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INADVERTENT INTRUDER ANALYSIS INPUT FOR RADIOLOGICAL PERFORMANCE ASSESSMENTS

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ACRONYMS

DCF	Dose Conversion Factor
EDE	Effective Dose Equivalent
FGR	Federal Guidance Report
ICRP	International Commission on Radiological Protection
NCRP	National Council on Radiation Protection and Measurements
PA	Performance Assessment
SRS	Savannah River Site
USEPA	United States Environmental Protection Agency
USDOE	United States Department of Energy

ABBREVIATIONS

ρ	bulk density
hr	hour
kg	kilogram
L	liter
m	meter
mrem	millirem
pCi	picocurie
sec	second
Sv	Sievert
yr	year

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1. INTRODUCTION

This report describes and identifies input parameter values used for the hypothetical inadvertent intruder analyses for Radiological PAs at SRS. It is intended to describe and document the input parameters residing in the input file ("IntruderInput") of the intruder analysis application developed by Koffman (2004).

1.1 Background

Intruder analysis estimates are performed in a performance assessment to determine radionuclide disposal limits that would bound the impacts on hypothetical individuals assumed to inadvertently access the disposal site. Cook (2003) estimates these limits for components in grout disposal for various exposure scenarios through application of associated pathway-specific dose coefficients using a Microsoft Excel spreadsheet. The intruder analysis application (Koffman 2004) was developed based on this spreadsheet with enhancements to automate many estimates and allow use of the application for other disposal types. This application accesses "IntruderInput" which contains the data that are the focus of this document

Inadvertent intruder analyses for PAs are performed for three potential exposure scenarios and their associated pathways. Disposal limits in Cook (2003) are set by taking the minimum of the resulting concentration limits from these exposure scenarios, and the air and groundwater pathways exposures estimated separately.

Dose coefficients (EDE per concentration) are estimated for each exposure scenario based on the sum of the pathway-specific dose coefficients. Scenario-specific dose coefficients are used to estimate disposal limits by:

$$DL_i = \frac{H}{DC_{iS}} \qquad \text{(Eq. 1.1-1)}$$

where

DL_i = the disposal limit for radionuclide i (μCi /cm^3)

H = Effective dose equivalent (rem/year), and

DC_{iS} = radionuclide- and scenario- specific dose coefficient (rem*cm^3/μCi*year).

The equations for the scenario-specific and the associated pathway-specific dose coefficients in the next two sections contain the input parameters described in subsequent sections of this document.

1.1.1 Exposure Scenarios

Inadvertent intruders are assumed to be exposed to buried waste via the agricultural, residential and post-drilling scenarios. Potential exposure pathways can vary with time after exposure. Brief descriptions of each exposure scenario and their associated pathways are below. Detailed descriptions of each exposure scenario can be found in McDowell-Boyer (2000). Equations for estimating dose coefficients for each exposure scenario are included in this section. Equations for the associated pathway-specific dose coefficients are in the subsequent section.

Agricultural Scenario

For the agricultural scenario, the inadvertent intruder is assumed to be exposed to waste exhumed from the disposal unit while excavating to build a foundation for a home. In addition, the waste is assumed to be mixed with the native soil in a vegetable garden. Potential exposure pathways for the inadvertent intruder under this scenario include:

- ingestion of vegetables grown in the garden soil mixed with exhumed waste,
- direct ingestion of contaminated soil,
- external exposure to the contaminated soil while working in the garden,
- external exposure to the contaminated soil while residing in the home,
- inhalation of contaminated particulates while working in the garden, and
- inhalation of contaminated particulates while residing in the home.

The agricultural scenario dose coefficient is estimated by summing the dose coefficient for these pathways:

$$DC_A = DC_{iv} + DC_{is} + DC_{ie} + DC_{ie}(A) + DC_{ia}(g) + DC_{ia}(h) \quad \text{(Eq. 1.1-2)}$$

where

DC_{iv} = vegetable consumption dose coefficient (rem*cm^3/μCi*year)

DC_{is} = soil ingestion dose coefficient (rem*cm^3/μCi*year)

DC_{ie} = garden exposure dose coefficient (rem*cm^3/μCi*year)

DC_{ie}(A) = agricultural residential exposure dose coefficient (rem*cm^3/μCi*year)

DC_{ia}(g)= garden exposure inhalation dose coefficient (rem*cm^3/μCi*year)

DC_{ia}(h)= home exposure inhalation dose coefficient (rem*cm^3/μCi*year).

Residential Scenario

Residential exposure is assumed to occur after penetration to the engineered barrier while excavating to build a home. The inadvertent intruder is assumed to build a home on top of the engineered barrier and is exposed through the external pathway while residing in the home. The residential scenario dose coefficient is estimated by:

$$DC_R = DC_{ie}(R) \quad \text{(Eq. 1.1-3)}$$

DC_{ie}(R) = residential exposure dose coefficient (rem*cm^3/μCi*year)

Post Drilling Scenario

For the post drilling scenario, inadvertent intruders are assumed to be exposed after drilling through the disposal unit mixing the drilling waste with the native soil in the vegetable garden. Potential exposure scenarios for this scenario include:

- ingestion of vegetables grown in the garden soil mixed with exhumed waste,
- direct ingestion of contaminated soil,
- external exposure to the contaminated soil while working in the garden, and
- inhalation of contaminated particulates while residing in the home.

The post-drilling residential scenario dose coefficient is estimated by:

$$DC_{PD} = 0.1 * \left(DC_{iv} + DC_{is} + DC_{ie} + DC_{ia}(g)\right) \qquad \text{(Eq. 1.1-4)}$$

where

0.1 = factor to adjust dilution factor for mixture of exhumed waste in vegetable garden to account for more dilution in post drilling because drilling brings less waste to the surface than excavation (McDowell Boyer et al. 2000).

1.1.2 Exposure Pathways

Ingestion Pathway

Potential ingestion pathways include ingestion of drinking water, consumption of vegetables grown in the contaminated native soil, and incidental ingestion of soil.

The drinking water dose coefficient is estimated by:

$$DC_{DW} = U_W * DCF_i \qquad \text{(Eq. 1.1-5)}$$

where

DC_{DW} = drinking water pathway dose coefficients (rem*L/μCi*year)

U_W = annual consumption of drinking water (L/year)

DCF_i = DCF for ingestion of radionuclide i (rem/μCi).

The vegetable consumption dose coefficient is estimated by:

$$DC_{iv} = \frac{B_{iv} * U_v * f_s * DCF_i}{\rho_s} \qquad \text{(Eq. 1.1-6)}$$

where

B_{iv} = plant-to-soil ratio for radionuclide i

U_v = annual consumption of vegetables (kg/year)

f_s = dilution factor for mixture of exhumed waste in vegetable garden

ρ_s = bulk density of soil (kg/cm^3).

