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6. SENSITIVITY ANALYSIS AND UNCERTAINTY QUANTIFICATION

This chapter provides a description of the methods used for the sensitivity and uncertainty quantification analyses and identifies the parameters and assumptions found to be most important in the determination of compliance with PA performance objectives, development of WAC, establishment of individual DU inventory limits, and other regulatory decisions.

- **Section 6.1** discusses the results of sensitivity analysis and uncertainty quantification for the PORFLOW flow and transport models of STs, ETs, LAWV, ILV, and NRCDAs.
- **Section 6.2** presents direct comparisons between PORFLOW and GoldSim® model results for the three trench DUs selected for sensitivity analysis and uncertainty quantification (ST06, ST09, and ET06).
- **Section 6.3** summarizes sensitivity simulations for the air and radon pathways using the ARM model, with a focus on water saturation; closure cap thickness and presence; diffusion coefficients; and the Henry's Law constant.

KEY TAKEAWAYS

- ✓ Limiting dose factors often occur at the beginning or end of the period of compliance.
- ✓ Limiting dose factors as determined by PORFLOW sensitivity calculations sometimes show significant increases over nominal values.
- ✓ PORFLOW results are particularly sensitive to K_d followed by infiltration.
- ✓ Dose uncertainty quantification based on the PORFLOW model highlights the most impacted exposure pathways and DUs.
- ✓ GoldSim® has been successfully calibrated to PORFLOW model results for C-14, H-3, I-129, and Np-237.
- ✓ Like PORFLOW, the GoldSim® trench system model identifies K_d as the dominant parameter controlling dose sensitivity.
- ✓ For trenches investigated (ST06, ST09, and ET06) and for most radionuclides, 95th-percentile peak concentrations calculated by GoldSim® are higher than nominal PA concentrations from the PORFLOW deterministic model.
- ✓ Air pathway and radon fluxes are sensitive to water saturation; however, sensitivity to other key parameters is mixed.
- ✓ Interplay between POA, DRFs, and transport time for the air pathway can result in lower peak doses.
- ✓ Sensitivity results for the air and radon pathways support use of the nominal PA/best estimate case for limits determination.

The sensitivity and uncertainty quantification analyses presented in this chapter focus on a small subset of the slit and engineered trenches (i.e., three of 29 possible trench DUs) as well as both vaults and both NRCDAs. The three trenches (i.e., ET06, ST06, and ST09) represent the typical VZ variations observed in the hydrostratigraphy across the ELLWF footprint. As discussed in Section 4.1.3.2, the key parameter considered in selecting these three trench DUs is the location of the water table surface with respect to the vertical location of the TCCZ. The water table lies above the TCCZ at ET06 and ST06 but drops below the TCCZ at ST09. The overall results presented for these 3 trench DUs reflect the overall behavior of all 29 trench DUs.

Based on the PORFLOW sensitivity analyses performed for the dose (and concentration) factors provided in

Chapter 5, a statistical analysis is performed to address PORFLOW model parameter uncertainties. Along with the projected 2065 closure inventories presented in Chapter 8, dose (and concentration) uncertainties associated with the selected DUs by exposure pathway are discussed.

6.1. PORFLOW MODELS

Sensitivity analysis and uncertainty quantification are conducted using the PORFLOW flow and transport models for the following seven DUs: ET06, ST06, ST09, ILV, LAWV, NR07E, and NR26E. For NR07E, disposal of radionuclides bound to Inconel in steel casks (SWF) is analyzed. For NR26E, both disposal of generic NR waste in bolted steel containers and of radionuclides bound to Zircaloy in steel casks (SWF) are analyzed.

For the eight cases listed above, sets of six to nine PORFLOW simulations are conducted to evaluate the sensitivity of the maximum all-pathways doses and GW protection concentrations and doses at the 100-meter POA to perturbations in select model parameters. The dose (or concentration) is the maximum dose during the compliance period originating from the disposal of one curie of parent radionuclide. All results provided are based on impacts to the 100-meter POA for each DU in isolation (i.e., plume interactions are not accounted for in this chapter but are addressed in Chapter 8). This dose is one step removed from preliminary disposal limits, which are calculated as follows:

$$\text{Preliminary Disposal Limit (Ci)} = \left[\frac{\text{Regulatory Dose Limit (mrem/yr)}}{\text{Maximum Dose at 100-meter POA per Ci parent (mrem/yr/Ci)}}\right] \quad \text{Eq. (6-1)}$$

Final disposal limits include the effects of plume interaction between DUs at the 100-meter POA.

The sensitivity analysis modeling approach includes VZ flow, VZ transport, and aquifer transport calculations using PORFLOW, followed by calculation of maximum doses and concentrations at the 100-meter POA. The aquifer flow field is calculated separately. PORFLOW is solved for a set of steady-state VZ flows to model variation in waste burial timing, material property changes (i.e., dynamic compaction in ETs and STs), and infiltration over time. A linear sorption isotherm is used in transport modeling. The selected sensitivity parameters are expected to result in the most impact on radionuclide transport. The six to nine sensitivity parameters tested for each DU are varied independently, and only one-sided variations are tested (i.e., a truncated star pattern). Performing one-at-a-time sensitivity studies does not capture the nonlinear effects in the modeling; however, the parameters investigated in this sensitivity analysis are independent, and the VZ and aquifer transport equations are linear with respect to concentration.

The purpose of the sensitivity study is to determine model parameters having the greatest impact on peak dose or concentration during the compliance period. Some sensitivity results show large differences from the dose calculated for the nominal PA case (PA base case). To illustrate this effect, Figure 6-1 shows three possible results with the end of the compliance period arbitrarily set to 1,100 years. If Peak 3 represents the nominal PA case, the dose during the compliance period at the 100-meter POA is quite small. If the peak occurs sooner because of increased infiltration and/or decreased K_d (e.g., Peak 2), a large increase in dose results. Similarly, if a decrease in infiltration and/or increase in K_d causes the peak dose to occur within the compliance period (Peak 1), it will also result in a large increase in dose. In this example, the all-time peak dose remains the same but the dose within the compliance period changes significantly. This behavior occurs with many of the sensitivity cases, particularly those having lower K_d values and greater infiltration rates which cause the peak concentration to occur earlier in the transient. At extreme combinations of decreased infiltration and/or increased K_d values, dose (or concentration) at the 100-meter POA may become extremely low, which can be seen in the results to follow.

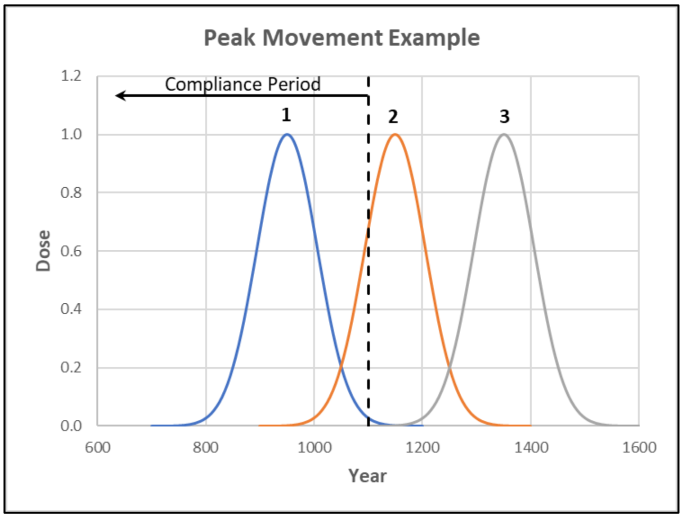


Figure 6-1. Representation of Possible Sensitivity Results for Dose at the 100-meter POA

Results from the sensitivity analysis calculations are also used to estimate uncertainty in the results using the methodology outlined in Section 6.1.2. Biases present when calculating dose in the nominal PA case from PORFLOW modeling results are discussed in Section 6.1.2.3. To address a key issue from PA2008, the sensitivity of the Tc-99 dose factor with respect to K_d is presented in Section 6.1.4.

6.1.1. Sensitivity Analysis Results

The sections that follow are organized by type of DU. The first table or tables in each section list the sensitivity parameters and values used to evaluate model sensitivity. Similar versions of these tables are presented in Chapter 5; however, here the tables are expanded to include the distributions used in the uncertainty calculations. The tables also include the absolute difference between the sensitivity parameter value used for sensitivity assessment and the nominal PA value as well as the number of standard deviations this absolute difference is assumed to represent.

Some variations exist in the sensitivity parameter and sensitivity case nomenclature used by individual modelers. For example, ST and ET results use a “Best Estimate” case to calculate nominal PA doses and limits. The vault models differentiate between nominal PA and best estimate cases because some conservative bias is introduced into the PA models for these DUs. For example, the PA Working Group recommends a 500-year lifetime assumption for concrete barriers whereas E-Area vault concrete is expected to last much longer. In the tables, the label “Nominal PA Case” is added to some “Best Estimate” cases to clarify the intended application. For all DU types, pessimistically biased infiltration rates (i.e., bounded closure cap design with best estimate rainfall) are employed in the nominal PA calculations.

The information presented tries to strike a balance between showing complete results (which often include small values of no consequence) and showing only the most significant results (which does not address the values of missing radionuclides). In PA2008, inventory limits greater than 1.0E+20 Ci are not reported. Also, only generic parent radionuclides (i.e., no SWF radionuclides are included) are addressed in this chapter.

6.1.1.1. Slit and Engineered Trenches

Table 6-1 lists sensitivity cases, sensitivity parameters, the change in the parameter used in sensitivity calculations, and the parameter distribution information for ET06. The same information is provided for ST06 and ST09 in Table 6-2. The bases for the temporal profiles of infiltration rate used in the nominal PA and sensitivity cases for STs and ETs are discussed in Sections 3.8.4.3.2 and 3.8.4.3.4. The infiltration rate profiles for the intact closure cap scenario used in the ST and ET sensitivity analyses are also shown in Figure 6-2 (linear-linear) and Figure 6-3 (log-linear). The nominal PA infiltration profile is designated as “Bounding cap design / best estimate (BE) rainfall” and the sensitivity case infiltration profile as “Bounding cap design / pessimistic rainfall.” A general description of the results for ET06 is provided in Section 6.1.1.1.1 and applies equally to ST06 and ST09; the description is not repeated for ST06 and ST09 results in Sections 6.1.1.1.2 and 6.1.1.1.3, respectively. Detailed descriptions of the PORFLOW flow and transport models for STs and ETs are given in Section 4.1. ET06, ST06, and ST09 have been selected for sensitivity analysis and uncertainty quantification because they represent vadose zones characterized by three different sets of hydrostratigraphic features.

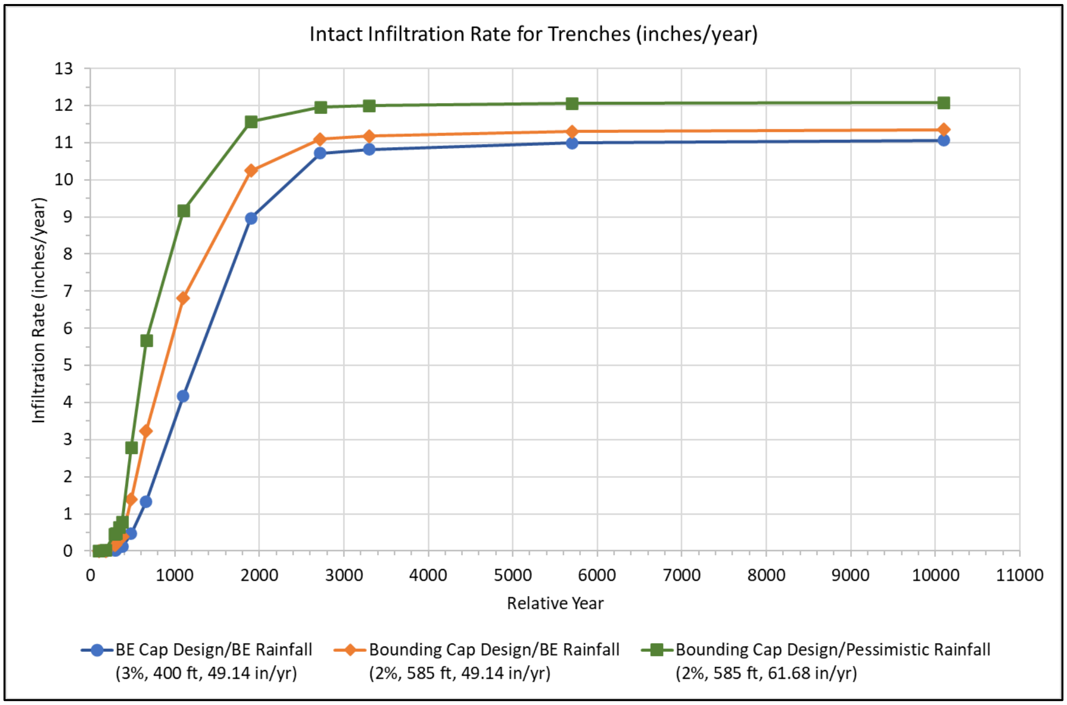


Figure 6-2. Linear-Linear Plot of Infiltration Rates for Intact Closure Cap Cases for Slit and Engineered Trenches

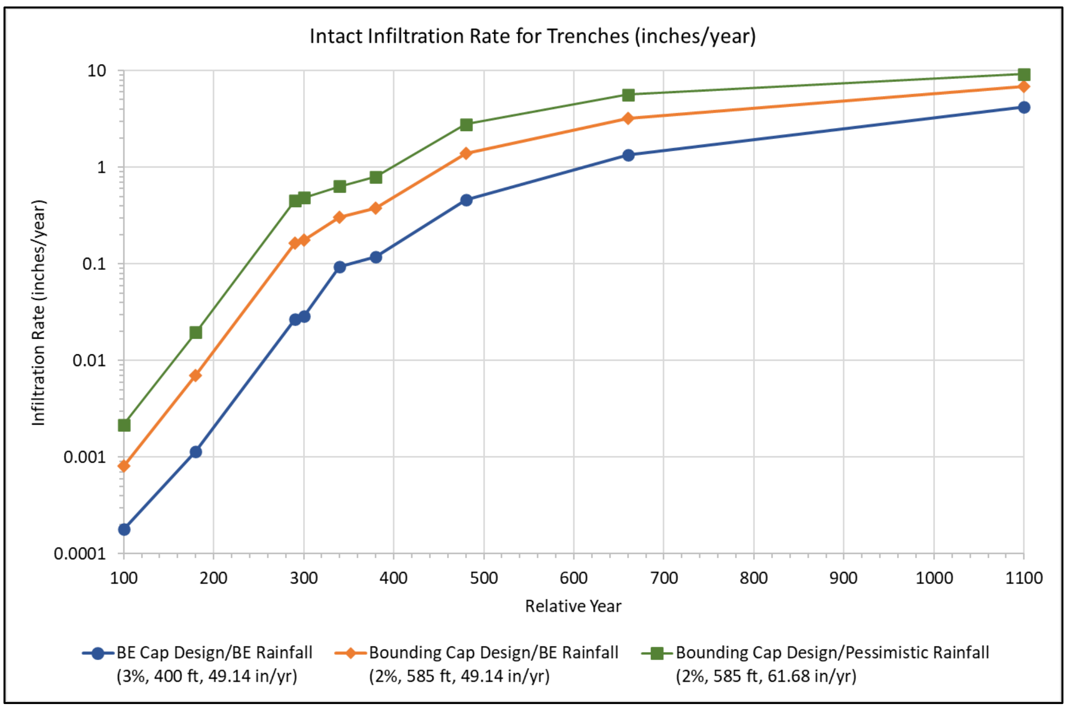


Figure 6-3. Log-Linear Plot of Infiltration Rates for Intact Closure Cap Cases for Slit and Engineered Trenches

Table 6-1. Sensitivity and Uncertainty Parameters for ET06

Intact Sensitivity Case No.	Topic	Nominal PA (Best Estimate) Case Parameter Value	Sensitivity Case Parameter Value	Δ(SV) (Sensitivity – Nominal)	Standard Deviations	Distribution	Mean	Standard Deviation	Minimum	Maximum
1	Waste Zone Hydraulic Conductivity (cm s^{-1})	2.20E-05[b]	4.08E-05[b]	1.88E-05	+4σ	Truncated Normal	2.20E-05	4.70E-06	-3σ	+3σ
		8.70E-06[a]	1.57E-05[a]	7.00E-06	+4σ	Truncated Normal	8.70E-06	1.75E-06	-3σ	+3σ
2	LVZ Porosity	0.381	0.420	0.0394	+1σ	Truncated Normal	0.381	0.040	-3σ	+3σ
3	Tan Clay Layer Thickness (feet)	5.00	2.50	-2.50	-2σ	Truncated Normal	5.00	1.25	-3σ	+3σ
4	Waste Zone Porosity	0.889[b]	0.939[b]	0.050	+1.5σ	Truncated Normal	0.889	0.033	-3σ	+3σ
		0.303[a]	0.615[a]	0.312	+6σ	Truncated Normal	0.303	0.050	-3σ	+3σ
5	Precipitation/ Infiltration (cm yr^{-1})	2019 HELP Model Bounding Cap Design with Best Estimate Rainfall[e]	2019 HELP Model Bounding Cap Design with Pessimistic Rainfall[e]	31.9	+1.6σ	Truncated Normal	124.8[c] 156.7[d]	19.9	-2σ	+2σ
6	K_d	2016 GeoChem Database	0.5*K_d	-0.5	-2.5σ	Truncated Normal	1	0.2	-3σ	+3σ
7	Waste Disposal Timing	0 (Start of Operations)	1 (End of Operations)	1	--	Uniform	--	--	0	1

Notes:

a After dynamic compaction

b Before dynamic compaction

c Annual average rainfall

d Pessimistic (+1.6σ) annual rainfall

e The nominal PA infiltration profile is designated as "Bounding cap design best estimate (BE) rainfall" and the sensitivity case infiltration profile as "Bounding cap design pessimistic rainfall." Refer to Figure 6-2 and Figure 6-3.

Table 6-2. Sensitivity and Uncertainty Parameters for ST06 and ST09

Intact Sensitivity Case No.	Topic	Nominal PA (Best Estimate) Case	Sensitivity Case	Δ(SV) (Sensitivity – Nominal)	Standard Deviations	Distribution	Mean	Standard Deviation	Minimum	Maximum
1	Waste Zone Hydraulic Conductivity (cm s^{-1})	9.40E-05 [b]	1.71E-04 [b]	7.70E-05	+4σ	Truncated Normal	9.40E-05	1.93E-05	-3σ	+3σ
		1.50E-05 [a]	2.79E-05 [a]	1.29E-05	+4σ	Truncated Normal	1.50E-05	3.23E-06	-3σ	+3σ
2	LVZ Porosity	0.380	0.420	0.040	+1σ	Truncated Normal	0.380	0.040	-3σ	+3σ
3	Tan Clay Thickness (feet)	11.00	5.50	-5.50	-2σ	Truncated Normal	11.00	2.75	-3σ	+3σ
4	Waste Zone Porosity	0.600 [b]	0.617 [b]	0.017	+1.5σ	Truncated Normal	0.600	0.017	-3σ	+3σ
		0.277 [a]	0.307 [a]	0.030	+1σ	Truncated Normal	0.277	0.030	-3σ	+3σ
5	Precipitation/ Infiltration (cm yr^{-1})	2019 HELP Model Bounding Cap Design with Best Estimate Rainfall [e]	2019 HELP Model Bounding Cap Design with Pessimistic Rainfall [e]	31.9	+1.6σ	Truncated Normal	124.8 [c] 156.7 [d]	19.9	-2σ	+2σ
6	K_d	2016 Chemistry Database	$0.5*K_d$	-0.5	-2.5σ	Truncated Normal	1	0.2	-3σ	+3σ
7	Waste Disposal Timing	0 (Start of Operations)	1 (End of Operations)	1	--	Uniform	--	--	0	1

Notes:

a After dynamic compaction

b Before dynamic compaction

c Annual average rainfall

d Pessimistic (+1.6σ) annual rainfall

e The nominal PA infiltration profile is designated as "Bounding cap design best estimate (BE) rainfall" and the sensitivity case infiltration profile as "Bounding cap design pessimistic rainfall."

6.1.1.1.1. ET06

Table 6-3 lists the maximum all-pathways dose factor (mrem yr^{-1} Ci^{-1} parent buried) at the 100-meter POA for each generic radionuclide modeled in ET06 during the compliance period. Results are shown for the intact and subsidence cases (see also Section 5.1.3) as well as for the maximum all-pathways dose factor among the two cases (CaseMX).

Table 6-3. Maximum All-Pathways Dose Factors for ET06 at 100-meter POA and Time of Maximum

Radionuclide [1]	Case01, Intact		Case11, Subsided		Case MX, Maximum	
	mrem yr^{-1} Ci^{-1}	Year	mrem yr^{-1} Ci^{-1}	Year	mrem yr^{-1} Ci^{-1}	Year
Pa-231	1.23E+02	1,171	1.19E+02	1,171	1.23E+02	1,171
I-129	6.76E+01	787	6.40E+01	787	6.76E+01	787
Np-237	2.83E+01	1,171	2.73E+01	1,171	2.83E+01	1,171
Cl-36	1.09E+00	1,052	1.04E+00	1,051	1.09E+00	1,052
Tc-99	3.34E-01	181	3.34E-01	181	3.34E-01	181
C-14	8.76E-03	1,171	1.11E-02	1,171	1.11E-02	1,171
Be-10	1.63E-03	1,171	6.55E-03	941	6.55E-03	941
Am-241	1.05E-03	1,171	1.10E-03	1,171	1.10E-03	1,171
K-40	9.74E-04	1,171	4.66E-02	963	4.66E-02	963
Cm-245	4.42E-04	1,171	5.46E-04	1,171	5.46E-04	1,171
Pu-241	3.16E-05	1,171	3.37E-05	1,171	3.37E-05	1,171
Th-231	1.08E-05	1,171	1.04E-05	1,171	1.08E-05	1,171
Cf-249	5.60E-06	1,171	7.90E-06	1,171	7.90E-06	1,171
H-3	9.84E-07	171	9.84E-07	171	9.84E-07	171
Pu-239	1.13E-07	1,171	1.46E-07	1,171	1.46E-07	1,171
Ni-59	4.15E-08	1,171	2.58E-04	1,050	2.58E-04	1,050
Pd-107	3.32E-08	1,171	2.07E-04	1,050	2.07E-04	1,050
Ag-108m	1.24E-09	1,171	1.78E-03	1,035	1.78E-03	1,035
Cs-135	8.04E-11	1,171	7.79E-03	1,149	7.79E-03	1,149
Rb-87	7.05E-11	1,171	6.83E-03	1,149	6.83E-03	1,149
Ni-63	3.64E-11	1,171	2.64E-06	693	2.64E-06	693
Sr-90	4.75E-14	1,153	4.49E-07	468	4.49E-07	468
Cs-137	1.39E-21	1,171	5.90E-10	654	5.90E-10	654
Ra-226	4.42E-24	1,171	3.14E-03	1,171	3.14E-03	1,171
Th-230	2.82E-26	1,171	3.09E-04	1,171	3.09E-04	1,171
U-234	2.39E-30	1,171	3.84E-07	1,171	3.84E-07	1,171

Notes:
1 Radionuclides are sorted from highest to lowest Case01 dose factor.

Similarly, Table 6-4, Table 6-5, Table 6-6, and Table 6-7 list maximum GW protection beta-gamma dose factors, gross-alpha concentration factors, radium concentration factors, and uranium concentration factors, respectively, at the 100-meter POA during the compliance period for all generic radionuclides included in the ET06 PORFLOW model. Results are shown for the intact and subsidence cases as well as for the maximum dose factor among the two cases (CaseMX). Non-alpha emitters and species without a radium- or uranium-containing decay chain are excluded from the tables. Gross-alpha, radium, and uranium calculations are not included in the sensitivity analysis.

Table 6-4. Maximum Beta-Gamma Dose Factors at 100-meter POA and Time of Maximum for ET06

Radionuclide [1]	Case01, Intact		Case11, Subsided		CaseMX, Maximum	
	mrem yr^{-1} Ci^{-1}	Year	mrem yr^{-1} Ci^{-1}	Year	mrem yr^{-1} Ci^{-1}	Year
I-129	1.16E+03	787	1.09E+03	787	1.16E+03	787
Np-237	1.88E+00	1,171	1.82E+00	1,171	1.88E+00	1,171
Cl-36	1.21E+00	1,052	1.16E+00	1,051	1.21E+00	1,052
Tc-99	9.19E-01	107	9.19E-01	107	9.19E-01	107
H-3	3.94E-01	47	3.94E-01	47	3.94E-01	47
Pa-231	3.42E-01	1,171	3.32E-01	1,171	3.42E-01	1,171
C-14	8.74E-03	1,171	1.11E-02	1,171	1.11E-02	1,171
Be-10	2.78E-03	1,171	1.11E-02	941	1.11E-02	941
K-40	1.01E-03	1,171	4.84E-02	963	4.84E-02	963
Am-241	6.96E-05	1,171	7.35E-05	1,171	7.35E-05	1,171
Cm-245	2.94E-05	1,171	3.63E-05	1,171	3.63E-05	1,171
Ni-59	4.00E-06	1,171	2.49E-02	1,050	2.49E-02	1,050
Pu-241	2.10E-06	1,171	2.24E-06	1,171	2.24E-06	1,171
Cf-249	3.72E-07	1,171	5.26E-07	1,171	5.26E-07	1,171
Pd-107	4.31E-08	1,171	2.69E-04	1,050	2.69E-04	1,050
Th-231	3.01E-08	1,171	2.93E-08	1,171	3.01E-08	1,171
Ni-63	8.46E-09	1,171	6.13E-04	693	6.13E-04	693
Ag-108m	1.66E-09	1,171	2.37E-03	1,035	2.37E-03	1,035
Pu-239	2.29E-10	1,171	3.44E-10	1,171	3.44E-10	1,171
Rb-87	1.81E-10	1,171	1.76E-02	1,149	1.76E-02	1,149
Cs-135	6.04E-11	1,171	5.85E-03	1,149	5.85E-03	1,149
Sr-90	4.06E-13	1,153	3.84E-06	468	3.84E-06	468
Cs-137	9.31E-22	1,171	3.96E-10	654	3.96E-10	654
Ra-226	8.55E-26	1,171	1.02E-04	1,171	1.02E-04	1,171
Th-230	5.50E-28	1,171	9.83E-06	1,171	9.83E-06	1,171
U-234	4.45E-32	1,171	1.20E-08	1,171	1.20E-08	1,171

Notes:

1 Radionuclides are sorted from highest to lowest Case01 dose factor.

Table 6-5. Maximum Gross-Alpha Concentration Factors at 100-meter POA and Time of Maximum for ET06

Radionuclide[1, 2]	Case01, Intact		Case11, Subsided		CaseMX, Maximum	
	pCi L^{-1} Ci^{-1}	Year	pCi L^{-1} Ci^{-1}	Year	pCi L^{-1} Ci^{-1}	Year
Np-237	1.41E+02	1,171	1.36E+02	1,171	1.41E+02	1,171
Pa-231	1.41E+02	1,171	1.36E+02	1,171	1.41E+02	1,171
Am-241	5.22E-03	1,171	5.51E-03	1,171	5.51E-03	1,171
Cm-245	2.20E-03	1,171	2.72E-03	1,171	2.72E-03	1,171
Pu-241	1.58E-04	1,171	1.68E-04	1,171	1.68E-04	1,171
Cf-249	2.79E-05	1,171	3.94E-05	1,171	3.94E-05	1,171
Th-231	1.24E-05	1,171	1.19E-05	1,171	1.24E-05	1,171
Pu-239	1.29E-07	1,171	1.67E-07	1,171	1.67E-07	1,171
Ra-226	1.76E-23	1,171	1.24E-02	1,171	1.24E-02	1,171
Th-230	1.12E-25	1,171	1.22E-03	1,171	1.22E-03	1,171
U-234	9.49E-30	1,171	1.51E-06	1,171	1.51E-06	1,171

Notes:

1 Non-alpha-emitting radionuclides are excluded.

2 Radionuclides are sorted from highest to lowest Case01 concentration factor.

Table 6-6. Maximum Radium Concentration Factors at 100-meter POA and Time of Maximum for ET06

Radionuclide[1]	Case01, Intact		Case11, Subsided		CaseMX, Maximum	
	pCi L^{-1} Ci^{-1}	Year	pCi L^{-1} Ci^{-1}	Year	pCi L^{-1} Ci^{-1}	Year
Ra-226	5.84E-24	1,171	4.11E-03	1,171	4.11E-03	1,171
Th-230	3.73E-26	1,171	4.04E-04	1,171	4.04E-04	1,171
U-234	3.16E-30	1,171	5.03E-07	1,171	5.03E-07	1,171

Notes:

1 Radionuclides without a radium-containing decay chain are excluded.

2 Radionuclides are sorted from highest to lowest Case01 concentration factor.

Table 6-7. Maximum Uranium Concentration Factors at 100-meter POA and Time of Maximum for ET06

Radionuclide[1]	Case01, Intact[2]		Case11, Subsided		CaseMX, Maximum	
	µg L^{-1} Ci^{-1}	Year	µg L^{-1} Ci^{-1}	Year	µg L^{-1} Ci^{-1}	Year
Np-237	1.12E-07	1,171	1.18E-07	1,171	1.18E-07	1,171
Am-241	1.98E-12	1,171	3.79E-12	1,171	3.79E-12	1,171
Cm-245	6.26E-13	1,171	2.25E-12	1,171	2.25E-12	1,171
Pu-241	5.36E-14	1,171	1.14E-13	1,171	1.14E-13	1,171
Cf-249	7.47E-15	1,171	3.58E-14	1,171	3.58E-14	1,171

Notes:

1 Radionuclides without a uranium-containing decay chain are excluded.

2 Radionuclides are sorted from highest to lowest Case01 concentration factor.

Table 6-8 and Table 6-9 provide the maximum all-pathways dose factors and GW protection beta-gamma dose factors, respectively, during the compliance period at the 100-meter POA for ET06. The six ET06 radionuclides listed in these tables are the only radionuclides selected for the sensitivity analysis. These six radionuclides are historically the largest contributors to total dose.

Table 6-8. ET06 Sensitivity and Uncertainty Cases: Maximum All-Pathways Dose Factors at 100-meter POA, Difference from Nominal PA Case, and Time of Maximum for Radionuclides in Sensitivity Analysis

Radio-nuclide	Nominal PA Case	Sensitivity Case 1		Sensitivity Case 2		Sensitivity Case 3		Sensitivity Case 4	
	Case01 (mrem yr^{-1} Ci^{-1})	Waste Zone Conductivity (mrem yr^{-1} Ci^{-1})	Ratio	LVZ Porosity (mrem yr^{-1} Ci^{-1})	Ratio	Tan Clay Thickness (mrem yr^{-1} Ci^{-1})	Ratio	Waste Zone Porosity (mrem yr^{-1} Ci^{-1})	Ratio
I-129	6.76E+01	6.67E+01	0.99	6.66E+01	0.98	5.23E+01	0.77	6.63E+01	0.98
Np-237	2.83E+01	2.86E+01	1.01	2.98E+01	1.05	4.08E+01	1.44	3.23E+01	1.14
Tc-99	3.34E-01	3.47E-01	1.04	3.45E-01	1.04	5.97E-01	1.79	3.70E-01	1.11
C-14	8.76E-03	9.24E-03	1.05	8.98E-03	1.02	1.17E-01	13.32	1.38E-02	1.58
H-3	9.84E-07	9.83E-07	1.00	9.86E-07	1.00	9.83E-07	1.00	9.85E-07	1.00
Sr-90	4.75E-14	5.66E-14	1.19	6.40E-14	1.35	6.83E-13	14.37	7.32E-14	1.54
Radio-nuclide	Nominal PA Case	Sensitivity Case 5		Sensitivity Case 6		Sensitivity Case 7		--	
	Case01 (mrem yr^{-1} Ci^{-1})	Infiltration (mrem yr^{-1} Ci^{-1})	Ratio	K_d (mrem yr^{-1} Ci^{-1})	Ratio	Disposal Time (mrem yr^{-1} Ci^{-1})	Ratio	--	--
I-129	6.76E+01	3.16E+01	0.47	4.70E+01	0.69	9.11E+01	1.35	--	--
Np-237	2.83E+01	4.27E+01	1.51	4.93E+01	1.74	8.57E+00	0.30	--	--
Tc-99	3.34E-01	8.48E-01	2.54	3.58E-01	1.07	1.42E+00	4.25	--	--
C-14	8.76E-03	9.12E-02	10.41	2.41E-01	27.55	1.65E-03	0.19	--	--
H-3	9.84E-07	9.62E-07	0.98	N/A	N/A	2.80E-06	2.84	--	--
Sr-90	4.75E-14	2.03E-11	428.16	1.93E-08	4.06E+05	4.38E-15	0.09	--	--

Radionuclide	Time of Peak Dose (Year)							
	Nominal PA Case	Sensitivity Case						
		1	2	3	4	5	6	7
	Case01	Waste Zone Conductivity	LVZ Porosity	Tan Clay Thickness	Waste Zone Porosity	Infiltration	K_d	Disposal Time
I-129	787	787	786	779	785	171	171	941
Np-237	1,171	1,171	1,171	1,171	1,171	1,068	942	1,171
Tc-99	181	180	180	172	180	171	171	818
C-14	1,171	1,171	1,171	1,171	1,171	1,171	1,171	1,171
H-3	171	171	171	171	171	171	N/A	171
Sr-90	1,153	1,136	1,140	1,049	1,148	342	274	1,171

Notes:

Green-highlighted cells indicate a time of peak dose that falls within the compliance period.

Table 6-9. ET06 Sensitivity and Uncertainty Cases: Maximum Beta-Gamma Dose Factors at 100-meter POA, Difference from Nominal PA Case, and Time of Maximum for Radionuclides in Sensitivity Analysis

Radio-nuclide	Nominal PA Case	Sensitivity Case 1		Sensitivity Case 2		Sensitivity Case 3		Sensitivity Case 4	
	Case01 (mrem yr^{-1} Ci^{-1})	Waste Zone Conductivity (mrem yr^{-1} Ci^{-1})	Ratio	LVZ Porosity (mrem yr^{-1} Ci^{-1})	Ratio	Tan Clay Thickness (mrem yr^{-1} Ci^{-1})	Ratio	Waste Zone Porosity (mrem yr^{-1} Ci^{-1})	Ratio
I-129	1.16E+03	1.14E+03	0.99	1.14E+03	0.98	8.95E+02	0.77	1.13E+03	0.98
Np-237	1.88E+00	1.90E+00	1.01	1.98E+00	1.05	2.71E+00	1.44	2.15E+00	1.14
Tc-99	9.19E-01	9.68E-01	1.05	9.60E-01	1.04	1.96E+00	2.14	1.03E+00	1.13
H-3	3.94E-01	3.99E-01	1.01	3.84E-01	0.98	3.98E-01	1.01	3.79E-01	0.96
C-14	8.74E-03	9.21E-03	1.05	8.95E-03	1.02	1.16E-01	13.32	1.38E-02	1.58
Sr-90	4.06E-13	4.84E-13	1.19	5.47E-13	1.35	5.84E-12	14.37	6.25E-13	1.54
Radio-nuclide	Nominal PA Case	Sensitivity Case 5		Sensitivity Case 6		Sensitivity Case 7		--	
	Case01 (mrem yr^{-1} Ci^{-1})	Infiltration (mrem yr^{-1} Ci^{-1})	Ratio	K_d (mrem yr^{-1} Ci^{-1})	Ratio	Disposal Time (mrem yr^{-1} Ci^{-1})	Ratio	--	--
I-129	1.16E+03	6.71E+02	0.58	1.82E+03	1.57	1.56E+03	1.35	--	--
Np-237	1.88E+00	2.84E+00	1.51	3.28E+00	1.74	5.70E-01	0.30	--	--
Tc-99	9.19E-01	5.50E+00	5.98	1.17E+01	12.68	2.15E+00	2.34	--	--
H-3	3.94E-01	5.95E-01	1.51	N/A	N/A	3.65E-05	9.28E-05	--	--
C-14	8.74E-03	9.10E-02	10.41	2.41E-01	27.55	1.65E-03	0.19	--	--
Sr-90	4.06E-13	1.74E-10	428.16	1.65E-07	4.06E+05	3.75E-14	0.09	--	--

Radionuclide	Time of Peak Dose (Year)							
	Nominal PA Case	Sensitivity Case						
		1	2	3	4	5	6	7
	Case01	Waste Zone Conductivity	LVZ Porosity	Tan Clay Thickness	Waste Zone Porosity	Infiltration	K_d	Disposal Time
I-129	787	787	786	779	785	128	89	941
Np-237	1,171	1,171	1,171	1,171	1,171	1,068	942	1,171
Tc-99	107	102	102	100	102	77	71	818
C-14	47	47	47	46	47	43	1,171	1,171
H-3	1,171	1,171	1,171	1,171	1,171	1,171	N/A	133
Sr-90	1,153	1,136	1,140	1,049	1,148	342	274	1,171

Notes:

Green-highlighted cells indicate a time of peak dose that falls within the compliance period.

Similarly, Table 6-10 and Table 6-11 list the maximum GW protection gross-alpha and uranium concentration factors, respectively, for ET06. Only one of six ET06 radionuclides selected for the sensitivity analysis, Np-237, is an alpha-emitter and has a uranium-containing (U-233) decay chain. None of the six isotopes in the ET06 sensitivity analysis has radium in their decay chain.

For ET06 radionuclides included in the sensitivity analysis, Figure 6-4 compares the all-pathways dose factor for the infiltration, K_d, and tan clay layer sensitivity cases to the nominal PA dose factor at the 100-meter POA during the compliance period. Figure 6-5 makes the same comparison for peak all-pathways dose factor over the entire simulation period. C-14 and Sr-90 are plotted using a logarithmic scale for the y-axis to better display the differences between cases. The influence of peak timing on maximum dose factor during the compliance period can be seen for Np-237 where the peak nominal value is observed at the end of the compliance period. Conversely, for the sensitivity cases, the peaks occur during the compliance period. H-3, I-129, and Tc-99 display their highest peak values before the start of the all-pathways compliance period. Figure 6-6 and Figure 6-7 make the same comparisons for beta-gamma dose factor.

Table 6-10. ET06 Sensitivity and Uncertainty Cases: Maximum Gross-Alpha Concentration Factors at 100-meter POA, Difference from Nominal PA Case, and Time of Maximum

Radio-nuclide	Nominal PA Case	Sensitivity Case 1		Sensitivity Case 2		Sensitivity Case 3		Sensitivity Case 4	
	Case01 (pCi L^{-1} Ci^{-1})	Waste Zone Conductivity (pCi L^{-1} Ci^{-1})	Ratio	LVZ Porosity (pCi L^{-1} Ci^{-1})	Ratio	Tan Clay Thickness (pCi L^{-1} Ci^{-1})	Ratio	Waste Zone Porosity (pCi L^{-1} Ci^{-1})	Ratio
Np-237	1.41E+02	1.42E+02	1.01	1.49E+02	1.05	2.04E+02	1.44	1.61E+02	1.14
	Nominal PA Case	Sensitivity Case 5		Sensitivity Case 6		Sensitivity Case 7		--	
	Case01 (pCi L^{-1} Ci^{-1})	Infiltration (pCi L^{-1} Ci^{-1})	Ratio	K_d (pCi L^{-1} Ci^{-1})	Ratio	Disposal Time (pCi L^{-1} Ci^{-1})	Ratio	--	--
	1.41E+02	2.13E+02	1.51	2.46E+02	1.74	4.27E+01	0.30	--	

Radionuclide	Time of Peak Concentration (Year)							
	Nominal PA Case	Sensitivity Case						
		1	2	3	4	5	6	7
	Case01	Waste Zone Conductivity	LVZ Porosity	Tan Clay Thickness	Waste Zone Porosity	Infiltration	K_d	Disposal Time
Np-237	1,171	1,171	1,171	1,171	1,171	1,068	942	1,171

Notes: Green-highlighted cells indicate a time of peak concentration that falls within the compliance period.

Table 6-11. ET06 Sensitivity and Uncertainty Cases: Maximum Uranium Concentration Factors at 100-meter POA, Difference from Nominal PA Case, and Time of Maximum

Radio-nuclide	Nominal PA Case	Sensitivity Case 1		Sensitivity Case 2		Sensitivity Case 3		Sensitivity Case 4	
	Case01 (µg L^{-1} Ci^{-1})	Waste Zone Conductivity (µg L^{-1} Ci^{-1})	Ratio	LVZ Porosity (µg L^{-1} Ci^{-1})	Ratio	Tan Clay Thickness (µg L^{-1} Ci^{-1})	Ratio	Waste Zone Porosity (µg L^{-1} Ci^{-1})	Ratio
Np-237	1.12E-07	1.16E-07	1.03	1.24E-07	1.11	2.65E-07	2.36	1.38E-07	1.23
	Nominal PA Case	Sensitivity Case 5		Sensitivity Case 6		Sensitivity Case 7		--	
	Case01 (µg L^{-1} Ci^{-1})	Infiltration (µg L^{-1} Ci^{-1})	Ratio	K_d (µg L^{-1} Ci^{-1})	Ratio	Disposal Time (µg L^{-1} Ci^{-1})	Ratio	--	--
	1.12E-07	4.96E-07	4.42	6.76E-07	6.02	1.50E-08	0.13	--	--

Radionuclide	Time of Peak Concentration (Year)							
	Nominal PA Case	Sensitivity Case						
		1	2	3	4	5	6	7
	Case01	Waste Zone Conductivity	LVZ Porosity	Tan Clay Thickness	Waste Zone Porosity	Infiltration	K_d	Disposal Time
Np-237	1,171	1,171	1,171	1,171	1,171	1,171	1,171	1,171

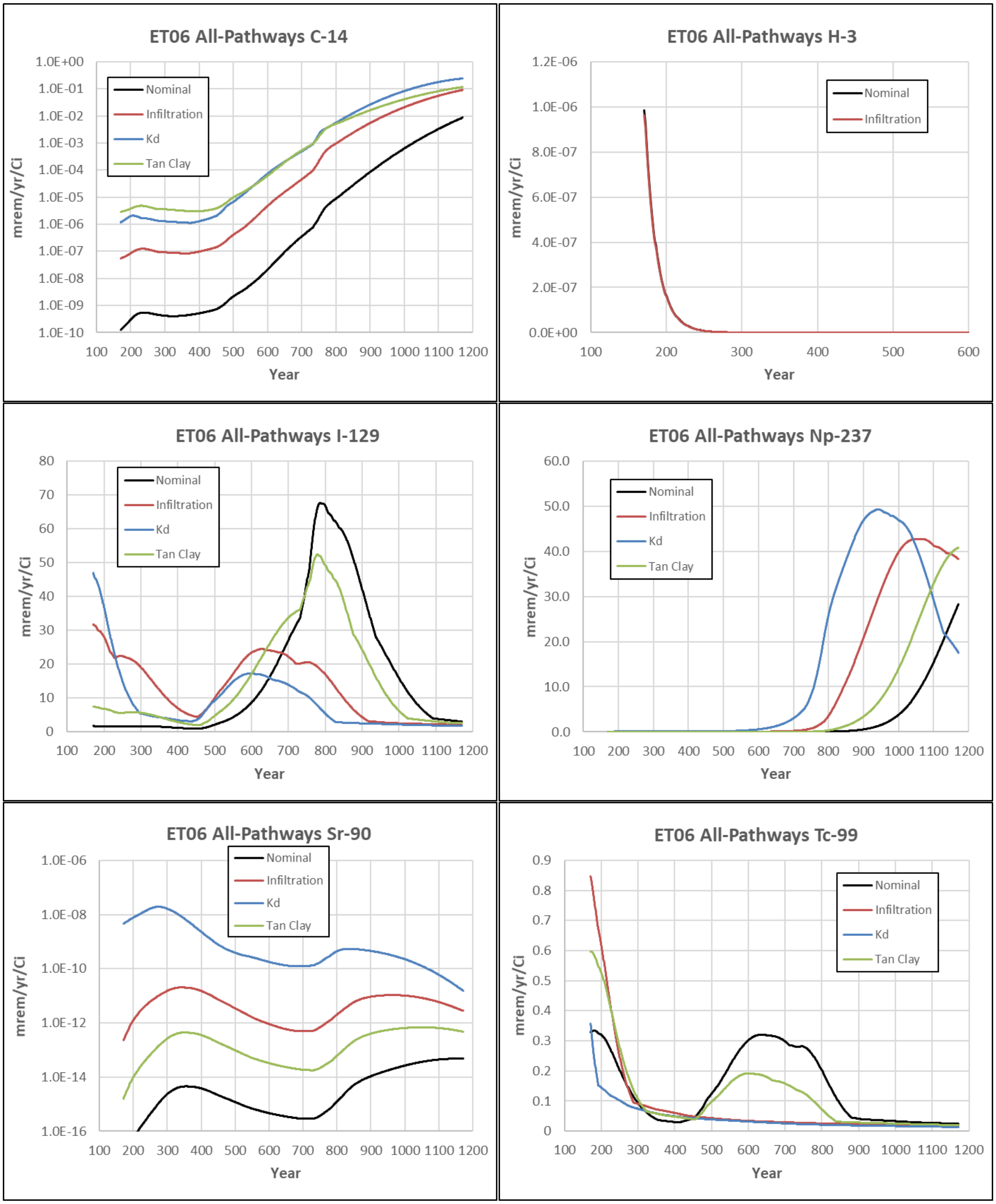


Figure 6-4. Comparison of All-Pathways Dose Factors (mrem yr^{-1} Ci^{-1} parent buried) for C-14, H-3, I-129, Np-237, Sr-90, and Tc-99 at 100-meter POA During Compliance Period for ET06 Nominal PA, Infiltration Sensitivity, K_d Sensitivity, and Tan Clay Layer Sensitivity Cases

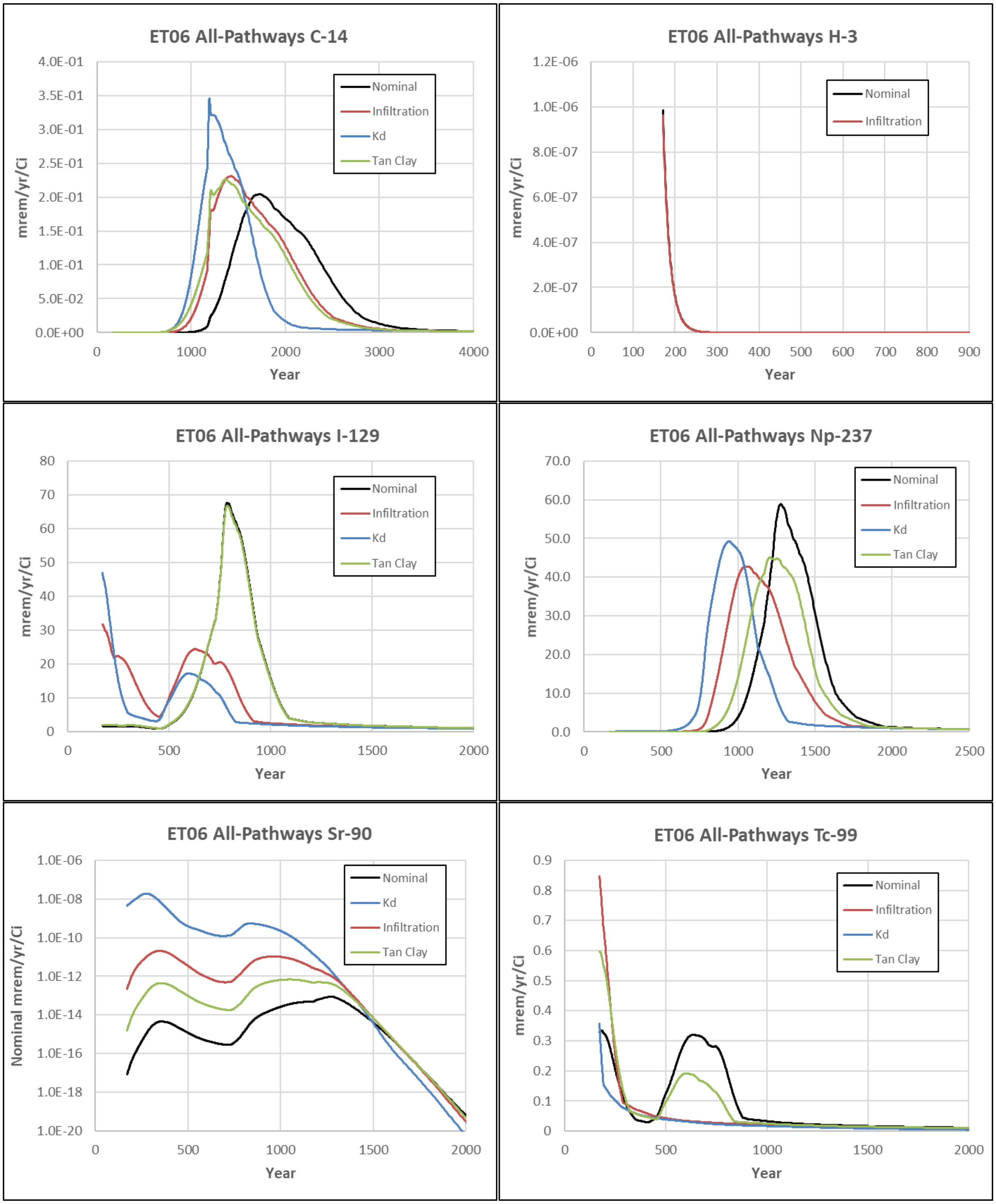


Figure 6-5. Comparison of All-Pathways Dose Factors (mrem yr^{-1} Ci^{-1} parent buried) for C-14, H-3, I-129, Np-237, Sr-90, and Tc-99 at 100-meter POA over the Entire Simulation Period for ET06 Nominal PA, Infiltration Sensitivity, K_d Sensitivity, and Tan Clay Layer Sensitivity Cases

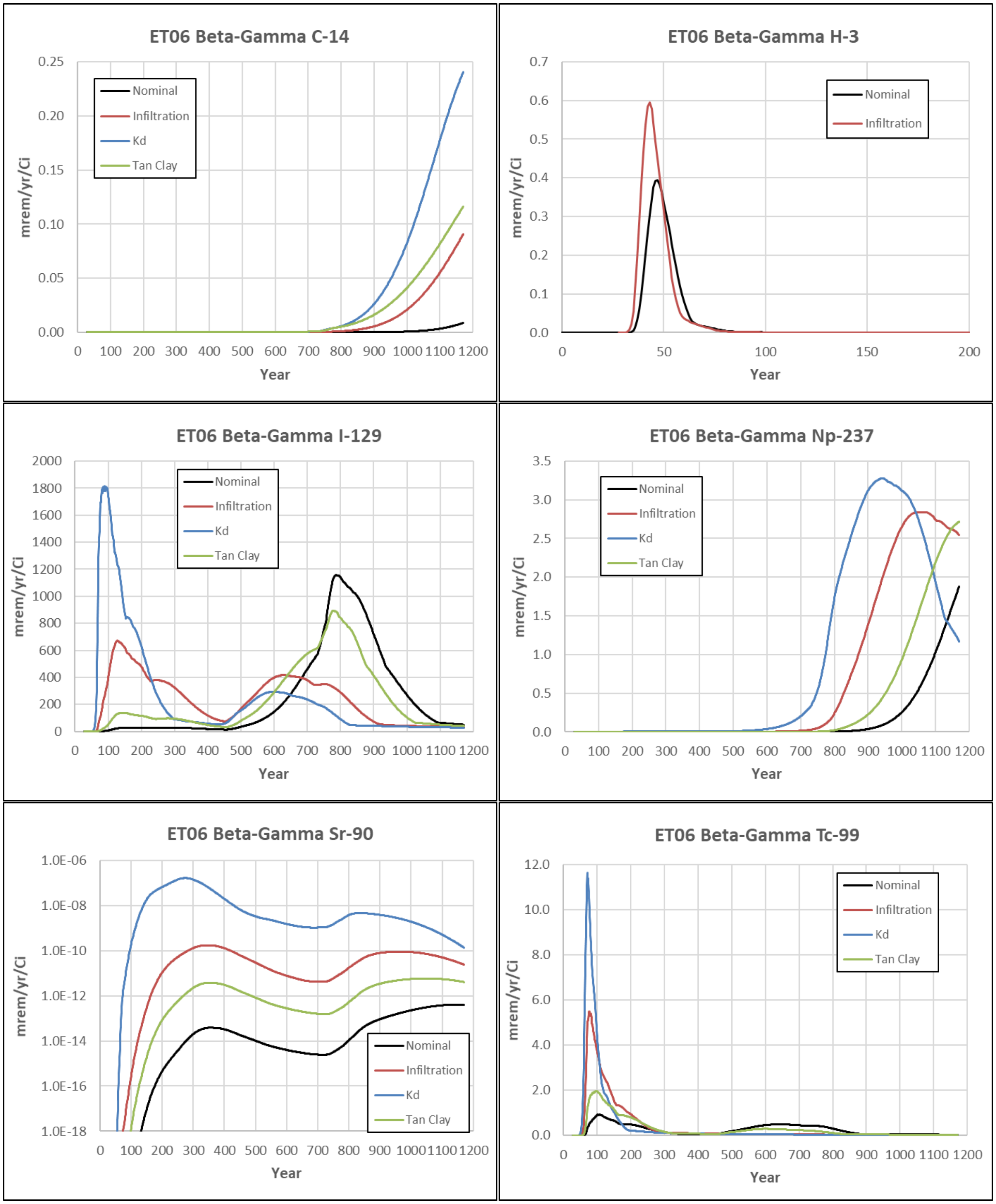


Figure 6-6. Comparison of Beta-Gamma Dose Factors (mrem yr^{-1} Ci^{-1} parent buried) for C-14, H-3, I-129, Np-237, Sr-90, and Tc-99 at 100-meter POA During Compliance Period for ET06 Nominal PA, Infiltration Sensitivity, *K_d* Sensitivity, and Tan Clay Layer Sensitivity Cases

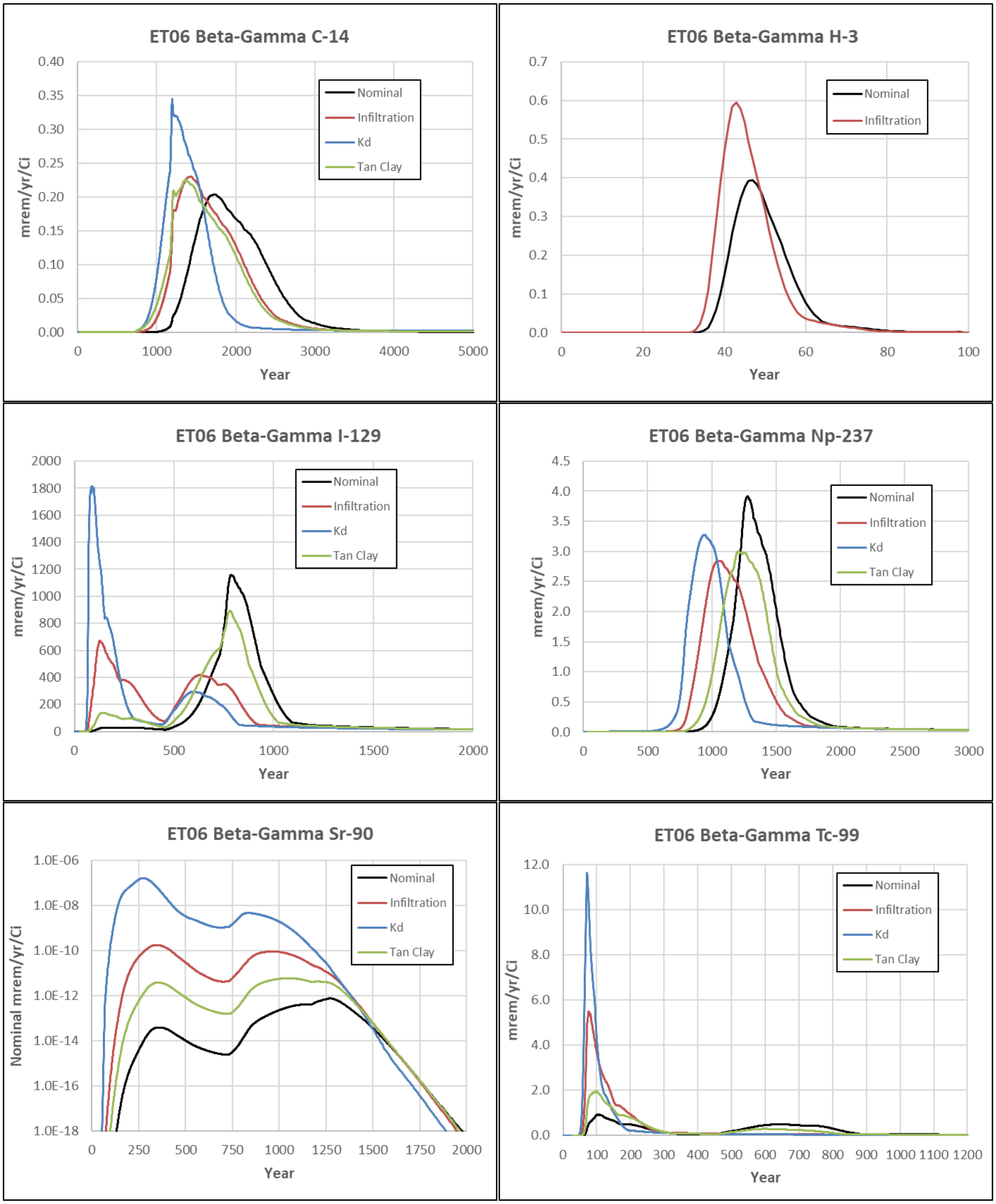


Figure 6-7. Comparison of Beta-Gamma Dose Factors (mrem yr^{-1} Ci^{-1} parent buried) for C-14, H-3, I-129, Np-237, Sr-90, and Tc-99 at 100-meter POA over the Entire Simulation Period for ET06 Nominal PA, Infiltration Sensitivity, K_d Sensitivity, and Tan Clay Layer Sensitivity Cases

6.1.1.1.2. ST06

The general description of the sensitivity analysis results for ET06 in Section 6.1.1.1.1 applies equally to ST06; therefore, the description is not repeated here. ST06 results are summarized in Table 6-12 through Table 6-20 and Figure 6-8 through Figure 6-11.

