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Revision 0

Calculation of Soil Radiological Preliminary Remedial Goals for the Construction Worker Scenario

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

Contractor for the U.S. Department of Energy
under Contract DE-AC06-08RL14788

P.O. Box 1600
Richland, Washington 99352

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R. D. Evans
INTERA, Inc.

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ch2m
P.O. Box 1600
Richland, Washington 99352

APPROVED
By Julia Raymer at 2:11 pm, Nov 07, 2016

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	Name /Position	Signature	Date
Preparer:	Doug Evans/Risk Assessor	Doug Evans	10/4/2016
Checker:	Sara Lindberg/Risk Assessor	S.L.	10/4/2016
Senior Reviewer:	Donna Morgans/Senior Risk Assessor	Donna L Morgans	10/4/16
Responsible Manager:	AH Aly/Risk & Model Integr Manager	A H Aly	10/5/16

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Required training for modelers completed:

	Name /Position	Signature	Date
Integration Lead	WE Nichols / Modeling Team Leader	Hume & Nichols	4 OCT 2016

Safety Software Approved:

	Name /Position	Signature	Date
Integration Lead	WE Nichols / Modeling Team Leader	Hume & Nichols	4 OCT 2016

CALCULATION APPROVED:

	Name /Position	Signature	Date
Risk/Modeling Integration Manager:	AH Aly/Risk & Model Integr Manager	A H Aly	10/5/16

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Terms

AOC	Area of Contaminated Zone
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
CHPRC	CH2M HILL Plateau Remediation Company
DOE	U.S. Department of Energy
ECF	environmental calculation file
EPA	U.S. Environmental Protection Agency
HISI	Hanford Information Systems Inventory
K_d	Distribution coefficients
mrem/yr	millirem per year
PEF_{sc}	particulate emission factor – subchronic
PRGs	Preliminary Remediation Goals
RAO	Remedial Action Objective
RESRAD	RESidual RADioactivity code
RI/FS	Remedial Investigation/Feasibility Study
SI	Sensitivity index

1 Purpose

This environmental calculation file (ECF) documents assumptions and methods for development of soil radiological Preliminary Remediation Goals (PRGs) for a construction worker exposure scenario for use in Remedial Investigation/Feasibility Study (RI/FS) Reports for the Inner Area source operable units (OUs) located within the Central Plateau of the Hanford Site. PRGs are concentration goals for a specific medium (e.g., soil) that are intended to protect specified receptors from exposure to contaminants through identified exposure pathways and routes.

The PRGs described in this ECF represent concentration goals that are protective of a potential future construction worker receptor. Potentially complete exposure pathways associated with this scenario include the direct contact (incidental soil ingestion and direct external gamma exposure) and inhalation pathways. The PRGs presented correspond to a 10^{-4} acceptable cancer risk level or a 500 mrem/yr radiation dose limit, whichever gives the lower soil concentration. PRGs protective of 10^{-5} and 10^{-6} acceptable cancer risk levels are also presented for information purposes.

2 Background

The methods and parameters used in this ECF support the Central Plateau Inner Area cleanup principles and are based on guidance from the U.S. Environmental Protection Agency (EPA). Soil PRGs for radionuclides are calculated using a methodology that is consistent with the methodology used for the baseline risk assessments previously conducted at the Hanford Site that have been reviewed and approved by the regulatory agencies.

For the purposes of developing PRGs in this ECF, the following target objective is used:

- Prevent unacceptable risk to human health from exposure to soils and/or debris contaminated with radiological contaminants. PRGs for radionuclides that achieve this objective achieve the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) cumulative risk range of 10^{-4} to 10^{-6} increased lifetime cancer risk, consistent with EPA 540-R-012-13, *Radiation Risk Assessment At CERCLA Sites: Q & A*; or they achieve a radiation dose limit of 500 mrem/yr, consistent with DOE M 435.1-1, *Radioactive Waste Management Manual*. These PRGs are intended to limit radiation risks for 1,000 years following the completion of a remedial action. According to ANL/EAD-4, *User's Manual for RESRAD,* the 1,000-year timeframe ensures that the PRGs account for the decay of radionuclides to daughter products that are more radioactive.

This target objective has been developed only for the purpose of calculating PRGs that are presented in this ECF. This target objective is not intended to supersede Remedial Action Objectives (RAOs) being developed as part of the CERCLA RI/FS process. This ECF will be revised as needed to incorporate updates to these PRGs that may result from changes in RAOs occurring during development of the Central Plateau RI/FS reports.

3 Methodology

The construction worker scenario for radionuclides in vadose zone material represents potential exposure from short-term work activities that include soil disturbance from a trench or excavation such as putting in an underground utility line or construction of a building. For the Hanford Site, this worker is assumed to spend 8 hours per day outdoors where contact with contaminated soil can occur, for 30 days over a one-year timeframe. The potentially complete exposure pathways considered are:

- Direct contact (incidental soil ingestion and external exposure to ionizing radiation)

- Inhalation of dust particulates emitted from soil.

PRGs are calculated as radionuclide-specific soil concentrations that are protective of a construction worker at a 10^{-4} target cancer risk level or a radiation dose limit of 500 mrem/year, whichever provides the lower concentration. PRGs protective of a construction worker scenario at 10^{-5} and 10^{-6} target cancer risk levels are also calculated for information purposes. The calculations are performed using the RESidual RADioactivity computer code (ANL 2014, *RESRAD for Windows, Version 7.0*). The code is implemented using the RESRAD v7.0 default DCFPAK 3.02 Morbidity risk factors, DCFPAK 3.02 (Adult) internal dose library, and DCFPAK 3.02 external dose library. The RESRAD model and computer code was developed as a multifunctional tool to assist in developing cleanup criteria and assessing the dose or risk associated with residual radioactive material (ANL/EAD-4). Software applications of RESRAD are presented in Section 5.

3.1 RESRAD Calculations

The specific steps taken to calculate radionuclide-specific PRGs in soil for the construction worker scenario using RESRAD are presented below. The RESRAD input parameters and radionuclide-specific distribution coefficients (K_ds) used for the PRG calculations are provided Tables 1 and 2.

1. Input the parameters from Tables 1 and 2 into RESRAD.
2. Input the arbitrary soil concentration of 1 pCi/g for each parent radionuclide evaluated into RESRAD.
3. Input calculation times of 1, 3, 10, 30, 100, 300, and 1,000 years into RESRAD.
4. Run RESRAD and review the results to identify the year at which the peak risk occurs:
    a. Generate a risk plot (View Output > Standard Graphics, specify Plot Type = Risk, Radionuclide = Individual, and Pathways = Summed)
    b. View each individual radionuclide and record the year of peak risk in an intermediate calculation worksheet (Appendix A, Table A-1)
    c. For radionuclides where peak risk occurs at a time other than 0 or 1,000 years, export the plot data to the intermediate calculation worksheet (Appendix A, Table A-1) (Edit > Export to Excel), then identify and highlight the year of peak risk.
5. Save the corresponding summary report (SUMMARY.REP) with a unique file name.
6. Save the existing RESRAD file with a new name.
7. Input calculation times associated with each unique year of peak risk into RESRAD. Re-run RESRAD.
8. Open the health risk report (View Output > Health Risk Report).
9. For each calculation time, copy and paste the risk results for each individual radionuclide from the "All Pathways" column into an intermediate Microsoft Excel® worksheet (Appendix A, Table A-2). Create a set of headers that identify the calculation times associated with each set of risk outputs. Create a column that identifies the maximum risk per pCi/g for each radionuclide. Create another column that identifies the year of maximum risk. Create a column that calculates a preliminary PRG

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for each radionuclide associated with a target risk of 1×10^{-4}. The preliminary PRG is calculated by dividing the target risk of 1×10^{-4} by the maximum risk per pCi/g.

10. Save the corresponding summary report and the health risk report (INTRISK.REP) with a unique file name.

11. Save the existing RESRAD file with a new name.

12. Input the preliminary PRG value for each individual radionuclide into the soil concentrations module.

13. Re-run RESRAD and verify that the estimated PRG value corresponds to a 1×10^{-4} risk (Appendix A, Table A-3); perform additional iterations as needed to obtain a soil concentration that corresponds to 1×10^{-4} risk to within 1 percent (this is to allow rounding of the PRG value as appropriate) (Appendix A, Table A-4), and record those concentrations as the 1×10^{-4} risk PRGs.

14. Save the corresponding summary report and the health risk report with unique file names.

15. Calculate concentrations in soil corresponding to 1×10^{-5} and 1×10^{-6} cancer risks. These are factors of 10 and 100 of the soil concentration corresponding to 1×10^{-4} cancer risk and can be calculated simply by division.

16. Obtain the annual radiation dose associated with the 1×10^{-4} risk PRG from the RESRAD summary report (dose at peak year). Compare the dose to the applicable dose limit of 500 mrem/year. If the dose exceeds 500 mrem/yr, the single radionuclide soil guideline for 500 mrem/yr found in the RESRAD summary report is used as the final PRG (Appendix A, Table A-5).

17. As an additional step to support the remedy selection process for uranium in Central Plateau soils, the RESRAD-calculated PRGs for the uranium isotopes are converted from activity-based concentrations (pCi/g) to mass-based concentrations (μg/kg) to facilitate development of a mass-based PRG for total uranium. The activity-based uranium isotope PRGs (pCi/g) are converted to mass-based PRGs (μg/kg) using the following equation (the conversion calculations are provided in Section 7).

$$\text{PRG } (\mu\text{g isotope/kg soil}) = [\text{PRG (pCi isotope/g soil)} / \text{Specific Activity (pCi isotope/g isotope)}] \times 1 \times 10^{6} (\mu\text{g isotope/g isotope}) \times 1000 \text{ (g soil/kg soil)} \quad (1)$$

3.2 Mass Loading for Inhalation

RESRAD uses a mass loading model to compute exposures from dust inhalation and requires users to input a value for the average airborne dust concentration at the site (referred to as "mass loading for inhalation"). Because the RESRAD default (0.0001 g/m^3) is based on typical farm activities (ANL/EAD-4), a site-specific value based on typical construction activities is developed and used in lieu of the RESRAD default in this ECF. The site-specific value is developed using EPA guidance provided in OSWER 9355.4-24, *Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites*, in which the inhalation of contaminants in the form of respirable particles is assessed using a subchronic particulate emission factor (PEF_{sc}). The PEF_{sc} relates the contaminant concentration in soil with the concentration of respirable particles in the air due to fugitive dust emissions from contaminated soil.

