



EPA's Composite Model for Leachate Migration with Transformation Products (EPACMTP)

Parameters/Data Background Document

April 2003

U.S. NUCLEAR REGULATORY COMMISSION
In the Matter of LOUISIANA ENERGY SERVICES, LP
Docket No. 70-3103-ML Official Exhibit No. 12
OFFERED by: Applicant/Licensee Intervenor NERS/PC
NRC Staff Other _____
IDENTIFIED on _____ Witness/Panel G. Rice
Action Taken: ADMITTED REJECTED WITHDRAWN
Reporter/Clerk _____

Office of Solid Waste (5305W)

Washington, DC 20460

EPA530-R-03-003

April 2003

www.epa.gov/osw

**EPA's COMPOSITE MODEL FOR LEACHATE MIGRATION
WITH TRANSFORMATION PRODUCTS (EPACMTP)**

PARAMETERS/DATA BACKGROUND DOCUMENT

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

April 2003

This page intentionally left blank.

TABLE OF CONTENTS

| | Page |
|-----------------------------------------------------------------------|------|
| ACKNOWLEDGMENTS | viii |
| LIST OF SYMBOLS AND ABBREVIATIONS | ix |
| 1.0 INTRODUCTION | 1-1 |
| 2.0 WASTE MANAGEMENT UNIT (SOURCE) PARAMETERS | 2-1 |
| 2.1 SOURCE PARAMETERS | 2-4 |
| 2.2 DATA SOURCES FOR WMU PARAMETERS | 2-4 |
| 2.3 LANDFILLS | 2-10 |
| 2.3.1 Landfill Area (A_w) | 2-10 |
| 2.3.2 Landfill Depth (D_L) | 2-11 |
| 2.3.3 Landfill Base Depth below Grade (d_{BG}) | 2-12 |
| 2.3.4 Waste Fraction (F_w) | 2-14 |
| 2.3.5 Waste Volume (PWS) | 2-14 |
| 2.3.6 Leaching Duration (t_p) | 2-15 |
| 2.4 SURFACE IMPOUNDMENTS | 2-16 |
| 2.4.1 Surface Impoundment Area (A_w) | 2-17 |
| 2.4.2 Surface Impoundment Ponding Depth (H_p) | 2-18 |
| 2.4.3 Surface Impoundment Total Thickness of Sediment (D_s) | 2-19 |
| 2.4.4 Surface Impoundment Liner Thickness (D_{in}) | 2-20 |
| 2.4.5 Surface Impoundment Liner Conductivity (K_{in}) | 2-21 |
| 2.4.6 Surface Impoundment Base Depth Below Grade (d_{BG}) | 2-22 |
| 2.4.7 Surface Impoundment Leak Density (ρ_{leak}) | 2-23 |
| 2.4.8 Distance to Nearest Surface Water Body (R_w) | 2-24 |
| 2.4.9 Surface Impoundment Leaching Duration (t_p) | 2-25 |
| 2.5 WASTE PILES | 2-26 |
| 2.5.1 Waste Pile Area (A_w) | 2-27 |
| 2.5.2 Waste Pile Leaching Duration (t_p) | 2-28 |
| 2.5.3 Waste Pile Base Depth below Grade (d_{BG}) | 2-28 |
| 2.6 LAND APPLICATION UNITS | 2-29 |
| 2.6.1 Land Application Unit Area (A_w) | 2-29 |
| 2.6.2 Land Application Unit Leaching Duration (t_p) | 2-30 |
| 3.0 WASTE AND CONSTITUENT PARAMETERS | 3-1 |
| 3.1 WASTE AND CONSTITUENT PARAMETERS | 3-2 |
| 3.2 WASTE CHARACTERISTICS | 3-3 |
| 3.2.1 Waste Density (ρ_{hw}) | 3-3 |
| 3.2.2 Concentration of Constituent in the Waste (C_w) | 3-5 |
| 3.2.3 Concentration of Constituent in the Leachate (C_L) | 3-5 |
| 3.3 CONSTITUENT PHYSICAL AND CHEMICAL CHARACTERISTICS | 3-7 |
| 3.3.1 All Constituents | 3-7 |
| 3.3.1.1 Molecular Diffusion Coefficient (D_i) | 3-8 |
| 3.3.1.2 Drinking Water Standard (DWS) | 3-8 |
| 3.3.1.3 Molecular Weight (MW) | 3-9 |

TABLE OF CONTENTS (continued)