Table 6-12. Maximum All-Pathways Dose Factors at 100-meter POA and Time of Maximum for ST06

Radionuclide [1]	Case01, Intact		Case11, Subsided		Case MX, Maximum	
	mrem yr^{-1} Ci^{-1}	Year	mrem yr^{-1} Ci^{-1}	Year	mrem yr^{-1} Ci^{-1}	Year
I-129	1.15E+02	827	1.09E+02	827	1.15E+02	827
Pa-231	1.15E+02	1,171	1.14E+02	1,171	1.15E+02	1,171
Np-237	2.68E+01	1,171	2.64E+01	1,171	2.68E+01	1,171
Tc-99	1.41E+00	694	1.33E+00	693	1.41E+00	694
Cl-36	1.33E+00	1,114	1.28E+00	1,113	1.33E+00	1,114
C-14	3.16E-02	1,171	3.66E-02	1,171	3.66E-02	1,171
K-40	1.29E-03	1,171	9.12E-02	881	9.12E-02	881
Am-241	1.18E-03	1,171	1.31E-03	1,171	1.31E-03	1,171
Be-10	1.14E-03	1,171	1.30E-02	720	1.30E-02	720
Cm-245	5.43E-04	1,171	7.45E-04	1,171	7.45E-04	1,171
Pu-241	3.65E-05	1,171	4.10E-05	1,171	4.10E-05	1,171
Th-231	1.02E-05	1,171	1.01E-05	1,171	1.02E-05	1,171
Cf-249	7.06E-06	1,171	1.14E-05	1,171	1.14E-05	1,171
H-3	9.15E-07	171	9.15E-07	171	9.15E-07	171
Pu-239	1.39E-07	1,171	2.04E-07	1,171	2.04E-07	1,171
Ni-59	3.36E-08	1,171	4.78E-04	1,052	4.78E-04	1,052
Pd-107	2.70E-08	1,171	3.83E-04	1,053	3.83E-04	1,053
Ag-108m	3.32E-10	1,171	3.42E-03	966	3.42E-03	966
Cs-135	7.47E-11	1,171	1.03E-02	1,171	1.03E-02	1,171
Rb-87	6.55E-11	1,171	9.05E-03	1,171	9.05E-03	1,171
Ni-63	2.65E-11	1,171	4.55E-06	676	4.55E-06	676
Sr-90	2.25E-14	1,171	2.32E-06	415	2.32E-06	415
Cs-137	8.93E-22	1,171	1.10E-09	577	1.10E-09	577
Ra-226	6.69E-24	1,171	6.81E-04	1,171	6.81E-04	1,171
Th-230	4.08E-26	1,171	7.49E-05	1,171	7.49E-05	1,171
U-234	5.87E-30	1,171	1.08E-07	1,171	1.08E-07	1,171

Notes:

1 Radionuclides are sorted from highest to lowest Case01 dose factor.

Table 6-13. Maximum Beta-Gamma Dose Factors at 100-meter POA and Time of Maximum for ST06

Radionuclide [1]	Case01, Intact		Case11, Subsided		CaseMX, Maximum	
	mrem yr^{-1} Ci^{-1}	Year	mrem yr^{-1} Ci^{-1}	Year	mrem yr^{-1} Ci^{-1}	Year
I-129	1.97E+03	827	1.87E+03	827	1.97E+03	827
Tc-99	2.14E+00	694	2.01E+00	693	2.14E+00	694
Np-237	1.78E+00	1,171	1.75E+00	1,171	1.78E+00	1,171
Cl-36	1.48E+00	1,114	1.42E+00	1,113	1.48E+00	1,114
H-3	6.86E-01	31	6.86E-01	31	6.86E-01	31
Pa-231	3.07E-01	1,171	3.06E-01	1,171	3.07E-01	1,171
C-14	3.15E-02	1,171	3.65E-02	1,171	3.65E-02	1,171
Be-10	1.94E-03	1,171	2.21E-02	720	2.21E-02	720
K-40	1.34E-03	1,171	9.48E-02	881	9.48E-02	881
Am-241	7.84E-05	1,171	8.71E-05	1,171	8.71E-05	1,171
Cm-245	3.61E-05	1,171	4.96E-05	1,171	4.96E-05	1,171
Ni-59	3.24E-06	1,171	4.61E-02	1,052	4.61E-02	1,052
Pu-241	2.43E-06	1,171	2.72E-06	1,171	2.72E-06	1,171
Cf-249	4.69E-07	1,171	7.59E-07	1,171	7.59E-07	1,171
Pd-107	3.50E-08	1,171	4.97E-04	1,053	4.97E-04	1,053
Th-231	2.74E-08	1,171	2.73E-08	1,171	2.74E-08	1,171
Ni-63	6.15E-09	1,171	1.06E-03	676	1.06E-03	676
Ag-108m	4.43E-10	1,171	4.56E-03	966	4.56E-03	966
Pu-239	2.86E-10	1,171	5.02E-10	1,171	5.02E-10	1,171
Rb-87	1.68E-10	1,171	2.33E-02	1,171	2.33E-02	1,171
Cs-135	5.61E-11	1,171	7.76E-03	1,171	7.76E-03	1,171
Sr-90	1.92E-13	1,171	1.98E-05	415	1.98E-05	415
Cs-137	6.00E-22	1,171	7.38E-10	577	7.38E-10	577
Ra-226	1.22E-25	1,171	2.44E-05	1,171	2.44E-05	1,171
Th-230	7.49E-28	1,171	2.64E-06	1,171	2.64E-06	1,171
U-234	9.42E-32	1,171	3.73E-09	1,171	3.73E-09	1,171

Notes:

1 Radionuclides are sorted from highest to lowest Case01 dose factor.

Table 6-14. Maximum Gross-Alpha Concentration Factors at 100-meter POA and Time of Maximum for ST06

Radionuclide [1,2]	Case01, Intact		Case11, Subsided		CaseMX, Maximum	
	pCi L^{-1} Ci^{-1}	Year	pCi L^{-1} Ci^{-1}	Year	pCi L^{-1} Ci^{-1}	Year
Np-237	1.34E+02	1,171	1.32E+02	1,171	1.34E+02	1,171
Pa-231	1.32E+02	1,171	1.30E+02	1,171	1.32E+02	1,171
Am-241	5.88E-03	1,171	6.53E-03	1,171	6.53E-03	1,171
Cm-245	2.71E-03	1,171	3.72E-03	1,171	3.72E-03	1,171
Pu-241	1.82E-04	1,171	2.04E-04	1,171	2.04E-04	1,171
Cf-249	3.52E-05	1,171	5.69E-05	1,171	5.69E-05	1,171
Th-231	1.17E-05	1,171	1.15E-05	1,171	1.17E-05	1,171
Pu-239	1.59E-07	1,171	2.33E-07	1,171	2.33E-07	1,171
Ra-226	2.66E-23	1,171	2.67E-03	1,171	2.67E-03	1,171
Th-230	1.62E-25	1,171	2.94E-04	1,171	2.94E-04	1,171
U-234	2.33E-29	1,171	4.25E-07	1,171	4.25E-07	1,171

Notes:

1 Non-alpha-emitting radionuclides are excluded.

2 Radionuclides are sorted from highest to lowest Case01 concentration factor.

Table 6-15. Maximum Radium Concentration Factors at 100-meter POA and Time of Maximum for ST06

Radionuclide [1,2]	Case01, Intact		Case11, Subsided		CaseMX, Maximum	
	pCi L^{-1} Ci^{-1}	Year	pCi L^{-1} Ci^{-1}	Year	pCi L^{-1} Ci^{-1}	Year
Ra-226	8.84E-24	1,171	8.87E-04	1,171	8.87E-04	1,171
Th-230	5.38E-26	1,171	9.76E-05	1,171	9.76E-05	1,171
U-234	7.76E-30	1,171	1.41E-07	1,171	1.41E-07	1,171

Notes:

1 Radionuclides without radium-containing decay chain are excluded.

2 Radionuclides are sorted from highest to lowest Case01 concentration factor.

Table 6-16. Maximum Uranium Concentration Factors at 100-meter POA and Time of Maximum for ST06

Radionuclide [1,2]	Case01, Intact		Case11, Subsided		CaseMX, Maximum	
	µg L^{-1} Ci^{-1}	Year	µg L^{-1} Ci^{-1}	Year	µg L^{-1} Ci^{-1}	Year
Np-237	5.26E-08	1,171	7.19E-08	1,171	7.19E-08	1,171
Am-241	1.37E-12	1,171	4.10E-12	1,171	4.10E-12	1,171
Cm-245	5.49E-13	1,171	2.49E-12	1,171	2.49E-12	1,171
Pu-241	4.05E-14	1,171	1.30E-13	1,171	1.30E-13	1,171
Cf-249	6.86E-15	1,171	3.85E-14	1,171	3.85E-14	1,171

Notes:

1 Radionuclides without a uranium-containing decay chain excluded.

2 Radionuclides sorted from highest to lowest Case01 concentration factor.

Table 6-17. ST06 Sensitivity and Uncertainty Cases: Maximum All-Pathways Dose Factors at 100-meter POA, Difference from Nominal PA Case, and Time of Maximum for Radionuclides in Sensitivity Analysis

Radio-nuclide	Nominal PA Case	Sensitivity Case 1		Sensitivity Case 2		Sensitivity Case 3		Sensitivity Case 4	
	Case01 (mrem yr^{-1} Ci^{-1})	Waste Zone Conductivity (mrem yr^{-1} Ci^{-1})	Ratio	LVZ Porosity (mrem yr^{-1} Ci^{-1})	Ratio	Tan Clay Thickness (mrem yr^{-1} Ci^{-1})	Ratio	Waste Zone Porosity (mrem yr^{-1} Ci^{-1})	Ratio
I-129	1.15E+02	1.14E+02	0.99	1.14E+02	0.99	1.17E+02	1.02	1.17E+02	1.02
Np-237	2.68E+01	2.92E+01	1.09	3.02E+01	1.13	3.08E+01	1.15	2.77E+01	1.03
Tc-99	1.41E+00	1.37E+00	0.97	1.38E+00	0.98	1.39E+00	0.98	1.42E+00	1.00
C-14	3.16E-02	3.40E-02	1.08	3.27E-02	1.03	5.30E-02	1.68	3.29E-02	1.04
H-3	9.15E-07	9.13E-07	1.00	9.21E-07	1.01	9.15E-07	1.00	9.16E-07	1.00
Sr-90	2.25E-14	3.50E-14	1.56	3.80E-14	1.69	2.74E-14	1.22	2.34E-14	1.04
Radio-nuclide	Nominal PA Case	Sensitivity Case 5		Sensitivity Case 6		Sensitivity Case 7		--	
	Case01 (mrem yr^{-1} Ci^{-1})	Infiltration (mrem yr^{-1} Ci^{-1})	Ratio	K_d (mrem yr^{-1} Ci^{-1})	Ratio	Disposal Time (mrem yr^{-1} Ci^{-1})	Ratio	--	--
I-129	1.15E+02	1.13E+02	0.98	1.03E+02	0.89	1.35E+02	1.17	--	--
Np-237	2.68E+01	5.95E+01	2.22	7.78E+01	2.90	1.15E+01	0.43	--	--
Tc-99	1.41E+00	6.99E-01	0.49	1.37E+00	0.97	2.08E+00	1.47	--	--
C-14	3.16E-02	9.64E-02	3.05	2.60E-01	8.22	1.48E-02	0.47	--	--
H-3	9.15E-07	8.88E-07	0.97	N/A	N/A	2.65E-06	2.90	--	--
Sr-90	2.25E-14	1.25E-11	557.56	1.61E-08	7.18E+05	5.57E-15	0.25	--	--

Radionuclide	Time of Peak Dose (Year)							
	Nominal PA Case	Sensitivity Case						
		1	2	3	4	5	6	7
	Case01	Waste Zone Conductivity	LVZ Porosity	Tan Clay Thickness	Waste Zone Porosity	Infiltration	K_d	Disposal Time
I-129	827	821	821	816	826	683	653	955
Np-237	1,171	1,171	1,171	1,171	1,171	1,149	982	1,171
Tc-99	694	688	690	686	692	578	626	826
C-14	1,171	1,171	1,171	1,171	1,171	1,171	1,171	1,171
H-3	171	171	171	171	171	171	N/A	171
Sr-90	1,171	1,171	1,171	1,171	1,171	318	262	1,171

Notes:

Green-highlighted cells indicate a time of peak dose that falls within the compliance period.

Table 6-18. ST06 Sensitivity and Uncertainty Cases: Maximum Beta-Gamma Dose Factors at 100-meter POA, Difference from Nominal PA Case, and Time of Maximum for Radionuclides in Sensitivity Analysis

Radio-nuclide	Nominal PA Case	Sensitivity Case 1		Sensitivity Case 2		Sensitivity Case 3		Sensitivity Case 4	
	Case01 (mrem yr^{-1} Ci^{-1})	Waste Zone Conductivity (mrem yr^{-1} Ci^{-1})	Ratio	LVZ Porosity (mrem yr^{-1} Ci^{-1})	Ratio	Tan Clay Thickness (mrem yr^{-1} Ci^{-1})	Ratio	Waste Zone Porosity (mrem yr^{-1} Ci^{-1})	Ratio
I-129	1.97E+03	1.95E+03	0.99	1.94E+03	0.99	2.01E+03	1.02	2.00E+03	1.02
Tc-99	2.14E+00	2.08E+00	0.97	2.10E+00	0.98	2.11E+00	0.98	2.15E+00	1.00
Np-237	1.78E+00	1.94E+00	1.09	2.01E+00	1.13	2.05E+00	1.15	1.84E+00	1.03
H-3	6.86E-01	6.94E-01	1.01	6.46E-01	0.94	6.93E-01	1.01	6.80E-01	0.99
C-14	3.15E-02	3.39E-02	1.08	3.26E-02	1.03	5.28E-02	1.68	3.28E-02	1.04
Sr-90	1.92E-13	2.99E-13	1.56	3.25E-13	1.69	2.34E-13	1.22	2.00E-13	1.04
Radio-nuclide	Nominal PA Case	Sensitivity Case 5		Sensitivity Case 6		Sensitivity Case 7		--	
	Case01 (mrem yr^{-1} Ci^{-1})	Infiltration (mrem yr^{-1} Ci^{-1})	Ratio	K_d (mrem yr^{-1} Ci^{-1})	Ratio	Disposal Time (mrem yr^{-1} Ci^{-1})	Ratio	--	--
I-129	1.97E+03	1.92E+03	0.98	1.92E+03	0.97	2.31E+03	1.17	--	--
Tc-99	2.14E+00	6.23E+00	2.91	2.83E+00	1.32	3.16E+00	1.47	--	--
Np-237	1.78E+00	3.95E+00	2.22	5.17E+00	2.90	7.62E-01	0.43	--	--
H-3	6.86E-01	9.38E-01	1.37	N/A	N/A	2.57E-03	3.75E-03	--	--
C-14	3.15E-02	9.61E-02	3.05	2.59E-01	8.22	1.48E-02	0.47	--	--
Sr-90	1.92E-13	1.07E-10	557.56	1.38E-07	7.18E+05	4.76E-14	0.25	--	--

Radionuclide	Time of Peak Dose (Year)							
	Nominal PA Case	Sensitivity Case						
		1	2	3	4	5	6	7
	Case01	Waste Zone Conductivity	LVZ Porosity	Tan Clay Thickness	Waste Zone Porosity	Infiltration	K_d	Disposal Time
I-129	827	821	821	816	826	683	72	955
Tc-99	694	688	690	686	692	74	63	826
Np-237	1,171	1,171	1,171	1,171	1,171	1,149	982	1,171
H-3	31	30	31	31	31	27	N/A	59
C-14	1,171	1,171	1,171	1,171	1,171	1,171	1,171	1,171
Sr-90	1,171	1,171	1,171	1,171	1,171	318	262	1,171

Notes:

Green-highlighted cells indicate a time of peak dose that falls within the compliance period.

Table 6-19. ST06 Sensitivity and Uncertainty Cases: Maximum Gross-Alpha Concentration Factors at 100-meter POA, Difference from Nominal PA Case, and Time of Maximum

Radio-nuclide	Nominal PA Case	Sensitivity Case 1		Sensitivity Case 2		Sensitivity Case 3		Sensitivity Case 4	
	Case01 (pCi L^{-1} Ci^{-1})	Waste Zone Conductivity (pCi L^{-1} Ci^{-1})	Ratio	LVZ Porosity (pCi L^{-1} Ci^{-1})	Ratio	Tan Clay Thickness (pCi L^{-1} Ci^{-1})	Ratio	Waste Zone Porosity (pCi L^{-1} Ci^{-1})	Ratio
Np-237	1.34E+02	1.45E+02	1.09	1.51E+02	1.13	1.54E+02	1.15	1.38E+02	1.03
	Nominal PA Case	Sensitivity Case 5		Sensitivity Case 6		Sensitivity Case 7		--	
	Case01 (pCi L^{-1} Ci^{-1})	Infiltration (pCi L^{-1} Ci^{-1})	Ratio	K_d (pCi L^{-1} Ci^{-1})	Ratio	Disposal Time (pCi L^{-1} Ci^{-1})	Ratio	--	--
	1.34E+02	2.97E+02	2.22	3.88E+02	2.90	5.71E+01	0.43	--	--

Radionuclide	Time of Peak Concentration (Year)							
	Nominal PA Case	Sensitivity Case						
		1	2	3	4	5	6	7
	Case01	Waste Zone Conductivity	LVZ Porosity	Tan Clay Thickness	Waste Zone Porosity	Infiltration	K_d	Disposal Time
Np-237	1,171	1,171	1,171	1,171	1,171	1,149	982	1,171

Notes:

Green-highlighted cells indicate a time of peak concentration that falls within the compliance period.

Table 6-20. ST06 Sensitivity and Uncertainty Cases: Maximum Uranium Concentration Factors, Difference from Nominal PA Case, and Time of Maximum

Radio-nuclide	Nominal PA Case	Sensitivity Case 1		Sensitivity Case 2		Sensitivity Case 3		Sensitivity Case 4	
	Case01 (µg L^{-1} Ci^{-1})	Waste Zone Conductivity (µg L^{-1} Ci^{-1})	Ratio	LVZ Porosity (µg L^{-1} Ci^{-1})	Ratio	Tan Clay Thickness (µg L^{-1} Ci^{-1})	Ratio	Waste Zone Porosity (µg L^{-1} Ci^{-1})	Ratio
Np-237	5.26E-08	6.10E-08	1.16	6.43E-08	1.22	6.30E-08	1.20	5.45E-08	1.04
	Nominal PA Case	Sensitivity Case 5		Sensitivity Case 6		Sensitivity Case 7		--	
	Case01 (µg L^{-1} Ci^{-1})	Infiltration (µg L^{-1} Ci^{-1})	Ratio	K_d (µg L^{-1} Ci^{-1})	Ratio	Disposal Time (µg L^{-1} Ci^{-1})	Ratio	--	--
	5.26E-08	3.10E-07	5.90	5.96E-07	11.32	1.45E-08	0.27	--	--

Radionuclide	Time of Peak Concentration (Year)							
	Nominal PA Case	Sensitivity Case						
		1	2	3	4	5	6	7
	Case01	Waste Zone Conductivity	LVZ Porosity	Tan Clay Thickness	Waste Zone Porosity	Infiltration	K_d	Disposal Time
Np-237	1,171	1,171	1,171	1,171	1,171	1,171	1,171	1,171

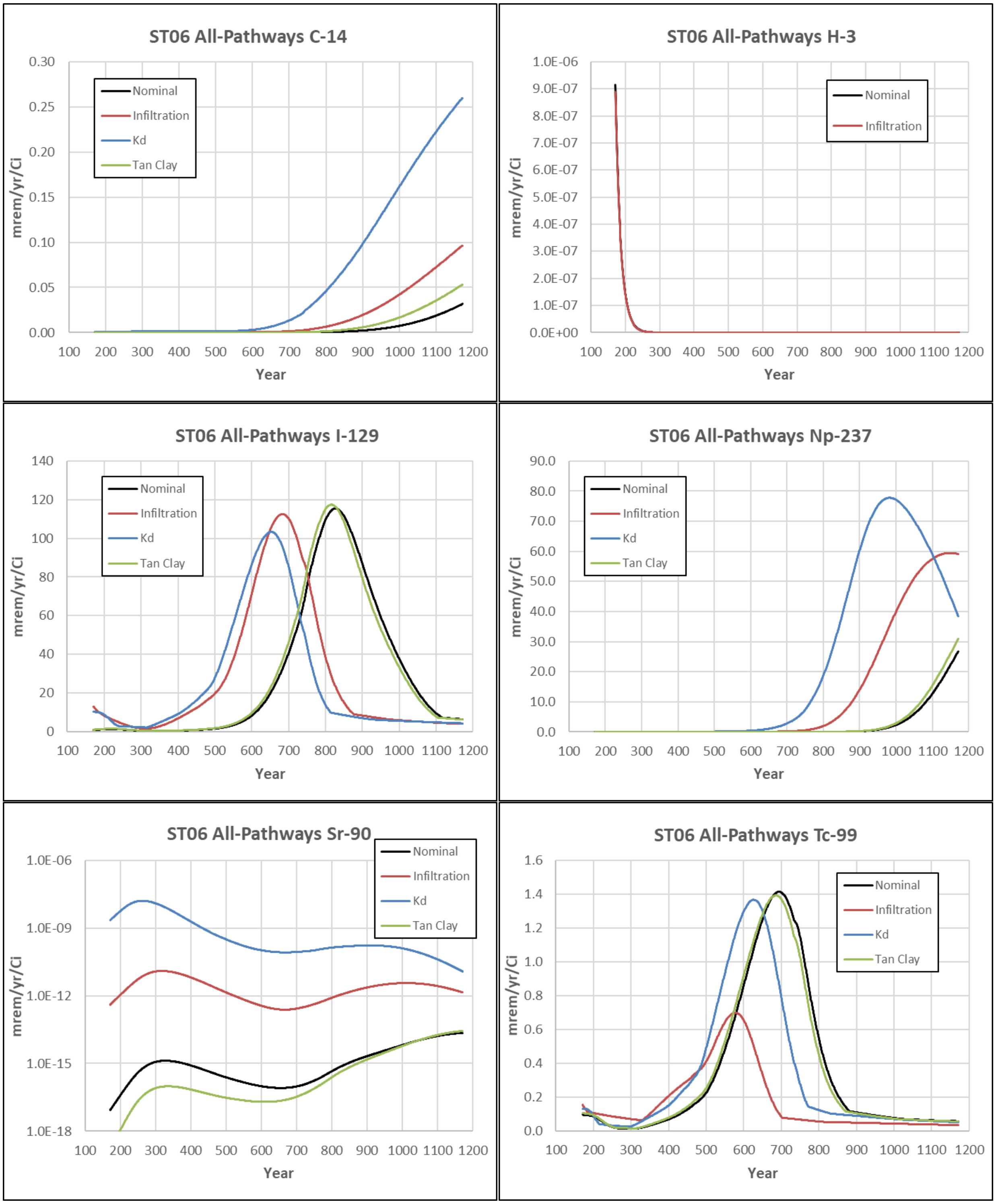


Figure 6-8. Comparison of All-Pathways Dose Factors (mrem yr^{-1} Ci^{-1} parent buried) for C-14, H-3, I-129, Np-237, Sr-90, and Tc-99 at 100-meter POA During Compliance Period for ST06 Nominal PA, Infiltration Sensitivity, K_d Sensitivity, and Tan Clay Layer Sensitivity Cases

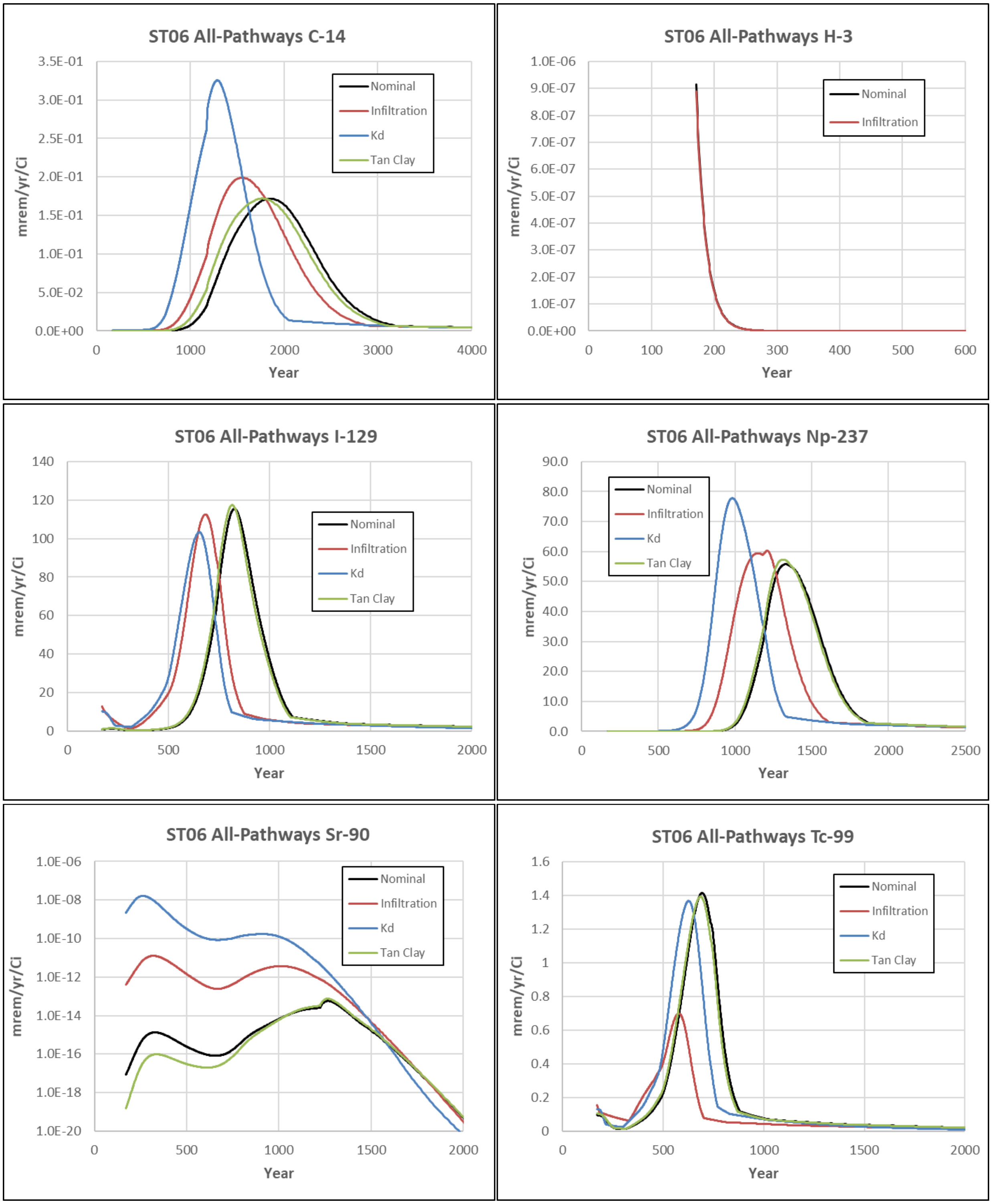


Figure 6-9. Comparison of All-Pathways Dose Factors (mrem yr^{-1} Ci^{-1} parent buried) for C-14, H-3, I-129, Np-237, Sr-90, and Tc-99 at 100-meter POA over the Entire Simulation Period for ST06 Nominal PA, Infiltration Sensitivity, K_d Sensitivity, and Tan Clay Layer Sensitivity Cases

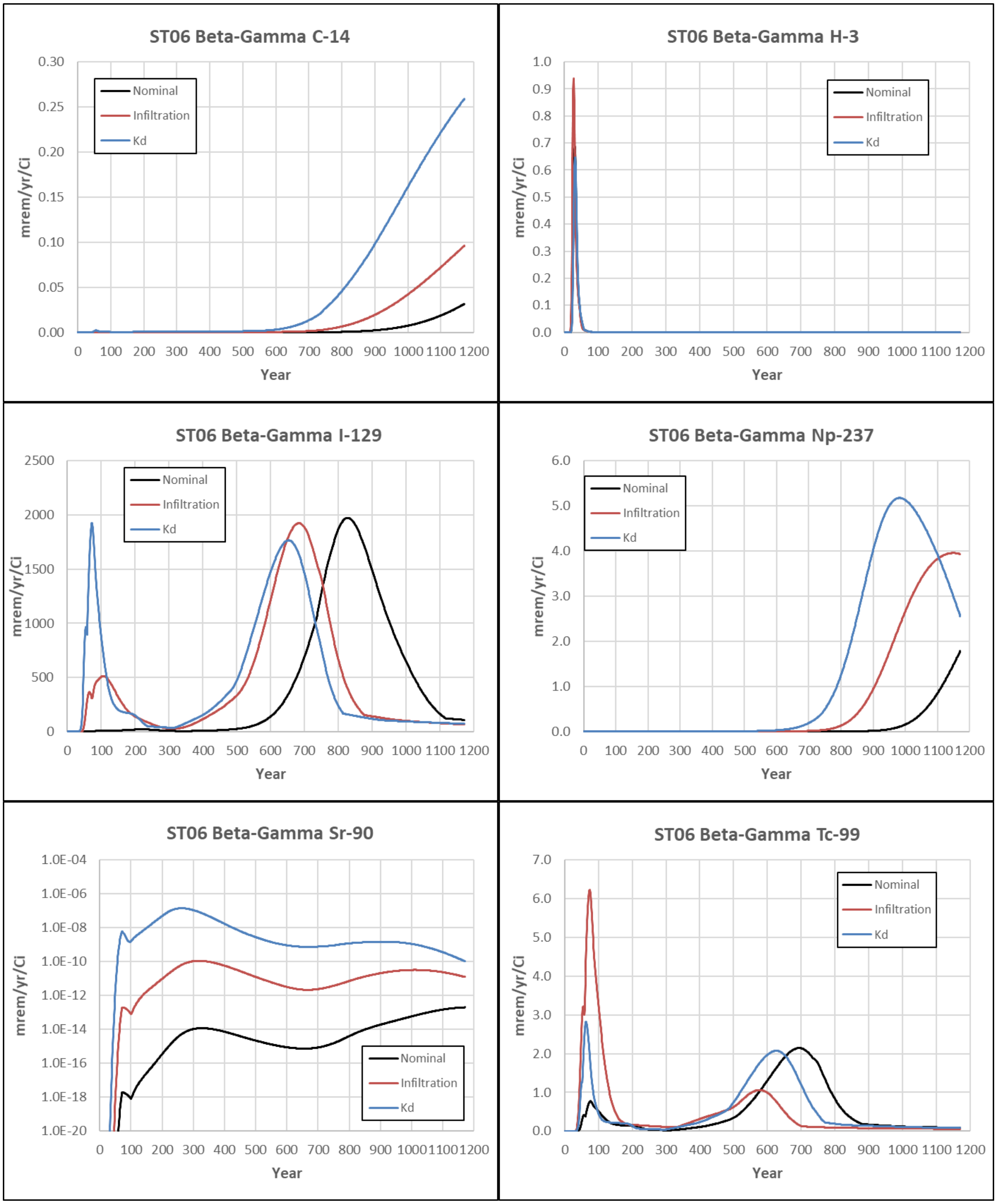


Figure 6-10. Comparison of Beta-Gamma Dose Factors (mrem yr^{-1} Ci^{-1} parent buried) for C-14, H-3, I-129, Np-237, Sr-90, and Tc-99 at 100-meter POA During Compliance Period for ST06 Nominal PA, Infiltration Sensitivity, *K_d* Sensitivity, and Tan Clay Layer Sensitivity Cases

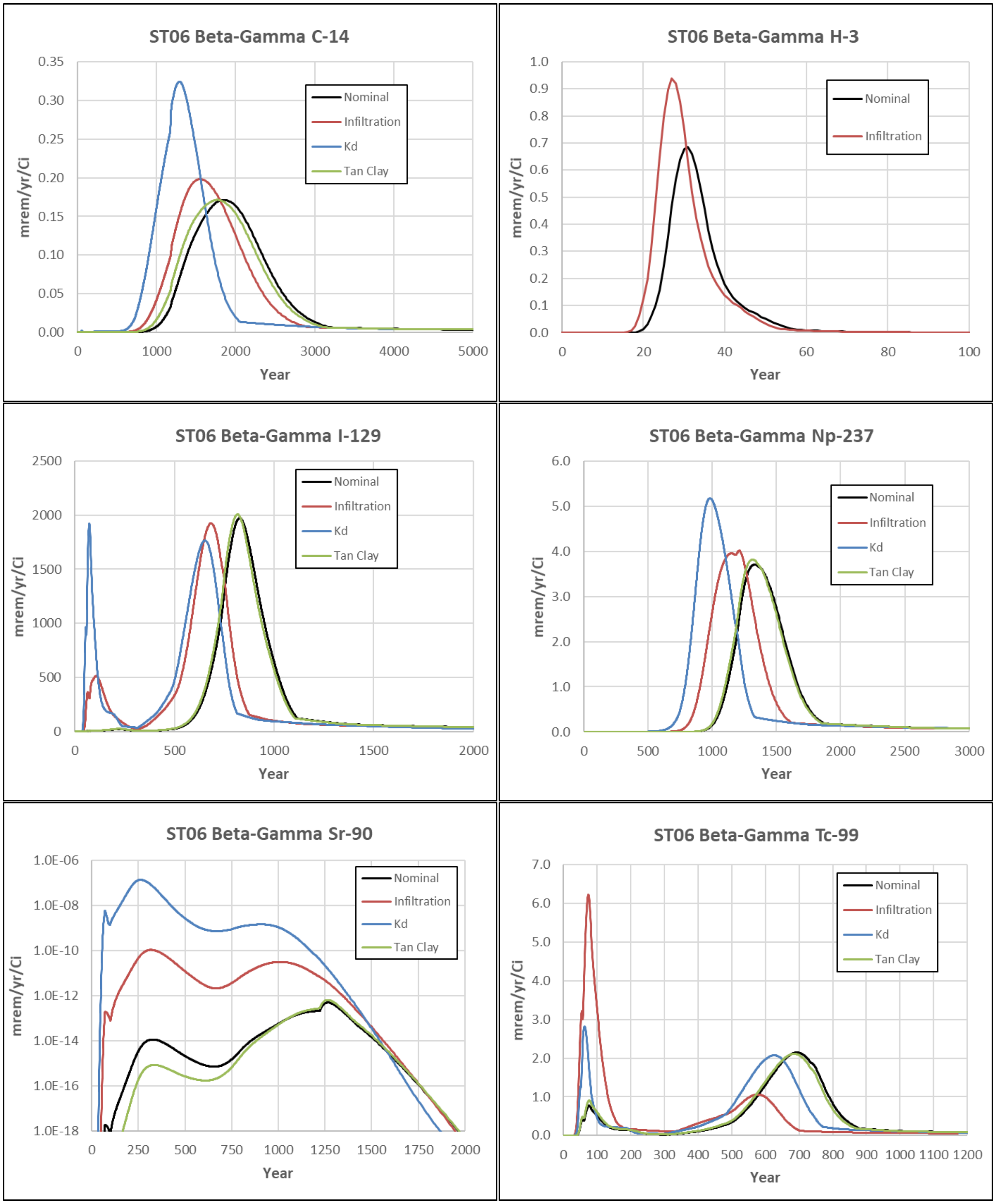


Figure 6-11. Comparison of Beta-Gamma Dose Factors (mrem yr^{-1} Ci^{-1} parent buried) for C-14, H-3, I-129, Np-237, Sr-90, and Tc-99 at 100-meter POA over the Entire Simulation Period for ST06 Nominal PA, Infiltration Sensitivity, *K_d* Sensitivity, and Tan Clay Layer Sensitivity Cases

6.1.1.1.3. ST09

The general description of the sensitivity analysis results for ET06 in Section 6.1.1.1.1 applies equally to ST09; therefore, the description is not repeated here. ST09 results are summarized in Table 6-21 through Table 6-29 and Figure 6-12 through Figure 6-15.

Table 6-21. Maximum All-Pathways Dose Factors at 100-meter POA and Time of Maximum for ST09

Radionuclide [1]	Case01, Intact		Case11, Subsided		Case MX, Maximum	
	mrem yr^{-1} Ci^{-1}	Year	mrem yr^{-1} Ci^{-1}	Year	mrem yr^{-1} Ci^{-1}	Year
I-129	1.24E+02	949	1.17E+02	949	1.24E+02	949
Pa-231	8.69E+00	1,171	1.17E+01	1,171	1.17E+01	1,171
Np-237	2.23E+00	1,171	2.93E+00	1,171	2.93E+00	1,171
Tc-99	1.82E+00	802	1.71E+00	802	1.82E+00	802
Cl-36	1.49E+00	1,171	1.43E+00	1,171	1.49E+00	1,171
C-14	8.56E-04	1,171	1.35E-02	349	1.35E-02	349
Am-241	2.48E-05	1,171	1.52E-04	1,171	1.52E-04	1,171
Cm-245	6.66E-06	1,171	1.88E-04	1,171	1.88E-04	1,171
H-3	1.06E-06	171	1.06E-06	171	1.06E-06	171
Th-231	8.52E-07	1,171	1.12E-06	1,171	1.12E-06	1,171
Pu-241	6.31E-07	1,171	4.86E-06	1,171	4.86E-06	1,171
Be-10	4.14E-07	1,171	1.83E-02	382	1.83E-02	382
K-40	1.11E-07	1,171	1.28E-01	419	1.28E-01	419
Cf-249	7.54E-08	1,171	4.11E-06	1,171	4.11E-06	1,171
Pu-239	1.68E-09	1,171	6.12E-08	1,171	6.12E-08	1,171
Ni-59	1.08E-13	1,171	6.51E-04	487	6.51E-04	487
Pd-107	8.69E-14	1,171	5.19E-04	487	5.19E-04	487
Ni-63	8.85E-17	1,171	7.24E-05	446	7.24E-05	446
Ag-108m	4.89E-17	1,171	9.61E-03	532	9.61E-03	532
Sr-90	8.92E-18	1,171	1.62E-04	331	1.62E-04	331
Cs-135	1.47E-18	1,171	1.69E-02	655	1.69E-02	655
Rb-87	1.29E-18	1,171	1.48E-02	655	1.48E-02	655
Cs-137	1.96E-29	1,171	4.62E-07	489	4.62E-07	489
Ra-226	1.12E-37	1,171	9.31E-02	1,171	9.31E-02	1,171
Th-230	1.43E-39	1,171	1.07E-02	1,171	1.07E-02	1,171
U-234	9.97E-44	1,171	1.59E-05	1,171	1.59E-05	1,171

Notes:

1 Radionuclides are sorted from highest to lowest Case01 dose factor.

Table 6-22. Maximum Beta-Gamma Dose Factors at 100-meter POA and Time of Maximum for ST09

Radionuclide [1]	Case01, Intact		Case11, Subsided		CaseMX, Maximum	
	mrem yr^{-1} Ci^{-1}	Year	mrem yr^{-1} Ci^{-1}	Year	mrem yr^{-1} Ci^{-1}	Year
I-129	2.11E+03	949	2.00E+03	949	2.11E+03	949
Tc-99	2.75E+00	802	2.59E+00	802	2.75E+00	802
Cl-36	1.66E+00	1,171	1.59E+00	1,171	1.66E+00	1,171
H-3	7.44E-01	35	7.44E-01	35	7.44E-01	35
Np-237	1.49E-01	1,171	1.95E-01	1,171	1.95E-01	1,171
Pa-231	1.60E-02	1,171	3.50E-02	339	3.50E-02	339
C-14	8.54E-04	1,171	1.35E-02	349	1.35E-02	349
Am-241	1.65E-06	1,171	1.01E-05	1,171	1.01E-05	1,171
Be-10	7.04E-07	1,171	3.11E-02	382	3.11E-02	382
Cm-245	4.43E-07	1,171	1.25E-05	1,171	1.25E-05	1,171
K-40	1.16E-07	1,171	1.33E-01	419	1.33E-01	419
Pu-241	4.20E-08	1,171	3.23E-07	1,171	3.23E-07	1,171
Cf-249	5.01E-09	1,171	2.73E-07	1,171	2.73E-07	1,171
Th-231	1.60E-09	1,171	3.08E-09	339	3.08E-09	339
Ni-59	1.05E-11	1,171	6.27E-02	487	6.27E-02	487
Pu-239	2.40E-12	1,171	1.97E-10	1,171	1.97E-10	1,171
Pd-107	1.13E-13	1,171	6.74E-04	487	6.74E-04	487
Ni-63	2.06E-14	1,171	1.68E-02	446	1.68E-02	446
Sr-90	7.62E-17	1,171	1.38E-03	331	1.38E-03	331
Ag-108m	6.52E-17	1,171	1.28E-02	532	1.28E-02	532
Rb-87	3.31E-18	1,171	3.81E-02	655	3.81E-02	655
Cs-135	1.10E-18	1,171	1.27E-02	655	1.27E-02	655
Cs-137	1.32E-29	1,171	3.10E-07	489	3.10E-07	489
Ra-226	1.50E-39	1,171	3.73E-03	1,171	3.73E-03	1,171
Th-230	1.94E-41	1,171	4.18E-04	1,171	4.18E-04	1,171
U-234	1.30E-45	1,171	5.99E-07	1,171	5.99E-07	1,171

Notes:

1 Radionuclides are sorted from highest to lowest Case01 dose factor.

Table 6-23. Maximum Gross-Alpha Concentration Factors at 100-meter POA and Time of Maximum for ST09

Radionuclide [1,2]	Case01, Intact		Case11, Subsided		CaseMX, Maximum	
	pCi L^{-1} Ci^{-1}	Year	pCi L^{-1} Ci^{-1}	Year	pCi L^{-1} Ci^{-1}	Year
Np-237	1.11E+01	1,171	1.46E+01	1,171	1.46E+01	1,171
Pa-231	9.91E+00	1,171	1.34E+01	1,171	1.34E+01	1,171
Am-241	1.24E-04	1,171	7.60E-04	1,171	7.60E-04	1,171
Cm-245	3.32E-05	1,171	9.39E-04	1,171	9.39E-04	1,171
Pu-241	3.15E-06	1,171	2.42E-05	1,171	2.42E-05	1,171
Th-231	9.72E-07	1,171	1.28E-06	1,171	1.28E-06	1,171
Cf-249	3.76E-07	1,171	2.05E-05	1,171	2.05E-05	1,171
Pu-239	1.91E-09	1,171	7.00E-08	1,171	7.00E-08	1,171
Ra-226	4.47E-37	1,171	3.64E-01	1,171	3.64E-01	1,171
Th-230	5.68E-39	1,171	4.19E-02	1,171	4.19E-02	1,171
U-234	3.97E-43	1,171	6.21E-05	1,171	6.21E-05	1,171

Notes:

1 Non-alpha-emitting radionuclides are excluded.

2 Radionuclides are sorted from highest to lowest Case01 concentration factor.

Table 6-24. Maximum Radium Concentration Factors at 100-meter POA and Time of Maximum for ST09

Radionuclide [1,2]	Case01, Intact		Case11, Subsided		CaseMX, Maximum	
	pCi L^{-1} Ci^{-1}	Year	pCi L^{-1} Ci^{-1}	Year	pCi L^{-1} Ci^{-1}	Year
Ra-226	1.49E-37	1,171	1.21E-01	1,171	1.21E-01	1,171
Th-230	1.89E-39	1,171	1.39E-02	1,171	1.39E-02	1,171
U-234	1.32E-43	1,171	2.06E-05	1,171	2.06E-05	1,171

Notes:

1 Radionuclides without a radium-containing decay chain are excluded.

2 Radionuclides are sorted from highest to lowest Case01 concentration factor.

Table 6-25. Maximum Uranium Concentration Factors at 100-meter POA and Time of Maximum for ST09

Radionuclide [1,2]	Case01, Intact		Case11, Subsided		CaseMX, Maximum	
	µg L^{-1} Ci^{-1}	Year	µg L^{-1} Ci^{-1}	Year	µg L^{-1} Ci^{-1}	Year
Np-237	1.91E-09	1,171	2.21E-08	1,171	2.21E-08	1,171
Am-241	1.56E-14	1,171	2.65E-12	1,171	2.65E-12	1,171
Cm-245	3.46E-15	1,171	1.97E-12	1,171	1.97E-12	1,171
Pu-241	3.63E-16	1,171	8.62E-14	1,171	8.62E-14	1,171
Cf-249	3.82E-17	1,171	3.37E-14	1,171	3.37E-14	1,171

Notes:

1 Radionuclides without a uranium-containing decay chain are excluded.

2 Radionuclides are sorted from highest to lowest Case01 concentration factor.

Table 6-26. ST09 Sensitivity and Uncertainty Cases: Maximum All-Pathways Dose Factors at 100-meter POA, Difference from Nominal PA Case, and Time of Maximum for Radionuclides in Sensitivity Analysis

Radio-nuclide	Nominal PA Case	Sensitivity Case 1		Sensitivity Case 2		Sensitivity Case 3		Sensitivity Case 4	
	Case01 (mrem yr^{-1} Ci^{-1})	Waste Zone Conductivity (mrem yr^{-1} Ci^{-1})	Ratio	LVZ Porosity (mrem yr^{-1} Ci^{-1})	Ratio	Tan Clay Thickness (mrem yr^{-1} Ci^{-1})	Ratio	Waste Zone Porosity (mrem yr^{-1} Ci^{-1})	Ratio
I-129	1.24E+02	1.21E+02	0.98	1.23E+02	0.99	1.25E+02	1.01	1.25E+02	1.01
Np-237	2.23E+00	3.17E+00	1.42	3.31E+00	1.48	1.01E+01	4.54	2.32E+00	1.04
Tc-99	1.82E+00	1.77E+00	0.97	1.79E+00	0.99	1.86E+00	1.02	1.83E+00	1.00
C-14	8.56E-04	1.10E-03	1.29	9.45E-04	1.10	4.83E-02	56.40	8.92E-04	1.04
H-3	1.06E-06	1.06E-06	1.00	1.08E-06	1.01	1.06E-06	1.00	1.06E-06	1.00
Sr-90	8.92E-18	2.71E-17	3.04	2.39E-17	2.68	3.20E-16	35.86	9.28E-18	1.04
Radio-nuclide	Nominal PA Case	Sensitivity Case 5		Sensitivity Case 6		Sensitivity Case 7		--	
	Case01 (mrem yr^{-1} Ci^{-1})	Infiltration (mrem yr^{-1} Ci^{-1})	Ratio	K_d (mrem yr^{-1} Ci^{-1})	Ratio	Disposal Time (mrem yr^{-1} Ci^{-1})	Ratio	--	--
I-129	1.24E+02	1.54E+02	1.25	1.50E+02	1.21	1.40E+02	1.13	--	--
Np-237	2.23E+00	5.84E+01	26.16	8.32E+01	37.27	2.12E-01	0.09	--	--
Tc-99	1.82E+00	1.92E+00	1.06	1.72E+00	0.95	2.13E+00	1.17	--	--
C-14	8.56E-04	3.32E-02	38.81	1.37E-01	159.41	1.19E-04	0.14	--	--
H-3	1.06E-06	9.87E-07	0.93	N/A	N/A	1.23E-06	1.16	--	--
Sr-90	8.92E-18	7.17E-14	8.04E+03	2.74E-12	3.07E+05	4.01E-19	0.04	--	--

Radionuclide	Time of Peak Dose (Year)							
	Nominal PA Case	Sensitivity Case						
		1	2	3	4	5	6	7
	Case01	Waste Zone Conductivity	LVZ Porosity	Tan Clay Thickness	Waste Zone Porosity	Infiltration	K_d	Disposal Time
I-129	949	946	945	905	948	762	747	1,058
Np-237	1,171	1,171	1,171	1,171	1,171	1,171	1111	1,171
Tc-99	802	789	790	763	802	627	642	912
C-14	1,171	1,171	1,171	1,171	1,171	1,171	1,171	1,171
H-3	171	171	171	171	171	171	N/A	171
Sr-90	1,171	1,171	1,171	1,171	1,171	1,171	1,137	1,171

Notes:

Green-highlighted cells indicate a time of peak dose that falls within the compliance period.

Table 6-27. ST09 Sensitivity and Uncertainty Cases: Maximum Beta-Gamma Dose Factors at 100-meter POA, Difference from Nominal PA Case, and Time of Maximum for Radionuclides in Sensitivity Analysis

Radio-nuclide	Nominal PA Case	Sensitivity Case 1		Sensitivity Case 2		Sensitivity Case 3		Sensitivity Case 4	
	Case01 (mrem yr^{-1} Ci^{-1})	Waste Zone Conductivity (mrem yr^{-1} Ci^{-1})	Ratio	LVZ Porosity (mrem yr^{-1} Ci^{-1})	Ratio	Tan Clay Thickness (mrem yr^{-1} Ci^{-1})	Ratio	Waste Zone Porosity (mrem yr^{-1} Ci^{-1})	Ratio
I-129	2.11E+03	2.06E+03	0.98	2.09E+03	0.99	2.14E+03	1.01	2.14E+03	1.01
Tc-99	2.75E+00	2.68E+00	0.97	2.72E+00	0.99	2.81E+00	1.02	2.77E+00	1.00
H-3	7.44E-01	7.52E-01	1.01	6.85E-01	0.92	7.54E-01	1.01	7.36E-01	0.99
Np-237	1.49E-01	2.11E-01	1.42	2.20E-01	1.48	6.74E-01	4.54	1.54E-01	1.04
C-14	8.54E-04	1.10E-03	1.29	9.42E-04	1.10	4.82E-02	56.40	8.89E-04	1.04
Sr-90	7.62E-17	2.32E-16	3.04	2.04E-16	2.68	2.73E-15	35.86	7.93E-17	1.04
Radio-nuclide	Nominal PA Case	Sensitivity Case 5		Sensitivity Case 6		Sensitivity Case 7		--	
	Case01 (mrem yr^{-1} Ci^{-1})	Infiltration (mrem yr^{-1} Ci^{-1})	Ratio	K_d (mrem yr^{-1} Ci^{-1})	Ratio	Disposal Time (mrem yr^{-1} Ci^{-1})	Ratio	--	--
I-129	2.11E+03	2.63E+03	1.25	2.56E+03	1.21	2.39E+03	1.13	--	--
Tc-99	2.75E+00	2.91E+00	1.06	2.61E+00	0.95	3.22E+00	1.17	--	--
H-3	7.44E-01	1.24E+00	1.67	N/A	N/A	2.86E-04	3.84E-04	--	--
Np-237	1.49E-01	3.89E+00	26.16	5.54E+00	3.73E+01	1.41E-02	0.09	--	--
C-14	8.54E-04	3.31E-02	38.81	1.36E-01	1.59E+02	1.18E-04	0.14	--	--
Sr-90	7.62E-17	6.12E-13	8038.55	2.34E-11	3.07E+05	3.43E-18	0.04	--	--

Radionuclide	Time of Peak Dose (Year)							
	Nominal PA Case	Sensitivity Case						
		1	2	3	4	5	6	7
	Case01	Waste Zone Conductivity	LVZ Porosity	Tan Clay Thickness	Waste Zone Porosity	Infiltration	K_d	Disposal Time
I-129	949	946	945	905	948	762	747	1058
Tc-99	802	789	790	763	802	627	642	912
H-3	35	34	36	35	35	30	N/A	97
Np-237	1,171	1,171	1,171	1,171	1,171	1,171	1111	1,171
C-14	1,171	1,171	1,171	1,171	1,171	1,171	1,171	1,171
Sr-90	1,171	1,171	1,171	1,171	1,171	1,171	1,137	1,171

Notes:

Green-highlighted cells indicate a time of peak dose that falls within the compliance period.

Table 6-28. ST09 Sensitivity and Uncertainty Cases: Maximum Gross-Alpha Concentration Factors at 100-meter POA, Difference from Nominal PA Case, and Time of Maximum

Radio-nuclide	Nominal PA Case	Sensitivity Case 1		Sensitivity Case 2		Sensitivity Case 3		Sensitivity Case 4	
	Case01 (pCi L^{-1} Ci^{-1})	Waste Zone Conductivity (pCi L^{-1} Ci^{-1})	Ratio	LVZ Porosity (pCi L^{-1} Ci^{-1})	Ratio	Tan Clay Thickness (pCi L^{-1} Ci^{-1})	Ratio	Waste Zone Porosity (pCi L^{-1} Ci^{-1})	Ratio
Np-237	1.11E+01	1.58E+01	1.42	1.65E+01	1.48	5.06E+01	4.54	1.16E+01	1.04
	Nominal PA Case	Sensitivity Case 5		Sensitivity Case 6		Sensitivity Case 7		--	
	Case01 (pCi L^{-1} Ci^{-1})	Infiltration (pCi L^{-1} Ci^{-1})	Ratio	K_d (pCi L^{-1} Ci^{-1})	Ratio	Disposal Time (pCi L^{-1} Ci^{-1})	Ratio	--	--
	1.11E+01	2.91E+02	26.16	4.15E+02	37.27	1.06E+00	0.09	--	--

Radionuclide	Time of Peak Concentration (Year)							
	Nominal PA Case	Sensitivity Case						
		1	2	3	4	5	6	7
	Case01	Waste Zone Conductivity	LVZ Porosity	Tan Clay Thickness	Waste Zone Porosity	Infiltration	K_d	Disposal Time
Np-237	1,171	1,171	1,171	1,171	1,171	1,171	1,111	1,171

Notes:

Green-highlighted cells indicate a time of peak concentration that falls within the compliance period.