In the construction worker exposure scenario, fugitive dust emissions are primarily generated by construction vehicle traffic on unpaved roads (OSWER 9355.4-24). The construction worker is assumed to be exposed to contaminants in the form of particulate matter with an aerodynamic particle diameter of less than 10 microns (PM10). The PEF_{sc} is calculated and then the RESRAD mass loading factor (g/m^3) is derived from the PEF_{sc} (m^3/kg) using the relationship g/m^3 = (1/ m^3/kg) × 1000 g/kg.

The following steps were used to calculate the PEF_{sc}:

1. Identify the applicable equations.
   a. Equation E-18 from OSWER Publication 9355.4-24 for the PEF_{sc},
   b. Equation E-19 from OSWER Publication 9355.4-24 for the inverse of the ratio of the 1-h. geometric mean air concentration to the emission flux along a straight road segment bisecting a square site (Q/C_{sr}),
   c. Equation E-16 from OSWER Publication 9355.4-24 for the dispersion correction factor (F_D).
2. Identify the default and site-specific factors for use in calculating PEF_{sc}, Q/C_{sr}, and F_D.
3. Calculate the PEF_{sc}.
4. Document the default and site-specific assumptions, and their primary sources in a summary table.

The PEF_{sc} is calculated with the following equations:

$$PEF_{sc} = \frac{Q}{C_{sr}} \times \frac{1}{F_D} \times \left[\frac{T \times A_R}{\frac{2.6 \times \left(\frac{s}{12}\right)^{0.8} \times \left(\frac{W}{3}\right)^{0.4}}{\left(\frac{M_{dry}}{0.2}\right)^{0.3}} \times \frac{(365-p)}{365} \times 281.9 \times \sum VKT} \right] \tag{2}$$

Where:

$$\frac{Q}{C_{sr}} = A \times exp\left[\frac{(lnA_s - B)^2}{C}\right] \tag{3}$$

And:

$$F_D = 0.1852 + \frac{5.3537}{t_c} + \frac{-9.6318}{{t_c}^2} \tag{4}$$

Definitions of the input variables for the PEF_{sc} equations are provided in Table 3. The calculated value for PEF_{sc} is 1.28×10^6 m^3/kg. The RESRAD mass loading factor is thus ($1/1.28 \times 10^6$ m^3/kg) x 1,000 g/kg = 0.000781 g/m^3.

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Table 1. Input Parameters Used in RESRAD for Calculation of Construction Worker PRGs for Radionuclides in Soil

RESRAD Category	Parameter	Units	User Input	Rationale	Reference
Dose and Risk Libraries	Internal (ingestion and inhalation) dose coefficients	mrem/pCi	DCFPAK3.02 (Adult)	Updated internal dose coefficients based on ICRP Publication 107	ICRP, 2008
	External dose coefficients	mrem/yr per pCi/g	DCFPAK3.02	Updated external dose coefficients based on ICRP Publication 107	ICRP, 2008
	Risk factors	Risk/pCi, Risk/yr per pCi/g	DCFPAK3.02 Morbidity	Updated risk coefficients based on ICRP Publication 107	ICRP, 2008
Graphic Parameters	Number of points	NA	32	RESRAD default	--
Exposure Pathways	External gamma: Inhalation: Plant ingestion: Meat ingestion: Milk ingestion: Aquatic foods: Drinking water: Soil ingestion: Radon:	NA	Active Active Suppressed Suppressed Suppressed Suppressed Suppressed Active Suppressed	Construction Worker Scenario	--
R011 – Contaminated Zone (CZ)	Area of CZ	m^2	10,000	Generic site model	Surface area presented in RESRAD user's guide, ANL/EAD-4
	Thickness of CZ	m	4.6	Direct exposure PRGs apply to the upper 4.6 m (15 ft)	--
	Length Parallel to Aquifer Flow	m	NA	Not applicable[a]	--
	Does Initial Contamination Penetrate Water Table?	NA	No	Not applicable[a]	--
R012 –Principal Radionuclides Concentrations	All radionuclide contaminants of concern	pCi/g	1	Unit concentrations are input to obtain radionuclide-specific risk to source ratios (risk per pCi/g) at time of peak risk	--

Table 1. Input Parameters Used in RESRAD for Calculation of Construction Worker PRGs for Radionuclides in Soil

RESRAD Category	Parameter	Units	User Input	Rationale	Reference
R013 - Cover and CZ Hydrological Data	Cover Depth	m	0	Conservatively assumes no cover is present and direct exposure to contamination may occur	--
	Density of Cover Material	g/cm^3	NA	No soil cover	--
	Cover Erosion Rate	m/yr	NA	No soil cover	--
	Density of CZ	g/cm^3	1.87	Thickness-weighted average[b]	PNNL-18564 (Table 6.2, site-wide values)
	CZ Erosion Rate	m/yr	0.001	RESRAD default	--
	CZ Total Porosity	Unitless	0.296	Thickness-weighted average[b]	PNNL-18564 (Table 6.3, site-wide values)
	CZ Field Capacity	Unitless	0.084	Thickness-weighted average[b]	PNNL-18564 (Table 6.5, best-estimate values)
	CZ Hydraulic Conductivity	m/yr	88.7	Thickness-weighted average[b]	PNNL-18564 (Table 6.7, site-wide values)
	CZ b Parameter	Unitless	2.89	Thickness-weighted average[b]	PNNL-18564 (Table 6.8)
	Humidity in Air	g/cm^3	8	RESRAD default	--
	Evapotranspiration Coefficient	Unitless	0.91	EPA, Region X guidance	Letter from EPA
	Wind Speed	m/s	3.4	Hanford Site average	PNNL-15160, Table 5.1
	Precipitation	m/yr	0.177	Based on 6.98 in. (0.177 m) normal annual rainfall	PNNL-15160, Table 4.1
	Irrigation Rate	m/yr	0	No irrigation assumed for OUs within the Inner Area of the Central Plateau	--
	Irrigation Mode	NA	Overhead	RESRAD default	--
	Runoff Coefficient	Unitless	0.2	RESRAD default	--

Table 1. Input Parameters Used in RESRAD for Calculation of Construction Worker PRGs for Radionuclides in Soil

RESRAD Category	Parameter	Units	User Input	Rationale	Reference
	Watershed Area for Nearby Stream or Pond	m^2	NA	Not applicable[a]	--
	Accuracy for Water/Soil Computations	Unitless	NA	Not applicable[a]	--
R014 – Saturated Zone (SZ) Hydrological Data	Density of SZ	g/cm^3	NA	Not applicable[a]	--
	SZ Total Porosity	Unitless	NA	Not applicable[a]	--
	SZ Effective Porosity	Unitless	NA	Not applicable[a]	--
	SZ Field Capacity	Unitless	NA	Not applicable[a]	--
	SZ Hydraulic Conductivity	m/yr	NA	Not applicable[a]	--
	SZ Hydraulic Gradient	Unitless	NA	Not applicable[a]	--
	SZ b Parameter	Unitless	NA	Not applicable[a]	--
	Water Table Drop Rate	m/yr	NA	Not applicable[a]	--
	Well Pump Intake Depth	m below water table	NA	Not applicable[a]	--
	Nondispersion (ND) or Mass-Balance (MB)	NA	NA	Not applicable[a]	--
	Well Pumping Rate	m^3/yr	NA	Not applicable[a]	--
R015 - Uncontaminated and Unsaturated Strata Hydrological Data	Number of Unsaturated Strata	NA	NA	Not applicable[a]	--
	Thickness	m	NA	Not applicable[a]	--
	Soil Density	g/cm^3	NA	Not applicable[a]	--
	Total Porosity	Unitless	NA	Not applicable[a]	--
	Effective Porosity	Unitless	NA	Not applicable[a]	--
	Field Capacity	Unitless	NA	Not applicable[a]	--

Table 1. Input Parameters Used in RESRAD for Calculation of Construction Worker PRGs for Radionuclides in Soil

RESRAD Category	Parameter	Units	User Input	Rationale	Reference
	Soil-specific b Parameter	Unitless	NA	Not applicable[a]	--
	Hydraulic Conductivity	m/yr	NA	Not applicable[a]	--
R016 - Distribution Coefficients (K_d) and Leach Rates	CZ K_d	mL/g	Contaminant-specific (see Table 2)	K_d values for the CZ are for sand-dominated sediment (Hss). K_d values for layers below the CZ are required by RESRAD but are used only to assess transport to groundwater and do not affect construction worker PRGs.	K_d values are taken from the following reference hierarchy: PNNL-18564, PNNL-13037, RESRAD default
	Time Since Material Placement	yr	0	RESRAD default	--
	Leach Rate	yr^{-1}	NA	Not applicable (K_ds are used for all leaching calculations)	--
	Solubility Limit	mol/L	NA	Not applicable (K_ds are used for all leaching calculations)	--
	Radiation Dose Limit	mrem/yr	500	DOE recommended dose limit for workers	DOE M 435.1-1
R017 - Inhalation and External Gamma	Inhalation Rate	m^3/yr	20,000	20 m^3/8 hr x 24 hr/day x 365 day/yr = 21,900 m^3/yr (value truncated at RESRAD upper bound input of 20,000 m^3/yr)	OSWER Directive 9285.6-03, Section 3.3
	Mass Loading for Inhalation	g/m^3	0.000781	Derived from the subchronic particulate emission factor (PEF_{sc}) using 1/ PEF_{sc} x 1000 g/kg (1/1.28E+06 m^3/kg x 1000 g/kg = 0.000781 g/m^3)	OSWER 9355.4-24
	Exposure duration	Yr	1	Site-specific	OSWER Publication 9355.4-24, Exhibit 5-1
	Indoor Dust Filtration Factor	Unitless	0	Assumes no time spent indoors	--

