	1.6E+05			1.7E+05	0.50 ^a	0.50 ^a
Tribromomethane (Bromoform)	75-25-2	8.00E-02	4.90E-01	1.22E-02		1.90E-02	12	0.94	12	5.9		17	0.20	0.32
Trichloro-1,2,2-trifluoro-ethane 1,1,2-	76-13-1		7.34E+02		9.50E+01		19		20	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}	24		
Trichlorobenzene 1,2,4-	120-82-1	7.00E-02	2.45E-01		8.30E-01		100	7.1	100	25.2	86 ^c	110		
Trichloroethane 1,1,1-	71-55-6	2.00E-01	6.85E+00		6.90E+00		610	0.11 ^a	640	0.96 ^a	0.96 ^a	920	3.5E-03 ^a	4.8E-03
Trichloroethane 1,1,2-	79-00-5	5.00E-03	9.79E-02	1.69E-03		1.10E-03	12	0.060	12	0.96 ^a	0.96 ^a	17	3.5E-03 ^a	4.8E-03
Trichloroethylene (1,1,2-Trichloroethylene)	79-01-6	5.00E-03		8.78E-03	1.90E+00	6.80E-03	11	0.057	12		0.50 ^a	16	0.14	0.11
Trichlorofluoromethane (Freon 11)	75-69-4		7.34E+00		2.10E+00		12		12	88	25	16		
Trichlorophenol 2,4,5-	95-95-4		2.45E+00				18		18	45		23		
Trichlorophenol 2,4,6-	88-06-2			8.78E-03		2.80E-01	12		12			17	0.15	2.0 ^a
Trichlorophenoxypropionic acid 2-(2,4,5- (Silvex)	93-72-1	5.00E-02	1.96E-01				11	0.54	11	1.0 ^a		16		
Trichlorophenoxyacetic acid 2,4,5-	93-76-5		2.45E-01				10		11	2.7		15		
Trichloropropane 1,2,3-	96-18-4		1.47E-01	1.38E-05	3.40E-02		12		13	1.9	0.44	18	2.5E-04	
Triethylamine	121-44-8				1.10E-01		10		11		1.2	15		
Trinitrobenzene (1,3,5-Trinitrobenzene) sym-	99-35-4		7.34E-01				10		11	8.1		15		
Tris(2,3-dibromopropyl)phosphate	126-72-7			9.89E-06			200		210			260	2.5E-03	
Vanadium	7440-62-2		1.71E-01							57				
Vinyl acetate	108-05-4		2.45E+01		1.20E+00		10		11	270	13	15		
Vinyl chloride	75-01-4	2.00E-03	7.34E-02	1.34E-04	2.90E-01	2.50E-03	10	0.021	11	0.20 ^a	0.20 ^a	15	2.0E-03	0.038
Xylene m-	108-38-3		4.90E+01		1.30E+00		22		22	1.0E+03 ^{b,c}		29	27	
Xylene o-	95-47-6		4.90E+01		1.40E+00		20		21	1.0E+03 ^{b,c}		29	25	
Xylene p-	106-42-3		4.90E+01		1.30E+00		23		23	1.0E+03 ^{b,c}		30	28	
Xylenes (total)	1330-20-7	1.00E+01	4.90E+01		1.40E+00		21	210 ^c	22	1.0E+03 ^{b,c}		30	27	
Zinc	7440-66-6		7.34E+00							180				

KEY:

- a - TC Rule cap d - Capped by daughter LCTV
b - 1,000 mg/L cap e - Constituent has no RGC; LCTV from daughter
c - Exceeds solubility

Table F-8: Waste Pile Single Clay Liner LCTVs

Common Name	CAS#	MCL (mg/L)	HBN (mg/L)				Peak DAF	LCTV based on MCL (mg/L)	Compacted Clay Liner					
		Ingestion	Ingestion		Inhalation				Non-Carcinogenic Effect (NC)		Carcinogenic Effect (C)			
			NC	C	NC	C			7-yr Avg DAF	LCTV based on Ingestion	LCTV based on Inhalation	30-yr Avg DAF	LCTV based on Ingestion	LCTV based on Inhalation
Acenaphthene	83-32-9		1.47E+00				210		210	300 ^c		210		
Acetaldehyde [Ethanal]	75-07-0				2.20E-01	4.10E-02	24		24		5.3	33		1.4
Acetone (2-propanone)	67-64-1		2.45E+00		1.50E+03		24		24	60	1.0E+03 ^b	33		
Acetonitrile (methyl cyanide)	75-05-8				3.10E+00		24		25		76	34		
Acetophenone	98-86-2		2.45E+00				24		24	60		33		
Acrolein	107-02-8		4.90E-01		3.30E-04		1.0E+30		1.0E+30	1.0E+03 ^b	1.0E+03 ^b	1.0E+30		
Acrylamide	79-06-1		4.90E-03	2.15E-05		5.10E+00	29		30	0.15		41	8.9E-04	210
Acrylic acid [propenoic acid]	79-10-7		1.22E+01		1.50E+01		24		24	300	360	33		
Acrylonitrile	107-13-1		2.45E-02	1.79E-04	3.80E-02	1.00E-03	25		26	0.11 ^d	0.98	36	6.6E-04 ^d	0.036
Aldrin	309-00-2		7.34E-04	5.68E-06		1.00E-05	2.6E+11		2.6E+11	1.0E+03 ^{b,c}		2.6E+11	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Allyl alcohol	107-18-6		1.22E-01				24		24	3		33		
Aniline (benzeneamine)	62-53-3			1.69E-02	9.30E-01	2.20E+00	24		24		23	33	0.56	73
Anthracene	120-12-7		7.34E+00				560		560	1.0E+03 ^{b,c}		560		
Antimony	7440-36-0	6.00E-03	9.79E-03					0.16		0.34				
Arsenic	7440-38-2	5.00E-02	7.34E-03	6.44E-05				2.0		0.38			0.012	
Barium	7440-39-3	2.00E+00	1.71E+00					48		50				
Benz(a)anthracene	56-55-3			8.05E-05		1.80E-02	2.2E+04		2.2E+04			2.2E+04	1.7 ^c	390 ^c
Benzene	71-43-2	5.00E-03		1.76E-03	1.90E-01	1.60E-03	26	0.13	27		0.50 ^a	35	0.06	0.056
Benzidine	92-87-5		7.34E-02	4.20E-07		2.60E+00	24		24	1.8		33	1.4E-05	87
Benzo(a)pyrene	50-32-8	2.00E-04		1.32E-05		5.40E-03	1.5E+06	290 ^c	1.5E+06			1.5E+06	19 ^c	1.0E+03 ^{b,c}
Benzo(b)fluoranthene	205-99-2			8.05E-05		6.30E-04	1.5E+06		1.5E+06			1.5E+06	120 ^c	950 ^c
Benzyl alcohol	100-51-6		7.34E+00				24		24	180		33		
Benzyl chloride	100-44-7			5.68E-04		5.20E-04	1.0E+30		1.0E+30	210 ^e		1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Beryllium	7440-41-7	4.00E-03	4.90E-02					21		52				
Bis(2-chloroethyl)ether	111-44-4			8.78E-05		1.10E-03	120		130		1.0E+03 ^e	180	0.016	0.20
Bis(2-chloroisopropyl)ether	39638-32-9		9.79E-01	1.38E-03		5.90E-03	32		33	32		42	0.058	0.25
Bis(2-ethylhexyl)phthalate	117-81-7	6.00E-03	4.90E-01	6.90E-03	1.80E+02	2.80E+01	1.0E+30	1.0E+03 ^{b,c}	1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}	1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Bromodichloromethane	75-27-4	8.00E-02	4.90E-01	1.56E-03		8.00E-04	29	2.3	30	15		40	0.063	0.032
Bromomethane	74-83-9		3.43E-02		1.50E-02		7.9E+09		8.0E+09	880 ^d	1.0E+03 ^b	1.7E+10		
Butadiene 1, 3-	106-99-0				6.00E-02	4.00E-05	28		28		1.7	37		1.5E-03
Butanol n-	71-36-3		2.45E+00				24		24	60		33		
Butyl benzyl phthalate	85-68-7		4.90E+00				760		760	1.0E+03 ^{b,c}		760		
Butyl-4,6-dinitrophenol,2-sec-(Dinoseb)	88-85-7	7.00E-03	2.45E-02				27	0.19	28	0.68		36		
Cadmium	7440-43-9	5.00E-03	1.22E-02					0.20		0.67				
Carbon disulfide	75-15-0		2.45E+00		1.90E+00		29		29	72	56	40		
Carbon tetrachloride	56-23-5	5.00E-03	1.71E-02	7.43E-04	2.10E-02	7.60E-04	42	0.21	43	0.50 ^a	0.50 ^a	57	0.043	0.044
Chlordane	57-74-9	2.00E-03	1.22E-02	2.76E-04	2.80E-02	1.50E-03	9.2E+06	0.030 ^a	9.5E+06	0.030 ^a	0.030 ^a	9.5E+06	0.030 ^a	
Chloro-1,3-butadiene 2-(Chloroprene)	126-99-8		4.90E-01		2.20E-02		26		26	13	0.58	35		
Chloroaniline p-	106-47-8		9.79E-02				24		24	2.4		33		
Chlorobenzene	108-90-7	1.00E-01	4.90E-01		2.00E-01		37	3.7	37	18	7.4	47		
Chlorobenzilate	510-15-6		4.90E-01	3.58E-04		1.20E+00	1.6E+03		1.6E+03	760 ^c		1.6E+03	0.56	1.0E+03 ^{b,c}
Chlorodibromomethane	124-48-1	8.00E-02	4.90E-01	1.15E-03		7.50E-04	29	2.3	29	14		40	0.046	0.030
Chloroethane [Ethyl chloride]	75-00-3				3.00E+01		24		24		730	33		
Chloroform	67-66-3	8.00E-02	2.45E-01		3.30E-01		26	2.0	26	6.0 ^a	6.0 ^a	35		
Chloromethane	74-87-3			7.43E-03	2.60E-01	5.90E-03	24		24		6.3	33	0.25	0.20
Chlorophenol 2-	95-57-8		1.22E-01		9.70E-03		26		27	3.3	0.26	35		
Chloropropene 3- (Allyl Chloride)	107-05-1				3.00E-03	1.90E-03	1.0E+30		1.0E+30		1.0E+03 ^b	1.0E+30		1.0E+03 ^b
Chromium (III) (Chromic Ion)	16065-83-1	1.00E-01	3.67E+01					160		1.0E+03 ^b				
Chromium (VI)	18540-29-9	1.00E-01	7.34E-02					5.0 ^a		5.0 ^a				

KEY:

a - TC Rule cap

d - Capped by daughter LCTV

b - 1,000 mg/L cap

e - Constituent has no RGC; LCTV from daughter

c - Exceeds solubility

Table F-8: Waste Pile Single Clay Liner LCTVs

Common Name	CAS#	MCL (mg/L)	HBN (mg/L)				Peak DAF	LCTV based on MCL (mg/L)	Compacted Clay Liner					
		Ingestion	Ingestion		Inhalation				Non-Carcinogenic Effect (NC)			Carcinogenic Effect (C)		
			NC	C	NC	C			7-yr Avg DAF	LCTV based on Ingestion	LCTV based on Inhalation	30-yr Avg DAF	LCTV based on Ingestion	LCTV based on Inhalation
Chrysene	218-01-9			8.05E-04		7.30E-03	2.2E+04		2.2E+04			2.2E+04	17 ^c	160 ^c
Cobalt	7440-48-4		4.90E-01							73				
Copper	7440-50-8	1.30E+00						370						
Cresol m-	108-39-4		1.22E+00		1.20E+03		26		26	32	200 ^a	35		
Cresol o-	95-48-7		1.22E+00		8.80E+02		26		26	32	200 ^a	35		
Cresol p-	106-44-5		1.22E-01		1.30E+03		26		26	3.2	200 ^a	35		
Cresols	1319-77-3		1.22E+00		1.10E+03		29		29	36	1.0E+03 ^b	38		
Cumene	98-82-8		2.45E+00		1.30E+00		110		110	260 ^c	140 ^c	120		
Cyclohexanol	108-93-0		4.16E-04		3.90E-04		24		24	0.01	9.5E-03	33		
Cyclohexanone	108-94-1		1.22E+02				26		26	1.0E+03 ^b		35		
DDD	72-54-8			4.02E-04			1.0E+30		1.0E+30			1.0E+30	1.0E+03 ^{b,c}	
DDE	72-55-9			2.84E-04			1.0E+30		1.0E+30			1.0E+30	1.0E+03 ^{b,c}	
DDT, p,p'-	50-29-3		1.22E-02		2.84E-04	8.80E-03	1.0E+30		1.0E+30	1.0E+03 ^{b,c}		1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Diallate	2303-16-4			1.58E-03			1.1E+07		1.1E+07			1.1E+07	1.0E+03 ^{b,c}	
Dibenz(a,h)anthracene	53-70-3			1.32E-05		3.80E-01	1.0E+30		1.0E+30			1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Dibromo-3-chloropropane 1,2-	96-12-8	2.00E-04		6.90E-05	2.90E-03	7.90E-02	35	7.1E-03	36		0.11	50	3.4E-03	3.9
Dichlorobenzene 1,2-	95-50-1	6.00E-01	2.20E+00		7.70E-01		64	38	64	140	49	73		
Dichlorobenzene 1,4-	106-46-7	7.50E-02		4.02E-03	3.00E+00	1.30E-03	61	4.6	61		7.5 ^a	70	0.28	0.091
Dichlorobenzidine 3,3'-	91-94-1			2.15E-04		4.90E+00	92		93			100	0.022	500 ^c
Dichlorodifluoromethane (Freon 12)	75-71-8		4.90E+00		5.80E-01		29		30	150	17	38		
Dichloroethane 1,1-	75-34-3		2.45E+00		1.60E+00	7.40E-03	28	0.11 ^e	29	0.45 ^d	0.45 ^d	40	0.010 ^e	0.19 ^d
Dichloroethane 1,2-	107-06-2	5.00E-03		1.06E-03	1.00E+01	6.30E-04	27	0.075 ^d	28	0.32 ^e	0.32 ^d	38	7.1E-03 ^d	0.024
Dichloroethylene cis-1,2-	156-59-2	7.00E-02	2.45E-01				25	1.8	26	6.3		35		
Dichloroethylene trans-1,2-	156-60-5	1.00E-01	4.90E-01				24	2.4	24	12		33		
Dichloroethylene 1,1-	75-35-4	7.00E-03	2.20E-01	1.61E-04	2.10E-01	2.20E-04	26	0.18	27	0.70 ^a	0.70 ^a	35	5.7E-03	7.8E-03
Dichlorophenol 2,4-	120-83-2		7.34E-02				34		35	2.6		44		
Dichlorophenoxyacetic acid 2,4-(2,4-D)	94-75-7	7.00E-02	2.45E-01				24	1.7	24	6		33		
Dichloropropane 1,2-	78-87-5	5.00E-03	2.20E+00	1.42E-03	1.40E-02		40	0.20	41	91	0.58	58	0.083	
Dichloropropene 1,3-(mixture of isomers)	542-75-6		7.34E-01	9.66E-04	6.10E-02	2.90E-03	24		24	18	1.5	33	0.032	0.10
Dichloropropene cis-1,3-	10061-01-5		7.34E-01	9.66E-04	7.00E-02	3.30E-03	1.0E+30		1.0E+30	1.0E+03 ^b	1.0E+03 ^b	1.0E+30	1.0E+03 ^b	1.0E+03 ^b
Dichloropropene trans-1,3-	10061-02-6		7.34E-01	9.66E-04	7.50E-02	3.50E-03	1.0E+30		1.0E+30	1.0E+03 ^b	1.0E+03 ^b	1.0E+30	1.0E+03 ^b	1.0E+03 ^b
Dieldrin	60-57-1		1.22E-03	6.04E-06		1.00E-04	1.0E+30		1.0E+30	1.0E+03 ^{b,c}		1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Diethyl phthalate	84-66-2		1.96E+01				40		41	800		55		
Diethylstilbestrol	56-53-1			2.05E-08			430		430			430	8.9E-06	
Dimethoate	60-51-5		4.90E-03				5.0E+04		5.3E+04	6.0 ^d	1.0E+03 ^e	7.6E+04		
Dimethoxybenzidine 3,3'-	119-90-4			6.90E-03			24		24			33	0.23	
Dimethyl formamide N,N- [DMF]	68-12-2		2.45E+00		7.10E+02		24		24	60	1.0E+03 ^b	33		
Dimethylbenz(a)anthracene 7,12-	57-97-6					3.00E-03	1.0E+30		1.0E+30			1.0E+30		1.0E+03 ^{b,c}
Dimethylbenzidine 3,3'-	119-93-7			1.05E-05			35		36			46	4.8E-04	
Dimethylphenol 2,4-	105-67-9		4.90E-01				31		31	15		39		
Di-n-butyl phthalate	84-74-2		2.45E+00				1.0E+03		1.0E+03	1.0E+03 ^{b,c}		1.0E+03		
Dinitrobenzene 1,3-	99-65-0		2.45E-03				24		24	0.06		33		
Dinitrophenol 2,4-	51-28-5		4.90E-02				24		24	1.2		33		
Dinitrotoluene 2,4-	121-14-2		4.90E-02	1.42E-04		8.12E-01	24		24	0.13 ^a		33	4.7E-03	0.13 ^a
Dinitrotoluene 2,6-	606-20-2		2.45E-02	1.42E-04			24		24	0.6		33	4.7E-03	
Di-n-octyl phthalate	117-84-0		4.90E-01				1.0E+30		1.0E+30	1.0E+03 ^{b,c}		1.0E+30		
Dioxane 1,4-	123-91-1			8.78E-03	1.09E+03	1.80E-01	24		24		1.0E+03 ^b	33	0.29	6.0
Diphenylamine	122-39-4		6.12E-01				87		89	54 ^c		95		