| | Page |
|---------------------------------------------------------------|------|
| 3.3.2 Organic Constituents | 3-10 |
| 3.3.2.1 Organic Carbon Partition Coefficient (k_{oc}) ... | 3-10 |
| 3.3.2.2 Parameters Related to Chemical Hydrolysis . | 3-12 |
| 3.3.2.2.1 Dissolved Phase Hydrolysis | |
| Decay Rate (λ_1) | 3-13 |
| 3.3.2.2.2 Sorbed Phase Hydrolysis | |
| Decay Rate (λ_2) | 3-14 |
| 3.3.2.2.3 Acid-Catalyzed Hydrolysis Rate | |
| Constant (K_a^{Tr}) | 3-14 |
| 3.3.2.2.4 Neutral Hydrolysis Rate | |
| Constant (K_n^{Tr}) | 3-16 |
| 3.3.2.2.5 Base-Catalyzed Hydrolysis Rate | |
| Constant (K_b^{Tr}) | 3-17 |
| 3.3.2.2.6 Reference Temperature (T_r) | 3-17 |
| 3.3.2.3 Parameters Related to Hydrolysis | |
| Transformation Products | 3-18 |
| 3.3.2.3.1 Daughter Species Number (ℓ) | 3-18 |
| 3.3.2.3.2 Number of Immediate Parents (M_i) .. | 3-19 |
| 3.3.2.3.3 Species Number(s) of Immediate | |
| Parent(s) ($m_i(i), i = 1, M_i$) | 3-20 |
| 3.3.2.3.4 Fraction of the Parent Species (ξ_{em}) .. | 3-21 |
| 3.3.3 Metals | 3-22 |
| 3.3.3.1 Empirical K_d Data | 3-23 |
| 3.3.3.1.1 K_d Data Compiled from a | |
| Literature Survey | 3-23 |
| 3.3.3.1.2 pH-based Isotherms | 3-24 |
| 3.3.3.2 MINTEQA2-Derived Sorption Isotherm Data . | 3-25 |
| 3.3.3.2.1 Metal Identification Number (ID) | 3-27 |
| 3.3.3.2.2 Soil and Aquifer pH (pH) | 3-29 |
| 3.3.3.2.3 Iron-Hydroxide Content (FeOx) | 3-30 |
| 3.3.3.2.4 Leachate Organic Matter (LOM) | 3-31 |
| 3.3.3.2.5 Percent Organic Matter (%OM) | 3-32 |
| 3.3.3.2.6 Fraction Organic Carbon (f_{oc}) | 3-34 |
| 3.3.3.2.7 Ground-water Type (IGWT) | 3-35 |
| 4.0 INFILTRATION AND RECHARGE PARAMETERS | 4-1 |
| 4.1 INFILTRATION AND RECHARGE PARAMETERS | 4-1 |
| 4.2 CLIMATE CENTER INDEX (ICLR) | 4-2 |
| 4.3 INFILTRATION RATES | 4-6 |
| 4.3.1 Landfill Infiltration Rate (I) | 4-7 |
| 4.3.2 Waste Pile Infiltration Rate (I) | 4-9 |
| 4.3.3 Land Application Unit Infiltration Rate (I) | 4-11 |
| 4.3.4 Surface Impoundment Infiltration Rate (I) | 4-13 |
| 4.4 RECHARGE RATE (I_R) | 4-15 |

TABLE OF CONTENTS (continued)

| | Page |
|----------------------------------------------------------------------------------------------|------|
| 5.0 HYDROGEOLOGICAL PARAMETERS | 5-1 |
| 5.1 HYDROGEOLOGICAL PARAMETERS | 5-2 |
| 5.2 UNSATURATED ZONE PARAMETERS | 5-2 |
| 5.2.1 Unsaturated Zone Thickness (D_u) | 5-2 |
| 5.2.2 Soil Type (ISTYPE) | 5-6 |
| 5.2.3 Soil Hydraulic Characteristics | 5-7 |
| 5.2.3.1 Soil Hydraulic Conductivity (K_s) | 5-7 |
| 5.2.3.2 Alpha (α) | 5-11 |
| 5.2.3.3 Beta (β) | 5-12 |
| 5.2.3.4 Residual Water Content (θ_r) | 5-13 |
| 5.2.3.5 Saturated Water Content (θ_s) | 5-15 |
| 5.2.3.6 Soil Bulk Density (ρ_b) | 5-16 |
| 5.2.3.7 Percent Organic Matter (%OM) | 5-17 |
| 5.2.4 Unsaturated Zone Dispersivity (α_{LW}) | 5-19 |
| 5.2.5 Freundlich Adsorption Isotherm Parameters | 5-21 |
| 5.2.5.1 Leading Coefficient of Freundlich Isotherm for Unsaturated Zone (K_d) | 5-23 |
| 5.2.5.2 Exponent of Freundlich Isotherm for Unsaturated Zone (η) | 5-24 |
| 5.2.6 Chemical Degradation Rate Coefficient for Unsaturated Zone (λ_{cu}) | 5-25 |
| 5.2.7 Biodegradation Rate Coefficient for Unsaturated Zone (λ_{bu}) | 5-26 |
| 5.2.8 Soil Temperature (T) | 5-26 |
| 5.2.9 Soil pH (pH) | 5-28 |
| 5.3 SATURATED ZONE PARAMETERS | 5-29 |
| 5.3.1 Particle Diameter (d) | 5-29 |
| 5.3.2 Porosity (ϕ) | 5-31 |
| 5.3.3 Bulk Density (ρ_b) | 5-33 |
| 5.3.4 Aquifer Characteristics | 5-35 |
| 5.3.4.1 Methodology | 5-38 |
| 5.3.4.2 Hydrogeologic Environment (IGWR) | 5-39 |
| 5.3.4.3 Saturated Zone Thickness (B) | 5-43 |
| 5.3.4.4 Hydraulic Conductivity (K) | 5-45 |
| 5.3.4.5 Regional Hydraulic Gradient (r) | 5-47 |
| 5.3.5 Seepage Velocity (V_x) | 5-49 |
| 5.3.6 Anisotropy Ratio (A_r) | 5-51 |
| 5.3.7 Retardation Coefficient for the Saturated Zone (R^s) | 5-52 |
| 5.3.8 Dispersivity | 5-53 |
| 5.3.8.1 Longitudinal Dispersivity (α_L) | 5-54 |
| 5.3.8.2 Horizontal Transverse Dispersivity (α_T) | 5-56 |
| 5.3.8.3 Vertical Dispersivity (α_v) | 5-58 |
| 5.3.9 Aquifer Temperature (T) | 5-59 |
| 5.3.10 Ground-water pH (pH) | 5-61 |
| 5.3.11 Fractional Organic Carbon Content (f_{oc}^s) | 5-63 |