The soil ingestion dose coefficient is estimated by:

$$DC_{is} = \frac{U_s * f_s * DCF_i}{\rho_s} \quad \text{(Eq. 1.1-7)}$$

where

U_s = annual consumption of soil (kg/year).

External Pathway

External exposure is assumed to occur while working in the vegetable garden, residing in the home on top of the disposal unit with no shielding other than the foundation of the home, and with shielding of a thickness dependent on the design of the disposal unit.

The external dose coefficient while working in the vegetable garden is estimated by:

$$DC_{ie} = U_g * f_s * DCF_{ie} \quad \text{(Eq. 1.1-8)}$$

where

U_g = fraction of a year exposed to contaminated soil in vegetable garden

DCF_{ie}= DCF for external exposure to 15 cm of soil uniformly contaminated with radionuclide i (rem*cm^3/µCi*year)

External dose coefficient while residing in the home directly on top of the disposal unit is estimated by:

$$DC_{ie}(0) = U_h * DCF_{it}(0) * S \quad \text{(Eq. 1.1-9)}$$

where

U_h = fraction of a year spent in home

$DCF_{it}(0)$ = DCF for external exposure to waste containing radionuclide i with no shielding (rem*cm^3/µCi*year)

S = shielding factor for radionuclides during indoor residence

External dose coefficient while residing in the home on top of the disposal unit shielded by a known thickness (t) is estimated by:

$$DC_{ie}(t) = U_h * DCF_{it}(t) * S \quad \text{(Eq. 1.1-10)}$$

where

DCF_{it} (t) = DCF for external exposure to waste containing radionuclide i with a known amount of shielding (t) (rem*cm^3/μCi*year)

Inhalation Pathway

The inadvertent intruder is assumed to inhale suspended radionuclides while working in the vegetable garden and residing in the home.

Inhalation dose coefficients for garden exposure are estimated by:

$$DC_{ia}(g) = \frac{f_a(g) * U_a * L_a(g) * DCF_{ia}}{\rho_s} \qquad \text{(Eq. 1.1-11)}$$

where

$f_a(g)$ = fraction of the year spent in garden

U_a = annual air intake (cm^3/year)

$L_a(g)$ = garden mass loading (kg/cm^3)

DCF_{ia} = DCF for inhalation of radionuclide i (rem/μCi).

Inhalation dose coefficients while residing in the home are estimated by:

$$DC_{ia}(h) = \frac{f_a(h) * f_s * U_a * L_a(h) * DCF_{ia}}{\rho_s} \qquad \text{(Eq. 1.1-12)}$$

where

$f_a(h)$ = fraction of the year spent in home

U_a = annual air intake (cm^3/year)

$L_a(h)$ = home mass loading (kg/cm^3)

DCF_{ia} = DCF for inhalation of radionuclide i (rem/μCi).

1.2 Report Structure

This section provided background information on the inadvertent intruder analyses for PAs placing in context the necessary input parameters. The remaining sections of this report describe radionuclide specific parameters (Section 2) including dose conversion factors, plant-to-soil ratios, half-life, and branching fractions in addition to physical and usage input parameters (Section 3) for these analyses. Section 4 discusses differences between input parameters documented here and those used in prior SRS PAs primarily due to errors found during design checks and updating to meet industry standards. Dose conversion factors and shielding dose coefficients for select radionuclides are listed in APPENDIX A and APPENDIX B, respectively.

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2. RADIONUCLIDE SPECIFIC INFORMATION

2.1 Half Life and Branching Fractions

Half-life data are taken from January, 2000 "Nuclear Wallet Cards" developed by Brookhaven National Laboratory (Tuli 2000). Branching fractions are taken from ICRP 38 and are listed for radionuclides that decay to radioactive daughters (ICRP 1983). Half-life data with branching fractions are listed for select radionuclides in Table 2.1-1. A comprehensive list is provided in the "IntruderInput" file (Koffman 2004).

Table 2.1-1 Nuclide Decay Data

Nuclide	Half Life	Units	Daughter1	Branch1	Daughter2	Branch2
Ac-227	2.18E+01	years	Fr-223	0.0138	Th-227	0.9856
Am-242	1.60E+01	hours	Pu-242	0.173	Cm-242	0.827
Am-242m	1.41E+02	years	Np-238	0.00476	Am-242	0.995
Bi-211	2.14E+00	minutes	Tl-207	0.9972	Po-211	0.0028
Bi-212	6.06E+01	minutes	Tl-208	0.3593	Po-212	0.6407
Bi-213	4.56E+01	minutes	Tl-209	0.0216	Po-213	0.9784
Bi-214	1.99E+01	minutes	Po-214	0.9998		
Cf-250	1.31E+01	years	Cm-246	0.9992		
Cf-252	2.65E+00	years	Cm-248	0.9691		
Cm-243	2.91E+01	years	Pu-239	0.9976	Am-243	0.0024
Cm-246	4.76E+03	years	Pu-242	0.9997		
Cm-248	3.48E+05	years	Pu-244	0.9174		
Cs-137	3.01E+01	years	Ba-137m	0.946		
Eu-152	1.35E+01	years	Gd-152	0.278		
Pa-234m	1.17E+00	minutes	Pa-234	0.0013	U-234	0.9987
Po-218	3.10E+00	minutes	Pb-214	0.9998	At-218	0.0002
Pu-244	8.00E+07	years	U-240	0.9988		
Sb-126m	1.92E+01	minutes	Sb-126	0.14		
Sn-121m	5.50E+01	years	Sn-121	0.76		

2.2 Plant-to-Soil Ratio

Element plant-to-soil ratios are taken from Baes et al (1984) unless noted below. These are contaminant specific ratios of fresh weight in vegetation (μCi/kg) per dry weight in soil (μCi/kg). Values taken from Baes et al. (1984) are reported in dry weight of vegetation and are multiplied by 0.43 to get fresh weight (McDowell-Boyer et al. 2000). Select plant-to-soil ratios in the "IntruderInput" file are listed in Table 2.2-1.

Table 2.2-1. Element plant-to-soil ratios in vegetables

Element	Soil Ratio	Element	Soil Ratio
Ac	1.51E-04	Np	4.30E-03
Am	1.08E-04	Pa	1.08E-04
At	6.45E-02	Pb	3.87E-03
Ba	6.45E-03	Pd	1.72E-02
Bi	2.15E-03	Po	1.72E-04
Bk	6.60E-06	Pu	1.94E-05
C*	5.60E-01	Ra	6.45E-03
Ca	1.51E-01	S	6.45E-01
Cd	6.50E-02	Sb	1.29E-02
Cf	6.60E-06	Sc	4.30E-04
Cl	3.01E+01	Se	1.08E-02
Cm	6.45E-06	Sm	1.72E-03
Co	3.01E-03	Sn	2.58E-03
Cs	1.29E-02	Sr	1.08E-01
Eu	1.72E-03	Tc	6.45E-01
Fr	1.29E-02	Th	3.66E-05
Gd	1.72E-03	Tl	1.72E-04
H**	4.80E+00	U	1.72E-03
I	2.15E-02	W	4.30E-03
K	2.37E-01	Y	2.58E-03
Mo	2.20E-03	Zr	2.15E-04
Nb	2.15E-03		

*C is based on Sheppard et al. (1991)
**H obtained from USNRC (1977)

2.3 Dose Conversion Factors

Radionuclide DCFs used to estimate the EDE are taken from FGRs developed by the USEPA (USEPA 1988 and 1993). Shielding dose coefficients developed by Kocher (2004) are used to evaluate EDEs for external exposure to various thicknesses of contaminated soil.

