Appendix D2

EBSL Calculations and Parameter Input Values

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Appendix D2

EBSL Calculations and Parameters Input Values

D2-1. EBSL EXPOSURE EQUATIONS AND PARAMETER DATA BASE

A need was identified for a method to quickly screen sites based on ecological based values that would remain protective of all receptors potentially present at a site. Basic similarity in receptors across the facility makes it possible to develop INEEL-wide screening levels. The use of INEEL-specific ecological based screening levels (EBSLs) provides a rational, consistent approach for allowing initial contaminant screening at each site within a WAG.

The purpose of this appendix is to document the exposure equations, receptors (functional groups), input parameters, and toxicity reference values (TRVs) used to calculate EBSLs for receptors at the INEEL. EBSLs are defined as concentrations of contaminants of potential concern (COPCs) in soil (or other media) that are not expected to produce any adverse effects to selected ecological receptors under chronic exposure conditions. These EBSLs are INEEL specific and are not applicable to other sites. The report compilations are limited to species and contaminants identified as present at the INEEL, and all values were specifically derived based on environmental conditions specific to the INEEL.

Section D2-2 presents development of EBSLs equations used for both nonradionuclide and radionuclide contaminants at the INEEL. Section D2-3 discusses the development of functional groups at the INEEL and documents the groups assessed at the INEEL. All subsequent information was compiled in such a form as to support the functional grouping approach at the INEEL. Section D2-4 presents the compilation of input parameters used in the EBSL equations. Section D2-5 presents the TRVs used to evaluate potential adverse effects to ecological receptors. Section D2-6 presents the EBSLs calculated for nonradionuclide and radionuclide contaminants.

D2-2. EBSL DEVELOPMENT

EBSLs are calculated by inverting the exposure equations as discussed in this section. Intake or exposure of ecological receptors to contaminants in the environment is generally calculated using basic foodweb models. In the risk assessment process these intake values are compared to toxicity reference TRVs to provide an evaluation of the potential effects to receptors. Manipulation of these equations allows the calculation of a contaminant concentration in a medium that would not be potentially harmful to the receptors with chronic exposure.

INEEL sites potentially contain both radionuclide and nonradionuclide contamination. Determining exposure to each of these types of contaminants requires different modeling. The approaches used to calculate EBSLs for either exposure to nonradionuclides or radionuclides are presented in the following sections.

D2-2.1 Development of EBSLs for Nonradionuclide Contaminants

D2-2.1.1 EBSLs for Soil/Sediment Exposure

The major pathways of contaminant exposure at the INEEL include soil/food and water ingestion. Exposure to contamination is expected to occur primarily via direct soil ingestion and food chain biotransfer (i.e., consumption of plant and animal matter containing chemicals derived from soil). Thus, Equation (D2-1) is a general exposure equation for receptors.

$$EE_{soil/food} = \frac{[(PP \times CP) + (PV \times CV) + (PS \times CS)] \times IR \times SUF \times ED}{BW} \quad \text{(D2-1)}$$

where

$EE_{soil/food}$	=	estimated intake from ingestion of food and soil (mg/kg body weight-day)
PP	=	percent of diet represented by prey ingested (kg prey/kg diet)
CP	=	concentration of COPC in prey item ingested (mg/kg prey)
PV	=	percent of diet represented by vegetation ingested (kg vegetation/kg diet)
CV	=	concentration of COPC in vegetation ingested (mg/kg vegetation)
PS	=	percent of diet represented by soil (kg soil/kg diet)
CS	=	concentration of COPC in soil (mg/kg soil)
IR	=	total food ingestion rate (kg dry weight/day)
SUF	=	site use factor (affected area/receptor home range [unitless]); defaulted to 1.0 for EBSL calculation
ED	=	exposure duration (fraction of year spent in the affected area [unitless]); defaulted to 1.0 for EBSL calculation
BW	=	receptor-specific body weight (kg).

Equation (D2-2) estimates the concentration of COPCs in prey items (CP).

$$CP = CS \times BAF \quad \text{(D2-2)}$$

where

CP	=	concentration of COPC in prey item ingested (mg/kg prey)
CS	=	concentration of COPC in soil (mg/kg soil)

BAF = prey-specific bioaccumulation factor (mg COPC/kg in tissue/mg COPC/kg soil).

The concentration of COPCs in vegetation (CV) was estimated using the Equation (D2-3).

$$CV = CS \times PUF \quad \text{(D2-3)}$$

where

CV = concentration of COPC in vegetation ingested (mg/kg vegetation)

CS = concentration of COPC in soil (mg/kg soil)

PUF = plant uptake factor (mg COPC/kg plant tissue/mg COPC/kg soil).

Equation (D2-4) combines the previous equations, thus the exposure equation can be rewritten as:

$$EE_{soil/food} = \frac{CS \times [(PP \times BAF) + (PV \times PUF) + (PS)] \times IR}{BW} \quad \text{(D2-4)}$$

where all parameters are as previously defined.

To calculate EBSLs for screening against nonradiological soil contamination concentrations, the target hazard quotient (THQ) will be determined. This is defined as a quantitative method for evaluating potential adverse impacts to exposed populations, and is calculated in Equation (D2-5).

$$THQ = \frac{EE_{soil/sediment}}{TRV} \quad \text{(D2-5)}$$

where

THQ = target hazard quotient (unitless), established at 1.0 for nonradionuclide contaminate exposure

$EE_{soil/sediment}$ = estimated exposure from soil and/or sediment (mg/kg body weight-day)

TRV = contaminant-specific toxicity reference value (mg/kg-day).

Thus, solving for the concentration of the nonradionuclide contaminant in the soil (Cs) and assuming that when THQ equals 1 that EE_{soil} = TRV. The EBSL for contaminant in the soil is calculated using the Equation (D2-6).

$$NR - EBSL_{soil} = \frac{TRV \times BW}{[(PP \times BAF) + (PV \times PUF) + (PS)] \times IR} \quad \text{(D2-6)}$$

where

$NR–EBSL_{soil}$ = WAG-specific EBSL for non-radionuclide contaminants in soil (mg/kg).

Exposure parameters including dietary composition (percent soil [PS], percent prey [PP], and percent vegetation [PV]), home range, temporal and spatial habitat use data (site use factor [SUF] and exposure duration [ED]), soil ingestion rate, food ingestion rate (IR), body weight (BW) and uptake factors (bioaccumulation factors [BAFs], and plant uptake factors [PUFs]) are input to calculate the EBSL. The input values for calculating EBSLs for each functional group/contaminant combination assume that members of the functional groups are exposed to stressors to the maximum extent, perhaps beyond what is actually expected. For example, it is assumed that a raptor captures 100% of its prey from a contaminated site, and that all the prey are exposed to maximum contaminant concentrations at the site. This is similar to the human risk assessment concept of the "maximally exposed individual," a hypothetical individual who is assumed to live and grow his own food at a location of maximum exposure to a stressor. Each parameter is discussed in Section D2-3 and Appendix D3 in more detail.

D2-2.1.2 EBSLs for Water Ingestion Exposure

If potentially contaminated surface water exists, the first step was to compare any observed effluent concentrations against water quality criteria or benchmarks that exist in the literature. If the effluent concentration exceeds the benchmark or if no benchmark currently exists, an EBSL for water ingestion was calculated. This EBSL is only applicable for those species that may be obtaining drinking water for terrestrial species. They are not applicable as benchmarks for the health of aquatic invertebrate or other species that might eventually use the surface water. Equation (D2-7) is the general equation for dose in mg/kg body weight-day from water ingestion.

$$EE_{water} = \frac{CW \times WI \times ED \times SUF}{BW} \qquad \text{(D2-7)}$$

where

EE_{water} = estimated intake from ingestion of food and water (mg/kg bodyweight-day)

CW = contaminant concentration in water (mg/L)

WI = water ingestion rate (L/day).

The water ingestion is found in Equations D2-8 and D2-9 (EPA 1993).

$$WI = 0.099\ BW^{0.90} \quad \textit{(for all mammals)} \qquad \text{(D2-8)}$$

$$WI = 0.059\ BW^{0.67} \quad \textit{(for all birds)} \qquad \text{(D2-9)}$$

where body weight is in units of kg.

To calculate EBSLs for screening against nonradiological soil contamination concentrations, the THQ will be determined. This is defined as a quantitative method for evaluating potential adverse impacts to exposed populations, and is calculated by Equation (D2-10).

$$THQ = \frac{EE_{water}}{TRV} \qquad \text{(D2-10)}$$

where

THQ	=	target hazard quotient (unitless), established at 1.0 for nonradionuclide contaminate exposure
EE_{water}	=	estimated exposure from water (mg/kg body weight-day)
TRV	=	contaminant-specific toxicity reference value (mg/kg-day).