TABLE OF CONTENTS (continued)

| | Page |
|-----------------------------------------------------------------------------------------|------|
| 5.3.12 Leading Coefficient of Freundlich Isotherm for Saturated Zone (K_d^s) | 5-64 |
| 5.3.13 Exponent of Freundlich Isotherm for Saturated Zone (η^s) | 5-66 |
| 5.3.14 Chemical Degradation Rate Coefficient for Saturated Zone (λ_c^s) | 5-67 |
| 5.3.15 Biodegradation Rate Coefficient for Saturated Zone (λ_b^s) | 5-68 |
| 6.0 RECEPTOR WELL PARAMETERS | 6-1 |
| 6.1 RECEPTOR WELL PARAMETERS | 6-1 |
| 6.2 RADIAL DISTANCE TO RECEPTOR WELL (R_{rw}) | 6-4 |
| 6.3 ANGLE OF WELL OFF OF PLUME CENTERLINE (θ_{rw}) | 6-5 |
| 6.4 DOWN-GRADIENT DISTANCE TO RECEPTOR WELL (x_{rw}) ... | 6-6 |
| 6.5 WELL DISTANCE FROM PLUME CENTERLINE (y_{rw}) | 6-8 |
| 6.6 DEPTH OF INTAKE POINT BELOW WATERTABLE (z_{rw}) | 6-10 |
| 6.7 AVERAGING PERIOD FOR Ground-water CONCENTRATION AT RECEPTOR WELL (t_d) | 6-11 |
| 7.0 REFERENCES | 7-1 |
| APPENDIX A: Determination of Infiltration and Recharge Rates | |
| APPENDIX B: Nonlinear Sorption Isotherms Calculated Using the MINTEQA2 Model | |
| APPENDIX C: Physical and Chemical Properties for Organic Constituents | |
| APPENDIX D: WMU and Hydrogeologic Environment Databases | |

LIST OF FIGURES

| | | Page |
|------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| Figure 2.1 | WMU Types Modeled in EPACMTP | 2-3 |
| Figure 2.2 | Geographic Locations of Landfill WMUs | 2-6 |
| Figure 2.3 | Geographic Locations of Surface Impoundment WMUs | 2-7 |
| Figure 2.4 | Geographic Locations of Waste Pile WMUs | 2-8 |
| Figure 2.5 | Geographic Locations of Land Application Unit WMUs | 2-9 |
| Figure 2.6 | WMU with Base Elevation below Ground Surface | 2-13 |
| Figure 2.7 | Schematic Cross-Section View of SI Unit | 2-17 |
| Figure 4.1 | Locations of EPACMTP Climate Stations | 4-5 |
| Figure 5.1 | Ground-water Temperature Distribution for Shallow Aquifers in the United States (from Todd, 1980) | 5-27 |
| Figure 5.2 | Geographical distribution of sites in the API-HGDB data base (Reproduced from API, 1989) | 5-37 |
| Figure 5.3 | Ground-water Temperature Distribution for Shallow Aquifers in the United States (from Todd, 1980) | 5-60 |
| Figure 6.1 | Schematic plan view showing procedure for determining the downstream location of the receptor well: (a) well location determined using radial distance, R_{rw} , and angle off center θ_{rw} ; and (b) well location generated uniformly within plume limit | 6-3 |

This page intentionally left blank.

LIST OF TABLES

| | | Page |
|------------|-----------------------------------------------------------------------------------------------|------|
| Table 2.1 | Waste Management Unit (Source) Parameters | 2-4 |
| Table 2.2 | Cumulative Frequency Distribution of Landfill Area | 2-11 |
| Table 2.3 | Cumulative Frequency Distribution of Landfill Depth | 2-12 |
| Table 2.4 | Cumulative Frequency Distribution of Surface Impoundment Area | 2-18 |
| Table 2.5 | Cumulative Frequency Distribution of Surface Impoundment Ponding Depth | 2-19 |
| Table 2.6 | Cumulative Frequency Distribution of Surface Impoundment Depth Below Grade | 2-22 |
| Table 2.7 | Cumulative Frequency Distribution of Leak Density for Composite-Lined SIs | 2-23 |
| Table 2.8 | Cumulative Frequency Distribution of Distance to Nearest Surface Water Body | 2-24 |
| Table 2.9 | Cumulative Frequency Distribution of Surface Impoundment Operating Life | 2-26 |
| Table 2.10 | Cumulative Frequency Distribution of Waste Pile Area | 2-27 |
| Table 2.11 | Cumulative Frequency Distribution of Land Application Unit Area | 2-30 |
| Table 3.1 | Waste and Constituent Parameters | 3-2 |
| Table 3.2 | Default Cumulative probability distribution of waste density | 3-4 |
| Table 3.3 | Empirical pH-dependent Adsorption Relations (Loux et al., 1990) | 3-25 |
| Table 3.4 | Metals that have MINTEQA2-derived Non-linear Isotherms | 3-28 |
| Table 3.5 | Probability distribution of soil and aquifer pH | 3-29 |
| Table 3.6 | Probability distribution of fraction iron hydroxide | 3-31 |
| Table 3.7 | Probability distribution of leachate organic matter | 3-32 |
| Table 3.8 | Probability distribution of percent organic matter in the unsaturated zone | 3-33 |
| Table 3.9 | Probability distribution of fraction organic carbon in the saturated zone | 3-35 |
| Table 4.1 | Climate Parameters | 4-2 |
| Table 4.2 | Climate Centers Used in the HELP Modeling to Develop Infiltration and Recharge Rates | 4-3 |
| Table 4.3 | Cumulative Frequency Distribution of Landfill Infiltration | 4-8 |
| Table 4.4 | Cumulative Frequency Distribution of Waste Pile Infiltration ... | 4-10 |
| Table 4.5 | Cumulative Frequency Distribution of Land Application Unit Infiltration | 4-12 |
| Table 4.6 | Cumulative Frequency Distribution of Surface Impoundment Infiltration | 4-14 |
| Table 4.7 | Cumulative Frequency Distribution of Regional Recharge Rate . | 4-16 |
| Table 5.1 | Hydrogeological Parameters | 5-3 |
| Table 5.2 | Cumulative Frequency Distribution of Unsaturated Zone Thickness | 5-5 |
| Table 5.3 | Default EPACMTP Soil Types | 5-6 |