KEY:

a - TC Rule cap

d - Capped by daughter LCTV

b - 1,000 mg/L cap

e - Constituent has no RGC; LCTV from daughter

c - Exceeds solubility

Table F-8: Waste Pile Single Clay Liner LCTVs

Common Name	CAS#	MCL (mg/L)	HBN (mg/L)				Peak DAF	LCTV based on MCL (mg/L)	Compacted Clay Liner					
		Ingestion	Ingestion		Inhalation				Non-Carcinogenic Effect (NC)			Carcinogenic Effect (C)		
			NC	C	NC	C			7-yr Avg DAF	LCTV based on Ingestion	LCTV based on Inhalation	30-yr Avg DAF	LCTV based on Ingestion	LCTV based on Inhalation
Diphenylhydrazine 1, 2-	122-66-7			1.21E-04		2.00E-02	45		45			56	0.007	1.1
Disulfoton	298-04-4		9.79E-04				1.6E+09		1.6E+09	1.0E+03 ^{b,c}		2.4E+09		
Endosulfan (Endosulfan I and II,mixture)	115-29-7		1.47E-01				138		139	20 ^c		150		
Endrin	72-20-8	2.00E-03	7.34E-03				5.5E+08	0.020 ^a	5.6E+08	0.020 ^a		5.6E+08		
Epichlorohydrin	106-89-8		4.90E-02	9.75E-03	6.00E-02	1.90E-01	1.0E+30		1.0E+30	1.0E+03 ^b	1.0E+03 ^b	1.0E+30	1.0E+03 ^b	1.0E+03 ^b
Epoxybutane 1, 2-	106-88-7				2.40E-01		24		24		5.8	33		
Ethoxyethanol 2-	110-80-5		9.79E+00		2.90E+03		24		24	240	1.0E+03 ^b	33		
Ethoxyethanol acetate 2-	111-15-9		7.34E+00		3.00E+02		24		24	180	1.0E+03 ^b	33		
Ethyl acetate	141-78-6		2.20E+01				150		150	1.0E+03 ^b		214		
Ethyl ether	60-29-7		4.90E+00				24		24	120		33		
Ethyl methacrylate	97-63-2		2.20E+00				58		60	130		82		
Ethyl methanesulfonate	62-50-0			3.30E-07			1.0E+30		1.0E+30			1.0E+30	1.0E+03 ^b	
Ethylbenzene	100-41-4	7.00E-01	2.45E+00		3.30E+00	1.10E-02	57	39.6	57	140	190 ^c	66		0.72
Ethylene dibromide (1,2-Dibromoethane)	106-93-4	5.00E-05		1.14E-06	9.80E-04	8.40E-05	900	0.045	930		0.91	1.4E+03	1.6E-03	0.11
Ethylene glycol	107-21-1		4.90E+01		1.20E+04		24		24	1.0E+03 ^b	1.0E+03 ^b	33		
Ethylene oxide	75-21-8			9.47E-05	4.10E-01	5.20E-04	1.0E+30		1.0E+30		1.0E+03 ^b	1.0E+30	1.0E+03 ^b	1.0E+03 ^b
Ethylene thiourea	96-45-7		1.96E-03	8.78E-04		1.60E+03	24		24	0.048		33	0.029	1.0E+03 ^b
Fluoranthene	206-44-0		9.79E-01				1.5E+03		1.5E+03	1.0E+03 ^{b,c}		1.5E+03		
Fluoride	16984-48-8	4.00E+00	2.90E+00					72		66				
Formaldehyde	50-00-0		4.90E+00		5.10E+01	1.50E+00	24		24	120	1.0E+03 ^b	33		50
Formic acid	64-18-6		4.90E+01				24		24	1.0E+03 ^b		33		
Furfural	98-01-1		7.34E-02		2.20E+01		24		24	1.8	530	33		
HCH beta-	319-85-7			5.36E-05		1.70E-02	110		110			120	6.5E-03	2.1 ^c
HCH (Lindane) gamma-	58-89-9	2.00E-04	7.34E-03	7.43E-05		1.60E-03	6.0E+09	0.4 ^{a,d}	6.1E+09	0.4 ^{a,d}	0.4 ^{a,e}	8.1E+09	0.4 ^{a,b,c}	0.4 ^{a,b,c}
HCH alpha-	319-84-6		1.96E-01	1.53E-05		3.60E-04	1.3E+10	38 ^e	1.4E+10	83 ^{c,d}	450 ^{c,e}	1.9E+10	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Heptachlor	76-44-8	4.00E-04	1.22E-02	2.15E-05		1.50E-05	1.0E+30	8.0E-03 ^a	1.0E+30	8.0E-03 ^a		1.0E+30	8.0E-03 ^a	8.0E-03 ^a
Heptachlor epoxide	1024-57-3	2.00E-04	3.18E-04	1.06E-05		2.80E-04	1.0E+30	1.0E+03 ^{b,c}	1.0E+30	1.0E+03 ^{b,c}		1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Hexachloro-1,3-butadiene	87-68-3		7.34E-03	1.24E-03		6.10E-04	1.1E+03		1.1E+03	0.50 ^a		1.1E+03	0.50 ^a	0.50 ^a
Hexachlorobenzene	118-74-1	1.00E-03	1.96E-02	6.04E-05		3.60E-05	3.4E+04	0.13 ^{a,c}	3.4E+04	0.13 ^{a,c}		3.4E+04	0.13 ^{a,c}	0.13 ^{a,c}
Hexachlorocyclopentadiene	77-47-4	5.00E-02	1.47E-01		6.90E-04		1.0E+30	1.0E+03 ^{b,c}	1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}	1.0E+30		
Hexachlorodibenzofurans [HxCDFs]	55684-94-1			6.19E-09		1.44E-07	1.0E+30		1.0E+30			1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Hexachlorodibenzo-p-dioxins [HxCDDs]	34465-46-8			6.19E-09		1.43E-07	1.0E+30		1.0E+30			1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Hexachloroethane	67-72-1		2.45E-02	6.90E-03		3.30E-03	160		160	3.0 ^a		170	1.2	0.55
Hexachlorophene	70-30-4		7.34E-03				4.6E+03		4.6E+03	34		4.6E+03		
Hexane n-	110-54-3		2.69E+02		6.60E-01		53		53	1.0E+03 ^{b,c}	35 ^c	63		
Hydrogen Sulfide	7783-06-4		7.34E-02				24		24	1.8		33		
Indeno[1,2,3-cd]pyrene	193-39-5			8.05E-05		3.80E-02	1.7E+14		1.7E+14			1.7E+14	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Isobutyl alcohol	78-83-1		7.34E+00				24		24	180		33		
Isophorone	78-59-1		4.90E+00	1.02E-01	5.33E+02		27		27	130	1.0E+03 ^b	36	3.6	
Kepone	143-50-0		1.22E-02				490		490	6		500		
Lead	7439-92-1	1.50E-02						5.0 ^a						
Manganese	7439-96-5		1.15E+00							37				
Mercury	7439-97-6	2.00E-03	2.45E-03		7.00E-04			0.039		0.058	0.019			
Methacrylonitrile	126-98-7		2.45E-03		6.50E-03		25		26	0.063	0.17	36		
Methanol	67-56-1		1.22E+01		1.54E+03		24		24	300	1.0E+03 ^b	33		
Methoxychlor	72-43-5	4.00E-02	1.22E-01				1.0E+30	10 ^{a,c}	1.0E+30	10 ^{a,c}		1.0E+30		
Methoxyethanol acetate 2-	110-49-6		4.90E-02		5.10E+02		24		24	1.2	1.0E+03 ^b	33		

KEY:

- a - TC Rule cap
b - 1,000 mg/L cap
c - Exceeds solubility
d - Capped by daughter LCTV
e - Constituent has no RGC; LCTV from daughter

Table F-8: Waste Pile Single Clay Liner LCTVs

Common Name	CAS#	MCL (mg/L)	HBN (mg/L)				Compacted Clay Liner							
			Ingestion	Inhalation		Peak DAF	LCTV based on MCL (mg/L)	Non-Carcinogenic Effect (NC)			Carcinogenic Effect (C)			
				NC	C			NC	C	7-yr Avg DAF	LCTV based on Ingestion	LCTV based on Inhalation	30-yr Avg DAF	LCTV based on Ingestion
Methoxyethanol 2-	109-86-4		2.45E-02		4.40E+02		24		24	0.6	1.0E+03 ^b	33		
Methyl ethyl ketone	78-93-3		1.47E+01		3.30E+01		24		24	200 ^a	200 ^a	33		
Methyl isobutyl ketone	108-10-1		1.96E+00		1.20E+00		24		24	48	29	33		
Methyl methacrylate	80-62-6		3.43E+01		5.30E+00		73		75	930 ^{b,d}	400	110		
Methyl parathion	298-00-0		6.12E-03				2.7E+07		2.8E+07	9.2 ^d	1.0E+03 ^e	4.5E+07		
Methyl tert-butyl ether [MTBE]	1634-04-4				1.70E+01		24		24		410	33		
Methylcholanthrene 3-	56-49-5					1.20E-03	1.0E+30		1.0E+30			1.0E+30		1.0E+03 ^{b,c}
Methylene bromide (Dibromomethane)	74-95-3		2.45E-01				24		24	6		33		
Methylene Chloride (Dichloromethane)	75-09-2	5.00E-03	1.47E+00	1.29E-02	1.00E+01	2.80E-02	25	0.12	25	37	250	34	0.44	1.0
Molybdenum	7439-98-7		1.22E-01							2.8				
Naphthalene	91-20-3		4.90E-01		1.90E-02		66		67	33 ^c	1.3	76		
Nickel	7440-02-0		4.90E-01							22				
Nitrobenzene	98-95-3		1.22E-02		1.50E-01		24		24	0.3	2.0 ^a	33		
Nitropropane 2-	79-46-9				3.30E-01	2.30E-05	24		24		8.0	33		7.7E-04
Nitrosodiethylamine N-	55-18-5			6.44E-07		4.30E-05	24		24			33	2.2E-05	1.4E-03
Nitrosodimethylamine N-	62-75-9		1.96E-04	1.89E-06		4.00E-04	24		24	4.80E-03		33	6.3E-05	0.013
Nitroso-di-n-butylamine N-	924-16-3			1.79E-05		2.00E-05	28		29			37	6.7E-04	7.4E-04
Nitroso-di-n-propylamine N-	621-64-7			1.38E-05		1.50E-03	24		24			33	4.6E-04	0.050
Nitrosodiphenylamine N-	86-30-6		4.90E-01	1.97E-02		5.20E-01	46		47	23		57	1.1	30
Nitrosomethylethylamine N-	10595-95-6			4.39E-06		4.50E-03	24		24			33	1.5E-04	0.15
Nitrosopiperidine N-	100-75-4					8.70E-03	24		24			33		0.29
Nitrosopyrrolidine N-	930-55-2			4.60E-05		9.20E-01	24		24			33	1.5E-03	31
Octamethyl pyrophosphoramidate	152-16-9		4.90E-02				26		27	1.3		37		
Parathion (ethyl)	56-38-2		1.47E-01				6.6E+17		7.0E+17	1.0E+03 ^{b,c}		9.4E+17		
Pentachlorobenzene	608-93-5		1.96E-02				2.9E+04		2.9E+04	560 ^c		2.9E+04		
Pentachlorodibenzofurans [PeCDFs]	30402-15-4			1.24E-09		6.29E-08	3.8E+03		3.8E+03			3.8E+03	4.7E-06	2.4E-04 ^c
Pentachlorodibenzo-p-dioxins [PeCDDs]	36088-22-9			6.19E-10		6.00E-08	3.6E+17		3.6E+17			3.6E+17	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Pentachloronitrobenzene (PCNB)	82-68-8		7.34E-02	3.71E-04			1.3E+03		1.3E+03	97 ^c		1.3E+03	0.49	
Pentachlorophenol	87-86-5	1.00E-03	7.34E-01	8.05E-04		5.40E+01	61	0.061	62	46		71	0.057	100 ^a
Phenol	108-95-2		1.47E+01		9.00E+02		24		24	360	1.0E+03 ^b	33		
Phenyl mercuric acetate	62-38-4		1.96E-03				24		24	0.048		33		
Phenylenediamine 1,3-	108-45-2		1.47E-01				24		24	3.6		33		
Phorate	298-02-2		4.90E-03				1.0E+30		1.0E+30	1.0E+03 ^{b,c}		1.0E+30		
Phthalic anhydride	85-44-9		4.90E+01		1.30E+04		1.0E+30		1.0E+30	1.0E+03 ^b	1.0E+03 ^b	1.0E+30		
Polychlorinated biphenyls (Aroclors)	1336-36-3	5.00E-04	4.90E-04	2.41E-04		1.40E-04	4.3E+11	1.0E+03 ^{b,c}	4.3E+11	1.0E+03 ^{b,c}		4.4E+11	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Pronamide	23950-58-5		1.84E+00				39		40	73 ^c		51		
Propylene oxide [1,2-Epoxypropane]	75-56-9			4.02E-04	4.90E-01	1.70E-02	24		24		11.9	33	0.013	0.57
Pyrene	129-00-0		7.34E-01				3.6E+03		3.6E+03	1.0E+03 ^{b,c}		3.6E+03		
Pyridine	110-86-1		2.45E-02		1.40E+00		24		24	0.6	5.0 ^a	33		
Safrole	94-59-7			5.36E-04			31		32			40	0.022	
Selenium	7782-49-2	5.00E-02	1.22E-01					0.87		1.0 ^a				
Silver	7440-22-4		1.22E-01							3.8				
Strychnine and salts	57-24-9		7.34E-03				26		27	0.2		36		
Styrene	100-42-5	1.00E-01	4.90E+00		3.60E+00		47	4.7	47	230	170	57		
Tetrachlorobenzene 1,2,4,5-	95-94-3		7.34E-03				670		670	4.9 ^c		670		
Tetrachlorodibenzofuran 2,3,7,8-	51207-31-9			6.19E-09		1.00E-07	1.0E+30		1.0E+30			1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Tetrachlorodibenzo-p-dioxin 2,3,7,8-	1746-01-6	3.00E-08	2.45E-08	6.44E-10		2.20E-09	8.9E+09	270 ^c	9.0E+09	220 ^c		9.0E+09	5.8 ^c	20 ^c
Tetrachloroethane 1,1,1,2-	630-20-6		7.34E-01	3.71E-03		1.90E-03	58	0.18 ^e	59	43		72	0.27	0.14