Table 1. Input Parameters Used in RESRAD for Calculation of Construction Worker PRGs for Radionuclides in Soil

RESRAD Category	Parameter	Units	User Input	Rationale	Reference
	External Gamma Shielding Factor	Unitless	0	Assumes no time spent indoors	--
	Indoor Time Fraction	Unitless	0	Assumes no time spent onsite indoors	OSWER 9355.4-24
	Outdoor Time Fraction	Unitless	0.0274	Fraction of the year spent onsite outdoors ([8 hr/day x 30 days/yr]/8,760 hr/yr = 0.0274)	OSWER 9355.4-24
	Shape Factor	NA	Circular	RESRAD default	--
R018 - Ingestion Pathway Data, Dietary Parameters	Fruits, Vegetables, and Grain Consumption	kg/yr	NA	Incomplete exposure pathway	--
	Leafy Vegetable Consumption	kg/yr	NA	Incomplete exposure pathway	--
	Milk Consumption	L/yr	NA	Incomplete exposure pathway	--
	Meat and Poultry Consumption	kg/yr	NA	Incomplete exposure pathway	--
	Fish Consumption	kg/yr	NA	Incomplete exposure pathway	--
	Other Seafood Consumption	kg/yr	NA	Incomplete exposure pathway	--
	Soil Ingestion	g/yr	120.45	(330 mg/day x 365 days/yr)/1,000 mg/g = 120.45 g/yr	OSWER Publication 9355.4-24, Exhibit 5-1
	Drinking Water Intake	L/yr	NA	Incomplete exposure pathway	--
	Drinking Water Contamination Fraction	Unitless	NA	Incomplete exposure pathway	--
	Household Water Contamination Fraction	Unitless	NA	Incomplete exposure pathway	--
	Livestock Water Contamination Fraction	Unitless	NA	Incomplete exposure pathway	--

Table 1. Input Parameters Used in RESRAD for Calculation of Construction Worker PRGs for Radionuclides in Soil

RESRAD Category	Parameter	Units	User Input	Rationale	Reference
	Irrigation Water Contamination Fraction	Unitless	NA	Incomplete exposure pathway	--
	Aquatic Food Contamination Fraction	Unitless	NA	Incomplete exposure pathway	--
	Plant Food Contamination Fraction	Unitless	NA	Incomplete exposure pathway	--
	Meat Contamination Fraction	Unitless	NA	Incomplete exposure pathway	--
	Milk Contamination Fraction	Unitless	NA	Incomplete exposure pathway	--
R019 - Ingestion Pathway Data, Nondietary	Livestock Fodder Intake for Meat	kg/d	NA	Incomplete exposure pathway	--
	Livestock Fodder Intake for Milk	kg/d	NA	Incomplete exposure pathway	--
	Livestock Water Intake for Meat	L/d	NA	Incomplete exposure pathway	--
	Livestock Water Intake for Milk	L/d	NA	Incomplete exposure pathway	--
	Livestock Intake of Soil	kg/d	NA	Incomplete exposure pathway	--
	Mass Loading for Foliar Deposition	g/m^3	NA	Incomplete exposure pathway	--
	Depth of Soil Mixing Layer	m	0.15	RESRAD default	--
	Depth of Roots	m	NA	Incomplete exposure pathway	--
R020 – Groundwater Usage	Groundwater Fractional Usage - Drinking Water	Unitless	NA	Incomplete exposure pathway	--
	Groundwater Fractional Usage - Household Usage	Unitless	NA	Incomplete exposure pathway	--

Table 1. Input Parameters Used in RESRAD for Calculation of Construction Worker PRGs for Radionuclides in Soil

RESRAD Category	Parameter	Units	User Input	Rationale	Reference
	Groundwater Fractional Usage - Livestock Water	Unitless	NA	Incomplete exposure pathway	--
	Groundwater Fractional Usage – Irrigation	Unitless	NA	Incomplete exposure pathway	--
R021 – Radon	Radon parameters are not used; Radon is not a Hanford Site contaminant of potential concern.				--

Notes:

a. Not applicable – the following parameters are not used in the model when drinking water and food ingestion pathways are suppressed: contaminated zone length parallel to aquifer flow; watershed area; accuracy for water/soil computations; saturated zone hydrological data (R014); and uncontaminated, unsaturated strata hydrological data (R015). These parameters are used in the model for estimating migration through soil and transport to groundwater and are not used to develop construction worker PRGs.

b. Contaminated zone hydrological parameters are weighted by the thickness of the stratigraphic units. See Appendix A, Table A-6.

CZ = contaminated zone.

DOE = U.S. Department of Energy.

NA = not applicable.

K_d = soil-water distribution coefficient.

PEF_{sc} = particulate emission factor – subchronic.

PRG = preliminary remediation goal.

RESRAD = RESidual RADioactivity code (ANL, 2014).

SZ = saturated zone.

ANL, 2014, RESRAD for Windows, Version 7.0.

ANL/EAD-4, *User's Manual for RESRAD Version 6.*

DOE M 435.1-1, *Radioactive Waste Management Manual.*

ICRP, 2008, *Nuclear Decay Data for Dosimetric Calculations*, ICRP Publication 107, Ann. ICRP 38 (3).

OSWER Directive 9285.6-03, *Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual Supplemental Guidance "Standard Default Exposure Factors" Interim Final.*

OSWER 9355.4-24, *Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites.*

PNNL-13037, *Geochemical Data Package for the 2005 Hanford Integrated Disposal Facility Performance Assessment.*

PNNL-15160, *Hanford Site Climatological Summary 2004 With Historical Data.*

PNNL-18564, *Selection and Traceability of Parameters to Support Hanford-Specific RESRAD Analyses – Fiscal Year 2008 Status Report.*

1

Table 2. Radionuclide-Specific Distribution Coefficients by RESRAD Model Layer

Radionuclide	K_d (cm^3/g)	K_d Reference	K_d (cm^3/g)	K_d Reference
	Contaminated Zone (assumed sand dominated, Hss)		Uncontaminated Unsaturated Zone and Saturated Zone[a] (assumed sandy gravel, Hg)	
Americium-241	300	PNNL-18564, Table 6.9, Sand-Dominated	180	PNNL-18564, Table 6.9, Sandy Gravel
Carbon-14	5	PNNL-18564, Table 6.9, Sand-Dominated	2.5	PNNL-18564, Table 6.9, Sandy Gravel
Cesium-137	2000	PNNL-18564, Table 6.9, Sand-Dominated	1200	PNNL-18564, Table 6.9, Sandy Gravel
Cobalt-60	10	PNNL-18564, Table 6.9, Sand-Dominated	6.2	PNNL-18564, Table 6.9, Sandy Gravel
Curium-243	300	PNNL-13037, Table 5.6	300	PNNL-13037, Table 5.6
Curium-243/244	300	PNNL-13037, Table 5.6	300	PNNL-13037, Table 5.6
Curium-244	300	PNNL-13037, Table 5.6	300	PNNL-13037, Table 5.6
Europium-152	300	PNNL-18564, Table 6.9, Sand-Dominated	180	PNNL-18564, Table 6.9, Sandy Gravel
Europium-154	300	PNNL-18564, Table 6.9, Sand-Dominated	180	PNNL-18564, Table 6.9, Sandy Gravel
Europium-155	300	PNNL-18564, Table 6.9, Sand-Dominated	180	PNNL-18564, Table 6.9, Sandy Gravel
Iodine-129	0.2	PNNL-18564, Table 6.9, Sand-Dominated	0.1	PNNL-18564, Table 6.9, Sandy Gravel
Neptunium-237	10	PNNL-18564, Table 6.9, Sand-Dominated	5	PNNL-18564, Table 6.9, Sandy Gravel
Nickel-63	300	PNNL-18564, Table 6.9, Sand-Dominated	180	PNNL-18564, Table 6.9, Sandy Gravel
Plutonium-238	600	PNNL-18564, Table 6.9, Sand-Dominated	370	PNNL-18564, Table 6.9, Sandy Gravel
Plutonium-239/240	600	PNNL-18564, Table 6.9, Sand-Dominated	370	PNNL-18564, Table 6.9, Sandy Gravel
Plutonium-241	600	PNNL-18564, Table 6.9, Sand-Dominated	370	PNNL-18564, Table 6.9, Sandy Gravel
Selenium-79	5	PNNL-18564, Table 6.9, Sand-Dominated	2.5	PNNL-18564, Table 6.9, Sandy Gravel