Table 6-29. ST09 Sensitivity and Uncertainty Cases: Maximum Uranium Concentration Factors at 100-meter POA, Difference from Nominal PA Case, and Time of Maximum

Radio-nuclide	Nominal PA Case	Sensitivity Case 1		Sensitivity Case 2		Sensitivity Case 3		Sensitivity Case 4	
	Case01 (µg L^{-1} Ci^{-1})	Waste Zone Conductivity (µg L^{-1} Ci^{-1})	Ratio	LVZ Porosity (µg L^{-1} Ci^{-1})	Ratio	Tan Clay Thickness (µg L^{-1} Ci^{-1})	Ratio	Waste Zone Porosity (µg L^{-1} Ci^{-1})	Ratio
Np-237	1.90E-09	2.89E-09	1.52	3.00E-09	1.58	1.08E-08	5.65	1.98E-09	1.04
	Nominal PA Case	Sensitivity Case 5		Sensitivity Case 6		Sensitivity Case 7		--	
	Case01 (µg L^{-1} Ci^{-1})	Infiltration (µg L^{-1} Ci^{-1})	Ratio	K_d (µg L^{-1} Ci^{-1})	Ratio	Disposal Time (µg L^{-1} Ci^{-1})	Ratio	--	--
	1.90E-09	1.45E-07	76.27	3.83E-07	200.94	1.32E-10	0.07	--	--

Radionuclide	Time of Peak Concentration (Year)							
	Nominal PA Case	Sensitivity Case						
		1	2	3	4	5	6	7
	Case01	Waste Zone Conductivity	LVZ Porosity	Tan Clay Thickness	Waste Zone Porosity	Infiltration	K_d	Disposal Time
Np-237	1,171	1,171	1,171	1,171	1,171	1,171	1,171	1,171

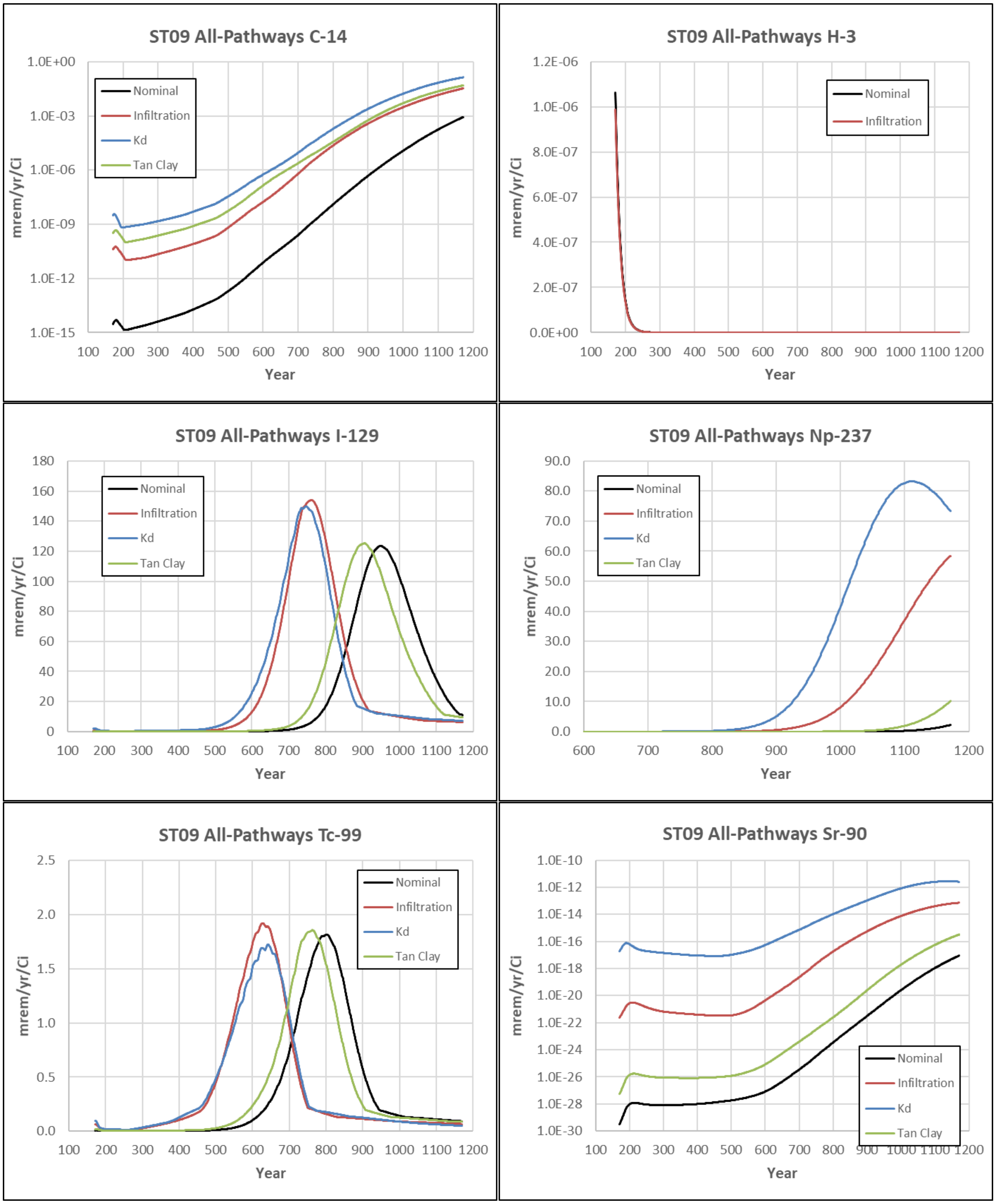


Figure 6-12. Comparison of All-Pathways Dose Factors (mrem yr^{-1} Ci^{-1} parent buried) for C-14, H-3, I-129, Np-237, Sr-90, and Tc-99 at 100-meter POA During Compliance Period for ST09 Nominal PA, Infiltration Sensitivity, K_d Sensitivity, and Tan Clay Layer Sensitivity Cases

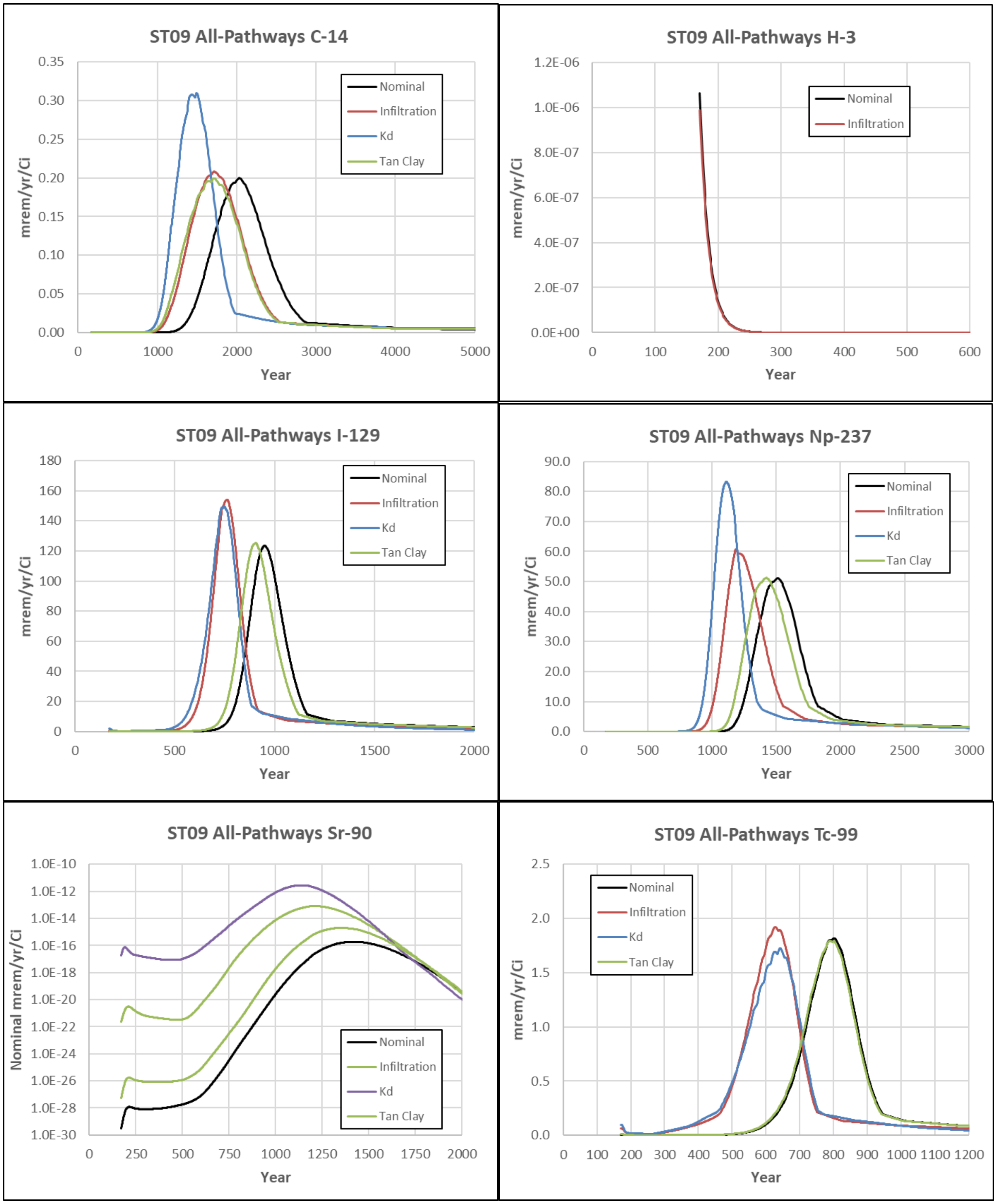


Figure 6-13. Comparison of All-Pathways Dose Factors (mrem yr^{-1} Ci^{-1} parent buried) for C-14, H-3, I-129, Np-237, Sr-90, and Tc-99 at 100-meter POA over the Entire Simulation Period for ST09 Nominal PA, Infiltration Sensitivity, K_d Sensitivity, and Tan Clay Layer Sensitivity Cases

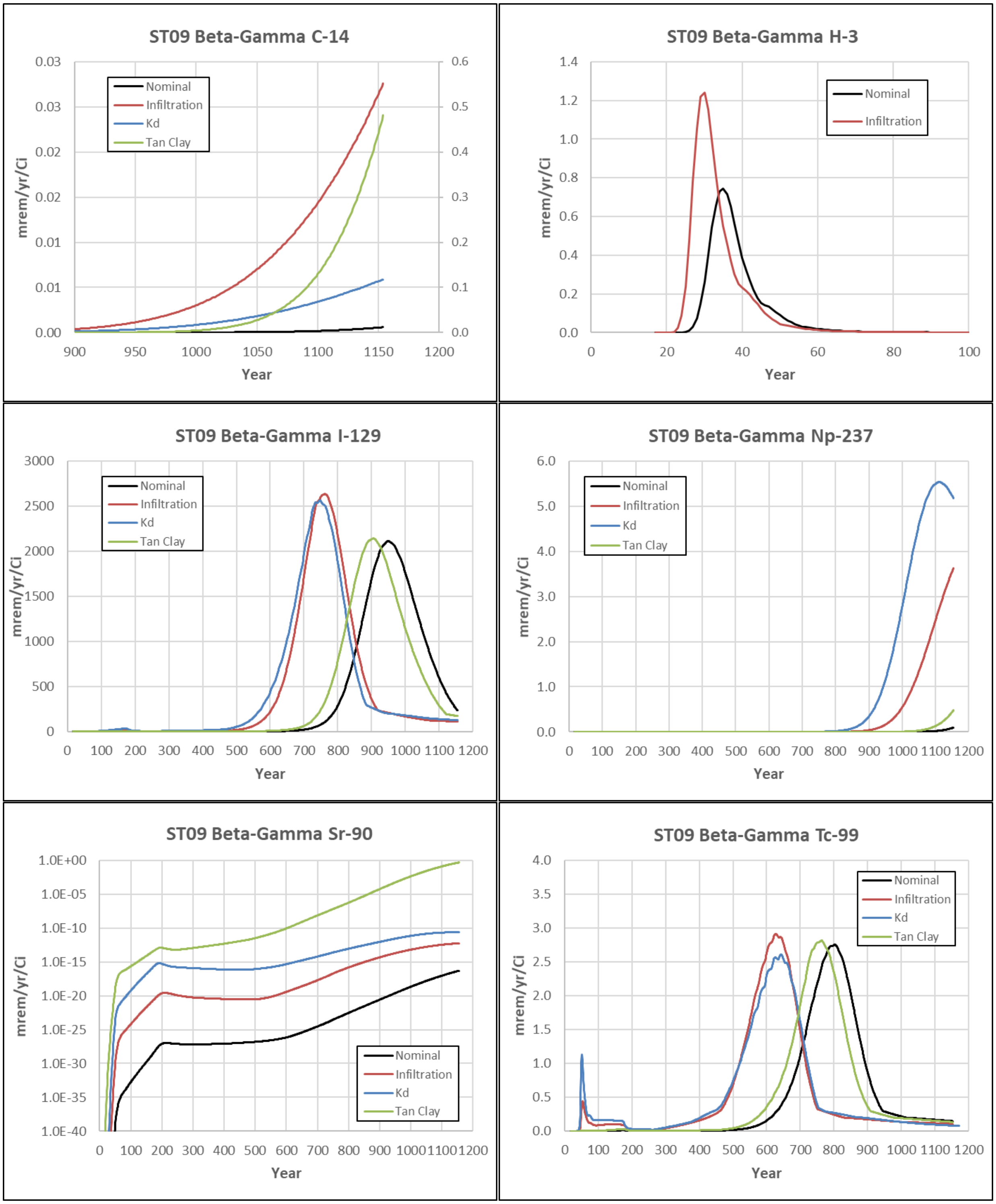


Figure 6-14. Comparison of Beta-Gamma Dose Factors (mrem yr^{-1} Ci^{-1} parent buried) for C-14, H-3, I-129, Np-237, Sr-90, and Tc-99 at 100-meter POA During Compliance Period for ST09 Nominal PA, Infiltration Sensitivity, *K_d* Sensitivity, and Tan Clay Layer Sensitivity Cases

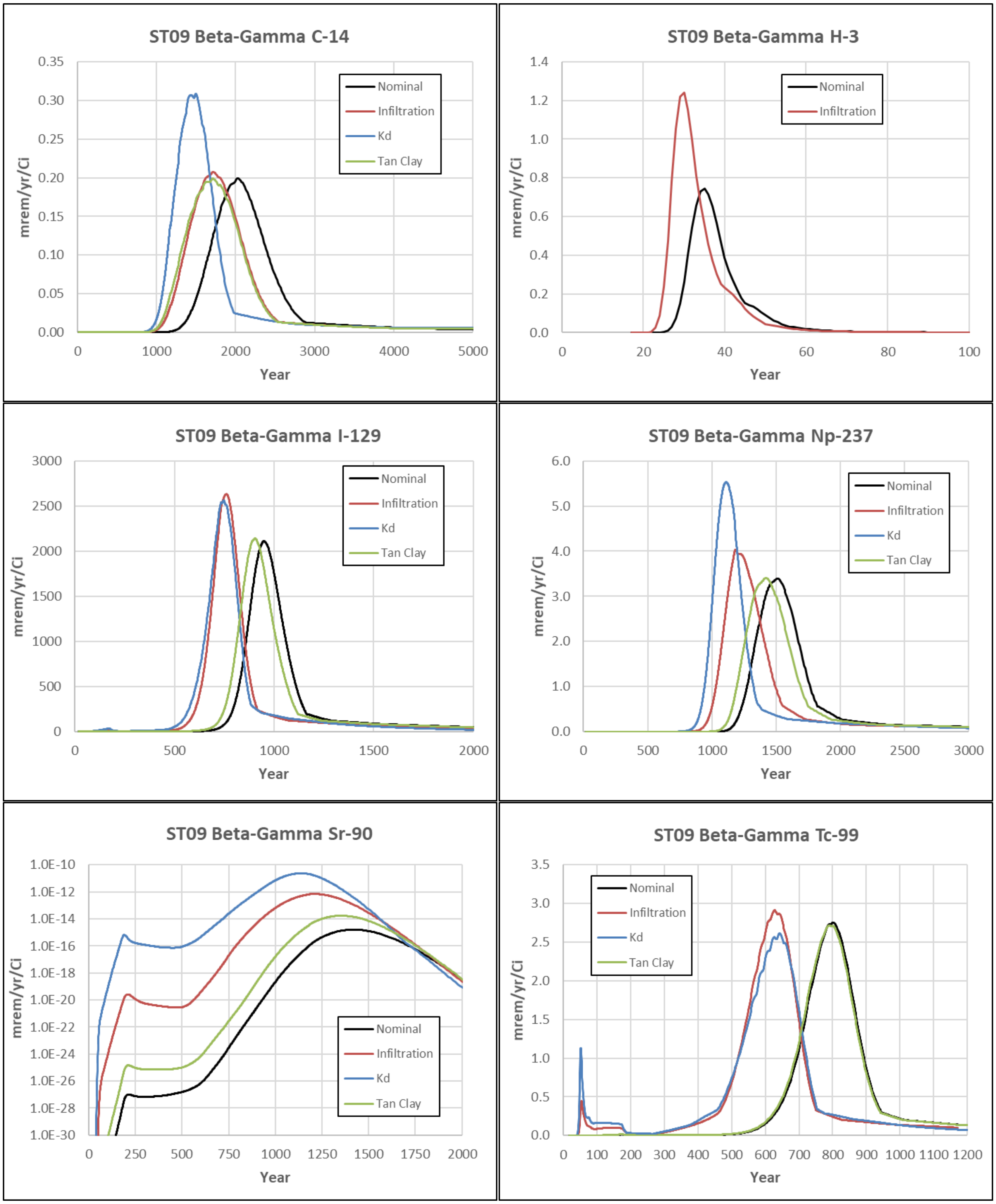


Figure 6-15. Comparison of Beta-Gamma Dose Factors (mrem yr^{-1} Ci^{-1} parent buried) for C-14, H-3, I-129, Np-237, Sr-90, and Tc-99 at 100-meter POA over the Entire Simulation Period for ST09 Nominal PA, Infiltration Sensitivity, K_d Sensitivity, and Tan Clay Layer Sensitivity Cases

6.1.1.2. Intermediate-Level Vault and Low-Activity Waste Vault

Table 6-30 defines the sensitivity analysis cases, sensitivity analysis parameters, the changes in parameter values used in the sensitivity analysis calculations, and the parameter distribution information for the ILV and LAWV. A general description of the results for the ILV is provided in Section 6.1.1.2.1 and generally applies to the LAWV; the description is not repeated for LAWV results in Section 6.1.1.2.2. Detailed descriptions of the PORFLOW flow and transport models for the LAWV and ILV are given in Sections 4.5.3 and 4.6.3, respectively.

There are several notable differences between the ILV and LAWV affecting vault performance. One is the location within the ELLWF which leads to differences in VZ and aquifer flow paths between the two vaults. Second, because ILV waste is grouted when a cell layer is complete, Kaplan (2016b) recommends that K_d values for cementitious material be employed in the waste zone transport model simulations of the ILV. On the other hand, because LAWV waste is not grouted and waste packages remain movable until closure, K_d values for clayey soil are used to model its waste zone. Thus, elution of radionuclides from the ILV is significantly slower than from the LAWV. An extreme example of this difference in K_d is Tc-99 with an assumed K_d of 0.6 mL g^{-1} in sandy soil, 1.8 mL g^{-1} in clayey soil, and 1,000 mL g^{-1} in reducing cement (which represents grout).

Table 6-30. Sensitivity Analysis and Uncertainty Quantification Parameters for Intermediate-Level and Low-Activity Waste Vaults

Sensitivity Case No.	Topic	Parameter Value								Δ(SV) (Sensitivity – Nominal)	Standard Deviations	Distribution	Mean	Standard Deviation	Minimum	Maximum
		Nominal PA Case		Best Estimate Case		Best Estimate Case 2		Sensitivity Case								
1	Initial Gravel Content in Concrete	roof	10%	roof	10%	roof	10%	roof	20%	10	+2σ	Truncated Normal	10	5	0	20
		walls	10%	walls	10%	walls	10%	walls	20%							
		floor	0%	floor	0%	floor	0%	floor	20%							
2	Concrete Degradation Rate	500 years following IC		1,000 years following IC		1,000 years following IC		1,000 years following IC		500	+5σ	Truncated Normal	500	100	0	1,000
3	Pore Volume Exchanges for Concrete Aging	I-II	50	I-II	50	I-II	50	I-II	25	N/A	N/A	Difficult to quantify, small impact on dose				
		II-III	500	II-III	500	II-III	500	II-III	250							
		III-Soil	4,000	III-Soil	4,000	III-Soil	4,000	III-Soil	1,500							
4	LVZ Porosity	0.3806		0.3806		0.3806		0.42		0.0394	+1σ	Truncated Normal	0.3806	0.0414	-3σ	+3σ
5	Waste Zone Porosity [a]	0.7366		0.300 (clayey soil)		0.300 (clayey soil)		0.300 (clayey soil)		-0.4366	-6σ	Truncated Normal	0.30	0.025	-3σ	+3σ
6	Precipitation/Infiltration (cm yr^{-1})	2019 HELP Model Bounding Cap Design with Best Estimate Rainfall [e]		2019 HELP Model Bounding Cap Design with Best Estimate Rainfall [e]		2019 HELP Model Bounding Cap Design with Best Estimate Rainfall [e]		2019 HELP Model Bounding Cap Design with Pessimistic Rainfall [e]		31.9	+1.6σ	Truncated Normal	124.8 [c] 156.7 [d]	19.9	-2σ	+2σ
7	K_d [b]	2016 GeoChem Database K_d Values		2016 GeoChem Database K_d Values		2016 GeoChem Database K_d Values		0.5 K_d		-0.50	-2.5σ	Truncated Normal	1	0.2	-3σ	+3σ
8	H-3 Diffusivity in Concrete	2.02 $cm^2\ yr^{-1}$		2.02 $cm^2\ yr^{-1}$		2.02 $cm^2\ yr^{-1}$		2.15 $cm^2\ yr^{-1}$		0.13	+1σ	Truncated Normal	2.02	0.13	-2σ	+2σ
9	Waste Disposal Timing	0		0		1		0		1		Uniform			0	1

Notes:

[a] Waste and soil are two different materials

[b] Element and material dependent; K_d changed in all materials by the same factor

[c] Annual average rainfall

[d] Pessimistic (+1.6σ) annual rainfall

[e] The nominal PA infiltration profile is designated as "Bounding cap design best estimate (BE) rainfall" and the sensitivity case infiltration profile as "Bounding cap design pessimistic rainfall." Refer to Figure 6-2 and Figure 6-3.

6.1.1.2.1. Intermediate-Level Vault

The maximum all-pathways dose factors (mrem yr^{-1} per Ci parent buried) at the 100-meter POA for the generic ILV radionuclides for the nominal PA case and two best estimate cases (BE and BE2) are listed in Table 6-31 (note that only radionuclides with dose factors greater than 1.0E-35 mrem yr^{-1} Ci^{-1} are listed). Also included in Table 6-31 is the relative difference in the 100-meter POA peak dose factor between the best estimate and nominal PA cases (i.e., shown in terms of a ratio value). The best estimate cases remove several factors included in the nominal PA case that intentionally introduce pessimistic bias into the PA calculations. Case BE degrades concrete hydraulic properties over a 1,000-year period instead of the 500 years recommended by the Performance Assessment Working Group (U.S. NRC, 2000). Analysis of E-Area vault concrete (SIMCO, 2012) leads SRNL to conclude that the ILV concrete is more robust than normal formulations and will likely resist degradation over a longer period. No credit is taken for this in the nominal PA case. Similarly, a large porosity or void volume is assumed in the ILV waste zone to avoid taking too much credit for K_d inhibition of radionuclide transport (Nichols and Butcher, 2020). The ILV waste storage region is grouted as it is operationally filled and has a much lower porosity than assumed in the nominal PA case. Case BE2 uses the Case BE parameter settings but assumes placement of waste at the end of operations instead of at the start. Placement of the entire waste inventory at the start of operations is pessimistically biased for most radionuclides. As Table 6-31 demonstrates, best estimate dose factors for all radionuclides except H-3 are lower than in the nominal PA case. In addition, Table 6-31 indicates that the maximum all-pathways dose factor decreases substantially beyond the top five radionuclides.

Table 6-31. Maximum All-Pathways Dose Factors at 100-meter POA and Time of Maximum for Intermediate-Level Vault Radionuclides

Radionuclide [1,2,3]	Nominal PA Case		Best Estimate Case		Ratio	Best Estimate 2 Case		Ratio
	mrem yr^{-1} Ci^{-1}	Year	mrem yr^{-1} Ci^{-1}	Year		mrem yr^{-1} Ci^{-1}	Year	
I-129	2.25E+01	1,171	2.73E+00	1,171	0.12	5.89E+00	1,171	0.26
Cl-36	4.27E-03	1,171	2.94E-03	1,171	0.69	2.20E-03	1,171	0.52
Ar-39	8.71E-06	759	3.65E-06	833	0.42	4.24E-06	833	0.49
Tc-99	5.26E-08	1,171	1.06E-10	1,171	2.01E-03	1.21E-10	1,171	2.30E-03
H-3	1.67E-09	171	3.31E-09	171	1.98	6.13E-09	171	3.67
K-40	7.82E-26	1,171	5.42E-26	1,171	0.69	4.51E-28	1,171	0.01
C-14	4.22E-30	1,171	1.58E-35	1,171	3.75E-06	3.98E-35	1,171	9.43E-06
Np-237	3.18E-30	1,171	6.21E-32	1,171	0.02	1.67E-31	1,171	0.05
U-235	2.41E-30	1,171	8.60E-32	1,171	0.04	2.18E-31	1,171	0.09
Am-241	5.54E-34	1,171	1.23E-35	1,171	0.02	3.26E-35	1,171	0.06
Cm-245	3.49E-34	1,171	7.74E-36	1,171	0.02	1.87E-35	1,171	0.05
Pu-241	1.81E-35	1,171	4.03E-37	1,171	0.02	1.06E-36	1,171	0.06

1 Radionuclides are sorted from highest to lowest nominal PA dose factor.

2 Only radionuclides with a Nominal PA dose factor >1.0E-35 mrem yr^{-1} per Ci parent buried are listed in table.

3 Radionuclide conditions with adverse impact to dose factors are highlighted in orange.

Table 6-32 lists the maximum all-pathways dose factors at the 100-meter POA for the ILV nominal PA case and seven sensitivity cases (S1 to S7) as well as the relative change in dose factor for the five radionuclides with the largest nominal PA dose factors (i.e., shown in terms of a ratio value). Time of occurrence of the maximum dose is also included.

Table 6-32. Intermediate-Level Vault Sensitivity and Uncertainty Cases: Maximum All-Pathways Dose Factors at 100-meter POA, Difference from Nominal PA Case, and Time of Maximum for Radionuclides with Highest Nominal PA Dose Factor

Radionuclide	Nominal PA Case (mrem yr^{-1} Ci^{-1})	Sensitivity Case 1		Sensitivity Case 2		Sensitivity Case 3		Sensitivity Case 4	
		Concrete Porosity (mrem yr^{-1} Ci^{-1})	Ratio	Concrete Degradation (mrem yr^{-1} Ci^{-1})	Ratio	Concrete Aging (mrem yr^{-1} Ci^{-1})	Ratio	LVZ Porosity (mrem yr^{-1} Ci^{-1})	Ratio
I-129	2.25E+01	2.37E+01	1.05	5.92E+00	0.26	2.23E+01	0.99	2.50E+01	1.11
Cl-36	4.27E-03	4.52E-03	1.06	2.24E-03	0.52	4.27E-03	1.00	5.19E-03	1.21
Ar-39	8.71E-06	8.40E-06	0.96	3.78E-06	0.43	8.71E-06	1.00	9.02E-06	1.04
Tc-99	5.26E-08	1.24E-07	2.36	1.24E-10	2.35E-03	5.26E-08	1.00	5.50E-08	1.04
H-3	1.67E-09	1.67E-09	1.00	1.67E-09	1.00	1.67E-09	1.00	1.58E-09	0.94
Radionuclide	Nominal PA Case (mrem yr^{-1} Ci^{-1})	Sensitivity Case 5		Sensitivity Case 6		Sensitivity Case 7		--	
		Waste Porosity (mrem yr^{-1} Ci^{-1})	Ratio	Infiltration (mrem yr^{-1} Ci^{-1})	Ratio	K_d (mrem yr^{-1} Ci^{-1})	Ratio	--	--
I-129	2.25E+01	1.07E+01	0.47	8.92E+01	3.96	8.59E+01	3.82	--	--
Cl-36	4.27E-03	4.85E-03	1.14	1.42E+00	333.43	1.54E+00	360.39	--	--
Ar-39	8.71E-06	1.04E-05	1.20	1.67E-05	1.92	8.71E-06	1.00	--	--
Tc-99	5.26E-08	4.94E-08	0.94	2.96E-06	56.20	9.39E-06	178.39	--	--
H-3	1.67E-09	3.32E-09	1.99	2.06E-09	1.23	1.67E-09	1.00	--	--

Radionuclide	Time of Peak Dose (Year)							
	Nominal PA Case	Sensitivity Case						
		1	2	3	4	5	6	7
		Concrete Porosity	Concrete Degradation	Concrete Aging	LVZ Porosity	Waste Zone Porosity	Infiltration	K_d
I-129	1,171	1,171	1,171	1,171	1,171	1,171	1,067	1,091
Cl-36	1,171	1,171	1,171	1,171	1,171	1,171	1,171	1,171
Ar-39	759	754	850	759	782	745	681	759
Tc-99	1,171	1,171	1,171	1,171	1,171	1,171	1,171	1,171
H-3	171	171	171	171	171	171	171	171

Notes:

Green-highlighted cells indicate a time of peak dose that falls within the compliance period.

All-pathways dose factors during the compliance period for the five ILV radionuclides included in the sensitivity analysis, plus K-40, are plotted in Figure 6-16.

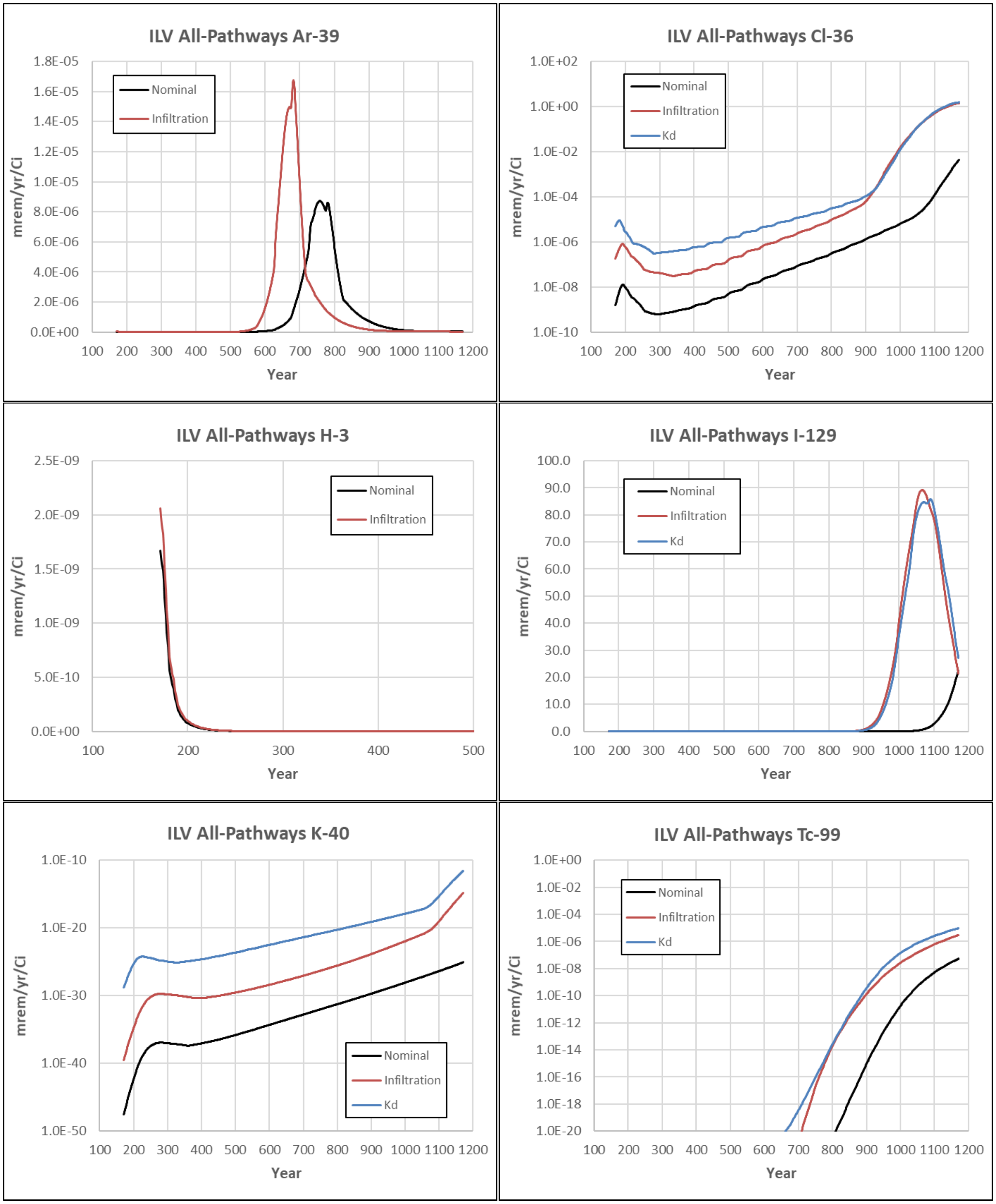


Figure 6-16. Comparison of All-Pathways Dose Factors (mrem yr^{-1} Ci^{-1} parent buried) for Ar-39, Cl-36, H-3, I-129, K-40, and Tc-99 at 100-meter POA During Compliance Period for Intermediate-Level Vault Nominal PA, Infiltration Sensitivity, and K_d Sensitivity Cases

Figure 6-17 shows peak all-pathways dose factors over the entire simulation period for comparison (i.e., Ar-39 and H-3 contributions are negligible beyond the compliance period and are not shown). The graphs compare nominal PA dose factor to dose factors obtained from the infiltration and K_d sensitivity studies.

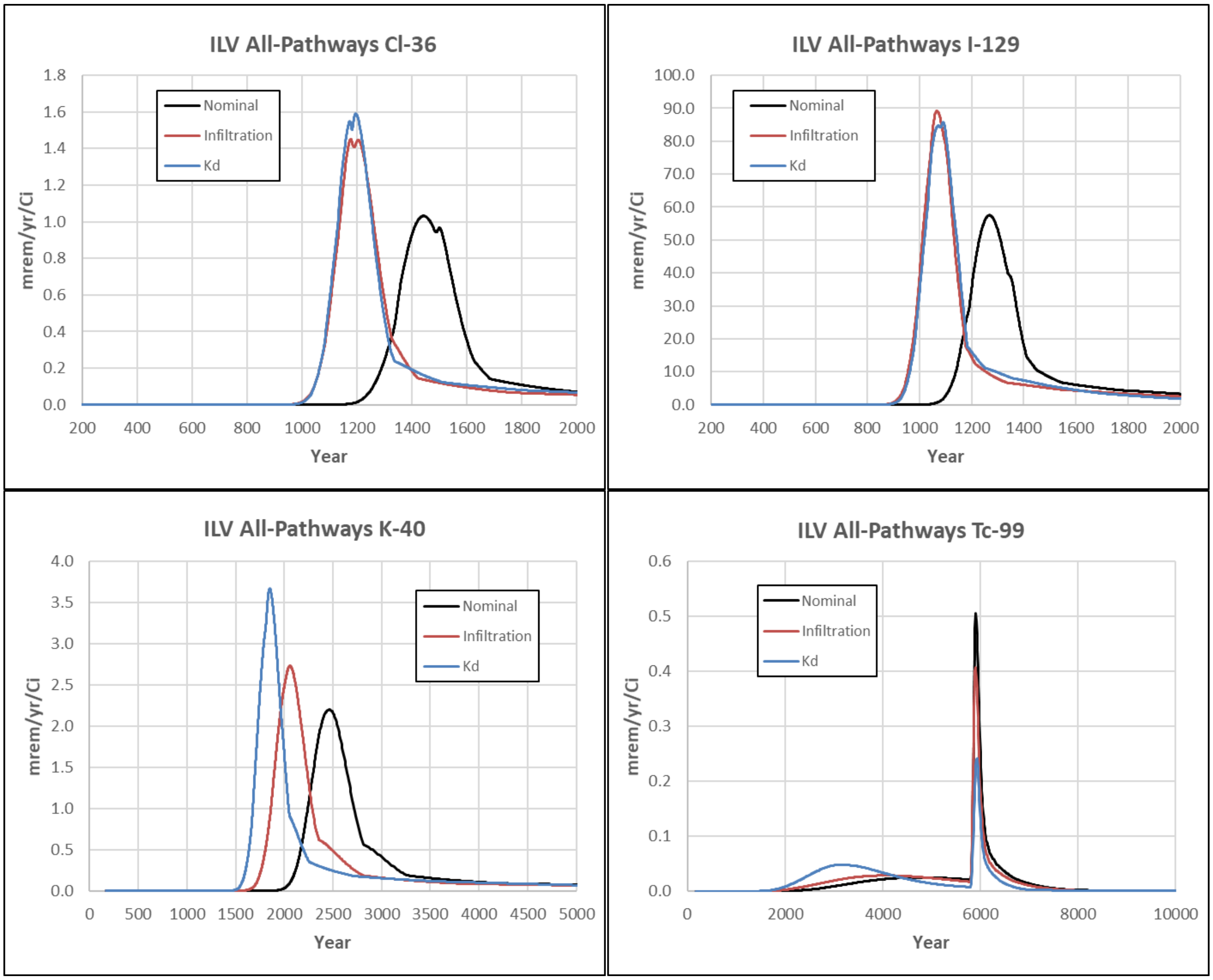


Figure 6-17. Comparison of All-Pathways Dose Factors (mrem yr^{-1} Ci^{-1} parent buried) for Cl-36, I-129, K-40, and Tc-99 at 100-meter POA over the Entire Simulation Period for Intermediate-Level Vault Nominal PA, Infiltration Sensitivity, and K_d Sensitivity Cases

Table 6-33 lists the maximum GW protection beta-gamma dose factors at the 100-meter POA for the generic radionuclides included in the ILV PORFLOW model for the nominal PA case and two best estimate cases (BE and BE2). (Note that only those radionuclides with dose factors greater than 1.0E-35 mrem yr^{-1} Ci^{-1} are listed.) Data are sorted from highest to lowest dose factor based on the nominal PA case which is the reference case for the sensitivity analysis. Table 6-33 indicates that the maximum all-pathways dose factor decreases substantially beyond the top four radionuclides.

Table 6-33. Maximum Beta-Gamma Dose Factors at 100-meter POA and Time of Maximum for Intermediate-Level Vault

Radionuclide [1,2,3]	Nominal PA Case		Best Estimate Case		Ratio	Best Estimate 2 Case		Ratio
	mrem yr^{-1} Ci^{-1}	Year	mrem yr^{-1} Ci^{-1}	Year		mrem yr^{-1} Ci^{-1}	Year	
I-129	3.85E+02	1,171	4.66E+01	1,171	0.12	1.01E+02	1,171	0.26
Cl-36	4.75E-03	1,171	3.26E-03	1,171	0.69	2.45E-03	1,171	0.52
Tc-99	7.98E-08	1,171	1.61E-10	1,171	2.01E-03	1.84E-10	1,171	2.30E-03
H-3	3.70E-08	98	7.63E-08	97	2.06	3.69E-08	97	1.00
K-40	8.13E-26	1,171	5.63E-26	1,171	0.69	4.68E-28	1,171	0.01
C-14	4.21E-30	1,171	1.58E-35	1,171	3.75E-06	3.97E-35	1,171	9.43E-06
Np-237	2.11E-31	1,171	4.13E-33	1,171	0.02	1.11E-32	1,171	0.05
U-235	1.60E-33	1,171	6.22E-35	1,171	0.04	1.57E-34	1,171	0.10
Am-241	3.69E-35	1,171	8.20E-37	1,171	0.02	2.17E-36	1,171	0.06
Cm-245	2.32E-35	1,171	5.14E-37	1,171	0.02	1.24E-36	1,171	0.05

Notes:

1 Radionuclides are sorted from highest to lowest nominal PA dose factor.

2 Only radionuclides with dose factor >1.0E-35 mrem yr^{-1} per Ci parent buried are listed in table.

3 Radionuclide conditions with adverse impact to dose factors are highlighted in orange.

Table 6-34 lists the maximum GW protection beta-gamma dose factor at the 100-meter POA for the ILV nominal PA case and seven sensitivity cases (S1 to S7). Also included in Table 6-34 are the relative change in maximum dose factor for each sensitivity case (i.e., shown in terms of a ratio value) and the year in which the maximum dose factor occurs. The four ILV radionuclides listed in Table 6-34 have the largest beta-gamma dose factors. Beta-gamma dose factors for all other radionuclides are less than 1.0E-20 mrem yr^{-1} per Ci parent buried. Figure 6-18 displays the maximum GW protection beta-gamma dose factors for the ILV radionuclides included in the sensitivity analysis, plus K-40, during the compliance period. The graphs compare nominal PA dose factors during the compliance period to dose factors obtained for the infiltration and K_d sensitivity cases. Cl-36, K-40, and Tc-99 are plotted using a logarithmic scale for the y-axis to facilitate visual comparison. Figure 6-19 shows peak GW protection beta-gamma dose factors over the entire simulation period.

Table 6-34. Intermediate-Level Vault Sensitivity and Uncertainty Cases: Maximum Beta-Gamma Dose Factors at 100-meter POA, Difference from Nominal PA Case, and Time of Maximum for Radionuclides with Highest Nominal PA Dose Factor

Radionuclide	Nominal PA Case (mrem yr^{-1} Ci^{-1})	Sensitivity Case 1		Sensitivity Case 2		Sensitivity Case 3		Sensitivity Case 4	
		Concrete Porosity (mrem yr^{-1} Ci^{-1})	Ratio	Concrete Degradation (mrem yr^{-1} Ci^{-1})	Ratio	Concrete Aging (mrem yr^{-1} Ci^{-1})	Ratio	LVZ Porosity (mrem yr^{-1} Ci^{-1})	Ratio
I-129	3.85E+02	4.05E+02	1.05	1.01E+02	0.26	3.81E+02	0.99	4.27E+02	1.11
Cl-36	4.75E-03	5.02E-03	1.06	2.49E-03	0.52	4.75E-03	1.00	5.77E-03	1.21
Tc-99	7.98E-08	1.88E-07	2.36	1.87E-10	2.35E-03	7.98E-08	1.00	8.33E-08	1.04
H-3	3.70E-08	3.70E-08	1.00	3.69E-08	1.00	3.70E-08	1.00	3.36E-08	0.91
Radionuclide	**Nominal PA Case (mrem yr^{-1} Ci^{-1})**	**Sensitivity Case 5**		**Sensitivity Case 6**		**Sensitivity Case 7**		**--**	
		Waste Porosity (mrem yr^{-1} Ci^{-1})	**Ratio**	**Infiltration (mrem yr^{-1} Ci^{-1})**	**Ratio**	**K_d (mrem yr^{-1} Ci^{-1})**	**Ratio**	**--**	**--**
I-129	3.85E+02	1.83E+02	0.47	1.52E+03	3.96	1.47E+03	3.82	--	--
Cl-36	4.75E-03	5.39E-03	1.14	1.58E+00	333.43	1.71E+00	360.39	--	--
Tc-99	7.98E-08	7.48E-08	0.94	4.48E-06	56.20	1.42E-05	178.39	--	--
H-3	3.70E-08	7.66E-08	2.07	5.79E-08	1.57	3.70E-08	1.00	--	--

Radionuclide	Time of Peak Dose (Year)							
	Nominal PA Case	Sensitivity Case						
		1	2	3	4	5	6	7
		Concrete Porosity	Concrete Degradation	Concrete Aging	LVZ Porosity	Waste Zone Porosity	Infiltration	K_d
I-129	1,171	1,171	1,171	1,171	1,171	1,171	1,067	1,091
Cl-36	1,171	1,171	1,171	1,171	1,171	1,171	1,171	1,171
Tc-99	1,171	1,171	1,171	1,171	1,171	1,171	1,171	1,171
H-3	98	98	98	98	99	97	92	98

Notes:

Green-highlighted cells indicate a time of peak dose that falls within the compliance period.

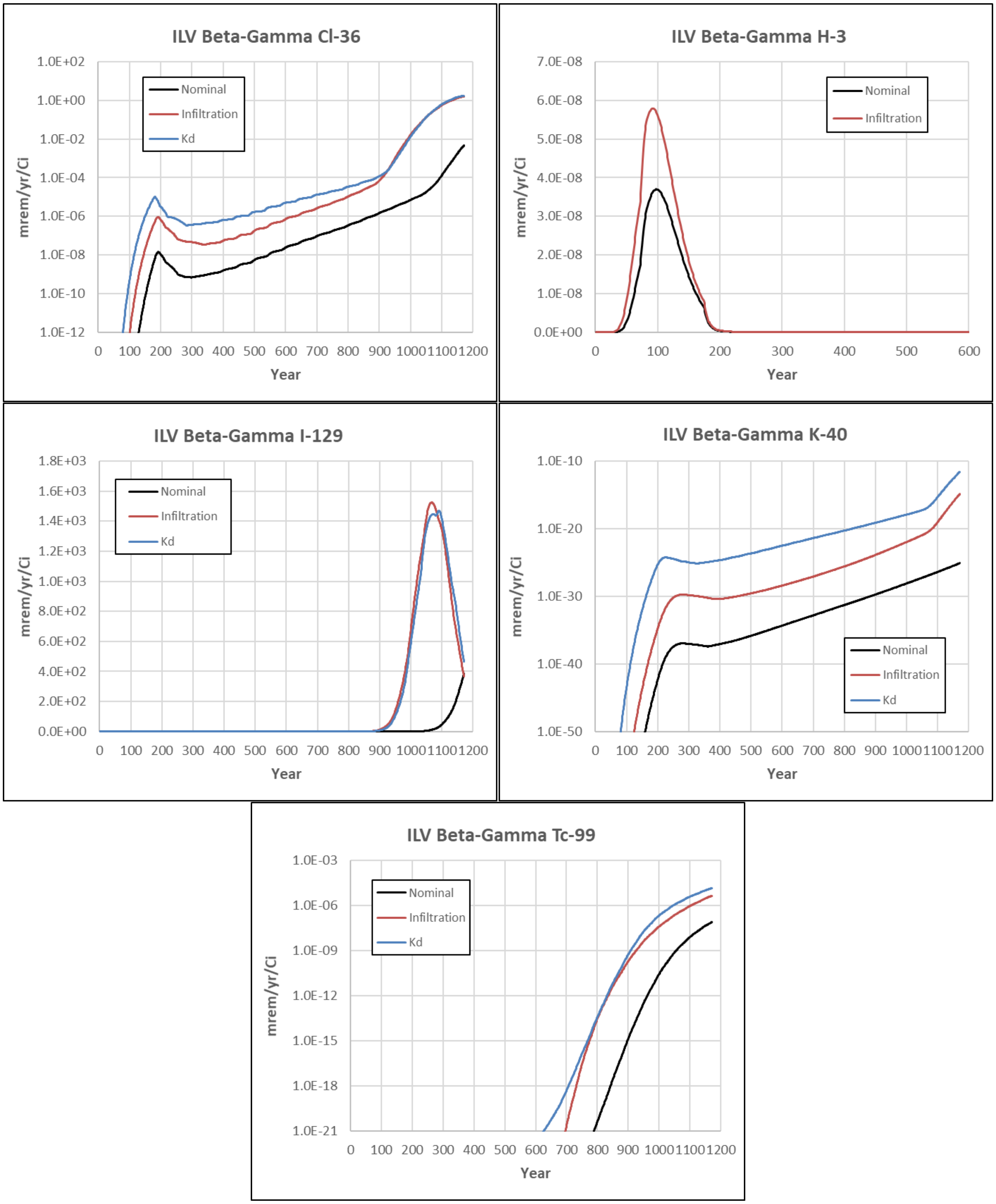


Figure 6-18. Comparison of Beta-Gamma Dose Factors (mrem yr^{-1} Ci^{-1} parent buried) for Cl-36, H-3, I-129, K-40, and Tc-99 at 100-meter POA During Compliance Period for Intermediate-Level Vault Nominal PA, Infiltration Sensitivity, and K_d Sensitivity Cases

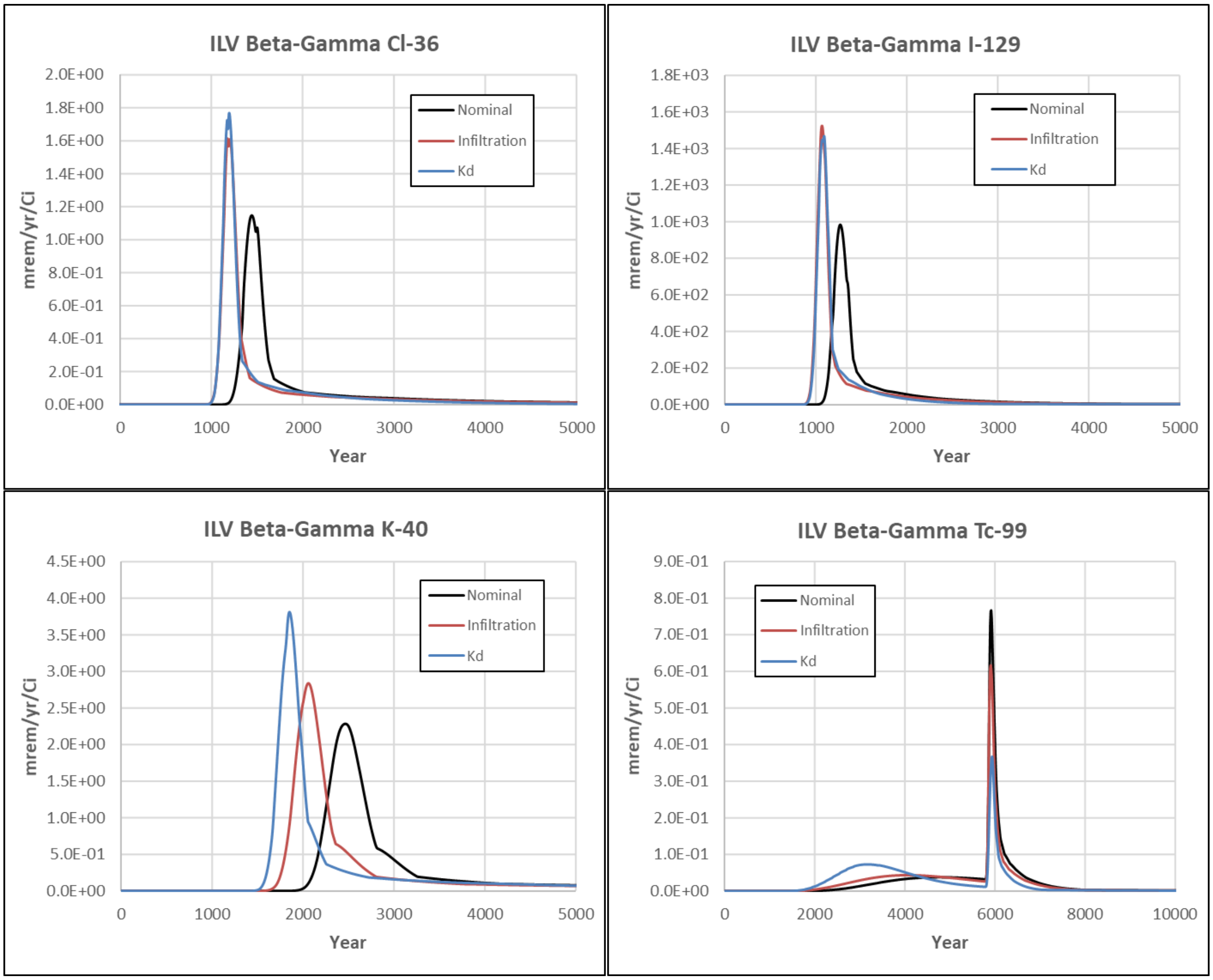


Figure 6-19. Comparison of Beta-Gamma Dose Factors (mrem yr^{-1} Ci^{-1} parent buried) for Cl-36, I-129, K-40, and Tc-99 at 100-meter POA over the Entire Simulation Period for Intermediate-Level Vault Nominal PA, Infiltration Sensitivity, and K_d Sensitivity Cases

Alpha-emitter and uranium peak concentration factors (pCi L^{-1} per Ci parent buried) for the ILV are calculated for GW protection and are presented in Table 6-35 and Table 6-36. Similarly, radium is completely inconsequential and is not analyzed. Table 6-35 lists maximum GW protection gross-alpha concentration factors at the 100-meter POA for the nominal PA and two best estimate cases for the generic alpha-emitting radionuclides included in the ILV model (note that only those radionuclides with concentration factors greater than 1.0E-40 pCi L^{-1} Ci^{-1} are listed). The resulting concentrations based on these factors are too low to impact disposal limits, but they do demonstrate the large relative changes in concentration factor that can occur as the elution peak moves into the compliance period time window. The peak uranium concentration factor at the 100-meter POA is 3.54E-27 µg L^{-1} Ci^{-1} for Np-237 for the K_d sensitivity case. For the sensitivity calculation, K_d is decreased by 50%, which represents a 2σ (95th percentile) variation. All other uranium concentration factors are less than 1.0E-50 mg L^{-1} Ci^{-1} parent buried; no further analysis of uranium for ILV was conducted.

Table 6-35. Maximum Gross-Alpha Concentration Factors at 100-meter POA and Time of Maximum for Intermediate-Level Vault Radionuclides

Radionuclide [1,2,3]	Nominal PA Case		Best Estimate Case		Ratio	Best Estimate 2 Case		Ratio
	pCi L^{-1} Ci^{-1}	Year	pCi L^{-1} Ci^{-1}	Year		pCi L^{-1} Ci^{-1}	Year	
Np-237	1.59E-29	1,171	3.10E-31	1,171	0.02	8.33E-31	1,171	0.05
U-235	2.74E-30	1,171	9.78E-32	1,171	0.04	2.47E-31	1,171	0.09
Am-241	2.76E-33	1,171	6.15E-35	1,171	0.02	1.62E-34	1,171	0.06
Cm-245	1.74E-33	1,171	3.86E-35	1,171	0.02	9.32E-35	1,171	0.05
Pu-241	9.01E-35	1,171	2.01E-36	1,171	0.02	5.31E-36	1,171	0.06
Cf-249	2.50E-35	1,171	5.39E-37	1,171	0.02	1.23E-36	1,171	0.05
Pu-239	7.51E-37	1,171	2.13E-38	1,171	0.03	4.70E-38	1,171	0.06

Notes:

1 Non-alpha-emitting radionuclides excluded.

2 Radionuclides sorted from highest to lowest nominal PA concentration factor.

3 Only radionuclides with concentration factor >1.0E-40 pCi L^{-1} per Ci parent buried are listed in table.

Table 6-36. Maximum Uranium Concentration Factors at 100-meter POA and Time of Maximum for Intermediate-Level Vault

Radionuclide [1,2,3]	Nominal PA Case		Best Estimate Case		Ratio	Best Estimate 2 Case		Ratio
	µg L^{-1} Ci^{-1}	Year	µg L^{-1} Ci^{-1}	Year		µg L^{-1} Ci^{-1}	Year	
Np-237	5.85E-40	1,171	1.27E-41	1,171	0.02	3.42E-41	1,171	0.06
Am-241	1.01E-43	1,171	2.50E-45	1,171	0.02	6.58E-45	1,171	0.07
Cm-245	6.25E-44	1,171	1.54E-45	1,171	0.02	3.72E-45	1,171	0.06
Pu-241	3.29E-45	1,171	8.16E-47	1,171	0.02	2.15E-46	1,171	0.07
Cf-249	8.89E-46	1,171	2.14E-47	1,171	0.02	4.86E-47	1,171	0.05

Notes:

1 Radionuclides without a uranium-containing decay chain are excluded.

2 Radionuclides are sorted from highest to lowest nominal PA concentration factor.

3 Only radionuclides with concentration factor >1.0E-50 µg L^{-1} per Ci parent buried are listed in table.

6.1.1.2.2. Low-Activity Waste Vault

The description of the ILV sensitivity analysis results in Section 6.1.1.2.1 generally applies to the LAWV and is not repeated here. LAWV results are summarized in Table 6-37 through Table 6-42 and Figure 6-20 through Figure 6-23.