KEY:

- a - TC Rule cap
b - 1,000 mg/L cap
c - Exceeds solubility
d - Capped by daughter LCTV
e - Constituent has no RGC; LCTV from daughter

Table F-8: Waste Pile Single Clay Liner LCTVs

Common Name	CAS#	MCL (mg/L)	HBN (mg/L)				Compacted Clay Liner							
			Ingestion		Inhalation		Peak DAF	LCTV based on MCL (mg/L)	Non-Carcinogenic Effect (NC)		Carcinogenic Effect (C)			
		Ingestion	NC	C	NC	C			7-yr Avg DAF	LCTV based on Ingestion	LCTV based on Inhalation	30-yr Avg DAF	LCTV based on Ingestion	LCTV based on Inhalation
Tetrachloroethane 1,1,2,2-	79-34-5		1.47E+00	4.83E-04		5.00E-04	510	0.18 ^a	520	770	0.64 ^a	710	0.34	0.32 ^d
Tetrachloroethylene	127-18-4	5.00E-03	2.45E-01	1.86E-03	9.40E-01	2.10E-02	30	0.15	30	0.70 ^a	0.70 ^a	39	0.072	0.70 ^a
Tetrachlorophenol 2,3,4,6-	58-90-2		7.34E-01				31		32	23		40		
Tetraethyl dithiopyrophosphate (Sulfotep)	3689-24-5		1.22E-02				1.0E+30		1.0E+30	1.0E+03 ^{b,c}		1.0E+30		
Thallium	7440-28-0	2.00E-03	1.96E-03					0.035		0.046				
Thiram [Thiuram]	137-26-8		1.22E-01				45		45	5.5		56		
Toluene	108-88-3	1.00E+00	4.90E+00		1.30E+00		33	33	34	170	44	43		
Toluenediamine 2,4-	95-80-7			3.02E-05		7.50E+00	24		24			33	1.0E-03	250
Toluidine o-	95-53-4			4.02E-04		3.60E-02	24		24			33	0.013	1.2
Toluidine p-	106-49-0			5.08E-04			24		24			33	0.017	
Toxaphene (chlorinated camphenes)	8001-35-2	3.00E-03		8.78E-05		3.60E-03	9.5E+06	0.50 ^a	9.7E+06			9.7E+06	0.50 ^a	0.50 ^a
Tribromomethane (Bromoform)	75-25-2	8.00E-02	4.90E-01	1.22E-02		1.90E-02	29	2.3	29	14		39	0.47	0.74
Trichloro-1,2,2-trifluoro-ethane 1,1,2-	76-13-1		7.34E+02		9.50E+01		54		55	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}	64		
Trichlorobenzene 1,2,4-	120-82-1	7.00E-02	2.45E-01		8.30E-01		340	24	340	83 ^c	280 ^c	340		
Trichloroethane 1,1,1-	71-55-6	2.00E-01	6.85E+00		6.90E+00		5.8E+03	0.25 ^d	6.0E+03	0.96 ^d	0.96 ^d	8.7E+03	7.8E-03 ^e	0.11 ^e
Trichloroethane 1,1,2-	79-00-5	5.00E-03	9.79E-02	1.69E-03		1.10E-03	29	0.14	30	0.96 ^d	0.96 ^e	40	7.8E-03 ^d	0.011 ^d
Trichloroethylene (1,1,2-Trichloroethylene)	79-01-6	5.00E-03		8.78E-03	1.90E+00	6.80E-03	28	0.14	29		0.50 ^a	37	0.33	0.25
Trichlorofluoromethane (Freon 11)	75-69-4		7.34E+00		2.10E+00		29		29	210	61	38		
Trichlorophenol 2,4,5-	95-95-4		2.45E+00				50		51	120		61		
Trichlorophenol 2,4,6-	88-06-2			8.78E-03		2.80E-01	30		31			40	0.35	2.0 ^a
Trichlorophenoxypropionic acid 2-(2,4,5- (Silvex)	93-72-1	5.00E-02	1.96E-01				26	1.0 ^a	26	1.0 ^a		35		
Trichlorophenoxyacetic acid 2,4,5-	93-76-5		2.45E-01				24		24	6		33		
Trichloropropane 1,2,3-	96-18-4		1.47E-01	1.38E-05	3.40E-02		32		32	4.8	1.1	44	6.1E-04	
Triethylamine	121-44-8				1.10E-01		24		24		2.7	33		
Trinitrobenzene (1,3,5-Trinitrobenzene) sym-	99-35-4		7.34E-01				24		24	18		33		
Tris(2,3-dibromopropyl)phosphate	126-72-7			9.89E-06			1.2E+03		1.2E+03			1.4E+03	0.014	
Vanadium	7440-62-2		1.71E-01							170				
Vinyl acetate	108-05-4		2.45E+01		1.20E+00		24		24	600	29	33		
Vinyl chloride	75-01-4	2.00E-03	7.34E-02	1.34E-04	2.90E-01	2.50E-03	24	0.048	24	0.2 ^a	0.20 ^a	33	4.5E-03	0.084
Xylene m-	108-38-3		4.90E+01		1.30E+00		65		65	1.0E+03 ^{b,c}	84	74		
Xylene o-	95-47-6		4.90E+01		1.40E+00		58		59	1.0E+03 ^{b,c}	83	68		
Xylene p-	106-42-3		4.90E+01		1.30E+00		67		68	1.0E+03 ^{b,c}	88	77		
Xylenes (total)	1330-20-7	1.00E+01	4.90E+01		1.40E+00		64	640 ^c	64	1.0E+03 ^{b,c}	89	73		
Zinc	7440-66-6		7.34E+00							430				

KEY:

- a - TC Rule cap d - Capped by daughter LCTV
b - 1,000 mg/L cap e - Constituent has no RGC; LCTV from daughter
c - Exceeds solubility

Table F-9: Waste Pile Composite Liner LCTVs

Common Name	CAS#	MCL (mg/L)	HBN (mg/L)				Peak DAF	LCTV based on MCL (mg/L)	Composite Liner					
		Ingestion	Ingestion		Inhalation				Non-Carcinogenic Effect (NC)			Carcinogenic Effect (C)		
			NC	C	NC	C			7-yr Avg DAF	LCTV based on Ingestion	LCTV based on Inhalation	30-yr Avg DAF	LCTV based on Ingestion	LCTV based on Inhalation
Acenaphthene	83-32-9		1.47E+00				1.0E+30		1.0E+30	1.0E+03 ^{b,c}		1.0E+30		
Acetaldehyde [Ethanal]	75-07-0				2.20E-01	4.10E-02	7.3E+07		7.3E+07		1.0E+03 ^b	7.9E+07		1.0E+03 ^b
Acetone (2-propanone)	67-64-1		2.45E+00		1.50E+03		6.9E+07		7.1E+07	1.0E+03 ^b	1.0E+03 ^b	7.6E+07		
Acetonitrile (methyl cyanide)	75-05-8				3.10E+00		7.4E+07		7.7E+07		1.0E+03 ^b	8.1E+07		
Acetophenone	98-86-2		2.45E+00				4.0E+08		4.0E+08	1.0E+03 ^b		4.0E+08		
Acrolein	107-02-8		4.90E-01		3.30E-04		1.0E+30		1.0E+30	1.0E+03 ^b	1.0E+03 ^b	1.0E+30		
Acrylamide	79-06-1		4.90E-03	2.15E-05		5.10E+00	1.0E+30		1.0E+30	1.0E+03 ^b		1.0E+30	1.0E+03 ^b	1.0E+03 ^b
Acrylic acid [propenoic acid]	79-10-7		1.22E+01		1.50E+01		7.1E+07		7.2E+07	1.0E+03 ^b	1.0E+03 ^b	7.4E+07		
Acrylonitrile	107-13-1		2.45E-02	1.79E-04	3.80E-02	1.00E-03	5.9E+08		6.0E+08	740 ^b	740 ^d	6.2E+08	750 ^d	750 ^d
Aldrin	309-00-2		7.34E-04	5.68E-06		1.00E-05	1.0E+30		1.0E+30	1.0E+03 ^{b,c}		1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Allyl alcohol	107-18-6		1.22E-01				4.7E+08		4.8E+08	1.0E+03 ^b		4.8E+08		
Aniline (benzenamine)	62-53-3			1.69E-02	9.30E-01	2.20E+00	7.3E+07		7.4E+07		1.0E+03 ^b	7.8E+07	1.0E+03 ^b	1.0E+03 ^b
Anthracene	120-12-7		7.34E+00				1.0E+30		1.0E+30	1.0E+03 ^{b,c}		1.0E+30		
Antimony	7440-36-0	6.00E-03	9.79E-03					1.0E+03 ^b		1.0E+03 ^b				
Arsenic	7440-38-2	5.00E-02	7.34E-03	6.44E-05				5.0 ^a		5.0 ^a			5.0 ^a	
Barium	7440-39-3	2.00E+00	1.71E+00					100 ^a		100 ^a				
Benz{a}anthracene	56-55-3			8.05E-05		1.80E-02	1.0E+30		1.0E+30			1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Benzene	71-43-2	5.00E-03		1.76E-03	1.90E-01	1.60E-03	9.2E+07	0.50 ^a	9.4E+07		0.50 ^a	9.7E+07	0.50 ^a	0.50 ^a
Benztidine	92-87-5		7.34E-02	4.20E-07		2.60E+00	8.3E+07		8.3E+07	1.0E+03 ^{b,c}		8.7E+07	36	1.0E+03 ^{b,c}
Benzo{a}pyrene	50-32-8	2.00E-04		1.32E-05		5.40E-03	1.0E+30	1.0E+03 ^{b,c}	1.0E+30			1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Benzo{b}fluoranthene	205-99-2			8.05E-05		6.30E-04	1.0E+30		1.0E+30			1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Benzyl alcohol	100-51-6		7.34E+00				3.2E+08		3.2E+08	1.0E+03 ^b		3.2E+08		
Benzyl chloride	100-44-7			5.68E-04		5.20E-04	1.0E+30		1.0E+30	1.0E+03 ^e		1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Beryllium	7440-41-7	4.00E-03	4.90E-02					1.0E+03 ^b		1.0E+03 ^b				
Bis(2-chloroethyl)ether	111-44-4			8.78E-05		1.10E-03	1.0E+30		1.0E+30		1.0E+03 ^e	1.0E+30	1.0E+03 ^b	1.0E+03 ^b
Bis(2-chloroisopropyl)ether	39638-32-9		9.79E-01	1.38E-03		5.90E-03	1.7E+08		1.7E+08	1.0E+03 ^b		1.8E+08	1.0E+03 ^b	1.0E+03 ^b
Bis(2-ethylhexyl)phthalate	117-81-7	6.00E-03	4.90E-01	6.90E-03	1.80E+02	2.80E+01	1.0E+30	1.0E+03 ^{b,c}	1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}	1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Bromodichloromethane	75-27-4	8.00E-02	4.90E-01	1.56E-03		8.00E-04	2.3E+09	1.0E+03 ^b	2.3E+09	1.0E+03 ^b		2.3E+09	1.0E+03 ^b	1.0E+03 ^b
Bromomethane	74-83-9		3.43E-02		1.50E-02		1.0E+30		1.0E+30	1.0E+03 ^b	1.0E+03 ^b	1.0E+30		
Butadiene 1, 3-	106-99-0				6.00E-02	4.00E-05	1.1E+08		1.1E+08		1.0E+03 ^{b,c}	1.2E+08		1.0E+03 ^{b,c}
Butanol n-	71-36-3		2.45E+00				3.0E+08		3.1E+08	1.0E+03 ^b		3.1E+08		
Butyl benzyl phthalate	85-68-7		4.90E+00				1.0E+30		1.0E+30	1.0E+03 ^{b,c}		1.0E+30		
Butyl-4,6-dinitrophenol,2-sec-(Dinoseb)	88-85-7	7.00E-03	2.45E-02				1.8E+09	1.0E+03 ^{b,c}	1.8E+09	1.0E+03 ^{b,c}		1.8E+09		
Cadmium	7440-43-9	5.00E-03	1.22E-02					1.0 ^a		1.0 ^a				
Carbon disulfide	75-15-0		2.45E+00		1.00E+01		1.2E+09		1.2E+09	1.0E+03 ^b	1.0E+03 ^b	1.2E+09		
Carbon tetrachloride	56-23-5	5.00E-03	1.71E-02	7.43E-04	2.10E-02	7.60E-04	1.0E+30	0.50 ^a	1.0E+30	0.50 ^a	0.50 ^a	1.0E+30	0.50 ^a	0.50 ^a
Chlordane	57-74-9	2.00E-03	1.22E-02	2.76E-04	2.80E-02	1.50E-03	1.0E+30	0.030 ^a	1.0E+30	0.030 ^a	0.030 ^a	1.0E+30	0.030 ^a	0.030 ^a
Chloro-1,3-butadiene 2-(Chloroprene)	126-99-8		4.90E-01		2.20E-02		9.2E+07		9.3E+07	1.0E+03 ^b	1.0E+03 ^b	9.6E+07		
Chloroaniline p-	106-47-8		9.79E-02				6.0E+08		6.0E+08	1.0E+03 ^b		6.0E+08		
Chlorobenzene	108-90-7	1.00E-01	4.90E-01		2.00E-01		1.9E+08	100 ^a	2.0E+08	100 ^a	100 ^a	2.0E+08		
Chlorobenzilate	510-15-6		4.90E-01	3.58E-04		1.20E+00	1.0E+30		1.0E+30	1.0E+03 ^{b,c}		1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Chlorodibromomethane	124-48-1	8.00E-02	4.90E-01	1.15E-03		7.50E-04	9.5E+08	1.0E+03 ^b	1.0E+09	1.0E+03 ^b		1.0E+09	1.0E+03 ^b	1.0E+03 ^b
Chloroethane [Ethyl chloride]	75-00-3				3.00E+01		7.5E+07		7.6E+07		1.0E+03 ^b	7.8E+07		
Chloroform	67-66-3	8.00E-02	2.45E-01		3.30E-01		2.2E+08	6.0 ^a	2.2E+08	6.0 ^a	6.0 ^a	2.3E+08		
Chloromethane	74-87-3			7.43E-03	2.60E-01	5.90E-03	7.2E+07		7.3E+07		1.0E+03 ^b	7.7E+07	1.0E+03 ^b	1.0E+03 ^b
Chlorophenol 2-	95-57-8		1.22E-01		9.70E-03		9.6E+07		9.8E+07	1.0E+03 ^b	1.0E+03 ^b	9.9E+07		

