SUPPLEMENTAL BACKGROUND DOCUMENT FOR THE NONGROUNDWATER RISK ASSESSMENT FOR THE PETROLEUM WASTE LISTING INTERIM NOTICE OF DATA AVAILABILITY

1.0 BACKGROUND

On November 20, 1995, the U.S. Environmental Protection Agency (EPA) proposed to amend the hazardous waste management regulations under the Resource Conservation and Recovery Act (RCRA) by listing as hazardous wastes three residuals from petroleum refining processes for which certain disposal practices may present an unacceptable risk to human health or the environment (60 FR 57747). The Agency proposed not to list as hazardous 11 process residuals. EPA received a number of comments on the risk analysis performed in support of the proposed rule. This document describes new or expanded analyses performed in response to a number of specific comments received regarding the nongroundwater risk assessment. Following is a brief summary of the comments addressed by this analysis.

- Waste stream volumes and land treatment unit (LTU) sizes. Comments on the proposed rule pointed out that the majority of active LTUs receiving the petroleum residuals are, in fact, Subtitle C units, and that such units must meet strict runon/runoff control permit requirements. Therefore, the commenters claimed that EPA's assumption on no runon/runoff controls for these units is incorrect. To respond to this comment, EPA examined the status of all land treatment units modeled and limited the unit characteristics used in risk modeling to those units that are not permitted hazardous waste units. EPA also modified the volume data somewhat to remove from modeling consideration all waste volumes that were classified as hazardous waste and could not be sent to a nonhazardous land treatment unit.

- Several commenters questioned the transport of soil from the land treatment area to the receptors as not being physically possible as described by EPA. Therefore, the commenters believed there to be no direct or indirect exposure to these subpopulations from soils. To respond to these comments, EPA revised its overland transport equations.

- Two commenters noted that EPA did not consider biodegradation of polynuclear aromatic hydrocarbons (PAHs) in soils at the receptor site. Commenters asserted that biodegradation can significantly affect long-term estimates of soil concentrations and therefore the failure to consider this loss mechanism may result in substantial overstatements of risks resulting from soil exposures. To respond to these comments, EPA included biodegradation in all soils.

- Commenters noted that EPA incorrectly calculated risks to home gardeners from consumption of root vegetables. The procedures used to compute the exposure from ingestion of soil and aboveground and belowground produce grown in these soils is also flawed. To respond to these comments, EPA reviewed all ingestion rate input parameters and corrected the values used in the analysis where necessary.

- Commenters noted that EPA failed to consider risks from dermal and inhalation exposure to groundwater contaminants such as benzene from household use of tapwater for activities such as bathing and showering. To respond to this comment, EPA reviewed numerous shower inhalation models and included a model for estimating risk through this pathway.

- Commenters noted that multiple petroleum wastes are often disposed of in the same treatment or disposal unit; therefore, risk estimates should consider this codisposal scenario in estimating risk of exposure to petroleum waste streams. To respond to this comment, EPA has evaluated specific codisposal scenarios to determine risk from disposal of multiple wastes in a single land treatment unit.

Changes to the nongroundwater risk assessment for petroleum refining waste streams in response to comments summarized above are discussed in the following sections:

- Section 2.0 – waste stream and waste management unit characteristics
- Section 3.0 – soil erosion and the use of the Universal Soil Loss Equation (USLE) for estimating soil concentrations in adjacent receptor sites
- Section 4.0 – biodegradation of PAH in soil
- Section 5.0 – changes to exposure factors used in the analysis.

The following sections present new analyses that have been added to the risk assessment in response to public comments:

- Section 6.0 – noningestion exposures to contaminated groundwater through bathing and showering
- Section 7.0 – risk assessment methodology for codisposal of petroleum waste streams in nonhazardous land treatment units.

In addition, the management in nonhazardous land treatment units of off-specification products and fines is evaluated for the first time. Application of this waste stream to land treatment units was not evaluated for the proposed rule because this management practice was not considered prevalent. However, as a result of public comments, EPA evaluated codisposal of petroleum refining wastes in nonhazardous land treatment units. Because this waste stream is now included in a codisposal scenario, it has been evaluated as a single waste stream, although management in land treatment units is not a common practice (i.e., according to EPA, a maximum quantity of 34 metric tons (t) of off-specification products and fines was managed in at least three onsite units and 21 t of this waste was managed in a single offsite land treatment unit in 1992).