Table 2. Radionuclide-Specific Distribution Coefficients by RESRAD Model Layer

Radionuclide	K_d (cm^3/g)	K_d Reference	K_d (cm^3/g)	K_d Reference
	Contaminated Zone (assumed sand dominated, Hss)		Uncontaminated Unsaturated Zone and Saturated Zone[a] (assumed sandy gravel, Hg)	
Strontium-90	20	PNNL-18564, Table 6.9, Sand-Dominated	12	PNNL-18564, Table 6.9, Sandy Gravel
Technetium-99	0	PNNL-18564, Table 6.9, Sand-Dominated	0	PNNL-18564, Table 6.9, Sandy Gravel
Tritium (H-3)	0	PNNL-18564, Table 6.9, Sand-Dominated	0	PNNL-18564, Table 6.9, Sandy Gravel
Uranium-233/234	0.8	PNNL-18564, Table 6.9, Sand-Dominated	0.4	PNNL-18564, Table 6.9, Sandy Gravel
Uranium-234	0.8	PNNL-18564, Table 6.9, Sand-Dominated	0.4	PNNL-18564, Table 6.9, Sandy Gravel
Uranium-235	0.8	PNNL-18564, Table 6.9, Sand-Dominated	0.4	PNNL-18564, Table 6.9, Sandy Gravel
Uranium-238	0.8	PNNL-18564, Table 6.9, Sand-Dominated	0.4	PNNL-18564, Table 6.9, Sandy Gravel
Daughter Radionuclides (included automatically by RESRAD with selection of parent)				
Actinium-227	300	PNNL-13037, Table 5.6	300	PNNL-13037, Table 5.6
Americium-243	300	PNNL-18564, Table 6.9, Sand-Dominated	180	PNNL-18564, Table 6.9, Sandy Gravel
Gadolinium-152[b]	-1	RESRAD default	-1	RESRAD default
Lead-210	50	PNNL-18564, Table 6.9	31	PNNL-18564, Table 6.9
Neodymium-144	158	RESRAD default	158	RESRAD default
Plutonium-240	600	PNNL-18564, Table 6.9, Sand-Dominated	370	PNNL-18564, Table 6.9, Sandy Gravel
Protactinium-231	50	RESRAD default	50	RESRAD default
Radium-226	20	PNNL-18564, Table 6.9	12	PNNL-18564, Table 6.9
Radium-228	20	PNNL-18564, Table 6.9	12	PNNL-18564, Table 6.9
Samarium-148[b]	-1	RESRAD default	-1	RESRAD default

Table 2. Radionuclide-Specific Distribution Coefficients by RESRAD Model Layer

Radionuclide	K_d (cm^3/g)	K_d Reference	K_d (cm^3/g)	K_d Reference
	Contaminated Zone (assumed sand dominated, Hss)		Uncontaminated Unsaturated Zone and Saturated Zone[a] (assumed sandy gravel, Hg)	
Thorium-228	1000	PNNL-13037, Table 5.6	1000	PNNL-13037, Table 5.6
Thorium-229	1000	PNNL-13037, Table 5.6	1000	PNNL-13037, Table 5.6
Thorium-230	1000	PNNL-13037, Table 5.6	1000	PNNL-13037, Table 5.6
Thorium-232	1000	PNNL-13037, Table 5.6	1000	PNNL-13037, Table 5.6
Uranium-233	0.8	PNNL-18564, Table 6.9, Sand-Dominated	0.4	PNNL-18564, Table 6.9, Sandy Gravel
Uranium-236	0.8	PNNL-18564, Table 6.9, Sand-Dominated	0.4	PNNL-18564, Table 6.9, Sandy Gravel

Notes:

a. K_ds for the uncontaminated unsaturated zone and saturated zone are not used to develop construction worker PRGs and are shown only for completeness. RESRAD requires K_d inputs for these layers but uses them only to assess water-dependent pathways, which are suppressed for the construction worker exposure scenario.

b. For gadolinium-152 and samarium-148, RESRAD displays a default value of -1 on the K_d input screen, indicating the K_d value is derived internally by the code.

K_d = soil-water distribution coefficient.

RESRAD = RESidual RADioactivity code (ANL 2014)

ANL, 2014, RESRAD for Windows, Version 7.0.

PNNL-13037, *Geochemical Data Package for the 2005 Hanford Integrated Disposal Facility Performance Assessment.*

PNNL-18564, *Selection and Traceability of Parameters to Support Hanford-Specific RESRAD Analyses – Fiscal Year 2008 Status Report.*

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Table 3. Summary of Input Parameters used to Calculate the Subchronic Particulate Emission Factor – Vehicle Traffic on Unpaved Roads

Input Parameter	Symbol	Value	Units	Reference
A Dispersion constant	A	12.9351	unitless	OSWER 9355.4-24, Equation E-19
Surface area of contaminated road segment	A_R	274.32	m^2	OSWER 9355.4-24, Equation E-18 ($A_R = L_R \times W_R$)
Areal extent of site surface soil contamination	A_s	0.5	acres	Recommended value, OSWER 9355.4-24, Equation 5-6
B Dispersion constant	B	5.7383	unitless	OSWER 9355.4-24, Equation E-19
C Dispersion constant	C	71.7711	unitless	OSWER 9355.4-24, Equation E-19
Exposure frequency – construction worker	DW_{cw}	5	days/week	Site-specific assumption
Exposure duration – construction worker	ED_{cw}	1	year	OSWER 9355.4-24, Exhibit 5-1
Exposure frequency – construction worker	EF_{cw}	30	days/year	Site-specific assumption
Exposure time – construction worker	ET_{cw}	8	hours/day	Site-specific assumption, 8 hours per 24 hr day
Exposure frequency – construction worker	EW_{cw}	6	weeks/year	Site-specific assumption
Dispersion correction factor	F_D	0.191	unitless	Equation 4
Length of road segment	L_R	45	m	Recommended value, OSWER 9355.4-24, page E-21 (assumes 0.5 acre contamination area [2,024 m^2] configured as a square with unpaved road segment dividing the square evenly, road length equal to square root of 2,024 m^2 or 45 m [0.045 km])
Road surface material moisture content under dry, uncontrolled conditions	M_{dry}	0.2	%	Default value, OSWER 9355.4-24, Equation E-18
Number of days per year with at least 0.01 inches of precipitation	p	120	days/year	Site-specific, interpreted from OSWER 9355.4-24, Exhibit E-4
Particulate emission factor – subchronic, unpaved road vehicle traffic	PEF_{sc}	1.28E+06	m^3/kg	Equation 2

Table 3. Summary of Input Parameters used to Calculate the Subchronic Particulate Emission Factor – Vehicle Traffic on Unpaved Roads

Input Parameter	Symbol	Value	Units	Reference
Inverse of the ratio of the 1-h. geometric mean air concentration to the emission flux along a straight road segment bisecting a square site	Q/C_{sr}	23.02	g/m^2-s per kg/m^3	Equation 3
Road surface silt content	s	8.5	%	Default value, OSWER 9355.4-24, Equation E-18 (mean value for "construction sites – scraper routes")
Total time over which construction traffic occurs	T	864,000	s	OSWER 9355.4-24, page E-27 ($T = ED_{cw}$ x EF_{cw} x ET_{cw} x 3600 seconds/hour)
Overall duration of construction	t_c	1,008	hrs	OSWER 9355.4-24, page E-27 ($t_c = ED_{cw}$ x EW_{cw} x 7 days/week x 24 hours/day)
Sum of fleet vehicle kilometers travelled during the exposure duration	∑VKT	40.5	km	OSWER 9355.4-24, page E-21 (∑VKT = total vehicles x distance x EW_{cw} x DW_{cw}), assumes each vehicle travels length of road once per day
Mean vehicle weight	W	8	tons	OSWER 9355.4-24, page E-20 (W = [number of cars x tons/car + number of trucks x tons/truck] / total vehicles), assumes 20 two-ton cars and 10 twenty-ton trucks = 30 total vehicles
Width of road segment	W_R	6.096	m	Recommended value, OSWER 9355.4-24, page E-20 (20 ft = 6.096 m)

Notes:

OSWER 9355.4 24, *Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites.*

4 Assumptions and Inputs

The RESRAD inputs and radionuclide-specific distribution coefficients (K_ds) used to calculate PRGs for the construction worker exposure scenario are presented in Tables 1 and 2. The inputs and associated assumptions used to calculate the site-specific subchronic PEF_{sc} to support the derivation of a mass loading factor for input to RESRAD are presented in Table 3. Other key assumptions are as follows:

- The PRGs for the construction worker are based on a site-specific scenario.
- This exposure scenario assumes that construction and trenching activities would occur 30 days per year over a one-year exposure duration. The scenario assumes that exposure occurs while performing short-term work activities such as trenching or excavation.
- The direct contact and inhalation exposure pathways are considered potentially complete for the construction worker scenario. The exposure routes involved with this scenario are incidental soil ingestion, inhalation of dust, and external gamma exposure.
- With the exception of exposure frequency and exposure duration, the exposure assumptions used to calculate the construction worker PRGs provide a Reasonable Maximum Exposure (RME) estimate.
- Under the State of Washington 2013 Model Toxics Control Act (MTCA), the point of compliance for industrial property soil cleanup levels is from the ground surface to 15 feet below ground surface [WAC 173-340-740(6)(d)]. However, points of compliance may be established on a site-specific basis. The 15-foot point of compliance was used to select soil thickness of the contaminated zone as a parameter in RESRAD and it is assumed that no cover material exists on top of the contaminated zone. A sensitivity analysis indicates that changes in the soil thickness do not affect the value of the PRG, so the PRGs developed in this ECF can be applied to points of compliance other than 15 feet below ground surface. Results of the sensitivity analysis are discussed in Section 7.
- For purposes of this ECF, the area of the contaminated zone is assumed to be 10,000 m^2. Actual thickness and areas of waste sites being cleaned up using these PRGs may differ from the assumptions in this ECF. A sensitivity analysis indicates that the soil concentrations presented in this ECF will be protective for sites with areas smaller than 10,000 m^2, and very slightly understate risks for sites with areas larger than 10,000 m^2. Results of the sensitivity analysis are presented in Section 7.
- A generic site model based on the 200 North Area hydrostratigraphic template presented in PNNL-14702, *Vadose Zone Hydrogeology Data Package for Hanford Assessments* (page A.13, template 200I-X) is used to assign RESRAD hydrological parameters. The hydrological parameters associated with the 15-foot contaminated zone are taken from PNNL-18564, *Selection and Traceability of Parameters to Support Hanford-Specific RESRAD Analyses – Fiscal Year 2008 Status Report* and are weighted by the thickness of the stratigraphic units (Appendix A, Table A-6).
- Distribution coefficients (K_d) are selected preferentially from PNNL-18564. In cases where PNNL-18564 does not include a radionuclide, the K_d value is selected from PNNL-13037, *Geochemical Data Package for the 2005 Hanford Integrated Disposal Facility Performance Assessment.* If no Kd value is available in either reference, the RESRAD default value is used. The K_d values are summarized in Table 2.