KEY:

- a - TC Rule cap
b - 1,000 mg/L cap
c - Exceeds solubility
d - Capped by daughter LCTV
e - Constituent has no RGC; LCTV from daughter

Table F-9: Waste Pile Composite Liner LCTVs

Common Name	CAS#	MCL (mg/L)	HBN (mg/L)				Composite Liner							
			Ingestion	Inhalation		Peak DAF	LCTV based on MCL (mg/L)	Non-Carcinogenic Effect (NC)			Carcinogenic Effect (C)			
				NC	C			NC	C	7-yr Avg DAF	LCTV based on Ingestion	LCTV based on Inhalation	30-yr Avg DAF	LCTV based on Ingestion
Chloropropene 3- (Allyl Chloride)	107-05-1				3.00E-03	1.90E-03	1.0E+30		1.0E+30		1.0E+03 ^b	1.0E+30		1.0E+03 ^b
Chromium (III) (Chromic Ion)	16065-83-1	1.00E-01	3.67E+01					1.0E+03 ^b		1.0E+03 ^b				
Chromium (VI)	18540-29-9	1.00E-01	7.34E-02					5.0 ^a		5.0 ^a				
Chrysene	218-01-9			8.05E-04		7.30E-03	1.0E+30		1.0E+30			1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Cobalt	7440-48-4		4.90E-01						1.0E+03 ^b					
Copper	7440-50-8	1.30E+00						1.0E+03 ^b						
Cresol m-	108-39-4		1.22E+00		1.20E+03		9.1E+07		9.1E+07	200 ^a	200 ^a	9.6E+07		
Cresol o-	95-48-7		1.22E+00		8.80E+02		9.1E+07		9.2E+07	200 ^a	200 ^a	9.6E+07		
Cresol p-	106-44-5		1.22E-01		1.30E+03		9.1E+07		9.1E+07	200 ^a	200 ^a	9.6E+07		
Cresols	1319-77-3		1.22E+00		1.10E+03		1.2E+08		1.2E+08	1.0E+03 ^b	1.0E+03 ^b	1.2E+08		
Cumene	98-82-8		2.45E+00		1.30E+00		1.2E+09		1.2E+09	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}	1.3E+09		
Cyclohexanol	108-93-0		4.16E-04		3.90E-04		7.7E+07		7.8E+07	1.0E+03 ^b	1.0E+03 ^b	8.3E+07		
Cyclohexanone	108-94-1		1.22E+02				8.7E+08		8.8E+08	1.0E+03 ^b		8.8E+08		
DDD	72-54-8			4.02E-04			1.0E+30		1.0E+30			1.0E+30	1.0E+03 ^{b,c}	
DDE	72-55-9			2.84E-04			1.0E+30		1.0E+30			1.0E+30	1.0E+03 ^{b,c}	
DDT p,p'-	50-29-3		1.22E-02	2.84E-04		8.80E-03	1.0E+30		1.0E+30	1.0E+03 ^{b,c}		1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Diallate	2303-16-4			1.58E-03			1.0E+30		1.0E+30			1.0E+30	1.0E+03 ^{b,c}	
Dibenz[a,h]anthracene	53-70-3			1.32E-05		3.80E-01	1.0E+30		1.0E+30			1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Dibromo-3-chloropropane 1,2-	96-12-8	2.00E-04		6.90E-05	2.90E-03	7.90E-02	1.0E+30	1.0E+03 ^b	1.0E+30		1.0E+03 ^b	1.0E+30	1.0E+03 ^b	1.0E+03 ^b
Dichlorobenzene 1,2-	95-50-1	6.00E-01	2.20E+00		7.70E-01		4.5E+08	1.0E+03 ^{b,c}	4.6E+08	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}	4.7E+08		
Dichlorobenzene 1,4-	106-46-7	7.50E-02		4.02E-03	3.00E+00	1.30E-03	4.3E+08	7.5 ^a	4.3E+08		7.5 ^a	4.5E+08	7.5 ^a	7.5 ^a
Dichlorobenzidine 3,3'-	91-94-1			2.15E-04		4.90E+00	1.3E+09		1.4E+09			1.4E+09	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Dichlorodifluoromethane (Freon 12)	75-71-8		4.90E+00		5.80E-01		1.2E+08		1.2E+08	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}	1.3E+08		
Dichloroethane 1,1-	75-34-3		2.45E+00		1.60E+00	7.40E-03	3.4E+14	0.45 ^e	3.5E+14	0.45 ^d	0.45 ^d	4.2E+14	0.45 ^e	0.45 ^d
Dichloroethane 1,2-	107-06-2	5.00E-03		1.06E-03	1.00E+01	6.30E-04	3.0E+21	0.32 ^d	3.0E+21	0.32 ^e	0.32 ^d	3.0E+21	0.32 ^d	0.32 ^d
Dichloroethylene cis-1,2-	156-59-2	7.00E-02	2.45E-01				7.3E+08	1.0E+03 ^b	7.4E+08	1.0E+03 ^b		7.4E+08		
Dichloroethylene trans-1,2-	156-60-5	1.00E-01	4.90E-01				5.8E+08	1.0E+03 ^b	5.8E+08	1.0E+03 ^b		5.8E+08		
Dichloroethylene 1,1-	75-35-4	7.00E-03	2.20E-01	1.61E-04	2.10E-01	2.20E-04	8.5E+07	0.70 ^a	8.7E+07	0.70 ^a	0.70 ^a	9.3E+07	0.70 ^a	0.70 ^a
Dichlorophenol 2,4-	120-83-2		7.34E-02				1.3E+11		1.3E+11	1.0E+03 ^b		1.3E+11		
Dichlorophenoxyacetic acid 2,4-(2,4-D)	94-75-7	7.00E-02	2.45E-01				3.1E+08	10 ^a	3.1E+08	10 ^a		3.1E+08		
Dichloropropane 1,2-	78-87-5	5.00E-03	2.20E+00	1.42E-03	1.40E-02		1.0E+30	1.0E+03 ^b	1.0E+30	1.0E+03 ^b	1.0E+03 ^b	1.0E+30	1.0E+03 ^b	
Dichloropropene 1,3-(mixture of isomers)	542-75-6		7.34E-01	9.66E-04	6.10E-02	2.90E-03	8.3E+07		8.5E+07	1.0E+03 ^b	1.0E+03 ^b	8.8E+07	1.0E+03 ^b	1.0E+03 ^b
Dichloropropene cis-1,3-	10061-01-5		7.34E-01	9.66E-04	7.00E-02	3.30E-03	1.0E+30		1.0E+30	1.0E+03 ^b	1.0E+03 ^b	1.0E+30	1.0E+03 ^b	1.0E+03 ^b
Dichloropropene trans-1,3-	10061-02-6		7.34E-01	9.66E-04	7.50E-02	3.50E-03	1.0E+30		1.0E+30	1.0E+03 ^b	1.0E+03 ^b	1.0E+30	1.0E+03 ^b	1.0E+03 ^b
Dieldrin	60-57-1		1.22E-03	6.04E-06		1.00E-04	1.0E+30		1.0E+30	1.0E+03 ^{b,c}		1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Diethyl phthalate	84-66-2		1.96E+01				1.0E+30		1.0E+30	1.0E+03 ^b		1.0E+30		
Diethylstilbestrol	56-53-1			2.05E-08			1.0E+30		1.0E+30			1.0E+30	1.0E+03 ^{b,c}	
Dimethoate	60-51-5		4.90E-03				1.0E+30		1.0E+30	1.0E+03 ^b	1.0E+03 ^e	1.0E+30		
Dimethoxybenzidine 3,3'-	119-90-4			6.90E-03			4.7E+08		4.9E+08			4.9E+08	1.0E+03 ^{b,c}	
Dimethyl formamide N,N- [DMF]	68-12-2		2.45E+00		7.10E+02		7.2E+07		7.2E+07	1.0E+03 ^b	1.0E+03 ^b	7.7E+07		
Dimethylbenz[a]anthracene 7,12-	57-97-6					3.00E-03	1.0E+30		1.0E+30			1.0E+30		1.0E+03 ^{b,c}
Dimethylbenzidine 3,3'-	119-93-7			1.05E-05			8.9E+11		9.1E+11			9.3E+11	1.0E+03 ^b	
Dimethylphenol 2,4-	105-67-9		4.90E-01				9.2E+09		9.4E+09	1.0E+03 ^b		9.4E+09		
Di-n-butyl phthalate	84-74-2		2.45E+00				1.0E+30		1.0E+30	1.0E+03 ^{b,c}		1.0E+30		
Dinitrobenzene 1,3-	99-65-0		2.45E-03				4.0E+08		4.0E+08	1.0E+03 ^{b,c}		4.0E+08		
Dinitrophenol 2,4-	51-28-5		4.90E-02				2.9E+08		2.9E+08	1.0E+03 ^b		2.9E+08		

KEY:

- a - TC Rule cap
b - 1,000 mg/L cap
c - Exceeds solubility
d - Capped by daughter LCTV
e - Constituent has no RGC; LCTV from daughter