The results of the revised risk analyses are presented in the following sections:

- Section 8.0 – crude oil tank sludge
- Section 9.0 – clarified slurry oil sludge
- Section 10.0 – unleaded gasoline tank sludge
- Section 11.0 – sulfur complex sludge
- Section 12.0 – hydrofluoric acid alkylation sludge
- Section 13.0 – sulfuric acid alkylation sludge
- Section 14.0 – off specification products and fines
- Section 15.0 – codisposal of petroleum wastes.

Appendix A presents the revised equations used for estimating soil erosion in the revised integrated setting (A-1 through A-4) and the equations added to the analysis for estimating risk through inhalation exposure to household use of groundwater (A-5). Appendix B presents the compound-specific input parameters for PAH compounds required for the risk analysis, including soil biodegradation rates applicable to nonamended soils at receptor locations.

2.0 WASTE STREAM AND WASTE MANAGEMENT UNIT CHARACTERIZATION

Waste stream and waste management unit characteristics are the basis for all potential release scenarios. The changes in these data as a result of EPA's reevaluation are presented in this section.

2.1 Waste Stream Characteristics

Waste stream quantity distributions have been recalculated to remove waste quantities that were already classified and managed as hazardous. All remaining waste stream characteristics (e.g., constituent concentration, percent organic carbon) remained identical to those presented in the background document for risk assessment supporting the proposed rule. Table 2.1 presents the recalculation of waste quantity distributions sent to land treatment units with hazardous wastes removed.

2.2 Characterization of Onsite Land Treatment Units

Onsite land treatment unit area distributions have been recalculated to remove land treatment units already permitted as hazardous (SAIC, 1997). All remaining waste management unit characteristics remain identical to those presented in the background document for risk assessment supporting the proposed rule. Table 2.2 presents the recalculation of land treatment unit areas with those permitted as hazardous waste facilities removed. No facilities reported disposing of sulfuric acid alkylation sludge in onsite nonhazardous land treatment units in the 3007 Questionnaire data; however, any facility that reported the presence of an operational sulfuric acid alkylation unit and the presence of an onsite nonhazardous land treatment unit that could be used for disposal of this waste were considered appropriate for disposal of this waste.

Table 2.1 Recalculated Quantity Distributions of Wastes Managed in Land Treatment Units with Hazardous Wastes Removed

Waste Stream	Onsite Waste Quantities (t)		Offsite Waste Quantities (t)	
	50th Percentile	90th Percentile	50th Percentile	90th Percentile
Crude Oil Tank Sludge	**29** **(38)**[a]	**181** **(1,839)**	**54** **(44)**	100[b]
Clarified Slurry Oil Sludge	**278** **(191)**	2,520	1,195	2,278
Unleaded Gasoline Tank Sludge	2	57	**48** **(2)**	94
Sulfur Complex Sludge	2	50	10	18
Hydrofluoric Acid Alkylation Sludge	6	542	686	686
Sulfuric Acid Alkylation Sludge	280	280	100	100
Off-Specification Products and Fines	**1**[c]	**34**[c]	**21**[c]	**21**[c]

[a] Revised volumes are boldfaced; volumes used in November 20, 1995, proposal are given in parentheses.
[b] Volumes in standard (nonbold) typeface have not changed from proposal.
[c] Not modeled for proposal.

Table 2.2 Revised Distribution of Areas for Onsite Land Treatment Units

Waste Stream	Land Treatment Unit Area (Acres)		
	10th Percentile	50th Percentile	90th Percentile
Crude Oil Tank Sludge	3	6.3	15.8
Clarified Slurry Oil Sludge	15.8	15.8	15.8
Unleaded Gasoline Tank Sludge	0.6	5	15.8
Sulfur Complex Sludge	3	7	7.5
Hydrofluoric Acid Alkylation Sludge	0.6	3	7
Sulfuric Acid Alkylation Sludge [a]	15.8	15.8	15.8
Off-Specification Products and Fines	0.6	7.5	15.8

[a] Calculated by limiting the population to refineries with a nonhazardous waste land treatment unit used for any waste stream and refineries with a sulfuric acid alkylation unit.

A single unit met these criteria and has been selected for modeling this waste stream in an onsite land treatment unit.

3.0 SOIL EROSION TO ADJACENT WATERBODY AND INTERVENING RECEPTOR SITE

Commenters questioned several aspects of the nongroundwater risk assessment utilizing the overland transport pathways (soil erosion) stating that the transport of soil from the land treatment area to the receptors is not physically possible as described by EPA. Therefore, the commenters believed that no direct or indirect exposure to subpopulations from soils was possible. Based on these comments, the overland transport pathways have been reviewed in detail and the following changes have been made in the application of the USLE for this purpose.