- The RESRAD mass loading factor is derived from the site-specific value calculated for PEF_{sc}, as described in Section 3.2. The calculated value is PEF_{sc} = 1.28E+06 m^3/kg (Table 3). The RESRAD mass loading factor = (1/1.28E+06 m^3/kg) × 1,000 g/kg = 0.000781 g/m^3.
- The specific activities used with Equation 1 to convert uranium isotope PRGs from activity-based concentrations (pCi/g) to mass-based concentrations (µg/kg) are shown in Table 4.

Table 4. Uranium Isotope Specific Activities

Isotope	Specific Activity (Bq/g)[a]	Conversion Factor (Bq/Ci)	Conversion Factor (pCi/Ci)	Specific Activity (pCi/g)[b]
Uranium-233/234	2.302E+08	3.70E+10	1.00E+12	6.222E+09
Uranium-234	2.302E+08	3.70E+10	1.00E+12	6.222E+09
Uranium-235	7.995E+04	3.70E+10	1.00E+12	2.161E+06
Uranium-238	1.243E+04	3.70E+10	1.00E+12	3.359E+05

a. Table of Isotopes 8th Edition, 1995, Last update 12th April, 1998.

b. Formula = Specific Activity (Bq/g) / Conversion Factor (Bq/Ci) x Conversion Factor (pCi/Ci)

5 Software Applications

RESRAD is approved for use by CH2M HILL Plateau Remediation Company (CHPRC) at the Hanford Site in accordance with the requirements of PRC-PRO-IRM-309, *Controlled Software Management*. All supporting calculations were performed on electronic spreadsheets using Microsoft Excel®. Electronic versions of all spreadsheets are provided with calculations included to facilitate checking of logical or lookup functions. This approach meets the requirements for "Single Use Software" as described in PRC-PRO-EP-40205, CHPRC *Environmental Calculation Preparation and Issue*. These spreadsheets are listed below in Section 6.

5.1 Description

The following presents the description of RESRAD used for this ECF. See CHPRC-00209, *RESRAD Software Management Plan* for further details regarding the use of this software:

- RESRAD for Windows
- Version 7.0, Created February 24, 2014
- HISI Identification Number: 2102
- Workstation type and property number: INTERA-00295 (Subcontractor Supplied Unique Property ID) and INTERA-00474.

5.2 Software Installation and Checkout

The software installation and checkout forms for RESRAD are provided as Appendix B to this ECF.

® Microsoft Excel is a registered product of the Microsoft Corporation.

5.3 Statement of Valid Software Application

The following presents the statement that RESRAD is a valid software application.

- RESRAD was developed for the U.S. Department of Energy (DOE) to assist in developing cleanup criteria and assessing the dose or risk associated with residual radioactive material. RESRAD has been used for this purpose in support of previous decision documents developed at the Hanford Site.
- RESRAD as it has been used in this ECF has been implemented within the range of its limitations. The parameters used in the modeling (shown in Tables 1 and 2) are presented in the modeling input files that accompany this ECF, and also in the modeling output files where they are shown alongside the default parameters provided with the model. As discussed in Section 7, a sensitivity analysis of selected parameters has been performed to evaluate the effects of variations in input values on model results.

6 Calculation

The PRG results for radionuclides in soil for the construction worker scenario are calculated with RESRAD and Microsoft Excel using the methodology described in Section 3 and the assumptions and inputs described in Section 4. Calculation results are summarized in Section 7. The PEF_{sc} calculations are validated by comparison with hand calculations, which are provided in Figure 1.

Supporting calculations are contained in the Excel workbook "ECF-HANFORD-16-0132_r0_Appendix.xlsx." This workbook contains the following worksheets:

- Appendix A, Table A-1, Identification of Peak Year Based on Peak Cancer Risk.
- Appendix A, Table A-2, Intermediate Calculation – Results of Cancer Risks at Year of Peak Risk and Preliminary PRGs for Individual Radionuclides.
- Appendix A, Table A-3, Intermediate Calculation – Results of Cancer Risk at Year of Peak Risk Based on Preliminary PRGs.
- Appendix A, Table A-4, Intermediate Calculation – Calculation of Relative Percent Difference.
- Appendix A, Table A-5, Intermediate Calculation – Comparison to Radiation Dose Limit and Determination of Final PRGs
- Appendix A, Table A-6, Calculation of Thickness-Weighted Average Hydrological Parameters for the Contaminated Zone.
- Appendix A, Table A-7, Sensitivity Analysis – Area of Contaminated Zone and Thickness of Contaminated Zone.

Input file names from RESRAD are organized as follows:

- RESRAD input file name for identifying year at peak cancer risk – "PRG_CW_PKYR.RAD"
- RESRAD input file name for calculating risk-to-source ratio (risk per unit concentration) based on year at peak cancer risk – "PRG_CW_RSR.RAD"
- RESRAD input file name for calculating risk based on PRGs – "PRG_CW_RISK.RAD"
- RESRAD input file name for sensitivity analysis – "PRG_CW_SA.RAD"

Output file names from RESRAD are organized as follows:

- RESRAD output summary file name for identifying year at peak cancer risk – "PRG_CW_PKYR.SUM"
- RESRAD output summary file name for calculating risk-to-source ratio (risk per unit concentration) based on year at peak cancer risk – "PRG_CW_RSR.SUM"
- RESRAD output health risk file name for calculating risk-to-source ratio (risk per unit concentration) based on year at peak cancer risk – "PRG_CW_RSR.INT"
- RESRAD output summary file name for calculating risk based on PRGs – "PRG_CW_RISK.SUM"
- RESRAD output health risk file name for calculating risk based on PRGs – "PRG_CW_RISK.INT"

All RESRAD input and output files (*.RAD, *.SUM, and *.INT) for the development of soil radiological PRGs for the construction worker scenario are archived under this ECF number in the Environmental Risk Management Archive.

Figure 1. Hand Calculations

Construction Water Service | ECF-Hanford-16- | Sara Lindberg
Rad PRGs Calculation | Rev 0 | 9/21/2016

Subchronic Particulate Emission Factor (Unpaved Road Traffic)

$$PEF_{sc} = \frac{Q}{C_{sr}} * \frac{1}{F_D} * \left[\frac{T * A_R}{\frac{2.6 * \left(\frac{s}{12}\right)^{0.8} * \left(\frac{W}{3}\right)^{0.4}}{\left(\frac{M_{dry}}{0.2}\right)^{0.3}} * \frac{(365-p)}{365} * 281.9 * \Sigma VKT} \right]$$

where $\frac{Q}{C_{sr}} = A * \exp\left[\frac{(\ln A_s - B)^2}{C}\right]$ ★

and $F_D = 0.1852 + \frac{5.3537}{t_c} + \frac{-9.6318}{t_c^2}$ ★★

★ $\frac{Q}{C_{sr}} = 12.9351 * \exp\left[\frac{(\ln[0.5\text{ acres}] - 5.7383)^2}{71.7711}\right]$

$= 23.01785 \rightarrow 23.02 \frac{g/m^2\text{-}s}{kg/m^3}$ ✓ (units per OSWER 9355.4-24)

★★ $F_D = 0.1852 + \frac{5.3537}{1008\text{ hrs}} + \frac{-9.6318}{(1008\text{ hrs})^2}$

(overall duration of construction) t_c = 6 weeks * 7 days/week * 24 hrs/day = 1008 hrs ✓

$= 0.191$ ✓ (unitless per OSWER 9355.4-24)

Construction Worker Scenario Rad PRGs Calculation	ECF-Hanford-16- Rev 0	Sara Lundberg 9/21/2016

Subchronic Particulate Emission Factor (Unpaved Road Traffic) cont

$$PEF_{sc} = 23.02 \frac{g/m^2 \cdot s}{kg/m^3} * \frac{1}{0.191} * \left[\frac{86400\,sec * 274.32\,m^2}{\frac{2.6 * \left(\frac{8.5}{12}\right)^{0.8} * \left(\frac{8\,tons}{3}\right)^{0.4}}{\left(\frac{0.2}{0.2}\right)^{0.3}} * \frac{(365-120)\,days}{365\,days} * 281.9 * 40.5\,km} \right]$$

$$= 120.5 * \left[\frac{237012480}{\frac{1.973165 * 1.480429}{1} * 0.6712329 * 281.9 * 40.5} \right]$$

(120.8 ✓ excell! no sig figs)

$$= 120.5 * 10587.585$$

$$= 1.28\,E{+}06\ m^3/kg \ ✓$$

AMPAD

7 Results/Conclusions

The soil radiological PRGs for the construction worker scenario for target cancer risk levels of 1×10^{-4}, 1×10^{-5}, and 1×10^{-6} are summarized in Table 5. For americium-241, curium-244, plutonium-238, plutonium-239/240, and plutonium-241, the dose levels corresponding to the 1×10^{-4} cancer risk PRG exceed the applicable dose limit of 500 mrem/year. For these radionuclides, the single radionuclide soil guideline was used as the final PRG. Dose levels corresponding to the 1×10^{-4} cancer risk PRG, single radionuclide soil guidelines, and final construction worker PRGs are presented in Table 6.

The human health direct contact PRGs for soil are based on the year that the peak risk occurs, within a 1,000-year timeframe. The peak cancer risk occurs at year 0 for all radionuclides except plutonium-241, which peaks at year 54 as a result of the contribution of risk from ingrowth daughter products. The year of peak cancer risk for each radionuclide is identified in Appendix A, Table A-1. Results of the preliminary PRG calculation for each radionuclide are presented in Appendix A, Table A-2. To verify that the estimated PRG value corresponds to a 1×10^{-4} risk, Appendix A, Table A-3 provides the results of maximum risk based on the preliminary PRG for each radionuclide. To ensure the calculated risks based on the PRGs are within 1 percent of the target cancer risk, relative percent difference was calculated as shown in Appendix A, Table A-4 using the target cancer risk and risk calculated in Appendix A, Table A-3. Because RESRAD restricts user-input soil concentrations to two significant figures when the values entered are greater than $1 \times 10^{+6}$ pCi/g, a relative percent difference within 1 percent of the target risk could not be achieved for nickel-63 and plutonium-241. Determination of final PRGs based on consideration of the 500 mrem/yr radiation dose limit is shown in Appendix A, Table A-5.