2.3.1 Internal DCFs

Ingestion and inhalation DCFs are taken from USEPA FGR 11 (USEPA 1988). Internal DCFs in FGR 11 represent the 50-year committed EDE per unit of activity, reported in SI units (Sv/Bq). They are converted to standard units for input into the model by multiplying the FGR DCF by 3.7 x 10^6. Internal DCFs in rem/µCi for selected radionuclides are listed in APPENDIX A. Where there are blanks in the table and/or the intruder application input file (Koffman 2004), there are no internal DCFs provided by USEPA (1988). For some radionuclides, ingestion DCFs are provided for two GI-tract absorption fractions and inhalation DCFs are provided for several lung clearance classes. In both cases, the highest reported DCF is used with the exception of the nickel isotopes. For Ni-59 and Ni-63, the highest inhalation DCFs are for the vapor form. These values are not used as with prior PAs (McDowell-Boyer et al. 2000) because nickel is assumed to be in vapor form only when it occurs in the chemical form of nickel carbonyl. However, in low-level waste, nickel should occur in a solid form.

2.3.2 External DCFs

External DCFs for uniformly distributed contamination at an infinite depth with no shielding and at 15 cm are taken from USEPA FGR 12 (USEPA 1993). External DCFs in FGR 12 represent the 50-year committed EDE per unit of activity of soil contaminated at various depths. Like the internal DCFs, they are reported in SI units (Sv/yr per Bq/m^3). They are converted to standard units for input into the model by multiplying the FGR DCF by 3.7 x 10^6. External DCFs in rem/yr per μCi/m^3 for selected radionuclides are listed in APPENDIX A. Zero DCF in the table, intruder application input file (Koffman 2004), and USEPA (1993) indicate that the photon energies are not sufficient for contribution to external dose.

For soil contaminated at various depths shielded by a layer of clean soil, external dose coefficients for absorbed dose at 1 m from a mono-energetic source were estimated by Kocher (1985). A comprehensive list of absorbed dose rates at finite thicknesses were provided by Kocher (2004) based on the work presented in Kocher (1985). These data were used to estimate shielding effective dose coefficients at various shielding thicknesses with contamination at finite depths.

$$DC_{EDE}(t) = 0.8 * DC_{AD}(t) * 1\times10^{-6}\,\frac{Ci}{\mu Ci} * 3.15\times10^{7}\,\frac{\sec}{year} \qquad \text{(Eq. 2.3-1)}$$

where

DC_{EDE}(t) = shielding effective dose coefficient for finite thickness (t) (rem*cm^3/year*Ci)

DC_{AD}(t)= shielding absorbed dose coefficient for finite thickness from Kocher (2004) (rad*cm^3/sec*Ci)

CF= time conversion (3.15 x 10^7 sec/year)

For contamination distributed at an infinite depth, the DC_{EDE} in Eq. 2.3-1 should be summed for all depths below the desired finite depth.

$$DC_{EDE}(\text{inf}) = \sum_{t=t_{ref}}^{t_{\max}} DC_{EDE}(t) \qquad \text{(Eq. 2.3-2)}$$

where

DC_{EDE} (inf) = shielding effective dose coefficient for infinite depth (rem*cm^3/year*Ci)

t_{ref} = reference finite shielding thickness

t_{max} = max shielding thickness.

Coefficients for shielding depths of 5 and 100 cm are used in the intruder analysis model (Koffman 2004) to estimate dose coefficients at various depths for the residential exposure scenario. Dose coefficients at those depths are listed in APPENDIX B. Dose coefficients for no shielding (0 cm) listed in APPENDIX B were not used in Koffman (2004) but are taken from USEPA (1993) and listed in APPENDIX A.

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3. INPUT PARAMETERS

Media-specific physical parameters and pathway-specific usage parameters are required for performing the inadvertent intruder analysis. This section provides a brief description of these parameters and documents their sources.

3.1 Physical Parameters

Physical parameters required for evaluating EDEs for the inadvertent intruder analysis are listed in Table 3.1-1. Soil density is taken from Baes and Sharp (1983). Dilution factors for mixing of exhumed waste with soil in vegetable gardens are taken from Napier et al. (1984) and are based on the assumptions regarding the area of excavation for a home and assuming that a relatively small fraction of the soil can contain the exhumed waste and maintain productivity. The dilution factor is reduced by a factor of 10 for the post drilling scenario based on an assumption that the volume for waste removal in drilling is less than that for excavation. Mass loading of soil particles for the inhalation pathway is based on professional judgment and mass loading data measured at SRS (McDowell-Boyer et al. 2000).

Table 3.1-1 Intruder Analysis Physical Parameters

Parameter	Value	Reference
Density of soil (kg/m^3)	1400	Baes and Sharp 1983
Dilution factor for mixing of waste with garden soil		
agriculture scenario	0.2	Napier et al. 1984
post drilling scenario	0.02	Professional judgment
Atmospheric mass loading of soil particulates (kg/m^3)		
working in garden	1.0E-07	Professional judgment
residing in home	1.0E-08	Professional judgment

3.2 Pathway Usage Parameters

Usage parameters required for evaluating EDEs for the inadvertent intruder analysis for the various pathways are listed in Table 3.2-1.

Drinking water and vegetable consumption rates are taken from Hamby (1992). These values are based on county specific statistics provided by the counties within the states of South Carolina and Georgia that fall within a 50-mile radius of SRS. Incidental ingestion of contaminated soil rates are recommended by the USEPA (USEPA 1989).

For the external and inhalation exposure pathways, Oztunali et al. (1981) determined that the inadvertent intruder person spends 1% of the year working in a garden (~100 h/year) and 50% of the year in their (~4000 hr/year) residence. A person is assumed to inhale 8000 m^3 in a year based on recommendations by the USNRC (USNRC 1977).

External dose is reduced because of shielding provided by the walls and floor of a home. The shielding factor of 0.7 (USNRC 1977) is used based on the conservative assumption that the flooring in a home is a thin layer of wood or other material.

A dose limit of 0.1 rem per year effective dose equivalent (EDE) for inadvertent intruders (USDOE 1999) is used to estimate radionuclide disposal limits.