3.1 Methodology in Proposed Listing Decision (Independent Settings)

The USLE is an empirical erosion model originally designed to estimate long-term average soil erosion losses to a nearby waterbody from an agricultural field having uniform slope, soil type, vegetative cover, and erosion-control practices. In the risk assessment conducted in support of the proposed listing decision, the USLE was used to estimate the mass of soil lost per year per unit area from a land treatment unit and deposited directly onto the adjacent receptor site. A fixed sediment delivery ratio was used to estimate the percentage of eroded soil that ultimately reached the receptor site. The quantity of soil eroded from the LTU and deposited directly on each receptor site (agricultural field, residential lot, home garden) was estimated independently of soil eroded from the LTU and deposited into the nearest surface waterbody.

3.2 Revised Methodology for Integrated Setting

In response to comments, the method of estimating risk from the overland transport pathways was modified by EPA's Office of Solid Waste (OSW) and the Office of Research and Development (ORD). The USLE was modified to estimate soil erosion and overland transport of sediment from LTUs across intervening areas to nearby waterbodies by evaluating this process in an integrated setting (Beaulieu et al., 1996). In the proposed rule, overland transport of sediment from LTUs to receptor locations was estimated independently from transport from the LTU to the waterbody. Because the USLE equation estimates only soil erosion to waterbodies, the receptor location is considered to be located between the LTU and the waterbody. The area including the LTU, the receptor site, and the intervening area is considered for the purposes of this analysis to be an independent drainage subbasin. The soil erosion load from the subbasin to the waterbody is estimated using a distance-based sediment delivery ratio and the sediment not reaching the waterbody is considered to be deposited evenly over the area of the subbasin. Thus, using mass balance equations, contributions to the constituent concentrations of the waterbody and of the receptor soil may be estimated. The equations implementing the concept of the integrated setting are based on the following assumptions:

- The area of the management unit (LTU) and the area between the management unit and the nearest waterbody, including the receptor site, make up a discrete drainage subbasin. These areas are shown in Figure 3.1.

- The sediment delivery ratio (SD_{SB}) and the soil loss rate per unit area are assumed to be constant for all areas within the subbasin.

- The amount of soil deposited onto the receptor site through soil erosion is estimated by assuming that the fraction of soil that does not reach the waterbody remains in the subbasin.

- The entire subbasin drainage system is assumed to be at steady-state. Consequently, steady-state soil concentrations for the different subareas (e.g., receptor site, surrounding area) can be calculated using a mass balance approach.

- The soils within the watershed are assumed (on the average) to have the same soil properties (e.g., bulk density, soil moisture content), a reasonable assumption for areas with similar irrigation rates with infrequent tilling.

- The soil/constituent movement within the entire watershed is evaluated separately from the soil/constituent movement that occurs in the drainage subbasin. Only air deposition of constituents contributes to the constituent concentrations in soil outside the subbasin. The contribution of each area within the watershed to the constituent concentration in the waterbody is estimated independently and summed to estimate the total waterbody concentration.

- No contributions to constituent concentrations are assumed to occur from sources other than the LTU within the subbasin.

Table 3.1 lists the modified equations for overland transport used to implement the integrated setting approach to soil erosion and indicates if these equations have been changed or added since the proposed rule. The equations are presented in detail in Appendix A. All soil parameters and environmental factors required to evaluate soil erosion using the revised USLE equations remain identical to those used for the proposed rule. The values for these factors are presented in Appendix A with the equations in which they are used.

3.2.1 Soil Load from LTU to Receptor Site

The mass of eroded soil (soil load) from the LTU to the receptor site ($SL_{O,F}$) is a major input required to calculate the receptor site soil constituent concentration (C_F). The receptor site (residential plot, home garden, or agricultural field) soil concentrations are used to estimate risk through the soil ingestion pathway for all scenarios and through the food chain pathways (e.g., aboveground and belowground produce) for the home gardener and subsistence farmer scenarios. By assuming that the probability of soil redeposition is equivalent for all areas within the