A generic site area of 10,000 m^2 and a generic site thickness of 4.6 m were assumed for developing the human health direct contact PRGs. Two sensitivity analyses were performed (see Appendix A, Table A-7) to determine how sensitive the PRG values are to changes in area of contamination (AOC) and thickness of contaminated zone. Each sensitivity analysis was performed by both reducing and increasing the selected input parameter by a common factor. A sensitivity index (SI) was calculated to determine which parameters have the greatest influence on the calculated PRGs by using the following formula.

$$SI = 1 - \frac{Risk_{Lower\ Value}}{Risk_{Upper\ Value}} \tag{5}$$

A positive value of the SI indicates that the risk (hence, PRG) is directly proportional to the parameter of interest, whereas a negative value indicates the risk (hence, PRG) is inversely proportional to the parameter of interest. A value less than 0.01 indicates that the risk is independent of the parameter. The further the value of SI is from zero (0), the more sensitive the parameter is.

For the sensitivity analyses of AOC, the common factor of 5 was selected. The risks were then calculated for the base (assigned value, 10,000 m^2), the lower value (2,000 m^2), and upper value (50,000 m^2). A common factor of 2 was selected for the sensitivity analyses for thickness of the contaminated zone. The risks were calculated for the base (assigned value, 4.6 m), the lower value (2.3 m), and upper value (9.2 m). Am-241, Cs-137 and Pu-239/240 were selected for the sensitivity analyses.

Appendix A, Table A-7 presents the results of the sensitivity analyses for both parameters. The maximum risks for the three radionuclides were obtained using the methods outlined in Section 3.1. The maximum risk results based on upper and lower values for each sensitive parameter were used to calculate the SI. The results of SI, based on AOC value showed that the assigned value for AOC is somewhat sensitive for americium-241 and plutonium-239/240 among three selected radionuclides. The results of SI, based on thickness of contaminated zone values showed that none of the selected radionuclides are sensitive for this parameter.

An additional evaluation was performed for americium-241 and plutonium-239/240 to determine how changes in AOC affect the PRG value. The PRG for americium-241 (22,030 pCi/g) decreases about 13 percent, to 19,130 pCi/g, with an increase in AOC from 10,000 m^2 to 50,000 m^2, and it increases about 15 percent, to 25,390 pCi/g, with a decrease in AOC from 10,000 m^2 to 2,000 m^2. Similarly, the PRG for plutonium-239/240 (18,660 pCi/g) decreases about 14 percent, to 16,100 pCi/g, with an increase in AOC, and it increases about 16 percent, to 21,610 pCi/g, with a decrease in AOC (Appendix A, Table A-7).

To calculate a PRG for total uranium, the RESRAD-calculated PRGs for the uranium isotopes are converted from activity-based concentrations (pCi/g) to mass-based concentrations (µg/kg), as shown in Table 7. The conversions are made using the PRGs protective at the 1×10^{-4} risk level, which represents the upper threshold of the EPA target risk range of 1×10^{-4} to 1×10^{-6}. To determine an appropriate PRG for total uranium from the mass-based uranium isotope PRGs shown in Table 7, consideration is given to the mass fractions of the uranium isotopes in total uranium. For the purposes of this ECF, uranium isotope mass fractions are calculated based on the Hanford Site uranium soil background concentrations reported in DOE/RL-96-12, *Hanford Site Soil Background: Part 2, Soil Background for Radioactive Analytes*. The mass fractions are calculated by converting each isotope's reported activity-based background concentration to a mass-based concentration, as shown in Table 8. This table shows that by mass, uranium-238 comprises over 98% of the total uranium soil background concentration. The mass-based PRG for uranium-238 of 62,768,681 µg/kg is therefore recommended for use as a PRG for total uranium. Use of the uranium-238 value is considered conservative in that the uranium-238 value is lower than the total uranium PRG value would be if uranium-233/234, uranium-234, and uranium-235 were also included.

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Table 5. Summary of Soil Radionuclide PRGs for the Construction Worker Exposure Scenario

Radionuclide	Selected Radionuclide Direct Exposure PRG at 10^{-4} Target Risk Level (pCi/g)	Selected Radionuclide Direct Exposure PRG at 10^{-5} Target Risk Level (pCi/g)	Selected Radionuclide Direct Exposure PRG at 10^{-6} Target Risk Level (pCi/g)
Americium-241	31,037	3,104	310
Carbon-14	4,800,000	480,000	48,000
Cesium-137	1,550	155	16
Cobalt-60	334	33	3.3
Curium-243	7,582	758	76
Curium-243/244[a]	7,582	758	76
Curium-244	44,783	4,478	448
Europium-152	739	74	7.4
Europium-154	691	69	6.9
Europium-155	32,415	3,242	324
Iodine-129	121,242	12,124	1,212
Neptunium-237	4,193	419	42
Nickel-63	28,600,000	2,860,000	286,000
Plutonium-238	29,806	2,981	298
Plutonium-239/240[b]	28,043	2,804	280
Plutonium-241	1,030,000	103,000	10,300
Selenium-79	3,200,000	320,000	32,000
Strontium-90	120,584	12,058	1,206
Technetium-99	5,800,000	580,000	58,000
Tritium (H-3)	325,733	32,573	3,257
Uranium-233/234[c]	55,066	5,507	551
Uranium-234	55,066	5,507	551
Uranium-235	5,984	598	60
Uranium-238	21,084	2,108	211

Notes:

a. Values presented are calculated for curium-243 (assumed to be the dominant isotope in undifferentiated curium-243/244).

Table 5. Summary of Soil Radionuclide PRGs for the Construction Worker Exposure Scenario

Radionuclide	Selected Radionuclide Direct Exposure PRG at 10^{-4} Target Risk Level (pCi/g)	Selected Radionuclide Direct Exposure PRG at 10^{-5} Target Risk Level (pCi/g)	Selected Radionuclide Direct Exposure PRG at 10^{-6} Target Risk Level (pCi/g)

b. Values presented are calculated for plutonium-239 (assumed to be the dominant isotope in undifferentiated plutonium-239/240).

c. Values presented are calculated for uranium-234 (assumed to be the dominant isotope in undifferentiated uranium-233/234).

Table 6. Final Soil Radiological PRGs for the Construction Worker Exposure Scenario

Radionuclide	Selected Radionuclide PRG at $1x10^{-4}$ Target Risk Level (pCi/g)	Selected Radionuclide Radiation Dose from Soil at 1×10^{-4} PRG (mrem/year)	Selected Radionuclide Soil Guideline if 500 mrem/year Dose Limit is Exceeded (pCi/g)	Selected Radionuclide Final PRG (pCi/g)
Americium-241	31,037	704	22,030	22,030
Carbon-14	4,800,000	115	--	4,800,000
Cesium-137	1,550	126	--	1,550
Cobalt-60	334	124	--	334
Curium-243	7,582	223	--	7,582
Curium-243/244[a]	7,582	223	--	7,582
Curium-244	44,783	565	39,630	39,630
Europium-152	739	125	--	739
Europium-154	691	125	--	691
Europium-155	32,415	130	--	32,415
Iodine-129	121,242	194	--	121,242
Neptunium-237	4,193	164	--	4,193
Nickel-63	28,600,000	66	--	28,600,000
Plutonium-238	29,806	722	20,650	20,650
Plutonium-239/240[b]	28,043	752	18,660	18,660
Plutonium-241	1,030,000	695	719,100	719,100
Selenium-79	3,200,000	112	--	3,200,000
Strontium-90	120,584	173	--	120,584
Technetium-99	5,800,000	77	--	5,800,000
Tritium (H-3)	325,733	114	--	325,733
Uranium-233/234[c]	55,066	137	--	55,066
Uranium-234	55,066	137	--	55,066
Uranium-235	5,984	128	--	5,984
Uranium-238	21,084	134	--	21,084

Notes:

Table 6. Final Soil Radiological PRGs for the Construction Worker Exposure Scenario

Radionuclide	Selected Radionuclide PRG at $1x10^{-4}$ Target Risk Level (pCi/g)	Selected Radionuclide Radiation Dose from Soil at 1×10^{-4} PRG (mrem/year)	Selected Radionuclide Soil Guideline if 500 mrem/year Dose Limit is Exceeded (pCi/g)	Selected Radionuclide Final PRG (pCi/g)

a. Values presented are calculated for curium-243 (assumed to be the dominant isotope in undifferentiated curium-243/244).

b. Values presented are calculated for plutonium-239 (assumed to be the dominant isotope in undifferentiated plutonium-239/240).

c. Values presented are calculated for uranium-234 (assumed to be the dominant isotope in undifferentiated uranium-233/234).

Table 7. Conversion from Activity- to Mass-Based PRGs for Uranium Isotopes

Uranium Isotope	Construction Worker Scenario PRG at 10^{-4} Risk Level (pCi isotope/ g soil)[a]	Specific Activity (pCi isotope/ g isotope)[b]	Conversion Factor (µg isotope/ g isotope)	Conversion Factor (g soil/ kg soil)	Construction Worker Scenario PRG at 10^{-4} Risk Level (µg isotope/ kg soil)[c]
U-233/234	55,066	6.222E+09	1,000,000	1,000	8,850
U-234	55,066	6.222E+09	1,000,000	1,000	8,850
U-235	5,984	2.161E+06	1,000,000	1,000	2,769,088
U-238	21,084	3.359E+05	1,000,000	1,000	62,768,681

a. See Table 6.

b. See Table 4.

c. Calculated using Equation 1 (see Section 3).