Table 6-37. Maximum All-Pathways Dose Factor at 100-meter POA and Time of Maximum for Low-Activity Waste Vault Radionuclides

Radionuclide [1,2,3]	Nominal PA Case		Best Estimate Case		Ratio	Best Estimate 2 Case		Ratio
	mrem yr^{-1} Ci^{-1}	Year	mrem yr^{-1} Ci^{-1}	Year		mrem yr^{-1} Ci^{-1}	Year	
I-129	1.02E+02	1,166	2.62E+01	1,171	0.26	2.61E+01	1,171	0.26
Tc-99	7.52E-04	1,171	4.02E-06	1,171	5.34E-03	3.99E-06	1,171	5.30E-03
Cl-36	6.41E-04	1,171	9.91E-05	1,171	0.15	9.72E-05	1,171	0.15
H-3	2.10E-11	171	4.23E-11	171	2.01	1.04E-10	175	4.93
Np-237	2.15E-20	1,171	5.13E-24	1,171	2.39E-04	4.82E-24	1,171	2.25E-04
U-235	1.09E-21	1,171	1.34E-25	1,171	1.24E-04	5.81E-26	1,171	5.35E-05
Am-241	2.30E-24	1,171	3.08E-28	1,171	1.34E-04	2.42E-30	1,171	1.05E-06
Cm-245	9.82E-25	1,171	5.78E-29	1,171	5.88E-05	1.37E-34	1,171	1.39E-10
Pu-241	7.41E-26	1,171	9.43E-30	1,171	1.27E-04	3.77E-46	1,171	5.09E-21
K-40	5.23E-26	1,171	1.54E-25	1,171	2.95	1.41E-25	1,171	2.69
Ca-41	1.75E-26	1,171	3.23E-27	1,171	0.19	2.97E-27	1,171	0.17
Pu-239	2.99E-28	1,171	1.96E-32	1,171	6.54E-05	2.70E-39	1,171	9.02E-12
C-14	4.86E-33	1,171	1.43E-36	1,171	2.94E-04	1.34E-36	1,171	2.75E-04

Notes:

1 Radionuclides are sorted from highest to lowest nominal PA dose factor.

2 Only radionuclides with dose factor >1.0E-35 mrem yr^{-1} per Ci parent buried are listed in table.

3 Radionuclide conditions with adverse impact to dose factors are highlighted in orange.

Table 6-38. Low-Activity Waste Vault Sensitivity and Uncertainty Cases: Maximum All-Pathways Dose Factors at 100-meter POA, Difference from Nominal PA Case, and Time of Maximum for Radionuclides with Highest Nominal PA Dose Factor

Radionuclide	Nominal PA Case (mrem yr^{-1} Ci^{-1})	Sensitivity Case 1		Sensitivity Case 2		Sensitivity Case 3		Sensitivity Case 4	
		Concrete Porosity (mrem yr^{-1} Ci^{-1})	Ratio	Concrete Degradation (mrem yr^{-1} Ci^{-1})	Ratio	Concrete Aging (mrem yr^{-1} Ci^{-1})	Ratio	LVZ Porosity (mrem yr^{-1} Ci^{-1})	Ratio
I-129	1.02E+02	9.80E+01	0.96	6.29E+01	0.62	1.02E+02	1.00	1.02E+02	1.00
Tc-99	7.52E-04	1.74E-03	2.32	6.84E-06	9.09E-03	7.52E-04	1.00	7.62E-04	1.01
Cl-36	6.41E-04	9.16E-04	1.43	4.57E-04	0.71	6.40E-04	1.00	6.93E-04	1.08
H-3	2.10E-11	1.53E-11	0.73	1.51E-11	0.72	2.10E-11	1.00	1.44E-11	0.69
Radionuclide	Nominal PA Case (mrem yr^{-1} Ci^{-1})	Sensitivity Case 5		Sensitivity Case 6		Sensitivity Case 7		--	
		Waste Porosity (mrem yr^{-1} Ci^{-1})	Ratio	Infiltration (mrem yr^{-1} Ci^{-1})	Ratio	K_d (mrem yr^{-1} Ci^{-1})	Ratio	--	--
I-129	1.02E+02	7.01E+01	0.69	1.34E+02	1.31	1.34E+02	1.32	--	--
Tc-99	7.52E-04	5.42E-04	0.72	1.43E-02	18.95	3.47E-02	46.14	--	--
Cl-36	6.41E-04	1.42E-04	0.22	1.39E+00	2166.31	1.76E+00	2747.34	--	--
H-3	2.10E-11	3.97E-11	1.89	1.53E-11	0.73	2.10E-11	1.00	--	--

Radionuclide	Time of Peak Dose (Year)							
	Nominal PA Case	Sensitivity Case						
		1	2	3	4	5	6	7
		Concrete Porosity	Concrete Degradation	Concrete Aging	LVZ Porosity	Waste Zone Porosity	Infiltration	K_d
I-129	1,166	1,162	1,171	1,166	1,164	1,171	921	960
Cl-36	1,171	1,171	1,171	1,171	1,171	1,171	1,171	1,171
Tc-99	1,171	1,171	1,171	1,171	1,171	1,171	1,171	1,171
H-3	171	171	171	171	171	171	171	171

Notes:

Green-highlighted cells indicate a time of peak dose that falls within the compliance period.

Table 6-39. Maximum Beta-Gamma Dose Factor at 100-meter POA and Time of Maximum for Low-Activity Waste Vault Radionuclides

Radionuclide [1,2,3]	Nominal PA Case		Best Estimate Case		Ratio	Best Estimate 2 Case		Ratio
	mrem yr^{-1} Ci^{-1}	Year	mrem yr^{-1} Ci^{-1}	Year		mrem yr^{-1} Ci^{-1}	Year	
I-129	1.75E+03	1,166	4.48E+02	1,171	0.26	4.47E+02	1,171	0.26
Tc-99	1.14E-03	1,171	6.09E-06	1,171	5.34E-03	6.05E-06	1,171	5.30E-03
Cl-36	7.13E-04	1,171	1.10E-04	1,171	0.15	1.08E-04	1,171	0.15
H-3	6.04E-10	71	1.43E-09	71	2.37	4.53E-10	175	0.75
Np-237	1.43E-21	1,171	3.41E-25	1,171	2.39E-04	3.21E-25	1,171	2.25E-04
U-235	8.03E-25	1,171	1.75E-28	1,171	2.17E-04	7.47E-29	1,171	9.30E-05
Am-241	1.53E-25	1,171	2.05E-29	1,171	1.34E-04	1.61E-31	1,171	1.05E-06
Cm-245	6.53E-26	1,171	3.84E-30	1,171	5.88E-05	9.09E-36	1,171	1.39E-10
K-40	5.44E-26	1,171	1.60E-25	1,171	2.95	1.46E-25	1,171	2.69
Ca-41	8.53E-27	1,171	1.58E-27	1,171	0.19	1.45E-27	1,171	0.17
Pu-241	4.93E-27	1,171	6.27E-31	1,171	1.27E-04	2.51E-47	1,171	5.09E-21
Pu-239	2.20E-31	1,171	2.52E-35	1,171	1.14E-04	3.36E-42	1,171	1.52E-11
C-14	4.85E-33	1,171	1.43E-36	1,171	2.94E-04	1.33E-36	1,171	2.75E-04

Notes:

1 Radionuclides are sorted from highest to lowest nominal PA dose factor.

2 Only radionuclides with dose factor >1.0E-35 mrem yr^{-1} per Ci parent buried are listed in table.

3 Radionuclide conditions with adverse impact to dose factors are highlighted in orange.

Table 6-40. Low-Activity Waste Vault Sensitivity and Uncertainty Cases: Maximum Beta-Gamma Dose Factors at 100-meter POA, Difference from Nominal PA Case, and Time of Maximum for Radionuclides with Highest Nominal PA Dose Factor

Radionuclide	Nominal PA Case (mrem yr^{-1} Ci^{-1})	Sensitivity Case 1		Sensitivity Case 2		Sensitivity Case 3		Sensitivity Case 4	
		Concrete Porosity (mrem yr^{-1} Ci^{-1})	Ratio	Concrete Degradation (mrem yr^{-1} Ci^{-1})	Ratio	Concrete Aging (mrem yr^{-1} Ci^{-1})	Ratio	LVZ Porosity (mrem yr^{-1} Ci^{-1})	Ratio
I-129	1.75E+03	1.68E+03	0.96	1.08E+03	0.62	1.74E+03	1.00	1.75E+03	1.00
Tc-99	1.14E-03	2.64E-03	2.32	1.04E-05	9.09E-03	1.14E-03	1.00	1.15E-03	1.01
Cl-36	7.13E-04	1.02E-03	1.43	5.08E-04	0.71	7.12E-04	1.00	7.70E-04	1.08
H-3	6.04E-10	4.97E-10	0.82	4.93E-10	0.82	6.04E-10	1.00	4.46E-10	0.74
Radionuclide	Nominal PA Case (mrem yr^{-1} Ci^{-1})	Sensitivity Case 5		Sensitivity Case 6		Sensitivity Case 7		--	
		Waste Porosity (mrem yr^{-1} Ci^{-1})	Ratio	Infiltration (mrem yr^{-1} Ci^{-1})	Ratio	K_d (mrem yr^{-1} Ci^{-1})	Ratio	--	--
I-129	1.75E+03	1.20E+03	0.69	2.28E+03	1.31	2.30E+03	1.32	--	--
Tc-99	1.14E-03	8.22E-04	0.72	2.16E-02	18.95	5.26E-02	46.14	--	--
Cl-36	7.13E-04	1.58E-04	0.22	1.54E+00	2166.31	1.96E+00	2747.34	--	--
H-3	6.04E-10	1.36E-09	2.25	7.28E-10	1.21	6.04E-10	1.00	--	--

Radionuclide	Time of Peak Dose (Year)							
	Nominal PA Case	Sensitivity Case						
		1	2	3	4	5	6	7
		Concrete Porosity	Concrete Degradation	Concrete Aging	LVZ Porosity	Waste Zone Porosity	Infiltration	K_d
I-129	1,166	1,162	1,171	1,166	1,164	1,171	921	983
Tc-99	1,171	1,171	1,171	1,171	1,171	1,171	1,171	1,171
Cl-36	1,171	1,171	1,171	1,171	1,171	1,171	1,171	1,171
H-3	71	71	71	71	71	71	71	71

Notes:

Green-highlighted cells indicate a time of peak dose that falls within the compliance period.

Table 6-41. Maximum Gross-Alpha Concentration Factors at 100-meter POA and Time of Maximum for Low-Activity Waste Vault Radionuclides

Radionuclide [1,2,3]	Nominal PA Case		Best Estimate Case		Ratio	Best Estimate 2 Case		Ratio
	pCi L^{-1} Ci^{-1}	Year	pCi L^{-1} Ci^{-1}	Year		pCi L^{-1} Ci^{-1}	Year	
Np-237	1.07E-19	1,171	2.01E-10	1,171	1.88E+09	1.32E-08	1,171	1.23E+11
U-235	1.23E-21	1,171	2.54E-12	1,171	2.05E+09	1.94E-10	1,171	1.57E+11
Am-241	1.15E-23	1,171	2.33E-14	1,171	2.03E+09	1.61E-12	1,171	1.40E+11
Cm-245	4.90E-24	1,171	1.06E-14	1,171	2.17E+09	7.94E-13	1,171	1.62E+11
Pu-241	3.69E-25	1,171	7.54E-16	1,171	2.04E+09	5.22E-14	1,171	1.41E+11
Pu-239	3.40E-28	1,171	7.35E-19	1,171	2.16E+09	6.27E-17	1,171	1.84E+11

Notes:

1 Non-alpha-emitting radionuclides are excluded.

2 Radionuclides are sorted from highest to lowest nominal PA concentration factor.

3 Only radionuclides with concentration factor >1.0E-30 pCi L^{-1} per Ci parent buried are listed in table.

Table 6-42. Maximum Uranium Concentration Factors for Low-Activity Waste Vault at 100-meter POA and Time of Maximum for Low-Activity Waste Vault Radionuclides

Radionuclide [1,2,3]	Nominal PA Case		Best Estimate Case		Ratio	Best Estimate 2 Case		Ratio
	µg L^{-1} Ci^{-1}	Year	µg L^{-1} Ci^{-1}	Year		µg L^{-1} Ci^{-1}	Year	
Np-237	4.48E-30	1,171	2.40E-33	1,171	5.36E-04	2.24E-33	1,171	5.00E-04
Am-241	4.77E-34	1,171	1.41E-37	1,171	2.96E-04	1.03E-39	1,171	2.16E-06
Cm-245	2.02E-34	1,171	2.59E-38	1,171	1.28E-04	5.41E-44	1,171	2.68E-10
Pu-241	1.54E-35	1,171	4.32E-39	1,171	2.81E-04	1.48E-55	1,171	9.61E-21

Notes:

1 Radionuclides without a uranium-containing decay chain are excluded.

2 Radionuclides are sorted from highest to lowest nominal PA concentration factor.

3 Only radionuclides with concentration factor >1.0E-35 µg L^{-1} per Ci parent buried are listed in table.

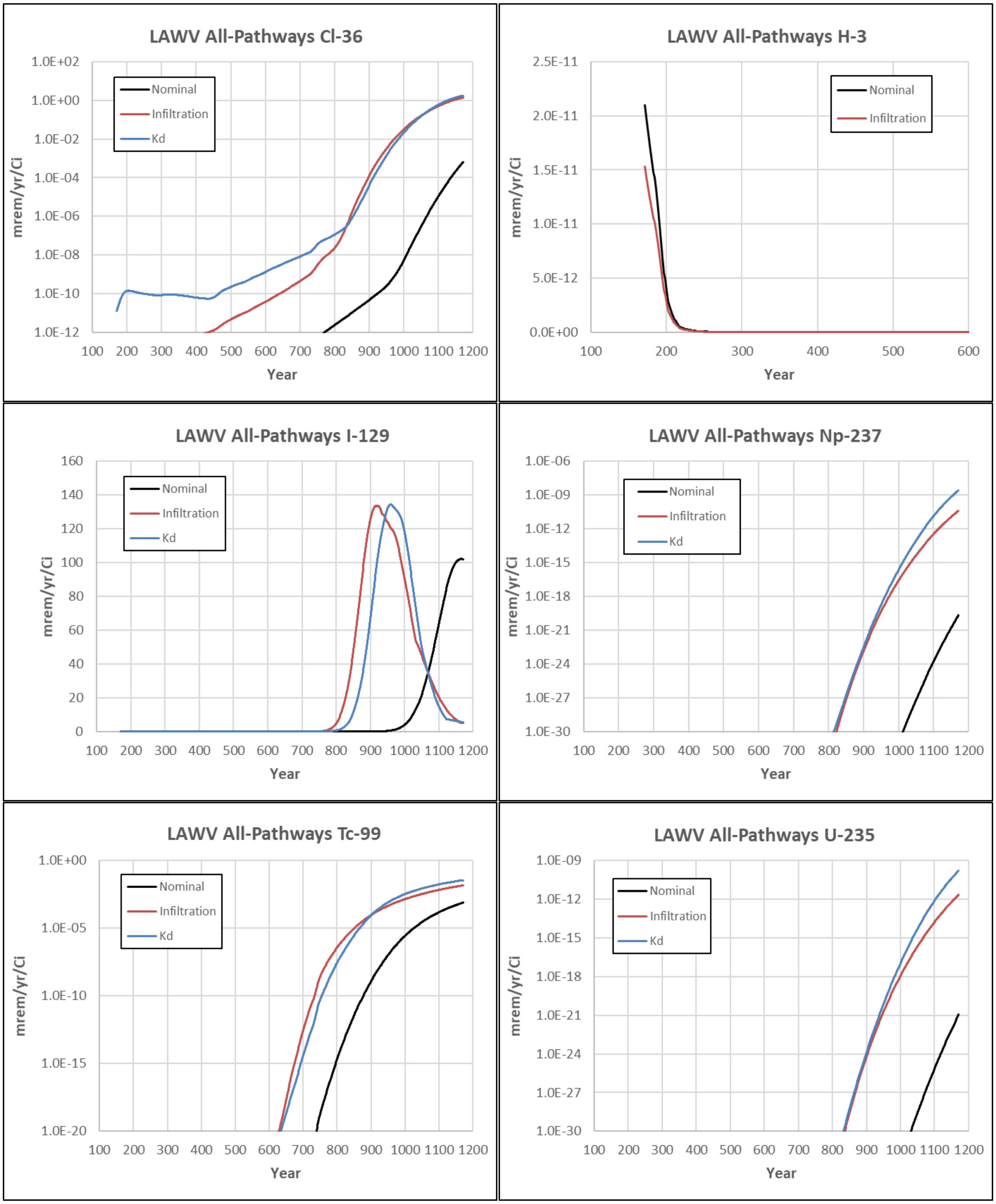


Figure 6-20. Comparison of All-Pathways Dose Factors (mrem yr^{-1} Ci^{-1} parent buried) for Cl-36, H-3, I-129, Np-237, Tc-99, and U-235 at 100-meter POA During Compliance Period for Low-Activity Waste Vault Nominal PA, Infiltration Sensitivity, and K_d Sensitivity Cases

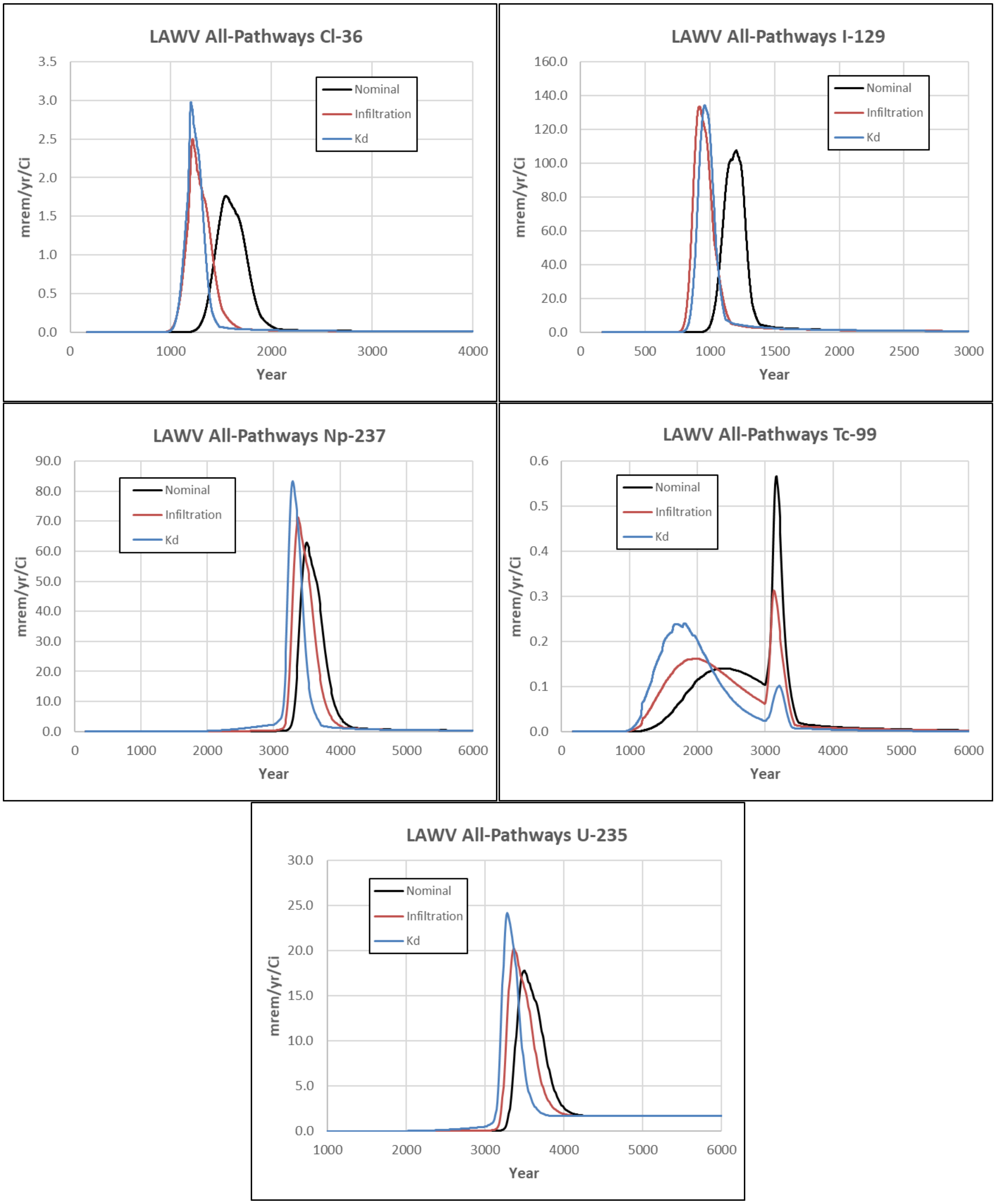


Figure 6-21. Comparison of All-Pathways Dose Factors (mrem yr^{-1} Ci^{-1} parent buried) for Cl-36, I-129, Np-237, Tc-99, and U-235 at 100-meter POA over the Entire Simulation Period for Low-Activity Waste Vault Nominal PA, Infiltration Sensitivity, and K_d Sensitivity Cases

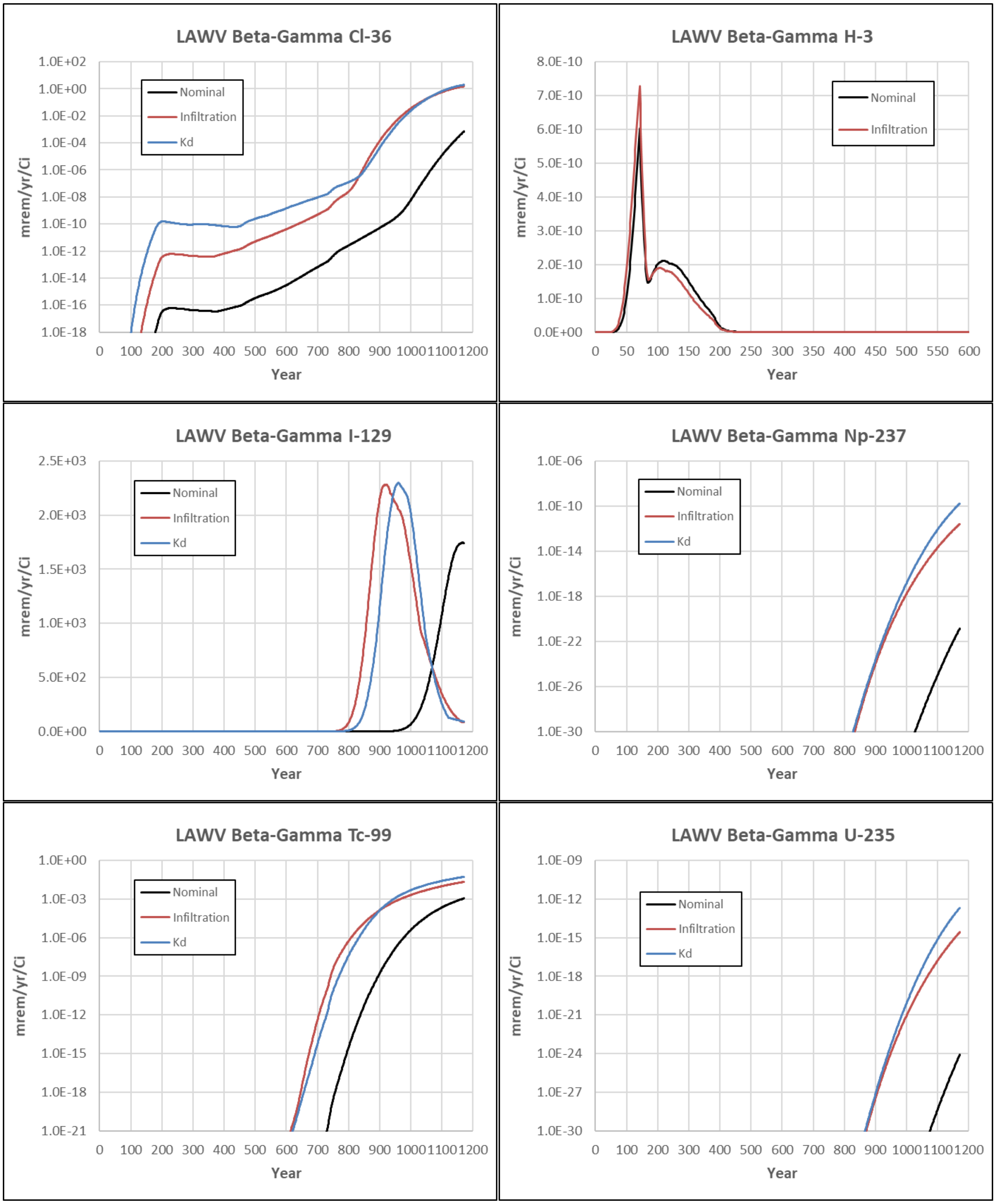


Figure 6-22. Comparison of Beta-Gamma Dose Factors (mrem yr^{-1} Ci^{-1} parent buried) for Cl-36, H-3, I-129, Np-237, Tc-99, and U-235 at 100-meter POA During Compliance Period for Low-Activity Waste Vault Nominal PA, Infiltration Sensitivity, and K_d Sensitivity Cases

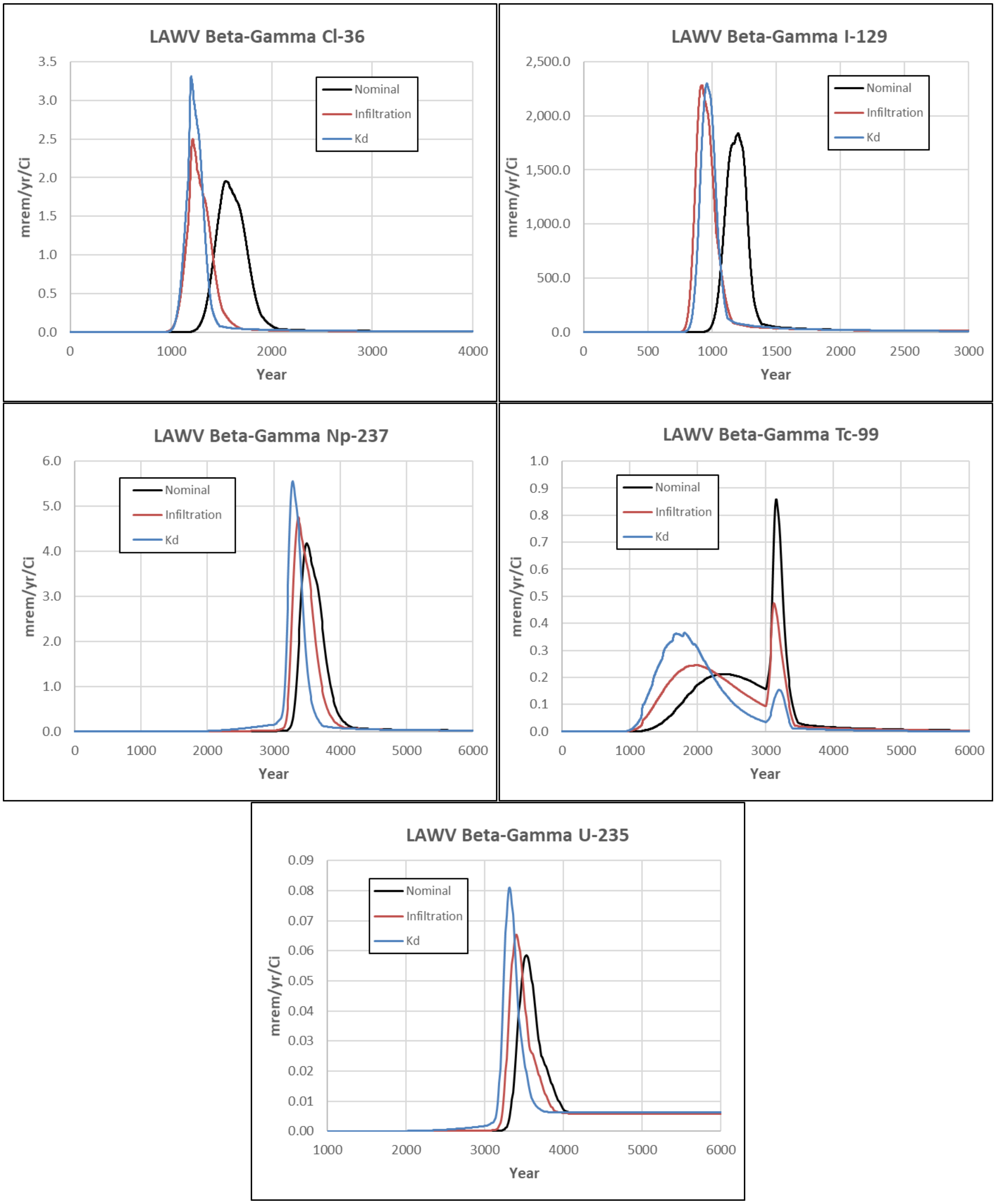


Figure 6-23. Comparison of Beta-Gamma Dose Factors (mrem yr^{-1} Ci^{-1} parent buried) for Cl-36, I-129, Np-237, Tc-99, and U-235 at 100-meter POA over the Entire Simulation Period for Low-Activity Waste Vault Nominal PA, Infiltration Sensitivity, and K_d Sensitivity Cases

6.1.1.3. Naval Reactor Component Disposal Areas

Table 6-43 and Table 6-44 summarize the sensitivity cases, sensitivity parameters, the changes in parameter values used in the sensitivity analyses, and the parameter distribution information for NR07E and NR26E, respectively. The sensitivity parameters and the changes in their values are identical for both NRCDAs. Two tables are provided to help track the various and different waste release and sensitivity cases simulated for the two NRCDAs.

NR07E is already closed; a soil cover was placed over the DU in 2005. NR26E is still in operation; a soil cover will be placed at the end of ELLWF operations in 2065. The nomenclature used to identify the different NRCDA waste release cases is as follows:

- **Case 1:** Waste disposed in bolted containers is released when the soil cover is placed over the NR pad.
- **Case 2:** Waste disposed in bolted containers is released 750 years after disposal.
- **Case 3:** Waste disposed in steel casks is released by corrosion of Inconel starting 750 years after disposal.
- **Case 4:** Waste disposed in steel casks is released by corrosion of Zircaloy starting 750 years after disposal.

In this PA, the integrity of the NR steel disposal casks and bolted containers is assumed to be compromised after 750 years due to corrosion, thereby releasing waste material to the environment. Steel disposal casks on the NRCDA pads contain contaminated metal components. A description of waste disposed in the NRCDAs is provided in Section 2.2.7.2. The PORFLOW flow and transport model of the NRCDA source and vadose zones is developed in Section 4.7.8.

Two scenarios are modeled: contaminant release caused by corrosion of (1) Zircaloy metal and (2) Inconel metal. Three of the four contaminant release cases for the two NRCDAs are modeled using a complete set of sensitivity parameters as follows:

- NR07E, Case 3
- NR26E, Case 1
- NR26E, Case 4

In addition, all four cases for the two NRCDAs are modeled assuming waste is disposed at the (a) start and (b) closure of NRCDA operations. These results are designated as "Disposal Time" sensitivity studies (Sensitivity Case S6). Table F-1 through Table F-20 in Appendix F provide 20 sets of supplemental tabular results for Sensitivity Case S6 (waste disposal timing) for NR07E and NR26E simulation cases (PORFLOW Cases 1 to 4) where no additional sensitivity analyses (Sensitivity Cases 1 to 5) are conducted. These results are of secondary interest because they are not complete sensitivity analyses.

Table 6-43. Sensitivity and Uncertainty Parameters for NR07E

NR07E Sensitivity Case No.[a]	Topic	Nominal PA (Best Estimate) Case	Sensitivity Case	Δ(SV) (Sensitivity – Nominal)	Standard Deviations	Distribution	Mean	Standard Deviation	Minimum	Maximum
3-1	Waste Zone Hydraulic Conductivity (cm s^{-1})	2.20E-05[b]	4.08E-05[b]	1.88E-05	+4σ	Truncated Normal	2.20E-05	4.70E-06	-4σ	+4σ
3-2	LVZ Porosity	0.381	0.420	0.039	+1σ	Truncated Normal	0.381	0.040	-3σ	+3σ
3-3	Waste Zone Porosity	0.889[b]	0.939[b]	0.050	+1.5σ	Truncated Normal	0.889	0.033	-3σ	+3σ
3-4	Precipitation/ Infiltration (cm yr^{-1})	2019 HELP Model Bounding Cap Design with Best Estimate Rainfall[e]	2019 HELP Model Bounding Cap Design with Pessimistic Rainfall[e]	31.9	+1.6σ	Truncated Normal	124.8[c] 156.7[d]	19.9	-2σ	+2σ
3-5	K_d	2016 GeoChem Database	0.5*K_d	-0.5	-2.5σ	Truncated Normal	1	0.2	-3σ	+3σ
3-6	Waste Disposal Timing	0 (Start of Operations)	1 (Soil Cover Placement)[b]	1	--	Uniform	--	--	0	1

Notes:

[a] NRCDA Case 3: Inconel corrosion starting 750 years after disposal

[b] 11 years after the start of operations

[c] Annual average rainfall

[d] Pessimistic (+1.6σ) annual rainfall

[e] The nominal PA infiltration profile is designated as “Bounding cap design best estimate (BE) rainfall” and the sensitivity case infiltration profile as “Bounding cap design pessimistic rainfall.” Refer to Figure 6-2 and Figure 6-3.

Table 6-44. Sensitivity and Uncertainty Parameters for NR26E

NR07E Sensitivity Case No.[a]	Topic	Nominal PA (Best Estimate) Case	Sensitivity Case	Δ(SV) (Sensitivity – Nominal)	Standard Deviations	Distribution	Mean	Standard Deviation	Minimum	Maximum
1-1 4-1	Waste Zone Hydraulic Conductivity ($cm\ s^{-1}$)	2.20E-05[b]	4.08E-05[b]	1.88E-05	+4σ	Truncated Normal	2.20E-05	4.70E-06	-4σ	+4σ
1-2 4-2	LVZ Porosity	0.381	0.420	0.039	+1σ	Truncated Normal	0.381	0.040	-3σ	+3σ
1-3 4-3	Waste Zone Porosity	0.889[b]	0.939[b]	0.050	+1.5σ	Truncated Normal	0.889	0.033	-3σ	+3σ
1-4 4-4	Precipitation/ Infiltration ($cm\ yr^{-1}$)	2019 HELP Model Bounding Cap Design with Best Estimate Rainfall[e]	2019 HELP Model Bounding Cap Design with Pessimistic Rainfall[e]	31.9	+1.6σ	Truncated Normal	124.8[c] 156.7[d]	19.9	-2σ	+2σ
1-5 4-5	K_d	2016 GeoChem Database	0.5*K_d	-0.5	-2.5σ	Truncated Normal	1	0.2	-3σ	+3σ
1-6 4-6	Waste Disposal Timing	0 (Start of Operations)	1 (Soil Cover Placement)[b]	1	--	Uniform	--	--	0	1

Notes:

[a] NRCDA Case 1: Instantaneous release at time of soil cover placement
NRCDA Case 4: Zircaloy corrosion starting 750 years after disposal

[b] 71 years after the start of operations

[c] Annual average rainfall

[d] Pessimistic (+1.6σ) annual rainfall

[e] The nominal PA infiltration profile is designated as “Bounding cap design best estimate (BE) rainfall” and the sensitivity case infiltration profile as “Bounding cap design pessimistic rainfall.” Refer to Figure 6-2 and Figure 6-3.

With two NR disposal locations, four waste release scenarios, and various sensitivity cases for all-pathways dose and GW protection, substantial PORFLOW model simulation output is available. These data are organized into the summary tables and graphs provided in Section 6.1.1.3.1 for NR07E and Section 6.1.1.3.2 for NR26E. A general description of the results is provided below for NR07E but is not repeated for NR26E.

6.1.1.3.1. NR07E

Table 6-45 summarizes all-pathways peak dose factors (mrem yr^{-1} Ci^{-1} parent buried at 100-meter POA) during the compliance period for NR07E (PORFLOW deterministic Case 3); the difference in peak dose factor relative to the nominal PA case; and time when the peak dose occurs. Reported results are limited to radionuclides with the highest nominal PA dose factor. For some of the radionuclides, all-pathways dose factors during the compliance period for the nominal PA, infiltration sensitivity, and K_d sensitivity cases are plotted in Figure 6-24 for C-14 as well as the five parent radionuclides contributing the largest all-pathways dose (i.e., I-129, Tc-99, Cl-36, Np-237, and U-235). Except for Tc-99, results are plotted using a logarithmic scale for the *y*-axis to highlight the difference between the nominal PA and sensitivity cases. Figure 6-24 displays the impact that infiltration rate and K_d have on dose factor. Figure 6-25 shows all-pathways peak dose factors over the entire simulation period for the same six radionuclides. This pattern is repeated for GW protection beta-gamma dose factor (mrem yr^{-1} Ci^{-1}) at the 100-meter POA (Table 6-46, Figure 6-26, and Figure 6-27). Only tabular results (Table 6-47 and Table 6-48, respectively) are provided for GW protection gross-alpha concentration factor (pCi L^{-1} Ci^{-1}) and uranium concentration factor (µg L^{-1} Ci^{-1}) because the peak values occur well beyond the compliance period. No results are shown for radium because there are no sources of radium in NRCDA waste materials.

For NR07E (Case 3), six of the parent radionuclides contributing to the largest all-pathways dose factors are I-129S, Tc-99S, Cl-36S, Np-237S, U-235S, and Am-241S as shown in Table 6-45. These same six radionuclides also contribute the largest nominal-PA beta-gamma dose factors for Case 3 (Table 6-46). In contrast, for PORFLOW deterministic Case 1, which assumes early release of waste, H-3 contributes the fifth-largest dose (results not shown). Only four parent radionuclides (Np-237S, U-235S, Am-241S, and Pu-241S) contribute to gross-alpha and uranium emissions (Table 6-47 and Table 6-48, respectively), with U-235S having a negligible uranium concentration factor.

Table 6-45. NR07E (Case 3) Sensitivity and Uncertainty Cases: Maximum All-Pathways Dose Factors at 100-meter POA, Difference from Nominal PA Case, and Time of Maximum

Radio-nuclide	Nominal PA Case (mrem yr^{-1} Ci^{-1})	Sensitivity Case 1		Sensitivity Case 2		Sensitivity Case 3	
		Waste Zone Conductivity (mrem yr^{-1} Ci^{-1})	Ratio	LVZ Porosity (mrem yr^{-1} Ci^{-1})	Ratio	Waste Zone Porosity (mrem yr^{-1} Ci^{-1})	Ratio
I-129S	3.59E-01	3.86E-01	1.07	3.95E-01	1.10	4.17E-01	1.16
Tc-99S	1.24E-01	1.28E-01	1.03	1.27E-01	1.02	1.30E-01	1.04
Cl-36S	1.17E-06	1.29E-06	1.10	1.32E-06	1.13	1.68E-06	1.43
Np-237S	3.25E-09	3.65E-09	1.12	4.65E-09	1.43	4.80E-09	1.47
U-235S	2.38E-10	2.66E-10	1.12	3.39E-10	1.43	3.50E-10	1.48
Am-241S	4.73E-13	5.30E-13	1.12	6.76E-13	1.43	6.98E-13	1.47
Pu-241S	1.55E-14	1.74E-14	1.12	2.21E-14	1.43	2.29E-14	1.47
C-14S	1.31E-14	1.45E-14	1.11	1.50E-14	1.15	2.14E-14	1.64
Be-10S	1.09E-17	1.23E-17	1.13	1.73E-17	1.59	1.71E-17	1.58
Ni-59S	6.69E-25	7.60E-25	1.13	1.12E-24	1.68	1.09E-24	1.63
Ni-63S	3.86E-28	4.38E-28	1.13	6.48E-28	1.68	6.29E-28	1.63
Radio-nuclide	**Nominal PA Case (mrem yr^{-1} Ci^{-1})**	**Sensitivity Case 4**		**Sensitivity Case 5**		**Sensitivity Case 6**	
		Infiltration (mrem yr^{-1} Ci^{-1})	**Ratio**	***K_d* (mrem yr^{-1} Ci^{-1})**	**Ratio**	**Disposal Time (mrem yr^{-1} Ci^{-1})**	**Ratio**
I-129S	3.59E-01	5.54E+00	1.54E+01	1.61E+01	4.47E+01	2.48E-01	0.69
Tc-99S	1.24E-01	2.25E-01	1.81E+00	2.54E-01	2.05E+00	1.05E-01	0.85
Cl-36S	1.17E-06	2.06E-04	1.76E+02	5.56E-03	4.76E+03	6.80E-07	0.58
Np-237S	3.25E-09	4.40E-06	1.35E+03	2.31E-04	7.10E+04	1.51E-09	0.46
U-235S	2.38E-10	3.21E-07	1.35E+03	1.71E-05	7.19E+04	1.10E-10	0.46
Am-241S	4.73E-13	6.40E-10	1.35E+03	3.38E-08	7.14E+04	2.19E-13	0.46
Pu-241S	1.55E-14	2.10E-11	1.35E+03	1.11E-09	7.14E+04	7.16E-15	0.46
C-14S	1.31E-14	1.04E-11	7.94E+02	1.99E-09	1.53E+05	6.86E-15	0.53
Be-10S	1.09E-17	6.05E-14	5.56E+03	5.42E-10	4.98E+07	4.33E-18	0.40
Ni-59S	6.69E-25	7.54E-21	1.13E+04	4.71E-16	7.03E+08	2.40E-25	0.36
Ni-63S	3.86E-28	4.40E-24	1.14E+04	2.84E-19	7.34E+08	1.58E-28	0.41

Radio-nuclide	Time of Peak Dose (Year)						
	Nominal PA Case	Sensitivity Case					
		1	2	3	4	5	6
		Waste Zone Conductivity	LVZ Porosity	Waste Zone Porosity	Infiltration	*K_d*	Disposal Time
I-129S	1,171	1,171	1,171	1,171	1,171	1,171	1,171
Tc-99S	1,171	1,171	1,171	1,171	1,171	1,150	1,171
Cl-36S	1,171	1,171	1,171	1,171	1,171	1,171	1,171
Np-237S	1,171	1,171	1,171	1,171	1,171	1,171	1,171
U-235S	1,171	1,171	1,171	1,171	1,171	1,171	1,171
Am-241S	1,171	1,171	1,171	1,171	1,171	1,171	1,171
Pu-241S	1,171	1,171	1,171	1,171	1,171	1,171	1,171
C-14S	1,171	1,171	1,171	1,171	1,171	1,171	1,171
Be-10S	1,171	1,171	1,171	1,171	1,171	1,171	1,171
Ni-59S	1,171	1,171	1,171	1,171	1,171	1,171	1,171
Ni-63S	1,171	1,171	1,171	1,171	1,171	1,171	1,171

Notes: NR07E Case 3 - Inconel waste in steel casks.

Green-highlighted cells indicate a time of peak dose that falls within the compliance period.

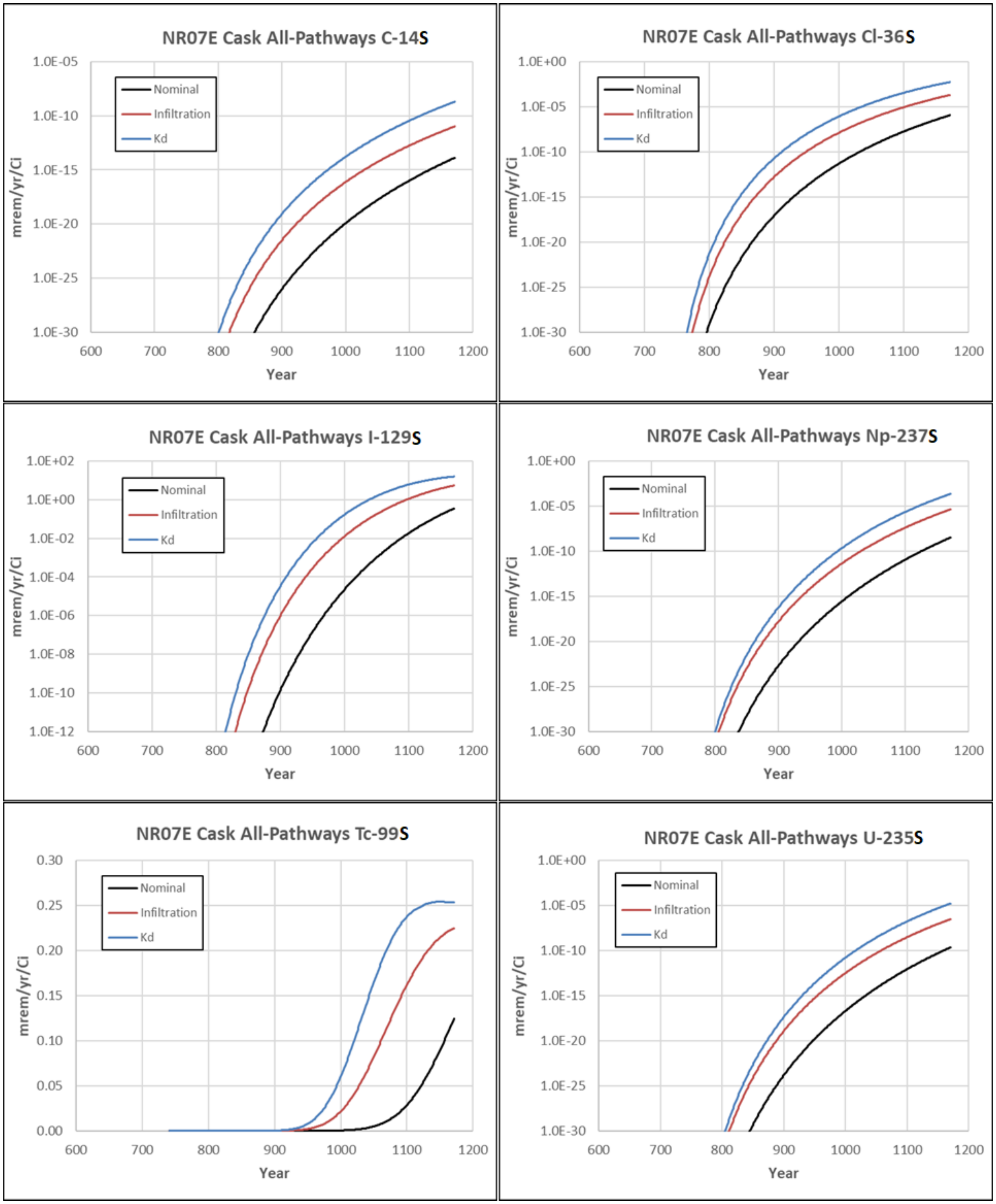


Figure 6-24. Comparison of All-Pathways Dose Factors (mrem yr^{-1} Ci^{-1} parent buried) for C-14S, Cl-36S, I-129S, Np-237S, Tc-99S, and U-235S at 100-meter POA During Compliance Period for NR07E (Case 3) Nominal PA, Infiltration Sensitivity, and K_d Sensitivity Cases

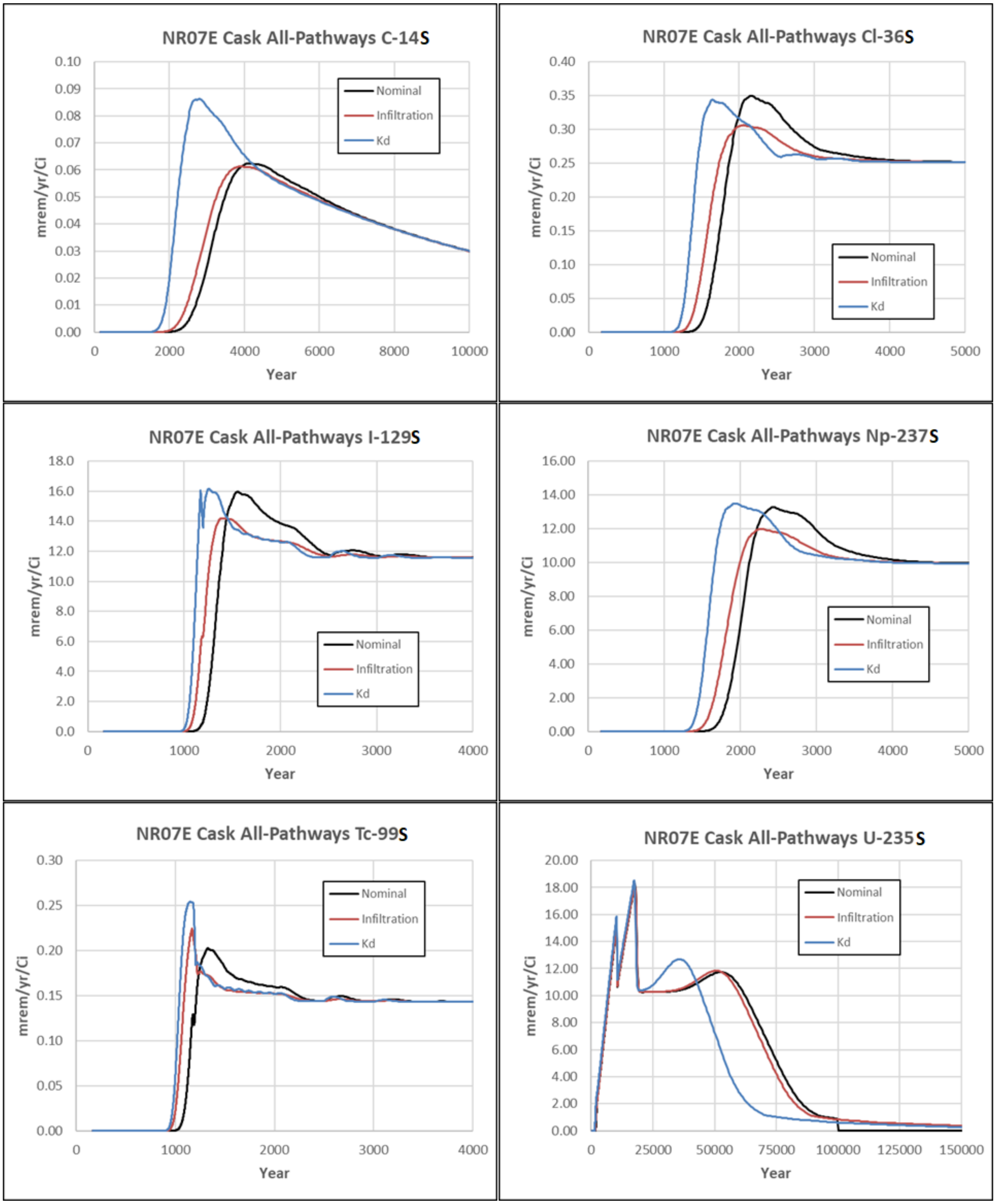


Figure 6-25. Comparison of All-Pathways Peak Dose Factors (mrem yr^{-1} Ci^{-1} parent buried) for C-14S, Cl-36S, I-129S, Np-237S, Tc-99S, and U-235S at 100-meter POA over the Entire Simulation Period for NR07E (Case 3) Nominal PA, Infiltration Sensitivity, and K_d Sensitivity Cases

Table 6-46. NR07E (Case 3) Sensitivity and Uncertainty Cases: Maximum Beta-Gamma Dose Factors at 100-meter POA, Difference from Nominal PA Case, and Time of Maximum

Radio-nuclide	Nominal PA Case (mrem yr^{-1} Ci^{-1})	Sensitivity Case 1		Sensitivity Case 2		Sensitivity Case 3	
		Waste Zone Conductivity (mrem yr^{-1} Ci^{-1})	Ratio	LVZ Porosity (mrem yr^{-1} Ci^{-1})	Ratio	Waste Zone Porosity (mrem yr^{-1} Ci^{-1})	Ratio
I-129S	6.14E+00	6.60E+00	1.07	6.75E+00	1.10	7.13E+00	1.16
Tc-99S	1.88E-01	1.94E-01	1.03	1.92E-01	1.02	1.96E-01	1.04
Cl-36S	1.30E-06	1.43E-06	1.10	1.47E-06	1.13	1.86E-06	1.43
Np-237S	2.16E-10	2.42E-10	1.12	3.09E-10	1.43	3.19E-10	1.47
U-235S	2.58E-13	2.90E-13	1.12	3.71E-13	1.44	3.81E-13	1.48
Am-241S	3.15E-14	3.53E-14	1.12	4.49E-14	1.43	4.64E-14	1.47
C-14S	1.30E-14	1.45E-14	1.11	1.50E-14	1.15	2.14E-14	1.64
Pu-241S	1.03E-15	1.16E-15	1.12	1.47E-15	1.43	1.52E-15	1.47
Be-10S	1.85E-17	2.09E-17	1.13	2.94E-17	1.59	2.92E-17	1.58
Ni-59S	6.45E-23	7.32E-23	1.13	1.08E-22	1.68	1.05E-22	1.63
Ni-63S	8.99E-26	1.02E-25	1.13	1.51E-25	1.68	1.46E-25	1.63
Radio-nuclide	Nominal PA Case (mrem yr^{-1} Ci^{-1})	Sensitivity Case 4		Sensitivity Case 5		Sensitivity Case 6	
		Infiltration (mrem yr^{-1} Ci^{-1})	Ratio	K_d (mrem yr^{-1} Ci^{-1})	Ratio	Disposal Time (mrem yr^{-1} Ci^{-1})	Ratio
I-129S	6.14E+00	9.47E+01	1.54E+01	2.74E+02	4.47E+01	4.23E+00	0.69
Tc-99S	1.88E-01	3.41E-01	1.81E+00	3.85E-01	2.05E+00	1.59E-01	0.85
Cl-36S	1.30E-06	2.29E-04	1.76E+02	6.18E-03	4.76E+03	7.56E-07	0.58
Np-237S	2.16E-10	2.93E-07	1.35E+03	1.54E-05	7.10E+04	1.00E-10	0.46
U-235S	2.58E-13	3.97E-10	1.54E+03	2.14E-08	8.28E+04	1.16E-13	0.45
Am-241S	3.15E-14	4.25E-11	1.35E+03	2.25E-09	7.14E+04	1.45E-14	0.46
C-14S	1.30E-14	1.03E-11	7.94E+02	1.99E-09	1.53E+05	6.84E-15	0.53
Pu-241S	1.03E-15	1.39E-12	1.35E+03	7.36E-11	7.14E+04	4.76E-16	0.46
Be-10S	1.85E-17	1.03E-13	5.56E+03	9.22E-10	4.98E+07	7.37E-18	0.40
Ni-59S	6.45E-23	7.27E-19	1.13E+04	4.53E-14	7.03E+08	2.31E-23	0.36
Ni-63S	8.99E-26	1.02E-21	1.14E+04	6.60E-17	7.34E+08	3.67E-26	0.41

Radio-nuclide	Time of Peak Dose (Year)						
	Nominal PA Case	Sensitivity Case					
		1	2	3	4	5	6
		Waste Zone Conductivity	LVZ Porosity	Waste Zone Porosity	Infiltration	K_d	Disposal Time
I-129S	1,171	1,171	1,171	1,171	1,171	1,171	1,171
Tc-99S	1,171	1,171	1,171	1,171	1,171	1,150	1,171
Cl-36S	1,171	1,171	1,171	1,171	1,171	1,171	1,171
Np-237S	1,171	1,171	1,171	1,171	1,171	1,171	1,171
U-235S	1,171	1,171	1,171	1,171	1,171	1,171	1,171
Am-241S	1,171	1,171	1,171	1,171	1,171	1,171	1,171
C-14S	1,171	1,171	1,171	1,171	1,171	1,171	1,171
Pu-241S	1,171	1,171	1,171	1,171	1,171	1,171	1,171
Be-10S	1,171	1,171	1,171	1,171	1,171	1,171	1,171
Ni-59S	1,171	1,171	1,171	1,171	1,171	1,171	1,171
Ni-63S	1,171	1,171	1,171	1,171	1,171	1,171	1,171

Notes: NR07E Case 3 - Inconel waste in steel casks.

Green-highlighted cells indicate a time of peak dose that falls within the compliance period.