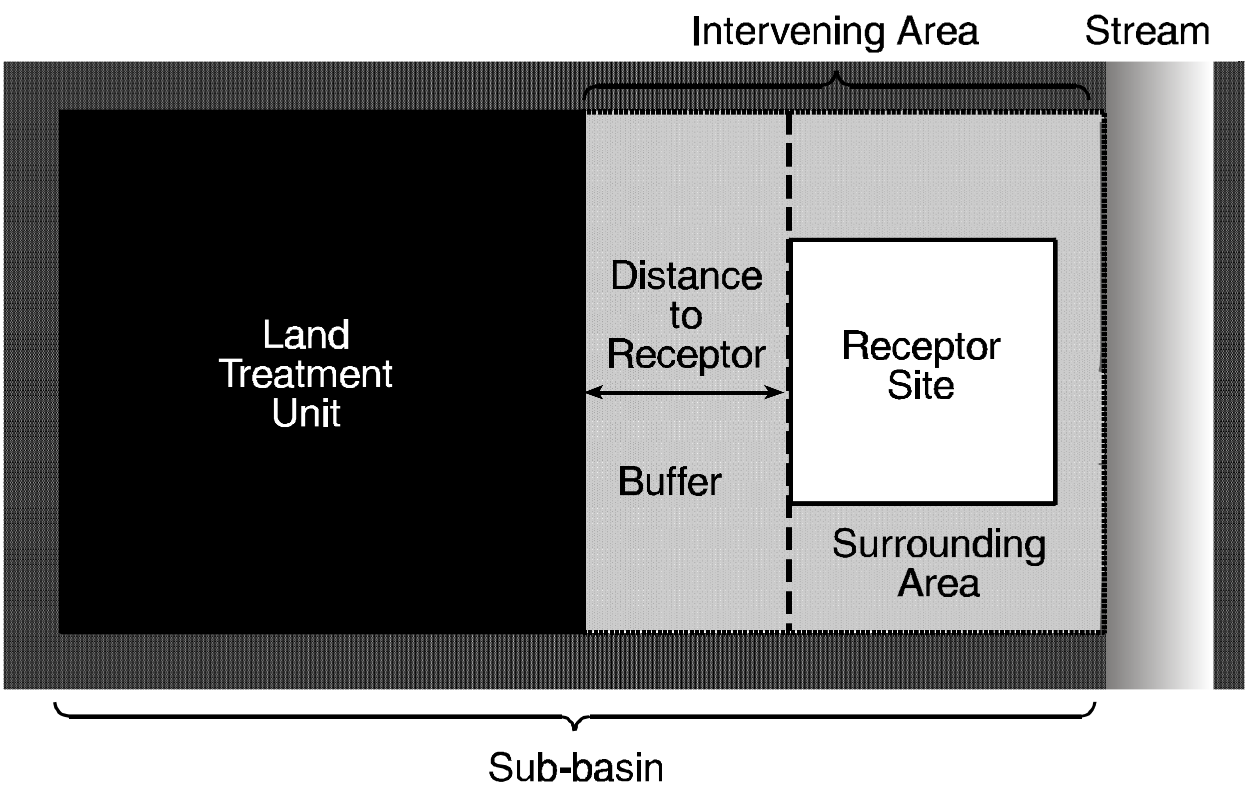

Figure 3-11. Diagram of Integrated Soil Erosion Setting

Table 3.1 Guide to Modified Equations for Overland Transport
(bolded parameter are calculated using indented parameters)

Parameter	Definition	Change/New
$\mathbf{L_T}$	**Total constituent load to waterbody**	Changed
L_E	Constituent load via soil erosion to waterbody	Changed
L_R	Constituent load from pervious runoff to waterbody	Changed
$\mathbf{L_E}$	**Constituent load via soil erosion to waterbody**	Changed
X_e	Unit soil loss	Unchanged
SD_{WS}	Sediment delivery ratio for watershed	Unchanged
θ	Soil volumetric water content	Unchanged
$S_{c,erode}$	Average constituent concentration based on erosion	New
SD_{SB}	Sediment delivery ratio for subbasin	New
D_{WS}	Sediment delivery ratio for watershed	Unchanged
$A_{B/Surr}$	Area of buffer and surrounding area	New
C_F	Constituent concentration in offsite field	Changed
$C_{B/Surr}$	Constituent concentration in buffer and surrounding	New
C_{WS}	Constituent concentration in watershed	Changed
$\mathbf{L_R}$	**Constituent load from pervious runoff to waterbody**	Changed
θ	Soil volumetric water content	Unchanged
$S_{c,run}$	Average constituent concentration based on area	New
$A_{B/Surr}$	Area of buffer and surrounding area	New
C_F	Constituent concentration in offsite field	Changed
$C_{B/Surr}$	Constituent concentration in buffer and surrounding	New
C_{WS}	Constituent concentration in watershed	Changed
$\mathbf{C_F}$	**Constituent concentration in offsite field**	Changed
$SL_{O,F}$	Soil load from site to offsite field	New
X_e	Unit soil loss	Unchanged
SD_{SB}	Sediment delivery ratio for subbasin	New
$A_{B/Surr}$	Area of buffer and surrounding area	New
$SF = SF_{O,F}$	Scaling factor	New
$A = A_S$	Area of source	
$SL_{B,F}$	Soil load from buffer to offsite field	New