Table 3.2-1 Intruder Analysis Usage Parameters

Parameter	Value	Reference
Consumption of contaminated drinking water (L/yr)	730	Hamby 1992
Consumption of contaminated vegetables (kg/yr)	90	Hamby 1992
Air intake (breathing rate) (m^3/yr)	8000	USNRC 1977
Consumption of contaminated soil (kg/yr)	0.037	USEPA 1989
Exposure time as fraction of year (/yr)		
Working in garden	0.01	Oztunali et al. 1981
Residing in home	0.50	Oztunali et al. 1981
Shielding factor of home for external exposure during indoor residence	0.7	USNRC 1977
Dose Limit (rem/yr)	0.1	USDOE 1999

4. RECENT CHANGES FROM PREVIOUS PERFORMANCE ASSESSMENTS

Previous performance assessments used internal and external DCFs from USDOE (1988a and 1988b). This document recommends use of DCFs from USEPA (1988 and 1993), which is consistent with DOE requirements (DOE 1999).

The updated intruder analysis model includes the Bateman equation and therefore estimates disposal limits for all progeny in decay chains (Koffman 2004) thereby extending the list of radionuclide specific input parameters. In prior intruder analyses using the intruder analysis spreadsheets, progeny EDEs and/or disposal limits were not estimated for some progeny based on professional judgment of the progeny's contribution to the overall disposal limit. EDEs for radionuclides with progeny were either listed separately or combined depending on the difference between the parent and daughter half-lives. Parent and daughter EDEs were listed separately and combined when estimating disposal limits where the half-life of the daughter radionuclide is sufficiently long such that it can exist without the parent. Otherwise, progeny were included with parent when estimating EDEs. Current methodology automates the daughter inclusion.

Lastly, parameters were updated to match the identified sources. Some input parameters were changed because they were input into Cook (2003) incorrectly due to transcription and/or rounding errors. These errors are identified in Koffman (2004) along with the resulting impact.

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APPENDIX A. INTERNAL AND EXTERNAL DOSE CONVERSION FACTORS

Taken from USEPA 1988 and 1993.

Nuclide	Internal DCFs (rem/μCi) Ingestion	Internal DCFs (rem/μCi) Inhalation	External DCFs (rem/yr per μCi/m^3) Infinite Depth	External DCFs (rem/yr per μCi/m^3) 15 cm
Ac-225	1.11E-01	1.08E+01	3.98E-05	3.90E-05
Ac-227	1.41E+01	6.70E+03	3.10E-07	3.06E-07
Ac-228	2.16E-03	3.08E-01	3.74E-03	3.22E-03
Al-26	1.46E-02	7.96E-02	1.09E-02	9.03E-03
Am-241	3.64E+00	4.44E+02	2.73E-05	2.73E-05
Am-242	1.41E-03	5.85E-02	3.12E-05	3.12E-05
Am-242m	3.52E+00	4.26E+02	1.06E-06	1.05E-06
Am-243	3.62E+00	4.40E+02	8.88E-05	8.88E-05
Ar-39			5.40E-07	5.31E-07
At-217			1.11E-06	1.01E-06
At-218			3.65E-06	3.65E-06
Ba-133	3.40E-03	7.81E-03	1.24E-03	1.15E-03
Ba-137m			2.25E-03	2.00E-03
Bi-210	6.39E-03	1.96E-01	2.25E-06	2.17E-06
Bi-211			1.60E-04	1.49E-04
Bi-212	1.06E-03	2.16E-02	7.32E-04	6.26E-04
Bi-213	7.22E-04	1.71E-02	4.79E-04	4.38E-04
Bi-214	2.83E-04	6.59E-03	6.13E-03	5.09E-03
Bk-249	1.20E-02	1.39E+00	2.91E-09	2.90E-09
C-14	2.09E-03	2.09E-03	8.41E-09	8.41E-09
Ca-41	1.27E-03	1.35E-03	0.00E+00	0.00E+00
Cd-113m	1.61E-01	1.53E+00	4.05E-07	3.99E-07
Cf-249	4.74E+00	5.77E+02	1.16E-03	1.07E-03
Cf-250	2.13E+00	2.62E+02	7.40E-08	7.40E-08
Cf-251	4.85E+00	5.88E+02	3.29E-04	3.22E-04
Cf-252	1.08E+00	1.57E+02	1.10E-07	1.10E-07
Cl-36	3.03E-03	2.19E-02	1.50E-06	1.42E-06
Cm-242	1.15E-01	1.73E+01	1.07E-07	1.06E-07
Cm-243	2.51E+00	3.07E+02	3.64E-04	3.53E-04
Cm-244	2.02E+00	2.48E+02	7.87E-08	7.87E-08
Cm-245	3.74E+00	4.55E+02	2.13E-04	2.10E-04
Cm-246	3.70E+00	4.51E+02	7.26E-08	7.26E-08
Cm-247	3.42E+00	4.14E+02	1.11E-03	1.03E-03
Cm-248	1.36E+01	1.65E+03	5.49E-08	5.49E-08
Co-60	2.69E-02	2.19E-01	1.01E-02	8.47E-03
Cs-134	7.32E-02	4.64E-02	5.92E-03	5.22E-03
Cs-135	7.07E-03	4.55E-03	2.39E-08	2.40E-08
Cs-137	5.00E-02	3.19E-02	4.70E-07	4.60E-07
Eu-152	6.48E-03	2.21E-01	4.38E-03	3.76E-03
Eu-154	9.55E-03	2.86E-01	4.80E-03	4.11E-03
Eu-155	1.53E-03	4.15E-02	1.14E-04	1.14E-04

Internal and External Dose Conversion Factors (cont.)