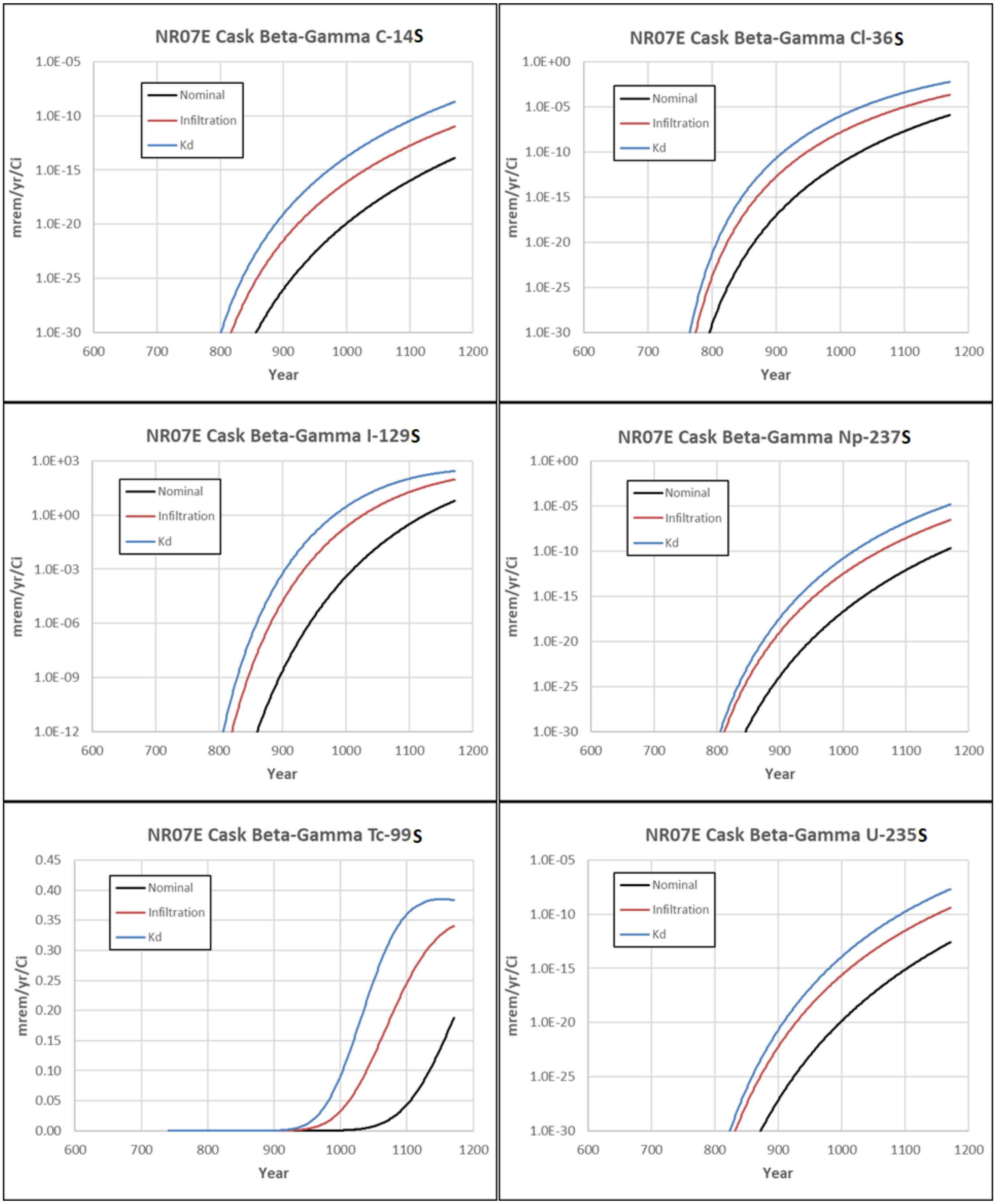


Figure 6-26. Comparison of Beta-Gamma Dose Factors (mrem yr^{-1} Ci^{-1} parent buried) for C-14S, Cl-36S, I-129S, Np-237S, Tc-99S, and U-235S at 100-meter POA During Compliance Period for NR07E (Case 3) Nominal PA, Infiltration Sensitivity, and K_d Sensitivity Cases

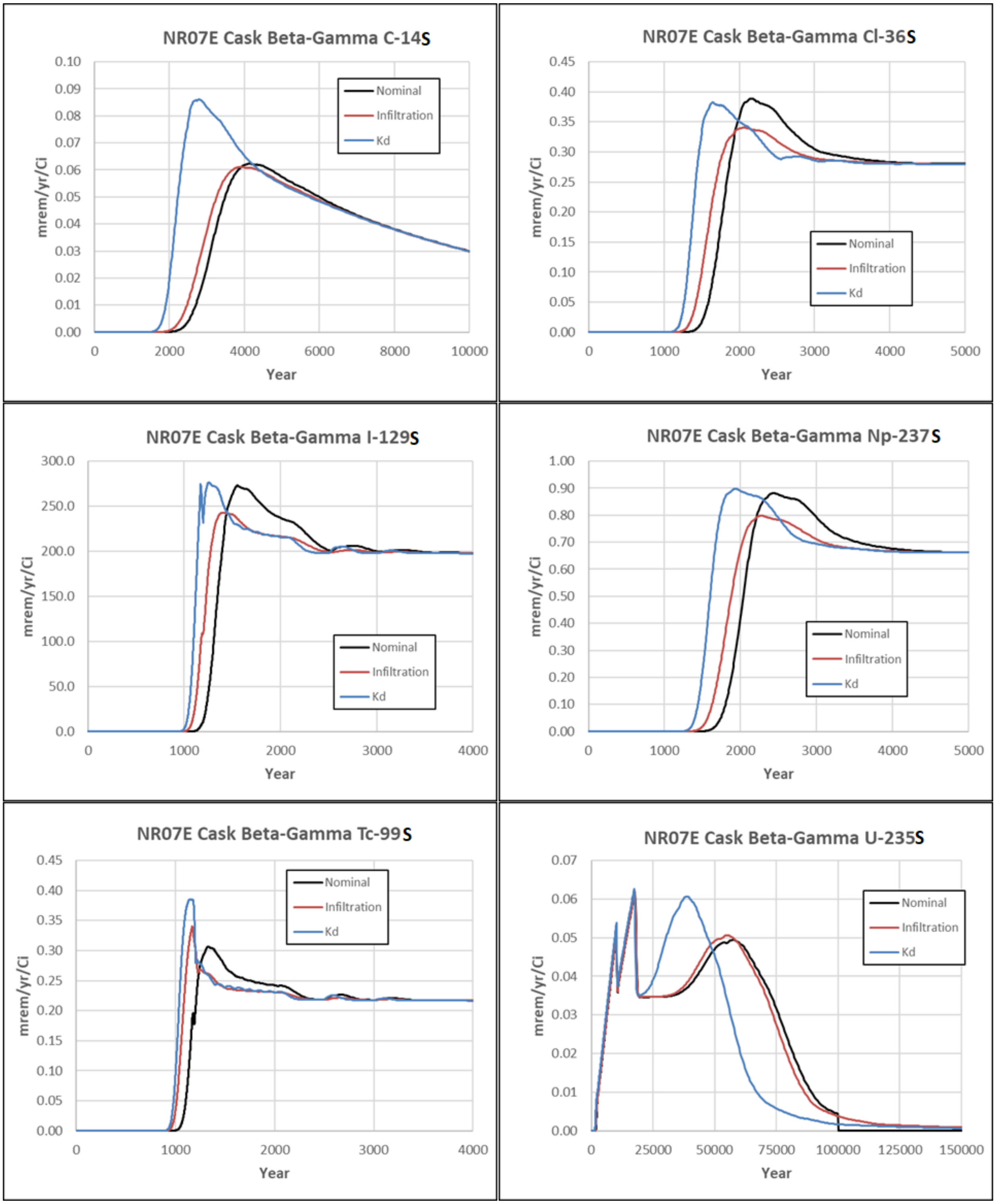


Figure 6-27. Comparison of Beta-Gamma Dose Factors (mrem yr^{-1} Ci^{-1} parent buried) for C-14S, Cl-36S, I-129S, Np-237S, Tc-99S, and U-235S at 100-meter POA over the Entire Simulation Period for NR07E (Case 3) Nominal PA, Infiltration Sensitivity, and K_d Sensitivity Cases

Table 6-47. NR07E (Case 3) Sensitivity and Uncertainty Cases: Maximum Gross-Alpha Concentration Factors at 100-meter POA, Difference from Nominal PA Case, and Time of Maximum

Radio-nuclide	Nominal PA Case (pCi L^{-1} Ci^{-1})	Sensitivity Case 1		Sensitivity Case 2		Sensitivity Case 3	
		Waste Zone Conductivity (pCi L^{-1} Ci^{-1})	Ratio	LVZ Porosity (pCi L^{-1} Ci^{-1})	Ratio	Waste Zone Porosity (pCi L^{-1} Ci^{-1})	Ratio
Np-237S	1.62E-08	1.82E-08	1.12	2.32E-08	1.43	2.39E-08	1.47
U-235S	2.70E-10	3.03E-10	1.12	3.86E-10	1.43	3.99E-10	1.48
Am-241S	2.36E-12	2.64E-12	1.12	3.37E-12	1.43	3.48E-12	1.47
Pu-241S	7.73E-14	8.66E-14	1.12	1.10E-13	1.43	1.14E-13	1.47
Radio-nuclide	**Nominal PA Case (pCi L^{-1} Ci^{-1})**	**Sensitivity Case 4**		**Sensitivity Case 5**		**Sensitivity Case 6**	
		Infiltration (pCi L^{-1} Ci^{-1})	**Ratio**	**K_d (pCi L^{-1} Ci^{-1})**	**Ratio**	**Disposal Time (pCi L^{-1} Ci^{-1})**	**Ratio**
Np-237S	1.62E-08	2.19E-05	1.35E+03	1.15E-03	7.10E+04	7.51E-09	0.46
U-235S	2.70E-10	3.66E-07	1.35E+03	1.94E-05	7.19E+04	1.25E-10	0.46
Am-241S	2.36E-12	3.19E-09	1.35E+03	1.68E-07	7.14E+04	1.09E-12	0.46
Pu-241S	7.73E-14	1.05E-10	1.35E+03	5.52E-09	7.14E+04	3.57E-14	0.46

Radio-nuclide	Time of Peak Concentration (Year)						
	Nominal PA Case	Sensitivity Case					
		1	2	3	4	5	6
		Waste Zone Conductivity	LVZ Porosity	Waste Zone Porosity	Infiltration	K_d	Disposal Time
Np-237S	1,171	1,171	1,171	1,171	1,171	1,171	1,171
U-235S	1,171	1,171	1,171	1,171	1,171	1,171	1,171
Am-241S	1,171	1,171	1,171	1,171	1,171	1,171	1,171
Pu-241S	1,171	1,171	1,171	1,171	1,171	1,171	1,171

Notes:

NR07E Case 3: Inconel waste in steel casks.

Table 6-48. NR07E (Case 3) Sensitivity and Uncertainty Cases: Maximum Uranium Concentration Factors at 100-meter POA, Difference from Nominal PA Case, and Time of Maximum

Radionuclide	Nominal PA Case (µg L⁻¹ Ci⁻¹)	Sensitivity Case 1		Sensitivity Case 2		Sensitivity Case 3	
		Waste Zone Conductivity (µg L⁻¹ Ci⁻¹)	Ratio	LVZ Porosity (µg L⁻¹ Ci⁻¹)	Ratio	Waste Zone Porosity (µg L⁻¹ Ci⁻¹)	Ratio
Np-237S	1.12E-18	1.26E-18	1.12	1.62E-18	1.44	1.66E-18	1.48
Am-241S	1.63E-22	1.83E-22	1.12	2.35E-22	1.44	2.41E-22	1.48
Pu-241S	5.35E-24	6.00E-24	1.12	7.69E-24	1.44	7.89E-24	1.48
U-235S	6.37E-87	7.31E-87	1.15	1.24E-86	1.94	1.12E-86	1.76
Radionuclide	Nominal PA Case (µg L⁻¹ Ci⁻¹)	Sensitivity Case 4		Sensitivity Case 5		Sensitivity Case 6	
		Infiltration (µg L⁻¹ Ci⁻¹)	Ratio	*K_d* (µg L⁻¹ Ci⁻¹)	Ratio	Disposal Time (µg L⁻¹ Ci⁻¹)	Ratio
Np-237S	1.12E-18	1.83E-15	1.63E+03	9.80E-14	8.72E+04	5.01E-19	0.45
Am-241S	1.63E-22	2.66E-19	1.63E+03	1.43E-17	8.76E+04	7.27E-23	0.45
Pu-241S	5.35E-24	8.70E-21	1.63E+03	4.69E-19	8.76E+04	2.38E-24	0.45
U-235S	6.37E-87	4.91E-82	7.71E+04	3.66E-79	5.75E+07	1.23E-87	0.19

Radio-nuclide	Time of Peak Concentration (Year)						
	Nominal PA Case	Sensitivity Case					
		1	2	3	4	5	6
		Waste Zone Conductivity	LVZ Porosity	Waste Zone Porosity	Infiltration	K_d	Disposal Time
Np-237S	1,171	1,171	1,171	1,171	1,171	1,171	1,171
Am-241S	1,171	1,171	1,171	1,171	1,171	1,171	1,171
Pu-241S	1,171	1,171	1,171	1,171	1,171	1,171	1,171
U-235S	1,171	1,171	1,171	1,171	1,171	1,171	1,171

Notes: NR07E Case 3: Inconel waste in steel casks.

6.1.1.3.2. NR26E

Similar results are provided for NR26E for select radionuclides as follows:

PORFLOW Deterministic Case 1

- All-Pathways: Table 6-49, Figure 6-28, and Figure 6-29
- Beta-Gamma: Table 6-51, Figure 6-32, and Figure 6-33
- Gross-Alpha: Table 6-53
- Uranium: Table 6-55

PORFLOW Deterministic Case 4

- All-Pathways: Table 6-50, Figure 6-30, and Figure 6-31
- Beta-Gamma: Table 6-52, Figure 6-34, and Figure 6-35
- Gross-Alpha: Table 6-54
- Uranium: Table 6-56

The six parent radionuclide species contributing the largest all-pathways dose factors for Case 1 are I-129, Tc-99, Np-237, Cl-36, U-235, and Am-241 (generic), and for Case 4 are I-129S, Tc-99S, Np-237S, Cl-36S, U-235S, and Am-241S (SWF0). These same radionuclides contribute the largest all-pathways dose factors for NR07E.

Table 6-49. NR26E (Case 1) Sensitivity and Uncertainty Cases: Maximum All-Pathways Dose Factors at 100-meter POA, Difference from Nominal PA Case, and Time of Maximum

Radio-nuclide	Nominal PA Case (mrem yr^{-1} Ci^{-1})	Sensitivity Case 1		Sensitivity Case 2		Sensitivity Case 3	
		Waste Zone Conductivity (mrem yr^{-1} Ci^{-1})	Ratio	LVZ Porosity (mrem yr^{-1} Ci^{-1})	Ratio	Waste Zone Porosity (mrem yr^{-1} Ci^{-1})	Ratio
I-129	4.66E+01	4.66E+01	1.00	4.65E+01	1.00	4.65E+01	1.00
Tc-99	1.69E+00	1.71E+00	1.01	1.78E+00	1.05	1.75E+00	1.03
Cl-36	3.87E-01	3.90E-01	1.01	4.05E-01	1.05	4.12E-01	1.07
Np-237	1.54E-01	1.56E-01	1.02	2.14E-01	1.39	1.81E-01	1.18
U-235	1.21E-03	1.23E-03	1.02	1.69E-03	1.40	1.43E-03	1.19
Am-241	3.98E-06	4.04E-06	1.02	5.55E-06	1.40	4.71E-06	1.18
C-14	1.26E-06	1.28E-06	1.02	1.42E-06	1.12	1.87E-06	1.49
H-3	1.07E-06	1.07E-06	1.00	1.09E-06	1.02	1.07E-06	1.00
Pu-241	1.02E-07	1.04E-07	1.02	1.43E-07	1.40	1.21E-07	1.19
Ni-59	1.68E-14	1.71E-14	1.02	3.29E-14	1.96	2.67E-14	1.59
Ni-63	1.10E-17	1.13E-17	1.02	2.17E-17	1.97	1.76E-17	1.60
Sr-90	3.69E-18	3.76E-18	1.02	7.51E-18	2.04	5.79E-18	1.57
Radio-nuclide	Nominal PA Case (mrem yr^{-1} Ci^{-1})	Sensitivity Case 4		Sensitivity Case 5		Sensitivity Case 6	
		Infiltration (mrem yr^{-1} Ci^{-1})	Ratio	K_d (mrem yr^{-1} Ci^{-1})	Ratio	Disposal Time (mrem yr^{-1} Ci^{-1})	Ratio
I-129	4.66E+01	1.34E+02	2.88E+00	2.48E+02	5.33E+00	4.66E+01	1.00
Tc-99	1.69E+00	4.25E+00	2.51E+00	3.19E+00	1.88E+00	1.70E+00	1.00
Cl-36	3.87E-01	8.10E-01	2.10E+00	9.34E-01	2.42E+00	3.87E-01	1.00
Np-237	1.54E-01	1.47E+01	9.55E+01	3.56E+01	2.32E+02	1.54E-01	1.00
U-235	1.21E-03	1.39E-01	1.15E+02	4.53E-01	3.75E+02	2.58E-04	0.21
Am-241	3.98E-06	4.42E-04	1.11E+02	1.33E-03	3.35E+02	8.65E-07	0.22
C-14	1.26E-06	4.75E-04	3.77E+02	6.19E-03	4.91E+03	1.27E-06	1.01
H-3	1.07E-06	9.17E-07	8.58E-01	1.07E-06	1.00E+00	4.42E-05	41.35
Pu-241	1.02E-07	1.18E-05	1.16E+02	3.76E-05	3.69E+02	1.29E-08	0.13
Ni-59	1.68E-14	6.69E-10	3.99E+04	2.76E-07	1.65E+07	1.68E-14	1.00
Ni-63	1.10E-17	4.53E-13	4.11E+04	1.93E-10	1.75E+07	1.76E-17	1.60
Sr-90	3.69E-18	3.50E-13	9.48E+04	1.92E-10	5.20E+07	1.86E-17	5.04

Radio-nuclide	Time of Peak Dose (Year)						
	Nominal PA Case	Sensitivity Case					
		1	2	3	4	5	6
		Waste Zone Conductivity	LVZ Porosity	Waste Zone Porosity	Infiltration	K_d	Disposal Time
I-129	956	955	951	953	191	181	956
Tc-99	184	184	184	184	171	171	184
Cl-36	1,171	1,171	1,171	1,171	1,050	962	1,171
Np-237	1,171	1,171	1,171	1,171	1,171	1,171	1,171
U-235	1,171	1,171	1,171	1,171	1,171	1,171	1,171
Am-241	1,171	1,171	1,171	1,171	1,171	1,171	1,171
C-14	1,171	1,171	1,171	1,171	1,171	1,171	1,171
H-3	171	171	171	171	171	171	171
Pu-241	1,171	1,171	1,171	1,171	1,171	1,171	1,171
Ni-59	1,171	1,171	1,171	1,171	1,171	1,171	1,171
Ni-63	1,171	1,171	1,171	1,171	1,171	1,171	1,171
Sr-90	260	260	260	260	260	219	260

Notes:

NR26E Case 1: Generic waste in bolted steel containers.

Green-highlighted cells indicate a time of peak dose that falls within the compliance period.

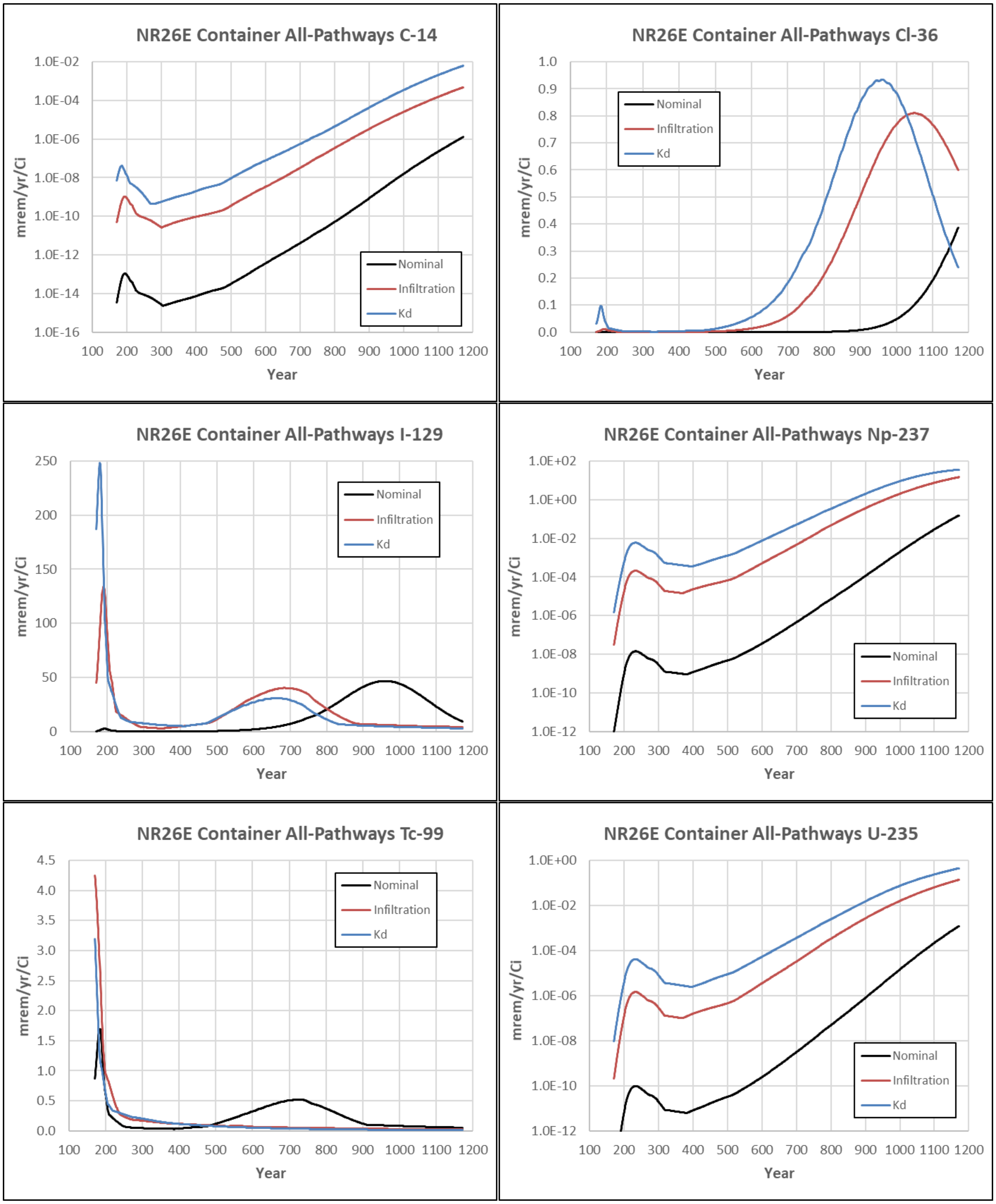


Figure 6-28. Comparison of All-Pathways Dose Factors (mrem yr^{-1} Ci^{-1} parent buried) for C-14, Cl-36, I-129, Np-237, Tc-99, and U-235 at 100-meter POA During Compliance Period for NR26E (Case 1) Nominal PA, Infiltration Sensitivity, and K_d Sensitivity Cases

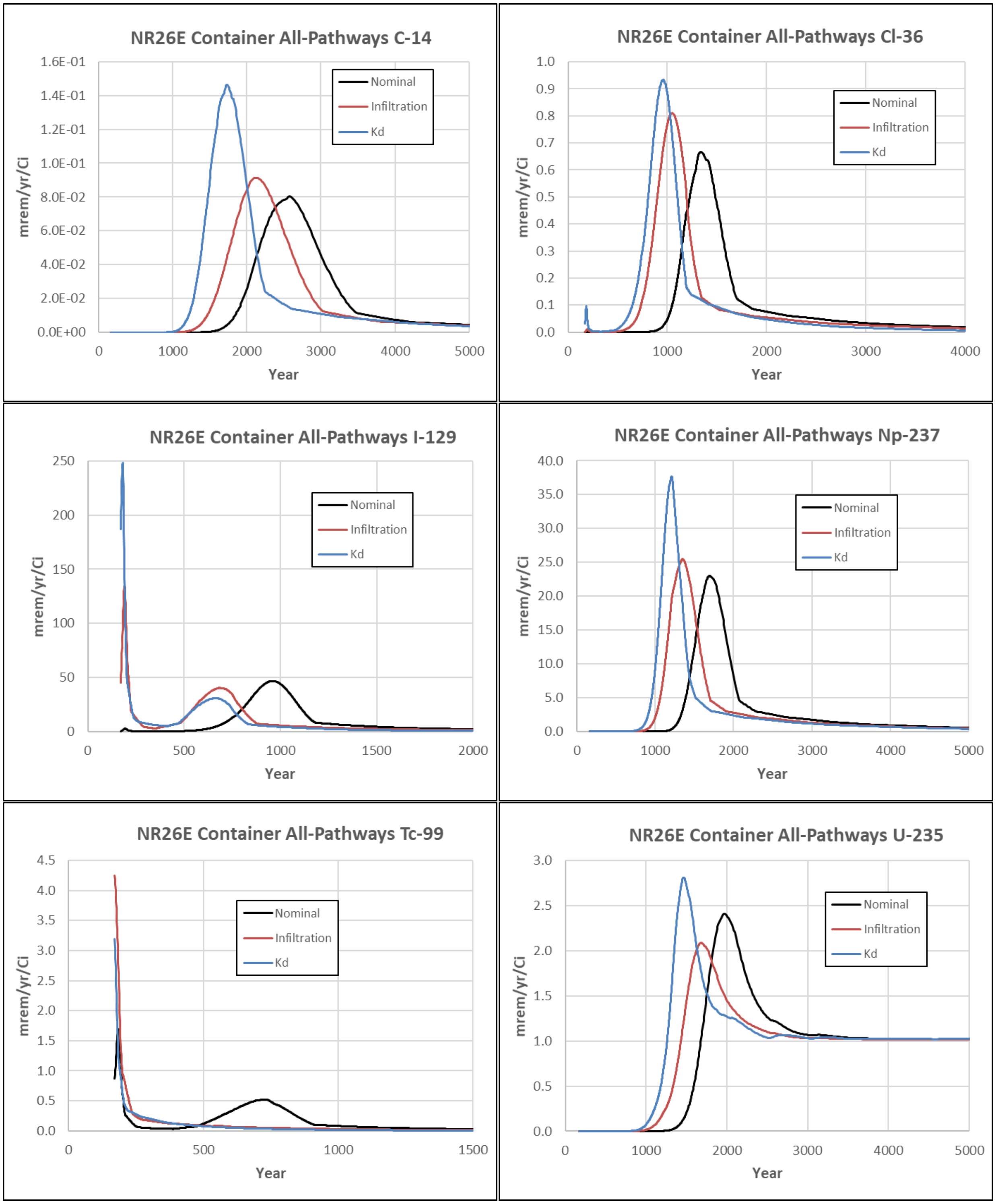


Figure 6-29. Comparison of All-Pathways Dose Factors (mrem yr^{-1} Ci^{-1} parent buried) for C-14, Cl-36, I-129, Np-237, Tc-99, and U-235 at 100-meter POA over the Entire Simulation Period for NR26E (Case 1) Nominal PA, Infiltration Sensitivity, and K_d Sensitivity Cases

Table 6-50. NR26E (Case 4) Sensitivity and Uncertainty Cases: Maximum All-Pathways Dose Factors at 100-meter POA, Difference from Nominal PA Case, and Time of Maximum

Radio-nuclide	Nominal PA Case (mrem yr^{-1} Ci^{-1})	Sensitivity Case 1		Sensitivity Case 2		Sensitivity Case 3	
		Waste Zone Conductivity (mrem yr^{-1} Ci^{-1})	Ratio	LVZ Porosity (mrem yr^{-1} Ci^{-1})	Ratio	Waste Zone Porosity (mrem yr^{-1} Ci^{-1})	Ratio
I-129S	5.35E-03	5.51E-03	1.03	6.31E-03	1.18	6.24E-03	1.17
Tc-99S	1.58E-03	1.60E-03	1.01	1.63E-03	1.03	1.64E-03	1.04
Cl-36S	3.55E-08	3.67E-08	1.03	4.40E-08	1.24	5.12E-08	1.44
Np-237S	1.29E-11	1.34E-11	1.04	2.29E-11	1.77	1.91E-11	1.48
U-235S	9.36E-13	9.72E-13	1.04	1.66E-12	1.77	1.39E-12	1.48
Am-241S	1.87E-15	1.94E-15	1.04	3.32E-15	1.77	2.77E-15	1.48
C-14S	5.85E-16	6.04E-16	1.03	7.45E-16	1.27	9.67E-16	1.65
Pu-241S	6.12E-17	6.36E-17	1.04	1.09E-16	1.77	9.08E-17	1.48
Be-10S	1.33E-20	1.38E-20	1.04	2.74E-20	2.06	2.10E-20	1.58
Ni-59S	2.89E-28	2.99E-28	1.04	6.43E-28	2.23	4.74E-28	1.64
Ni-63S	1.80E-31	1.87E-31	1.04	4.01E-31	2.23	2.95E-31	1.64
Radio-nuclide	**Nominal PA Case (mrem yr^{-1} Ci^{-1})**	**Sensitivity Case 4**		**Sensitivity Case 5**		**Sensitivity Case 6**	
		Infiltration (mrem yr^{-1} Ci^{-1})	**Ratio**	**K_d (mrem yr^{-1} Ci^{-1})**	**Ratio**	**Disposal Time (mrem yr^{-1} Ci^{-1})**	**Ratio**
I-129S	5.35E-03	8.30E-02	1.55E+01	1.78E-01	3.32E+01	1.00E-03	0.19
Tc-99S	1.58E-03	2.17E-03	1.38E+00	2.37E-03	1.50E+00	7.96E-04	0.50
Cl-36S	3.55E-08	8.88E-06	2.50E+02	1.86E-04	5.23E+03	3.16E-09	0.09
Np-237S	1.29E-11	4.75E-08	3.68E+03	5.32E-06	4.13E+05	4.12E-13	0.03
U-235S	9.36E-13	3.45E-09	3.69E+03	3.92E-07	4.19E+05	2.96E-14	0.03
Am-241S	1.87E-15	6.88E-12	3.68E+03	7.76E-10	4.15E+05	5.93E-17	0.03
C-14S	5.85E-16	8.97E-13	1.53E+03	1.73E-10	2.96E+05	3.30E-17	0.06
Pu-241S	6.12E-17	2.26E-13	3.68E+03	2.54E-11	4.15E+05	1.94E-18	0.03
Be-10S	1.33E-20	2.74E-16	2.07E+04	3.14E-12	2.37E+08	2.09E-22	0.02
Ni-59S	2.89E-28	1.48E-23	5.12E+04	1.46E-18	5.06E+09	2.79E-30	0.01
Ni-63S	1.80E-31	9.34E-27	5.19E+04	9.59E-22	5.33E+09	2.74E-33	0.02

Radio-nuclide	Time of Peak Dose (Year)						
	Nominal PA Case	Sensitivity Case					
		1	2	3	4	5	6
		Waste Zone Conductivity	LVZ Porosity	Waste Zone Porosity	Infiltration	K_d	Disposal Time
I-129S	1,171	1,171	1,171	1,171	1,171	1,171	1,171
Tc-99S	1,171	1,171	1,171	1,171	1,168	1,120	1,171
Cl-36S	1,171	1,171	1,171	1,171	1,171	1,171	1,171
Np-237S	1,171	1,171	1,171	1,171	1,171	1,171	1,171
U-235S	1,171	1,171	1,171	1,171	1,171	1,171	1,171
Am-241S	1,171	1,171	1,171	1,171	1,171	1,171	1,171
C-14S	1,171	1,171	1,171	1,171	1,171	1,171	1,171
Pu-241S	1,171	1,171	1,171	1,171	1,171	1,171	1,171
Be-10S	1,171	1,171	1,171	1,171	1,171	1,171	1,171
Ni-59S	1,171	1,171	1,171	1,171	1,171	1,171	1,171
Ni-63S	1,171	1,171	1,171	1,171	1,171	1,171	1,171

Notes:

NR26E Case 4: Zircaloy waste in steel casks.

Green-highlighted cells indicate a time of peak dose that falls within the compliance period.

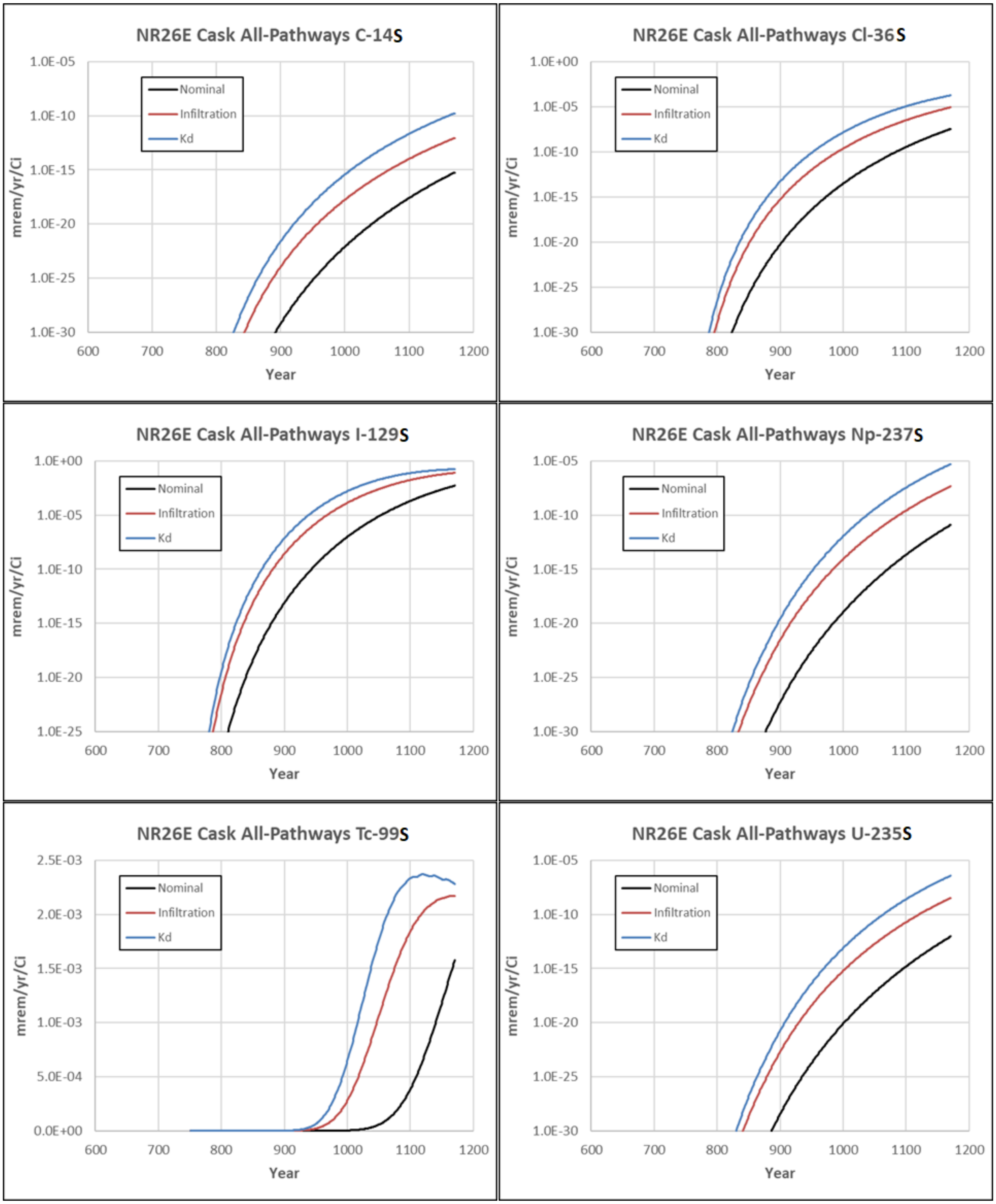


Figure 6-30. Comparison of All-Pathways Dose Factors (mrem yr^{-1} Ci^{-1} parent buried) for C-14S, Cl-36S, I-129S, Np-237S, Tc-99S, and U-235S at 100-meter POA During Compliance Period for NR26E (Case 4) Nominal PA, Infiltration Sensitivity, and K_d Sensitivity Cases

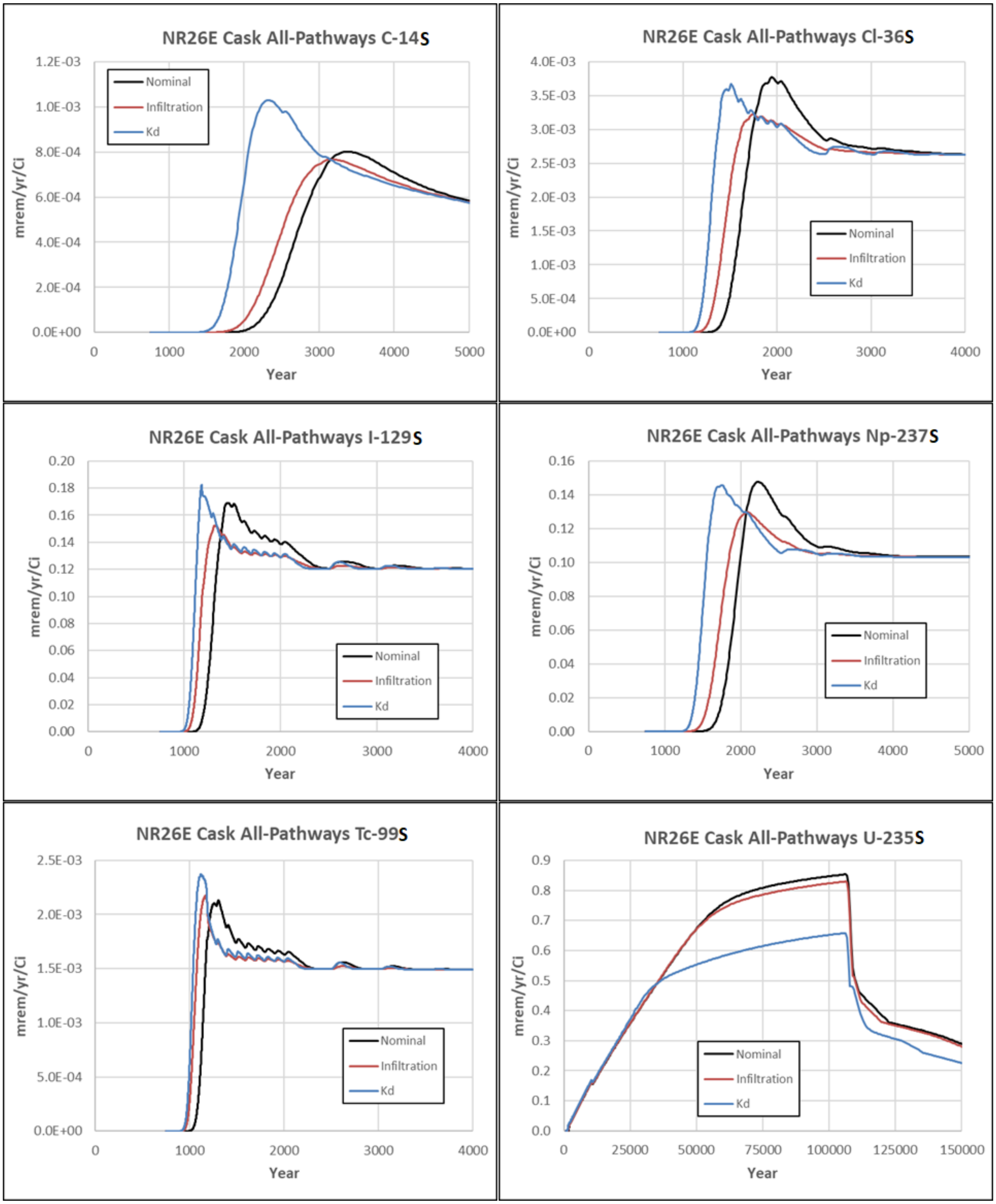


Figure 6-31. Comparison of All-Pathways Dose Factors (mrem yr^{-1} Ci^{-1} parent buried) for C-14S, Cl-36S, I-129S, Np-237S, Tc-99S, and U-235S at 100-meter POA over the Entire Simulation Period for NR26E (Case 4) Nominal PA, Infiltration Sensitivity, and K_d Sensitivity Cases

Table 6-51. NR26E (Case 1) Sensitivity and Uncertainty Cases: Maximum Beta-Gamma Dose Factors at 100-meter POA, Difference from Nominal PA Case, and Time of Maximum

Radio-nuclide	Nominal PA Case (mrem yr^{-1} Ci^{-1})	Sensitivity Case 1		Sensitivity Case 2		Sensitivity Case 3	
		Waste Zone Conductivity (mrem yr^{-1} Ci^{-1})	Ratio	LVZ Porosity (mrem yr^{-1} Ci^{-1})	Ratio	Waste Zone Porosity (mrem yr^{-1} Ci^{-1})	Ratio
I-129	7.97E+02	7.97E+02	1.00	7.95E+02	1.00	7.95E+02	1.00
Tc-99	2.57E+00	2.59E+00	1.01	2.70E+00	1.05	2.65E+00	1.03
Cl-36	4.30E-01	4.33E-01	1.01	4.50E-01	1.05	4.58E-01	1.07
Np-237	1.02E-02	1.04E-02	1.02	1.42E-02	1.39	1.21E-02	1.18
H-3	4.08E-03	4.11E-03	1.01	3.71E-03	0.91	4.01E-03	0.98
U-235	2.45E-06	2.49E-06	1.02	3.46E-06	1.41	2.92E-06	1.19
C-14	1.26E-06	1.28E-06	1.02	1.41E-06	1.12	1.87E-06	1.49
Am-241	2.64E-07	2.69E-07	1.02	3.69E-07	1.40	3.13E-07	1.18
Pu-241	6.78E-09	6.89E-09	1.02	9.48E-09	1.40	8.04E-09	1.19
Ni-59	1.61E-12	1.65E-12	1.02	3.17E-12	1.96	2.57E-12	1.59
Ni-63	2.56E-15	2.62E-15	1.02	5.04E-15	1.97	4.09E-15	1.60
Sr-90	3.15E-17	3.21E-17	1.02	6.42E-17	2.04	4.94E-17	1.57
Radio-nuclide	Nominal PA Case (mrem yr^{-1} Ci^{-1})	Sensitivity Case 4		Sensitivity Case 5		Sensitivity Case 6	
		Infiltration (mrem yr^{-1} Ci^{-1})	Ratio	K_d (mrem yr^{-1} Ci^{-1})	Ratio	Disposal Time (mrem yr^{-1} Ci^{-1})	Ratio
I-129	7.97E+02	2.29E+03	2.88E+00	4.25E+03	5.33E+00	7.97E+02	1.00
Tc-99	2.57E+00	6.71E+00	2.61E+00	7.37E+00	2.87E+00	2.57E+00	1.00
Cl-36	4.30E-01	9.01E-01	2.10E+00	1.04E+00	2.42E+00	4.30E-01	1.00
Np-237	1.02E-02	9.76E-01	9.55E+01	2.37E+00	2.32E+02	1.02E-02	1.00
H-3	4.08E-03	7.84E-03	1.92E+00	4.08E-03	1.00E+00	1.69E-01	41.35
U-235	2.45E-06	3.63E-04	1.49E+02	1.23E-03	5.03E+02	5.02E-07	0.21
C-14	1.26E-06	4.74E-04	3.77E+02	6.17E-03	4.91E+03	1.27E-06	1.01
Am-241	2.64E-07	2.94E-05	1.11E+02	8.86E-05	3.35E+02	5.76E-08	0.22
Pu-241	6.78E-09	7.88E-07	1.16E+02	2.50E-06	3.69E+02	8.59E-10	0.13
Ni-59	1.61E-12	6.45E-08	3.99E+04	2.66E-05	1.65E+07	1.62E-12	1.00
Ni-63	2.56E-15	1.05E-10	4.11E+04	4.48E-08	1.75E+07	4.10E-15	1.60
Sr-90	3.15E-17	2.99E-12	9.48E+04	1.64E-09	5.20E+07	1.59E-16	5.04

Radio-nuclide	Time of Peak Dose (Year)						
	Nominal PA Case	Sensitivity Case					
		1	2	3	4	5	6
		Waste Zone Conductivity	LVZ Porosity	Waste Zone Porosity	Infiltration	K_d	Disposal Time
I-129	956	955	951	953	191	181	956
Tc-99	184	184	184	184	166	155	184
Cl-36	1,171	1,171	1,171	1,171	1,050	962	1,171
Np-237	1,171	1,171	1,171	1,171	1,171	1,171	1,171
H-3	100	100	101	100	93	100	100
U-235	1,171	1,171	1,171	1,171	1,171	1,171	1,171
C-14	1,171	1,171	1,171	1,171	1,171	1,171	1,171
Am-241	1,171	1,171	1,171	1,171	1,171	1,171	1,171
Pu-241	1,171	1,171	1,171	1,171	1,171	1,171	1,171
Ni-59	1,171	1,171	1,171	1,171	1,171	1,171	1,171
Ni-63	1,171	1,171	1,171	1,171	1,171	1,171	1,171
Sr-90	260	260	260	260	260	219	260

Notes:

NR26E Case 1: Generic waste in bolted steel containers.

Green-highlighted cells indicate a time of peak dose that falls within the compliance period.

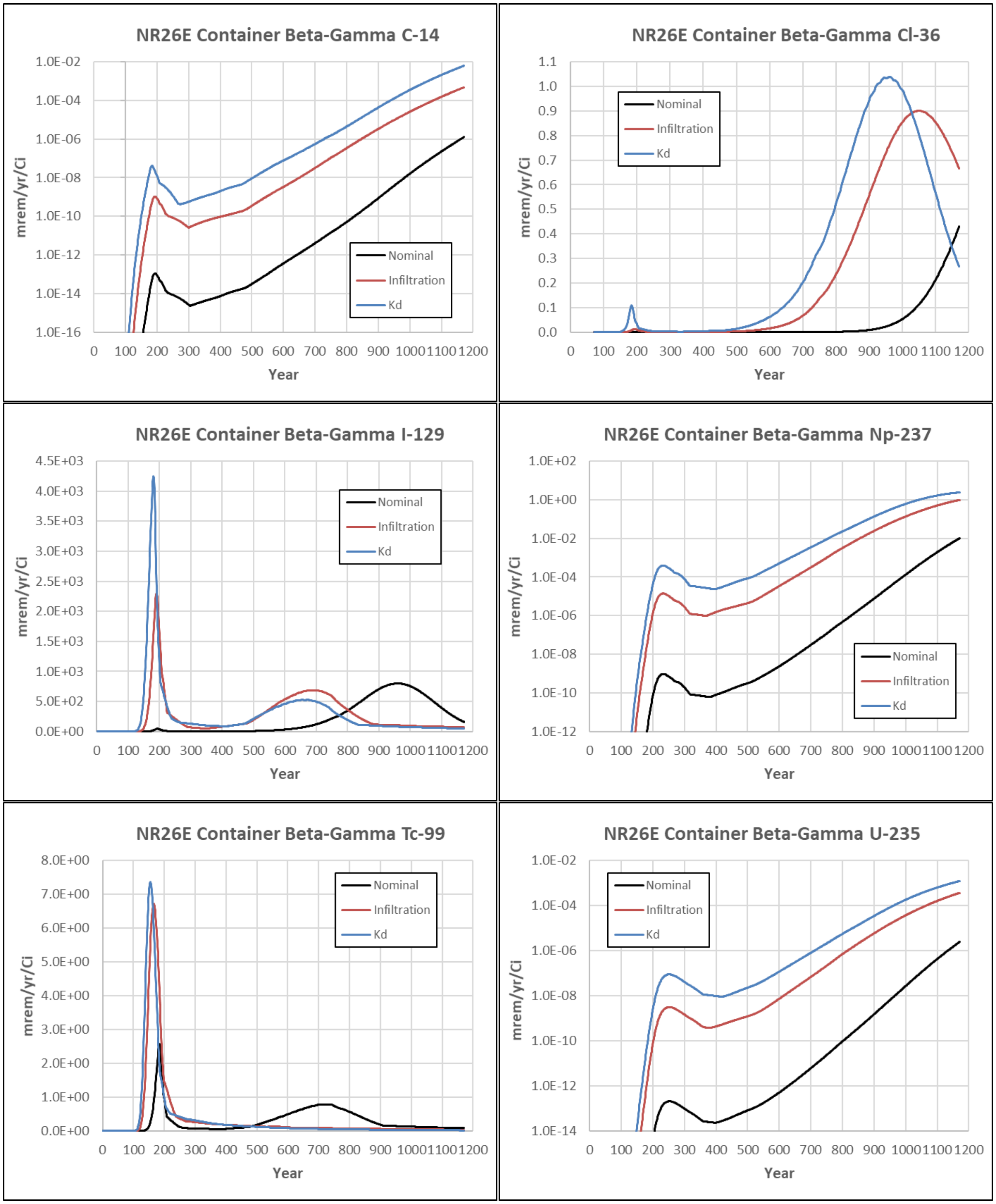


Figure 6-32. Comparison of Beta-Gamma Dose Factors (mrem yr^{-1} Ci^{-1} parent buried) for C-14, Cl-36, I-129, Np-237, Tc-99, and U-235 at 100-meter POA During Compliance Period for NR26E (Case 1) Nominal PA, Infiltration Sensitivity, and K_d Sensitivity Cases

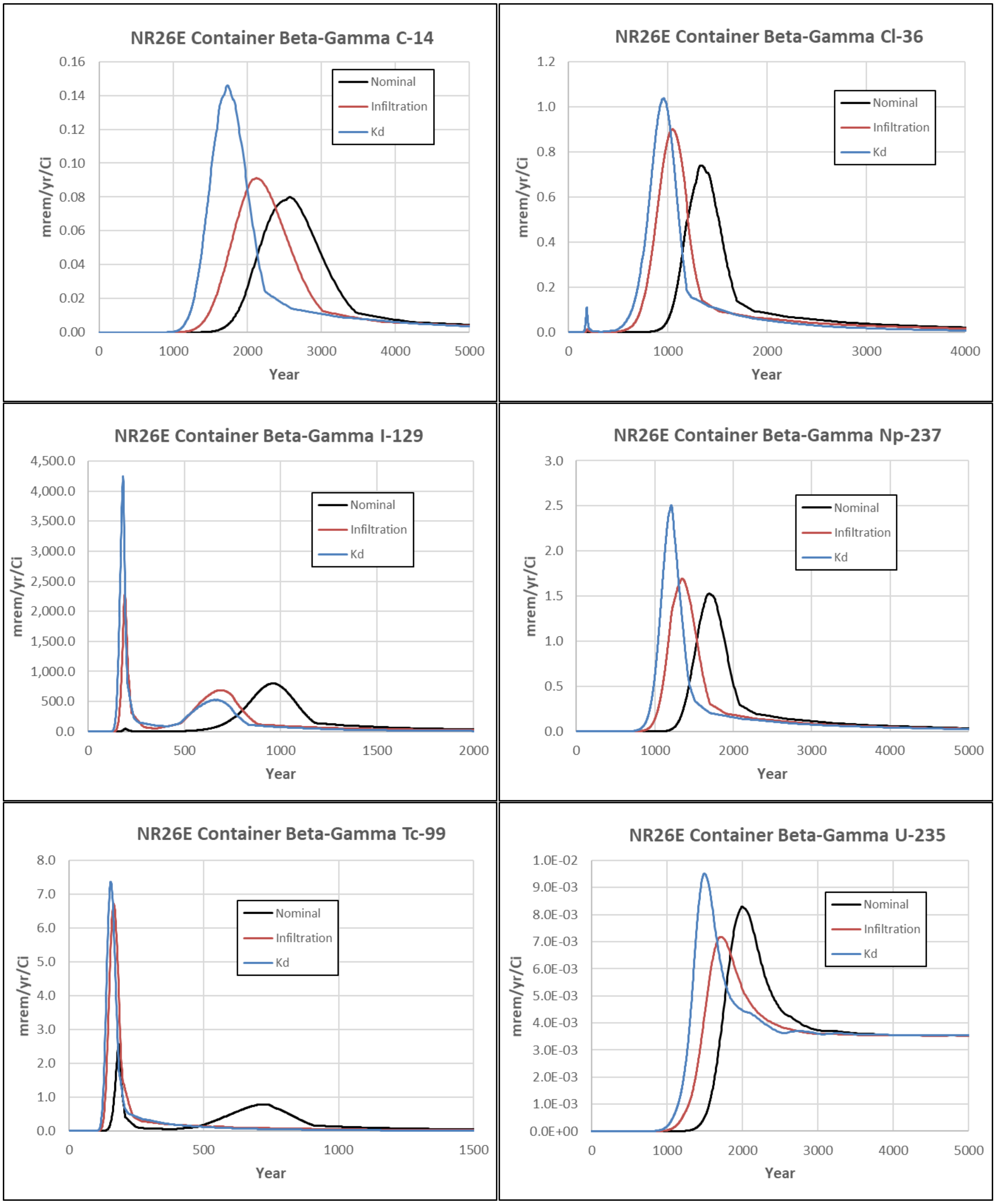


Figure 6-33. Comparison of Beta-Gamma Dose Factors (mrem yr^{-1} Ci^{-1} parent buried) for C-14, Cl-36, I-129, Np-237, Tc-99, and U-235 at 100-meter POA over the Entire Simulation Period for NR26E (Case 1) Nominal PA, Infiltration Sensitivity, and K_d Sensitivity Cases

Table 6-52. NR26E (Case 4) Sensitivity and Uncertainty Cases: Maximum Beta-Gamma Dose Factors at 100-meter POA, Difference from Nominal PA Case, and Time of Maximum

Radio-nuclide	Nominal PA Case (mrem yr^{-1} Ci^{-1})	Sensitivity Case 1		Sensitivity Case 2		Sensitivity Case 3	
		Waste Zone Conductivity (mrem yr^{-1} Ci^{-1})	Ratio	LVZ Porosity (mrem yr^{-1} Ci^{-1})	Ratio	Waste Zone Porosity (mrem yr^{-1} Ci^{-1})	Ratio
I-129S	9.14E-02	9.41E-02	1.03	1.08E-01	1.18	1.07E-01	1.17
Tc-99S	2.39E-03	2.42E-03	1.01	2.47E-03	1.03	2.48E-03	1.04
Cl-36S	3.94E-08	4.08E-08	1.03	4.89E-08	1.24	5.69E-08	1.44
Np-237S	8.58E-13	8.90E-13	1.04	1.52E-12	1.77	1.27E-12	1.48
U-235S	9.40E-16	9.76E-16	1.04	1.68E-15	1.79	1.39E-15	1.48
C-14S	5.84E-16	6.03E-16	1.03	7.43E-16	1.27	9.64E-16	1.65
Am-241S	1.24E-16	1.29E-16	1.04	2.20E-16	1.77	1.84E-16	1.48
Pu-241S	4.07E-18	4.23E-18	1.04	7.22E-18	1.77	6.04E-18	1.48
Be-10S	2.26E-20	2.34E-20	1.04	4.65E-20	2.06	3.57E-20	1.58
Ni-59S	2.78E-26	2.88E-26	1.04	6.19E-26	2.23	4.56E-26	1.64
Ni-63S	4.19E-29	4.34E-29	1.04	9.34E-29	2.23	6.87E-29	1.64
Radio-nuclide	Nominal PA Case (mrem yr^{-1} Ci^{-1})	Sensitivity Case 4		Sensitivity Case 5		Sensitivity Case 6	
		Infiltration (mrem yr^{-1} Ci^{-1})	Ratio	K_d (mrem yr^{-1} Ci^{-1})	Ratio	Disposal Time (mrem yr^{-1} Ci^{-1})	Ratio
I-129S	9.14E-02	1.42E+00	1.55E+01	3.03E+00	3.32E+01	1.72E-02	0.19
Tc-99S	2.39E-03	3.29E-03	1.38E+00	3.59E-03	1.50E+00	1.21E-03	0.50
Cl-36S	3.94E-08	9.87E-06	2.50E+02	2.06E-04	5.23E+03	3.51E-09	0.09
Np-237S	8.58E-13	3.16E-09	3.68E+03	3.54E-07	4.13E+05	2.74E-14	0.03
U-235S	9.40E-16	4.01E-12	4.27E+03	4.69E-10	4.99E+05	2.63E-17	0.03
C-14S	5.84E-16	8.95E-13	1.53E+03	1.73E-10	2.96E+05	3.29E-17	0.06
Am-241S	1.24E-16	4.58E-13	3.68E+03	5.16E-11	4.15E+05	3.95E-18	0.03
Pu-241S	4.07E-18	1.50E-14	3.68E+03	1.69E-12	4.15E+05	1.29E-19	0.03
Be-10S	2.26E-20	4.67E-16	2.07E+04	5.34E-12	2.37E+08	3.56E-22	0.02
Ni-59S	2.78E-26	1.43E-21	5.12E+04	1.41E-16	5.06E+09	2.69E-28	0.01
Ni-63S	4.19E-29	2.17E-24	5.19E+04	2.23E-19	5.33E+09	6.38E-31	0.02

Radio-nuclide	Time of Peak Dose (Year)						
	Nominal PA Case	Sensitivity Case					
		1	2	3	4	5	6
		Waste Zone Conductivity	LVZ Porosity	Waste Zone Porosity	Infiltration	K_d	Disposal Time
I-129S	1,171	1,171	1,171	1,171	1,171	1,171	1,171
Tc-99S	1,171	1,171	1,171	1,171	1,168	1,120	1,171
Cl-36S	1,171	1,171	1,171	1,171	1,171	1,171	1,171
Np-237S	1,171	1,171	1,171	1,171	1,171	1,171	1,171
U-235S	1,171	1,171	1,171	1,171	1,171	1,171	1,171
C-14S	1,171	1,171	1,171	1,171	1,171	1,171	1,171
Am-241S	1,171	1,171	1,171	1,171	1,171	1,171	1,171
Pu-241S	1,171	1,171	1,171	1,171	1,171	1,171	1,171
Be-10S	1,171	1,171	1,171	1,171	1,171	1,171	1,171
Ni-59S	1,171	1,171	1,171	1,171	1,171	1,171	1,171
Ni-63S	1,171	1,171	1,171	1,171	1,171	1,171	1,171

Notes:

NR26E Case 4: Zircaloy waste in steel casks.