(continued)

Table 3.1 (continued)

Parameter	Definition	Change/New
X_e	Unit soil loss	Unchanged
SD_{SB}	Sediment delivery ratio for subbasin	New
$A_{B/Surr}$	Area of buffer and surrounding area	New
$SF = SF_{B,F}$	Scaling factor	New
$A = A_B$	Area of buffer	
$C_{B/Surr}$	Constituent concentration in buffer and surrounding	New
$Ds_{(1),F}$	Aerial deposition rate term	Unchanged
ks_F	Constituent loss constant for offsite field	Changed
ksl	Loss constant due to leaching	Unchanged
θ	Soil volumetric water content	Unchanged
kse	Loss constant due to erosion	Changed
X_e	Unit soil loss	Unchanged
SD_{SB}	Sediment delivery ratio for subbasin	New
$A_{B/Surr}$	Area of buffer and surrounding area	New
θ	Soil volumetric water content	Unchanged
$CF = CF_F$	Correction factor	New
A_{BF}	Area between field and waterbody	New
ksr	Loss constant due to runoff	Unchanged
θ	Soil volumetric water content	Unchanged
ksv	Loss constant due to volatilization	Unchanged
$A = A_F$	Area of offsite field	
M_F	Mass of soil within mixing depth of offsite field	New
$A = A_F$	Area of offsite field	
$C_{B/Surr}$	**Concentration in buffer and surrounding area**	New
$SL_{O,B/Surr}$	Soil load to buffer and surrounding area	New
X_e	Unit soil loss	Unchanged
SD_{SB}	Sediment delivery ratio for subbasin	New
$A_{B/Surr}$	Area of buffer and surrounding area	New
$SF = SF_{O,B/Surr}$	Scaling factor	New
$A = A_S$	Area of buffer	New
$Ds_{(1),B/Surr}$	Aerial deposition rate term	New

(continued)

Table 3.1 (continued)

Parameter	Definition	Change/New
$ks_{B/Surr}$	Constituent loss constant for buffer and surrounding	New
ksl	Loss constant due to leaching	Unchanged
θ	Soil volumetric water content	Unchanged
kse	Loss constant due to erosion	Changed
X_e	Unit soil loss	Unchanged
SD_{SB}	Sediment delivery ratio for subbasin	New
$A_{B/Surr}$	Area of buffer and surrounding area	New
θ	Soil volumetric water content	Unchanged
$CF = CF_{B/Surr}$	Correction factor	New
ksr	Loss constant due to runoff	Unchanged
θ	Soil volumetric water content	Unchanged
ksv	Loss constant due to volatilization	Unchanged
$A = A_{B/Surr}$	Area of buffer and surrounding	New
$M_{B/Surr}$	Mass of soil within mixing depth of buffer/surround	New
$A = A_{B/Surr}$	Area of buffer and surrounding	New
C_{WS}	**Constituent concentration in watershed**	Changed
$Ds_{(1),WS}$	Aerial deposition rate term	Unchanged
ks_{WS}	Constituent loss constant for watershed	Unchanged
ksl	Loss constant due to leaching	Unchanged
θ	Soil volumetric water content	Unchanged
kse	Loss constant due to erosion	Changed
X_e	Unit soil loss	Unchanged
SD_{WS}	Sediment delivery ratio for watershed	Unchanged
θ	Soil volumetric water content	Unchanged
$CF = CF_{WS}$	Correction factor	New
ksr	Loss constant due to runoff	Unchanged
θ	Soil volumetric water content	Unchanged
ksv	Loss constant due to volatilization	Unchanged
$A = A_{WS}$	Area of watershed	

Source: Beualieu et al., 1996.

subbasin (i.e., the LTU, intervening area, and the receptor site), the amount of contaminated soil that erodes onto any area can be calculated by using a simple ratio of the area of concern to the total area for soil deposition:

$$DS_{0,F} = X_{c,s} \times A_s \times (1 - SD_{SB}) \times SF_{0,F} \qquad (3\text{-}1)$$

where

$DS_{0,F}$	=	soil delivery rate from source (LTU) to receptor (kg/yr)
$X_{c,s}$	=	unit soil loss rate from LTU (kg/m^2-yr)
A_S	=	area of the LTU (m^2)
SD_{SB}	=	sediment delivery ratio of the subbasin to the nearest waterbody (unitless)
$SF_{0,F}$	=	deposition area scaling factor (m^2/m^2)
	=	ratio of the receiving field area to the entire area available for deposition
	=	$A_F/(A_S + A_{B/Surr} + A_F)$
A_F	=	area of the receptor site (m^2)
$A_{B/Surr}$	=	area of the buffer and surrounding areas within the subbasin (m^2).