LIST OF TABLES (continued)

| | | Page |
|------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| Table 5.4 | Statistical parameters for soil properties for three soil types used in the EPACMTP model (Carsel and Parrish, 1988 and Carsel et al., 1988). All values are in arithmetic space | 5-8 |
| Table 5.5 | Cumulative Frequency Distribution of Soil Hydraulic Conductivity | 5-9 |
| Table 5.6 | Descriptive statistics for van Genuchten water retention model parameters, α , β , and γ (Carsel and Parrish, 1988) | 5-10 |
| Table 5.7 | Cumulative Frequency Distribution of Alpha | 5-11 |
| Table 5.8 | Cumulative Frequency Distribution of Beta | 5-13 |
| Table 5.9 | Cumulative Frequency Distribution of Residual Water Content . | 5-14 |
| Table 5.10 | Cumulative Frequency Distribution of Saturated Water Content | 5-15 |
| Table 5.11 | Cumulative Frequency Distribution of Soil Bulk Density | 5-17 |
| Table 5.12 | Cumulative Frequency Distribution of Percent Organic Matter .. | 5-18 |
| Table 5.13 | Cumulative Frequency Distribution of Dispersivity | 5-20 |
| Table 5.14 | Compilation of field dispersivity values (EPRI, 1985) | 5-21 |
| Table 5.15 | Empirical distribution of mean particle diameter (based on Shea, 1974) | 5-30 |
| Table 5.16 | Cumulative Frequency Distribution of Particle Diameter | 5-30 |
| Table 5.17 | Ratio between effective and total porosity as a function of particle diameter (after McWorter and Sunada, 1977) | 5-33 |
| Table 5.18 | Cumulative Frequency Distribution of Bulk Density | 5-34 |
| Table 5.19 | HGDB Hydrogeologic Environments (from Newell et al., 1990) . | 5-35 |
| Table 5.20 | Cumulative Frequency Distribution of Saturated Zone Thickness | 5-44 |
| Table 5.21 | Cumulative Frequency Distribution of Hydraulic Conductivity ... | 5-45 |
| Table 5.22 | Cumulative Frequency Distribution of Regional hydraulic gradient | 5-48 |
| Table 5.23 | Cumulative Frequency Distribution of Ground-water Seepage Velocity | 5-50 |
| Table 5.24 | Probabilistic representation of longitudinal dispersivity | 5-55 |
| Table 5.25 | Cumulative Frequency Distribution of Longitudinal Dispersivity . | 5-55 |
| Table 5.26 | Cumulative Frequency Distribution of Horizontal Transverse Dispersivity | 5-57 |
| Table 5.27 | Cumulative Frequency Distribution of Vertical Dispersivity | 5-59 |
| Table 5.28 | Probability distribution of aquifer pH | 5-62 |
| Table 5.29 | Probability distribution of fraction organic carbon in the saturated zone | 5-64 |
| Table 6.1 | Receptor Well Parameters | 6-1 |
| Table 6.2 | Cumulative Probability of Distance to Nearest Receptor Well for Landfills (from EPA, 1993) | 6-4 |

ACKNOWLEDGMENTS

A large number of individuals have been involved with the development of EPACMTP since its inception in the early 1990's. Dr. Zubair A. Saleem of the U.S. EPA, Office of Solid Waste (EPA/OSW) has coordinated and guided the development of EPACMTP throughout much of this period. Ms. Ann Johnson, Mr. David Cozzie, and Mr. Timothy Taylor provided review for the development of this background document. This report was prepared by the staffs of HydroGeoLogic, Inc. (HGL), and Resource Management Concepts, Inc. (RMC), under EPA Contract Number 68-W-01-004.

This page intentionally left blank.