Thus, solving for the concentration of the nonradionuclide contaminant in the water and assuming that when THQ equals 1 that EE_{water} = TRV. ED and SUF are defaulted to 1.0 and therefore are dropped from the equation.

$$EBSL_{water} = \frac{TRV \times BW}{WI} \qquad \text{(D2-11)}$$

Because of the complexity of water ingestion by reptiles, no general reptilian water ingestion equation is available. It was generally assumed that desert reptiles, such as those found at the INEEL, get their water from prey. Plant uptake of contaminated surface water is also not considered.

D2-2.2 Development of EBSLs for Radionuclide Contaminants

The method used for relating the amount of radiation to specific biological effects is the radiation dose rate, which is a measure of the amount of radiation energy that is dissipated in a given volume of living tissue. Radionuclide exposure can occur from both external contact and internal ingestion. These issues will be presented separately.

D2-2.2.1 Internal Radiation Dose Rate from Soil Exposure

Internal radiation dose rate estimates are calculated by assuming that the steady-state whole body concentration is equivalent to the steady-state concentration of radionuclides in reproductive organs using Equation (D2-12). This is as presented in IAEA (1992).

$$DR_{internal} = \frac{TC \times ED \times SUF \times ADE \times FA \times 3200\ dis/day\ -\ pCi}{6.24 \times 10^{9}\ MeV/g\ -\ Gy} \qquad \text{(D2-12)}$$

where

$DR_{internal}$	=	internal radiation dose rate estimate (Gy/day)
TC	=	tissue radionuclide concentration (pCi/g)
ED	=	exposure duration (fraction of year spent in affected area) (unitless)
SUF	=	site use factor (affected area/receptor home range [unitless]; defaulted to 1.0 for EBSL calculation
ADE	=	average decay energy per disintegration (MeV/dis)
FA	=	fraction of decay energy absorbed (unitless)

Since tissue levels of radionuclides are derived by multiplying the concentration of radionuclide in soil by a radionuclide-specific concentration factor (CF) for all terrestrial animals or terrestrial plants, the above equation can be rewritten as Equation (D2-13).

$$DR_{internal} = \frac{CS \times CF \times ED \times ADE \times FA \times 3200\ dis/day\ -\ pCi}{6.24x10^{9}\ MeV/g\ -\ Gy} \quad \text{(D2-13)}$$

where

CS = concentration of contaminant in soil ingested (pCi/g)

CF = concentration factor (unitless).

Solving for the concentration of contaminant in soil (CS) and redefining this concentration as an EBSL, the EBSL for internal consumption of radiological contaminants from contaminated soil media is estimated using the Equation (D2-14).

$$EBSL_{internal} = \frac{TRV \times 6.24 \times 10^{9}\ MeV/g\ -\ Gy}{CF \times ED \times ADE \times FA \times 3200\ dis/day\ -\ pCi} \quad \text{(D2-14)}$$

where

$EBSL_{internal}$ = internal ecological based screening level for radionuclides in soil (pCi/g)

TRV = toxicity reference value (Gy/day).

Assumptions used in the calculation of the ADE values were for radiations whose energy would be deposited in small tissue volume (ß,a), the FA was set equal to 1. For gamma radiation, the FA was conservatively set equal to 0.3 (30%). This assumption was assumed to be conservative (IAEA 1992). Only radiations with an intensity of 1% or greater were considered, and Auger and conversion electrons were not considered. The ADE values were calculated using Equation (D2-15) (Kocher 1981):

$$ADE = \sum_{i=1}^{n} Y_i\ E_i \quad \text{(D2-15)}$$

where

ADE = average decay energy per disintegration (MeV/dis)

Y_i = yield or intensity

E_i = energy of radiation, for ß = average energy.

CFs for radionuclides are discussed in Appendix D3. For EBSL development the CF values for animals are assumed to be 1 for contaminants and receptors unless the reported values is greater (in this case the larger value was used). This is a conservative assumption used to develop screening level values.

D2-2.2.2 Internal Radiation Dose Rate from Water Ingestion

Water ingestion of radionuclides may occur and will be assessed by using a differential equation [Equation (D2-16)].

$$\frac{dTC}{dt} = I - \lambda_1(TC) - \lambda_2(TC) - L \qquad \text{(D2-16)}$$

where

TC = tissue concentration (pCi/g tissue)

I = intake [(pCi/L)(L/g tissue-day)]

λ_1 = radiological decay constant (1/day)

λ_2 = biological loss constant (1/day)

L = other loss (e.g., through urination) [(pCi/L)(L/g tissue-day)].

Conservatively assuming L = 0 and solving for TC at equilibrium (i.e., dTC/dt = 0) gives Equation (D2-17).

$$TC = \frac{I}{\lambda_1 + \lambda_2} \qquad \text{(D2-17)}$$

The daily ingestion rate of the radionuclide from water, I, is calculated using Equation (D2-18).

$$I = \frac{CW \times WI}{BW \times 1{,}000\ g/kg} \qquad \text{(D2-18)}$$

where

I = intake [(pCi/L)(L/kg tissue-day)]

CW = concentration of the radionuclide in water (pCi/L)

WI = water ingestion rate (L/d)

BW = body weight (kg).

So the tissue concentration due to water ingestion determined by Equation (D2-19).

$$TC = \frac{CW \times WI}{BW \times (\lambda_1 + \lambda_2) \times 1{,}000\ g/kg} \qquad \text{(D2-19)}$$

The water ingestion is found using Equations (D2-8) and (D2-9).

Multiplying this equation by (ED × ADE × FA × 3200)/6.24 × 10^9) results in a dose rate analogous to that calculated in equation D2-13. Solving for the concentration of CW and redefining this

concentration, the EBSL for water ingestion of radiological contaminants from contaminated water media is estimated using the Equation (D2-20).

$$EBSL_{water} = \left[TRV \times BW \times (\lambda_1 + \lambda_2) \times 1000 \times 6.24 \times 10^9\right] / (WI \times ED \times ADE \times FA \times 3200). \quad \text{(D2-20)}$$

where:

$EBSL_{water}$ = ecological based screening level for radionuclide ingestion from water (pCi/L).

D2-2.2.3 External Radiation

External dose rate EBSLs are derived using formulas outlined in Shleien (1992). Dose rate to tissue in an infinite medium uniformly contaminated by a gamma emitter is calculated by Equation (D2-21).

$$DR_{external} = \frac{2.12 \times ADE \times C}{\rho} \quad \text{(D2-21)}$$

where

$DR_{external}$ = external dose rate to tissue (rads/hr)

ADE = average gamma decay energy per disintegration (MeV/dis)

C = concentration of contaminant ($\mu Ci/cm^3$)

ρ = density of the medium (g/cm^3).

Solving the equation for the concentration in soil assuming an acceptable dose to animals is 1 mGy/day (0.1 rad/day, which is equal to 4.12E-03 rad/hr) (IAEA 1992) and redefining this concentration as an EBSL, the EBSL for external dose from radiological contaminants in soil is estimated using Equation (D2-22).

$$\text{EBSL}_{\text{external}} = \frac{\text{DR}_{\text{external}} \times 10^6\ \text{pCi}/\mu\text{Ci}}{2.12 \times \text{ADE}} \quad \text{(D2-22)}$$

where

$EBSL_{external}$ = ecologically based screening level for external exposure to radionuclides in soil (pCi/g)

$DR_{external}$ = external dose rate to tissue (rads/hr)

ADE = average gamma decay energy per disintegration (MeV/dis).

This equation conservatively estimates the dose to burrowing terrestrial functional groups (AV210A, AV222A, M122A, M210A, and M422). This equation also conservatively reflects that these functional groups spend 100% of their time with external exposure. For the nonburrowing functional groups, it is conservatively assumed that they are exposed to 50% (hemisphere) of radiation.

The dose rate for use in the external EBSL calculation is 4.12E-03 rads/hr as discussed above. Contaminant-specific average decay energies and FA values for the radionuclides of concern are presented in Appendix D3, Attachment 1.

D2-3. EBSL PARAMETER INPUT VALUES

EBSLs were calculated using the models presented in Section D2-2 and species-specific input values (PV, PP, PS, IR, WI, BW, ED, SUF) compiled from the literature. Exposures for each functional group or species incorporate best estimates to reflect species-specific life history and feeding habits. Defaults and assumptions for selecting EBSL soil/sediment and drinking water model input values are given in Table D2-3-1. Finalized parameter input values used to model contaminant intake through consumption of food or water by functional groups and individual species evaluated as part of the initial ERA screenings are presented in Table D2-3-2. These values have been explicitly developed to reflect INEEL contaminant issues. Individual parameter values and literature sources are discussed in the following subsections.

D2-3.1 Diet (PV, PP, PS)

Group and individual species diets are represented in the EBSL equations by the sum of three parameters (percent vegetation [PV], percent prey [PP], and percent soil [PS]), constrained to equal 100%. For herbivores, PV is represented by 1 – PS, (where PP = 0). No distinction was made between the types of vegetation consumed. Although some primarily herbivorous species may consume a small percent of its diet as insect prey, this was considered in the trophic assignment as part of the functional grouping criteria (VanHorn et al. 1995).