Table F-9: Waste Pile Composite Liner LCTVs

Common Name	CAS#	MCL (mg/L)	HBN (mg/L)				Composite Liner							
		Ingestion	Ingestion		Inhalation		Peak DAF	LCTV based on MCL (mg/L)	Non-Carcinogenic Effect (NC)			Carcinogenic Effect (C)		
			NC	C	NC	C			7-yr Avg DAF	LCTV based on Ingestion	LCTV based on Inhalation	30-yr Avg DAF	LCTV based on Ingestion	LCTV based on Inhalation
Dinitrotoluene 2,4-	121-14-2		4.90E-02	1.42E-04	8.12E-01		8.9E+07		9.1E+07	0.13 ^a		9.5E+07	0.13 ^a	0.13 ^a
Dinitrotoluene 2,6-	606-20-2		2.45E-02	1.42E-04			4.4E+08		4.5E+08	1.0E+03 ^{b,c}		4.5E+08	1.0E+03 ^{b,c}	
Di-n-octyl phthalate	117-84-0		4.90E-01				1.0E+30		1.0E+30	1.0E+03 ^{b,c}		1.0E+30		
Dioxane 1,4-	123-91-1			8.78E-03	1.09E+03	1.80E-01	7.2E+07		7.2E+07		1.0E+03 ^b	7.6E+07	1.0E+03 ^b	1.0E+03 ^b
Diphenylamine	122-39-4		6.12E-01				1.0E+30		1.0E+30	1.0E+03 ^{b,c}		1.0E+30		
Diphenylhydrazine 1, 2-	122-66-7			1.21E-04		2.00E-02	3.0E+08		3.0E+08			3.1E+08	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Disulfoton	298-04-4		9.79E-04				1.0E+30		1.0E+30	1.0E+03 ^{b,c}		1.0E+30		
Endosulfan (Endosulfan I and II,mixture)	115-29-7		1.47E-01				1.0E+30		1.0E+30	1.0E+03 ^{b,c}		1.0E+30		
Endrin	72-20-8	2.00E-03	7.34E-03				1.0E+30	0.020 ^a	1.0E+30	0.020 ^a		1.0E+30		
Epichlorohydrin	106-89-8		4.90E-02	9.75E-03	6.00E-02	1.90E-01	1.0E+30		1.0E+30	1.0E+03 ^b	1.0E+03 ^b	1.0E+30	1.0E+03 ^b	1.0E+03 ^b
Epoxybutane 1, 2-	106-88-7				2.40E-01		7.3E+07		7.3E+07		1.0E+03 ^b	7.8E+07		
Ethoxyethanol 2-	110-80-5		9.79E+00		2.90E+03		7.3E+07		7.4E+07	1.0E+03 ^b	1.0E+03 ^b	7.7E+07		
Ethoxyethanol acetate 2-	111-15-9		7.34E+00		3.00E+02		7.8E+07		8.0E+07	1.0E+03 ^b	1.0E+03 ^b	8.2E+07		
Ethyl acetate	141-78-6		2.20E+01				1.0E+30		1.0E+30	1.0E+03 ^b		1.0E+30		
Ethyl ether	60-29-7		4.90E+00				3.0E+08		3.0E+08	1.0E+03 ^b		3.0E+08		
Ethyl methacrylate	97-63-2		2.20E+00				1.0E+30		1.0E+30	1.0E+03 ^b		1.0E+30		
Ethyl methanesulfonate	62-50-0			3.30E-07			1.0E+30		1.0E+30			1.0E+30	1.0E+03 ^b	
Ethylbenzene	100-41-4	7.00E-01	2.45E+00		3.30E+00	1.10E-02	4.0E+08	1.0E+03 ^{b,c}	4.0E+08	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}	4.2E+08		1.0E+03 ^b
Ethylene dibromide (1,2-Dibromoethane)	106-93-4	5.00E-05		1.14E-06	9.80E-04	8.40E-05	1.0E+30	1.0E+03 ^b	1.0E+30		1.0E+03 ^b	1.0E+30	1.0E+03 ^b	1.0E+03 ^b
Ethylene glycol	107-21-1		4.90E+01		1.20E+04		7.3E+07		7.3E+07	1.0E+03 ^b	1.0E+03 ^b	7.9E+07		
Ethylene oxide	75-21-8			9.47E-05	1.00E+01	5.20E-04	1.0E+30		1.0E+30		1.0E+03 ^b	1.0E+30	1.0E+03 ^b	1.0E+03 ^b
Ethylene thiourea	96-45-7		1.96E-03	8.78E-04		1.60E+03	7.5E+07		7.5E+07	1.0E+03 ^b		7.8E+07	1.0E+03 ^b	1.0E+03 ^b
Fluoranthene	206-44-0		9.79E-01				1.0E+30		1.0E+30	1.0E+03 ^{b,c}		1.0E+30		
Fluoride	16984-48-8	4.00E+00	2.90E+00					1.0E+03 ^b		1.0E+03 ^b				
Formaldehyde	50-00-0		4.90E+00		5.10E+01	1.50E+00	7.4E+07		7.4E+07	1.0E+03 ^b	1.0E+03 ^b	7.8E+07		1.0E+03 ^b
Formic acid	64-18-6		4.90E+01				2.9E+08		2.9E+08	1.0E+03 ^b		2.9E+08		
Furfural	98-01-1		7.34E-02		2.20E+01		7.5E+07		7.6E+07	1.0E+03 ^b	1.0E+03 ^b	8.0E+07		
HCH beta-	319-85-7			5.36E-05		1.70E-02	1.4E+09		1.4E+09			1.5E+09	1.0E+03 ^{b,c}	1.0E+03 ^b
HCH (Lindane) gamma-	58-89-9	2.00E-04	7.34E-03	7.43E-05		1.60E-03	1.0E+30	0.4 ^{a,b,c}	1.0E+30	0.4 ^{a,b,c}	0.4 ^{a,b}	1.0E+30	0.4 ^{a,b,c}	0.4 ^{a,b}
HCH alpha-	319-84-6		1.96E-01	1.53E-05		3.60E-04	1.0E+30	1.0E+03 ^{b,c}	1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}	1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^b
Heptachlor	76-44-8	4.00E-04	1.22E-02	2.15E-05		1.50E-05	1.0E+30	8.0E-03 ^a	1.0E+30	8.0E-03 ^a		1.0E+30	8.0E-03 ^a	8.0E-03
Heptachlor epoxide	1024-57-3	2.00E-04	3.18E-04	1.06E-05		2.80E-04	1.0E+30	1.0E+03 ^{b,c}	1.0E+30	1.0E+03 ^{b,c}		1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^b
Hexachloro-1,3-butadiene	87-68-3		7.34E-03	1.24E-03		6.10E-04	1.0E+30		1.0E+30	0.50 ^a		1.0E+30	0.50	0.50
Hexachlorobenzene	118-74-1	1.00E-03	1.96E-02	6.04E-05		3.60E-05	1.0E+30	0.13 ^{a,b,c}	1.0E+30	0.13 ^{a,b,c}		1.0E+30	0.13 ^{a,b}	0.13 ^{a,b}
Hexachlorocyclopentadiene	77-47-4	5.00E-02	1.47E-01		6.90E-04		1.0E+30	1.0E+03 ^{b,c}	1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}	1.0E+30		
Hexachlorodibenzofurans [HxCDFs]	55684-94-1			6.19E-09		1.44E-07	1.0E+30		1.0E+30			1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^b
Hexachlorodibenzo-p-dioxins [HxCDDs]	34465-46-8			6.19E-09		1.43E-07	1.0E+30		1.0E+30			1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^b
Hexachloroethane	67-72-1		2.45E-02	6.90E-03		3.30E-03	2.1E+09		2.1E+09	3.0 ^a		2.1E+09	3.0	3.0
Hexachlorophene	70-30-4		7.34E-03				1.0E+30		1.0E+30	1.0E+03 ^{b,c}		1.0E+30		
Hexane n-	110-54-3		2.69E+02		6.60E-01		3.8E+08		3.9E+08	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}	4.0E+08		
Hydrogen Sulfide	7783-06-4		7.34E-02				2.9E+08		2.9E+08	1.0E+03 ^b		2.9E+08		
Indeno{1,2,3-cd}pyrene	193-39-5			8.05E-05		3.80E-02	1.0E+30		1.0E+30			1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Isobutyl alcohol	78-83-1		7.34E+00				3.0E+08		3.0E+08	1.0E+03 ^b		3.0E+08		
Isophorone	78-59-1		4.90E+00	1.02E-01	5.33E+02		1.0E+08		1.1E+08	1.0E+03 ^b	1.0E+03 ^b	1.1E+08	1.0E+03 ^b	
Kepone	143-50-0		1.22E-02				1.0E+30		1.0E+30	1.0E+03 ^{b,c}		1.0E+30		
Lead	7439-92-1	1.50E-02						5.0 ^a						

KEY:

- a - TC Rule cap
b - 1,000 mg/L cap
c - Exceeds solubility
- d - Capped by daughter LCTV
e - Constituent has no RGC; LCTV from daughter

Table F-9: Waste Pile Composite Liner LCTVs

Common Name	CAS#	MCL (mg/L)	HBN (mg/L)				Peak DAF	LCTV based on MCL (mg/L)	Composite Liner					
		Ingestion	Ingestion		Inhalation				Non-Carcinogenic Effect (NC)		Carcinogenic Effect (C)			
			NC	C	NC	C			7-yr Avg DAF	LCTV based on Ingestion	LCTV based on Inhalation	30-yr Avg DAF	LCTV based on Ingestion	LCTV based on Inhalation
Manganese	7439-96-5		1.15E+00						1.0E+03 ^b					
Mercury	7439-97-6	2.00E-03	2.45E-03		7.00E-04			0.20 ^{a,c}		0.20 ^{a,c}				
Methacrylonitrile	126-98-7		2.45E-03		6.50E-03		6.2E+08		6.2E+08	1.0E+03 ^b	1.0E+03 ^b	6.4E+08		
Methanol	67-56-1		1.22E+01		1.54E+03		7.3E+07		7.5E+07	1.0E+03 ^b	1.0E+03 ^b	7.8E+07		
Methoxychlor	72-43-5	4.00E-02	1.22E-01				1.0E+30	10 ^{a,c}	1.0E+30	10 ^{a,c}		1.0E+30		
Methoxyethanol acetate 2-	110-49-6		4.90E-02		5.10E+02		7.1E+07		7.2E+07	1.0E+03 ^b	1.0E+03 ^b	7.4E+07		
Methoxyethanol 2-	109-86-4		2.45E-02		4.40E+02		7.4E+07		7.6E+07	1.0E+03 ^b	1.0E+03 ^b	8.0E+07		
Methyl ethyl ketone	78-93-3		1.47E+01		3.30E+01		7.1E+07		7.2E+07	200 ^a	200 ^a	7.6E+07		
Methyl isobutyl ketone	108-10-1		1.96E+00		1.20E+00		7.9E+07		8.1E+07	1.0E+03 ^b	1.0E+03 ^b	8.3E+07		
Methyl methacrylate	80-62-6		3.43E+01		5.30E+00		1.0E+30		1.0E+30	1.0E+03 ^{b,d}	1.0E+03 ^b	1.0E+30		
Methyl parathion	298-00-0		6.12E-03				1.0E+30		1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^e	1.0E+30		
Methyl tert-butyl ether [MTBE]	1634-04-4				1.70E+01		7.6E+07		7.7E+07		1.0E+03 ^b	8.0E+07		
Methylcholanthrene 3-	56-49-5					1.20E-03	1.0E+30		1.0E+30			1.0E+30		1.0E+03 ^{b,c}
Methylene bromide (Dibromomethane)	74-95-3		2.45E-01				3.8E+08		3.8E+08	1.0E+03 ^b		3.8E+08		
Methylene Chloride (Dichloromethane)	75-09-2	5.00E-03	1.47E+00	1.29E-02	1.00E+01	2.80E-02	3.7E+08	1.0E+03 ^b	3.7E+08	1.0E+03 ^b	1.0E+03 ^b	3.9E+08	1.0E+03 ^b	1.0E+03 ^b
Molybdenum	7439-98-7		1.22E-01							1.0E+03 ^b				
Naphthalene	91-20-3		4.90E-01		1.90E-02		5.1E+08		5.1E+08	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}	5.2E+08		
Nickel	7440-02-0		4.90E-01							1.0E+03 ^b				
Nitrobenzene	98-95-3		1.22E-02		1.50E-01		8.1E+07		8.4E+07	2.0 ^a	2.0 ^a	8.7E+07		
Nitropropane 2-	79-46-9				3.30E-01	2.30E-05	7.4E+07		7.6E+07		1.0E+03 ^b	8.0E+07		1.0E+03 ^b
Nitrosodiethylamine N-	55-18-5			6.44E-07		4.30E-05	7.4E+07		7.5E+07			7.8E+07		50 1.0E+03 ^b
Nitrosodimethylamine N-	62-75-9		1.96E-04	1.89E-06		4.00E-04	7.3E+07		7.5E+07	1.0E+03 ^b		7.8E+07		150 1.0E+03 ^b
Nitroso-di-n-butylamine N-	924-16-3			1.79E-05		2.00E-05	1.2E+08		1.2E+08			1.3E+08	1.0E+03 ^b	1.0E+03 ^b
Nitroso-di-n-propylamine N-	621-64-7			1.38E-05		1.50E-03	8.0E+07		8.0E+07			8.2E+07	1.0E+03 ^b	1.0E+03 ^b
Nitrosodiphenylamine N-	86-30-6		4.90E-01	1.97E-02		5.20E-01	3.2E+08		3.2E+08	1.0E+03 ^{b,c}		3.3E+08	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Nitrosomethylethylamine N-	10595-95-6			4.39E-06		4.50E-03	7.4E+07		7.5E+07			7.7E+07		340 1.0E+03 ^b
Nitrosopiperidine N-	100-75-4					8.70E-03	7.3E+07		7.3E+07			7.7E+07		1.0E+03 ^b
Nitrosopyrrolidine N-	930-55-2			4.60E-05		9.20E-01	7.1E+07		7.2E+07			7.6E+07	1.0E+03 ^b	1.0E+03 ^b
Octamethyl pyrophosphoramidate	152-16-9		4.90E-02				3.1E+09		3.1E+09	1.0E+03 ^b		3.1E+09		
Parathion (ethyl)	56-38-2		1.47E-01				1.0E+30		1.0E+30	1.0E+03 ^{b,c}		1.0E+30		
Pentachlorobenzene	608-93-5		1.96E-02				1.0E+30		1.0E+30	1.0E+03 ^{b,c}		1.0E+30		
Pentachlorodibenzofurans [PeCDFs]	30402-15-4			1.24E-09		6.29E-08	1.0E+30		1.0E+30			1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Pentachlorodibenzo-p-dioxins [PeCDDs]	36088-22-9			6.19E-10		6.00E-08	1.0E+30		1.0E+30			1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Pentachloronitrobenzene (PCNB)	82-68-8		7.34E-02	3.71E-04			1.0E+30		1.0E+30	1.0E+03 ^{b,c}		1.0E+30	1.0E+03 ^{b,c}	
Pentachlorophenol	87-86-5	1.00E-03	7.34E-01	8.05E-04		5.40E+01	4.6E+08	100 ^a	4.6E+08	100 ^a		4.8E+08	100 ^a	100 ^a
Phenol	108-95-2		1.47E+01		9.00E+02		7.9E+07		8.0E+07	1.0E+03 ^b	1.0E+03 ^b	8.4E+07		
Phenyl mercuric acetate	62-38-4		1.96E-03				2.9E+08		3.0E+08	1.0E+03 ^b		3.0E+08		
Phenylenediamine 1,3-	108-45-2		1.47E-01				2.9E+08		2.9E+08	1.0E+03 ^b		2.9E+08		
Phorate	298-02-2		4.90E-03				1.0E+30		1.0E+30	1.0E+03 ^{b,c}		1.0E+30		
Phthalic anhydride	85-44-9		4.90E+01		1.30E+04		1.0E+30		1.0E+30	1.0E+03 ^b	1.0E+03 ^b	1.0E+30		
Polychlorinated biphenyls (Aroclors)	1336-36-3	5.00E-04	4.90E-04	2.41E-04		1.40E-04	1.0E+30	1.0E+03 ^{b,c}	1.0E+30	1.0E+03 ^{b,c}		1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Pronamide	23950-58-5		1.84E+00				1.0E+30		1.0E+30	1.0E+03 ^{b,c}		1.0E+30		
Propylene oxide [1,2-Epoxypropane]	75-56-9			4.02E-04	4.90E-01	1.70E-02	8.4E+07		8.5E+07		1.0E+03 ^b	8.9E+07	1.0E+03 ^b	1.0E+03 ^b
Pyrene	129-00-0		7.34E-01				1.0E+30		1.0E+30	1.0E+03 ^{b,c}		1.0E+30		
Pyridine	110-86-1		2.45E-02		1.40E+00		7.5E+07		7.5E+07	5.0 ^a	5.0 ^a	8.0E+07		
Safrole	94-59-7			5.36E-04			1.6E+10		1.6E+10			1.6E+10	1.0E+03 ^{b,c}	

KEY:
a - TC Rule cap
b - 1,000 mg/L cap
c - Exceeds solubility
d - Capped by daughter LCTV
e - Constituent has no RGC; LCTV from daughter