	Internal DCFs (rem/µCi)		External DCFs (rem/yr per µCi/m^3)	
Nuclide	**Ingestion**	**Inhalation**	**Infinite Depth**	**15 cm**
Fr-221			9.60E-05	9.23E-05
Fr-223	8.62E-03	6.22E-03	1.24E-04	1.18E-04
Gd-152	1.61E-01	2.43E+02	0.00E+00	0.00E+00
H-3	6.40E-05	6.40E-05	0.00E+00	0.00E+00
I-129	2.76E-01	1.74E-01	8.10E-06	8.10E-06
K-40	1.86E-02	1.24E-02	6.51E-04	5.34E-04
Kr-85			8.94E-06	8.14E-06
Mo-93	1.35E-03	2.84E-02	3.69E-07	3.69E-07
Nb-93m	5.22E-04	2.92E-02	6.50E-08	6.50E-08
Nb-94	7.14E-03	4.14E-01	6.05E-03	5.29E-03
Ni-59	2.10E-04	1.32E-03	0.00E+00	0.00E+00
Ni-63	5.77E-04	3.10E-03	0.00E+00	0.00E+00
Np-237	4.44E+00	5.40E+02	4.87E-05	4.86E-05
Np-238	4.00E-03	3.71E-02	2.15E-03	1.84E-03
Np-239	3.26E-03	2.51E-03	4.71E-04	4.56E-04
Np-240	2.37E-04	8.14E-05	4.83E-03	4.26E-03
Np-240m			1.26E-03	1.11E-03
Pa-231	1.06E+01	1.28E+03	1.19E-04	1.12E-04
Pa-233	3.63E-03	9.55E-03	6.38E-04	6.03E-04
Pa-234	2.16E-03	8.14E-04	7.22E-03	6.28E-03
Pa-234m			5.61E-05	4.90E-05
Pb-209	2.13E-04	9.49E-05	4.83E-07	4.76E-07
Pb-210	5.37E+00	1.36E+01	1.53E-06	1.53E-06
Pb-211	5.26E-04	8.71E-03	1.91E-04	1.70E-04
Pb-212	4.55E-02	1.69E-01	4.40E-04	4.23E-04
Pb-214	6.25E-04	7.81E-03	8.39E-04	7.83E-04
Pd-107	1.49E-04	1.28E-02	0.00E+00	0.00E+00
Po-210	1.90E+00	9.40E+00	3.27E-08	2.86E-08
Po-211			2.98E-05	2.62E-05
Po-212			0.00E+00	0.00E+00
Po-213			0.00E+00	0.00E+00
Po-214			3.21E-07	2.80E-07
Po-215			6.35E-07	5.82E-07
Po-216			6.52E-08	5.69E-08
Po-218			3.53E-08	3.07E-08
Pu-238	3.20E+00	3.92E+02	9.46E-08	9.43E-08
Pu-239	3.54E+00	4.29E+02	1.85E-07	1.78E-07
Pu-240	3.54E+00	4.29E+02	9.17E-08	9.16E-08
Pu-241	6.85E-02	8.25E+00	3.69E-09	3.68E-09
Pu-242	3.36E+00	4.11E+02	8.00E-08	8.00E-08
Pu-243	3.34E-04	1.64E-04	4.98E-05	4.90E-05
Pu-244	3.32E+00	4.03E+02	4.72E-08	4.72E-08
Ra-223	6.59E-01	7.84E+00	3.77E-04	3.62E-04

Internal and External Dose Conversion Factors (cont.)

Nuclide	Internal DCFs (rem/µCi) Ingestion	Inhalation	External DCFs (rem/yr per µCi/m^3) Infinite Depth	15 cm
Ra-224	3.66E-01	3.16E+00	3.20E-05	3.06E-05
Ra-225	3.85E-01	7.77E+00	6.89E-06	6.89E-06
Ra-226	1.32E+00	8.58E+00	1.99E-05	1.93E-05
Ra-228	1.44E+00	4.77E+00	0.00E+00	0.00E+00
Rb-87	4.92E-03	3.23E-03	8.81E-08	8.78E-08
Re-188	3.07E-03	2.01E-03	2.01E-04	1.83E-04
Rn-219			1.93E-04	1.80E-04
Rn-220			1.44E-06	1.28E-06
Rn-222			1.47E-06	1.33E-06
S-35	7.33E-04	2.48E-03	9.31E-09	9.31E-09
Sb-126	1.07E-02	1.17E-02	1.07E-02	9.50E-03
Sb-126m	9.36E-05	3.39E-05	5.82E-03	5.19E-03
Sc-46	6.40E-03	2.96E-02	7.93E-03	6.77E-03
Se-79	8.70E-03	9.84E-03	1.16E-08	1.16E-08
Sm-151	3.89E-04	3.00E-02	6.15E-10	6.15E-10
Sn-121	9.02E-04	5.11E-04	1.23E-07	1.21E-07
Sn-121m	1.55E-03	1.15E-02	1.23E-06	1.23E-06
Sn-126	1.95E-02	9.95E-02	9.22E-05	9.22E-05
Sr-90	1.42E-01	1.30E+00	4.40E-07	4.34E-07
Tc-99	1.46E-03	8.33E-03	7.85E-08	7.82E-08
Th-227	3.81E-02	1.62E+01	3.26E-04	3.10E-04
Th-228	3.96E-01	3.42E+02	4.96E-06	4.87E-06
Th-229	3.53E+00	2.15E+03	2.01E-04	1.99E-04
Th-230	5.48E-01	3.26E+02	7.56E-07	7.46E-07
Th-231	1.35E-03	8.77E-04	2.28E-05	2.27E-05
Th-232	2.73E+00	1.64E+03	3.26E-07	3.25E-07
Th-234	1.37E-02	3.50E-02	1.51E-05	1.51E-05
Tl-207			1.24E-05	1.11E-05
Tl-208			1.44E-02	1.13E-02
Tl-209			8.08E-03	6.76E-03
U-232	1.31E+00	6.59E+02	5.64E-07	5.57E-07
U-233	2.89E-01	1.35E+02	8.74E-07	8.46E-07
U-234	2.83E-01	1.32E+02	2.51E-07	2.50E-07
U-235	2.66E-01	1.23E+02	4.51E-04	4.38E-04
U-236	2.69E-01	1.25E+02	1.34E-07	1.33E-07
U-238	2.55E-01	1.18E+02	6.45E-08	6.45E-08
U-240	4.45E-03	2.27E-03	8.90E-07	8.90E-07
W-181	3.44E-04	1.51E-04	4.78E-05	4.78E-05
W-185	1.99E-03	7.50E-04	2.71E-07	2.69E-07
W-188	9.40E-03	4.09E-03	6.05E-06	5.75E-06
Y-90	1.08E-02	8.44E-03	1.50E-05	1.40E-05
Zr-93	1.66E-03	3.21E-01	0.00E+00	0.00E+00

APPENDIX B. EXTERNAL PATHWAY SHIELDING DOSE COEFFICIENTS (rem/yr per μCi/m³)