For carnivores, PP is represented by 1 – PS, (where PV = 0). Values for the fraction of overall diet represented by prey were taken from species specific or representative species diets as reported in the literature.

Dietary composition for omnivores is represented by (PV-PS/2) + (PP-PS/2) + PS = 1 unless PP or PV are 10% or less, in which case, PS was subtracted from the greater of the two. Dietary profiles for functional groups were based on diets for representative species developed from studies conducted at the INEEL and other regional locations (noted on Table D2-3-3). Since most dietary studies report only in terms of prey or vegetation material, the dietary fraction comprised of soil was evenly subtracted from prey and vegetation fractions of the diet to account for inclusion of ingested soil without exceeding 1. The number of individual species comprising prey was not considered. The contribution of prey items to overall diet was based on relative biomass rather than the most numerous individual components. Dietary composition for functional groups is represented by the species having the largest PS within that group.

The values for PS were taken primarily from soil ingestion data presented by Beyer et al. (1994). Species for which values were presented in Beyer et al. (1994) are limited, so soil ingestion values were assigned using professional judgement to match dietary habits with species most similar to INEEL species.

Finalized EBSL dietary input values and literature sources for functional groups and individual species are presented on Table D2-3-3. Further refinement in the diet of individual species and functional groups is beyond the scope of both screening and WAG-level ERA. More detailed dietary models will be implemented in the OU 10-04 ERA (Appendix D1).

Table D2-3-1. Parameter defaults and assumptions for EBSL calculations.

Parameter	EBSL Soil/Sediment Calculations	EBSL Water Calculations
PV	Herbivores—100 minus PS Insectivores—0 Carnivores—0 Omnivores—PV from literature minus PS/2	N/A
PP	Herbivores—0 Insectivores—100 minus PS Carnivores—100 minus PS Omnivores—PP from literature minus PS/2.	N/A
PS	The highest value (i.e., greatest exposure) was selected from species within functional group. Individual species evaluated using values as presented.	N/A
IR	Allometric equations from Nagy (1987). The largest IR/BW ratio was used from the species within a functional group.	N/A
WI	N/A	Allometric equations for birds and mammals (EPA 1993). The largest WI/BW ratio was selected from species within each functional group.
BW	The smallest BW/IR ratio was selected from species within each functional group.	The smallest BW/WI ratio (smallest BW) was selected from species within each functional group
ED	Defaulted to 1.	Defaulted to 1.
SUF	Defaulted to 1.	Defaulted to 1.

Table D2-3-2. Parameter input values for EBSL calculations.

Functional Groups	PP	PV	PS	SUF	ED	IR (kg/day)	BW (kg)
Amphibians (A232)	9.41E-01	0.00E+00	5.90E-02	1.00E-00	1.00E-00	6.49E-05	8.00E-03
Avian herbivores (AV121)	0.00E+00	9.90E-01	1.00E-02	1.00E-00	1.00E-00	3.50E-03	1.29E-02
Avian herbivores (AV122)	0.00E+00	9.07E-01	9.30E-02	1.00E-00	1.00E-00	1.46E-03	3.50E-03
Avian herbivores (AV132)	0.00E+00	8.20E-01	1.80E-01	1.00E-00	1.00E-00	1.07E-02	7.46E-02
Avian herbivores (AV142)	0.00E+00	9.18E-01	8.20E-02	1.00E-00	1.00E-00	2.75E-02	3.16E-01
Trumpeter swan	0.00E+00	9.18E-01	8.20E-02	1.00E-00	1.00E-00	2.75E-01	1.09E+01
Avian herbivores (AV143)	0.00E+00	9.18E-01	8.20E-02	1.00E-00	1.00E-00	2.92E-02	3.47E-01
Avian insectivores (AV210)	9.80E-01	0.00E+00	2.00E-02	1.00E-00	1.00E-00	2.90E-03	1.00E-02
Black tern	9.80E-01	0.00E+00	2.00E-02	1.00E-00	1.00E-00	9.84E-03	6.53E-02
Avian insectivores (AV210A)	9.70E-01	0.00E+00	3.00E-02	1.00E-00	1.00E-00	3.89E-03	1.46E-02
Avian insectivores (AV221)	9.70E-01	0.00E+00	3.00E-02	1.00E-00	1.00E-00	1.99E-03	6.65E-03
Avian insectivores (AV222)	9.07E-01	0.00E+00	9.30E-02	1.00E-00	1.00E-00	3.07E-03	1.09E-02
Avian insectivores (AV222A)	9.07E-01	0.00E+00	9.30E-02	1.00E-00	1.00E-00	2.82E-03	1.00E-02
Avian insectivores (AV232)	8.20E-01	0.00E+00	1.80E-01	1.00E-00	1.00E-00	1.12E-03	2.32E-02
Avian insectivores (AV233)	8.20E-01	0.00E+00	1.80E-01	1.00E-00	1.00E-00	4.78E-03	2.15E-02
White-faced ibis	8.90E-01	0.00E+00	1.10E-01	1.00E-00	1.00E-00	4.27E-02	6.22E-01
Avian insectivores (AV241)	8.20E-01	0.00E+00	1.80E-01	1.00E-00	1.00E-00	6.41E-03	3.38E-02
Avian insectivores (AV242)	8.20E-01	0.00E+00	1.80E-01	1.00E-00	1.00E-00	1.13E-02	8.10E-02
Avian carnivores (AV310)	9.80E-01	0.00E+00	2.00E-02	1.00E-00	1.00E-00	1.61E-02	1.39E-01
Northern goshawk	9.80E-01	0.00E+00	2.00E-02	1.00E-00	1.00E-00	6.00E-02	1.05E-00
Peregrine falcon	9.80E-01	0.00E+00	2.00E-02	1.00E-00	1.00E-00	4.96E-02	7.82E-01
Avian carnivores (AV322)	9.80E-01	0.00E+00	2.00E-02	1.00E-00	1.00E-00	7.44E-03	4.25E-02
Bald eagle	9.80E-01	0.00E+00	2.00E-02	1.00E-00	1.00E-00	1.60E-01	4.74E-00
Ferruginous hawk	9.80E-01	0.00E+00	2.00E-02	1.00E-00	1.00E-00	6.19E-02	1.10E-00
Loggerhead shrike	9.80E-01	0.00E+00	2.00E-02	1.00E-00	1.00E-00	7.44E-03	4.25E-02
Avian carnivores (AV322A)	9.70E-01	0.00E+00	3.00E-02	1.00E-00	1.00E-00	1.73E-02	1.55E-01
Burrowing owl	9.70E-01	0.00E+00	3.00E-02	1.00E-00	1.00E-00	1.73E-02	1.55E-01
Avian carnivores (AV333)	8.20E-01	0.00E+00	1.80E-01	1.00E-00	1.00E-00	1.84E-02	1.71E-01
Avian carnivores (AV342)	9.80E-01	0.00E+00	2.00E-02	1.00E-00	1.00E-00	4.64E-02	7.06E-01
Avian omnivores (AV422)	6.27E-01	2.80E-01	9.30E-02	1.00E-00	1.00E-00	1.13E-02	8.02E-02
Avian omnivores (AV432)	5.70E-01	2.50E-01	1.80E-01	1.00E-00	1.00E-00	2.75E-02	3.16E-01
Avian omnivores (AV433)	5.70E-01	2.50E-01	1.80E-01	1.00E-00	1.00E-00	5.33E-02	8.74E-01

Table D2-3-2. (continued).