Table F-9: Waste Pile Composite Liner LCTVs

Common Name	CAS#	MCL (mg/L)	HBN (mg/L)				Peak DAF	LCTV based on MCL (mg/L)	Composite Liner					
			Ingestion		Inhalation				Non-Carcinogenic Effect (NC)			Carcinogenic Effect (C)		
			NC	C	NC	C			7-yr Avg DAF	LCTV based on Ingestion	LCTV based on Inhalation	30-yr Avg DAF	LCTV based on Ingestion	LCTV based on Inhalation
Selenium	7782-49-2	5.00E-02	1.22E-01					1.0 ^a		1.0 ^a				
Silver	7440-22-4		1.22E-01							5.0 ^a				
Strychnine and salts	57-24-9		7.34E-03				1.1E+09		1.2E+09	1.0E+03 ^{b,c}		1.2E+09		
Styrene	100-42-5	1.00E-01	4.90E+00		3.60E+00		3.0E+08	1.0E+03 ^{b,c}	3.0E+08	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}	3.1E+08		
Tetrachlorobenzene 1,2,4,5-	95-94-3		7.34E-03				1.0E+30		1.0E+30	1.0E+03 ^{b,c}		1.0E+30		
Tetrachlorodibenzofuran 2,3,7,8-	51207-31-9			6.19E-09		1.00E-07	1.0E+30		1.0E+30			1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Tetrachlorodibenzo-p-dioxin 2,3,7,8-	1746-01-6	3.00E-08	2.45E-08	6.44E-10		2.20E-09	1.0E+30	1.0E+03 ^{b,c}	1.0E+30	1.0E+03 ^{b,c}		1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Tetrachloroethane 1,1,1,2-	630-20-6		7.34E-01	3.71E-03		1.90E-03	1.0E+30	0.64 ^e	1.0E+30	1.0E+03 ^b		1.0E+30	0.64 ^d	0.64 ^d
Tetrachloroethane 1,1,2,2-	79-34-5		1.47E+00	4.83E-04		5.00E-04	1.0E+30	0.64 ^e	1.0E+30	1.0E+03 ^b	0.64 ^e	1.0E+30	0.64 ^d	0.64 ^d
Tetrachloroethylene	127-18-4	5.00E-03	2.45E-01	1.86E-03	9.40E-01	2.10E-02	1.3E+08	0.70 ^a	1.3E+08	0.70 ^a	0.70 ^a	1.3E+08	0.70 ^a	0.70 ^a
Tetrachlorophenol 2,3,4,6-	58-90-2		7.34E-01				1.3E+10		1.3E+10	1.0E+03 ^{b,c}		1.3E+10		
Tetraethyl dithiopyrophosphate (Sulfotep)	3689-24-5		1.22E-02				1.0E+30		1.0E+30	1.0E+03 ^{b,c}		1.0E+30		
Thallium	7440-28-0	2.00E-03	1.96E-03					1.0E+03 ^b		1.0E+03 ^b				
Thiram [Thiuram]	137-26-8		1.22E-01				1.0E+30		1.0E+30	1.0E+03 ^{b,c}		1.0E+30		
Toluene	108-88-3	1.00E+00	4.90E+00		1.30E+00		1.7E+08	1.0E+03 ^{b,c}	1.7E+08	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}	1.7E+08		
Toluenediamine 2,4-	95-80-7			3.02E-05		7.50E+00	7.1E+07		7.3E+07			7.5E+07	1.0E+03 ^b	1.0E+03 ^b
Toluidine o-	95-53-4			4.02E-04		3.60E-02	8.3E+07		8.3E+07			8.6E+07	1.0E+03 ^b	1.0E+03 ^b
Toluidine p-	106-49-0			5.08E-04			3.9E+08		3.9E+08			3.9E+08	1.0E+03 ^{b,c}	
Toxaphene (chlorinated camphenes)	8001-35-2	3.00E-03		8.78E-05		3.60E-03	1.0E+30	0.50 ^a	1.0E+30			1.0E+30	0.50 ^a	0.50 ^a
Tribromomethane (Bromoform)	75-25-2	8.00E-02	4.90E-01	1.22E-02		1.90E-02	4.4E+08	1.0E+03 ^b	4.4E+08	1.0E+03 ^b		4.7E+08	1.0E+03 ^b	1.0E+03 ^b
Trichloro-1,2,2-trifluoro-ethane 1,1,2-	76-13-1		7.34E+02		9.50E+01		3.7E+08		3.8E+08	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}	3.8E+08		
Trichlorobenzene 1,2,4-	120-82-1	7.00E-02	2.45E-01		8.30E-01		1.6E+10	1.0E+03 ^{b,c}	1.6E+10	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}	1.6E+10		
Trichloroethane 1,1,1-	71-55-6	2.00E-01	6.85E+00		6.90E+00		1.0E+30	0.96 ^d	1.0E+30	0.96 ^d	0.96 ^d	1.0E+30	0.96 ^e	0.96 ^e
Trichloroethane 1,1,2-	79-00-5	5.00E-03	9.79E-02	1.69E-03		1.10E-03	3.3E+09	0.96 ^d	3.3E+09	0.96 ^d	0.96 ^e	3.5E+09	0.96 ^d	0.96 ^d
Trichloroethylene (1,1,2-Trichloroethylene)	79-01-6	5.00E-03		8.78E-03	1.90E+00	6.80E-03	1.1E+08	0.50 ^a	1.1E+08		0.50 ^a	1.2E+08	0.50 ^a	0.50 ^a
Trichlorofluoromethane (Freon 11)	75-69-4		7.34E+00		2.10E+00		1.1E+08		1.1E+08	1.0E+03 ^b	1.0E+03 ^b	1.2E+08		
Trichlorophenol 2,4,5-	95-95-4		2.45E+00				1.0E+30		1.0E+30	400 ^a		1.0E+30		
Trichlorophenol 2,4,6-	88-06-2			8.78E-03		2.80E-01	1.4E+08		1.4E+08			1.5E+08	2.0 ^a	2.0 ^a
Trichlorophenoxypropionic acid 2-(2,4,5- (Silvex)	93-72-1	5.00E-02	1.96E-01				7.5E+08	1.0 ^a	7.5E+08	1.0 ^a		7.5E+08		
Trichlorophenoxyacetic acid 2,4,5-	93-76-5		2.45E-01				4.7E+08		4.7E+08	1.0E+03 ^{b,c}		4.7E+08		
Trichloropropane 1,2,3-	96-18-4		1.47E-01	1.38E-05	3.40E-02		1.0E+30		1.0E+30	1.0E+03 ^b	1.0E+03 ^b	1.0E+30	1.0E+03 ^b	
Triethylamine	121-44-8				1.10E-01		8.2E+07		8.5E+07		1.0E+03 ^b	8.8E+07		
Trinitrobenzene (1,3,5-Trinitrobenzene) sym-	99-35-4		7.34E-01				3.5E+08		3.5E+08	1.0E+03 ^{b,c}		3.5E+08		
Tris(2,3-dibromopropyl)phosphate	126-72-7			9.89E-06			1.0E+30		1.0E+30			1.0E+30	1.0E+03 ^{b,c}	
Vanadium	7440-62-2		1.71E-01							1.0E+03 ^b				
Vinyl acetate	108-05-4		2.45E+01		1.20E+00		7.4E+07		7.5E+07	1.0E+03 ^b	1.0E+03 ^b	7.8E+07		
Vinyl chloride	75-01-4	2.00E-03	7.34E-02	1.34E-04	2.90E-01	2.50E-03	7.6E+07	0.20 ^a	7.8E+07	0.20 ^a	0.20 ^a	8.1E+07	0.20 ^a	0.20 ^a
Xylene m-	108-38-3		4.90E+01		1.30E+00		4.6E+08		4.7E+08	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}	4.8E+08		
Xylene o-	95-47-6		4.90E+01		1.40E+00		4.1E+08		4.1E+08	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}	4.2E+08		
Xylene p-	106-42-3		4.90E+01		1.30E+00		5.0E+08		5.2E+08	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}	5.2E+08		
Xylenes (total)	1330-20-7	1.00E+01	4.90E+01		1.40E+00		4.8E+08	1.0E+03 ^{b,c}	4.8E+08	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}	4.9E+08		
Zinc	7440-66-6		7.34E+00							1.0E+03 ^b				

KEY:

- a - TC Rule cap
b - 1,000 mg/L cap
c - Exceeds solubility
d - Capped by daughter LCTV
e - Constituent has no RGC; LCTV from daughter

Table F-10: Land Application Unit LCTVs (No-Liner)

Common Name	CAS#	MCL (mg/L)	HBN (mg/L)				Peak DAF	LCTV based on MCL (mg/L)	No Liner/In-Situ Soil					
		Ingestion	Ingestion		Inhalation				Non-Carcinogenic Effect (NC)			Carcinogenic Effect (C)		
			NC	C	NC	C			7-yr Avg DAF	LCTV based on Ingestion	LCTV based on Inhalation	30-yr Avg DAF	LCTV based on Ingestion	LCTV based on Inhalation
Acenaphthene	83-32-9		1.47E+00				8.5		8.5	13 ^c		8.8		
Acetaldehyde [Ethanal]	75-07-0				2.20E-01	4.10E-02	1.9		1.9		0.42	2.2		0.090
Acetone (2-propanone)	67-64-1		2.45E+00		1.50E+03		1.9		1.9	4.7	1.0E+03 ^b	2.2		
Acetonitrile (methyl cyanide)	75-05-8				3.10E+00		1.9		1.9		6.0	2.2		
Acetophenone	98-86-2		2.45E+00				1.9		1.9	4.7		2.2		
Acrolein	107-02-8		4.90E-01		3.30E-04		1.0E+30		1.0E+30	1.0E+03 ^b	1.0E+03 ^b	1.0E+30		
Acrylamide	79-06-1		4.90E-03	2.15E-05		5.10E+00	2.2		2.2	0.011		2.6	5.6E-05	13
Acrylic acid [propenoic acid]	79-10-7		1.22E+01		1.50E+01		1.9		1.9	23	29	2.2		
Acrylonitrile	107-13-1		2.45E-02	1.79E-04	3.80E-02	1.00E-03	2.0		2.0	8.2E-03 ^d	0.076	2.3	4.2E-05 ^d	2.3E-03
Aldrin	309-00-2		7.34E-04	5.68E-06		1.00E-05	7.6E+07		7.7E+07	1.0E+03 ^{b,c}		7.8E+07	440 ^c	780 ^c
Allyl alcohol	107-18-6		1.22E-01				1.9		1.9	0.23		2.2		
Aniline (benzeneamine)	62-53-3			1.69E-02	9.30E-01	2.20E+00	1.9		1.9		1.8	2.2	0.037	4.8
Anthracene	120-12-7		7.34E+00				21		22	160 ^c		22		
Antimony	7440-36-0	6.00E-03	9.79E-03					0.013		0.024				
Arsenic	7440-38-2	5.00E-02	7.34E-03	6.44E-05				0.13		0.026			5.6E-04	
Barium	7440-39-3	2.00E+00	1.71E+00					3.5		3.6				
Benz(a)anthracene	56-55-3			8.05E-05		1.80E-02	370		370			370	0.030 ^c	6.7 ^c
Benzene	71-43-2	5.00E-03		1.76E-03	1.90E-01	1.60E-03	2.0	9.9E-03	2.0		0.38	2.3	4.0E-03	3.7E-03
Benzidine	92-87-5		7.34E-02	4.20E-07		2.60E+00	1.9		1.9	0.14		2.2	9.2E-07	5.7
Benzo(a)pyrene	50-32-8	2.00E-04		1.32E-05		5.40E-03	9.2E+03	1.8 ^c	9.3E+03			9.3E+03	0.12 ^c	50 ^c
Benzo(b)fluoranthene	205-99-2			8.05E-05		6.30E-04	9.5E+03		9.5E+03			9.5E+03	0.77 ^c	6.0 ^c
Benzyl alcohol	100-51-6		7.34E+00				1.9		1.9	14		2.2		
Benzyl chloride	100-44-7			5.68E-04		5.20E-04	1.0E+30		1.0E+30	16 ^c		1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Beryllium	7440-41-7	4.00E-03	4.90E-02					5.0		9.8				
Bis(2-chloroethyl)ether	111-44-4			8.78E-05		1.10E-03	6.8		7.0		1.0E+03 ^e	8.2	7.2E-04	9.0E-03
Bis(2-chloroisopropyl)ether	39638-32-9		9.79E-01	1.38E-03		5.90E-03	2.2		2.2	2.2		2.5	3.4E-03	0.015
Bis(2-ethylhexyl)phthalate	117-81-7	6.00E-03	4.90E-01	6.90E-03	1.80E+02	2.80E+01	1.0E+30	1.0E+03 ^{b,c}	1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}	1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Bromodichloromethane	75-27-4	8.00E-02	4.90E-01	1.56E-03		8.00E-04	2.2	0.17	2.2	1.1		2.5	3.9E-03	2.0E-03
Bromomethane	74-83-9		3.43E-02		1.50E-02		6.9E+07		6.9E+07	69 ^c	1.0E+03 ^b	1.2E+08		
Butadiene 1, 3-	106-99-0				6.00E-02	4.00E-05	2.0		2.1		0.12	2.3		9.3E-05
Butanol n-	71-36-3		2.45E+00				1.9		1.9	4.7		2.2		
Butyl benzyl phthalate	85-68-7		4.90E+00				26		26	130 ^c		27		
Butyl-4,6-dinitrophenol,2-sec-(Dinoseb)	88-85-7	7.00E-03	2.45E-02				2.0	0.014	2.0	0.049		2.3		
Cadmium	7440-43-9	5.00E-03	1.22E-02					0.015		0.038				
Carbon disulfide	75-15-0		2.45E+00		1.90E+00		2.1		2.2	5.3	4.1	2.5		
Carbon tetrachloride	56-23-5	5.00E-03	1.71E-02	7.43E-04	2.10E-02	7.60E-04	2.8	0.014	2.8	0.048	0.059	3.2	2.4E-03	2.4E-03
Chlordane	57-74-9	2.00E-03	1.22E-02	2.76E-04	2.80E-02	1.50E-03	3.5E+04	0.030 ^a	3.6E+04	0.030 ^a	0.030 ^a	3.6E+04	0.030 ^a	0.030 ^a
Chloro-1,3-butadiene 2-(Chloroprene)	126-99-8		4.90E-01		2.20E-02		2.0		2.0	0.98	0.044	2.3		
Chloroaniline p-	106-47-8		9.79E-02				1.9		1.9	0.19		2.2		
Chlorobenzene	108-90-7	1.00E-01	4.90E-01		2.00E-01		2.4	0.24	2.4	1.2	0.48	2.7		
Chlorobenzilate	510-15-6		4.90E-01	3.58E-04		1.20E+00	39		39	19 ^c		40	0.014	48 ^c
Chlorodibromomethane	124-48-1	8.00E-02	4.90E-01	1.15E-03		7.50E-04	2.1	0.17	2.2	1.1		2.5	2.8E-03	1.9E-03
Chloroethane [Ethyl chloride]	75-00-3				3.00E+01		1.9		1.9		57	2.2		
Chloroform	67-66-3	8.00E-02	2.45E-01		3.30E-01		2.0	0.16	2.0	0.49	0.66	2.3		
Chloromethane	74-87-3			7.43E-03		5.90E-03	1.9		1.9		0.50	2.2	0.016	0.013
Chlorophenol 2-	95-57-8		1.22E-01		9.70E-03		2.0		2.0	0.24	0.019	2.3		
Chloropropene 3- (Allyl Chloride)	107-05-1				3.00E-03	1.90E-03	1.0E+30		1.0E+30		1.0E+03 ^b	1.0E+30		1.0E+03 ^b
Chromium (III) (Chromic Ion)	16065-83-1	1.00E-01	3.67E+01					43		260				
Chromium (VI)	18540-29-9	1.00E-01	7.34E-02					5.0 ^a		5.0 ^a				