LIST OF SYMBOLS AND ABBREVIATIONS

| Symbol | Definition | Section |
|------------|-------------------------------------------------------------------------------|----------------------------|
| A_r | anisotropy ratio = K_x/K_z | 5.3.6 |
| A_w | area of a WMU (m^2) | 2.3.1, 2.4.1, 2.5.1, 2.6.1 |
| B | thickness of the saturated zone (m) | 5.3.4.3, 6.6 |
| C_d | metal concentration in the dissolved phase at equilibrium (mg/L) | 3.3.3.2 |
| C_s | metal concentration in the sorbed phase at equilibrium (mg/L) | 3.3.3.2 |
| C_L | leachate concentration (mg/L) | 3.2.3 |
| CV | coefficient of variation (%) | 5.2.4 |
| C_w | constituent concentration in the waste (mg/kg) | 3.2.2 |
| d_{BG} | depth below grade of WMU (m) | 2.3.3, 2.4.6, 2.5.3 |
| D_i | molecular diffusion coefficient in free water for species i (m^2/yr) | 3.3.1.1 |
| D_{LF} | landfill depth (m) | 2.3.2 |
| D_{lin} | liner thickness (m) | 2.4.4 |
| D_s | total sediment thickness (m) | 2.4.3 |
| D_u | total depth of the unsaturated zone (m) | 5.2.1 |
| D^* | effective molecular diffusion coefficient for species of interest (m^2/y) | 6.6 |
| DWS | drinking water standard (mg/L) | 3.3.1.2 |
| E_a | Arrhenius activation energy (Kcal/mol) | 3.3.2.2.3 |
| F_h | volume fraction of the waste in the landfill at time of closure (m^3/m^3) | 2.3.4 |
| FeOx | iron hydroxide content (wt % Fe) | 3.3.3.2.3 |
| f_{oc} | fractional organic carbon content (dimensionless) | 3.3.3.2.6 |
| f_{oc}^a | fractional organic carbon content of the aquifer material (dimensionless) | 5.3.11 |
| g | gravitational acceleration (m/s^2) | 5.3.4.4 |
| $[H^+]$ | hydrogen ion concentration (mol/L) | 3.3.2.2.1 |
| H_p | SI ponding depth (m) | 2.4.2 |
| I | annual infiltration rate through the source (m/y) | 4.3.1, 4.3.2, 4.3.3, 4.3.4 |
| ICLR | climate center index | 4.2 |
| ID | metal identification number (unitless) | 3.3.3.2.1 |
| IGWR | hydrogeologic environment index (unitless) | 3.3.3.2.7, 5.3.4.2 |
| IGWT | ground-water type: carbonate/non-carbonate (unitless) | 3.3.3.2.7 |
| ISTYPE | soil type | 5.2.2 |

LIST OF SYMBOLS AND ABBREVIATIONS (continued)

| Symbol | Definition | Section |
|------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------|
| IWLOC | R_{rw} (Receptor well) origination method | 6.5 |
| I_R | effective recharge rate outside the strip source area (m/y) or recharge rate outside the source area (m/y) | 4.4 |
| J | symbol used to denote a for the acid-catalyzed reaction, b for the base-catalyzed reaction and n for the neutral reaction | 3.3.2.2.3 |
| K | hydraulic conductivity (m/yr) | 5.3.4.4 |
| k_f | nonlinear Freundlich parameter for the unsaturated zone (mg constituent/kg dry soil) | 5.2.9 |
| K_a^T | acid-catalyzed hydrolysis rate constant (1/(mol.yr)) | 3.3.2.2.1 |
| K_a^{Tr} | acid-catalyzed hydrolysis rate constant at reference temperature (1/(mol.yr)) | 3.3.2.2.3 |
| K_b^T | base-catalyzed hydrolysis rate constant (1/(mol.yr)) | 3.3.2.2.2 |
| K_b^{Tr} | base-catalyzed hydrolysis rate constant at reference temperature (1/(mol.yr)) | 3.3.2.2.5 |
| K_d | distribution (solid-aqueous phase) partition coefficient in the unsaturated zone (cm ³ /g) (Freundlich Coefficient) | 3.3.3, 5.2.8 |
| K_d^s | solid-liquid distribution coefficient of the aquifer (cm ³ /g) | 5.3.12 |
| K_J^T | hydrolysis rate constant for reaction process J, corrected for the subsurface temperature T (1/(mol.yr) for the acid- and base-catalyzed reactions; 1/yr for the neutral reaction) | 3.3.2.2.3 |
| K_J^{Tr} | hydrolysis rate constant for reaction process J, measured at the reference temperature T_r (1/(mol.yr) for the acid- and base-catalyzed reactions; 1/yr for the neutral reaction) | 3.3.2.2.3 |
| K_{ln} | saturated hydraulic conductivity of liner (m/y) | 2.4.5 |
| K_n^T | neutral hydrolysis rate constant at (1/yr) | 3.3.2.2.1 |
| K_n^{Tr} | neutral hydrolysis rate constant at reference temperature (1/yr) | 3.3.2.2.3 |
| k_d | soil-water partition coefficient (L/kg) | 3.3.2.1 |
| k_{oc} | constituent-specific organic carbon partition coefficient (cm ³ /g) | 3.3.2.1 |
| k_{ow} | octanol-water partition coefficient (cm ³ /g) | 3.3.2.1 |
| K_s | saturated hydraulic conductivity (cm/hr) | 5.2.3 |
| K_x | hydraulic conductivity in the x direction (m/y) | 5.3.5 |
| K_y | hydraulic conductivity in the horizontal transverse (y) direction (m/y) | 5.3.6 |
| i | daughter species number | 3.3.2.3.1 |
| LOM | leachate organic acid concentration (mol/L) | 3.3.3.2.4 |
| LYCHK | constraint on well distance from plume centerline | 6.5 |
| LZCHK | constraint on depth of intake point below water table | 6.6 |