Green-highlighted cells indicate a time of peak dose that falls within the compliance period.

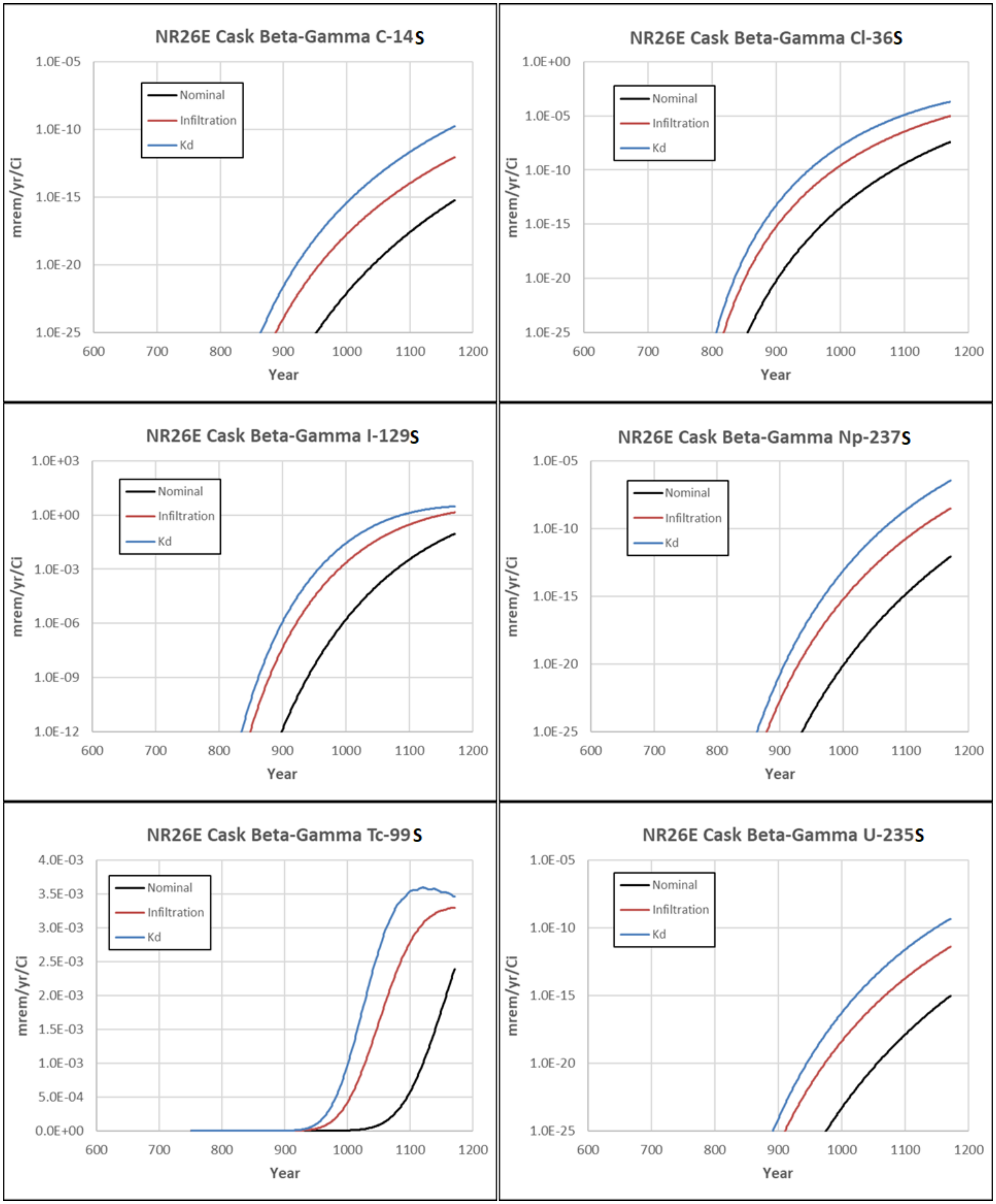


Figure 6-34. Comparison of Beta-Gamma Dose Factors (mrem yr^{-1} Ci^{-1} parent buried) for C-14S, Cl-36S, I-129S, Np-237S, Tc-99S, and U-235S at 100-meter POA During Compliance Period for NR26E (Case 4) Nominal PA, Infiltration Sensitivity, and K_d Sensitivity Cases

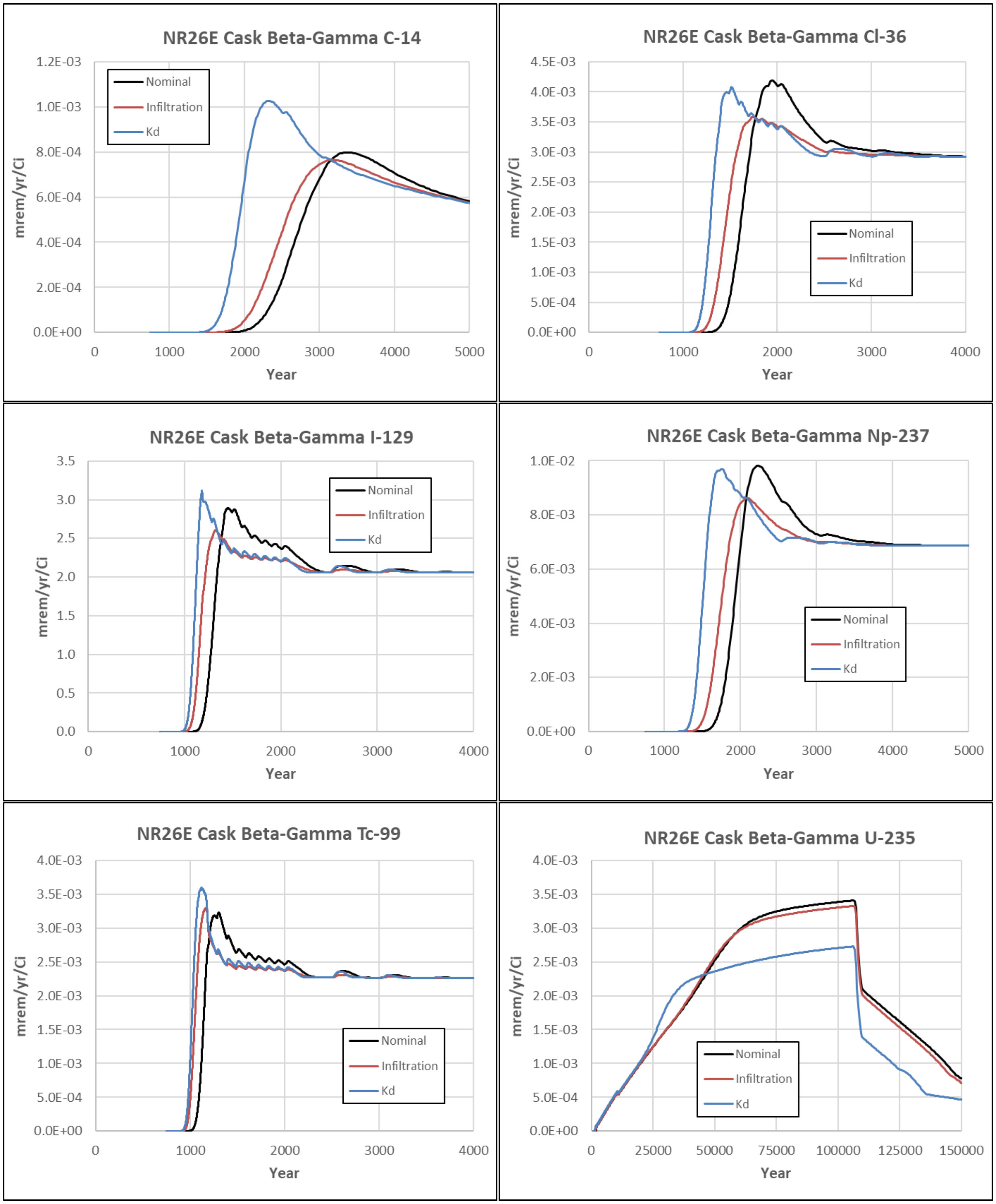


Figure 6-35. Comparison of Beta-Gamma Dose Factors (mrem yr^{-1} Ci^{-1} parent buried) for C-14S, Cl-36S, I-129S, Np-237S, Tc-99S, and U-235S at 100-meter POA over the Entire Simulation Period for NR26E (Case 4) Nominal PA, Infiltration Sensitivity, and K_d Sensitivity Cases

Table 6-53. NR26E (Case 1) Sensitivity and Uncertainty Cases: Maximum Gross-Alpha Concentration Factors at 100-meter POA, Difference from Nominal PA Case, and Time of Maximum

Radio-nuclide	Nominal PA Case (pCi L^{-1} Ci^{-1})	Sensitivity Case 1		Sensitivity Case 2		Sensitivity Case 3	
		Waste Zone Conductivity (pCi L^{-1} Ci^{-1})	Ratio	LVZ Porosity (pCi L^{-1} Ci^{-1})	Ratio	Waste Zone Porosity (pCi L^{-1} Ci^{-1})	Ratio
Np-237	7.67E-01	7.79E-01	1.02	1.07E+00	1.39	9.05E-01	1.18
U-235	1.38E-03	1.40E-03	1.02	1.93E-03	1.40	1.64E-03	1.19
Am-241	1.98E-05	2.02E-05	1.02	2.77E-05	1.40	2.35E-05	1.18
Pu-241	5.09E-07	5.17E-07	1.02	7.11E-07	1.40	6.03E-07	1.19
Radio-nuclide	Nominal PA Case (pCi L^{-1} Ci^{-1})	Sensitivity Case 4		Sensitivity Case 5		Sensitivity Case 6	
		Infiltration (pCi L^{-1} Ci^{-1})	Ratio	K_d (pCi L^{-1} Ci^{-1})	Ratio	Disposal Time (pCi L^{-1} Ci^{-1})	Ratio
Np-237	7.67E-01	7.32E+01	9.55E+01	1.78E+02	231.65	7.67E-01	1.00
U-235	1.38E-03	1.58E-01	1.15E+02	5.17E-01	375.26	2.94E-04	0.21
Am-241	1.98E-05	2.20E-03	1.11E+02	6.65E-03	335.10	4.32E-06	0.22
Pu-241	5.09E-07	5.91E-05	1.16E+02	1.88E-04	369.05	6.44E-08	0.13

Radio-nuclide	Time of Peak Concentration (Year)						
	Nominal PA Case	Sensitivity Case					
		1	2	3	4	5	6
		Waste Zone Conductivity	LVZ Porosity	Waste Zone Porosity	Infiltration	K_d	Disposal Time
Np-237	1,171	1,171	1,171	1,171	1,171	1,171	1,171
U-235	1,171	1,171	1,171	1,171	1,171	1,171	1,171
Am-241	1,171	1,171	1,171	1,171	1,171	1,171	1,171
Pu-241	1,171	1,171	1,171	1,171	1,171	1,171	1,171

Notes:

NR26E Case 1: Generic waste in bolted steel containers.

Table 6-54. NR26E (Case 4) Sensitivity and Uncertainty Cases: Maximum Gross-Alpha Concentration Factors at 100-meter POA, Difference from Nominal PA Case, and Time of Maximum

Radio-nuclide	Nominal PA Case (pCi L^{-1} Ci^{-1})	Sensitivity Case 1		Sensitivity Case 2		Sensitivity Case 3	
		Waste Zone Conductivity (pCi L^{-1} Ci^{-1})	Ratio	LVZ Porosity (pCi L^{-1} Ci^{-1})	Ratio	Waste Zone Porosity (pCi L^{-1} Ci^{-1})	Ratio
Np-237S	6.43E-11	6.68E-11	1.04	1.14E-10	1.77	9.54E-11	1.48
U-235S	1.07E-12	1.11E-12	1.04	1.89E-12	1.77	1.58E-12	1.48
Am-241S	9.32E-15	9.68E-15	1.04	1.65E-14	1.77	1.38E-14	1.48
Pu-241S	3.05E-16	3.17E-16	1.04	5.42E-16	1.77	4.53E-16	1.48
Radio-nuclide	Nominal PA Case (pCi L^{-1} Ci^{-1})	Sensitivity Case 4		Sensitivity Case 5		Sensitivity Case 6	
		Infiltration (pCi L^{-1} Ci^{-1})	Ratio	K_d (pCi L^{-1} Ci^{-1})	Ratio	Disposal Time (pCi L^{-1} Ci^{-1})	Ratio
Np-237S	6.43E-11	2.37E-07	3.68E+03	2.65E-05	4.13E+05	2.06E-12	0.03
U-235S	1.07E-12	3.93E-09	3.69E+03	4.46E-07	4.19E+05	3.36E-14	0.03
Am-241S	9.32E-15	3.43E-11	3.68E+03	3.87E-09	4.15E+05	2.96E-16	0.03
Pu-241S	3.05E-16	1.12E-12	3.68E+03	1.27E-10	4.15E+05	9.69E-18	0.03

Table 6-54 (cont'd). NR26E (Case 4) Sensitivity and Uncertainty Cases: Maximum Gross-Alpha Concentration Factors at 100-meter POA, Difference from Nominal PA Case, and Time of Maximum

Radio-nuclide	Time of Peak Concentration (Year)						
	Nominal PA Case	Sensitivity Case					
		1	2	3	4	5	6
		Waste Zone Conductivity	LVZ Porosity	Waste Zone Porosity	Infiltration	K_d	Disposal Time
Np-237S	1,171	1,171	1,171	1,171	1,171	1,171	1,171
U-235S	1,171	1,171	1,171	1,171	1,171	1,171	1,171
Am-241S	1,171	1,171	1,171	1,171	1,171	1,171	1,171
Pu-241S	1,171	1,171	1,171	1,171	1,171	1,171	1,171

Notes:

NR26E Case 4: Zircaloy waste in steel casks.

Table 6-55. NR26E (Case 1) Sensitivity and Uncertainty Cases: Maximum Uranium Concentration Factors at 100-meter POA, Difference from Nominal PA Case, and Time of Maximum

Radio-nuclide	Nominal PA Case (µg L^{-1} Ci^{-1})	Sensitivity Case 1		Sensitivity Case 2		Sensitivity Case 3	
		Waste Zone Conductivity (µg L^{-1} Ci^{-1})	Ratio	LVZ Porosity (µg L^{-1} Ci^{-1})	Ratio	Waste Zone Porosity (µg L^{-1} Ci^{-1})	Ratio
Np-237	1.62E-10	1.64E-10	1.02	2.30E-10	1.43	1.94E-10	1.20
Am-241	4.10E-15	4.17E-15	1.02	5.87E-15	1.43	4.93E-15	1.20
Pu-241	1.05E-16	1.06E-16	1.02	1.50E-16	1.43	1.26E-16	1.20
U-235	1.36E-70	1.39E-70	1.02	3.67E-70	2.70	2.46E-70	1.81
Radio-nuclide	Nominal PA Case (µg L^{-1} Ci^{-1})	Sensitivity Case 4		Sensitivity Case 5		Sensitivity Case 6	
		Infiltration (µg L^{-1} Ci^{-1})	Ratio	K_d (µg L^{-1} Ci^{-1})	Ratio	Disposal Time (µg L^{-1} Ci^{-1})	Ratio
Np-237	1.62E-10	3.28E-08	202.71	1.09E-07	676.20	1.62E-10	1.00
Am-241	4.10E-15	9.14E-13	222.88	3.35E-12	817.39	8.22E-16	0.20
Pu-241	1.05E-16	2.40E-14	229.52	9.04E-14	864.32	1.16E-17	0.11
U-235	1.36E-70	1.98E-64	1.46E+06	2.46E-61	1.81E+09	1.36E-70	1.00

Radio-nuclide	Time of Peak Concentration (Year)						
	Nominal PA Case	Sensitivity Case					
		1	2	3	4	5	6
		Waste Zone Conductivity	LVZ Porosity	Waste Zone Porosity	Infiltration	K_d	Disposal Time
Np-237	1,171	1,171	1,171	1,171	1,171	1,171	1,171
Am-241	1,171	1,171	1,171	1,171	1,171	1,171	1,171
Pu-241	1,171	1,171	1,171	1,171	1,171	1,171	1,171
U-235	1,171	1,171	1,171	1,171	1,171	1,171	1,171

Notes:

NR26E Case 1: Generic waste in bolted steel containers.

Table 6-56. NR26E (Case 4) Sensitivity and Uncertainty Cases: Maximum Uranium Concentration Factors at 100-meter POA, Difference from Nominal PA Case, and Time of Maximum

Radio-nuclide	Nominal PA Case (µg L^{-1} Ci^{-1})	Sensitivity Case 1		Sensitivity Case 2		Sensitivity Case 3	
		Waste Zone Conductivity (µg L^{-1} Ci^{-1})	Ratio	LVZ Porosity (µg L^{-1} Ci^{-1})	Ratio	Waste Zone Porosity (µg L^{-1} Ci^{-1})	Ratio
Np-237S	3.98E-21	4.13E-21	1.04	7.12E-21	1.79	5.90E-21	1.48
Am-241S	5.76E-25	5.98E-25	1.04	1.03E-24	1.79	8.54E-25	1.48
Pu-241S	1.89E-26	1.96E-26	1.04	3.38E-26	1.79	2.80E-26	1.48
U-235S	6.54E-104	6.80E-104	1.04	1.77E-103	2.71	1.17E-103	1.79
Radio-nuclide	Nominal PA Case (µg L^{-1} Ci^{-1})	Sensitivity Case 4		Sensitivity Case 5		Sensitivity Case 6	
		Infiltration (µg L^{-1} Ci^{-1})	Ratio	K_d (µg L^{-1} Ci^{-1})	Ratio	Disposal Time (µg L^{-1} Ci^{-1})	Ratio
Np-237S	3.98E-21	1.80E-17	4.52E+03	2.11E-15	5.29E+05	1.08E-22	0.03
Am-241S	5.76E-25	2.61E-21	4.52E+03	3.06E-19	5.32E+05	1.55E-26	0.03
Pu-241S	1.89E-26	8.54E-23	4.52E+03	1.00E-20	5.32E+05	5.09E-28	0.03
U-235S	6.54E-104	5.68E-98	8.68E+05	1.24E-94	1.89E+09	5.97E-108	0.00

Radio-nuclide	Time of Peak Concentration (Year)						
	Nominal PA Case	Sensitivity Case					
		1	2	3	4	5	6
		Waste Zone Conductivity	LVZ Porosity	Waste Zone Porosity	Infiltration	K_d	Disposal Time
Np-237S	1,171	1,171	1,171	1,171	1,171	1,171	1,171
Am-241S	1,171	1,171	1,171	1,171	1,171	1,171	1,171
Pu-241S	1,171	1,171	1,171	1,171	1,171	1,171	1,171
U-235S	1,171	1,171	1,171	1,171	1,171	1,171	1,171

Notes:

NR26E Case 4: Zircaloy waste in steel casks

6.1.2. PORFLOW Model Uncertainty Quantification

The objective of the uncertainty quantification calculations presented in this section is to use the sensitivity results from Section 6.1.1 to obtain an estimate of uncertainty in the nominal PA (base case) dose factor for each parent radionuclide. With an estimated uncertainty in the dose (and concentration) factors, along with a projected closure inventory, estimates are provided as to the uncertainty associated with total dose at the DU level.

6.1.2.1. Uncertainty Quantification Methodology

The response surface method is used to quantify dose uncertainty based on PORFLOW model calculations of concentration at or beyond the 100-meter POA. This method relies on the results of the sensitivity analysis reported in Section 6.1.1. The assumption is made that the quantity of interest for a particular DU (Q_{DU}) is a function of the sensitivity variables as represented by Eq. (6-2):

$$Q_{DU} = f_{DU}\left(s_1, s_2, \ldots, s_n\right) \qquad \text{Eq. (6-2)}$$

where:

Q_{DU} DU-specific quantity of interest (e.g., dose or concentration)

f_{DU} DU-specific generic function (varies)

s_i i^{th} sensitivity (random) variable (varies)

n Number of sensitivity variable (unitless)

The quantity of interest may be maximum dose or concentration at the 100-meter POA, or the inventory limits themselves. Eq. (6-3) relates the differential change in Q_{DU} corresponding to a differential change in each of the sensitivity variables (perturbation expansion):

$$dQ_{DU} = \frac{\partial f_{DU}}{\partial s_1} ds_1 + \frac{\partial f_{DU}}{\partial s_2} ds_2 + \ldots + \frac{\partial f_{DU}}{\partial s_n} ds_n \qquad \text{Eq. (6-3)}$$

Replacing the differentials with incremental changes leads to Eq. (6-4):

$$\delta Q_{DU} = \frac{\partial f_{DU}}{\partial s_1} \delta s_1 + \frac{\partial f_{DU}}{\partial s_2} \delta s_2 + \ldots + \frac{\partial f_{DU}}{\partial s_n} \delta s_n \qquad \text{Eq. (6-4)}$$

where:

δ Finite incremental change in a variable (unitless)

The change in the quantity of interest due to an incremental change in each variable as measured in the sensitivity analysis is assumed to provide an estimate for the partial derivatives in Eq. (6-4) and is calculated using Eq. (6-5):

$$\delta Q_{DU} = \left[\frac{\Delta f_{DU}}{\Delta s_1}\right]_1 \delta s_1 + \left[\frac{\Delta f_{DU}}{\Delta s_1}\right]_2 \delta s_2 + \ldots + \left[\frac{\Delta f_{DU}}{\Delta s_n}\right]_n \delta s_n = \sum_{i=1}^{n} \left[\frac{\Delta f_{DU}}{\Delta s_i}\right]_i \delta s_i \qquad \text{Eq. (6-5)}$$

where:

$\frac{\Delta f_{DU}}{\Delta s_i}$ Finite approximation to the actual derivative (varies)

The terms in brackets in Eq. (6-5) are fixed values determined for each DU through the sensitivity analysis. The quantity of interest (e.g., maximum dose at 100-meter POA) and each sensitivity variable have a nominal PA value designated by a circumflex accent mark in Eq. (6-6):

$$Q_{DU} - \hat{Q}_{DU} = \sum_{i=1}^{n} \left[\frac{\Delta f_{DU}}{\Delta s_i}\right]_i \left(s_i - \hat{s}_i\right) = \sum_{i=1}^{n} \phi_i \left(s_i - \hat{s}_i\right) \qquad \text{Eq. (6-6)}$$

where:

$\hat{x}_i$ Value of a variable or quantity at nominal PA conditions (varies)

ϕ_i Value of derivative at nominal PA conditions (varies)

Collecting constant terms leads to Eq. (6-7):

$$Q_{DU} = \hat{Q}_{DU} + \sum_{i=1}^{n} \phi_i s_i - \sum_{i=1}^{n} \phi_i \hat{s}_i = \hat{F}_{DU} + \sum_{i=1}^{n} \phi_i s_i \qquad \text{Eq. (6-7)}$$

The assumption is then made that the expected variation in each sensitivity variable can be represented by a statistical distribution. Randomly selecting values for the sensitivity variables from the assumed distributions (such as during a Monte Carlo realization) and using Eq. (6-7) yields a prediction of Q_{DU}. Repeating this for many realizations provides a distribution of possible values for Q_{DU} from which the confidence intervals are calculated. This calculation is implemented in the GoldSim® software (GoldSim Technology Group, 2018a) to take advantage of its ability to randomly sample distributions using Latin Hypercube Sampling and quickly perform many realizations. Employing 20,000 realizations for the uncertainty quantification, the GoldSim® statistical calculations and subsequent output of results take about one minute. Test cases exceeding 20,000+ realizations did not alter the results significantly.

6.1.2.2. Uncertainty Quantification Results

Results from the response surface uncertainty quantification calculations are presented in Table 6-57 through Table 6-96. The tables are grouped by type of DU (STs and ETs; LAWV and ILV; NRCDAs) and sorted by dose (all-pathways and beta-gamma) and concentration (gross-alpha and uranium) factors. The sorting is done based on the results of the nominal PA case. The "Nominal PA Case" column lists the dose or concentration factors obtained from PORFLOW deterministic modeling used to establish PA disposal limits (see Chapter 5). The calculations assume normal distributions with symmetric truncation for the uncertainty parameters. With this approach, the calculated statistical distributions are expected to display mean and 50th-percentile values equal to or very close to the nominal PA case (except for those extreme conditions mentioned in the previous section).

The last tables in each DU grouping list ratios of the peak all-pathways dose obtained for each sensitivity case to the nominal value. Comparisons of peak ratios for the sensitivity cases to the uncertainty bounds show that wide confidence bounds reflect the substantial change in dose factors observed in the sensitivity calculations. A large sensitivity response occurs when the peak dose factor falls at the end of the compliance period. When a large sensitivity response occurs, the infiltration and K_d sensitivity analyses, which shift the peak to earlier times, result in large changes in the peak dose factor.

The uncertainty analysis is performed for all ET06, ST06, and ST09 radionuclides having sensitivity case results. None of the uncertainty calculations address radium. Radium is either nonexistent in the radionuclides included in the sensitivity analysis or is at such a low concentration that it contributes negligible dose.

For trenches and vaults in general, the uncertainty analysis performed well for most radionuclides. Performance for the NRCDAs is not as good with 50th-percentile values, often deviating from the nominal PA case. The NRCDA steel casks (NR07E, Case 3 and NR26E, Case 4) slowly release radionuclides because of corrosion of contaminated Inconel or Zircaloy metal. This release mechanism may have affected the statistical modeling. Release from bolted containers (NR26E, Case 1) is instantaneous and, except for radionuclides present at low concentrations, statistical results for this case appear to be more reliable. In all cases, calculated uncertainties in all-pathways dose, beta-gamma dose, and concentration for a radionuclide within each DU give similar results.

In summary, the response surface uncertainty quantification provides a quick way to assess uncertainty in model results using the data obtained from sensitivity analysis calculations performed with the PA model. The alternative approach of abstracting the PA model into a simplified, faster model requires considerable effort and benchmarking to produce reliable results. Some features of this approach as applied here could be improved:

- In this PA, K_d values are changed simultaneously for all radionuclides in all materials. A better method would be to change K_d for each radionuclide in each material separately and use material-specific distributions.
- Changing K_d by a factor of one-half (2.5σ) as done in this PA causes large changes in the dose factor. A 1.5σ variation would give results that are more comparable to the other sensitivity cases.
- Waste disposal timing is not included in the uncertainty quantification because only two extreme conditions with disposal at the start and end of operations are tested in this PA. If the nominal PA case was to assume waste disposal at the midpoint of operations, waste disposal timing could be included in the analysis.
- Nominal PA waste porosities are given an artificially high value; therefore, the true impact of uncertainty in porosity cannot be accurately captured.

Note that all of the sensitivity distributions are symmetrical and when only a small number of Monte Carlo realizations yields zero dose (or concentration) factors, then the resulting mean and median (50^{th} percentile) estimates will equal the nominal PA value. In some extreme cases, over half of the Monte Carlo realizations yield zero values, resulting in estimated median values equal to zero.

6.1.2.2.1. Slit and Engineered Trenches

Table 6-57. Peak All-Pathways Dose Factors for ET06

Radio-	Nominal PA Case	Mean		50th Percentile		75th Percentile		90th Percentile		95th Percentile	
nuclide	mrem yr^{-1} Ci^{-1}	mrem yr^{-1} Ci^{-1}	Ratio	mrem yr^{-1} Ci^{-1}	Ratio	mrem yr^{-1} Ci^{-1}	Ratio	mrem yr^{-1} Ci^{-1}	Ratio	mrem yr^{-1} Ci^{-1}	Ratio
I-129	6.76E+01	6.76E+01	1.00E+00	6.76E+01	1.00E+00	8.37E+01	1.24E+00	9.72E+01	1.44E+00	1.05E+02	1.55E+00
Np-237	2.83E+01	2.84E+01	1.00E+00	2.83E+01	1.00E+00	3.74E+01	1.32E+00	4.55E+01	1.61E+00	5.04E+01	1.78E+00
Tc-99	3.34E-01	3.56E-01	1.07E+00	3.35E-01	1.00E+00	5.53E-01	1.66E+00	7.43E-01	2.23E+00	8.46E-01	2.54E+00
C-14	8.76E-03	5.06E-02	5.78E+00	8.41E-03	9.60E-01	8.66E-02	9.88E+00	1.57E-01	1.79E+01	1.98E-01	2.26E+01
H-3	9.84E-07	9.84E-07	1.00E+00	9.84E-07	1.00E+00	9.93E-07	1.01E+00	1.00E-06	1.02E+00	1.00E-06	1.02E+00
Sr-90	4.75E-14	3.05E-09	6.42E+04	0.00E+00	0.00E+00	5.19E-09	1.09E+05	9.84E-09	2.07E+05	1.26E-08	2.65E+05

Table 6-58. Peak All-Pathways Dose Factors for ST06

Radio-	Nominal PA Case	Mean		50th Percentile		75th Percentile		90th Percentile		95th Percentile	
nuclide	mrem yr^{-1} Ci^{-1}	mrem yr^{-1} Ci^{-1}	Ratio	mrem yr^{-1} Ci^{-1}	Ratio	mrem yr^{-1} Ci^{-1}	Ratio	mrem yr^{-1} Ci^{-1}	Ratio	mrem yr^{-1} Ci^{-1}	Ratio
I-129	1.15E+02	1.15E+02	1.00E+00	1.15E+02	1.00E+00	1.19E+02	1.03E+00	1.23E+02	1.06E+00	1.25E+02	1.08E+00
Np-237	2.68E+01	2.91E+01	1.09E+00	2.66E+01	9.93E-01	4.56E+01	1.70E+00	6.20E+01	2.31E+00	7.18E+01	2.68E+00
Tc-99	1.41E+00	1.41E+00	1.00E+00	1.41E+00	1.00E+00	1.70E+00	1.20E+00	1.94E+00	1.37E+00	2.07E+00	1.47E+00
C-14	3.16E-02	5.69E-02	1.80E+00	3.17E-02	1.00E+00	9.77E-02	3.09E+00	1.57E-01	4.97E+00	1.93E-01	6.11E+00
H-3	9.15E-07	9.15E-07	1.00E+00	9.15E-07	1.00E+00	9.27E-07	1.01E+00	9.36E-07	1.02E+00	9.42E-07	1.03E+00
Sr-90	2.25E-14	2.55E-09	1.14E+05	0.00E+00	0.00E+00	4.34E-09	1.93E+05	8.24E-09	3.66E+05	1.05E-08	4.69E+05

Table 6-59. Peak All-Pathways Dose Factors for ST09

Radio-	Nominal PA Case	Mean		50th Percentile		75th Percentile		90th Percentile		95th Percentile	
nuclide	mrem yr^{-1} Ci^{-1}	mrem yr^{-1} Ci^{-1}	Ratio	mrem yr^{-1} Ci^{-1}	Ratio	mrem yr^{-1} Ci^{-1}	Ratio	mrem yr^{-1} Ci^{-1}	Ratio	mrem yr^{-1} Ci^{-1}	Ratio
I-129	1.24E+02	1.24E+02	1.00E+00	1.23E+02	9.99E-01	1.38E+02	1.11E+00	1.50E+02	1.21E+00	1.57E+02	1.27E+00
Np-237	2.23E+00	1.92E+01	8.58E+00	1.98E+00	8.85E-01	3.32E+01	1.49E+01	6.03E+01	2.70E+01	7.60E+01	3.40E+01
Tc-99	1.82E+00	1.82E+00	1.00E+00	1.82E+00	1.00E+00	1.87E+00	1.03E+00	1.92E+00	1.05E+00	1.94E+00	1.07E+00
C-14	8.56E-04	2.48E-02	2.90E+01	7.26E-04	8.47E-01	4.24E-02	4.95E+01	7.98E-02	9.32E+01	1.01E-01	1.18E+02
H-3	1.06E-06	1.06E-06	1.00E+00	1.06E-06	1.00E+00	1.09E-06	1.03E+00	1.12E-06	1.06E+00	1.14E-06	1.07E+00
Sr-90	8.92E-18	4.34E-13	4.87E+04	1.10E-16	1.24E+01	7.37E-13	8.26E+04	1.40E-12	1.57E+05	1.79E-12	2.01E+05

Table 6-60. Peak Beta-Gamma Dose Factors for ET06

Radio-	Nominal PA Case	Mean		50th Percentile		75th Percentile		90th Percentile		95th Percentile	
nuclide	mrem yr^{-1} Ci^{-1}	mrem yr^{-1} Ci^{-1}	Ratio	mrem yr^{-1} Ci^{-1}	Ratio	mrem yr^{-1} Ci^{-1}	Ratio	mrem yr^{-1} Ci^{-1}	Ratio	mrem yr^{-1} Ci^{-1}	Ratio
I-129	1.16E+03	1.16E+03	1.00E+00	1.16E+03	1.00E+00	1.42E+03	1.23E+00	1.67E+03	1.44E+00	1.81E+03	1.57E+00
Np-237	1.88E+00	1.89E+00	1.00E+00	1.88E+00	1.00E+00	2.49E+00	1.32E+00	3.02E+00	1.61E+00	3.35E+00	1.78E+00
Tc-99	9.19E-01	2.48E+00	2.70E+00	8.93E-01	9.72E-01	4.30E+00	4.68E+00	7.33E+00	7.97E+00	9.11E+00	9.91E+00
H-3	3.94E-01	3.94E-01	1.00E+00	3.93E-01	9.99E-01	4.75E-01	1.21E+00	5.44E-01	1.38E+00	5.80E-01	1.47E+00
C-14	8.74E-03	5.05E-02	5.78E+00	8.39E-03	9.60E-01	8.64E-02	9.88E+00	1.57E-01	1.79E+01	1.98E-01	2.26E+01
Sr-90	4.06E-13	2.61E-08	6.42E+04	0.00E+00	0.00E+00	4.43E-08	1.09E+05	8.41E-08	2.07E+05	1.08E-07	2.65E+05

Table 6-61. Peak Beta-Gamma Dose Factors for ST06

Radio-	Nominal PA Case	Mean		50th Percentile		75th Percentile		90th Percentile		95th Percentile	
nuclide	mrem yr^{-1} Ci^{-1}	mrem yr^{-1} Ci^{-1}	Ratio	mrem yr^{-1} Ci^{-1}	Ratio	mrem yr^{-1} Ci^{-1}	Ratio	mrem yr^{-1} Ci^{-1}	Ratio	mrem yr^{-1} Ci^{-1}	Ratio
I-129	1.97E+03	1.97E+03	1.00E+00	1.97E+03	1.00E+00	2.01E+03	1.02E+00	2.05E+03	1.04E+00	2.07E+03	1.05E+00
Tc-99	2.14E+00	2.35E+00	1.10E+00	2.14E+00	9.98E-01	3.79E+00	1.77E+00	5.19E+00	2.42E+00	5.93E+00	2.77E+00
Np-237	1.78E+00	1.94E+00	1.09E+00	1.77E+00	9.93E-01	3.03E+00	1.70E+00	4.12E+00	2.31E+00	4.77E+00	2.68E+00
H-3	6.86E-01	6.86E-01	1.00E+00	6.86E-01	1.00E+00	7.89E-01	1.15E+00	8.77E-01	1.28E+00	9.25E-01	1.35E+00
C-14	3.15E-02	5.67E-02	1.80E+00	3.16E-02	1.00E+00	9.74E-02	3.09E+00	1.57E-01	4.97E+00	1.93E-01	6.11E+00
Sr-90	1.92E-13	2.18E-08	1.14E+05	0.00E+00	0.00E+00	3.71E-08	1.93E+05	7.04E-08	3.66E+05	9.01E-08	4.69E+05

Table 6-62. Peak Beta-Gamma Dose Factors for ST09

Radio-	Nominal PA Case	Mean		50th Percentile		75th Percentile		90th Percentile		95th Percentile	
nuclide	mrem yr^{-1} Ci^{-1}	mrem yr^{-1} Ci^{-1}	Ratio	mrem yr^{-1} Ci^{-1}	Ratio	mrem yr^{-1} Ci^{-1}	Ratio	mrem yr^{-1} Ci^{-1}	Ratio	mrem yr^{-1} Ci^{-1}	Ratio
I-129	2.11E+03	2.11E+03	1.00E+00	2.11E+03	9.99E-01	2.35E+03	1.11E+00	2.56E+03	1.21E+00	2.68E+03	1.27E+00
Tc-99	2.75E+00	2.75E+00	1.00E+00	2.75E+00	1.00E+00	2.83E+00	1.03E+00	2.90E+00	1.05E+00	2.94E+00	1.07E+00
H-3	7.44E-01	7.44E-01	1.00E+00	7.43E-01	9.99E-01	9.45E-01	1.27E+00	1.12E+00	1.50E+00	1.21E+00	1.62E+00
Np-237	1.49E-01	1.27E+00	8.58E+00	1.31E-01	8.85E-01	2.21E+00	1.49E+01	4.01E+00	2.70E+01	5.05E+00	3.40E+01
C-14	8.54E-04	2.48E-02	2.90E+01	7.24E-04	8.47E-01	4.22E-02	4.95E+01	7.96E-02	9.32E+01	1.01E-01	1.18E+02
Sr-90	7.62E-17	3.71E-12	4.87E+04	9.41E-16	1.24E+01	6.30E-12	8.26E+04	1.19E-11	1.57E+05	1.53E-11	2.01E+05

Table 6-63. Peak Gross-Alpha Concentration Factors for ET06

Radio-nuclide	Nominal PA Case	Mean		50th Percentile		75th Percentile		90th Percentile		95th Percentile	
	pCi L^{-1} Ci^{-1}	pCi L^{-1} Ci^{-1}	Ratio	pCi L^{-1} Ci^{-1}	Ratio	pCi L^{-1} Ci^{-1}	Ratio	pCi L^{-1} Ci^{-1}	Ratio	pCi L^{-1} Ci^{-1}	Ratio
Np-237	1.41E+02	1.42E+02	1.00E+00	1.41E+02	1.00E+00	1.87E+02	1.32E+00	2.27E+02	1.61E+00	2.51E+02	1.78E+00

Table 6-64. Peak Gross-Alpha Concentration Factors for ST06

Radio-nuclide	Nominal PA Case	Mean		50th Percentile		75th Percentile		90th Percentile		95th Percentile	
	pCi L^{-1} Ci^{-1}	pCi L^{-1} Ci^{-1}	Ratio	pCi L^{-1} Ci^{-1}	Ratio	pCi L^{-1} Ci^{-1}	Ratio	pCi L^{-1} Ci^{-1}	Ratio	pCi L^{-1} Ci^{-1}	Ratio
Np-237	1.34E+02	1.45E+02	1.09E+00	1.33E+02	9.93E-01	2.27E+02	1.70E+00	3.09E+02	2.31E+00	3.58E+02	2.68E+00

Table 6-65. Peak Gross-Alpha Concentration Factors for ST09

Radio-nuclide	Nominal PA Case	Mean		50th Percentile		75th Percentile		90th Percentile		95th Percentile	
	pCi L^{-1} Ci^{-1}	pCi L^{-1} Ci^{-1}	Ratio	pCi L^{-1} Ci^{-1}	Ratio	pCi L^{-1} Ci^{-1}	Ratio	pCi L^{-1} Ci^{-1}	Ratio	pCi L^{-1} Ci^{-1}	Ratio
Np-237	1.11E+01	9.55E+01	8.58E+00	9.86E+00	8.85E-01	1.65E+02	1.49E+01	3.01E+02	2.70E+01	3.79E+02	3.40E+01

Table 6-66. Peak Uranium Concentration Factors for ET06

Radio-nuclide	Nominal PA Case	Mean		50th Percentile		75th Percentile		90th Percentile		95th Percentile	
	µg L^{-1} Ci^{-1}	µg L^{-1} Ci^{-1}	Ratio	µg L^{-1} Ci^{-1}	Ratio	µg L^{-1} Ci^{-1}	Ratio	µg L^{-1} Ci^{-1}	Ratio	µg L^{-1} Ci^{-1}	Ratio
Np-237	1.12E-07	1.91E-07	1.70E+00	1.12E-07	9.97E-01	3.31E-07	2.95E+00	5.19E-07	4.62E+00	6.38E-07	5.68E+00

Table 6-67. Peak Uranium Concentration Factors for ST06

Radio-nuclide	Nominal PA Case	Mean		50th Percentile		75th Percentile		90th Percentile		95th Percentile	
	µg L^{-1} Ci^{-1}	µg L^{-1} Ci^{-1}	Ratio	µg L^{-1} Ci^{-1}	Ratio	µg L^{-1} Ci^{-1}	Ratio	µg L^{-1} Ci^{-1}	Ratio	µg L^{-1} Ci^{-1}	Ratio
Np-237	5.26E-08	1.32E-07	2.51E+00	5.09E-08	9.66E-01	2.30E-07	4.37E+00	3.85E-07	7.32E+00	4.78E-07	9.08E+00

Table 6-68. Peak Uranium Concentration Factors for ST09

Radio-nuclide	Nominal PA Case	Mean		50th Percentile		75th Percentile		90th Percentile		95th Percentile	
	µg L^{-1} Ci^{-1}	µg L^{-1} Ci^{-1}	Ratio	µg L^{-1} Ci^{-1}	Ratio	µg L^{-1} Ci^{-1}	Ratio	µg L^{-1} Ci^{-1}	Ratio	µg L^{-1} Ci^{-1}	Ratio
Np-237	1.90E-09	6.92E-08	3.63E+01	1.55E-09	8.12E-01	1.18E-07	6.19E+01	2.22E-07	1.17E+02	2.83E-07	1.49E+02

Table 6-69. Ratios of All-Pathways Dose Factors for Sensitivity Cases to the Nominal PA Dose Factor for ET06

Radionuclide	Nominal PA Case	Sensitivity Cases						
		Waste Zone Conductivity	LVZ Porosity	Tan Clay Thickness	Waste Zone Porosity	Infiltration	K_d	Disposal Time
	mrem yr^{-1} Ci^{-1}	Ratio (unitless)						
C-14	8.76E-03	1.05	1.02	13.32	1.58	10.41	27.55	0.19
H-3	9.84E-07	1.00	1.00	1.00	1.00	0.98	1.00	2.84
I-129	6.76E+01	0.99	0.98	0.77	0.98	0.47	0.69	1.35
Np-237	2.83E+01	1.01	1.05	1.44	1.14	1.51	1.74	0.30
Sr-90	4.75E-14	1.19	1.35	14.37	1.54	428.16	4.06E+05	0.09
Tc-99	3.34E-01	1.04	1.04	1.79	1.11	2.54	1.07	4.25

Notes:

Ratio values between 100 and 1,000 are highlighted in blue while values greater than 1,000 are highlighted in orange.

Table 6-70. Ratios of All-Pathways Dose Factors for Sensitivity Cases to the Nominal PA Dose Factor for ST06

Radionuclide	Nominal PA Case (mrem yr^{-1} Ci^{-1})	Sensitivity Cases						
		Waste Zone Conductivity	LVZ Porosity	Tan Clay Thickness	Waste Zone Porosity	Infiltration	K_d	Disposal Time
		Ratio (unitless)						
C-14	3.16E-02	1.08	1.03	1.68	1.04	3.05	8.22	0.47
H-3	9.15E-07	1.00	1.01	1.00	1.00	0.97	1.00	2.90
I-129	1.15E+02	0.99	0.99	1.02	1.02	0.98	0.89	1.17
Np-237	2.68E+01	1.09	1.13	1.15	1.03	2.22	2.9	0.43
Sr-90	2.25E-14	1.56	1.69	1.22	1.04	557.56	7.18E+05	0.25
Tc-99	1.41E+00	0.97	0.98	0.98	1.00	0.49	0.97	1.47

Notes:

Ratio values between 100 and 1,000 are highlighted in blue while values greater than 1,000 are highlighted in orange.

Table 6-71. Ratios of All-Pathways Dose Factors for Sensitivity Cases to the Nominal PA Dose Factor for ST09

Radionuclide	Nominal PA Case (mrem yr^{-1} Ci^{-1})	Sensitivity Cases						
		Waste Zone Conductivity	LVZ Porosity	Tan Clay Thickness	Waste Zone Porosity	Infiltration	K_d	Disposal Time
		Ratio (unitless)						
C-14	8.56E-04	1.29	1.1	56.4	1.04	38.81	159.41	0.14
H-3	1.06E-06	1.00	1.01	1.00	1.00	0.93	1.00	1.16
I-129	1.24E+02	0.98	0.99	1.01	1.01	1.25	1.21	1.13
Np-237	2.23E+00	1.42	1.48	4.54	1.04	26.16	37.27	0.09
Sr-90	8.92E-18	3.04	2.68	35.86	1.04	8.04E+03	3.07E+05	0.04
Tc-99	1.82E+00	0.97	0.99	1.02	1.00	1.06	0.95	1.17

Notes:

Ratio values between 100 and 1,000 are highlighted in blue while values greater than 1,000 are highlighted in orange.

6.1.2.2.2. Low-Activity Waste and Intermediate-Level Vaults

Table 6-72. Peak All-Pathways Dose Factors for Low-Activity Waste Vault

Radio-	Nominal PA Case	Mean		50th Percentile		75th Percentile		90th Percentile		95th Percentile	
nuclide	mrem yr^{-1} Ci^{-1}	mrem yr^{-1} Ci^{-1}	Ratio	mrem yr^{-1} Ci^{-1}	Ratio	mrem yr^{-1} Ci^{-1}	Ratio	mrem yr^{-1} Ci^{-1}	Ratio	mrem yr^{-1} Ci^{-1}	Ratio
I-129	1.02E+02	1.02E+02	1.00E+00	1.02E+02	1.00E+00	1.18E+02	1.16E+00	1.32E+02	1.29E+00	1.40E+02	1.37E+00
Tc-99	7.52E-04	6.54E-03	8.69E+00	6.47E-04	8.60E-01	1.13E-02	1.50E+01	2.06E-02	2.74E+01	2.62E-02	3.48E+01
Cl-36	6.41E-04	4.17E-01	6.50E+02	1.84E-04	2.87E-01	7.18E-01	1.12E+03	1.35E+00	2.11E+03	1.70E+00	2.66E+03
H-3	2.10E-11	2.10E-11	1.00E+00	2.11E-11	1.00E+00	2.65E-11	1.26E+00	3.14E-11	1.49E+00	3.44E-11	1.63E+00
Np-237	2.15E-20	4.19E-10	1.95E+10	1.71E-13	7.95E+06	7.13E-10	3.32E+10	1.35E-09	6.31E+10	1.74E-09	8.09E+10
U-235	1.09E-21	2.69E-11	2.48E+10	0.00E+00	0.00E+00	4.58E-11	4.22E+10	8.70E-11	8.01E+10	1.11E-10	1.03E+11
Am-241	2.30E-24	5.11E-14	2.22E+10	4.05E-17	1.76E+07	8.69E-14	3.78E+10	1.65E-13	7.17E+10	2.12E-13	9.20E+10
Cm-245	9.82E-25	2.52E-14	2.57E+10	0.00E+00	0.00E+00	4.28E-14	4.36E+10	8.14E-14	8.29E+10	1.04E-13	1.06E+11
Pu-241	7.41E-26	1.66E-15	2.24E+10	1.51E-18	2.04E+07	2.82E-15	3.81E+10	5.35E-15	7.23E+10	6.87E-15	9.27E+10
K-40	5.23E-26	2.34E-11	4.48E+14	0.00E+00	0.00E+00	3.98E-11	7.61E+14	7.56E-11	1.44E+15	9.69E-11	1.85E+15
Ca-41	1.75E-26	5.89E-11	3.38E+15	0.00E+00	0.00E+00	1.00E-10	5.74E+15	1.90E-10	1.09E+16	2.44E-10	1.40E+16
Pu-239	2.99E-28	8.71E-18	2.91E+10	0.00E+00	0.00E+00	1.48E-17	4.94E+10	2.81E-17	9.40E+10	3.60E-17	1.20E+11
C-14	4.86E-33	3.46E-19	7.11E+13	0.00E+00	0.00E+00	5.87E-19	1.21E+14	1.12E-18	2.29E+14	1.43E-18	2.94E+14
Ni-59	4.44E-41	2.35E-21	5.30E+19	0.00E+00	0.00E+00	4.00E-21	9.01E+19	7.58E-21	1.71E+20	9.71E-21	2.19E+20
Sr-90	3.16E-42	8.75E-26	2.77E+16	0.00E+00	0.00E+00	1.51E-25	4.77E+16	2.86E-25	9.04E+16	3.66E-25	1.16E+17
Ni-63	3.00E-44	1.66E-24	5.52E+19	0.00E+00	0.00E+00	2.82E-24	9.38E+19	5.34E-24	1.78E+20	6.84E-24	2.28E+20
Ag-108m	6.69E-55	--	--	--	--	--	--	--	--	--	--
Cs-137	1.02E-58	--	--	--	--	--	--	--	--	--	--
Ra-226	2.17E-108	--	--	--	--	--	--	--	--	--	--

Notes:

Entries with “--” represent numbers below single precision.

Table 6-73. Peak All-Pathways Dose Factors for Intermediate-Level Vault

Radio-nuclide	Nominal PA Case	Mean		50th Percentile		75th Percentile		90th Percentile		95th Percentile	
	mrem yr^{-1} Ci^{-1}	mrem yr^{-1} Ci^{-1}	Ratio	mrem yr^{-1} Ci^{-1}	Ratio	mrem yr^{-1} Ci^{-1}	Ratio	mrem yr^{-1} Ci^{-1}	Ratio	mrem yr^{-1} Ci^{-1}	Ratio
I-129	2.25E+01	3.14E+01	1.40E+00	2.27E+01	1.01E+00	5.40E+01	2.40E+00	8.09E+01	3.60E+00	9.59E+01	4.26E+00
Cl-36	4.27E-03	4.02E-01	9.41E+01	5.21E-03	1.22E+00	6.95E-01	1.63E+02	1.31E+00	3.06E+02	1.63E+00	3.82E+02
Ar-39	8.71E-06	8.74E-06	1.00E+00	8.72E-06	1.00E+00	1.20E-05	1.37E+00	1.48E-05	1.70E+00	1.62E-05	1.86E+00
Tc-99	5.26E-08	1.64E-06	3.11E+01	5.26E-08	1.00E+00	2.79E-06	5.30E+01	5.27E-06	1.00E+02	6.72E-06	1.28E+02
H-3	1.67E-09	1.67E-09	1.00E+00	1.67E-09	1.00E+00	1.85E-09	1.11E+00	2.00E-09	1.20E+00	2.09E-09	1.25E+00
K-40	7.82E-26	4.15E-13	5.31E+12	0.00E+00	0.00E+00	7.05E-13	9.02E+12	1.34E-12	1.71E+13	1.71E-12	2.19E+13
C-14	4.22E-30	9.99E-22	2.37E+08	0.00E+00	0.00E+00	1.70E-21	4.02E+08	3.22E-21	7.63E+08	4.13E-21	9.79E+08
Np-237	3.18E-30	1.89E-18	5.94E+11	0.00E+00	0.00E+00	3.21E-18	1.01E+12	6.09E-18	1.91E+12	7.79E-18	2.45E+12
U-235	2.41E-30	2.36E-18	9.77E+11	0.00E+00	0.00E+00	4.01E-18	1.66E+12	7.61E-18	3.15E+12	9.75E-18	4.04E+12
Am-241	5.54E-34	4.14E-22	7.47E+11	0.00E+00	0.00E+00	7.04E-22	1.27E+12	1.34E-21	2.41E+12	1.71E-21	3.09E+12
Cm-245	3.49E-34	3.84E-22	1.10E+12	0.00E+00	0.00E+00	6.54E-22	1.87E+12	1.24E-21	3.55E+12	1.59E-21	4.55E+12
Pu-241	1.81E-35	1.37E-23	7.59E+11	0.00E+00	0.00E+00	2.33E-23	1.29E+12	4.43E-23	2.45E+12	5.67E-23	3.14E+12
Cf-249	5.02E-36	6.71E-24	1.34E+12	0.00E+00	0.00E+00	1.14E-23	2.28E+12	2.16E-23	4.32E+12	2.77E-23	5.53E+12
Pu-239	6.61E-37	8.37E-25	1.27E+12	0.00E+00	0.00E+00	1.42E-24	2.16E+12	2.70E-24	4.09E+12	3.46E-24	5.23E+12
Ni-59	1.72E-46	--	--	--	--	--	--	--	--	--	--
Ni-63	1.15E-49	--	--	--	--	--	--	--	--	--	--
Sr-90	9.66E-51	--	--	--	--	--	--	--	--	--	--
Cs-137	2.01E-53	--	--	--	--	--	--	--	--	--	--
Ag-108m	3.94E-63	--	--	--	--	--	--	--	--	--	--
Ra-226	1.06E-99	--	--	--	--	--	--	--	--	--	--

Notes:

Entries with "--" represent numbers below single precision.

Table 6-74. Peak Beta-Gamma Dose Factors for Low-Activity Waste Vault

Radio-nuclide	Nominal PA Case	Mean		50th Percentile		75th Percentile		90th Percentile		95th Percentile	
	mrem yr-1 Ci-1	mrem yr-1 Ci-1	Ratio	mrem yr-1 Ci-1	Ratio	mrem yr-1 Ci-1	Ratio	mrem yr-1 Ci-1	Ratio	mrem yr-1 Ci-1	Ratio
I-129	1.75E+03	1.75E+03	1.00E+00	1.75E+03	1.00E+00	2.02E+03	1.16E+00	2.26E+03	1.29E+00	2.40E+03	1.37E+00
Tc-99	1.14E-03	9.91E-03	8.69E+00	9.80E-04	8.60E-01	1.71E-02	1.50E+01	3.12E-02	2.74E+01	3.97E-02	3.48E+01
Cl-36	7.13E-04	4.63E-01	6.50E+02	2.05E-04	2.87E-01	7.98E-01	1.12E+03	1.50E+00	2.11E+03	1.89E+00	2.66E+03
H-3	6.04E-10	6.04E-10	1.00E+00	6.03E-10	1.00E+00	7.34E-10	1.22E+00	8.47E-10	1.40E+00	9.17E-10	1.52E+00
Np-237	1.43E-21	2.79E-11	1.95E+10	1.13E-14	7.95E+06	4.74E-11	3.32E+10	9.00E-11	6.31E+10	1.15E-10	8.09E+10
U-235	8.03E-25	3.32E-14	4.13E+10	0.00E+00	0.00E+00	5.64E-14	7.01E+10	1.07E-13	1.33E+11	1.37E-13	1.71E+11
Am-241	1.53E-25	3.40E-15	2.22E+10	2.69E-18	1.76E+07	5.78E-15	3.78E+10	1.10E-14	7.17E+10	1.41E-14	9.20E+10
Cm-245	6.53E-26	1.68E-15	2.57E+10	0.00E+00	0.00E+00	2.85E-15	4.36E+10	5.41E-15	8.29E+10	6.93E-15	1.06E+11
K-40	5.44E-26	2.44E-11	4.48E+14	0.00E+00	0.00E+00	4.14E-11	7.61E+14	7.86E-11	1.44E+15	1.01E-10	1.85E+15
Ca-41	8.53E-27	2.88E-11	3.38E+15	0.00E+00	0.00E+00	4.89E-11	5.74E+15	9.29E-11	1.09E+16	1.19E-10	1.40E+16
Pu-241	4.93E-27	1.10E-16	2.24E+10	1.00E-19	2.04E+07	1.87E-16	3.81E+10	3.56E-16	7.23E+10	4.57E-16	9.27E+10
Pu-239	2.20E-31	1.06E-20	4.83E+10	0.00E+00	0.00E+00	1.81E-20	8.20E+10	3.43E-20	1.56E+11	4.40E-20	2.00E+11
C-14	4.85E-33	3.45E-19	7.11E+13	0.00E+00	0.00E+00	5.85E-19	1.21E+14	1.11E-18	2.29E+14	1.43E-18	2.94E+14
Ni-59	4.27E-39	2.26E-19	5.30E+19	0.00E+00	0.00E+00	3.85E-19	9.01E+19	7.30E-19	1.71E+20	9.35E-19	2.19E+20
Sr-90	2.70E-41	7.58E-25	2.80E+16	0.00E+00	0.00E+00	1.29E-24	4.77E+16	2.44E-24	9.04E+16	3.13E-24	1.16E+17
Ni-63	6.98E-42	3.85E-22	5.52E+19	0.00E+00	0.00E+00	6.55E-22	9.38E+19	1.24E-21	1.78E+20	1.59E-21	2.28E+20
Ag-108m	8.93E-55	--	--	--	--	--	--	--	--	--	--
Cs-137	6.84E-59	--	--	--	--	--	--	--	--	--	--
Ra-226	1.69E-110	--	--	--	--	--	--	--	--	--	--

Notes:

Entries with “--” represent numbers below single precision.