KEY:

- a - TC Rule cap d - Capped by daughter LCTV
b - 1,000 mg/L cap e - Constituent has no RGC; LCTV from daughter
c - Exceeds solubility

Table F-10: Land Application Unit LCTVs (No-Liner)

Common Name	CAS#	MCL (mg/L)	HBN (mg/L)				No Liner/In-Situ Soil							
			Ingestion	Inhalation		Peak DAF	LCTV based on MCL (mg/L)	Non-Carcinogenic Effect (NC)			Carcinogenic Effect (C)			
				NC	C			NC	C	7-yr Avg DAF	LCTV based on Ingestion	LCTV based on Inhalation	30-yr Avg DAF	LCTV based on Ingestion
Chrysene	218-01-9			8.05E-04		7.30E-03	370		370			370	0.30 ^c	2.7 ^c
Cobalt	7440-48-4		4.90E-01							5				
Copper	7440-50-8	1.30E+00						61						
Cresol m-	108-39-4		1.22E+00		1.20E+03		2.0		2.0	2.4	200 ^a	2.3		
Cresol o-	95-48-7		1.22E+00		8.80E+02		2.0		2.0	2.4	200 ^a	2.3		
Cresol p-	106-44-5		1.22E-01		1.30E+03		2.0		2.0	0.24	200 ^a	2.3		
Cresols	1319-77-3		1.22E+00		1.10E+03		2.1		2.1	2.5	1.0E+03 ^b	2.4		
Cumene	98-82-8		2.45E+00		1.30E+00		5.0		5.0	12	6.5	5.2		
Cyclohexanol	108-93-0		4.16E-04		3.90E-04		1.9		1.9	8.0E-04	7.5E-04	2.2		
Cyclohexanone	108-94-1		1.22E+02				2.0		2.0	240		2.3		
DDD	72-54-8			4.02E-04			1.0E+30		1.0E+30			1.0E+30	1.0E+03 ^{b,c}	
DDE	72-55-9			2.84E-04			1.0E+30		1.0E+30			1.0E+30	1.0E+03 ^{b,c}	
DDT p,p'-	50-29-3		1.22E-02	2.84E-04		8.80E-03	1.0E+30		1.0E+30	1.0E+03 ^{b,c}		1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Diallate	2303-16-4			1.58E-03			6.8E+04		6.9E+04			7.1E+04	110 ^c	
Dibenz[a,h]anthracene	53-70-3			1.32E-05		3.80E-01	1.0E+30		1.0E+30			1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Dibromo-3-chloropropane 1,2-	96-12-8	2.00E-04		6.90E-05	2.90E-03	7.90E-02	2.5	4.9E-04	2.5		7.2E-03	2.8	2.0E-04	0.22
Dichlorobenzene 1,2-	95-50-1	6.00E-01	2.20E+00		7.70E-01		3.4	2.0	3.4	7.4	2.6	3.7		
Dichlorobenzene 1,4-	106-46-7	7.50E-02		4.02E-03	3.00E+00	1.30E-03	3.3	0.25	3.3		7.5 ^a	3.6	0.014	4.6E-03
Dichlorobenzidine 3,3'-	91-94-1			2.15E-04		4.90E+00	4.4		4.4			4.7	1.0E-03	23 ^c
Dichlorodifluoromethane (Freon 12)	75-71-8		4.90E+00		5.80E-01		2.1		2.1	10	1.2	2.4		
Dichloroethane 1,1-	75-34-3		2.45E+00		1.60E+00	7.40E-03	2.1	8.5E-03 ^e	2.2	0.32 ^d	0.45 ^d	2.5	6.6E-04 ^e	0.012 ^d
Dichloroethane 1,2-	107-06-2	5.00E-03		1.06E-03	1.00E+01	6.30E-04	2.1	6.0E-03 ^d	2.1	0.22 ^e	0.32 ^d	2.4	4.7E-04 ^d	1.5E-03
Dichloroethylene cis-1,2-	156-59-2	7.00E-02	2.45E-01				1.9	0.14	2.0	0.48		2.3		
Dichloroethylene trans-1,2-	156-60-5	1.00E-01	4.90E-01				1.9	0.19	1.9	0.94		2.2		
Dichloroethylene 1,1-	75-35-4	7.00E-03	2.20E-01	1.61E-04	2.10E-01	2.20E-04	2.0	0.014	2.0	0.44	0.42	2.3	3.7E-04	5.0E-04
Dichlorophenol 2,4-	120-83-2		7.34E-02				2.3		2.3	0.17		2.6		
Dichlorophenoxyacetic acid 2,4-(2,4-D)	94-75-7	7.00E-02	2.45E-01				1.9	0.13	1.9	0.47		2.2		
Dichloropropane 1,2-	78-87-5	5.00E-03	2.20E+00	1.42E-03	1.40E-02		3.0	0.015	3.0	6.6	0.042	3.4	4.8E-03	
Dichloropropene 1,3-(mixture of isomers)	542-75-6		7.34E-01	9.66E-04	6.10E-02	2.90E-03	1.9		1.9	1.4	0.12	2.2	2.1E-03	6.4E-03
Dichloropropene cis-1,3-	10061-01-5		7.34E-01	9.66E-04	7.00E-02	3.30E-03	1.0E+30		1.0E+30	1.0E+03 ^b	1.0E+03 ^b	1.0E+30	1.0E+03 ^b	1.0E+03 ^b
Dichloropropene trans-1,3-	10061-02-6		7.34E-01	9.66E-04	7.50E-02	3.50E-03	1.0E+30		1.0E+30	1.0E+03 ^b	1.0E+03 ^b	1.0E+30	1.0E+03 ^b	1.0E+03 ^b
Dieldrin	60-57-1		1.22E-03	6.04E-06		1.00E-04	1.0E+30		1.0E+30	1.0E+03 ^{b,c}		1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Diethyl phthalate	84-66-2		1.96E+01				2.7		2.7	53		3.1		
Diethylstilbestrol	56-53-1			2.05E-08			17		17			17	3.5E-07	
Dimethoate	60-51-5		4.90E-03				1.3E+03		1.3E+03	0.47 ^d	1.0E+03 ^e	1.6E+03		
Dimethoxybenzidine 3,3'-	119-90-4			6.90E-03			1.9		1.9			2.2	0.015	
Dimethyl formamide N,N- [DMF]	68-12-2		2.45E+00		7.10E+02		1.9		1.9	4.7	1.0E+03 ^b	2.2		
Dimethylbenz[a]anthracene 7,12-	57-97-6					3.00E-03	1.0E+30		1.0E+30			1.0E+30		1.0E+03 ^{b,c}
Dimethylbenzidine 3,3'-	119-93-7			1.05E-05			2.3		2.3			2.6	2.7E-05	
Dimethylphenol 2,4-	105-67-9		4.90E-01				2.1		2.1	1.1		2.4		
Di-n-butyl phthalate	84-74-2		2.45E+00				36		36	88 ^c		36		
Dinitrobenzene 1,3-	99-65-0		2.45E-03				1.9		1.9	4.7E-03		2.2		
Dinitrophenol 2,4-	51-28-5		4.90E-02				1.9		1.9	0.094		2.2		
Dinitrotoluene 2,4-	121-14-2		4.90E-02	1.42E-04		8.12E-01	1.9		1.9	0.094		2.2	3.1E-04	0.13 ^a
Dinitrotoluene 2,6-	606-20-2		2.45E-02	1.42E-04			1.9		1.9	0.047		2.2	3.1E-04	
Di-n-octyl phthalate	117-84-0		4.90E-01				1.0E+30		1.0E+30	1.0E+03 ^{b,c}		1.0E+30		
Dioxane 1,4-	123-91-1			8.78E-03	1.09E+03	1.80E-01	1.9		1.9		1.0E+03 ^b	2.2	0.019	0.39
Diphenylamine	122-39-4		6.12E-01				4.3		4.3	2.6		4.5		

KEY:

- a - TC Rule cap
b - 1,000 mg/L cap
c - Exceeds solubility
d - Capped by daughter LCTV
e - Constituent has no RGC; LCTV from daughter

Table F-10: Land Application Unit LCTVs (No-Liner)

Common Name	CAS#	MCL (mg/L)	HBN (mg/L)				Peak DAF	LCTV based on MCL (mg/L)	No Liner/In-Situ Soil					
		Ingestion	Ingestion		Inhalation				Non-Carcinogenic Effect (NC)		Carcinogenic Effect (C)			
			NC	C	NC	C			7-yr Avg DAF	LCTV based on Ingestion	LCTV based on Inhalation	30-yr Avg DAF	LCTV based on Ingestion	LCTV based on Inhalation
Diphenylhydrazine 1, 2-	122-66-7			1.21E-04		2.00E-02	2.7		2.7			3.0	3.6E-04	0.060
Disulfoton	298-04-4		9.79E-04				1.3E+07		1.3E+07	1.0E+03 ^{b,c}		1.5E+07		
Endosulfan (Endosulfan I and II,mixture)	115-29-7		1.47E-01				6.1		6.1	0.90 ^c		6.4		
Endrin	72-20-8	2.00E-03	7.34E-03				2.0E+06	0.020 ^a	2.0E+06	0.020 ^a		2.0E+06		
Epichlorohydrin	106-89-8		4.90E-02	9.75E-03	6.00E-02	1.90E-01	1.0E+30		1.0E+30	1.0E+03 ^b	1.0E+03 ^b	1.0E+30	1.0E+03 ^b	1.0E+03 ^b
Epoxybutane, 1, 2-	106-88-7				2.40E-01		1.9		1.9		0.46	2.2		
Ethoxyethanol 2-	110-80-5		9.79E+00		2.90E+03		1.9		1.9	19	1.0E+03 ^b	2.2		
Ethoxyethanol acetate 2-	111-15-9		7.34E+00		3.00E+02		1.9		1.9	14	570	2.2		
Ethyl acetate	141-78-6		2.20E+01				6.7		6.8	150		8.0		
Ethyl ether	60-29-7		4.90E+00				1.9		1.9	9.4		2.2		
Ethyl methacrylate	97-63-2		2.20E+00				3.4		3.4	7.6		4.0		
Ethyl methanesulfonate	62-50-0			3.30E-07			1.0E+30		1.0E+30			1.0E+30	1.0E+03 ^b	
Ethylbenzene	100-41-4	7.00E-01	2.45E+00		3.30E+00	1.10E-02	3.1	2.2	3.2	7.7	10	3.4		0.038
Ethylene dibromide (1,2-Dibromoethane)	106-93-4	5.00E-05		1.14E-06	9.80E-04	8.40E-05	31	1.5E-03	32		0.031	38	4.4E-05	3.2E-03
Ethylene glycol	107-21-1		4.90E+01		1.20E+04		1.9		1.9	94	1.0E+03 ^b	2.2		
Ethylene oxide	75-21-8			9.47E-05	4.10E-01	5.20E-04	1.0E+30		1.0E+30		1.0E+03 ^b	1.0E+30	1.0E+03 ^b	1.0E+03 ^b
Ethylene thiourea	96-45-7		1.96E-03	8.78E-04		1.60E+03	1.9		1.9	3.7E-03		2.2	1.9E-03	1.0E+03 ^b
Fluoranthene	206-44-0		9.79E-01				55		55	54 ^c		55		
Fluoride	16984-48-8	4.00E+00	2.90E+00					6.2		5.2				
Formaldehyde	50-00-0		4.90E+00		5.10E+01	1.50E+00	1.9		1.9	9.4	97	2.2		3.3
Formic acid	64-18-6		4.90E+01				1.9		1.9	94		2.2		
Furfural	98-01-1		7.34E-02		2.20E+01		1.9		1.9	0.14	42	2.2		
HCH beta-	319-85-7			5.36E-05		1.70E-02	5.2		5.3			5.5	2.9E-04	0.093
HCH (Lindane) gamma-	58-89-9	2.00E-04	7.34E-03	7.43E-05		1.60E-03	2.1E+07	0.4 ^{a,d}	2.1E+07	0.4 ^{a,d}	0.4 ^{a,e}	2.3E+07	0.4 ^{a,b,c}	0.4 ^{a,b,c}
HCH alpha-	319-84-6		1.96E-01	1.53E-05		3.60E-04	4.1E+07	1.5 ^e	4.1E+07	3.3 ^{c,d}	18 ^{c,e}	4.4E+07	680 ^c	1.0E+03 ^{b,c}
Heptachlor	76-44-8	4.00E-04	1.22E-02	2.15E-05		1.50E-05	1.0E+30	8.0E-03 ^a	1.0E+30	8.0E-03 ^a		1.0E+30	8.0E-03 ^a	8.0E-03 ^a
Heptachlor epoxide	1024-57-3	2.00E-04	3.18E-04	1.06E-05		2.80E-04	2.8E+15	1.0E+03 ^{b,c}	2.8E+15	1.0E+03 ^{b,c}		2.8E+15	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Hexachloro-1,3-butadiene	87-68-3		7.34E-03	1.24E-03		6.10E-04	39		39	0.29		39	0.049	0.024
Hexachlorobenzene	118-74-1	1.00E-03	1.96E-02	6.04E-05		3.60E-05	500	0.13 ^{a,c}	500	0.13 ^{a,c}		500	0.030 ^c	0.018 ^c
Hexachlorocyclopentadiene	77-47-4	5.00E-02	1.47E-01		6.90E-04		1.0E+30	1.0E+03 ^{b,c}	1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}	1.0E+30		
Hexachlorodibenzofurans [HxCDFs]	55684-94-1			6.19E-09		1.44E-07	1.0E+30		1.0E+30			1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Hexachlorodibenzo-p-dioxins [HxCDDs]	34465-46-8			6.19E-09		1.43E-07	2.0E+14		2.0E+14			2.0E+14	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Hexachloroethane	67-72-1		2.45E-02	6.90E-03		3.30E-03	6.9		6.9	0.17		7.2	0.050	0.024
Hexachlorophene	70-30-4		7.34E-03				130		130	0.95		130		
Hexane n-	110-54-3		2.69E+02		6.60E-01		3.0		3.0	820 ^c	2.0	3.3		
Hydrogen Sulfide	7783-06-4		7.34E-02				1.9		1.9	0.14		2.2		
Indeno(1,2,3-cd)pyrene	193-39-5			8.05E-05		3.80E-02	3.0E+09		3.1E+09			3.1E+09	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Isobutyl alcohol	78-83-1		7.34E+00				1.9		1.9	14		2.2		
Isophorone	78-59-1		4.90E+00	1.02E-01	5.33E+02		2.0		2.0	9.8	1.0E+03 ^b	2.3	0.23	
Kepone	143-50-0		1.22E-02				19		19	0.23		19		
Lead	7439-92-1	1.50E-02						0.25						
Manganese	7439-96-5		1.15E+00							2.4				
Mercury	7439-97-6	2.00E-03	2.45E-03		7.00E-04			3.3E-03		4.4E-03	1.3E-03			
Methacrylonitrile	126-98-7		2.45E-03		6.50E-03		2.0		2.0	4.9E-03	0.013	2.3		
Methanol	67-56-1		1.22E+01		1.54E+03		1.9		1.9	23	1.0E+03 ^b	2.2		
Methoxychlor	72-43-5	4.00E-02	1.22E-01				1.0E+30	10 ^{a,c}	1.0E+30	1.0E+01 ^{a,c}		1.0E+30		
Methoxyethanol acetate 2-	110-49-6		4.90E-02		5.10E+02		1.9		1.9	0.094	970	2.2		
Methoxyethanol 2-	109-86-4		2.45E-02		4.40E+02		1.9		1.9	0.047	840	2.2		
Methyl ethyl ketone	78-93-3		1.47E+01		3.30E+01		1.9		1.9	28	63	2.2		