LIST OF SYMBOLS AND ABBREVIATIONS (continued)

| Symbol | Definition | Section |
|-----------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------|
| i | daughter species number | 3.3.2.3.1 |
| LN | log normal distribution | 5.2.2 |
| M | number of immediate parent species | 3.3.2.3.2 |
| m | species number of immediate parent | 3.3.2.3.3 |
| MW_i | molecular weight of species i (g/mol.) | 3.3.1.3 |
| N | sample size | 5.2.4 |
| NO | Normal distribution | 5.2.2 |
| $[OH]$ | hydroxyl ion concentration (mol/L) | 3.3.2.2.2 |
| %OM | percent organic matter (dimensionless) | 3.3.3.2.5, 5.2.7 |
| PWS | waste volume (m^3) | 2.3.5 |
| pH | ground-water pH (standard units) | 3.3.3.2.2, 5.2.10, 5.2.13 |
| Q_1^F | background ground-water flux (m^2/y) | 6.6 |
| Q_4^F | recharge flux downgradient of the source (m^2/y) | 6.6 |
| r | regional hydraulic gradient (m/m) | 5.3.4.5 |
| R_g | Universal Gas Constant (1.987E-3 Kcal/deg-mol) | 3.3.2.2.3 |
| R_i | retardation factor for species i (dimensionless) | 3.3.2.1 |
| R_{rw} | radial distance between waste management unit and well (m) | 6.2 |
| R_s | distance between the center of the source and the nearest downgradient boundary where the boundary location has no perceptible effects on the heads near the source (m) | 2.4.8 |
| R^s | retardation coefficient (dimensionless) | 5.3.7 |
| SB | log ratio distribution | 5.2.2 |
| SD | standard deviation | 5.2.4 |
| T_r | hydrolysis reference temperature ($^{\circ}C$) | 3.3.2.2.6 |
| T | ground-water/subsurface temperature ($^{\circ}C$) | 3.3.2.2.3, 5.2.12, 5.3.9 |
| t_d | exposure time interval of interest (yr) | 6.8 |
| t_p | leaching duration (yr) | 2.3.6, 2.4.9, 2.5.2, 2.6.2 |
| V_x | longitudinal ground-water (seepage) velocity (in the x-direction) (m/y) | 5.3.5 |
| \bar{X} | sample mean | 5.2.4 |
| x | principal Cartesian coordinate along the regional flow direction (m) | 6.4 |
| x_{rw} | distance from the downgradient boundary of the WMU to the receptor well (m) | 6.4 |

LIST OF SYMBOLS AND ABBREVIATIONS (continued)

| Symbol | Definition | Section |
|----------------------|--------------------------------------------------------------------------------------------------------|----------------|
| x_t | average travel distance in the x direction (m) | 5.3.8.1 |
| x_w | length of the WMU in the x-direction (parallel to ground-water flow) (m) | 6.6 |
| y | principal Cartesian coordinate normal to the flow direction, or distance from the plume centerline (m) | 6.5 |
| y_D | source width along the y-axis (m) | 6.5 |
| y_{rw} | Cartesian coordinate of the receptor well in the y-direction (m) | 6.5 |
| z | principal Cartesian coordinate in the vertical direction (m) | 6.6 |
| z_{rw}^* | z-coordinate of the receptor well positive downward from the water table(m) | 6.6 |
| GREEK SYMBOLS | | |
| α | van Genuchten soil-specific shape parameter (1/cm) | 5.2.2, 5.2.4.1 |
| α_L | longitudinal dispersivity of the aquifer (m) | 5.3.8.1, 6.6 |
| α_{Lu} | longitudinal dispersivity in the unsaturated zone (m) | 5.2.6 |
| α_{ref} | reference longitudinal dispersivity, as determined from the probabilistic distribution (m) | 5.3.8.1 |
| α_T | horizontal transverse dispersivity (m) | 5.3.8.2, 6.5 |
| α_V | vertical transverse dispersivity (m) | 5.3.8.2, 6.6 |
| β | van Genuchten soil-specific shape parameter (dimensionless) | 5.2.2, 5.2.4.2 |
| γ | van Genuchten soil-specific shape parameter (dimensionless) = $1 - 1/\beta$ | 5.2.4 |
| η | species-specific nonlinear Freundlich exponent for the unsaturated zone | 5.2.9 |
| η^s | Freundlich exponent for the saturated zone (dimensionless) | 5.3.13 |
| θ | soil water content (dimensionless) | 3.3.2.1 |
| θ_r | residual soil water content (dimensionless) | 5.2.4.3 |
| θ_{rw} | angle measured counter-clockwise from the plume centerline (degrees) | 6.3 |
| θ_s | saturated soil water content (dimensionless) | 5.2.4.4 |
| λ | overall first-order hydrolysis transformation rate(1/y) | 3.3.2.2 |
| λ_1 | hydrolysis constant for dissolved phase (1/y) | 3.3.2.2.2 |
| λ_2 | hydrolysis constant for sorbed phase (1/y) | 3.3.2.2.1 |
| λ_b^s | biodegradation rate in the saturated zone (1/yr) | 5.3.15 |
| λ_c^s | chemical degradation rate in the saturated zone (1/yr) | 5.3.14 |
| λ_{bu} | transformation coefficient due to biological transformation (1/y) | 5.2.11 |

LIST OF SYMBOLS AND ABBREVIATIONS (continued)

| Symbol | Definition | Section |
|----------------|-------------------------------------------------------------------------------------------------------------|----------------|
| λ_{cw} | transformation coefficient due to chemical transformation (1/y) | 5.2.10 |
| μ | dynamic viscosity of water (N-s/m ²) | 5.3.4.4 |
| ξ_m | stoichiometric fraction of parent m that degrades into daughter <i>l</i> /speciation factor (dimensionless) | 3.3.2.3.4 |
| ρ | density of water (kg/m ³) | 5.3.4.4 |
| ρ_b | bulk density of the aquifer (g/cm ³) | 3.3.2.1, 5.3.3 |
| ρ_{bu} | soil bulk density of the unsaturated zone (g/cm ³) | 5.2.5 |
| ϕ | porosity/water content in the unsaturated zone (dimensionless) | 3.3.2.2, 5.3.2 |
| ϕ_e | effective porosity of the saturated zone (dimensionless) | 6.6 |

This page intentionally left blank.