Functional Groups	PP	PV	PS	SUF	ED	IR (kg/day)	BW (kg)
Avian omnivores (AV442)	6.20E-01	2.70E-01	1.10E-01	1.00E-00	1.00E-00	4.41E-02	6.54E-01
Mammalian herbivores (M121)	0.00E+00	9.80E-01	2.00E-02	1.00E-00	1.00E-00	3.14E-01	5.80E-00
Mammalian herbivores (M122)	0.00E+00	9.37E-01	6.30E-02	1.00E-00	1.00E-00	3.30E-03	1.10E-02
Mammalian herbivores (M122A)	0.00E+00	9.23E-01	7.70E-02	1.00E-00	1.00E-00	4.27E-03	1.57E-02
Pygmy rabbit	0.00E+00	9.80E-01	2.00E-02	1.00E-00	1.00E-00	4.53E-02	4.04E-01
Mammalian herbivores (M123)	0.00E+00	9.23E-01	7.70E-02	1.00E-00	1.00E-00	1.51E-02	8.89E-02
Mammalian insectivores (M210)	9.80E-01	0.00E+00	2.00E-02	1.00E-00	1.00E-00	1.43E-03	9.03E-03
Mammalian insectivores (M210A)	9.80E-01	0.00E+00	2.00E-02	1.00E-00	1.00E-00	1.43E-03	4.65E-03
Townsend's western big-eared bat	9.90E-01	0.00E+00	1.00E-02	1.00E-00	1.00E-00	2.37E-03	1.10E-02
Small-footed myotis	9.90E-01	0.00E+00	1.00E-02	1.00E-00	1.00E-00	1.44E-03	4.69E-03
Long-eared myotis	9.90E-01	0.00E+00	1.00E-02	1.00E-00	1.00E-00	1.77E-03	6.65E-03
Mammalian insectivores (M222)	9.76E-01	0.00E+00	2.40E-02	1.00E-00	1.00E-00	1.66E-03	6.00E-03
Mammalian carnivores (M322)	9.23E-01	0.00E+00	7.70E-02	1.00E-00	1.00E-00	1.66E-02	1.78E-01
Mammalian omnivores (M422)	8.06E-01	1.00E-01	9.40E-02	1.00E-00	1.00E-00	3.06E-03	1.70E-02
Mammalian omnivores (M422A)	8.06E-01	1.00E-01	9.40E-02	1.00E-00	1.00E-00	2.60E-01	5.05E-00
Reptilian insectivores (R222)	9.76E-01	0.00E+00	2.40E-02	1.00E-00	1.00E-00	5.60E-05	6.61E-03
Sagebrush lizard	9.76E-01	0.00E+00	2.40E-02	1.00E-00	1.00E-00	5.60E-05	6.61E-03
Reptilian carnivores (R322)	9.52E-01	0.00E+00	4.80E-02	1.00E-00	1.00E-00	6.80E-03	1.50E-02
Plants	0.00E+00	0.00E+00	1.00E-00	1.00E-00	1.00E-00		

Table D2-3-3. Summary of EBSL input values and literature sources for dietary parameters (PP, PV and PS).

Functional Groups	PP	PV	PS	PS Model Species[a]
Amphibians (A232)	9.41E-01	0.00E+01	5.90E-02	Eastern painted turtle
Avian herbivores (AV121)	0.00E+00	9.90E-01	1.00E-02	Estimated
Avian herbivores (AV122)	0.00E+00	9.07E-01	9.30E-02	Wild turkey
Avian herbivores (AV132)	0.00E+00	8.20E-01	1.80E-01	Western sandpiper
Avian herbivores (AV142)	0.00E+00	9.18E-01	8.20E-02	Canada goose
Avian herbivores (AV143)	0.00E+00	9.18E-01	8.20E-02	Canada goose
Trumpeter swan	0.00E+00	9.18E-01	8.20E-02	Canada goose
Avian insectivores (AV210)	9.80E-01	0.00E+00	2.00E-02	Estimated
Black tern	7.50E-01	0.00E+00	2.00E-02	Estimated
Avian insectivores (AV210A)	9.70E-01	0.00E+00	3.00E-02	Burrowing owl
Avian insectivores (AV221)	9.70E-01	0.00E+00	3.00E-02	Burrowing owl
Avian insectivores (AV222)	9.07E-01	0.00E+00	9.30E-02	Wild turkey
Avian insectivores (AV222A)	9.07E-01	0.00E+00	9.30E-02	Wild turkey
Avian insectivores (AV232)	8.20E-01	0.00E+00	1.80E-01	Western sandpiper
Avian insectivores (AV233)	8.20E-01	0.00E+00	1.80E-01	Western sandpiper
White-faced ibis	8.90E-01	0.00E+00	1.10E-01	Western sandpiper
Avian insectivores (AV241)	8.20E-01	0.00E+00	1.80E-01	Western sandpiper
Avian insectivores (AV242)	8.20E-01	0.00E+00	1.10E-01	Wood duck
Avian carnivores (AV310)	9.80E-01	0.00E+00	2.00E-02	Wood duck
Northern goshawk	9.80E-01	0.00E+00	2.00E-02	Estimated
Peregrine falcon	9.80E-01	0.00E+00	2.00E-02	Estimated
Avian carnivores (AV322)	9.80E-01	0.00E+00	2.00E-02	Estimated
Bald eagle	9.80E-01	0.00E+00	2.00E-02	Estimated
Ferruginous hawk	9.80E-01	0.00E+00	2.00E-02	Estimated
Loggerhead shrike	9.80E-01	0.00E+00	2.00E-02	Estimated
Avian carnivores (AV322A)	9.70E-01	0.00E+00	3.00E-02	Burrowing owl
Burrowing owl	9.70E-01	0.00E+00	3.00E-02	Burrowing owl
Avian carnivores (AV333)	8.20E-01	0.00E+00	1.80E-01	Western sandpiper
Avian carnivores (AV342)	9.80E-01	0.00E+00	2.00E-02	NOT MODELED
Avian omnivores (AV422)[b]	6.27E-01	2.80E-01	9.30E-02	Wild turkey
Avian omnivores (AV432)[b]	5.70E-01	2.50E-01	1.80E-01	Western sandpiper
Avian omnivores (AV433)[b]	5.70E-01	2.50E-01	1.80E-01	Western sandpiper
Avian omnivores (AV442)[b]	6.20E-01	2.70E-01	1.10E-01	Wood duck
Mammalian herbivores (M121)	0.00E+00	9.80E-01	2.00E-02	Mule deer
Mammalian herbivores (M122)	0.00E+00	9.37E-01	6.30E-02	Black-tailed jackrabbit[c]
Mammalian herbivores (M122A)	0.00E+00	9.23E-01	7.70E-02	Black-tailed prairie dog
Pygmy rabbit	0.00E+00	9.80E-01	2.00E-02	Black-tailed prairie dog
Mammalian herbivores (M123)	0.00E+00	9.23E-01	7.70E-02	Black-tailed prairie dog
Mammalian insectivores[d] (M210)	9.80E-01	0.00E+00	2.00E-02	Beetle specialist
Mammalian insectivores[d] M210A)	9.80E-01	0.00E+00	2.00E-02	Beetle specialist
Townsend's western big-eared bat	9.90E-01	0.00E+00	1.00E-02	Moth specialist

Table D2-3-3. (continued).

Functional Groups	PP	PV	PS	PS Model Species[a]
Small-footed myotis	9.90E-01	0.00E+00	1.00E-02	Moth specialist
Long-eared myotis	9.90E-01	0.00E+00	1.00E-02	Beetle specialist
Mammalian insectivores (M222)	9.76E-01	0.00E+00	2.40E-02	Meadow vole
Mammalian carnivore (M322)	9.23E-01	0.00E+00	7.70E-02	Black-tailed prairie dog
Mammalian omnivores[e] (M422)	8.06E-01	1.00E-01	9.40E-02	Raccoon
Mammalian omnivores[e] (M422A)	8.06E-01	1.00E-01	9.40E-02	Fox
Reptilian insectivores (R222)	9.76E-01	0.00E+00	2.40E-02	Meadow vole
Sagebrush lizard	9.76E-01	0.00E+00	2.40E-02	Meadow vole
Reptilian carnivores (R322)	9.52E-01	0.00E+00	4.80E-02	Fox plus 2%

a. From Beyer et al., 1994 unless otherwise noted.

b. Dietary composition percent prey and percent vegetation based on avian models from EPA 1993.

c. Arthur and Gates 1988.

d. Soil ingestion rates for bats were estimated based on primary prey life histories – Beetle strategists = 2% and moth strategists =1%.

e. Dietary composition 90% prey and 10%vegetation based on INEEL data for the coyote (Johnson and Hansen 1979).

D2-3.2 Body Weight (BW)

Body weights (BWs) for mammals, amphibians, and reptiles were extracted from numerous local and regional studies. Body weights for birds were taken primarily from Dunning (1993) unless local or regional values were available. Values were chosen in order of preference for study locale: (1) INEEL, (2) Idaho, (3) Regional (sagebrush steppe in Washington, Oregon, Wyoming, Nevada and northern Utah), and (4) U.S.-wide. Where no distinction in sex was reported, mean adult weights were used. In cases where only separate means for male and female were reported, the average of the two was calculated. In cases where only a range in weights could be found, a median value was used. Functional group weight represents the smallest individual species body weight in the group. Finalized body weights for functional groups and individual EBSL calculations and literature sources are given on Table D2-3-4.

D2-3.3 Food and Water Ingestion Rates (IR, WI)

Food/prey ingestion rates (IR) for most INEEL species were calculated using allometric equations given in Nagy (1987). Food intake rates (grams dry weight per day) for passerine birds, nonpasserine birds, rodents, herbivores, all other mammals, and insectivorous reptiles were estimated using the following allometric equations (Nagy 1987).

$$Food\ intake\ rate = 0.398\ BW^{0.850}\ (passerines) \quad \text{(D2-23)}$$

$$Food\ intake\ rate = 1.110\ BW^{0.445}\ (desert\ bird) \quad \text{(D2-24)}$$

$$Food\ intake\ rate = 0.648\ BW^{0.651}\ (all\ birds) \quad \text{(D2-25)}$$

$$Food\ intake\ rate = 0.583\ BW^{0.585}\ (rodents) \quad \text{(D2-26)}$$

$$Food\ intake\ rate = 0.577\ BW^{0.727}\ (mammalian\ herbivores) \quad \text{(D2-27)}$$

Table D2-3-4. Summary of EBSL body weight (BW) input values.