KEY:

a - TC Rule cap

d - Capped by daughter LCTV

b - 1,000 mg/L cap

e - Constituent has no RGC; LCTV from daughter

c - Exceeds solubility

Table F-10: Land Application Unit LCTVs (No-Liner)

Common Name	CAS#	MCL (mg/L)	HBN (mg/L)				Peak DAF	LCTV based on MCL (mg/L)	No Liner/In-Situ Soil					
		Ingestion	Ingestion		Inhalation				Non-Carcinogenic Effect (NC)			Carcinogenic Effect (C)		
			NC	C	NC	C			7-yr Avg DAF	LCTV based on Ingestion	LCTV based on Inhalation	30-yr Avg DAF	LCTV based on Ingestion	LCTV based on Inhalation
Methyl isobutyl ketone	108-10-1		1.96E+00		1.20E+00		1.9		1.9	3.7	2.3	2.2		
Methyl methacrylate	80-62-6		3.43E+01		5.30E+00		4.0		4.1	73 ^a	22	4.7		
Methyl parathion	298-00-0		6.12E-03				3.6E+05		3.7E+05	1.1 ^d	1.0E+03 ^e	3.8E+05		
Methyl tert-butyl ether [MTBE]	1634-04-4				1.70E+01		1.9		1.9		33	2.2		
Methylcholanthrene 3-	56-49-5					1.20E-03	1.0E+30		1.0E+30			1.0E+30		1.0E+03 ^{b,c}
Methylene bromide (Dibromomethane)	74-95-3		2.45E-01				1.9		1.9	0.47		2.2		
Methylene Chloride (Dichloromethane)	75-09-2	5.00E-03	1.47E+00	1.29E-02	1.00E+01	2.80E-02	1.9	9.7E-03	2.0	2.9	20	2.2	0.029	0.063
Molybdenum	7439-98-7		1.22E-01							0.22				
Naphthalene	91-20-3		4.90E-01		1.90E-02		3.5		3.5	1.7	0.066	3.8		
Nickel	7440-02-0		4.90E-01							1.2				
Nitrobenzene	98-95-3		1.22E-02		1.50E-01		1.9		1.9	0.023	0.29	2.2		
Nitropropane 2-	79-46-9				3.30E-01	2.30E-05	1.9		1.9		0.63	2.2		5.0E-05
Nitrosodiethylamine N-	55-18-5			6.44E-07		4.30E-05	1.9		1.9			2.2	1.4E-06	9.4E-05
Nitrosodimethylamine N-	62-75-9		1.96E-04	1.89E-06		4.00E-04	1.9		1.9	3.7E-04		2.2	4.1E-06	8.8E-04
Nitroso-di-n-butylamine N-	924-16-3			1.79E-05		2.00E-05	2.0		2.1			2.3	4.2E-05	4.7E-05
Nitroso-di-n-propylamine N-	621-64-7			1.38E-05		1.50E-03	1.9		1.9			2.2	3.0E-05	3.3E-03
Nitrosodiphenylamine N-	86-30-6		4.90E-01	1.97E-02		5.20E-01	2.8		2.8	1.4		3.0	0.060	1.6
Nitrosomethylethylamine N-	10595-95-6			4.39E-06		4.50E-03	1.9		1.9			2.2	9.6E-06	9.9E-03
Nitrosopiperidine N-	100-75-4					8.70E-03	1.9		1.9			2.2		0.019
Nitrosopyrrolidine N-	930-55-2			4.60E-05		9.20E-01	1.9		1.9			2.2	1.0E-04	2.0
Octamethyl pyrophosphoramidate	152-16-9		4.90E-02				2.0		2.0	0.098		2.3		
Parathion (ethyl)	56-38-2		1.47E-01				3.1E+12		3.1E+12	1.0E+03 ^{b,c}		3.4E+12		
Pentachlorobenzene	608-93-5		1.96E-02				440		440	8.6 ^c		440		
Pentachlorodibenzofurans [PeCDFs]	30402-15-4			1.24E-09		6.29E-08	110		110			110	1.5E-07	7.1E-06
Pentachlorodibenzo-p-dioxins [PeCDDs]	36088-22-9			6.19E-10		6.00E-08	3.0E+10		3.1E+10			3.1E+10	20 ^c	1.0E+03 ^{b,c}
Pentachloronitrobenzene (PCNB)	82-68-8		7.34E-02	3.71E-04			48		48	3.6 ^c		48	0.018	
Pentachlorophenol	87-86-5	1.00E-03	7.34E-01	8.05E-04		5.40E+01	3.3	3.3E-03	3.3	2.4		3.6	2.9E-03	100 ^a
Phenol	108-95-2		1.47E+01		9.00E+02		1.9		1.9	28	1.0E+03 ^b	2.2		
Phenyl mercuric acetate	62-38-4		1.96E-03				1.9		1.9	3.7E-03		2.2		
Phenylenediamine 1,3-	108-45-2		1.47E-01				1.9		1.9	0.28		2.2		
Phorate	298-02-2		4.90E-03				1.0E+30		1.0E+30	1.0E+03 ^{b,c}		1.0E+30		
Phthalic anhydride	85-44-9		4.90E+01		1.30E+04		1.0E+30		1.0E+30	1.0E+03 ^b	1.0E+03 ^b	1.0E+30		
Polychlorinated biphenyls (Aroclors)	1336-36-3	5.00E-04	4.90E-04	2.41E-04		1.40E-04	1.1E+08	1.0E+03 ^{b,c}	1.1E+08	1.0E+03 ^{b,c}		1.1E+08	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Pronamide	23950-58-5		1.84E+00				2.5		2.5	4.6		2.8		
Propylene oxide [1,2-Epoxypropane]	75-56-9			4.02E-04	4.90E-01	1.70E-02	1.9		1.9		0.94	2.2	8.8E-04	0.037
Pyrene	129-00-0		7.34E-01				110		110	79 ^c		110		
Pyridine	110-86-1		2.45E-02		1.40E+00		1.9		1.9	0.047	2.7	2.2		
Safrole	94-59-7			5.36E-04			2.2		2.2			2.4	1.3E-03	
Selenium	7782-49-2	5.00E-02	1.22E-01					0.078		0.21				
Silver	7440-22-4		1.22E-01							0.26				
Strychnine and salts	57-24-9		7.34E-03				2.0		2.0	0.015		2.3		
Styrene	100-42-5	1.00E-01	4.90E+00		3.60E+00		2.8	0.28	2.8	14	10.0	3.0		
Tetrachlorobenzene 1,2,4,5-	95-94-3		7.34E-03				25		26	0.19		26		
Tetrachlorodibenzofuran 2,3,7,8-	51207-31-9			6.19E-09		1.00E-07	1.0E+30		1.0E+30			1.0E+30	1.0E+03 ^{b,c}	1.0E+03 ^{b,c}
Tetrachlorodibenzo-p-dioxin 2,3,7,8-	1746-01-6	3.00E-08	2.45E-08	6.44E-10		2.20E-09	6.6E+06	0.20 ^c	6.6E+06	0.16 ^c		6.7E+06	4.3E-03 ^c	0.015 ^c
Tetrachloroethane 1,1,1,2-	630-20-6		0.734	3.71E-03		1.90E-03	3.3	0.013 ^e	3.3	2.5		3.7	0.014	7.1E-03
Tetrachloroethane 1,1,2,2-	79-34-5		1.47E+00	4.83E-04		5.00E-04	18	0.013 ^e	18	26	0.64 ^e	21	1.0E-02	0.010
Tetrachloroethylene	127-18-4	5.00E-03	2.45E-01	1.86E-03	9.40E-01	2.10E-02	2.1	0.011	2.1	0.52	0.70 ^a	2.4	4.5E-03	0.050
Tetrachlorophenol 2,3,4,6-	58-90-2		7.34E-01				2.1		2.2	1.6		2.4		

KEY:

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Table F-10: Land Application Unit LCTVs (No-Liner)

Common Name	CAS#	MCL (mg/L)	HBN (mg/L)				No Liner/In-Situ Soil							
		Ingestion	Ingestion		Inhalation		Peak DAF	LCTV based on MCL (mg/L)	Non-Carcinogenic Effect (NC)			Carcinogenic Effect (C)		
			NC	C	NC	C			7-yr Avg DAF	LCTV based on Ingestion	LCTV based on Inhalation	30-yr Avg DAF	LCTV based on Ingestion	LCTV based on Inhalation
Tetraethyl dithiopyrophosphate (Sulfotep)	3689-24-5		1.22E-02				1.0E+30		1.0E+30	1.0E+03 ^{b,c}		1.0E+30		
Thallium	7440-28-0	2.00E-03	1.96E-03					3.2E-03		3.7E-03				
Thiram [Thiuram]	137-26-8		1.22E-01				2.7		2.7	0.33		3.0		
Toluene	108-88-3	1.00E+00	4.90E+00		1.30E+00		2.2	2.2	2.3	11	2.9	2.5		
Toluenediamine 2,4-	95-80-7			3.02E-05		7.50E+00	1.9		1.9			2.2	6.6E-05	16
Toluidine o-	95-53-4			4.02E-04		3.60E-02	1.9		1.9			2.2	8.8E-04	0.079
Toluidine p-	106-49-0			5.08E-04			1.9		1.9			2.2	1.1E-03	
Toxaphene (chlorinated camphenes)	8001-35-2	3.00E-03		8.78E-05		3.60E-03	6.7E+04	0.50 ^a	6.7E+04			6.8E+04	0.50 ^a	0.50 ^a
Tribromomethane (Bromoform)	75-25-2	8.00E-02	4.90E-01	1.22E-02		1.90E-02	2.1	0.17	2.1	1		2.4	0.030	0.046
Trichloro-1,2,2-trifluoro- ethane 1,1,2-	76-13-1		7.34E+02		9.50E+01		3.1		3.1	1.0E+03 ^{b,c}	290 ^c	3.3		
Trichlorobenzene 1,2,4-	120-82-1	7.00E-02	2.45E-01		8.30E-01		13	0.93	13	3.3	11	14		
Trichloroethane 1,1,1-	71-55-6	2.00E-01	6.85E+00		6.90E+00		150	0.019 ^d	150	0.61 ^d	0.58 ^d	170	5.1E-04 ^e	6.9E-04 ^e
Trichloroethane 1,1,2-	79-00-5	5.00E-03	9.79E-02	1.69E-03		1.10E-03	2.2	0.011	2.2	0.21	0.58 ^e	2.5	5.1E-04 ^d	6.9E-04 ^d
Trichloroethylene (1,1,2-Trichloroethylene)	79-01-6	5.00E-03		8.78E-03	1.90E+00	6.80E-03	2.0	0.010	2.1		0.50 ^a	2.3	0.021	0.016
Trichlorofluoromethane (Freon 11)	75-69-4		7.34E+00		2.10E+00		2.0		2.1	15	4.4	2.4		
Trichlorophenol 2,4,5-	95-95-4		2.45E+00				2.9		2.9	7.2		3.2		
Trichlorophenol 2,4,6-	88-06-2			8.78E-03		2.80E-01	2.1		2.1			2.4	0.021	0.68
Trichlorophenoxypropionic acid 2-(2,4,5- (Silvex)	93-72-1	5.00E-02	1.96E-01				2.0	0.098	2.0	0.39		2.3		
Trichlorophenoxyacetic acid 2,4,5-	93-76-5		2.45E-01				1.9		1.9	0.47		2.2		
Trichloropropane 1,2,3-	96-18-4		1.47E-01	1.38E-05	3.40E-02		2.3		2.4	0.35	0.080	2.7	3.7E-05	
Triethylamine	121-44-8				1.10E-01		1.9		1.9		0.21	2.2		
Trinitrobenzene (1,3,5-Trinitrobenzene) sym-	99-35-4		7.34E-01				1.9		1.9	1.4		2.2		
Tris(2,3-dibromopropyl)phosphate	126-72-7			9.89E-06			29		29			31	3.1E-04	
Vanadium	7440-62-2		1.71E-01							34				
Vinyl acetate	108-05-4		2.45E+01		1.20E+00		1.9		1.9	47	2.3	2.2		
Vinyl chloride	75-01-4	2.00E-03	7.34E-02	1.34E-04	2.90E-01	2.50E-03	1.9	3.8E-03	1.9	0.14	0.20 ^a	2.2	2.9E-04	5.5E-03
Xylene m-	108-38-3		4.90E+01		1.30E+00		3.4		3.4	170 ^c	4.4	3.7		
Xylene o-	95-47-6		4.90E+01		1.40E+00		3.2		3.2	160	4.5	3.5		
Xylene p-	106-42-3		4.90E+01		1.30E+00		3.5		3.5	170	4.6	3.8		
Xylenes (total)	1330-20-7	1.00E+01	4.90E+01		1.40E+00		3.4	34	3.4	170	4.7	3.7		
Zinc	7440-66-6		7.34E+00							45				

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