1.0 INTRODUCTION

This document provides background information on the parameters and data sources used in EPA's Composite Model for Leachate Migration with Transformation Products (EPACMTP). EPACMTP is a subsurface fate and transport model used by EPA's Office of Solid Waste in the RCRA program to establish regulatory levels for concentrations of constituents in wastes managed in land-based units. This document describes the EPACMTP input parameters, data sources and default parameter values and distributions that EPA has assembled for its use of EPACMTP as a ground-water assessment tool. EPA has also developed a complementary document, the *EPACMTP Technical Background Document* (U.S. EPA, 2003a), which presents the mathematical formulation, assumptions and solution methods underlying the EPACMTP. These two documents together are the primary reference documents for EPACMTP, and are intended to be used together.

The remainder of this section describes how this background document is organized. The parameters and data are documented in six main categories, as follows:

- Section 2 describes the Waste Management Unit (Source) Parameters;
- Section 3 describes the Waste and Constituent Parameters;
- Section 4 describes the Infiltration and Recharge Parameters;
- Section 5 describes the Subsurface Parameters;
- Section 6 describes the Ground-water Well Location Parameters; and
- Section 7 provides a list of References

Several appendices provide complete listings of data distributions for a number of the EPACMTP input parameters.

To facilitate the cross-referencing of information between this document and the *EPACMTP Technical Background Document* (U.S. EPA, 2003a), each section begins with a table that lists the parameters described in that section, and provides, for each parameter, a reference to the equation(s) and/or section number in the *EPACMTP Technical Background Document* (U.S. EPA, 2003a) that describes how each parameter is used in the EPACMTP computer code.

This page intentionally left blank.

2.0 WASTE MANAGEMENT UNIT (SOURCE) PARAMETERS

EPACMTP can simulate the subsurface migration of leachate from four different types of waste management units (WMUs). Each of the four unit types reflects waste management practices that are likely to occur at Industrial Subtitle D facilities. The WMU can be a landfill, a waste pile, a surface impoundment, or a land application unit. The latter is also sometimes called a land treatment unit. Figure 2.1 presents schematic diagrams of the different types of WMUs modeled in EPACMTP.

Landfill. Landfills (LFs) are facilities for the final disposal of solid waste on land. EPACMTP is typically used to model closed LFs with an earthen cover. LFs may be unlined, or they may have some type of engineered liner, but the model assumes no leachate collection system exists underneath the 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 EPACMTP simulation is the time at which 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 LF. The type of liner that is present (if any) controls, to a large extent, the amount of leachate that is released over time from the unit. LFs are modeled in EPACMTP as WMUs with a rectangular footprint and a uniform depth. The EPACMTP model does not explicitly account for any loss processes occurring during the unit's active life (for example, due to leaching, volatilization, runoff or erosion, or biochemical degradation), however these processes will be taken into account if the input value for leachate concentration is based on a site-specific chemical analysis of the waste (such as results from a Toxicity Characteristic Leaching Procedure (TCLP) or Synthetic Precipitation Leaching Procedure (SPLP) analysis). The leachate concentration used as a model input is the expected initial leachate concentration when the waste is 'fresh'. Because the LF is closed, the concentration of the waste constituents will diminish with time due to depletion of the landfilled wastes; the model is equipped to simulate this "depleting source" scenario for LFs, but other source options are available, and are explained in Section 2.3.

Surface Impoundment. A surface impoundment (SI) is a WMU which is designed to hold liquid waste or wastes containing free liquid. SIs may be either ground level or below ground level flow-through units. They may be unlined, or they may have some type of engineered liner. Release of leachate is driven by the ponding of water in the impoundment, which creates a hydraulic head gradient across the barrier underneath the unit. The EPACMTP model considers a SI to be a temporary WMU with a finite operational life. 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, there is a clean closure of the SI). SIs are modeled as pulse-type sources; leaching occurs at a constant leachate concentration over a fixed period of time equal to the unit's operating life. The EPACMTP model assumes a constant

ponding depth (depth of waste water in SI) during the operational life (see Section 2.2.4).

Waste Pile. Waste piles (WPs) are typically used as temporary storage or treatment units for solid wastes. Due to their temporary nature, they are typically not covered. Similar to LFs, WPs may be unlined, or they may have some type of engineered liner. EPACMTP assumes that WPs have a fixed operational life, after which the WP is removed. Thus, WPs are modeled 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 (see Section 2.5.2).

Land Application Unit. Land application units (LAUs) (or land treatment units) are areas of land receiving regular applications of waste that is either tilled directly into the soil or sprayed onto the soil and then tilled. EPACMTP models the leaching of wastes after they have been tilled with soil. EPACMTP does not account for the losses due to volatilization during or after waste application. LAUs are only evaluated for the no-liner scenario because liners are not typically used at this type of facility. EPACMTP assumes that an LAU is a temporary WMU with a fixed operational life, after which the waste is no longer land-applied. Thus, LAUs are modeled in EPACMTP as a constant pulse-type leachate source, with a leaching duration equal to the unit's operational life (see Section 2.6.2).