Functional Groups	BW (kg)	Representative Species	Reference
Amphibians (A232)	8.00E-03	Boreal chorus frog	Steenhof 1983 (calculated from SVL[a] for spadefoot toads – 0.6 SVL)
Avian herbivores (AV121)	1.29E-02	American goldfinch	Dunning 1993 (mean adult)
Avian herbivores (AV122)	3.50E-03	Rufous hummingbird	Dunning 1993 (mean adult)
Avian herbivores (AV132)	7.46E-02	Sora	Dunning 1993 (mean adult)
Avian herbivores (AV142)	3.16E-01	Green-winged teal	Steenhof 1983 (mean adult)
Avian herbivores (AV143)	3.47E-01	Cinnamon teal	Steenhof 1983 (mean adult)
Trumpeter swan	1.09E+01	Trumpter swan	Dunning 1993 (mean adult)
Avian insectivores (AV210)	1.00E-02	Western flycatcher	Dunning 1993 (mean adult)
Black tern	6.53E-02	Black tern	Dunning 1993 (mean adult)
Avian insectivores (AV210A)	1.46E-02	Bank swallow	Dunning 1993 (mean adult)
Avian insectivores (AV221)	6.65E-03	Ruby-crowned kinglet	Dunning 1993 (mean adult)
Avian insectivores (AV222)	1.09E-02	House wren	Dunning 1993 (mean adult)
Avian insectivores (AV222A)	1.00E-02	Canyon wren	Steenhof 1983 (mean adult)
Avian insectivores (AV232)	2.32E-02	Least sandpiper	Dunning 1993 (mean adult)
Avian insectivores (AV233)	2.15E-02	Willet	Dunning 1993 (mean adult)
White-faced ibis	6.22E-01	White-faced ibis	Dunning 1993 (mean adult)
Avian insectivores (AV241)	8.10E-02	Lesser yellowlegs	Dunning 1993 (mean adult)
Avian insectivores (AV242)	2.12E-01	Bonaparte's gull	Dunning 1993 (mean adult)
Avian carnivores (AV310)	1.39E-01	Sharp-shinned hawk	Dunning 1993 (mean adult)
Northern goshawk	1.05E-00	Northern goshawk	Dunning 1993 (mean adult)
Peregrine falcon	7.82E-01	Peregrine falcon	Dunning 1993 (mean adult)
Avian carnivores (AV322)	4.25E-02	Loggerhead shrike	Fraser and Luukkonen 1986 (mean adult)
Bald eagle	4.74E-00	Bald eagle	Dunning 1993 (mean adult)
Ferruginous hawk	1.10E-00	Ferruginous hawk	Steenhof 1993 (mean adult)
Loggerhead shrike	4.25E-02	Loggerhead shrike	Fraser and Luukkonen 1986 (mean adult)
Avian carnivores (AV322A)	1.55E-01	Burrowing owl	Dunning 1993 (mean adult)
Burrowing owl	1.55E-01	Burrowing owl	Dunning 1993 (mean adult)
Avian carnivores (AV333)	1.71E-01	Greater yellowlegs	Dunning 1993 (mean adult)
Avian carnivores (AV342)	7.06E-01	American bittern	Dunning 1993 (mean adult)
Avian omnivores (AV422)	8.02E-02	Scrub jay	Dunning 1993 (mean adult)
Avian omnivores (AV432)	3.16E-01	American avocet	Dunning 1993 (mean adult)
Avian omnivores (AV433)	8.74E-01	Great egret	Dunning 1993 (mean adult)
Avian omnivores (AV442)	6.54E-01	American coot	Steenhof 1983 (mean adult
Mammalian herbivores (M121)	5.80E-00	American porcupine	Steenhof 1983 (mean adult)
Mammalian herbivores (M122)	1.10E-02	Western harvest mouse	Steenhof 1983 (mean adult)
Mammalian herbivores (M122A)	1.57E-02	Sagebrush vole	Mullican 1985 (median adult)
Pygmy rabbit	4.04E-01	Pygmy rabbit	Arthur and Markham 1978 (mean adult)
Mammalian herbivores (M123)	8.89E-02	Northern pocket gopher	Wakely 1978 (mean adult)
Mammalian insectivores (M210)	9.03E-03	Silver-haired bat	Barclay et al. 1988 (mean adult)

Table D2-3-4. (continued).

Functional Groups	BW (kg)	Representative Species	Reference
Mammalian insectivores (M210A)	4.65E-03	California myotis	Black 1974 (mean adult)
Townsend's western big-eared bat	1.10E-02	Townsend's western big-eared bat	Burt and Grossenheider 1980 (median adult)
Small-footed myotis	4.69E-03	Small-footed myotis	Barclay et al. 1988 (mean adult)
Long-eared myotis	6.65E-03	Long-eared myotis	Barclay et al. 1988 (mean adult)
Mammalian insectivores (M222)	6.00E-03	Merriam's shrew	Steenhof 1983 (mean adult)
Mammalian carnivores (M322)	1.78E-01	Long-tailed weasel	Steenhof 1983 (mean adult)
Mammalian omnivores (M422)	1.70E-02	House mouse	Burt and Grossenheider 1980 (median adult)
Mammalian omnivores (M422A)	5.05E-00	Red fox	Lindstedt et al. 1986 (mean adult)
Reptilian insectivores (R222)	6.61E-03	Sagebrush lizard	Burkholder 1978 (mean adult)
Sagebrush lizard	6.61E-03	Sagebrush lizard	Burkholder 1978 (mean adult)
Reptilian carnivores (R322)	1.50E-02	Night snake	Steenhof 1983 (mean adult)

a. SVL = snout to vent length.

$$Food\ intake\ rate = 0.235\ BW^{0.822}\ (all\ other\ mammals) \quad \text{(D2-28)}$$

$$Food\ intake\ rate = 0.15\ BW^{0.874}\ (desert\ mammals) \quad \text{(D2-29)}$$

$$Food\ intake\ rate = 0.013\ BW^{0.773}\ (reptile\ insectivores) \quad \text{(D2-30)}$$

where BW = body weight in grams.

The original equation for rodents (D2-26) has been modified slightly (Nagy 1987), based on errors discovered in that report. An equation for ingestion rates for carnivorous reptiles (R322) was constructed using data reported by Diller and Johnson (1988).

$$Food\ intake\ rate = 0.01\ BW^{1.6}\ (reptile\ carnivores) \quad \text{(D2-31)}$$

where BW = body weight in kilograms.

These equations were applied to estimate the ingestion rate (g dry weight/day) as a function of body weight (see Section D2-2). The application of individual equations for species and groups varies according to taxonomic Class and/or Order and in some cases, on habitat (e.g., aquatic species). In cases where more than one of Nagy's (1987) equations could be applied to a functional group, such as all mammals or desert rodents, the larger of the two rates was applied. For functional groups in which mixed species occur, intake rates were calculated using the most representative or generic equation returning the largest IR. Finalized ingestion rates for functional groups and individual species are presented in Table D2-3-5.

A cursory comparison of food ingestion values generated using Nagy's (1987) equations to a few experimental values from the literature indicate that the equations may substantially underestimate ingestion rates for some species.

Table D2-3-5. Summary of EBSL input values and equations for calculation of food ingestion (IR) for groups and individuals.

Functional Groups	IR (kg/day)	Nagy Equation
Amphibians (A232)	6.49E-05	reptile insectivores
Avian herbivores (AV121)	3.50E-03	passerines
Avian herbivores (AV122)	1.46E-03	all birds
Avian herbivores (AV132)	1.07E-02	all birds
Avian herbivores (AV142)	2.75E-02	all birds
Trumpeter swan	2.75E-01	all birds
Avian herbivores (AV143)	2.92E-02	all birds
Avian insectivores (AV210)	2.90E-03	all birds
Black tern	9.84E-03	all birds
Avian insectivores (AV210A)	3.89E-03	passerines
Avian insectivores (AV221)	1.99E-03	passerines
Avian insectivores (AV222)	3.07E-03	all birds
Avian insectivores (AV222A)	2.82E-03	passerines
Avian insectivores (AV232)	1.12E-03	all birds
Avian insectivores (AV233)	4.78E-03	all birds
White-faced ibis	4.27E-02	all birds
Avian insectivores (AV241)	6.41E-03	all birds
Avian insectivores (AV242)	1.13E-02	all birds
Avian carnivores (AV310)	1.61E-02	all birds
Northern goshawk	6.00E-02	all birds
Peregrine falcon	4.96E-02	all birds
Avian carnivores (AV322)	7.44E-03	all birds
Bald eagle	1.60E-01	all birds
Ferruginous hawk	6.19E-02	all birds
Loggerhead shrike	7.44E-03	all birds
Avian carnivores (AV322A)	1.73E-02	all birds
Burrowing owl	1.73E-02	all birds
Avian carnivores (AV333)	1.84E-02	all birds
Avian carnivores (AV342)	4.64E-02	all birds
Avian omnivores (AV422)	1.13E-02	all birds
Avian omnivores (AV432)	2.75E-02	all birds
Avian omnivores (AV433)	5.33E-02	all birds
Avian omnivores (AV442)	4.41E-02	all birds
Mammalian herbivores (M121)	3.14E-01	mammal herbivore
Mammalian herbivores (M122)	3.30E-03	mammal herbivore

Table D2-3-5. (continued).