Radionuclide	0 cm	5 cm	100 cm	Radionuclide	0 cm	5 cm	100 cm
AC-225	3.51E-05	1.01E-05	1.05E-11	AU-199	2.65E-04	8.53E-05	3.15E-12
AC-227	3.66E-07	8.25E-08	1.52E-16	BA-131	2.04E-03	8.96E-04	2.18E-08
AC-228	4.66E-03	2.41E-03	7.19E-07	BA-133	1.58E-03	6.57E-04	2.23E-09
AG-106M	1.42E-02	7.26E-03	2.04E-06	BA-133M	4.94E-04	8.31E-05	5.98E-11
AG-108	8.77E-05	4.19E-05	1.40E-09	BA-135M	1.97E-04	6.92E-05	3.78E-11
AG-108M	8.08E-03	3.88E-03	1.57E-07	BA-137M	3.04E-03	1.49E-03	6.64E-08
AG-109M	1.14E-05	1.25E-06	3.05E-17	BA-139	1.22E-04	4.65E-05	9.74E-09
AG-110	1.55E-04	7.63E-05	3.89E-09	BA-140	8.99E-04	4.12E-04	6.81E-09
AG-110M	1.41E-02	7.29E-03	1.80E-06	BA-141	4.25E-03	2.07E-03	7.64E-07
AG-111	1.21E-04	5.16E-05	1.92E-10	BA-142	4.49E-03	2.31E-03	6.00E-07
AL-26	1.36E-02	7.46E-03	7.87E-06	BE-7	2.44E-04	1.12E-04	1.33E-09
AL-28	9.18E-03	5.34E-03	7.22E-06	BI-206	1.64E-02	8.44E-03	3.28E-06
AM-241	2.70E-05	2.06E-06	7.90E-22	BI-207	7.65E-03	3.92E-03	1.09E-06
AM-242	3.31E-05	7.91E-06	7.27E-15	BI-208	1.33E-02	8.16E-03	3.03E-05
AM-242M	2.83E-06	1.18E-07	9.06E-17	BI-211	2.17E-04	9.34E-05	3.38E-10
AM-243	7.90E-05	1.22E-05	3.76E-15	BI-212	9.41E-04	4.94E-04	2.08E-07
AM-244	4.02E-03	2.01E-03	1.88E-07	BI-213	6.65E-04	3.01E-04	7.52E-09
AM-245	1.02E-04	3.47E-05	9.01E-12	BI-214	7.74E-03	4.25E-03	3.83E-06
AM-246	5.02E-03	2.64E-03	6.38E-07	BK-250	4.57E-03	2.41E-03	5.17E-07
AR-41	6.63E-03	3.66E-03	1.86E-06	BR-77	1.48E-03	6.67E-04	2.04E-08
AS-72	9.01E-03	4.46E-03	1.23E-06	BR-80	3.77E-04	1.81E-04	6.76E-09
AS-73	5.82E-06	3.00E-07		BR-80M	1.50E-05	4.27E-08	
AS-74	3.84E-03	1.83E-03	5.15E-08	BR-82	1.36E-02	6.96E-03	1.62E-06
AS-76	2.18E-03	1.09E-03	3.10E-07	BR-83	3.72E-05	1.75E-05	3.28E-10
AS-77	3.62E-05	1.48E-05	1.31E-10	BR-84	9.10E-03	5.30E-03	1.71E-05
AT-211	6.65E-05	1.50E-05	2.24E-10	BR-85	3.42E-04	1.79E-04	5.50E-08
AT-217	1.20E-06	5.76E-07	1.70E-11	C-11	5.06E-03	2.36E-03	3.78E-08
AU-194	5.19E-03	2.72E-03	2.15E-06	CA-45	1.91E-13		
AU-195	4.44E+01	1.83E-05	1.07E-14	CA-47	5.48E-03	3.00E-03	1.44E-06
AU-195M	7.58E-04	2.86E-04	1.21E-10	CA-49	1.58E-02	1.00E-02	5.60E-05
AU-196	2.05E-03	8.73E-04	4.67E-09	CD-109	1.03E-05	1.88E-13	
AU-198	1.94E-03	8.65E-04	8.07E-09	CD-111M	1.05E-03	3.80E-04	7.95E-11

External Pathway Shielding Dose Coefficient (cont.)

Radionuclide	0 cm	5 cm	100 cm	Radionuclide	0 cm	5 cm	100 cm
CD-115	1.00E-03	4.68E-04	7.95E-09	CR-49	4.92E-03	2.25E-03	3.86E-06
CD-115M	1.13E-04	5.99E-05	1.69E-08	CR-51	1.45E-04	6.13E-05	1.43E-10
CD-117	5.50E-03	2.92E-03	1.58E-06	CS-126	5.57E-03	2.62E-03	2.52E-07
CD-117M	1.04E-02	5.86E-03	7.19E-06	CS-129	1.22E-03	5.30E-04	4.54E-09
CE-139	4.53E-04	1.44E-04	4.67E-12	CS-131	1.68E-05	3.83E-09	
CE-141	2.22E-04	6.98E-05	1.21E-12	CS-132	3.55E-03	1.74E-03	9.69E-08
CE-143	1.17E-03	5.11E-04	1.73E-08	CS-134	7.95E-03	3.95E-03	3.33E-07
CE-144	4.72E-05	1.35E-05	1.19E-13	CS-134M	5.43E-05	1.41E-05	8.15E-14
CF-248	6.45E-07	6.99E-11		CS-136	1.09E-02	5.61E-03	1.09E-06
CF-249	1.53E-03	6.65E-04	3.05E-09	CS-138	1.21E-02	6.74E-03	8.10E-06
CF-250	6.66E-07	6.13E-09	5.00E-21	CS-139	1.57E-03	8.97E-04	1.29E-06
CF-251	3.43E-04	1.08E-04	1.51E-11	CU-61	4.08E-03	1.92E-03	9.64E-08
CF-252	6.12E-07	3.08E-09	5.40E-23	CU-62	5.00E-03	2.33E-03	5.17E-08
CF-253	1.09E-08	8.03E-12		CU-64	9.39E-04	4.40E-04	1.77E-08
CF-254	1.82E-11	2.23E-13		CU-67	3.60E-04	1.18E-04	2.09E-11
CL-38	7.64E-03	4.52E-03	8.55E-06	DY-157	1.48E-03	6.15E-04	1.77E-09
CM-242	8.66E-07	2.13E-09		DY-165	9.90E-05	4.35E-05	1.46E-09
CM-243	4.15E-04	1.42E-04	5.80E-11	DY-166	6.02E-05	1.33E-05	5.40E-11
CM-244	7.68E-07	1.24E-09		ER-169	3.93E-09	1.06E-09	1.11E-18
CM-245	1.79E-04	4.93E-05	5.55E-13	ER-l71	1.53E-03	6.23E-04	5.53E-09
CM-246	6.80E-07	1.76E-10		ES-253	1.40E-06	3.50E-07	2.14E-14
CM-247	1.50E-03	6.56E-04	3.61E-09	ES-254	1.56E-05	2.33E-06	2.10E-12
CM-248	5.45E-07	1.07E-09		ES-254M	2.84E-03	1.39E-03	6.56E-08
CM-249	9.37E-05	4.46E-05	1.37E-09	ES-255	4.84E-08	6.26E-12	
CO-56	1.85E-02	1.03E-02	1.83E-05	EU-152	5.66E-03	2.93E-03	9.86E-07
CO-57	3.37E-04	1.00E-04	1.56E-10	EU-152M	1.56E-03	7.98E-04	1.45E-07
CO-58	5.00E-03	2.51E-03	2.44E-07	EU-154	6.27E-03	3.28E-03	1.04E-06
CO-58M	7.45E-09	6.56E-16		EU-155	1.09E-04	2.32E-05	7.06E-15
CO-60	1.30E-02	7.13E-03	3.33E-06	EU-156	6.87E-03	3.81E-03	3.96E-06
CO-60M	1.82E-05	9.51E-06	5.17E-09	F-18	4.91E-03	2.29E-03	3.68E-08
CO-61	2.44E-04	9.74E-05	1.23E-08	FE-52	3.37E-03	1.50E-03	2.13E-08

External Pathway Shielding Dose Coefficient (cont.)