3.2.2 Total Constituent Load to Waterbody

The total load to the waterbody (L_T) is the sum of the constituent load via erosion (L_E) and the constituent load from pervious runoff (L_R). The total load to the waterbody is used to estimate risk to the subsistence and/or recreational fisher from the ingestion of fish. The estimation of L_E requires the calculation of a weighted average constituent concentration in watershed soils based on the eroded soil contribution ($S_{c,erode}$), and the L_R term requires the calculation of a weighted average constituent concentration based on the pervious runoff contribution ($S_{c,run}$). The weighted average constituent concentration represents the effective watershed soil concentration based on contributions from the subbasin and the remainder of the watershed. Most important, the weighted average concentration accounts for the differences in constituent concentrations in the different areas within the watershed. The calculation of L_T requires constituent concentrations for each of the following areas within the watershed: the source (LTU), the receptor site, the buffer and surrounding area, and the watershed area outside the drainage subbasin. For the watershed soils outside the subbasin, it is assumed that constituents reach the watershed solely via air deposition (i.e., no erosion component).

Calculation of L_T requires constituent concentrations for each of the following areas within the watershed: the source (LTU); the offsite field, the buffer, and surrounding area within the subbasin); and the watershed area outside the drainage subbasin. If we consider the erosion load (L_E) to the surface waterbody for each of these areas individually, the equation may be written as:

$$L_E = [X_{e,SB} \times ER \times SD_{SB} \times A_0 \times C_0 \times (\frac{Kd_s\ BD}{\theta + Kd_s\ BD}) \times 0.001] + \tag{3-2}$$

$$[X_{e,SB} \times ER \times SD_{SB} \times A_F \times C_F \times (\frac{Kd_s\ BD}{\theta + Kd_s\ BD}) \times 0.001] +$$

$$[X_{e,SB} \times ER \times SD_{SB} \times A_{B/Surr} \times C_{B/Surr} \times (\frac{Kd_s\ BD}{\theta + Kd_s\ BD}) \times 0.001] +$$

$$[X_e \times ER \times SD_{WS} \times [A_{WS} - (A_0 + A_F + A_{B/Surr})] \times C_{WS} \times (\frac{Kd_s\ BD}{\theta + Kd_s\ BD}) \times 0.001$$

where

L_E	=	constituent load to watershed due to erosion (g/yr)
$X_{e,SB}$	=	unit soil loss in subbasin (kg/m^2/yr)
ER	=	enrichment ratio
SD_{SB}	=	sediment delivery ratio for subbasin
A_0	=	area of source (m^2)
C_0	=	constituent concentration at the source (mg/kg)
Kd_s	=	soil water partition coefficient (L/kg)
BD	=	bulk density of soil (g/cm^3)
θ	=	volumetric soil content of soil (cm^3/cm^3)
0.001	=	unit conversion factor ([g/kg]/[mg/kg]).
A_F	=	area of receptor field (m^2)
C_F	=	constituent concentration in receptor site field (mg/kg)
$A_{B/Surr}$	=	area of buffer and surrounding area (m^2)
$C_{B/Surr}$	=	constituent concentration in buffer and surrounding area (mg/kg)
X_e	=	unit soil loss in watershed outside of subbasin (kg/m^2/yr)
SD_{SB}	=	sediment delivery ratio for watershed (unitless)
A_{WS}	=	area of entire watershed (m^2)
C_{WS}	=	constituent concentration in watershed soils outside of subbasin (mg/kg).

The enrichment ratio (ER) has been added to the revised soil erosion equations. It was not included in the equations used for the proposal rule. This factor represents the reality that erosion favors the lighter soil particles, which have higher surface-area-to-volume ratios and are higher in organic matter content. Therefore, concentrations of organic constituents, which are a function of organic carbon content of sorbing media, would be expected to be higher in eroded soil then in in situ soil. This factor is generally assigned values in the range of 1 to 5. A value of 3 for organic contaminants and a value of 1 for metals would be reasonable first estimates and have been used in this analysis (U.S. EPA, 1994).