Functional Groups	IR (kg/day)	Nagy Equation
Mammalian herbivores (M122A)	4.27E-03	mammal herbivore
Pygmy rabbit	4.53E-02	mammal herbivore
Mammalian herbivores (M123)	1.51E-02	all mammals
Mammalian insectivores (M210)	1.43E-03	rodents
Mammalian insectivores (M210A)	1.43E-03	rodents
Townsend's western big-eared bat	2.37E-03	rodents
Small-footed myotis	1.44E-03	rodents
Long-eared myotis	1.77E-03	rodents
Mammalian insectivores (M222)	1.66E-03	rodents
Mammalian carnivores (M322)	1.66E-02	all mammals
Mammalian omnivores (M422)	3.06E-03	rodents
Mammalian omnivores (M422A)	2.60E-01	all mammals
Reptilian insectivores (R222)	5.60E-05	reptile insectivores
Sagebrush lizard	5.60E-05	reptile insectivores
Reptilian carnivores (R322)	6.80E-03	literature value[a]

a. Diller and Johnson 1988

D2-3.4 Exposure Duration (ED)

Exposure duration (ED) represents the fraction of year an animal spends in the affected area. Because EBSL screening values were designed to be conservative, ED was assumed to be 1 for all receptors, assuming 100% of their time is spent in the assessment area.

D2-3.5 Site Use Factor (SUF)

The site use factor (SUF) represents the proportion of a species home range that overlaps the area of contamination. An SUF of 1 indicates that the home range is less than or equal to the area of contaminant exposure. For EBSL screening, the SUF was assumed to be 1 (100% use occurs in the area of contamination) for all groups and species (see VanHorn et al. 1995).

D2-3.6 Bioaccumulation Factors (BAF, PUF)

The uptake of contaminants in the terrestrial food chain is important for realistically calculating exposure to contamination. These contaminant-specific factors are referred to in the literature as uptake factors or plant uptake factors (PUFs) for plants and food-chain transfer coefficients or factors for wildlife. The PUF is the plant tissue concentration of the contaminant divided by the soil or sediment concentration. The food-chain transfer factor is the animal tissue concentration of a contaminant divided by the concentration in its food. To estimate the tissue levels of contaminants in prey, the PUF was multiplied by the transfer factors to derive a "bioaccumulation factor" (BAF), which is the concentration

of a contaminant in the tissues of an animal divided by the soil or sediment concentration. The BAF accounts for all ingestion exposure routes. For example, the BAF for a herbivorous small mammal is the PUF times the plant-to-herbivore transfer coefficient. Multiplying the small mammal BAF times the concentration of a contaminant in soil provides an estimate of the tissue levels of the contaminant in small mammals. This tissue level may then be used to estimate exposure for the carnivore/omnivore functional groups that are predators of small mammals.

Attachments 2 and 3 to Appendix D3 contain discussions of the BAFs and PUFs developed for the INEEL and used in the ERAs, respectively. For use in the calculation of screening level values and EBSLs, these values were defaulted to 1.0 if not greater.

There is a great deal of uncertainty associated with using BAFs and PUFs to calculate dose. Very limited values are available in the scientific literature, since they must be both contaminant- and receptor-specific. In the absence of specific BAF or PUF, a value of 1 was assumed. This assumption could over- or underestimate the true dose from the contaminant, and the magnitude of error cannot be quantified. Travis and Arms (1988) and Baes et al. (1984) report BAFs for contaminants to beef and milk, many of these are less than 1 for the contaminants at the INEEL. If the terrestrial receptors of concern accumulate metals and PCBs in a similar way and to a comparable degree as beef and dairy cattle, the use of a BAF of 1 for all contaminants and receptors would overestimate the dose. On the other hand, if the terrestrial receptors of concern at INEEL accumulate metals and PCBs to a much larger degree than beef and dairy cattle, the assumption of BAFs equal to 1 could underestimate the true dose from the COPCs. This same logic is true of PUFs.

D2-4. TOXICITY REFERENCE VALUE (TRV) DEVELOPMENT

The exposure modeled using the equations presented previous is then divided by a toxicity reference value (TRV) developed for each COPC/receptor combination to produce an HQ. For EBSL development the TRV provides the value used to calculate acceptable levels below which no adverse effect should be observed. A TRV is defined as a contaminant concentration or dose for a receptor that is likely to be without appreciable risk of adverse effects from chronic exposure. TRV development is documented in Appendix D4. TRVs used for EBSL development are presented in Table D3-4-1 and D3-4-2.

D2-5. SUMMARY AND EBSLS PRESENTATION

In summary, the EBSLs for radionuclides are presented in Table D2-5-1. First the lowest EBSLs calculated for all species and functional groups was selected for both the internal and external dose. From these values the lowest EBSLs from either the internal or external dose was used in the selection of the final EBSL for the radionuclide. The EBSLs for nonradionuclides are presented in Table D2-5-2. The lowest EBSLs calculated for all species and functional groups was selected for the nonradionuclide. The EBSLs calculated for all species and functional groups is presented in Attachment EBSL. These EBSLs are applicable to terrestrial sites at the INEEL; but are site specific and should be used with caution at other sites.

Table D2-5-1. Overall minimum EBSLs in soil for radionuclide dose.

Radionuclide	External Dose Minimum EBSL	Internal Dose Minimum EBSL	Overall Minimum EBSL
Ac-225	2.92E+05	1.70E+01	1.70E+01
Ac-227	2.40E+07	2.04E+05	2.04E+05
Ac-228	3.29E+03	3.10E+03	3.10E+03
Ag-108	1.82E+03	1.78E+03	1.78E+03
Ag-108m	1.82E+03	4.01E+03	1.82E+03
Ag-109m	9.01E+05	1.99E+06	9.01E+05
Ag-110	1.06E+03	9.37E+02	9.37E+02
Ag-110m	1.08E+03	2.20E+03	1.08E+03
Am-241	1.32E+05	1.78E+01	1.78E+01
Am-242	6.63E+08	5.33E+02	5.33E+02
Am-243	5.70E+04	1.85E+01	1.85E+01
At-217	1.24E+07	1.38E+01	1.38E+01
Au-198	7.28E+03	1.54E+04	7.28E+03
Ba-133	7.34E+03	1.62E+04	7.34E+03
Ba-137m	4.95E+03	1.09E+04	4.95E+03
Ba-140	1.99E+04	5.85E+03	5.85E+03
Be-7	5.92E+04	1.31E+05	5.92E+04
Be-10	NA[a]	9.63E+03	9.63E+03
Bi-210	NA	5.01E+03	5.01E+03
Bi-212	1.23E+03	6.66E+02	6.66E+02
Bi-213	2.09E+03	1.15E+03	1.15E+03
Bi-214	1.99E+03	3.83E+03	1.99E+03
Br-82	9.76E+02	1.51E+03	9.76E+02
C-14	NA	3.94E+04	3.94E+04
Ca-45	NA	2.53E+04	2.53E+04
Cd-104	1.29E+04	2.84E+04	1.29E+04
Cd-109	1.98E+05	4.36E+05	1.98E+05
Ce-139	2.21E+04	4.88E+04	2.21E+04
Ce-141	4.22E+04	1.18E+04	1.18E+04
Ce-144	1.87E+05	2.27E+04	2.27E+04
Cf-252	1.45E+08	1.64E+01	1.64E+01
Cl-36	NA	7.84E+03	7.84E+03

Table D2-5-1. (continued).