Radionuclide	0 cm	5 cm	100 cm	Radionuclide	0 cm	5 cm	100 cm
FE-59	6.13E-03	3.33E-03	1.31E-06	I-133	3.05E-03	1.47E-03	1.17E-07
FM-254	7.56E-07	1.34E-08	1.50E-19	I-134	1.35E-02	7.03E-03	2.10E-06
FM-255	8.03E-06	5.23E-07	3.20E-15	I-135	8.10E-03	4.46E-03	3.15E-06
FR-221	1.07E-04	3.71E-05	8.70E-12	I-136	1.29E-02	7.51E-03	1.78E-05
FR-223	1.32E-04	4.43E-05	8.28E-10	IN-111	1.42E-03	5.02E-04	8.45E-11
GA-66	1.25E-02	7.12E-03	2.45E-05	IN-113M	1.22E-03	5.35E-04	2.83E-09
GA-67	5.19E-04	1.94E-04	8.53E-10	IN-114	1.60E-04	7.75E-05	5.63E-09
GA-68	4.72E-03	2.22E-03	7.49E-08	IN-114M	4.03E-04	1.78E-04	6.69E-09
GA-72	1.39E-02	7.74E-03	1.15E-05	IN-115M	7.41E-04	3.16E-04	9.64E-10
GD-153	1.65E-04	2.96E-05	7.52E-15	IN-116M	1.26E-02	6.94E-03	4.79E-06
GD-159	1.60E-04	6.67E-05	2.72E-10	IN-117	3.19E-03	1.45E-03	2.90E-08
GD-162	2.03E-03	9.08E-04	6.56E-09	IN-117M	3.66E-04	1.46E-04	3.81E-10
GE-68	1.62E-07			IR-190	6.55E-03	3.01E-03	1.16E-07
GE-71	1.64E-07			IR-190M	2.05E-11	1.74E-17	
GE-77	5.05E-03	2.42E-03	6.86E-07	IR-190M2	5.64E-05	6.39E-06	3.18E-16
HF-181	2.47E-03	1.09E-03	1.17E-08	IR-192	3.82E-03	1.68E-03	1.72E-08
HG-197	9.35E-05	1.46E-05	1.48E-13	IR-193M	4.13E-07	5.08E-08	7.39E-21
HG-197M	2.37E-04	7.20E-05	1.91E-11	IR-194	4.38E-04	2.06E-04	2.80E-08
HG-203	9.35E-04	3.68E-04	2.93E-10	IR-194M	1.14E-02	5.33E-03	1.43E-07
HO-166	1.09E-04	5.58E-05	3.89E-08	K-40	8.05E-04	4.54E-04	3.41E-07
HO-166M	7.71E-03	3.72E-03	2.95E-07	K-42	1.42E-03	8.07E-04	6.89E-07
I-122	4.83E-03	2.28E-03	2.22E-07	K-43	4.78E-03	2.23E-03	6.74E-08
I-123	5.21E-04	1.76E-04	5.90E-10	KR-79	1.20E-03	5.51E-04	2.57E-08
I-124	5.33E-03	2.73E-03	1.49E-06	KR-81	4.44E-05	1.66E-05	1.19E-11
I-125	3.05E-05	4.64E-09		KR-83M	8.95E-07	4.72E-12	
I-126	2.28E-03	1.09E-03	5.27E-08	KR-85	1.11E-05	5.18E-06	8.53E-11
I-128	3.65E-04	1.67E-04	3.41E-09	KR-85M	5.51E-04	1.97E-04	1.46E-10
I-129	1.83E-05	1.84E-08		KR-87	3.98E-03	2.22E-03	4.77E-06
I-130	1.08E-02	5.32E-03	3.78E-07	KR-88	9.90E-03	5.80E-03	1.27E-05
I-131	1.81E-03	8.02E-04	9.28E-09	KR-89	9.24E-03	5.20E-03	1.20E-05
I-132	1.17E-02	5.95E-03	1.19E-06	KR-90	6.37E-03	3.41E-03	2.75E-06

External Pathway Shielding Dose Coefficient (cont.)

Radionuclide	0 cm	5 cm	100 cm	Radionuclide	0 cm	5 cm	100 cm
LA-140	1.19E-02	6.51E-03	5.68E-06	NB-97	3.39E-03	1.66E-03	8.53E-08
LA-141	2.20E-04	1.23E-04	8.45E-08	NB-97M	3.75E-03	1.87E-03	1.31E-07
LA-142	1.39E-02	8.09E-03	2.11E-05	ND-147	5.39E-04	2.32E-04	4.16E-09
LU-l77	1.08E-04	3.54E-05	5.45E-12	ND-149	1.59E-03	6.71E-04	1.64E-08
LU-l77M	3.78E-03	1.48E-03	4.39E-09	NI-56	8.42E-03	4.15E-03	8.45E-07
MG-27	4.61E-03	2.39E-03	3.53E-07	NI-57	9.77E-03	5.31E-03	3.91E-06
MG-28	6.94E-03	3.71E-03	1.65E-06	NI-65	2.83E-03	1.56E-03	9.86E-07
MN-52	1.78E-02	9.43E-03	3.66E-06	NP-235	6.23E-06	9.34E-07	4.21E-16
MN-52M	1.22E-02	6.40E-03	2.95E-06	NP-236	3.32E-04	9.24E-05	1.43E-12
MN-54	4.32E-03	2.21E-03	2.40E-07	NP-236M	1.44E-04	4.91E-05	1.21E-09
MN-56	8.72E-03	4.83E-03	5.12E-06	NP-237	5.09E-05	1.09E-05	1.34E-13
MN-57	3.29E-04	1.57E-04	4.39E-08	NP-238	2.84E-03	1.50E-03	3.13E-07
MO-101	7.57E-03	4.05E-03	2.78E-06	NP-239	5.36E-04	1.83E-04	1.20E-10
MO-91	4.85E-03	2.27E-03	1.52E-07	NP-240	5.67E-03	2.81E-03	3.61E-07
MO-93	6.28E-06	2.78E-20		NP-240M	1.66E-03	8.20E-04	1.43E-07
MO-99	7.60E-04	3.70E-04	2.49E-08	O-15	5.07E-03	2.36E-03	3.78E-08
N-13	5.06E-03	2.36E-03	3.78E-08	OS-185	3.41E-03	1.66E-03	9.28E-08
N-16	2.16E-02	1.45E-02	2.28E-04	OS-190M	7.58E-03	3.48E-03	7.01E-08
NA-22	1.11E-02	5.74E-03	1.79E-06	OS-191	1.43E-04	3.50E-05	1.98E-13
NA-24	2.10E-02	1.26E-02	3.83E-05	OS-191M	5.47E-06	6.20E-07	2.30E-20
NB-90	2.10E-02	1.19E-02	2.07E-05	OS-193	2.69E-04	1.13E-04	1.12E-09
NB-91	1.41E-05	3.87E-06	6.23E-11	PA-230	3.17E-03	1.58E-03	2.21E-07
NB-91M	2.24E-04	1.20E-04	4.77E-08	PA-231	1.26E-04	4.90E-05	7.97E-11
NB-92	7.67E-03	3.87E-03	4.47E-07	PA-233	8.69E-04	3.50E-04	7.90E-10
NB-92M	4.97E-03	2.59E-03	4.89E-07	PA-234	9.68E-03	4.91E-03	1.18E-06
NB-93M	1.12E-06	4.97E-21		PA-234M	5.75E-05	2.98E-05	5.20E-09
NB-94	8.10E-03	4.11E-03	3.96E-07	PB-203	3.62E-03	2.94E-03	1.02E-09
NB-94M	2.56E-05	1.10E-05	1.40E-09	PB-204M	1.06E-02	5.36E-03	6.81E-07
NB-95	3.94E-03	1.98E-03	1.56E-07	PB-205	6.74E-07		
NB-95M	2.28E-04	8.16E-05	1.57E-11	PB-210	2.51E-06	3.87E-08	
NB-96	1.26E-02	6.44E-03	1.10E-06	PB-211	2.55E-04	1.24E-04	8.30E-09