Alternatively, this equation can be written in terms of an average weighted soil concentration for the watershed that results in the same constituent load as a function of erosion and sediment delivery. The $S_{c,erode}$ term shown at the end of Equation 3-3 reflects this modification:

$$L_E = [X_e \times ER \times SD_{WS} \times A_{WS} \times (\frac{Kd_s \ BD}{\theta + Kd_s \ BD}) \times 0.001] \times S_{c,erode} \qquad (3\text{-}3)$$

L_T also requires the constituent load from pervious runoff (L_R). The L_R term is calculated using equation 3-4.

$$L_R = R \times (A_{ws} - A_I) \times \frac{S_c \times BD}{\theta + Kd_s \times BD} \times 0.01 \qquad (3\text{-}4)$$

where

L_R	=	pervious surface runoff load (g/yr)
R	=	average annual surface runoff (cm/yr)
A_{ws}	=	area of entire watershed (m^2)
A_I	=	impervious watershed area receiving constituent deposition (m^2)
S_c	=	weighted average constituent concentration in total watershed soils (watershed and sub-basin) based on surface area (mg/kg)
BD	=	soil bulk density (g/cm^3)
θ	=	volumetric soil content of soil (cm^3/cm^3)
Kd_s	=	soil water partition coefficient (L/kg) or (cm^3/g)
0.01	=	units conversion factor ($kg\text{-}cm^2/mg\text{-}m^2$).

Assuming that the ratio of pervious and impervious soils is the same for each of the designated areas, a correction for areas that do not erode (streets, rocks, etc.) can be added to Equation 3-3 by replacing A_{WS} with A_{WS} - A_I , where A_I equals the total impervious area in the watershed. Setting the L_R equal to each other in the previous two equations and solving for $S_{c,erode}$ yields:

$$S_{c,erode} = \frac{(X_{e,SB} \times A_s \times C_0 \times SD_{SB}) + (X_{e,SB} \times A_{B/Surr} \times C_{B/Surr} \times SD_{SB}) + (X_{e,SB} \times A_F \times C_F \times SD_{SB})}{X_e \times SD_{WS} \times A_{WS}} + \frac{\{[A_{WS} - (A_0 + A_F + A_{B/Surr})] \times C_{WS}\}}{A_{WS}} \qquad (3\text{-}5)$$

Equation 3-5 accounts for differences in the sediment delivery ratios (SD), surface areas (A), and mixing depths (Z) for discrete areas of the watershed (i.e., source, receptor field, buffer/

surrounding areas, and the remaining watershed). Similarly, the weighted average for runoff losses (ksr) was derived using the areas for various watershed components (e.g., receptor site field, watershed outside drainage subbasin); however, different sediment delivery ratios were not required because soils in the area were considered to be similar and the slope was considered uniform. It was possible to generate simple area-based weighting factors because the rainfall runoff per unit area was assumed to be constant for the entire watershed area.

Constituent Concentrations in Various Watershed Components

The constituent concentrations for the receptor site field (C_F), the buffer and surrounding area ($C_{B/Surr}$), and the watershed area outside of the drainage subbasin (C_{WS}) are required to solve $S_{c,erode}$. As suggested previously, a mass balance approach was used to calculate the constituent concentrations for all watershed components. For the receptor site field, the mass balance equation is given by:

$$M_F\,(dC_F\,/dt) = [C_0\,SL_{0,F} + (M_F\,Ds_{(1),F})] + (SL_{B,F}\,C_{B/Surr}) - (M_F\,ks_F\,C_F) \qquad (3\text{-}6)$$

where

M_F	=	mass of the field (kg)
C_F	=	constituent concentration in the receptor site field (mg/kg)
$SL_{0,F}$	=	soil load from source to the field (kg/yr)
$Ds_{(1),F}$	=	air deposition rate from source to the field (mg/kg-yr)
$SL_{B,F}$	=	soil load from buffer to the field (kg/yr)
ks_F	=	constituent loss rate coefficient for the field (per yr).

At steady state, this equation can be solved for the constituent concentration in the receptor site field as follows:

$$C_F = [(C_0\,SL_{0,F} + M_F\,Ds_{(1),F}) + (SL_{B,F}\,C_{B/Surr})] / (M_F\,ks_F) \qquad (3\text{-}7)$$

As with the constituent concentration in the receptor site field, the concentration in the buffer and surrounding area is given by:

$$M_{B/Surr}(dC_{B/Surr}\,/\,dt) = (SL_{0,B/surr}\,C_0) + [M_{B/Surr}\,(Ds_{(1),B/Surr} - ks_{B/Surr}\,C_{B/Surr})] \qquad (3\text{-}8)$$

where

$M_{B/Surr}$	=	mass of the buffer and surrounding area (kg)
$C_{B/Surr}$	=	constituent concentration in the buffer and surrounding area (mg/kg)
$SL_{0,B/Surr}$	=	soil load from source to buffer/surrounding areas (kg/yr)
C_0	=	soil constituent concentration at the source (mg/kg)
$Ds_{(1),B/Surr}$	=	air deposition rate from source to buffer and surrounding area (mg/kg-yr)

$ks_{B/Surr}$ = constituent loss rate coefficient for the buffer/surrounding area (per/yr).