Table 6-75. Peak Beta-Gamma Dose Factors for Intermediate-Level Vault

Radio-nuclide	Nominal PA Case	Mean		50th Percentile		75th Percentile		90th Percentile		95th Percentile	
	mrem yr^{-1} Ci^{-1}	mrem yr^{-1} Ci^{-1}	Ratio	mrem yr^{-1} Ci^{-1}	Ratio	mrem yr^{-1} Ci^{-1}	Ratio	mrem yr^{-1} Ci^{-1}	Ratio	mrem yr^{-1} Ci^{-1}	Ratio
I-129	3.85E+02	5.37E+02	1.40E+00	3.88E+02	1.01E+00	9.22E+02	2.40E+00	1.38E+03	3.60E+00	1.64E+03	4.26E+00
Cl-36	4.75E-03	4.47E-01	9.41E+01	5.79E-03	1.22E+00	7.72E-01	1.63E+02	1.45E+00	3.06E+02	1.81E+00	3.82E+02
Tc-99	7.98E-08	2.48E-06	3.11E+01	7.98E-08	1.00E+00	4.23E-06	5.30E+01	7.99E-06	1.00E+02	1.02E-05	1.28E+02
H-3	3.70E-08	3.70E-08	1.00E+00	3.70E-08	1.00E+00	4.58E-08	1.24E+00	5.32E-08	1.44E+00	5.73E-08	1.55E+00
K-40	8.13E-26	4.31E-13	5.31E+12	0.00E+00	0.00E+00	7.33E-13	9.02E+12	1.39E-12	1.71E+13	1.78E-12	2.19E+13
C-14	4.21E-30	2.09E-21	4.97E+08	0.00E+00	0.00E+00	3.55E-21	8.45E+08	6.75E-21	1.60E+09	8.64E-21	2.05E+09
Np-237	2.11E-31	1.25E-19	5.94E+11	0.00E+00	0.00E+00	2.13E-19	1.01E+12	4.05E-19	1.91E+12	5.18E-19	2.45E+12
U-235	1.60E-33	2.31E-21	1.45E+12	0.00E+00	0.00E+00	3.94E-21	2.46E+12	7.46E-21	4.66E+12	9.56E-21	5.97E+12
Am-241	3.69E-35	2.75E-23	7.47E+11	0.00E+00	0.00E+00	4.68E-23	1.27E+12	8.88E-23	2.41E+12	1.14E-22	3.09E+12
Cm-245	2.32E-35	2.55E-23	1.10E+12	0.00E+00	0.00E+00	4.35E-23	1.87E+12	8.24E-23	3.55E+12	1.06E-22	4.55E+12
Pu-241	1.20E-36	9.12E-25	7.59E+11	0.00E+00	0.00E+00	1.55E-24	1.29E+12	2.94E-24	2.45E+12	3.77E-24	3.14E+12
Cf-249	3.34E-37	4.46E-25	1.34E+12	0.00E+00	0.00E+00	7.59E-25	2.28E+12	1.44E-24	4.32E+12	1.84E-24	5.53E+12
Pu-239	4.33E-40	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ni-59	1.66E-44	1.41E-25	8.48E+18	0.00E+00	0.00E+00	2.40E-25	1.45E+19	4.56E-25	2.75E+19	5.84E-25	3.52E+19
Ni-63	2.67E-47	--	--	--	--	--	--	--	--	--	--
Sr-90	8.25E-50	--	--	--	--	--	--	--	--	--	--
Cs-137	1.35E-53	--	--	--	--	--	--	--	--	--	--
Ag-108m	5.26E-63	--	--	--	--	--	--	--	--	--	--
Ra-226	2.01E-101	--	--	--	--	--	--	--	--	--	--
Ar-39	0.00E+00	--	--	--	--	--	--	--	--	--	--

Notes:

Entries with "--" represent numbers below single precision.

Table 6-76. Peak Gross-Alpha Concentration Factors for Low-Activity Waste Vault

Radio-	Nominal PA Case	Mean		50th Percentile		75th Percentile		90th Percentile		95th Percentile	
nuclide	pCi L^{-1} Ci^{-1}	pCi L^{-1} Ci^{-1}	Ratio	pCi L^{-1} Ci^{-1}	Ratio	pCi L^{-1} Ci^{-1}	Ratio	pCi L^{-1} Ci^{-1}	Ratio	pCi L^{-1} Ci^{-1}	Ratio
Np-237	1.07E-19	2.09E-09	1.95E+10	8.51E-13	7.95E+06	3.55E-09	3.32E+10	6.75E-09	6.31E+10	8.66E-09	8.09E+10
U-235	1.23E-21	3.07E-11	2.48E+10	0.00E+00	0.00E+00	5.21E-11	4.22E+10	9.91E-11	8.02E+10	1.27E-10	1.03E+11
Am-241	1.15E-23	2.55E-13	2.22E+10	2.02E-16	1.76E+07	4.33E-13	3.78E+10	8.23E-13	7.17E+10	1.05E-12	9.20E+10
Cm-245	4.90E-24	1.26E-13	2.57E+10	0.00E+00	0.00E+00	2.14E-13	4.36E+10	4.06E-13	8.29E+10	5.20E-13	1.06E+11
Pu-241	3.69E-25	8.27E-15	2.24E+10	7.53E-18	2.04E+07	1.41E-14	3.81E+10	2.67E-14	7.23E+10	3.42E-14	9.27E+10
Pu-239	3.40E-28	9.92E-18	2.91E+10	0.00E+00	0.00E+00	1.68E-17	4.95E+10	3.20E-17	9.41E+10	4.10E-17	1.20E+11
Ra-226	8.68E-108	--	--	--	--	--	--	--	--	--	--

Notes:

Entries with “--” represent numbers below single precision.

Table 6-77. Peak Gross-Alpha Concentration Factors for Intermediate-Level Vault

Radio-	Nominal PA Case	Mean		50th Percentile		75th Percentile		90th Percentile		95th Percentile	
nuclide	pCi L^{-1} Ci^{-1}	pCi L^{-1} Ci^{-1}	Ratio	pCi L^{-1} Ci^{-1}	Ratio	pCi L^{-1} Ci^{-1}	Ratio	pCi L^{-1} Ci^{-1}	Ratio	pCi L^{-1} Ci^{-1}	Ratio
Np-237	1.59E-29	9.41E-18	5.94E+11	0.00E+00	0.00E+00	1.60E-17	1.01E+12	3.04E-17	1.91E+12	3.89E-17	2.45E+12
U-235	2.74E-30	2.68E-18	9.78E+11	0.00E+00	0.00E+00	4.57E-18	1.66E+12	8.66E-18	3.15E+12	1.11E-17	4.04E+12
Am-241	2.76E-33	2.06E-21	7.47E+11	0.00E+00	0.00E+00	3.51E-21	1.27E+12	6.66E-21	2.41E+12	8.53E-21	3.09E+12
Cm-245	1.74E-33	1.92E-21	1.10E+12	0.00E+00	0.00E+00	3.26E-21	1.87E+12	6.18E-21	3.55E+12	7.91E-21	4.55E+12
Pu-241	9.01E-35	6.84E-23	7.59E+11	0.00E+00	0.00E+00	1.16E-22	1.29E+12	2.21E-22	2.45E+12	2.83E-22	3.14E+12
Cf-249	2.50E-35	3.35E-23	1.34E+12	0.00E+00	0.00E+00	5.70E-23	2.28E+12	1.08E-22	4.32E+12	1.38E-22	5.53E+12
Pu-239	7.51E-37	9.53E-25	1.27E+12	0.00E+00	0.00E+00	1.62E-24	2.16E+12	3.07E-24	4.09E+12	3.94E-24	5.24E+12
Ra-226	4.22E-99	--	--	--	--	--	--	--	--	--	--

Notes:

Entries with “--” represent numbers below single precision.

Table 6-78. Peak Uranium Concentration Factors for Low-Activity Waste Vault

Radio-nuclide	Nominal PA Case	Mean		50th Percentile		75th Percentile		90th Percentile		95th Percentile	
	µg L-1 Ci-1	µg L-1 Ci-1	Ratio	µg L-1 Ci-1	Ratio	µg L-1 Ci-1	Ratio	µg L-1 Ci-1	Ratio	µg L-1 Ci-1	Ratio
Np-237	4.48E-30	2.09E-19	4.66E+10	0.00E+00	0.00E+00	3.55E-19	7.91E+10	6.74E-19	1.50E+11	8.64E-19	1.93E+11
Am-241	4.77E-34	2.51E-23	5.27E+10	0.00E+00	0.00E+00	4.27E-23	8.96E+10	8.12E-23	1.70E+11	1.04E-22	2.18E+11
Cm-245	2.02E-34	1.22E-23	6.05E+10	0.00E+00	0.00E+00	2.07E-23	1.03E+11	3.94E-23	1.95E+11	5.05E-23	2.50E+11
Pu-241	1.54E-35	8.15E-25	5.31E+10	0.00E+00	0.00E+00	1.39E-24	9.02E+10	2.63E-24	1.72E+11	3.37E-24	2.20E+11
U-235	4.13E-184	--	--	--	--	--	--	--	--	--	--
Pu-239	8.55E-191	--	--	--	--	--	--	--	--	--	--

Notes:

Entries with "--" represent numbers below single precision.

Table 6-79. Peak Uranium Concentration Factors for Intermediate-Level Vault

Radio-nuclide	Nominal PA Case	Mean		50th Percentile		75th Percentile		90th Percentile		95th Percentile	
	µg L-1 Ci-1	µg L-1 Ci-1	Ratio	µg L-1 Ci-1	Ratio	µg L-1 Ci-1	Ratio	µg L-1 Ci-1	Ratio	µg L-1 Ci-1	Ratio
Np-237	5.85E-40	--	--	--	--	--	--	--	--	--	--
Am-241	1.01E-43	--	--	--	--	--	--	--	--	--	--
Cm-245	6.25E-44	--	--	--	--	--	--	--	--	--	--
Pu-241	3.29E-45	--	--	--	--	--	--	--	--	--	--
Cf-249	8.89E-46	--	--	--	--	--	--	--	--	--	--
U-235	5.48E-176	--	--	--	--	--	--	--	--	--	--
Pu-239	1.05E-183	--	--	--	--	--	--	--	--	--	--

Notes:

Entries with "--" represent numbers below single precision.

Table 6-80. Ratios of All-Pathways Dose Factors for Best Estimate and Sensitivity Cases to the Nominal PA Dose Factor for Low-Activity Waste Vault

Radionuclide	Nominal PA Case (mrem yr^{-1} Ci^{-1})	Best Estimate Cases		Sensitivity Cases						
		BE	BE2	Concrete Porosity	Concrete Degradation	Concrete Aging	LVZ Porosity	Waste Porosity	Infiltration	K_d
		Ratio (unitless)								
Ag-108m	6.69E-55	9.84E+00	7.64E+00	1.06E+06	5.20E+01	1.00E+00	3.85E+00	1.83E-01	2.50E+18	1.79E+23
Am-241	2.30E-24	1.34E-04	1.05E-06	6.73E+02	5.40E-04	1.00E+00	1.72E+00	2.26E-01	2.03E+09	1.40E+11
C-14	4.86E-33	2.94E-04	2.75E-04	1.03E+04	1.51E-03	9.56E-01	1.19E+00	1.86E-01	3.04E+12	4.49E+14
Ca-41	1.75E-26	1.85E-01	1.70E-01	5.19E+03	8.78E-01	1.03E+00	2.44E+00	1.92E-01	9.17E+13	2.13E+16
Cl-36	6.41E-04	1.55E-01	1.52E-01	1.43E+00	7.13E-01	9.99E-01	1.08E+00	2.21E-01	2.17E+03	2.75E+03
Cm-245	9.82E-25	5.88E-05	1.39E-10	3.41E+02	2.39E-04	1.00E+00	1.72E+00	2.18E-01	2.17E+09	1.62E+11
Cs-137	1.02E-58	2.30E+01	2.27E+01	3.13E+02	1.29E+02	1.00E+00	3.79E+00	1.64E-01	5.73E+16	3.04E+21
H-3	2.10E-11	2.01E+00	4.93E+00	7.28E-01	7.20E-01	1.00E+00	6.86E-01	1.89E+00	7.28E-01	1.00E+00
I-129	1.02E+02	2.56E-01	2.56E-01	9.60E-01	6.16E-01	9.98E-01	1.00E+00	6.87E-01	1.31E+00	1.32E+00
K-40	5.23E-26	2.95E+00	2.69E+00	4.89E+01	1.66E+01	1.00E+00	2.38E+00	1.76E-01	1.61E+13	2.83E+15
Ni-59	4.44E-41	1.03E+00	9.04E-01	2.87E+04	5.47E+00	1.00E+00	3.11E+00	1.74E-01	8.15E+16	3.35E+20
Ni-63	3.00E-44	1.04E+00	1.50E+00	2.89E+04	5.56E+00	1.00E+00	3.11E+00	1.74E-01	8.31E+16	3.49E+20
Np-237	2.15E-20	2.39E-04	2.25E-04	1.11E+03	9.64E-04	1.00E+00	1.71E+00	2.34E-01	1.88E+09	1.23E+11
Pu-239	2.99E-28	6.54E-05	9.02E-12	8.18E+02	3.24E-04	1.00E+00	1.72E+00	2.05E-01	2.16E+09	1.84E+11
Pu-241	7.41E-26	1.27E-04	5.09E-21	6.45E+02	5.13E-04	1.00E+00	1.72E+00	2.25E-01	2.04E+09	1.41E+11
Ra-226	2.17E-108	4.46E+03	4.47E-06	1.12E+08	2.41E+04	1.00E+00	5.60E+00	1.55E-01	1.12E+22	2.20E+30
Sr-90	3.16E-42	1.38E-01	6.97E-01	3.14E+04	6.46E-01	1.00E+00	2.49E+00	2.00E-01	2.22E+14	1.77E+17
Tc-99	7.52E-04	5.34E-03	5.30E-03	2.32E+00	9.09E-03	1.00E+00	1.01E+00	7.21E-01	1.90E+01	4.61E+01
U-235	1.09E-21	1.24E-04	5.35E-05	1.14E+03	5.75E-04	1.00E+00	1.72E+00	2.15E-01	2.05E+09	1.57E+11

Notes:

Ratio values between 100 and 1,000 are highlighted in blue while values greater than 1,000 are highlighted in orange.

Table 6-81. Ratios of All-Pathways Dose Factors for Best Estimate and Sensitivity Cases to the Nominal PA Dose Factor for Intermediate-Level Vault

Radionuclide	Nominal PA Case (mrem yr^{-1} Ci^{-1})	Best Estimate Cases		Sensitivity Cases						
		BE	BE2	Concrete Porosity	Concrete Degradation	Concrete Aging	LVZ Porosity	Waste Porosity	Infiltration	K_d
		Ratio (unitless)								
Ag-108m	3.94E-63	4.19E-01	3.39E-05	1.12E+00	1.17E+00	1.00E+00	8.38E+00	3.59E-01	3.01E+12	4.73E+20
Am-241	5.54E-34	2.22E-02	5.88E-02	2.88E+02	6.34E-02	1.00E+00	3.14E+00	3.44E-01	7.07E+09	4.72E+12
Ar-39	8.71E-06	4.19E-01	4.86E-01	9.65E-01	4.34E-01	1.00E+00	1.04E+00	1.20E+00	1.92E+00	1.00E+00
C-14	4.22E-30	3.75E-06	9.43E-06	9.63E-01	1.06E-05	9.89E-01	1.48E+00	3.61E-01	8.29E+06	3.14E+09
Cf-249	5.02E-36	2.16E-02	4.91E-02	2.83E+02	6.13E-02	1.00E+00	3.16E+00	3.41E-01	1.15E+10	8.46E+12
Cl-36	4.27E-03	6.87E-01	5.16E-01	1.06E+00	5.25E-01	1.00E+00	1.21E+00	1.14E+00	3.33E+02	3.60E+02
Cm-245	3.49E-34	2.22E-02	5.36E-02	2.92E+02	6.31E-02	1.00E+00	3.16E+00	3.42E-01	9.81E+09	6.96E+12
Cs-137	2.01E-53	7.07E-01	2.29E-05	9.91E-01	1.16E+00	1.00E+00	7.64E+00	6.12E-01	2.01E+09	6.23E+15
H-3	1.67E-09	1.98E+00	3.67E+00	9.99E-01	9.98E-01	1.00E+00	9.44E-01	1.99E+00	1.23E+00	1.00E+00
I-129	2.25E+01	1.21E-01	2.62E-01	1.05E+00	2.63E-01	9.90E-01	1.11E+00	4.74E-01	3.96E+00	3.82E+00
K-40	7.82E-26	6.93E-01	5.77E-03	1.07E+00	1.12E+00	1.00E+00	3.50E+00	6.16E-01	1.75E+10	3.35E+13
Ni-59	1.72E-46	9.82E-02	1.16E-03	5.10E+00	2.57E-01	1.00E+00	8.30E+00	4.39E-01	2.67E+13	5.39E+19
Ni-63	1.15E-49	1.03E-01	1.56E-03	5.05E+00	2.71E-01	1.00E+00	8.27E+00	4.38E-01	2.67E+13	5.62E+19
Np-237	3.18E-30	1.95E-02	5.25E-02	2.47E+02	5.61E-02	1.00E+00	3.14E+00	3.43E-01	5.76E+09	3.75E+12
Pu-239	6.61E-37	2.83E-02	6.26E-02	3.61E+02	7.79E-02	1.00E+00	3.12E+00	3.59E-01	1.17E+10	8.01E+12
Pu-241	1.81E-35	2.23E-02	5.89E-02	2.91E+02	6.36E-02	1.00E+00	3.14E+00	3.44E-01	7.17E+09	4.80E+12
Ra-226	1.06E-99	3.67E-01	1.11E-07	9.90E-01	1.01E+00	1.00E+00	1.35E+01	3.65E-01	1.37E+13	5.11E+25
Sr-90	9.66E-51	1.13E-02	5.03E-02	6.98E+01	2.86E-02	1.00E+00	6.44E+00	4.76E-01	2.33E+12	1.67E+17
Tc-99	5.26E-08	2.01E-03	2.30E-03	2.36E+00	2.35E-03	1.00E+00	1.04E+00	9.38E-01	5.62E+01	1.78E+02
U-235	2.41E-30	3.56E-02	9.02E-02	3.97E+02	9.58E-02	1.00E+00	3.11E+00	3.70E-01	9.39E+09	6.18E+12

Notes:

Ratio values between 100 and 1,000 are highlighted in blue while values greater than 1,000 are highlighted in orange.

6.1.2.2.3. Naval Reactor Component Disposal Areas

Table 6-82. Peak All-Pathways Dose Factors for NR07E Casks (Case 3)

Radio-nuclide	Nominal PA Case 3 (mrem yr^{-1} Ci^{-1})	Mean		50th Percentile		75th Percentile		90th Percentile		95th Percentile	
		mrem yr^{-1} Ci^{-1}	Ratio	mrem yr^{-1} Ci^{-1}	Ratio	mrem yr^{-1} Ci^{-1}	Ratio	mrem yr^{-1} Ci^{-1}	Ratio	mrem yr^{-1} Ci^{-1}	Ratio
I-129S	3.59E-01	2.92E+00	8.13E+00	3.32E-01	9.24E-01	5.03E+00	1.40E+01	9.23E+00	2.57E+01	1.17E+01	3.25E+01
Tc-99S	1.24E-01	1.26E-01	1.01E+00	1.24E-01	1.00E+00	1.77E-01	1.42E+00	2.23E-01	1.80E+00	2.49E-01	2.01E+00
Cl-36S	1.17E-06	8.82E-04	7.54E+02	2.85E-06	2.44E+00	1.49E-03	1.28E+03	2.85E-03	2.44E+03	3.65E-03	3.12E+03
Np-237S	3.25E-09	3.66E-05	1.12E+04	6.08E-08	1.87E+01	6.21E-05	1.91E+04	1.18E-04	3.63E+04	1.52E-04	4.66E+04
U-235S	2.38E-10	2.70E-06	1.14E+04	3.73E-09	1.57E+01	4.59E-06	1.93E+04	8.73E-06	3.68E+04	1.12E-05	4.72E+04
Am-241S	4.73E-13	5.35E-09	1.13E+04	8.66E-12	1.83E+01	9.08E-09	1.92E+04	1.73E-08	3.65E+04	2.22E-08	4.69E+04
Pu-241S	1.55E-14	1.75E-10	1.13E+04	2.82E-13	1.82E+01	2.98E-10	1.92E+04	5.66E-10	3.65E+04	7.26E-10	4.69E+04
C-14S	1.31E-14	3.15E-10	2.41E+04	0.00E+00	0.00E+00	5.35E-10	4.10E+04	1.02E-09	7.78E+04	1.30E-09	9.98E+04
Be-10S	1.09E-17	8.57E-11	7.88E+06	0.00E+00	0.00E+00	1.46E-10	1.34E+07	2.76E-10	2.54E+07	3.54E-10	3.25E+07
Ni-59S	6.69E-25	7.45E-17	1.11E+08	0.00E+00	0.00E+00	1.27E-16	1.89E+08	2.40E-16	3.59E+08	3.07E-16	4.59E+08
Ni-63S	3.86E-28	4.49E-20	1.16E+08	0.00E+00	0.00E+00	7.63E-20	1.97E+08	1.45E-19	3.74E+08	1.85E-19	4.80E+08

Table 6-83. Peak All-Pathways Dose Factors for NR26E Casks (Case 4)

Radio-nuclide	Nominal PA Case 4 (mrem yr^{-1} Ci^{-1})	Mean		50th Percentile		75th Percentile		90th Percentile		95th Percentile	
		mrem yr^{-1} Ci^{-1}	Ratio	mrem yr^{-1} Ci^{-1}	Ratio	mrem yr^{-1} Ci^{-1}	Ratio	mrem yr^{-1} Ci^{-1}	Ratio	mrem yr^{-1} Ci^{-1}	Ratio
I-129S	5.35E-03	5.98E-01	1.12E+02	7.87E-03	1.47E+00	1.06E+00	1.97E+02	1.95E+00	3.65E+02	2.44E+00	4.55E+02
Tc-99S	1.58E-03	1.61E-02	1.02E+01	1.65E-03	1.04E+00	2.85E-02	1.81E+01	5.15E-02	3.26E+01	6.40E-02	4.05E+01
Cl-36S	3.55E-08	6.54E-05	1.84E+03	0.00E+00	0.00E+00	1.15E-04	3.25E+03	2.12E-04	5.99E+03	2.66E-04	7.49E+03
Np-237S	1.29E-11	5.35E-07	4.15E+04	0.00E+00	0.00E+00	9.08E-07	7.04E+04	1.74E-06	1.35E+05	2.23E-06	1.73E+05
U-235S	9.36E-13	3.92E-08	4.19E+04	0.00E+00	0.00E+00	6.65E-08	7.11E+04	1.27E-07	1.36E+05	1.64E-07	1.75E+05
Am-241S	1.87E-15	7.79E-11	4.17E+04	0.00E+00	0.00E+00	1.32E-10	7.07E+04	2.53E-10	1.35E+05	3.25E-10	1.74E+05
C-14S	5.85E-16	1.51E-11	2.57E+04	0.00E+00	0.00E+00	2.56E-11	4.37E+04	4.88E-11	8.34E+04	6.30E-11	1.08E+05
Pu-241S	6.12E-17	2.55E-12	4.17E+04	0.00E+00	0.00E+00	4.33E-12	7.07E+04	8.29E-12	1.35E+05	1.07E-11	1.74E+05
Be-10S	1.33E-20	2.48E-13	1.87E+07	0.00E+00	0.00E+00	4.21E-13	3.18E+07	8.00E-13	6.04E+07	1.02E-12	7.72E+07
Ni-59S	2.89E-28	1.16E-19	4.00E+08	0.00E+00	0.00E+00	1.96E-19	6.81E+08	3.73E-19	1.29E+09	4.77E-19	1.65E+09
Ni-63S	1.80E-31	7.59E-23	4.21E+08	0.00E+00	0.00E+00	1.29E-22	7.16E+08	2.45E-22	1.36E+09	3.13E-22	1.74E+09

Table 6-84. Peak All-Pathways Dose Factors for NR26E Bolted Containers (Case 1)

Radio-nuclide	Nominal PA Case 1 (mrem yr^{-1} Ci^{-1})	Mean		50th Percentile		75th Percentile		90th Percentile		95th Percentile	
		mrem yr^{-1} Ci^{-1}	Ratio	mrem yr^{-1} Ci^{-1}	Ratio	mrem yr^{-1} Ci^{-1}	Ratio	mrem yr^{-1} Ci^{-1}	Ratio	mrem yr^{-1} Ci^{-1}	Ratio
I-129	4.66E+01	6.51E+01	1.40E+00	4.64E+01	9.94E-01	1.10E+02	2.37E+00	1.67E+02	3.59E+00	2.01E+02	4.31E+00
Tc-99	1.69E+00	1.79E+00	1.06E+00	1.69E+00	9.98E-01	2.78E+00	1.64E+00	3.72E+00	2.20E+00	4.21E+00	2.49E+00
Cl-36	3.87E-01	4.04E-01	1.04E+00	3.87E-01	1.00E+00	6.08E-01	1.57E+00	8.06E-01	2.08E+00	9.12E-01	2.36E+00
Np-237	1.54E-01	6.55E+00	4.26E+01	8.00E-02	5.20E-01	1.12E+01	7.30E+01	2.11E+01	1.37E+02	2.69E+01	1.75E+02
U-235	1.21E-03	7.83E-02	6.48E+01	1.00E-03	8.31E-01	1.33E-01	1.10E+02	2.52E-01	2.09E+02	3.22E-01	2.66E+02
Am-241	3.98E-06	2.34E-04	5.87E+01	3.03E-06	7.62E-01	3.99E-04	1.00E+02	7.54E-04	1.90E+02	9.64E-04	2.42E+02
C-14	1.26E-06	9.86E-04	7.82E+02	1.05E-06	8.35E-01	1.66E-03	1.32E+03	3.20E-03	2.54E+03	4.07E-03	3.23E+03
H-3	1.07E-06	1.07E-06	1.00E+00	1.07E-06	1.00E+00	1.13E-06	1.06E+00	1.19E-06	1.11E+00	1.21E-06	1.14E+00
Pu-241	1.02E-07	6.54E-06	6.41E+01	9.37E-08	9.19E-01	1.11E-05	1.09E+02	2.11E-05	2.07E+02	2.69E-05	2.64E+02
Ni-59	1.68E-14	4.37E-08	2.61E+06	1.87E-11	1.12E+03	7.44E-08	4.44E+06	1.41E-07	8.42E+06	1.81E-07	1.08E+07
Ni-63	1.10E-17	3.05E-11	2.77E+06	7.98E-15	7.24E+02	5.18E-11	4.70E+06	9.83E-11	8.92E+06	1.26E-10	1.14E+07
Sr-90	3.69E-18	3.03E-11	8.22E+06	0.00E+00	0.00E+00	5.15E-11	1.40E+07	9.77E-11	2.65E+07	1.25E-10	3.40E+07

Table 6-85. Peak Beta-Gamma Dose Factors for NR07E Casks (Case 3)

Radio-nuclide	Nominal PA Case 3 (mrem yr^{-1} Ci^{-1})	Mean		50th Percentile		75th Percentile		90th Percentile		95th Percentile	
		mrem yr^{-1} Ci^{-1}	Ratio	mrem yr^{-1} Ci^{-1}	Ratio	mrem yr^{-1} Ci^{-1}	Ratio	mrem yr^{-1} Ci^{-1}	Ratio	mrem yr^{-1} Ci^{-1}	Ratio
I-129S	6.14E+00	4.99E+01	8.13E+00	5.67E+00	9.24E-01	8.59E+01	1.40E+01	1.58E+02	2.57E+01	2.00E+02	3.25E+01
Tc-99S	1.88E-01	1.90E-01	1.01E+00	1.88E-01	1.00E+00	2.68E-01	1.42E+00	3.38E-01	1.80E+00	3.78E-01	2.01E+00
Cl-36S	1.30E-06	9.80E-04	7.54E+02	3.17E-06	2.44E+00	1.66E-03	1.28E+03	3.17E-03	2.44E+03	4.05E-03	3.12E+03
Np-237S	2.16E-10	2.43E-06	1.12E+04	4.04E-09	1.87E+01	4.13E-06	1.91E+04	7.85E-06	3.63E+04	1.01E-05	4.66E+04
U-235S	2.58E-13	3.38E-09	1.31E+04	3.24E-12	1.26E+01	5.75E-09	2.23E+04	1.09E-08	4.23E+04	1.40E-08	5.43E+04
Am-241S	3.15E-14	3.56E-10	1.13E+04	5.76E-13	1.83E+01	6.04E-10	1.92E+04	1.15E-09	3.65E+04	1.47E-09	4.69E+04
C-14S	1.30E-14	3.14E-10	2.41E+04	0.00E+00	0.00E+00	5.34E-10	4.10E+04	1.01E-09	7.78E+04	1.30E-09	9.98E+04
Pu-241S	1.03E-15	1.17E-11	1.13E+04	1.88E-14	1.82E+01	1.98E-11	1.92E+04	3.76E-11	3.65E+04	4.83E-11	4.69E+04
Be-10S	1.85E-17	1.46E-10	7.88E+06	0.00E+00	0.00E+00	2.48E-10	1.34E+07	4.70E-10	2.54E+07	6.02E-10	3.25E+07
Ni-59S	6.45E-23	7.17E-15	1.11E+08	0.00E+00	0.00E+00	1.22E-14	1.89E+08	2.31E-14	3.59E+08	2.96E-14	4.59E+08
Ni-63S	8.99E-26	1.04E-17	1.16E+08	0.00E+00	0.00E+00	1.77E-17	1.97E+08	3.37E-17	3.74E+08	4.31E-17	4.80E+08

Table 6-86. Peak Beta-Gamma Dose Factors for NR26E Casks (Case 4)

Radio-nuclide	Nominal PA Case 4 (mrem yr^{-1} Ci^{-1})	Mean		50th Percentile		75th Percentile		90th Percentile		95th Percentile	
		mrem yr^{-1} Ci^{-1}	Ratio	mrem yr^{-1} Ci^{-1}	Ratio	mrem yr^{-1} Ci^{-1}	Ratio	mrem yr^{-1} Ci^{-1}	Ratio	mrem yr^{-1} Ci^{-1}	Ratio
I-129S	9.14E-02	5.98E-01	6.54E+00	8.55E-02	9.36E-01	1.03E+00	1.13E+01	1.87E+00	2.05E+01	2.37E+00	2.59E+01
Tc-99S	2.39E-03	2.39E-03	1.00E+00	2.39E-03	1.00E+00	2.87E-03	1.20E+00	3.30E-03	1.38E+00	3.53E-03	1.48E+00
Cl-36S	3.94E-08	3.27E-05	8.30E+02	1.05E-07	2.67E+00	5.53E-05	1.40E+03	1.06E-04	2.69E+03	1.35E-04	3.43E+03
Np-237S	8.58E-13	5.60E-08	6.53E+04	0.00E+00	0.00E+00	9.50E-08	1.11E+05	1.81E-07	2.11E+05	2.32E-07	2.70E+05
U-235S	9.40E-16	7.42E-11	7.89E+04	0.00E+00	0.00E+00	1.26E-10	1.34E+05	2.39E-10	2.55E+05	3.07E-10	3.27E+05
C-14S	5.84E-16	2.74E-11	4.69E+04	0.00E+00	0.00E+00	4.65E-11	7.96E+04	8.82E-11	1.51E+05	1.13E-10	1.94E+05
Am-241S	1.24E-16	8.17E-12	6.57E+04	0.00E+00	0.00E+00	1.39E-11	1.11E+05	2.64E-11	2.12E+05	3.38E-11	2.72E+05
Pu-241S	4.07E-18	2.68E-13	6.57E+04	0.00E+00	0.00E+00	4.54E-13	1.12E+05	8.64E-13	2.12E+05	1.11E-12	2.72E+05
Be-10S	2.26E-20	8.45E-13	3.75E+07	0.00E+00	0.00E+00	1.44E-12	6.37E+07	2.72E-12	1.21E+08	3.49E-12	1.55E+08
Ni-59S	2.78E-26	2.23E-17	8.01E+08	0.00E+00	0.00E+00	3.79E-17	1.36E+09	7.18E-17	2.58E+09	9.20E-17	3.31E+09
Ni-63S	4.19E-29	3.53E-20	8.43E+08	0.00E+00	0.00E+00	6.00E-20	1.43E+09	1.14E-19	2.72E+09	1.46E-19	3.48E+09

Table 6-87. Peak Beta-Gamma Dose Factors for NR26E Bolted Containers (Case 1)

Radio-nuclide	Nominal PA Case 1 (mrem yr^{-1} Ci^{-1})	Mean		50th Percentile		75th Percentile		90th Percentile		95th Percentile	
		mrem yr^{-1} Ci^{-1}	Ratio	mrem yr^{-1} Ci^{-1}	Ratio	mrem yr^{-1} Ci^{-1}	Ratio	mrem yr^{-1} Ci^{-1}	Ratio	mrem yr^{-1} Ci^{-1}	Ratio
I-129	7.97E+02	6.51E+01	8.17E-02	4.64E+01	5.82E-02	1.10E+02	1.38E-01	1.67E+02	2.10E-01	2.01E+02	2.52E-01
Tc-99	2.57E+00	1.79E+00	6.99E-01	1.69E+00	6.59E-01	2.78E+00	1.08E+00	3.72E+00	1.45E+00	4.21E+00	1.64E+00
Cl-36	4.30E-01	4.04E-01	9.39E-01	3.87E-01	9.01E-01	6.08E-01	1.41E+00	8.06E-01	1.87E+00	9.12E-01	2.12E+00
Np-237	1.02E-02	6.55E+00	6.40E+02	8.00E-02	7.83E+00	1.12E+01	1.10E+03	2.11E+01	2.06E+03	2.69E+01	2.64E+03
H-3	4.08E-03	1.07E-06	2.62E-04	1.07E-06	2.62E-04	1.13E-06	2.77E-04	1.19E-06	2.91E-04	1.21E-06	2.98E-04
U-235	2.45E-06	7.83E-02	3.20E+04	1.00E-03	4.11E+02	1.33E-01	5.45E+04	2.52E-01	1.03E+05	3.22E-01	1.31E+05
C-14	1.26E-06	9.86E-04	7.85E+02	1.05E-06	8.37E-01	1.66E-03	1.32E+03	3.20E-03	2.55E+03	4.07E-03	3.24E+03
Am-241	2.64E-07	2.34E-04	8.83E+02	3.03E-06	1.15E+01	3.99E-04	1.51E+03	7.54E-04	2.85E+03	9.64E-04	3.65E+03
Pu-241	6.78E-09	6.54E-06	9.64E+02	9.37E-08	1.38E+01	1.11E-05	1.64E+03	2.11E-05	3.11E+03	2.69E-05	3.97E+03
Ni-59	1.61E-12	4.37E-08	2.71E+04	1.87E-11	1.16E+01	7.44E-08	4.61E+04	1.41E-07	8.74E+04	1.81E-07	1.12E+05
Ni-63	2.56E-15	3.05E-11	1.19E+04	7.98E-15	3.11E+00	5.18E-11	2.02E+04	9.83E-11	3.84E+04	1.26E-10	4.92E+04
Sr-90	3.15E-17	3.03E-11	9.62E+05	0.00E+00	0.00E+00	5.15E-11	1.64E+06	9.77E-11	3.10E+06	1.25E-10	3.97E+06

Table 6-88. Peak Gross-Alpha Concentration Factors for NR07E Casks (Case 3)

Radionuclide	Nominal PA Case 3	Mean		50th Percentile		75th Percentile		90th Percentile		95th Percentile	
	pCi L-1 Ci-1	pCi L-1 Ci-1	Ratio	pCi L-1 Ci-1	Ratio	pCi L-1 Ci-1	Ratio	pCi L-1 Ci-1	Ratio	pCi L-1 Ci-1	Ratio
Np-237S	1.62E-08	1.82E-04	1.12E+04	3.03E-07	1.87E+01	3.10E-04	1.91E+04	5.89E-04	3.63E+04	7.56E-04	4.66E+04
U-235S	2.70E-10	3.08E-06	1.14E+04	4.24E-09	1.57E+01	5.23E-06	1.93E+04	9.94E-06	3.68E+04	1.28E-05	4.72E+04
Am-241S	2.36E-12	2.67E-08	1.13E+04	4.32E-11	1.83E+01	4.53E-08	1.92E+04	8.61E-08	3.65E+04	1.11E-07	4.69E+04
Pu-241S	7.73E-14	8.74E-10	1.13E+04	1.41E-12	1.82E+01	1.48E-09	1.92E+04	2.82E-09	3.65E+04	3.62E-09	4.69E+04

Table 6-89. Peak Gross-Alpha Concentration Factors for NR26E Casks (Case 4)

Radionuclide	Nominal PA Case 4	Mean		50th Percentile		75th Percentile		90th Percentile		95th Percentile	
	pCi L-1 Ci-1	pCi L-1 Ci-1	Ratio	pCi L-1 Ci-1	Ratio	pCi L-1 Ci-1	Ratio	pCi L-1 Ci-1	Ratio	pCi L-1 Ci-1	Ratio
Np-237S	6.43E-11	4.20E-06	6.53E+04	0.00E+00	0.00E+00	7.13E-06	1.11E+05	1.36E-05	2.11E+05	1.74E-05	2.70E+05
U-235S	1.07E-12	7.06E-08	6.63E+04	0.00E+00	0.00E+00	1.20E-07	1.12E+05	2.28E-07	2.14E+05	2.92E-07	2.74E+05
Am-241S	9.32E-15	6.13E-10	6.57E+04	0.00E+00	0.00E+00	1.04E-09	1.11E+05	1.98E-09	2.12E+05	2.53E-09	2.72E+05
Pu-241S	3.05E-16	2.01E-11	6.57E+04	0.00E+00	0.00E+00	3.41E-11	1.12E+05	6.48E-11	2.12E+05	8.30E-11	2.72E+05

Table 6-90. Peak Gross-Alpha Concentration Factors for NR26E Bolted Containers (Case 1)

Radionuclide	Nominal PA Case 1	Mean		50th Percentile		75th Percentile		90th Percentile		95th Percentile	
	pCi L-1 Ci-1	pCi L-1 Ci-1	Ratio	pCi L-1 Ci-1	Ratio	pCi L-1 Ci-1	Ratio	pCi L-1 Ci-1	Ratio	pCi L-1 Ci-1	Ratio
Np-237	7.67E-01	3.27E+01	4.26E+01	3.99E-01	5.20E-01	5.60E+01	7.30E+01	1.05E+02	1.37E+02	1.34E+02	1.75E+02
U-235	1.38E-03	8.95E-02	6.49E+01	1.16E-03	8.40E-01	1.52E-01	1.10E+02	2.88E-01	2.09E+02	3.67E-01	2.67E+02
Am-241	1.98E-05	1.16E-03	5.87E+01	1.51E-05	7.62E-01	1.99E-03	1.00E+02	3.76E-03	1.90E+02	4.81E-03	2.42E+02
Pu-241	5.09E-07	3.26E-05	6.41E+01	4.67E-07	9.19E-01	5.54E-05	1.09E+02	1.05E-04	2.07E+02	1.34E-04	2.64E+02

Table 6-91. Peak Uranium Concentration Factors for NR07E Casks (Case 3)

Radionuclide	Nominal PA Case 3	Mean		50th Percentile		75th Percentile		90th Percentile		95th Percentile	
	µg L-1 Ci-1	µg L-1 Ci-1	Ratio	µg L-1 Ci-1	Ratio	µg L-1 Ci-1	Ratio	µg L-1 Ci-1	Ratio	µg L-1 Ci-1	Ratio
Np-237S	1.12E-18	1.55E-14	1.38E+04	1.37E-17	1.22E+01	2.64E-14	2.34E+04	5.01E-14	4.46E+04	6.43E-14	5.72E+04
Am-241S	1.63E-22	2.26E-18	1.39E+04	2.14E-21	1.31E+01	3.85E-18	2.36E+04	7.31E-18	4.48E+04	9.38E-18	5.75E+04
Pu-241S	5.35E-24	7.42E-20	1.39E+04	7.04E-23	1.32E+01	1.26E-19	2.36E+04	2.39E-19	4.48E+04	3.07E-19	5.75E+04
U-235S	6.37E-87	--	--	--	--	--	--	--	--	--	--

Notes: Entries with "--" represent numbers below single precision.

Table 6-92. Peak Uranium Concentration Factors for NR26E Casks (Case 4)

Radionuclide	Nominal PA Case 4	Mean		50th Percentile		75th Percentile		90th Percentile		95th Percentile	
	μg L-1 Ci-1	μg L-1 Ci-1	Ratio	μg L-1 Ci-1	Ratio	μg L-1 Ci-1	Ratio	μg L-1 Ci-1	Ratio	μg L-1 Ci-1	Ratio
Np-237S	3.98E-21	3.33E-16	8.37E+04	0.00E+00	0.00E+00	5.65E-16	1.42E+05	1.08E-15	2.70E+05	1.38E-15	3.46E+05
Am-241S	5.76E-25	4.85E-20	8.42E+04	0.00E+00	0.00E+00	8.23E-20	1.43E+05	1.57E-19	2.72E+05	2.01E-19	3.48E+05
Pu-241S	1.89E-26	1.59E-21	8.42E+04	0.00E+00	0.00E+00	2.70E-21	1.43E+05	5.13E-21	2.72E+05	6.57E-21	3.48E+05
U-235S	6.54E-104	--	--	--	--	--	--	--	--	--	--

Notes: Entries with "--" represent numbers below single precision.

Table 6-93. Peak Uranium Concentration Factors for NR26E Bolted Containers (Case 1)

Radionuclide	Nominal PA Case 1	Mean		50th Percentile		75th Percentile		90th Percentile		95th Percentile	
	μg L-1 Ci-1	μg L-1 Ci-1	Ratio	μg L-1 Ci-1	Ratio	μg L-1 Ci-1	Ratio	μg L-1 Ci-1	Ratio	μg L-1 Ci-1	Ratio
Np-237	1.62E-10	1.88E-08	1.16E+02	7.91E-11	4.89E-01	3.21E-08	1.98E+02	6.07E-08	3.75E+02	7.74E-08	4.79E+02
Am-241	4.10E-15	5.69E-13	1.39E+02	3.73E-16	9.09E-02	9.68E-13	2.36E+02	1.84E-12	4.48E+02	2.35E-12	5.73E+02
Pu-241	1.05E-16	1.53E-14	1.46E+02	0.00E+00	0.00E+00	2.60E-14	2.49E+02	4.95E-14	4.73E+02	6.32E-14	6.04E+02
U-235	1.36E-70	--	--	--	--	--	--	--	--	--	--

Notes: Entries with "--" represent numbers below single precision.

Table 6-94. Ratios of All-Pathways Dose Factors for Sensitivity Cases to the Nominal PA Dose Factor for NR07E Casks (Case 3)

Radionuclide	Nominal PA Case 3 (mrem yr-1 Ci-1)	Sensitivity Cases					
		Waste Zone Conductivity	LVZ Porosity	Waste Zone Porosity	Infiltration	K_d	Disposal Time
		Ratio (unitless)					
Am-241S	4.73E-13	1.12	1.43	1.47	1.35E+03	7.14E+04	0.46
Be-10S	1.09E-17	1.13	1.59	1.58	5.56E+03	4.98E+07	0.4
C-14S	1.31E-14	1.11	1.15	1.64	7.94E+02	1.53E+05	0.53
Cl-36S	1.17E-06	1.1	1.13	1.43	1.76E+02	4.76E+03	0.58
I-129S	3.59E-01	1.07	1.1	1.16	1.54E+01	4.47E+01	0.69
Ni-59S	6.69E-25	1.13	1.68	1.63	1.13E+04	7.03E+08	0.36
Ni-63S	3.86E-28	1.13	1.68	1.63	1.14E+04	7.34E+08	0.41
Np-237S	3.25E-09	1.12	1.43	1.47	1.35E+03	7.10E+04	0.46
Pu-241S	1.55E-14	1.12	1.43	1.47	1.35E+03	7.14E+04	0.46
Tc-99S	1.24E-01	1.03	1.02	1.04	1.81E+00	2.05E+00	0.85
U-235S	2.38E-10	1.12	1.43	1.48	1.35E+03	7.19E+04	0.46

Notes: Ratio values between 100 and 1,000 are highlighted in blue while values greater than 1,000 are highlighted in orange.

Table 6-95. Ratios of All-Pathways Dose Factors for Sensitivity Cases to the Nominal PA Dose Factor for NR26E Casks (Case 4)

Radionuclide	Nominal PA Case 4 (mrem yr^{-1} Ci^{-1})	Sensitivity Cases					
		Waste Zone Conductivity	LVZ Porosity	Waste Zone Porosity	Infiltration	K_d	Disposal Time
		Ratio (unitless)					
Am-241S	1.87E-15	1.04	1.77	1.48	3.68E+03	4.15E+05	0.03
Be-10S	1.33E-20	1.04	2.06	1.58	2.07E+04	2.37E+08	0.02
C-14S	5.85E-16	1.03	1.27	1.65	1.53E+03	2.96E+05	0.06
Cl-36S	3.55E-08	1.03	1.24	1.44	2.50E+02	5.23E+03	0.09
I-129S	5.35E-03	1.03	1.18	1.17	1.55E+01	3.32E+01	0.19
Ni-59S	2.89E-28	1.04	2.23	1.64	5.12E+04	5.06E+09	0.01
Ni-63S	1.80E-31	1.04	2.23	1.64	5.19E+04	5.33E+09	0.02
Np-237S	1.29E-11	1.04	1.77	1.48	3.68E+03	4.13E+05	0.03
Pu-241S	6.12E-17	1.04	1.77	1.48	3.68E+03	4.15E+05	0.03
Tc-99S	1.58E-03	1.01	1.03	1.04	1.38E+00	1.50E+00	0.50
U-235S	9.36E-13	1.04	1.77	1.48	3.69E+03	4.19E+05	0.03

Notes: Ratio values between 100 and 1,000 are highlighted in blue while values greater than 1,000 are highlighted in orange.

Table 6-96. Ratios of All-Pathways Dose Factors for Sensitivity Cases to the Nominal PA Dose Factor for NR26E Bolted Containers (Case 1)

Radionuclide	Nominal PA Case 1 (mrem yr^{-1} Ci^{-1})	Sensitivity Cases					
		Waste Zone Conductivity	LVZ Porosity	Waste Zone Porosity	Infiltration	K_d	Disposal Time
		Ratio (unitless)					
Am-241	3.98E-06	1.02	1.40	1.18	1.11E+02	3.35E+02	0.22
C-14	1.26E-06	1.02	1.12	1.49	3.77E+02	4.91E+03	1.01
Cl-36	3.87E-01	1.01	1.05	1.07	2.10E+00	2.42E+00	1.00
H-3	1.07E-06	1.00	1.02	1.00	8.58E-01	1.00E+00	41.35
I-129	4.66E+01	1.00	1.00	1.00	2.88E+00	5.33E+00	1.00
Ni-59	1.68E-14	1.02	1.96	1.59	3.99E+04	1.65E+07	1.00
Ni-63	1.10E-17	1.02	1.97	1.60	4.11E+04	1.75E+07	1.60
Np-237	1.54E-01	1.02	1.39	1.18	9.55E+01	2.32E+02	1.00
Pu-241	1.02E-07	1.02	1.40	1.19	1.16E+02	3.69E+02	0.13
Sr-90	3.69E-18	1.02	2.04	1.57	9.48E+04	5.20E+07	5.04
Tc-99	1.69E+00	1.01	1.05	1.03	2.51E+00	1.88E+00	1.00
U-235	1.21E-03	1.02	1.40	1.19	1.15E+02	3.75E+02	0.21

Notes: Ratio values between 100 and 1,000 are highlighted in blue while values greater than 1,000 are highlighted in orange.

6.1.2.3. Dose Impacts

The statistical results provided in Section 6.1.2.2 focus on individual radionuclide dose (or concentration) factors. To review the impact on individual and composite doses at the 100-meter POA, radionuclide inventories must also be considered. An upper-bound estimate of the total (or a partial sum) dose (or concentration) value for a specific DU is computed by:

$$D_T\left(\check{s}\right) = \eta_{DU} \sum_{i=1}^{M} D_i\left(\check{s}\right) = \eta_{DU} \sum_{i=1}^{M} I_i \times \hat{D}_i\left(\check{s}\right) \qquad \text{Eq. (6-8)}$$

where:

$\check{s}$	Vector of selected sensitivity variables (j=1,n)
$D_T\left(\check{s}\right)$	Total dose (concentration) for specific DU at 100-meter POA (mrem yr^{-1} or pCi L^{-1})
$D_i\left(\check{s}\right)$	i^{th} radionuclide dose (concentration) contribution (mrem yr^{-1} or pCi L^{-1})
$\hat{D}_i\left(\check{s}\right)$	i^{th} radionuclide dose (concentration) factor (mrem yr^{-1} or pCi L^{-1} per Ci buried)
η_{DU}	PIF for specific DU (unitless)
I_i	i^{th} radionuclide projected total inventory within specific DU (Ci)
M	Number of parent radionuclides within specific DU being considered (unitless)
n	Number of sensitivity (random) variables (unitless)

Eq. (6-8) is an upper-bound estimate because the dose factors employed are peak values over the entire compliance period (i.e., in addition, time windowing is not considered), where peak values do not align with respect to timing in many cases. As Eq. (6-8) indicates, the total estimated dose (or concentration) for a given DU is also a function of the model parameters through the dose (or concentration) factors.

In this section, the resulting statistical dose (or concentration) factors presented Section 6.1.2.2 are employed where the projected 2065 closure inventories provided in Appendix H.7.2 (and then used in Chapter 9) are considered. In most cases, the total doses shown represent only a partial sum of radionuclides. However, in general, the partial listings include the dominant contributors. The relative impact associated with model parameter uncertainty is addressed by comparing these partial sums to their partial sums at the nominal PA conditions (i.e., ratios are provided). PIFs are set equal to 1.0 here because only partial sets of radionuclides are addressed and the main influences under consideration are relative dose impacts. Also, PIFs are not considered here because time windowing aspects are not addressed.

Section 6.1.2.2 provides the statistical dose (or concentration) factors on a radionuclide basis where the following results are considered:

- Nominal PA value
- Mean value
- 50th percentile (i.e., median value)
- 75th percentile
- 90th percentile
- 95th percentile

To illustrate how a statistical total dose (or concentration) is computed given statistical dose (or concentration) factors, the following expression is provided for the mean total dose (or concentration):

$$\langle D_T \rangle = \frac{1}{R}\sum_{r=1}^{R} D_T^r = \frac{\eta_{DU}}{R}\sum_{r=1}^{R}\left[\sum_{i=1}^{M} I_i \times \hat{D}_i^r\right] = \eta_{DU}\sum_{i=1}^{M} I_i \cdot \left[\frac{1}{R}\sum_{r=1}^{R}\hat{D}_i^r\right] = \eta_{DU}\sum_{i=1}^{M} I_i \times \langle \hat{D}_i \rangle \quad \text{Eq. (6-9)}$$

where:

$\langle D_T \rangle$	Mean value of total dose (concentration) for specific DU at 100-meter POA (mrem yr^{-1} or pCi L^{-1})
$\langle \hat{D}_i \rangle$	i^{th} radionuclide mean value of total dose (concentration) factor for specific DU at 100-meter POA (mrem yr^{-1} or pCi L^{-1} per Ci buried)
D_T^r	Total dose (concentration) for r^{th} realization (mrem yr^{-1} or pCi L^{-1})
$\hat{D}_i^r$	i^{th} radionuclide dose (concentration) factor for r^{th} realization (mrem yr^{-1} or pCi L^{-1} per Ci buried)
I_i	i^{th} radionuclide projected total inventory within specific DU (Ci)
R	Number of Monte Carlo realizations (unitless)

As Eq. (6-9) indicates, a statistical value for total dose (or concentration) is computed by inventory weighting of their statistical dose (or concentration) factors.

As described in Section 6.1.2.1, a linear response surface for computed dose (or concentration) factors generally occurs except under certain extreme combinations of parameter settings. Under these extreme conditions, zero values are applied. Because the chosen sensitivity variables have assumed symmetrical distributions and the response surface centers about the nominal PA values, the following applies:

- When only a small number of Monte Carlo realizations result in zero values, the mean and median will equal the nominal PA value.
- When a modest fraction of Monte Carlo realizations result in zero values, the mean and median will exceed the nominal PA value.

The statistical results shown below for each DU are provided in tabular form for the all-pathways and beta-gamma exposure pathways as both individual and total doses and for the gross-alpha and uranium pathways as total concentrations. For comparison purposes, the relative total dose results for the nominal PA, mean, and median doses are also presented in graphical form.

The individual dose contributions and their sum (i.e., total dose) are based on dose (or concentration) factors representing their peak values over the entire compliance period. In establishing inventory limits in Chapter 8, multiple time windows are employed; therefore, these doses and concentrations are in general upper bounds.

The following DU-specific summary results are listed in each table:

- Total dose (or concentration) based on the dominant contributors
- SOF computed by pathway PO
- Ratio of total dose (or concentration) relative to its nominal PA value

Output extracted from the GoldSim® model is limited to single-precision numbers and, in a few situations, the computed dose (or concentration) factors are below the single-precision limit and therefore are truncated to zero. The radionuclide with the maximum contribution is highlighted in red.

Table 6-97 provides a summary of the "Total SOF" values by exposure pathway and DU. Note that these SOFs: (1) do not include all radionuclide contributors; (2) are not based on time windowing; and (3) do not use PIFs. As such, the SOFs are only a general indicator when considering POs. Table 6-98 lists the actual computed total SOFs at facility closure when the above three exclusions are addressed as discussed in detail in Chapter 8.