External Pathway Shielding Dose Coefficient (cont.)

Radionuclide	0 cm	5 cm	100 cm	Radionuclide	0 cm	5 cm	100 cm
PB-212	4.99E-04	1.76E-04	5.58E-11	PU-238	7.77E-07	1.73E-09	
PB-214	1.09E-03	4.59E-04	4.84E-09	PU-239	4.22E-07	3.74E-08	5.25E-17
PD-103	1.00E-05	2.29E-07	9.11E-13	PU-240	7.43E-07	1.71E-09	
PD-109	3.41E-06	1.59E-06	2.51E-11	PU-242	6.18E-07	1.85E-09	
PM-143	1.48E-03	7.31E-04	5.10E-08	PU-243	4.83E-05	1.24E-05	2.51E-11
PM-144	7.77E-03	3.76E-03	1.56E-07	PU-244	5.26E-07	1.60E-10	
PM-145	2.60E-05	5.41E-07	5.12E-20	PU-245	1.99E-03	9.42E-04	7.24E-08
PM-146	3.71E-03	1.78E-03	8.53E-08	PU-246	3.20E-04	1.08E-04	1.05E-11
PM-147	9.45E-09	2.74E-09	9.28E-18	RA-222	4.21E-05	1.79E-05	4.64E-11
PM-148	2.94E-03	1.57E-03	7.75E-07	RA-223	4.47E-04	1.63E-04	2.95E-10
PM-148M	1.00E-02	4.88E-03	3.15E-07	RA-224	3.76E-05	1.37E-05	4.67E-12
PM-149	5.20E-05	2.22E-05	4.29E-10	RA-225	1.09E-05	6.79E-08	
PM-151	1.47E-03	6.44E-04	1.81E-08	RA-226	2.16E-05	7.21E-06	3.89E-13
PO-209	1.59E-05	7.63E-06	8.65E-10	RB-81	2.81E-03	1.25E-03	2.35E-08
PO-210	4.40E-08	2.23E-08	2.10E-12	RB-82	5.46E-03	2.57E-03	8.93E-08
PO-211	3.97E-05	1.99E-05	1.97E-09	RB-83	2.49E-03	1.17E-03	2.32E-08
PO-213	1.57E-07	7.93E-08	6.66E-12	RB-84	4.58E-03	2.30E-03	3.10E-07
PO-214	4.30E-07	2.18E-07	2.00E-11	RB-86	7.09E+01	7.09E+01	7.09E+01
PO-215	7.23E-07	3.25E-07	2.62E-12	RB-88	3.27E-03	1.88E-03	3.23E-06
PO-216	7.49E-08	3.80E-08	3.61E-12	RB-89	1.06E-02	5.98E-03	8.30E-06
PR-142	3.01E-04	1.72E-04	1.62E-07	RB-90	1.07E-02	6.66E-03	4.64E-05
PR-143	4.58E-11	2.29E-11	1.59E-15	RB-90M	1.66E-02	9.67E-03	3.18E-05
PR-144	1.63E-04	9.16E-05	1.36E-07	RE-182	2.65E+01	4.01E-03	1.40E-06
PR-144M	8.73E-06	3.57E-08		RE-182M	5.72E-03	3.04E-03	1.37E-06
PT-191	1.04E-03	4.26E-04	5.53E-09	RE-183	3.37E-04	9.53E-05	4.31E-11
PT-193M	1.38E-05	1.89E-06	1.47E-15	RE-184	4.32E-03	2.18E-03	2.65E-07
PT-195M	1.05E-04	1.85E-05	3.86E-14	RE-184M	1.61E-03	7.43E-04	8.60E-08
PT-197	4.87E-05	1.27E-05	1.03E-12	RE-186	5.03E-05	1.46E-05	5.63E-11
PT-197M	2.58E-04	9.75E-05	2.88E-10	RE-188	2.38E-04	1.06E-04	1.17E-08
PU-236	9.03E-07	5.27E-09		RH-103M	1.07E-06	1.45E-10	
PU-237	1.07E-04	2.56E-05	1.66E-14	RH-105	3.55E-04	1.50E-04	3.23E-10

External Pathway Shielding Dose Coefficient (cont.)

Radionuclide	0 cm	5 cm	100 cm	Radionuclide	0 cm	5 cm	100 cm
RH-105M	8.18E-05	2.31E-05	1.58E-13	SR-85	2.54E-03	1.18E-03	1.95E-08
RH-106	1.04E-03	5.06E-04	4.72E-08	SR-85M	7.96E-04	2.85E-04	3.89E-11
RN-218	3.82E-06	1.84E-06	5.98E-11	SR-87M	1.53E-03	6.73E-04	3.43E-09
RN-219	2.51E-04	1.05E-04	3.53E-10	SR-89	7.07E-07	3.67E-07	5.45E-11
RN-220	2.62E-06	1.24E-06	2.70E-11	SR-91	3.54E-03	1.83E-03	3.43E-07
RN-222	1.93E-06	9.02E-07	1.46E-11	SR-92	6.90E-03	3.83E-03	2.32E-06
RU-103	2.39E-03	1.11E-03	1.74E-08	SR-93	1.13E-02	6.02E-03	4.79E-06
RU-105	3.93E-03	1.91E-03	1.12E-07	TA-182	6.34E-03	3.36E-03	1.22E-06
RU-97	8.71E-04	3.19E-04	8.35E-10	TB-157	3.55E-06	5.92E-08	
SB-117	5.89E-04	2.11E-04	5.88E-09	TB-160	5.42E-03	2.80E-03	6.66E-07