Radionuclide	External Dose Minimum EBSL	Internal Dose Minimum EBSL	Overall Minimum EBSL
Cm-242	1.24E+08	1.60E+01	1.60E+01
Cm-244	2.30E+08	1.68E+01	1.68E+01
Cm-248	3.35E+08	2.10E+01	2.10E+01
Co-57	2.45E+04	5.40E+04	2.45E+04
Co-58	3.66E+03	7.17E+03	3.66E+03
Co-60	1.18E+03	2.30E+03	1.18E+03
Cr-51	9.39E+04	2.07E+05	9.39E+04
Cs-134	1.90E+03	3.14E+03	1.90E+03
Cs-136	1.38E+03	2.63E+03	1.38E+03
Cs-137	4.95E+03	5.58E+03	4.95E+03
Er-169	2.25E+08	1.96E+04	1.96E+04
Eu-152	2.27E+03	2.18E+03	2.18E+03
Eu-154	2.48E+03	3.31E+03	2.48E+03
Eu-155	5.95E+04	3.25E+04	3.25E+04
Fe-55	2.01E+06	4.42E+06	2.01E+06
Fe-59	2.48E+03	4.12E+03	2.48E+03
Fr-221	8.98E+04	1.53E+01	1.53E+01
Fr-223	5.85E+04	5.47E+03	5.47E+03
Gd-152	NA	4.53E+01	4.53E+01
Gd-153	5.32E+04	1.17E+05	5.32E+04
H-3	NA	3.43E+05	3.43E+05
Hf-175	9.47E+03	2.09E+04	9.47E+03
Hf-181	5.69E+03	7.12E+03	5.69E+03
Hg-208	1.37E+04	1.59E+04	1.37E+04
I-125	1.28E+06	2.82E+06	1.28E+06
I-129	9.88E+05	4.76E+04	4.76E+04
I-131	7.80E+03	6.61E+03	6.61E+03
I-132	1.29E+03	1.66E+03	1.29E+03
I-133	4.89E+03	3.32E+03	3.32E+03
In-113m	1.13E+04	2.50E+04	1.13E+04
Ir-192	3.64E+03	4.69E+03	3.64E+03
Kr-85	1.88E+04	3.70E+03	3.70E+03

Table D2-5-1. (continued).

Radionuclide	External Dose Minimum EBSL	Internal Dose Minimum EBSL	Overall Minimum EBSL
La-140	1.43E+03	1.67E+03	1.43E+03
Mn-53	2.25E+06	4.96E+06	2.25E+06
Mn-54	3.53E+03	7.79E+03	3.53E+03
Mn-56	1.81E+03	1.48E+03	1.48E+03
Mo-99	1.04E+04	4.15E+03	4.15E+03
Na-22	2.31E+03	3.38E+03	2.31E+03
Na-24	7.16E+02	1.09E+03	7.16E+02
Nb-93m	1.51E+06	3.33E+06	1.51E+06
Nb-94	1.87E+03	3.14E+03	1.87E+03
Nb-95	3.56E+03	6.69E+03	3.56E+03
Ni-59	1.24E+06	2.74E+06	1.24E+06
Ni-63	NA	1.14E+05	1.14E+05
Np-237	1.46E+05	1.94E+01	1.94E+01
Np-238	1.71E+04	1.17E+04	1.17E+04
Np-240m	8.83E+03	2.83E+03	2.83E+03
P-32	NA	2.79E+03	2.79E+03
Pa-231	9.89E+04	2.37E+01	2.37E+01
Pa-233	1.90E+04	1.70E+04	1.70E+04
Pa-234m	2.58E+05	2.37E+03	2.37E+03
Pb-210	1.57E+06	2.74E+05	2.74E+05
Pb-212	2.53E+04	1.45E+04	1.45E+04
Pb-214	1.29E+04	6.78E+03	6.78E+03
Pm-147	NA	3.15E+04	3.15E+04
Po-210	NA	1.84E+01	1.84E+01
Po-212	NA	1.11E+01	1.11E+01
Po-214	NA	1.27E+01	1.27E+01
Po-216	NA	1.44E+01	1.44E+01
Po-218	NA	1.62E+01	1.62E+01
Pr-143	NA	6.19E+03	6.19E+03
Pr-144	2.86E+05	1.61E+03	1.61E+03
Pu-238	1.06E+08	1.78E+01	1.78E+01
Pu-239	5.21E+07	1.89E+01	1.89E+01

Table D2-5-1. (continued).

Radionuclide	External Dose Minimum EBSL	Internal Dose Minimum EBSL	Overall Minimum EBSL
Pu-240	1.09E+08	1.89E+01	1.89E+01
Pu-241	NA	3.73E+05	3.73E+05
Pu-242	1.31E+08	2.00E+01	2.00E+01
Pu-244	2.70E+06	2.12E+01	2.12E+01
Ra-224	3.11E+05	2.56E+01	2.56E+01
Ra-225	2.54E+05	2.00E+04	2.00E+04
Ra-226	4.83E+05	2.04E+01	2.04E+01
Ra-228	NA	1.97E+05	1.97E+05
Rb-86	3.13E+04	2.80E+03	2.80E+03
Re-188	5.09E+04	2.49E+03	2.49E+03
Rh-103m	1.71E+06	3.78E+06	1.71E+06
Rh-106	1.62E+04	1.33E+03	1.33E+03
Rn-220	5.36E+06	1.55E+01	1.55E+01
Rn-222	7.20E+07	1.78E+01	1.78E+01
Ru-103	6.38E+03	9.23E+03	6.38E+03
Ru-106	NA	1.94E+05	1.94E+05
S-35	NA	2.59E+04	2.59E+04
Sb-124	1.65E+03	1.38E+03	1.38E+03
Sb-125	7.12E+03	6.02E+03	6.02E+03
Sc-44	2.51E+03	1.33E+03	1.33E+03
Sc-46	1.47E+03	2.73E+03	1.47E+03
Se-75	7.63E+03	1.68E+04	7.63E+03
Sm-147	NA	4.34E+01	4.34E+01
Sn-113	5.99E+05	1.32E+06	5.99E+05
Sn-117m	1.87E+04	4.13E+04	1.87E+04
Sn-119m	7.65E+05	1.69E+06	7.65E+05
Sr-85	4.06E+03	8.96E+03	4.06E+03
Sr-89	1.62E+07	3.34E+03	3.34E+03
Sr-90	NA	3.34E+03	3.34E+03
Sr-91	4.23E+03	2.26E+03	2.26E+03
Sr-92	2.20E+03	3.24E+03	2.20E+03
Ta-182	2.31E+03	3.85E+03	2.31E+03

Table D2-5-1. (continued).

Radionuclide	External Dose Minimum EBSL	Internal Dose Minimum EBSL	Overall Minimum EBSL
Tc-99	2.36E+04	1.60E+04	1.60E+04
Tc-99m	2.32E+04	5.12E+04	2.32E+04
Te-125m	8.42E+04	1.86E+05	8.42E+04
Te-132	1.28E+04	1.52E+04	1.28E+04
Th-228	1.51E+06	1.81E+01	1.81E+01
Th-229	7.15E+04	3.60E+01	3.60E+01
Th-230	7.76E+06	2.09E+01	2.09E+01
Th-231	1.63E+05	2.33E+04	2.33E+04
Th-232	1.81E+07	2.43E+01	2.43E+01
Th-234	3.66E+05	4.16E+04	4.16E+04
Tl-204	NA	8.21E+03	8.21E+03
Tm-170	1.07E+06	6.17E+03	6.17E+03
U-232	1.21E+07	1.54E+01	1.54E+01
U-233	1.02E+07	2.03E+01	2.03E+01
U-234	1.98E+07	2.05E+01	2.05E+01
U-235	2.16E+04	2.27E+01	2.27E+01
U-236	7.23E+07	2.17E+01	2.17E+01
U-238	8.50E+07	2.32E+01	2.32E+01
U-240	4.39E+05	1.54E+04	1.54E+04
V-48	1.01E+03	2.23E+03	1.01E+03
W-185	1.18E+08	1.54E+04	1.54E+04
Xe-131m	1.47E+05	3.23E+05	1.47E+05
Xe-133	6.51E+04	1.72E+04	1.72E+04
Y-88	1.10E+03	2.42E+03	1.10E+03
Y-90	4.68E+03	1.74E+03	1.74E+03
Y-91	5.52E+03	2.56E+03	2.56E+03
Y-92	1.17E+04	1.29E+03	1.29E+03
Y-93	3.31E+04	1.63E+03	1.63E+03
Yb-164	1.19E+03	2.62E+03	1.19E+03

Table D2-5-1. (continued).

Radionuclide	External Dose Minimum EBSL	Internal Dose Minimum EBSL	Overall Minimum EBSL
Zn-65	5.21E+03	1.13E+04	5.21E+03
Zr-93	NA	9.95E+04	9.95E+04
Zr-95	3.69E+03	5.49E+03	3.69E+03

a. NA—not available. This radionuclide has zero or negligible external dose.

Table D2-5-2. Minimum EBSL and plant benchmarks for nonradionuclide contaminants.