At steady state, this equation may be solved for $C_{B/Surr}$ as follows:

$$C_{B/Surr} = (C_0 \, SL_{0,B/Surr} + M_{B/Surr} \, Ds_{(1),B/Surr}) / (M_{B/Surr} \, ks_{B/Surr}) \ . \quad (3\text{-}9)$$

For the watershed soils outside of the subbasin, we assumed that constituents reached the watershed solely via air deposition (i.e., no erosion component). Using similar mass balance and steady-state assumptions, the constituent concentration in watershed soils outside the subbasin may be calculated using:

$$C_{WS} = Ds_{(1),WS} / ks_{WS} \quad (3\text{-}10)$$

where

C_{WS} = soil constituent concentration in the watershed (mg/kg)
$Ds_{(1),WS}$ = air deposition rate from source to the watershed (mg/kg/yr)
ks_{WS} = constituent loss rate coefficient for the watershed (per yr).

3.2.3 Summary

The equations and default input parameter values used to calculate receptor site soil concentrations and the waterbody concentrations of constituents of concern, including the revised overland transport pathways, are presented in Appendix A.

Contaminated particles are transported from the land treatment unit to receptor sites via air deposition as well as runoff/erosion. For a complete discussion of the equations for estimating the contribution to the constituent soil concentration from air deposition, consult the background document for the risk assessment for the proposed rule. For the revised integrated setting analysis, mass balance was applied for each area of interest (e.g., buffer area between source and receptor site, receptor site, or surrounding area). Consequently, the respective air deposition value for each area of interest is included in the evaluation of the mass balance. The air deposition over the entire subbasin area was considered to be uniform and equal to the air deposition modeled for the receptor site.

However, in reviewing the spreadsheet equations used to implement the equations presented in the background document it was discovered that a unit conversion from $\mu g/m^2$ to g/m^2 was performed in two locations, creating an underestimation of risk due to air deposition of 6 orders of magnitude. This error has been corrected in the risk analysis presented in this document. The unit conversion correction makes the risk due to air deposition from windblown soil from the LTU the same order of magnitude as the risk attributed to soil erosion in each case; i.e., if the risk due to soil erosion is in the range of 10E-6, the risk due to air deposition is also 10E-6.

The revised risk assessment results presented in Sections 8 through 15 of this document are estimated using the integrated setting approach and include the overland transport equations presented in Appendix A and the corrected spreadsheet equations described above and presented in Appendix E of the background document for the proposed rule.

4.0 BIODEGRADATION OF PAHS IN SOIL

Biodegradation of polynuclear aromatic hydrocarbons in soil was considered only within the boundaries of the land treatment unit in the risk analysis performed for the proposed rule. Biodegradation was included within the LTU because this soil is frequently amended to ensure the presence of soil organisms adapted for the degradation of petroleum wastes. For the proposal, the *Handbook of Environmental Degradation Rates* (Howard et al., 1991) was used to identify a range of values for soil degradation rates representing a variety of soil types and climates. EPA selected the lowest soil biodegradation rate reported for use in the risk analysis. Biodegradation outside LTU was not considered for the proposed rule. Commenters questioned EPA's conservative assumption that no biodegradation occurred from the LTU and to the receptor. In response, EPA incorporated biodegradation of PAHs in soils outside the LTU. For this revised risk analysis, the same biodegradation rate has been assumed for all soils, including all soils inside and outside the LTU. Table 4.1 presents the soil half-lives used to calculate the biodegradation rates used in this analysis. The biodegradation rates are also presented in Appendix B with the compound-specific input data.

Table 4.1 Biodegradation Rates Used for Receptor Site Soil Loss Equations

CAS Number	Chemical Name	Biodegradation Rate (per yr)
50-32-8	Benzo(*a*)pyrene	0.478
53-70-3	Dibenz(*a*,*h*)anthracene	0.269
56-49-5	3-Methylcholanthrene	0.181
56-55-3	Benz(*a*)anthracene	0.373
57-97-6	Dimethylbenz(*a*)anthracene	9.04
193-39-5	Indeno(*1*,*2*,*3*-*cd*)pyrene	0.347
205-99-2	Benzo(*b*)fluoranthene	0.415
207-08-9	Benzo(*k*)fluoranthene	0.118
218-01-9	Chrysene	0.255

Source: Soil half-lives presented in Howard et al., 1991.