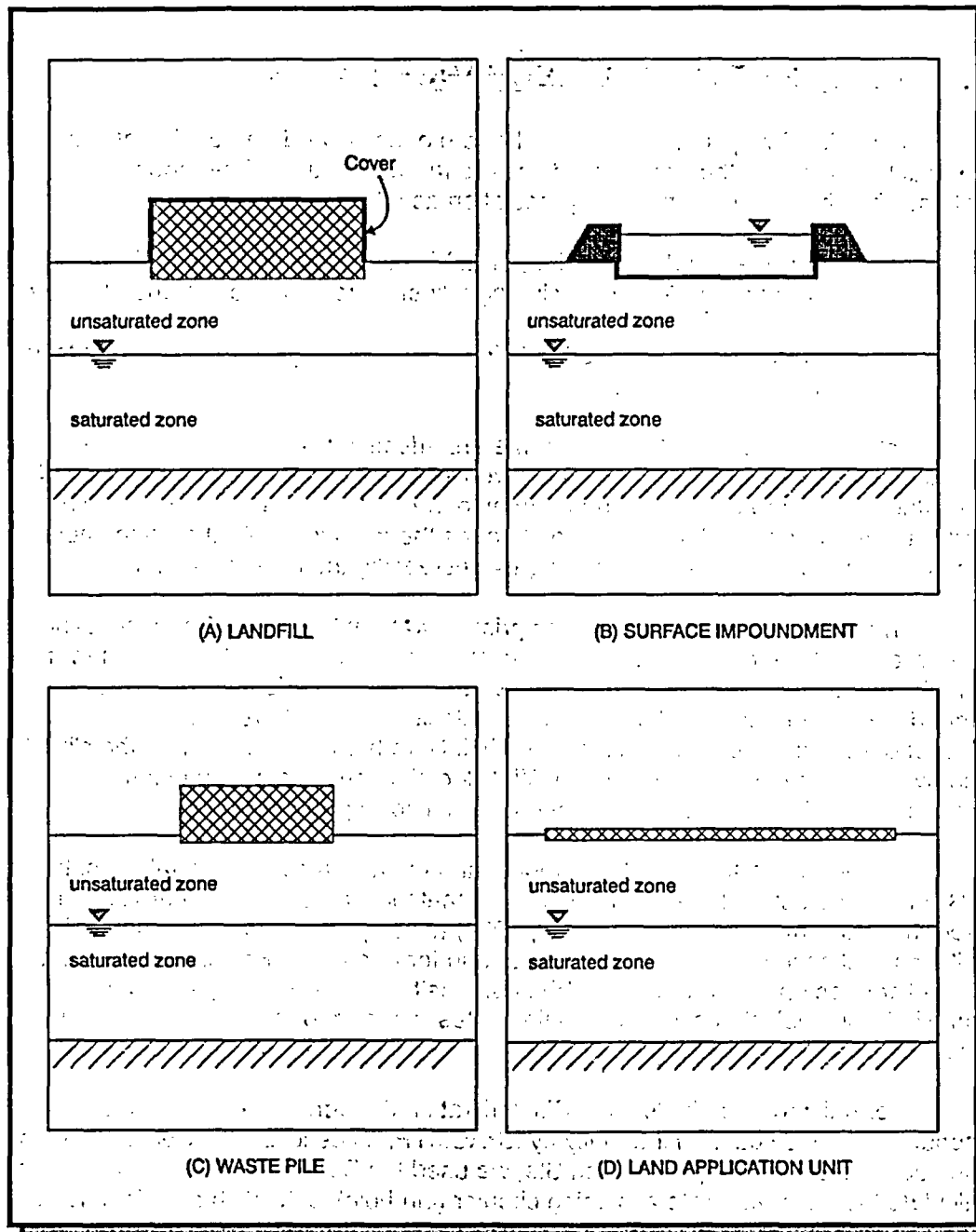


Figure 2.1 WMU Types Modeled in EPACMTP.

APPENDIX A

DETERMINATION OF INFILTRATION AND RECHARGE RATES

A.1 INFILTRATION AND RECHARGE RATES

EPACMTP 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 as 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 EPACMTP, using a different default liner scenario changes the modeled 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 run-off, and regional soil type.

In developing the EPACMTP model and the accompanying databases, the U.S. EPA 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 4.3.4 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 A.1 through A.4 summarize the liner assumptions and infiltration rate calculations for LFs, WPs, SIs, and LAUs. The remainder of this appendix provides background on how we 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 a detailed discussion of how we developed infiltration rates for different default liner designs for each type of WMU.

A.1.1 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. 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.

HELP Versions 3.03 and 3.07 (which include WMU- and liner-specific distributions of infiltration rates) were used to construct the EPACMTP site data files. We started with an existing database of no-liner infiltration rates for LFs, WPs and LAUs. Also existing were recharge rates for 97 climate stations in the lower 48 contiguous United States (ABB, 1995), that are representative of 25 specific climatic regions (developed with HELP version 3.03). We then added five climate stations (located in Alaska, Hawaii, and Puerto Rico) to ensure coverage throughout all of the United States. Figure A.1 shows the locations of the 102 climate stations.

The current version of HELP (version 3.07) was used for the modeling of the additional climate stations 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 that are presented in Tables A.11 to A.14. For instance, Table A.11 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.

Table A.1 Methodology Used to Compute Infiltration for LFs

| | 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. |
| EPACMTP 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 A.2 Methodology Used to Compute Infiltration for SIs

| | 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. |
| EPACMTP 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 |

Table A.3 Methodology Used to Compute Infiltration for WPs

| | 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. |
| EPACMTP 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 A.4 Methodology Used to Compute Infiltration for LAUs

| | 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 |
| EPACMTP Infiltration Rate | Monte Carlo selection from HELP generated location specific values. | N/A | N/A |