Contaminant	Minimum EBSL for Avian	Minimum EBSL for Mammalian	Minimum EBSL	Plant Benchmark
1,1-Dichloroethane	0.00E+00	6.95E+00	6.95E+00	NA
1,1-Dichloroethylene	0.00E+00	2.19E+00	2.19E+00	NA
1,1,1-trichloroethane	0.00E+00	8.13E+02	8.13E+02	NA
1,1,2,2-Tetrachloroethane	0.00E+00	1.67E+01	1.67E+01	NA
1,2 Dichloroethane	1.39E+00	1.11E+01	1.39E+00	NA
1,2,4-Trichlorobenzene	0.00E+00	1.82E+00	1.82E+00	NA
1,3 Dinitrobenzene	0.00E+00	7.82E-02	7.82E-02	NA
1,4 Dioxane	0.00E+00	1.58E-02	1.58E-02	NA
2-Butanone	0.00E+00	3.83E+01	3.83E+01	NA
2-Chlorotoluene	0.00E+00	1.07E+01	1.07E+01	NA
2-Propanol	0.00E+00	7.04E+02	7.04E+02	NA
2,3,7,8-Tetrachlorodibenzodioxin	4.76E-06	1.07E-06	1.07E-06	NA
2,4-Dichlorophenoxyacetic acid	0.00E+00	1.07E+00	1.07E+00	NA
2,4-Dimethylphenol	0.00E+00	3.75E+01	3.75E+01	NA
2,4-Dinitrotoluene	0.00E+00	1.54E+00	1.54E+00	NA
2,6-Dinitrotoluene	0.00E+00	2.18E+00	2.18E+00	NA
4-Chloroaniline	0.00E+00	5.35E-01	5.35E-01	NA
4-Methylphenol	0.00E+00	4.92E+00	4.92E+00	NA
4-Chloro-3-methylphenol	0.00E+00	1.80E+01	1.80E+01	NA
Acenaphthene	0.00E+00	4.74E+01	4.74E+01	NA
Acetone	0.00E+00	5.53E-01	5.53E-01	NA
Acetonitrile	0.00E+00	3.08E-01	3.08E-01	NA
Acrylonitrile	0.00E+00	1.15E-02	1.15E-02	NA
Aluminum	1.55E+02	8.50E+00	8.50E+00	50
Aluminum chloride	0.00E+00	1.04E+01	1.04E+01	NA
Aluminum hydroxide	6.04E+02	3.99E+01	3.99E+01	NA
Aluminum nitrate	0.00E+00	4.87E+01	4.87E+01	NA
Aluminum sulfate	2.79E+01	0.00E+00	2.79E+01	NA
Ammonia	0.00E+00	4.67E+00	4.67E+00	NA
Anthracene	0.00E+00	1.35E+02	1.35E+02	NA
Antimony	0.00E+00	1.35E+00	1.35E+00	5

Table D2-5-2. (continued).

Contaminant	Minimum EBSL for Avian	Minimum EBSL for Mammalian	Minimum EBSL	Plant Benchmark
Aroclor 1254	1.66E-01	3.57E-01	1.66E-01	40
Aroclor 1260	0.00E+00	8.02E+00	8.02E+00	40
Arsenic	1.28E+00	8.44E-01	8.44E-01	10
Asbestos	0.00E+00	2.17E+02	2.17E+02	NA
Barium	0.00E+00	1.10E+01	1.10E+01	500
Benzene	0.00E+00	5.50E+00	5.50E+00	NA
Benzine	0.00E+00	5.19E-01	5.19E-01	NA
Benzo(a)anthracene	0.00E+00	3.02E+01	3.02E+01	NA
Benzo(a)pyrene	0.00E+00	2.69E+00	2.69E+00	NA
Beryllium	0.00E+00	7.14E-01	7.14E-01	10
Bis(tri-n-butyltin)oxide	6.56E+00	3.72E+02	6.56E+00	NA
Boron	9.25E+00	2.56E+00	5.00E-01	0.5
Butyl Alcohol	0.00E+00	1.35E+02	1.35E+02	NA
Butylbenzylphthalate	0.00E+00	1.43E+01	1.43E+01	NA
Cadmium	3.83E-02	2.36E-03	2.36E-03	3
Carbon disulfide	0.00E+00	5.91E-01	5.91E-01	NA
Carbon tetrachloride	0.00E+00	9.71E+00	9.71E+00	NA
Cerium chloride	0.00E+00	2.82E+01	2.82E+01	NA
Chloroform	0.00E+00	1.54E+01	1.54E+01	NA
Chromium III	2.82E+00	8.11E+02	1.00E+00	1
Chromium VI	0.00E+00	1.62E-01	1.62E-01	1
Cobalt	4.35E-01	4.27E-01	4.27E-01	NA
Copper	9.54E+00	2.11E+00	2.11E+00	100
Cyanide	1.43E-01	5.84E+00	1.43E-01	NA
Diethyl phthalate	0.00E+00	1.53E+02	1.53E+02	NA
Di-2-ethylhexylphthalate	0.00E+00	2.56E+00	2.56E+00	NA
Di-n-butylphthalate	0.00E+00	1.50E+01	1.50E+01	200
Di-n-octylphthalate	0.00E+00	4.71E+01	4.71E+01	NA
Ethanol	0.00E+00	1.59E+00	1.59E+00	NA
Ethylbenzene	0.00E+00	5.52E+01	5.52E+01	NA
Fluoranthene	0.00E+00	3.38E+01	3.38E+01	NA
Fluorene	0.00E+00	3.38E+01	3.38E+01	NA

Table D2-5-2. (continued).

Contaminant	Minimum EBSL for Avian	Minimum EBSL for Mammalian	Minimum EBSL	Plant Benchmark
Fluoride	2.69E+00	3.40E+01	2.69E+00	NA
Formaldehyde	0.00E+00	4.59E-01	4.59E-01	NA
Hydrazine	0.00E+00	1.42E-03	1.42E-03	NA
Hydrofluoric acid	0.00E+00	5.26E+00	5.26E+00	NA
Lead	9.94E-01	8.76E+00	9.94E-01	50
Manganese	1.86E+01	1.05E+01	1.05E+01	500
Mercury(Inorganic)	4.18E+00	3.57E-01	3.00E-01	0.3
Mercury(Organic)	6.21E-03	6.49E-02	6.21E-03	0.3
Methanol	0.00E+00	5.52E+02	5.52E+02	NA
Methyl isobutyl ketone	0.00E+00	6.82E+01	6.82E+01	NA
Methylene chloride	0.00E+00	1.00E+00	1.00E+00	NA
Molybdenum	0.00E+00	1.07E+01	2.00E+00	2
Naphthalene	0.00E+00	1.43E+00	1.43E+00	NA
Nickel	6.83E+01	6.17E+01	3.00E+01	30
Nitrate	1.84E+01	5.52E+01	1.84E+01	NA
Nitric Acid	0.00E+00	3.28E+01	3.28E+01	NA
Nitrobenzene	0.00E+00	1.96E+00	1.95E+00	NA
Pentachloronitrobenzene	2.44E+00	0.00E+00	2.44E+00	NA
Pentachlorophenol	0.00E+00	1.30E-01	1.30E-01	NA
Phenanthrene	0.00E+00	1.35E+02	1.35E+02	NA
Phenol	0.00E+00	8.23E+00	8.23E+00	70
Potassium chloride	0.00E+00	2.01E+01	2.01E+01	NA
Potassium hydroxide	0.00E+00	1.66E+00	1.66E+00	NA
Potassium nitrate	0.00E+00	5.52E+01	5.52E+01	NA
Potassium phosphate	0.00E+00	1.88E+01	1.88E+01	NA
Potassium sulfate	0.00E+00	3.25E+01	3.25E+01	NA
Pyrene	0.00E+00	4.22E+01	4.22E+01	NA
Selenium	1.72E-01	4.22E-01	1.72E-01	1
Silver	3.02E+01	3.67E+01	2.00E+00	2
Sodium chloride	0.00E+00	9.35E+00	9.35E+00	NA
Sodium hydroxide	0.00E+00	6.82E+00	6.82E+00	NA
Sodium phosphate	0.00E+00	5.23E+01	5.23E+01	NA

Table D2-5-2. (continued).

Contaminant	Minimum EBSL for Avian	Minimum EBSL for Mammalian	Minimum EBSL	Plant Benchmark
Strontium	0.00E+00	5.91E+00	5.91E+00	NA
Sulfate	1.78E+01	1.72E+01	1.72E+01	NA
Sulfuric acid	0.00E+00	1.20E-01	1.20E-01	NA
Terphenyl	0.00E+00	7.50E+00	7.50E+00	NA
Tetrachloroethylene	0.00E+00	3.33E+00	3.33E+00	NA
Thallium	1.01E-01	1.30E-01	1.01E-01	1
Tin	0.00E+00	3.73E+00	3.73E+00	50
Toluene	0.00E+00	6.04E+01	6.04E+01	NA
Tributyl phosphate	0.00E+00	3.99E+01	3.99E+01	NA
Trichloroethylene	0.00E+00	1.74E+01	1.74E+01	NA
Trimethylolpropane-triester	0.00E+00	1.30E-01	1.30E-01	NA
Uranium	2.69E+01	1.66E+00	1.66E+00	NA
Vanadium	7.87E+00	1.49E+00	1.49E+00	200
Xylene	0.00E+00	2.78E-01	2.78E-01	NA
Zinc	3.29E+00	3.18E+01	3.29E+00	50
Zirconium	0.00E+00	3.23E+02	3.23E+02	NA

D2-5.1 References

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