Table 8. Calculation of Uranium Isotope Mass Fractions

Uranium Isotope	Background Activity (pCi isotope/ g soil)[a]	Activity Fraction	Specific Activity (pCi isotope/ g isotope)[b]	Background Mass (µg isotope/ kg soil)[c]	Mass Fraction
U-233/234	1.10	0.458	6.222E+09	0.177	0.00006
U-234	1.10	0.458	6.222E+09	0.177	0.00006
U-235	0.11	0.048	2.161E+06	50.4	0.016
U-238	1.06	0.467	3.359E+05	3155	0.98

a. DOE/RL-96-12, *Hanford Site Soil Background: Part 2, Soil Background for Radioactive Analytes.*

b. See Table 4.

c. Formula = Background Activity (pCi/g) / Specific Activity (pCi/g) x 1E+06 (µg/g) x 1E+03 (g/kg)

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Appendix A

RESRAD Output Summaries

Table A-1
Identification of Peak Year Based on Peak Cancer Risk

Radionuclide	Year of Maximum Risk
Americium-241	0
Carbon-14	0
Cesium-137	0
Cobalt-60	0
Curium-243	0
Curium-243/244	0
Curium-244	0
Europium-152	0
Europium-154	0
Europium-155	0
Iodine-129	0
Neptunium-237	0
Nickel-63	0
Plutonium-238	0
Plutonium-239/240	0
Plutonium-241	54
Selenium-79	0
Strontium-90	0
Technetium-99	0
Tritium (H-3)	0
Uranium-233/234	0
Uranium-234	0
Uranium-235	0
Uranium-238	0

Year	Plutonium-241[a]
	Risk - Selected Pathways Summed
1.0	5.81E-11
1.3	5.88E-11
1.7	5.97E-11
2.2	6.09E-11
2.9	6.24E-11
3.0	6.26E-11
3.8	6.42E-11
4.9	6.65E-11
6.4	6.92E-11
8.4	7.25E-11
10	7.50E-11
11	7.63E-11
14	8.05E-11
19	8.50E-11
24	8.94E-11
30	9.25E-11
32	9.32E-11
41	9.61E-11
54	**9.74E-11**
70	9.70E-11
92	9.49E-11
100	9.38E-11
119	9.12E-11
156	8.61E-11
203	7.98E-11
265	7.23E-11
300	6.83E-11
346	6.35E-11
451	5.37E-11
588	4.31E-11
767	3.23E-11
1,000	2.23E-11

a. Bold indicates peak cancer risk value.

Table A-2
Intermediate Calculation - Results of Cancer Risks at Year of Peak Risk and Preliminary PRGs for Individual Radionuclides

Nuclide	Year 0	Year 54	Maximum risk per pCi/g	Year at Peak Risk	PRG at 10^{-4} Target Risk (pCi/g)
Americium-241	3.22E-09	2.95E-09	3.22E-09	0	31,037
Carbon-14	2.08E-11	0.00E+00	2.08E-11	0	4.81E+06
Cesium-137	6.45E-08	1.87E-08	6.45E-08	0	1,550
Cobalt-60	3.00E-07	2.45E-10	3.00E-07	0	334
Curium-243	1.32E-08	3.65E-09	1.32E-08	0	7,582
Curium-243/244	1.32E-08	3.65E-09	1.32E-08	0	7,582
Curium-244	2.23E-09	2.91E-10	2.23E-09	0	44,783
Europium-152	1.35E-07	8.52E-09	1.35E-07	0	739
Europium-154	1.45E-07	1.86E-09	1.45E-07	0	691
Europium-155	3.09E-09	1.19E-12	3.09E-09	0	32,415
Iodine-129	8.25E-10	6.05E-10	8.25E-10	0	121,242
Neptunium-237	2.42E-08	2.40E-08	2.42E-08	0	4,139
Nickel-63	3.50E-12	2.41E-12	3.50E-12	0	2.86E+07
Plutonium-238	3.36E-09	2.19E-09	3.36E-09	0	29,806
Plutonium-239/240	3.57E-09	3.56E-09	3.57E-09	0	28,043
Plutonium-241	5.57E-11	9.74E-11	9.74E-11	54	1.03E+06
Selenium-79	3.15E-11	3.10E-11	3.15E-11	0	3.17E+06
Strontium-90	8.29E-10	2.25E-10	8.29E-10	0	120,584
Technetium-99	1.72E-11	4.31E-12	1.72E-11	0	5.81E+06
Tritium (H-3)	3.07E-10	2.53E-18	3.07E-10	0	325,733
Uranium-233/234	1.82E-09	1.66E-09	1.82E-09	0	55,066
Uranium-234	1.82E-09	1.66E-09	1.82E-09	0	55,066
Uranium-235	1.67E-08	1.53E-08	1.67E-08	0	5,984
Uranium-238	4.74E-09	4.32E-09	4.74E-09	0	21,084

Table A-3
Intermediate Calculation - Results of Cancer Risk at Year of Peak Risk Based on Preliminary PRGs

Nuclide	Year 0	Year 54	Maximum risk	Year at Peak Risk
Americium-241	1.00E-04	9.17E-05	1.00E-04	0
Carbon-14	9.98E-05	0.00E+00	9.98E-05	0
Cesium-137	1.00E-04	2.89E-05	1.00E-04	0
Cobalt-60	1.00E-04	8.19E-08	1.00E-04	0
Curium-243	1.00E-04	2.76E-05	1.00E-04	0
Curium-243/244	1.00E-04	2.76E-05	1.00E-04	0
Curium-244	1.00E-04	1.30E-05	1.00E-04	0
Europium-152	1.00E-04	6.30E-06	1.00E-04	0
Europium-154	1.00E-04	1.28E-06	1.00E-04	0
Europium-155	1.00E-04	3.85E-08	1.00E-04	0
Iodine-129	1.00E-04	7.33E-05	1.00E-04	0
Neptunium-237	1.00E-04	9.92E-05	1.00E-04	0
Nickel-63	1.02E-04	6.99E-05	1.02E-04	0
Plutonium-238	1.00E-04	6.53E-05	1.00E-04	0
Plutonium-239/240	1.00E-04	9.98E-05	1.00E-04	0
Plutonium-241	5.57E-05	9.74E-05	9.74E-05	54
Selenium-79	1.01E-04	9.93E-05	1.01E-04	0
Strontium-90	1.00E-04	2.71E-05	1.00E-04	0
Technetium-99	9.98E-05	2.50E-05	9.98E-05	0
Tritium (H-3)	1.00E-04	8.23E-13	1.00E-04	0
Uranium-233/234	1.00E-04	9.12E-05	1.00E-04	0
Uranium-234	1.00E-04	9.12E-05	1.00E-04	0
Uranium-235	1.00E-04	9.13E-05	1.00E-04	0
Uranium-238	1.00E-04	9.11E-05	1.00E-04	0

Table A-4
Intermediate Calculation - Calculation of Relative Percent Difference (RPD)

Nuclide	Target Risk = 1 x 10^{-4}	1st precision run	%RPD	Value entered into RESRAD (pCi/g)	2nd precision run	%RPD	Value entered into RESRAD (pCi/g)
Americium-241	1.00E-04	1.00E-04	0.01	31,037	--	--	--
Carbon-14	1.00E-04	9.98E-05	0.23	4,800,000	--	--	--
Cesium-137	1.00E-04	1.00E-04	0.00	1,550	--	--	--
Cobalt-60	1.00E-04	1.00E-04	-0.10	334	--	--	--
Curium-243	1.00E-04	1.00E-04	0.01	7,582	--	--	--
Curium-243/244	1.00E-04	1.00E-04	0.01	7,582	--	--	--
Curium-244	1.00E-04	1.00E-04	0.01	44,783	--	--	--
Europium-152	1.00E-04	1.00E-04	0.01	739	--	--	--
Europium-154	1.00E-04	1.00E-04	0.00	691	--	--	--
Europium-155	1.00E-04	1.00E-04	0.00	32,415	--	--	--
Iodine-129	1.00E-04	1.00E-04	0.00	121,242	--	--	--
Neptunium-237	1.00E-04	1.00E-04	0.02	4,193	--	--	--
Nickel-63	1.00E-04	1.02E-04	-1.59	29,000,000	9.81E-05	1.96	28,000,000
Plutonium-238	1.00E-04	1.00E-04	0.00	29,806	--	--	--
Plutonium-239/240	1.00E-04	1.00E-04	0.00	28,043	--	--	--
Plutonium-241	1.00E-04	9.74E-05	2.63	1,000,000	1.07E-04	-6.86	1,100,000
Selenium-79	1.00E-04	1.01E-04	-0.90	3,200,000	--	--	--
Strontium-90	1.00E-04	1.00E-04	0.00	120,584	--	--	--
Technetium-99	1.00E-04	9.98E-05	0.23	5,800,000	--	--	--
Tritium (H-3)	1.00E-04	1.00E-04	0.01	325,733	--	--	--
Uranium-233/234	1.00E-04	1.00E-04	0.00	55,066	--	--	--
Uranium-234	1.00E-04	1.00E-04	0.00	55,066	--	--	--
Uranium-235	1.00E-04	1.00E-04	0.02	5,984	--	--	--
Uranium-238	1.00E-04	1.00E-04	0.01	21,084	--	--	--

Table A-5
Intermediate Calculation - Comparison to Radiation Dose Limit and Determination of Final PRGs

Nuclide	PRG at 10^{-4} Target Risk	Radiation Dose from Soil at 10^{-4} PRG (mrem/yr)	Selected Radionuclide Soil Guideline if 500 mrem/yr Dose Limit is Exceeded (pCi/g)	Final Radionuclide PRG (pCi/g)
Americium-241	31,037	704	22,030	22,030
Carbon-14	4,800,000	115	--	4,800,000
Cesium-137	1,550	126	--	1,550
Cobalt-60	334	124	--	334
Curium-243	7,582	223	--	7,582
Curium-243/244	7,582	223	--	7,582
Curium-244	44,783	565	39,630	39,630
Europium-152	739	125	--	739
Europium-154	691	125	--	691
Europium-155	32,415	130	--	32,415
Iodine-129	121,242	194	--	121,242
Neptunium-237	4,193	164	--	4,193
Nickel-63	28,600,000	66	--	28,600,000
Plutonium-238	29,806	722	20,650	20,650
Plutonium-239/240	28,043	752	18,660	18,660
Plutonium-241	1,030,000	695	719,100	719,100
Selenium-79	3,200,000	112	--	3,200,000
Strontium-90	120,584	173	--	120,584
Technetium-99	5,800,000	77	--	5,800,000
Tritium (H-3)	325,733	114	--	325,733
Uranium-233/234	55,066	137	--	55,066
Uranium-234	55,066	137	--	55,066
Uranium-235	5,984	128	--	5,984
Uranium-238	21,084	134	--	21,084

Table A-6
Calculation of Thickness-Weighted Average Hydrological Parameters for the Contaminated Zone

The 200 North Area hydrostratigraphic template from PNNL-14702 (pg. A.13, 200I-X) is used to represent a generic vadoze zone stratigraphic sequence

Hss	3 ft	
Hg	167 ft	
total	170 ft	(depth to groundwater = 170 ft below ground surface)

Thickness-weighted average parameter values are calculated for an assumed 15 ft thick contaminated zone (CZ) using the following mixture

Hss	3 ft
Hg	12 ft
total CZ	15 ft

Formula used is Pcz = (3*PHss+12*PHg)/15 where Pcz is weighted average parameter and PHss and PHg are corresponding parameters of Hss and Hg units respectively

Parameter	Units	PHss	PHg	Reference	Pcz
Density of CZ	g/cm3	1.61	1.93	PNNL-18564, Table 6.2, site-wide values	1.87
CZ total porosity	unitless	0.448	0.258	PNNL-18564, Table 6.3, site-wide values	0.296
CZ field capacity	unitless	0.175	0.061	PNNL-18564, Table 6.5, best-estimate values	0.084
CZ hydraulic conductivity	m/yr	8.58E-05 (cm/s)	3.30E-04 (cm/s)	PNNL-18564, Table 6.7, site-wide values	88.7
CZ zone "b" parameter	unitless	2.63	2.96	PNNL-18564, Table 6.8	2.89

PNNL-14702, *Vadose Zone Hydrology Data Package for Hanford Assessments.*

PNNL-18564, *Selection and Traceability of Parameters to Support Hanford-Specific RESRAD Analyses – Fiscal Year 2008 Status Report.*

PHss = Parameter corresponding to Hanford formation silty sand.
PHg = Parameter corresponding to Hanford formation gravel.

Table A-7
Sensitivity Analysis - Area of Contaminated Zone and Thickness of Contaminated Zone

Radionuclides	Parameter	Upper Value Max Risk (Risk per pCi/g)	Base Value Max Risk (Risk per pCi/g)	Lower Value Max Risk (Risk per pCi/g)	SI[a]	Comments[b]	Upper Value 50,000 m²				Base Value 10,000 m²				Lower Value 2,000 m²			
							PRG at 10^{-4} Target Risk (pCi/g)	Dose from 10^{-4} PRG (mrem/yr)	Radionuclide Soil Guideline for 500 mrem/yr (pCi/g)	Final PRG (pCi/g)	PRG at 10^{-4} Target Risk (pCi/g)	Dose from 10^{-4} PRG (mrem/yr)	Radionuclide Soil Guideline for 500 mrem/yr (pCi/g)	Final PRG (pCi/g)	PRG at 10^{-4} Target Risk (pCi/g)	Dose from 10^{-4} PRG (mrem/yr)	Radionuclide Soil Guideline for 500 mrem/yr (pCi/g)	Final PRG (pCi/g)
	Area of Contaminated Zone	50,000 m²	10,000 m²	2,000 m²														
Am-241		3.59E-09	3.22E-09	2.88E-09	0.20	Sensitive	27,871	729	19,130	19,130	31,037	704	22,030	22,030	34,722	684	26,390	26,390
Cs-137		6.62E-08	6.45E-08	6.19E-08	0.06	Not sensitive as SI <0.1	Not Calculated											
Pu-239/240		4.10E-09	3.57E-09	3.10E-09	0.24	Sensitive	24,384	757	16,100	16,100	28,043	752	18,660	18,660	32,216	745	21,610	21,610
		9.2 m	4.6 m	2.3 m														
Am-241	Thickness of Contaminated Zone	3.22E-09	3.22E-09	3.22E-09	0.00	Independent	Not Calculated											
Cs-137		6.45E-08	6.45E-08	6.45E-08	0.00	Independent												
Pu-239/240		3.57E-09	3.57E-09	3.57E-09	0.00	Independent												

Notes:

a. The sensitivity index (SI) is SI = 1 – (f(p)min / f(p)max): where: f(p) is the maximum risk associated with the upper and lower parameter values.

b. A positive value of the SI indicates that the risk is directly proportional to the parameter of interest, whereas a negative value indicates the risk is inversely proportional to the parameter of interest. A value less than 0.01 indicates that the risk is independent of the parameter. The further the value of SI is from zero (0), the more sensitive the parameter is.

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Appendix B

Software Installation and Checkout Forms

1

CHPRC SOFTWARE INSTALLATION AND CHECKOUT FORM

Software Owner Instructions:
Complete Fields 1-13, then run test cases in Field 14. Compare test case results listed in Field 15 to corresponding Test Report outputs. If results are the same, sign and date Field 19. If not, resolve differences and repeat above steps.

Software Subject Matter Expert Instructions:
Assign test personnel. Approve the installation of the code by signing and dating Field 21, then maintain form as part of the software support documentation.

GENERAL INFORMATION:

1. Software Name: RESRAD Software Version No.: 7.0

EXECUTABLE INFORMATION:

2. Executable Name (include path):

   c:\RESRAD Family\RESRAD\7.0\RESWIN6.EXE

3. Executable Size (bytes): 1.876 MB

COMPILATION INFORMATION:

4. Hardware System (i.e., property number or ID):

   Compiled by Vendor (ANL)

5. Operating System (include version number):

   Compiled by Vendor (ANL)

INSTALLATION AND CHECKOUT INFORMATION:

6. Hardware System (i.e., property number or ID):

   Intera-00295

7. Operating System (include version number):

   Windows 7 Professional Service Pack 1

8. Open Problem Report? ◉ No ○ Yes PR/CR No.

TEST CASE INFORMATION:

9. Directory/Path:

   C:\RESRAD Family\RESRAD\7.0\QAfiles

10. Procedure(s):

    per CHPRC-00210 Rev 2, RESRAD Software Test Plan

11. Libraries:

    N/A

12. Input Files:

    Created in RESRAD per installation test instruction

13. Output Files:

    SUMMARY.REP

14. Test Cases:

    RESRAD-ITC-1

15. Test Case Results:

    Test results matched expected results; pass.

16. Test Performed By: RD Evans

17. Test Results: ◉ Satisfactory, Accepted for Use ○ Unsatisfactory

18. Disposition (include HISI update):

    Installation accepted; computer and user added to HISI entry for RESRAD software.

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CHPRC SOFTWARE INSTALLATION AND CHECKOUT FORM (continued)

1. Software Name: RESRAD Software Version No.: 7.0

Prepared By:

19.	Software Owner (Signature)	WE Nichols Print	30 APRIL 2015 Date

20. Test Personnel:

Sign	RD Evans Print	4/30/2015 Date
Sign	Print	Date
Sign	Print	Date

Approved By:

21.	Software SME (Signature)	N/R per SMP Print	Date

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CHPRC SOFTWARE INSTALLATION AND CHECKOUT FORM

Software Owner Instructions:
Complete Fields 1-13, then run test cases in Field 14. Compare test case results listed in Field 15 to corresponding Test Report outputs. If results are the same, sign and date Field 19. If not, resolve differences and repeat above steps.

Software Subject Matter Expert Instructions:
Assign test personnel. Approve the installation of the code by signing and dating Field 21, then maintain form as part of the software support documentation.

GENERAL INFORMATION:

1. Software Name: RESRAD Software Version No.: 7.0

EXECUTABLE INFORMATION:

2. Executable Name (include path):

   c:\RESRAD Family\RESRAD\7.0\RESWIN7.EXE

3. Executable Size (bytes): 1.852 KB

COMPILATION INFORMATION:

4. Hardware System (i.e., property number or ID):

   Compiled by Vendor (ANL)

5. Operating System (include version number):

   Compiled by Vendor (ANL)

INSTALLATION AND CHECKOUT INFORMATION:

6. Hardware System (i.e., property number or ID):

   Intera-00474

7. Operating System (include version number):

   Windows 10 Pro

8. Open Problem Report? ◉ No ○ Yes PR/CR No.

TEST CASE INFORMATION:

9. Directory/Path:

   C:\RESRAD Family\RESRAD\7.0

10. Procedure(s):

    per CHPRC-00210 Rev 2, RESRAD Software Test Plan

11. Libraries:

    N/A

12. Input Files:

    Created in RESRAD per installation test instruction

13. Output Files:

    SUMMARY.REP

14. Test Cases:

    RESRAD-ITC-1

15. Test Case Results:

    Test results matched expected results; pass.

16. Test Performed By: SL Lindberg

17. Test Results: ◉ Satisfactory, Accepted for Use ○ Unsatisfactory

18. Disposition (include HISI update):

    Approved; installation added to HISI entry software user list.

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CHPRC SOFTWARE INSTALLATION AND CHECKOUT FORM (continued)

1. Software Name: RESRAD Software Version No.: 7.0

Prepared By:

19.	Software Owner (Signature)	WE Nichols Print	3 Aug 2016 Date

20. Test Personnel:

Sign	SL Lindberg Print	08/03/2016 Date
Sign	Print	Date
Sign	Print	Date

Approved By:

21.	Software SME (Signature)	N/R per SMP Print	Date

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