Table 6-97. Peak Total SOF Statistical Values by Exposure Pathway and Disposal Unit

Exposure Pathway	DU	Nominal PA	Mean	50th Percentile	75th Percentile	90th Percentile	95th Percentile
All-Pathways	ST06	0.041	0.043	0.040	0.063	0.083	0.095
	ST09	0.016	0.035	0.015	0.051	0.082	0.100
	ILV	0.004	0.005	0.004	0.009	0.013	0.015
	LAWV	0.002	0.003	0.002	0.003	0.004	0.004
	NR07E (Case3)	0.001	0.001	0.001	0.001	0.001	0.001
	NR26E (Case4)	0.002	0.023	0.002	0.041	0.075	0.093
	NR26E (Case1)	0.002	0.002	0.002	0.004	0.006	0.007
Beta-Gamma	ST06	0.578	0.587	0.577	0.689	0.783	0.835
	ST09	0.626	0.634	0.625	0.743	0.845	0.900
	ILV	0.443	0.585	0.446	0.965	1.413	1.661
	LAWV	0.252	0.254	0.252	0.294	0.331	0.353
	NR07E (Case3)	0.007	0.007	0.007	0.010	0.013	0.015
	NR26E (Case4)	0.022	0.022	0.022	0.027	0.031	0.033
	NR26E (Case1)	0.029	0.015	0.010	0.025	0.039	0.046
Gross-Alpha	ST06	0.248	0.270	0.246	0.422	0.574	0.665
	ST09	0.021	0.177	0.018	0.307	0.559	0.704
	ILV	1.10E-31	6.67E-20	0.00E+00	1.13E-19	2.15E-19	2.75E-19
	LAWV	9.98E-22	1.95E-11	7.94E-15	3.31E-11	6.29E-11	8.07E-11
	NR07E (Case3)	2.35E-13	2.66E-09	4.29E-12	4.51E-09	8.58E-09	1.10E-08
	NR26E (Case4)	1.22E-15	8.04E-11	0.00E+00	1.36E-10	2.59E-10	3.32E-10
	NR26E (Case1)	1.93E-08	1.12E-06	1.50E-08	1.91E-06	3.61E-06	4.61E-06
Uranium	ST06	4.89E-11	1.22E-10	4.72E-11	2.14E-10	3.58E-10	4.44E-10
	ST09	1.77E-12	6.43E-11	1.44E-12	1.09E-10	2.06E-10	2.63E-10
	ILV	1.98E-42	--	--	--	--	--
	LAWV	2.09E-32	9.72E-22	0.00E+00	1.65E-21	3.14E-21	4.02E-21
	NR07E (Case3)	8.13E-24	1.13E-19	1.07E-22	1.92E-19	3.64E-19	4.67E-19
	NR26E (Case4)	2.83E-24	2.39E-19	0.00E+00	4.05E-19	7.70E-19	9.87E-19
	NR26E (Case1)	2.00E-18	2.75E-16	2.49E-19	4.67E-16	8.88E-16	1.13E-15

Notes:

Entries with "--" represent numbers below single precision.

Table 6-98. Total SOF at Closure based on Limits System by Exposure Pathway and Disposal Unit

Exposure Pathway	DU	Total SOF
All-Pathways	ST06	0.094
	ST09	0.063
	ILV	0.010
	LAWV	0.009
	NR07E	0.015
	NR26E	0.096
Beta-Gamma	ST06	1.000
	ST09	1.000
	ILV	1.000
	LAWV	1.000
	NR07E	0.138
	NR26E	1.000
Gross-Alpha	ST06	0.752
	ST09	0.027
	ILV	0.000
	LAWV	0.000
	NR07E	4.70E-12
	NR26E	1.16E-07
Uranium	ST06	2.03E-10
	ST09	2.03E-11
	ILV	0.00E-00
	LAWV	0.00E-00
	NR07E	3.02E-24
	NR26E	1.20E-17

Notes:

Total SOFs highlighted in orange represent the limiting pathway that established the upper inventory limits for a DU. NR07E is a closed DU that did not reach its activity capacity and therefore is highlighted in blue.

To better assess the uncertainty impact on the actual total SOF, the total SOF statistical results in Table 6-97 are scaled based on the actual total SOFs in Table 6-98 to yield the scaled total SOFs in Table 6-99.

Table 6-99. Scaled Total SOF Statistical Values by Exposure Pathway and Disposal Unit

Exposure Pathway	DU	Nominal PA	Mean	50th Percentile	75th Percentile	90th Percentile	95th Percentile
All-Pathways	ST06	0.094	0.101	0.094	0.148	0.194	0.221
	ST09	0.063	0.138	0.062	0.203	0.326	0.397
	ILV	0.010	0.013	0.010	0.021	0.031	0.036
	LAWV	0.009	0.010	0.009	0.012	0.015	0.016
	NR07E (Case3)	0.015	0.015	0.015	0.021	0.026	0.029
	NR26E (Case4)	0.096	0.981	0.100	1.738	3.141	3.897
	NR26E (Case1)	0.096	0.155	0.096	0.249	0.387	0.463
Beta-Gamma	ST06	1.000	1.016	0.999	1.192	1.356	1.445
	ST09	1.000	1.013	0.999	1.187	1.349	1.437
	ILV	1.000	1.322	1.007	2.181	3.192	3.753
	LAWV	1.000	1.006	0.999	1.167	1.314	1.400
	NR07E (Case3)	0.138	0.143	0.138	0.202	0.259	0.291
	NR26E (Case4)	1.000	1.015	1.000	1.228	1.431	1.543
	NR26E (Case1)	1.000	0.528	0.326	0.848	1.318	1.577
Gross-Alpha	ST06	0.752	0.817	0.747	1.280	1.740	2.015
	ST09	0.026	0.227	0.023	0.393	0.715	0.901
	ILV	--	--	--	--	--	--
	LAWV	--	--	--	--	--	--
	NR07E (Case3)	4.70E-12	5.31E-08	8.58E-11	9.02E-08	1.72E-07	2.20E-07
	NR26E (Case4)	1.16E-07	7.60E-03	0.00E+00	1.29E-02	2.45E-02	3.14E-02
	NR26E (Case1)	1.16E-07	6.71E-06	9.00E-08	1.14E-05	2.16E-05	2.76E-05
Uranium	ST06	2.03E-10	5.08E-10	1.96E-10	8.86E-10	1.48E-09	1.84E-09
	ST09	2.03E-11	7.37E-10	1.65E-11	1.25E-09	2.37E-09	3.02E-09
	ILV	--	--	--	--	--	--
	LAWV	--	--	--	--	--	--
	NR07E (Case3)	3.02E-24	4.19E-20	3.97E-23	7.13E-20	1.35E-19	1.74E-19
	NR26E (Case4)	1.20E-17	1.01E-12	0.00E+00	1.71E-12	3.25E-12	4.17E-12
	NR26E (Case1)	1.20E-17	1.65E-15	1.50E-18	2.80E-15	5.33E-15	6.80E-15

Notes:

Entries with "--" represent numbers below single precision.

Scaled total SOFs exceeding 1.0 are highlighted in orange for values between 1.0 to 2.0 and in blue for values greater than 2.0.

As mentioned above, various built-in conservatisms are included in the SOFs presented in Table 6-99 (e.g., the infiltration rates employed in the nominal PA calculations are based on a bounding closure cap model). If these conservatisms were not included, the SOFs would be lower.

Statistical results for each DU of interest are presented below.

6.1.2.3.1. Slit and Engineered Trenches

Relative dose (or concentration) results for ST06 and ST09 for the four exposure pathways are presented below. ET06 is excluded from this PA; therefore, projected 2065 closure inventories are not computed in Appendix H.

For ST06:

- **All-pathways:** Table 6-100 and Figure 6-36

- **Beta-gamma:** Table 6-101 and Figure 6-37
- **Gross-alpha:** Table 6-102 and Figure 6-38
- **Uranium:** Table 6-103 and Figure 6-39

For the ST09:

- **All-pathways:** Table 6-104 and Figure 6-40
- **Beta-gamma:** Table 6-105 and Figure 6-41
- **Gross-alpha:** Table 6-106 and Figure 6-42
- **Uranium:** Table 6-107 and Figure 6-43

Table 6-100. Peak All-Pathways Relative Dose for ST06

Radionuclide	Closure Inventory (Ci)	Nominal PA	Mean	50th Percentile	75th Percentile	90th Percentile	95th Percentile
		mrem yr^{-1}					
C-14	5.51E-02	1.74E-03	3.13E-03	1.74E-03	5.38E-03	8.65E-03	1.06E-02
H-3	1.38E+00	1.26E-06	1.26E-06	1.26E-06	1.27E-06	1.29E-06	1.30E-06
I-129	5.07E-04	5.85E-02	5.85E-02	5.85E-02	6.05E-02	6.22E-02	6.33E-02
Np-237	2.79E-02	7.46E-01	8.11E-01	7.41E-01	1.27E+00	1.73E+00	2.00E+00
Sr-90	1.91E+02	4.29E-12	4.87E-07	0.00E+00	8.28E-07	1.57E-06	2.01E-06
Tc-99	1.48E-01	2.09E-01	2.09E-01	2.09E-01	2.51E-01	2.87E-01	3.06E-01
Sum		1.01	1.08	1.01	1.59	2.08	2.38
SOF		0.041	0.043	0.040	0.063	0.083	0.095
Ratio		1.00	1.07	1.00	1.56	2.05	2.34

Notes:
Ratios highlighted in orange represent the total dose relative to the total nominal PA dose.
Largest contributor is highlighted in red.

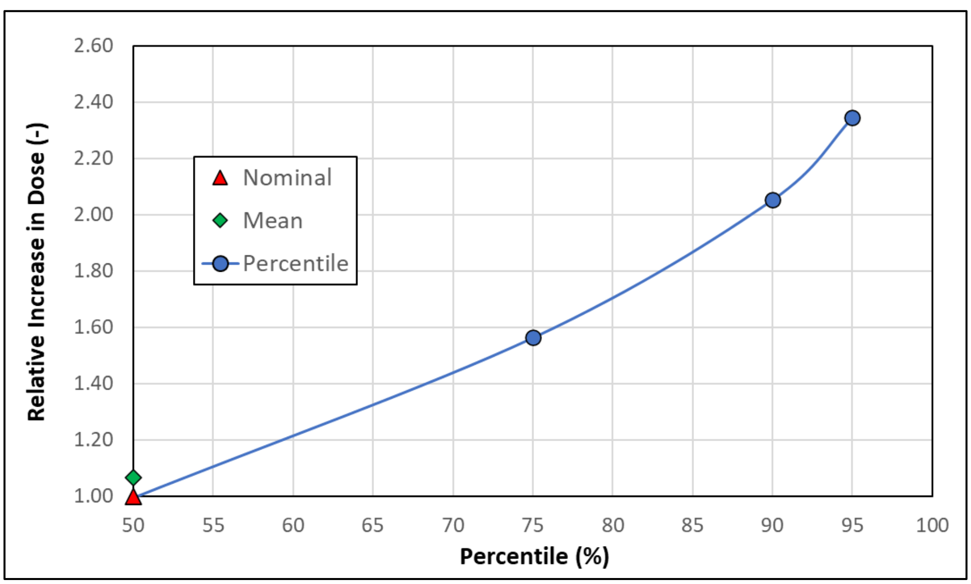


Figure 6-36. Peak All-Pathways Relative Dose for ST06

Table 6-101. Peak Beta-Gamma Relative Dose for ST06

Radionuclide	Closure Inventory (Ci)	Nominal PA	Mean	50th Percentile	75th Percentile	90th Percentile	95th Percentile
		mrem yr^{-1}					
C-14	5.51E-02	1.74E-03	3.12E-03	1.74E-03	5.36E-03	8.63E-03	1.06E-02
H-3	1.38E+00	9.43E-01	9.43E-01	9.43E-01	1.09E+00	1.21E+00	1.27E+00
I-129	5.07E-04	1.00E+00	1.00E+00	1.00E+00	1.02E+00	1.04E+00	1.05E+00
Np-237	2.79E-02	4.96E-02	5.39E-02	4.93E-02	8.45E-02	1.15E-01	1.33E-01
Sr-90	1.91E+02	3.66E-11	4.16E-06	0.00E+00	7.07E-06	1.34E-05	1.72E-05
Tc-99	1.48E-01	3.16E-01	3.47E-01	3.16E-01	5.59E-01	7.66E-01	8.75E-01
Sum		2.31	2.35	2.31	2.75	3.13	3.34
SOF		0.578	0.587	0.577	0.689	0.783	0.835
Ratio		1.00	1.02	1.00	1.19	1.36	1.44

Notes:

Ratios highlighted in orange represent the total dose relative to the total nominal PA dose.

Largest contributor is highlighted in red.

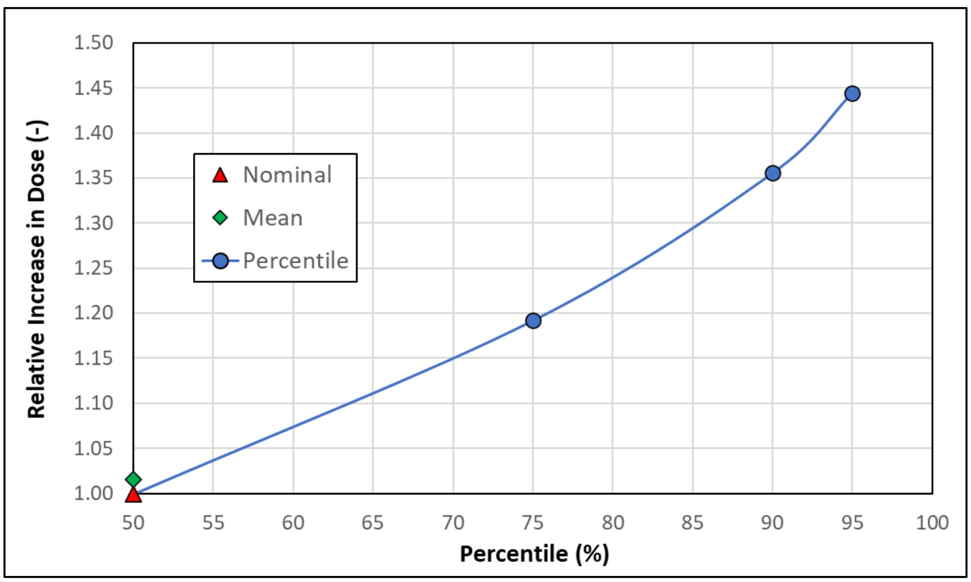


Figure 6-37. Peak Beta-Gamma Relative Dose for ST06

Table 6-102. Peak Gross-Alpha Relative Concentration for ST06

Radionuclide	Closure Inventory (Ci)	Nominal PA	Mean	50th Percentile	75th Percentile	90th Percentile	95th Percentile
		pCi L-1					
Np-237	2.79E-02	3.72E+00	4.05E+00	3.70E+00	6.34E+00	8.61E+00	9.97E+00
Sum		3.72	4.05	3.70	6.34	8.61	9.97
SOF		0.248	0.270	0.246	0.422	0.574	0.665
Ratio		1.00	1.09	0.99	1.70	2.31	2.68

Notes:
Ratios highlighted in orange represent the total concentration relative to the total nominal PA concentration.
Largest contributor is highlighted in red.

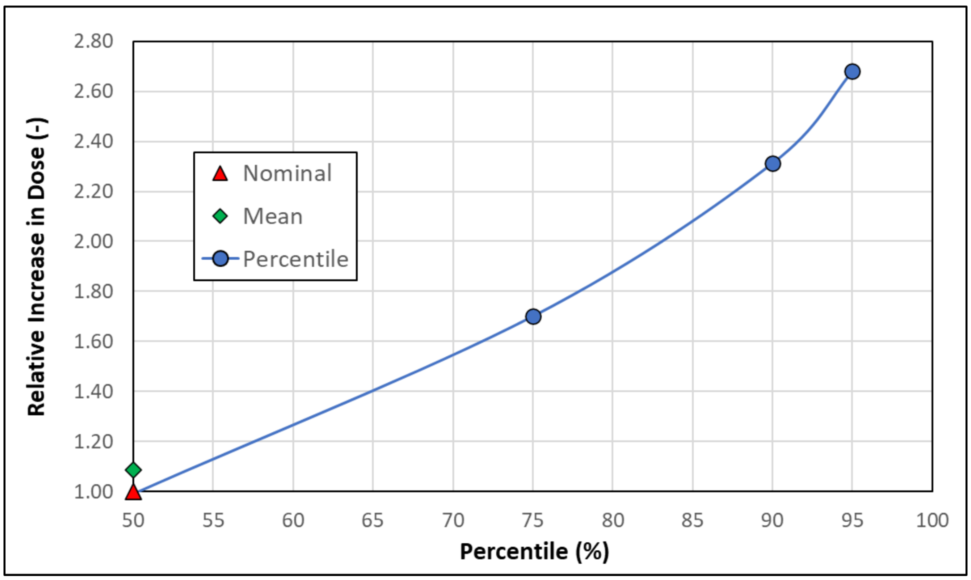


Figure 6-38. Peak Gross-Alpha Relative Concentration for ST06

Table 6-103. Peak Uranium Relative Concentration for ST06

Radionuclide	Closure Inventory (Ci)	Nominal PA	Mean	50th Percentile	75th Percentile	90th Percentile	95th Percentile
		µg L^{-1}					
Np-237	2.79E-02	1.47E-09	3.67E-09	1.42E-09	6.41E-09	1.07E-08	1.33E-08
Sum		1.47E-09	3.67E-09	1.42E-09	6.41E-09	1.07E-08	1.33E-08
SOF		4.89E-11	1.22E-10	4.72E-11	2.14E-10	3.58E-10	4.44E-10
Ratio		1.00	2.51	0.97	4.37	7.32	9.08

Notes:

Ratios highlighted in orange represent the total concentration relative to the total nominal PA concentration.

Largest contributor is highlighted in red.

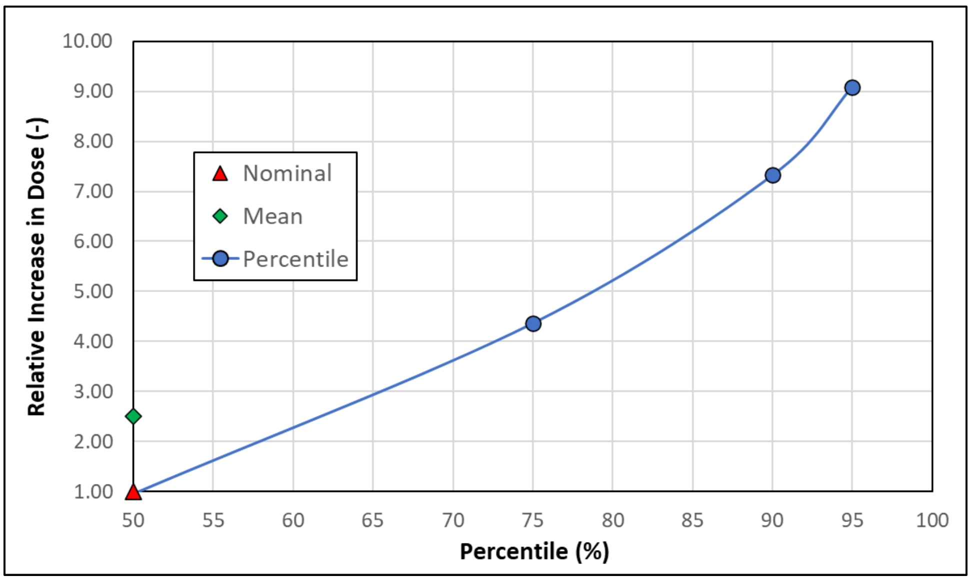


Figure 6-39. Peak Uranium Relative Concentration for ST06

Table 6-104. Peak All-Pathways Relative Dose for ST09

Radionuclide	Closure Inventory (Ci)	Nominal PA	Mean	50th Percentile	75th Percentile	90th Percentile	95th Percentile
		mrem yr^{-1}					
C-14	5.51E-02	4.72E-05	1.37E-03	4.00E-05	2.33E-03	4.39E-03	5.57E-03
H-3	1.38E+00	1.46E-06	1.46E-06	1.46E-06	1.51E-06	1.54E-06	1.56E-06
I-129	5.07E-04	6.27E-02	6.27E-02	6.26E-02	6.97E-02	7.59E-02	7.94E-02
Np-237	2.79E-02	6.22E-02	5.34E-01	5.51E-02	9.24E-01	1.68E+00	2.12E+00
Sr-90	1.91E+02	1.70E-15	8.27E-11	2.10E-14	1.40E-10	2.66E-10	3.42E-10
Tc-99	1.48E-01	2.68E-01	2.68E-01	2.68E-01	2.76E-01	2.83E-01	2.87E-01
Sum		0.39	0.87	0.39	1.27	2.04	2.49
SOF		0.02	0.03	0.02	0.05	0.08	0.10
Ratio		1.00	2.20	0.98	3.24	5.20	6.33

Notes:

Ratios highlighted in orange represent the total dose relative to the total nominal PA dose.

Largest contributor is highlighted in red.

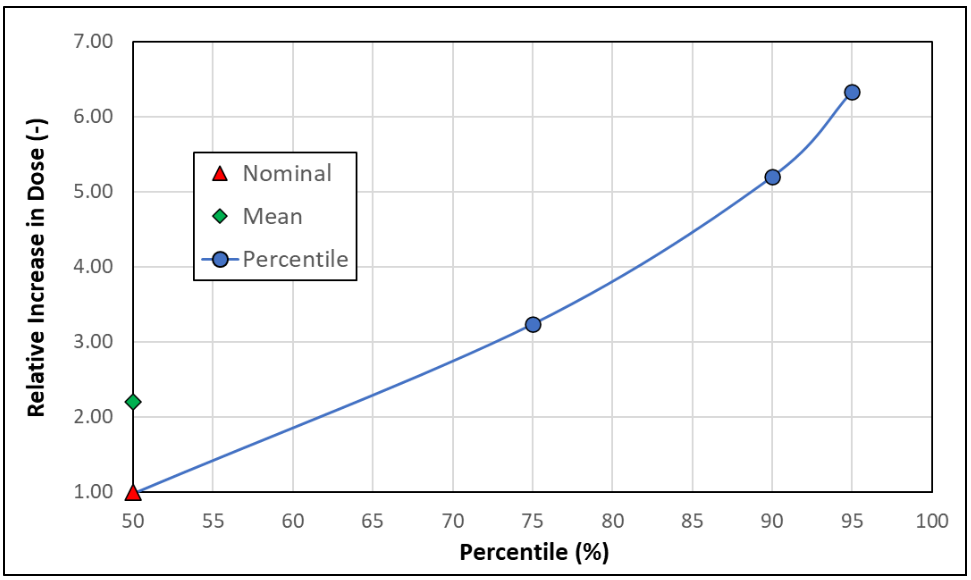


Figure 6-40. Peak All-Pathways Relative Dose for ST09

Table 6-105. Peak Beta-Gamma Relative Dose for ST09

Radionuclide	Closure Inventory (Ci)	Nominal PA	Mean	50th Percentile	75th Percentile	90th Percentile	95th Percentile
		mrem yr^{-1}					
C-14	5.51E-02	4.70E-05	1.36E-03	3.98E-05	2.33E-03	4.38E-03	5.55E-03
H-3	1.38E+00	1.02E+00	1.02E+00	1.02E+00	1.30E+00	1.54E+00	1.66E+00
I-129	5.07E-04	1.07E+00	1.07E+00	1.07E+00	1.19E+00	1.30E+00	1.36E+00
Np-237	2.79E-02	4.14E-03	3.55E-02	3.66E-03	6.14E-02	1.12E-01	1.41E-01
Sr-90	1.91E+02	1.45E-14	7.07E-10	1.79E-13	1.20E-09	2.27E-09	2.92E-09
Tc-99	1.48E-01	4.06E-01	4.06E-01	4.06E-01	4.18E-01	4.28E-01	4.34E-01
Sum		2.50	2.54	2.50	2.97	3.38	3.60
SOF		0.63	0.63	0.63	0.74	0.84	0.90
Ratio		1.00	1.01	1.00	1.19	1.35	1.44

Notes:

Ratios highlighted in orange represent the total dose relative to the total nominal PA dose.

Largest contributor is highlighted in red.

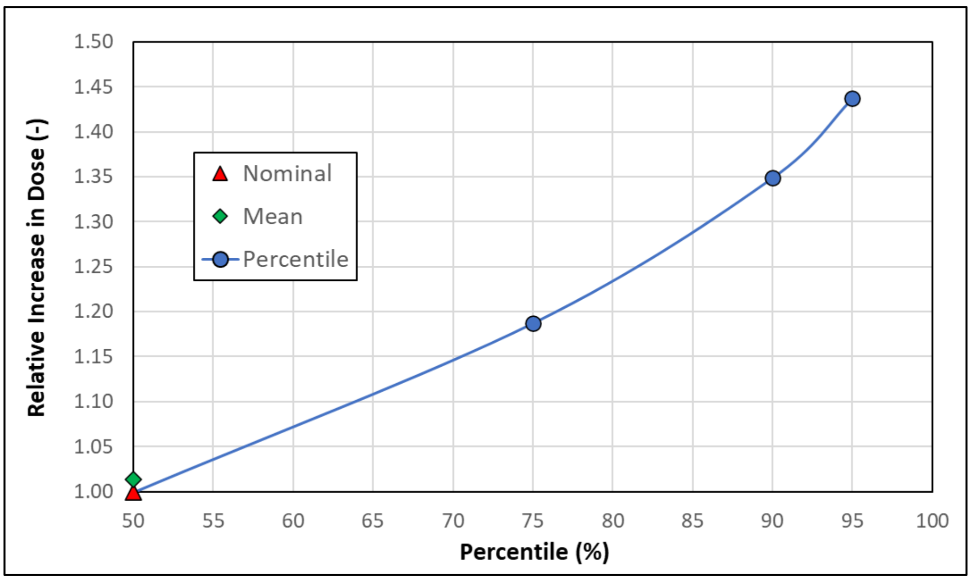


Figure 6-41. Peak Beta-Gamma Relative Dose for ST09

Table 6-106. Peak Gross-Alpha Relative Concentration for ST09

Radionuclide	Closure Inventory (Ci)	Nominal PA	Mean	50th Percentile	75th Percentile	90th Percentile	95th Percentile
		pCi L^{-1}					
Np-237	2.79E-02	3.10E-01	2.66E+00	2.75E-01	4.61E+00	8.38E+00	1.06E+01
Sum		0.31	2.66	0.27	4.61	8.38	10.56
SOF		0.02	0.18	0.02	0.31	0.56	0.70
Ratio		1.00	8.58	0.89	14.85	27.00	34.02

Notes:

Ratios highlighted in orange represent the total concentration relative to the total nominal PA concentration.

Largest contributor is highlighted in red.

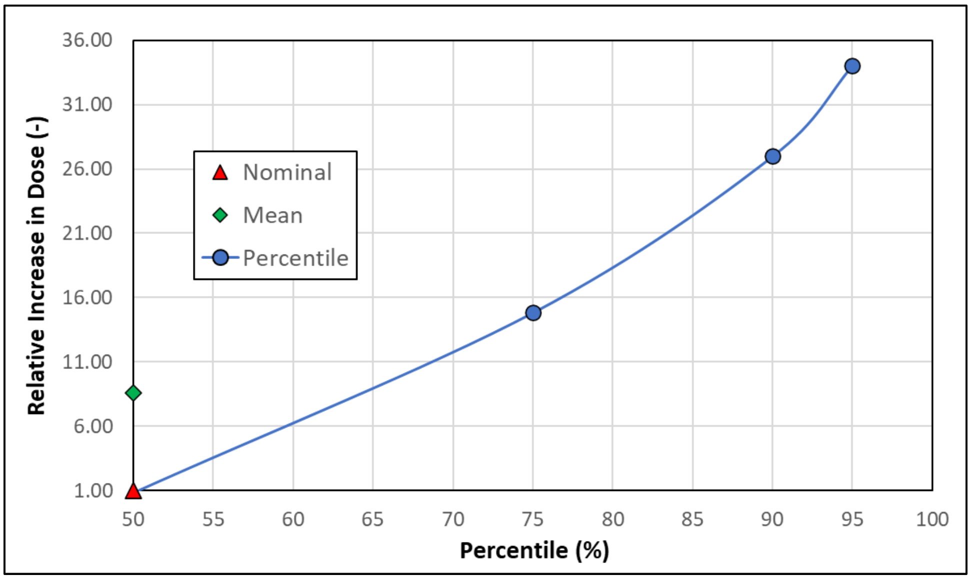


Figure 6-42. Peak Gross-Alpha Relative Concentration for ST09

Table 6-107. Peak Uranium Relative Concentration for ST09

Radionuclide	Closure Inventory (Ci)	Nominal PA	Mean	50th Percentile	75th Percentile	90th Percentile	95th Percentile
		µg L^{-1}					
Np-237	2.79E-02	5.31E-11	1.93E-09	4.31E-11	3.28E-09	6.19E-09	7.89E-09
Sum		5.31E-11	1.93E-09	4.31E-11	3.28E-09	6.19E-09	7.89E-09
SOF		1.77E-12	6.43E-11	1.44E-12	1.09E-10	2.06E-10	2.63E-10
Ratio		1.00	36.35	0.81	61.86	116.68	148.77

Notes:
Ratios highlighted in orange represent the total concentration relative to the total nominal PA concentration.
Largest contributor is highlighted in red.

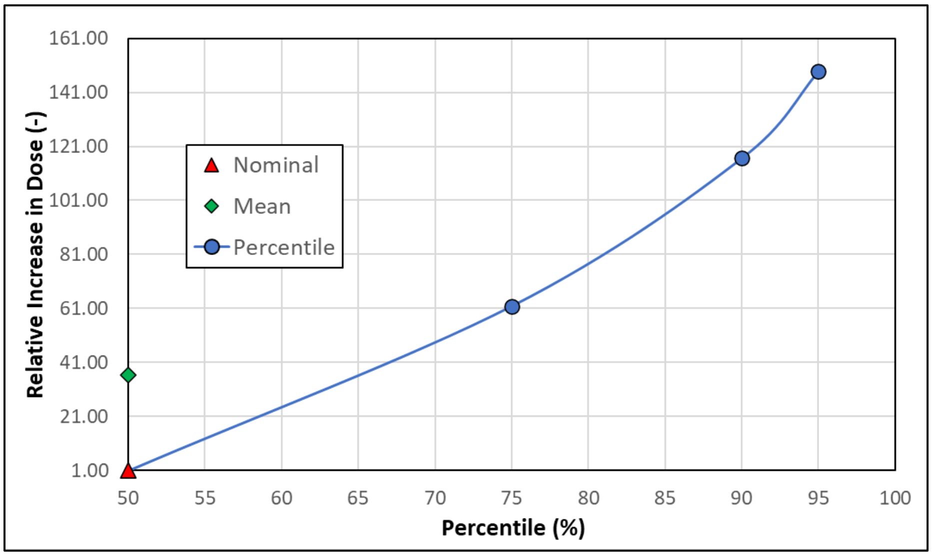


Figure 6-43. Peak Uranium Relative Concentration for ST09

6.1.2.3.2. Low-Activity Waste and Intermediate-Level Vaults

Relative dose (or concentration) results for the LAWV and ILV for the four exposure pathways are presented below.

For the LAWV:

- **All-pathways:** Table 6-108 and Figure 6-44
- **Beta-gamma:** Table 6-109 and Figure 6-45
- **Gross-alpha:** Table 6-110 and Figure 6-46
- **Uranium:** Table 6-111 and Figure 6-47

For the ILV:

- **All-pathways:** Table 6-112 and Figure 6-48
- **Beta-gamma:** Table 6-113 and Figure 6-49
- **Gross-alpha:** Table 6-114 and Figure 6-50
- **Uranium:** Table 6-115 (graph excluded; all concentrations below single precision)

Table 6-108. Peak All-Pathways Relative Dose for Low-Activity Waste Vault

Radionuclide	Closure Inventory (Ci)	Nominal PA	Mean	50th Percentile	75th Percentile	90th Percentile	95th Percentile
		mrem yr^{-1}					
Ag-108m	2.91E-04	1.95E-58	--	--	--	--	--
Am-241	1.36E+00	3.13E-24	6.96E-14	5.52E-17	1.18E-13	2.25E-13	2.88E-13
C-14	6.35E-01	3.09E-33	2.19E-19	0.00E+00	3.72E-19	7.08E-19	9.08E-19
Ca-41	6.72E-05	1.17E-30	3.96E-15	0.00E+00	6.73E-15	1.28E-14	1.64E-14
Cl-36	6.40E-03	4.10E-06	2.67E-03	1.18E-06	4.59E-03	8.66E-03	1.09E-02
Cm-245	7.53E-03	7.40E-27	1.90E-16	0.00E+00	3.23E-16	6.13E-16	7.85E-16
Cs-137	2.74E+02	2.79E-56	--	--	--	--	--
H-3	1.39E+06	2.92E-05	2.92E-05	2.92E-05	3.68E-05	4.36E-05	4.77E-05
I-129	5.77E-04	5.89E-02	5.89E-02	5.89E-02	6.81E-02	7.62E-02	8.08E-02
K-40	1.84E-06	9.61E-32	4.30E-17	0.00E+00	7.31E-17	1.39E-16	1.78E-16
Ni-59	5.05E+00	2.24E-40	1.19E-20	0.00E+00	2.02E-20	3.83E-20	4.91E-20
Ni-63	8.64E+02	2.59E-41	1.43E-21	0.00E+00	2.43E-21	4.62E-21	5.91E-21
Np-237	1.39E-01	2.99E-21	5.84E-11	2.38E-14	9.93E-11	1.89E-10	2.42E-10
Pu-239	5.27E+00	1.58E-27	4.59E-17	0.00E+00	7.80E-17	1.48E-16	1.90E-16
Pu-241	3.56E+01	2.64E-24	5.90E-14	5.37E-17	1.00E-13	1.91E-13	2.44E-13
Ra-226	1.28E-01	2.79E-109	--	--	--	--	--
Sr-90	7.89E+02	2.50E-39	6.91E-23	0.00E+00	1.19E-22	2.26E-22	2.89E-22
Tc-99	4.04E-01	3.04E-04	2.64E-03	2.61E-04	4.56E-03	8.33E-03	1.06E-02
U-235	1.65E-02	1.79E-23	4.45E-13	0.00E+00	7.55E-13	1.44E-12	1.84E-12
Sum		0.06	0.06	0.06	0.08	0.09	0.10
SOF		0.002	0.003	0.002	0.003	0.004	0.004
Ratio		1.00	1.08	1.00	1.30	1.57	1.73

Notes:

Ratios highlighted in orange represent the total dose relative to the total nominal PA dose.

Largest contributor is highlighted in red.

Entries with "--" represent numbers below single precision.

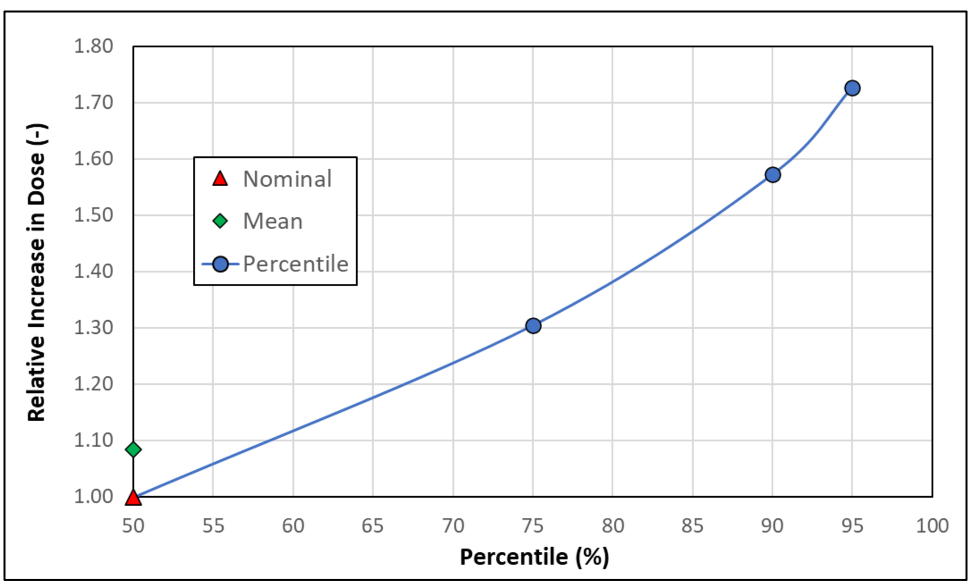


Figure 6-44. Peak All-Pathways Relative Dose for Low-Activity Waste Vault

Table 6-109. Peak Beta-Gamma Relative Dose for Low-Activity Waste Vault

Radionuclide	Closure Inventory (Ci)	Nominal PA	Mean	50th Percentile	75th Percentile	90th Percentile	95th Percentile
		mrem yr^{-1}					
Ag-108m	2.91E-04	2.60E-58	--	--	--	--	--
Am-241	1.36E+00	2.08E-25	4.63E-15	3.67E-18	7.87E-15	1.50E-14	1.92E-14
C-14	6.35E-01	3.08E-33	2.19E-19	0.00E+00	3.71E-19	7.06E-19	9.05E-19
Ca-41	6.72E-05	5.74E-31	1.94E-15	0.00E+00	3.29E-15	6.25E-15	8.01E-15
Cl-36	6.40E-03	4.56E-06	2.97E-03	1.31E-06	5.11E-03	9.63E-03	1.21E-02
Cm-245	7.53E-03	4.92E-28	1.26E-17	0.00E+00	2.14E-17	4.08E-17	5.22E-17
Cs-137	2.74E+02	1.87E-56	--	--	--	--	--
H-3	1.39E+06	8.38E-04	8.38E-04	8.38E-04	1.02E-03	1.18E-03	1.27E-03
I-129	5.77E-04	1.01E+00	1.01E+00	1.01E+00	1.16E+00	1.30E+00	1.38E+00
K-40	1.84E-06	9.99E-32	4.47E-17	0.00E+00	7.59E-17	1.44E-16	1.85E-16
Ni-59	5.05E+00	2.16E-38	1.14E-18	0.00E+00	1.94E-18	3.69E-18	4.73E-18
Ni-63	8.64E+02	6.03E-39	3.33E-19	0.00E+00	5.66E-19	1.07E-18	1.38E-18
Np-237	1.39E-01	1.99E-22	3.88E-12	1.58E-15	6.60E-12	1.25E-11	1.61E-11
Pu-239	5.27E+00	1.16E-30	5.60E-20	0.00E+00	9.51E-20	1.81E-19	2.32E-19
Pu-241	3.56E+01	1.75E-25	3.92E-15	3.57E-18	6.67E-15	1.27E-14	1.63E-14
Ra-226	1.28E-01	2.17E-111	--	--	--	--	--
Sr-90	7.89E+02	2.13E-38	5.98E-22	0.00E+00	1.02E-21	1.93E-21	2.47E-21
Tc-99	4.04E-01	4.61E-04	4.00E-03	3.96E-04	6.91E-03	1.26E-02	1.60E-02
U-235	1.65E-02	1.33E-26	5.48E-16	0.00E+00	9.30E-16	1.77E-15	2.27E-15
Sum		1.01	1.01	1.01	1.18	1.33	1.41
SOF		0.25	0.25	0.25	0.29	0.33	0.35
Ratio		1.00	1.01	1.00	1.17	1.31	1.40

Notes:

Ratios highlighted in orange represent the total dose relative to the total nominal PA dose.

Largest contributor is highlighted in red.

Entries with “--” represent numbers below single precision.

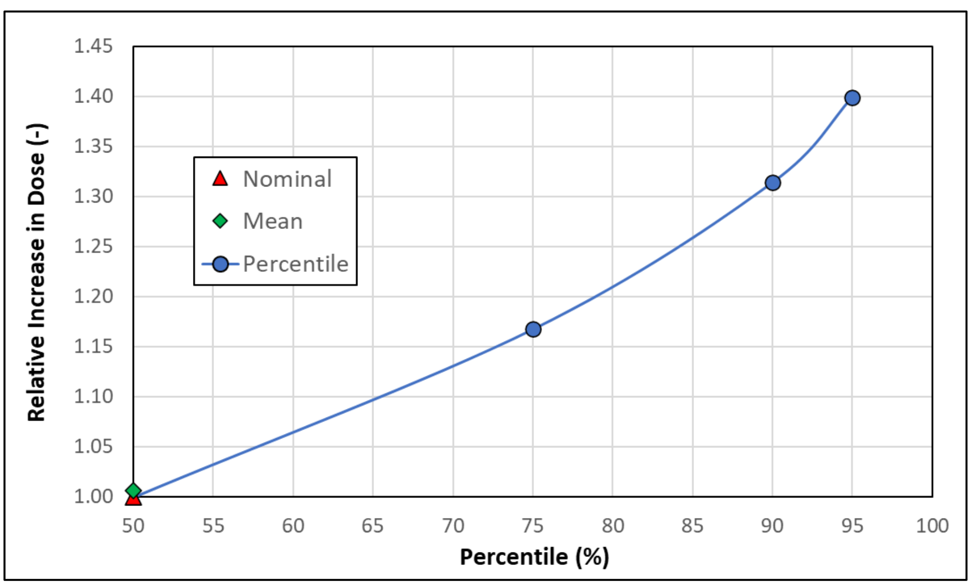


Figure 6-45. Peak Beta-Gamma Relative Dose for Low-Activity Waste Vault

Table 6-110. Peak Gross-Alpha Relative Concentration for Low-Activity Waste Vault

Radionuclide	Closure Inventory (Ci)	Nominal PA	Mean	50th Percentile	75th Percentile	90th Percentile	95th Percentile
		pCi L^{-1}					
Am-241	1.36E+00	1.56E-23	3.47E-13	2.75E-16	5.91E-13	1.12E-12	1.44E-12
Cm-245	7.53E-03	3.69E-26	9.47E-16	0.00E+00	1.61E-15	3.06E-15	3.92E-15
Np-237	1.39E-01	1.49E-20	2.91E-10	1.19E-13	4.95E-10	9.41E-10	1.21E-09
Pu-239	5.27E+00	1.79E-27	5.23E-17	0.00E+00	8.88E-17	1.69E-16	2.16E-16
Pu-241	3.56E+01	1.32E-23	2.94E-13	2.68E-16	5.00E-13	9.50E-13	1.22E-12
Ra-226	1.28E-01	1.11E-108	--	--	--	--	--
U-235	1.65E-02	2.04E-23	5.06E-13	0.00E+00	8.60E-13	1.63E-12	2.09E-12
Sum		1.50E-20	2.92E-10	1.19E-13	4.97E-10	9.44E-10	1.21E-09
SOF		9.98E-22	1.95E-11	7.94E-15	3.31E-11	6.29E-11	8.07E-11
Ratio		1.00	1.95E+10	7.96E+06	3.32E+10	6.31E+10	8.09E+10

Notes:

Ratios highlighted in orange represent the total concentration relative to the total nominal PA concentration.

Largest contributor is highlighted in red.

Entries with "--" represent numbers below single precision.

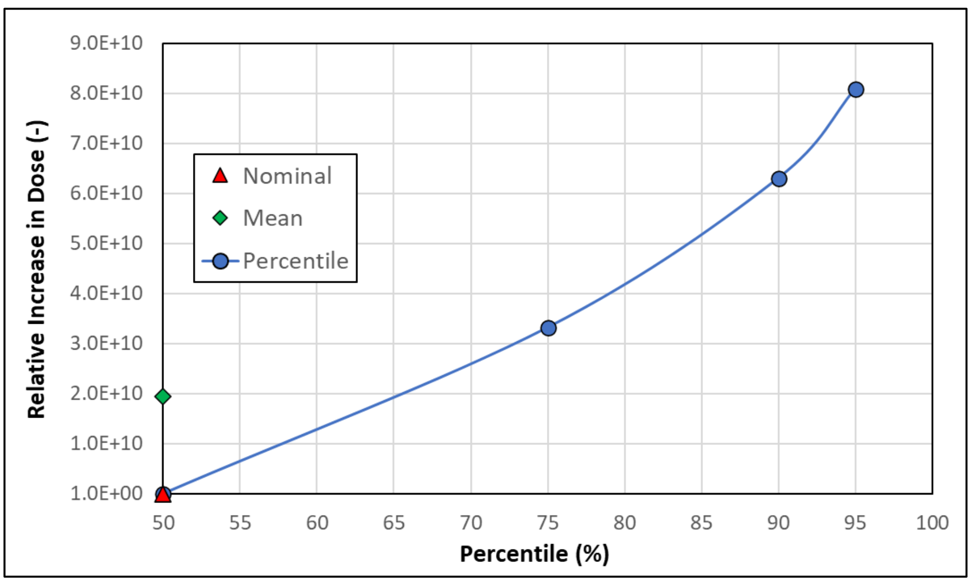


Figure 6-46. Peak Gross-Alpha Relative Concentration for Low-Activity Waste Vault

Table 6-111. Peak Uranium Relative Concentration for Low-Activity Waste Vault

Radionuclide	Closure Inventory (Ci)	Nominal PA	Mean	50th Percentile	75th Percentile	90th Percentile	95th Percentile
		µg L-1					
Am-241	1.36E+00	6.50E-34	3.43E-23	0.00E+00	5.82E-23	1.11E-22	1.42E-22
Cm-245	7.53E-03	1.52E-36	9.19E-26	0.00E+00	1.56E-25	2.97E-25	3.80E-25
Np-237	1.39E-01	6.25E-31	2.91E-20	0.00E+00	4.94E-20	9.40E-20	1.20E-19
Pu-239	5.27E+00	4.50E-190	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pu-241	3.56E+01	5.46E-34	2.90E-23	0.00E+00	4.93E-23	9.38E-23	1.20E-22
U-235	1.65E-02	6.82E-186	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sum		6.26E-31	2.92E-20	0.00E+00	4.95E-20	9.42E-20	1.21E-19
SOF		2.09E-32	9.72E-22	0.00E+00	1.65E-21	3.14E-21	4.02E-21
Ratio		1.00	4.66E+10	0.00E+00	7.91E+10	1.50E+11	1.93E+11

Notes:
Ratios highlighted in orange represent the total concentration relative to the total nominal PA concentration.
Largest contributor is highlighted in red.

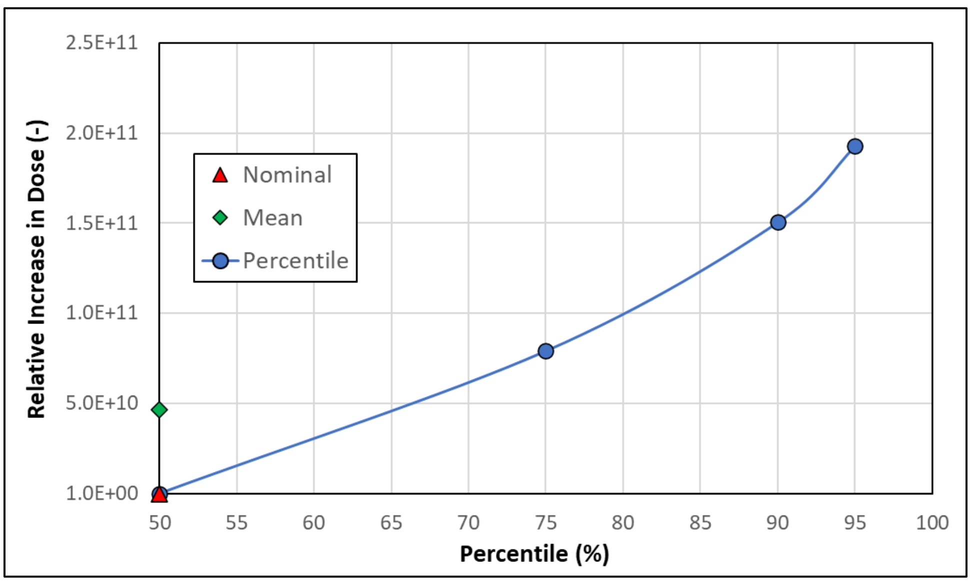


Figure 6-47. Peak Uranium Relative Concentration for Low-Activity Waste Vault

Table 6-112. Peak All-Pathways Relative Dose for Intermediate-Level Vault

Radionuclide	Closure Inventory (Ci)	Nominal PA	Mean	50th Percentile	75th Percentile	90th Percentile	95th Percentile
		mrem yr^{-1}					
Ag-108m	2.62E-04	1.03E-66	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Am-241	4.42E+00	2.45E-33	1.83E-21	0.00E+00	3.11E-21	5.91E-21	7.56E-21
Ar-39	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
C-14	3.17E+00	1.34E-29	3.17E-21	0.00E+00	5.38E-21	1.02E-20	1.31E-20
Cf-249	1.03E-02	5.16E-38	6.91E-26	0.00E+00	1.18E-25	2.23E-25	2.86E-25
Cl-36	4.87E-04	2.08E-06	1.96E-04	2.54E-06	3.38E-04	6.36E-04	7.95E-04
Cm-245	1.62E-02	5.64E-36	6.21E-24	0.00E+00	1.06E-23	2.00E-23	2.57E-23
Cs-137	2.42E+03	4.87E-50	--	--	--	--	--
H-3	8.98E+06	1.50E-02	1.50E-02	1.50E-02	1.66E-02	1.80E-02	1.87E-02
I-129	3.74E-03	8.42E-02	1.18E-01	8.49E-02	2.02E-01	3.03E-01	3.59E-01
K-40	3.63E-02	2.84E-27	1.51E-14	0.00E+00	2.56E-14	4.86E-14	6.23E-14
Ni-59	6.20E+00	1.07E-45	--	--	--	--	--
Ni-63	7.57E+02	8.69E-47	--	--	--	--	--
Np-237	1.00E-01	3.19E-31	1.90E-19	0.00E+00	3.22E-19	6.11E-19	7.83E-19
Pu-239	5.19E+00	3.43E-36	4.35E-24	0.00E+00	7.39E-24	1.40E-23	1.80E-23
Pu-241	2.81E+01	5.08E-34	3.86E-22	0.00E+00	6.56E-22	1.24E-21	1.59E-21
Ra-226	5.01E+00	5.33E-99	--	--	--	--	--
Sr-90	7.27E+02	7.02E-48	--	--	--	--	--
Tc-99	7.67E-01	4.04E-08	1.26E-06	4.04E-08	2.14E-06	4.04E-06	5.16E-06
U-235	1.63E-02	3.94E-32	3.85E-20	0.00E+00	6.55E-20	1.24E-19	1.59E-19
Sum		0.10	0.13	0.10	0.22	0.32	0.38
SOF		0.004	0.01	0.004	0.01	0.01	0.02
Ratio		1.00	1.34	1.01	2.21	3.24	3.81

Notes:

Ratios highlighted in orange represent the total dose relative to the total nominal PA dose.

Largest contributor is highlighted in red.

Entries with “--” represent numbers below single precision.

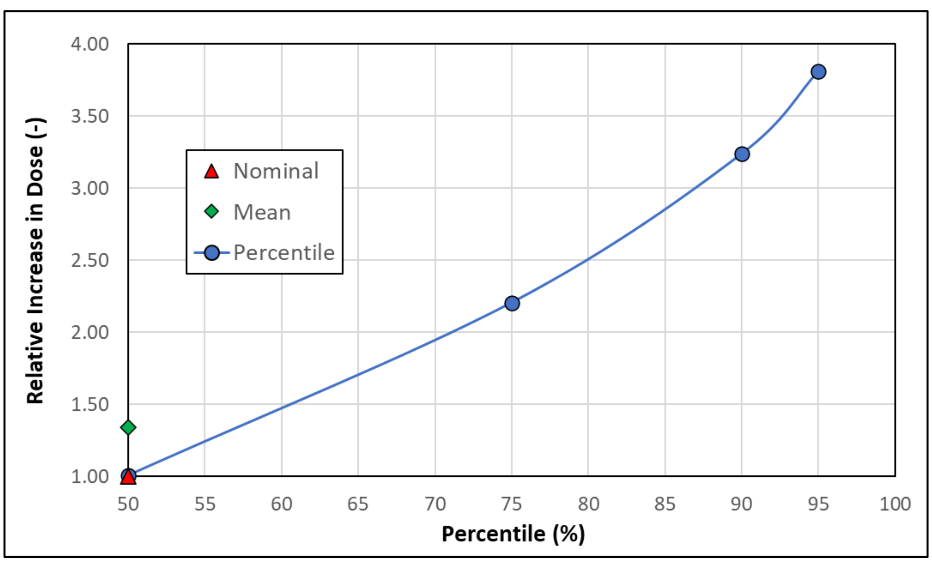


Figure 6-48. Peak All-Pathways Relative Dose for Intermediate-Level Vault

Table 6-113. Peak Beta-Gamma Relative Dose for Intermediate-Level Vault

Radionuclide	Closure Inventory (Ci)	Nominal PA	Mean	50th Percentile	75th Percentile	90th Percentile	95th Percentile
		mrem yr^{-1}					
Ag-108m	2.62E-04	1.38E-66	--	--	--	--	--
Am-241	4.42E+00	1.63E-34	1.22E-22	0.00E+00	2.07E-22	3.93E-22	5.03E-22
Ar-39	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
C-14	3.17E+00	1.34E-29	6.64E-21	0.00E+00	1.13E-20	2.14E-20	2.74E-20
Cf-249	1.03E-02	3.43E-39	4.59E-27	0.00E+00	7.82E-27	1.48E-26	1.90E-26
Cl-36	4.87E-04	2.31E-06	2.18E-04	2.82E-06	3.76E-04	7.07E-04	8.84E-04
Cm-245	1.62E-02	3.75E-37	4.13E-25	0.00E+00	7.03E-25	1.33E-24	1.71E-24
Cs-137	2.42E+03	3.27E-50	--	--	--	--	--
H-3	8.98E+06	3.32E-01	3.32E-01	3.32E-01	4.11E-01	4.78E-01	5.14E-01
I-129	3.74E-03	1.44E+00	2.01E+00	1.45E+00	3.45E+00	5.17E+00	6.13E+00
K-40	3.63E-02	2.95E-27	1.57E-14	0.00E+00	2.66E-14	5.05E-14	6.47E-14
Ni-59	6.20E+00	1.03E-43	8.72E-25	0.00E+00	1.49E-24	2.83E-24	3.62E-24
Ni-63	7.57E+02	2.02E-44	--	--	--	--	--
Np-237	1.00E-01	2.12E-32	1.26E-20	0.00E+00	2.14E-20	4.07E-20	5.21E-20
Pu-239	5.19E+00	2.25E-39	--	--	--	--	--
Pu-241	2.81E+01	3.38E-35	2.56E-23	0.00E+00	4.36E-23	8.27E-23	1.06E-22
Ra-226	5.01E+00	1.00E-100	--	--	--	--	--
Sr-90	7.27E+02	6.00E-47	--	--	--	--	--
Tc-99	7.67E-01	6.12E-08	1.90E-06	6.12E-08	3.24E-06	6.12E-06	7.81E-06
U-235	1.63E-02	2.61E-35	3.78E-23	0.00E+00	6.43E-23	1.22E-22	1.56E-22
Sum		1.77	2.34	1.78	3.86	5.65	6.64
SOF		0.443	0.59	0.446	0.97	1.41	1.66
Ratio		1.00	1.32	1.01	2.18	3.19	3.75

Notes:

Ratios highlighted in orange represent the total dose relative to the total nominal PA dose.

Largest contributor is highlighted in red.

Entries with "--" represent numbers below single precision.

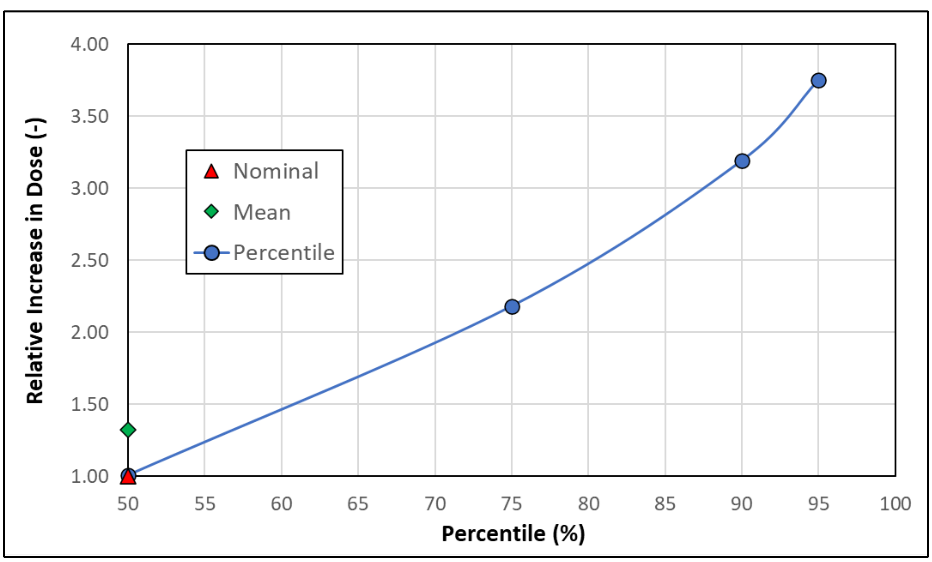


Figure 6-49. Peak Beta-Gamma Relative Dose for Intermediate-Level Vault

Table 6-114. Peak Gross-Alpha Relative Concentration for Intermediate-Level Vault

Radionuclide	Closure Inventory (Ci)	Nominal PA	Mean	50th Percentile	75th Percentile	90th Percentile	95th Percentile
		pCi L^{-1}					
Am-241	4.42E+00	1.22E-32	9.13E-21	0.00E+00	1.55E-20	2.95E-20	3.77E-20
Cf-249	1.03E-02	2.58E-37	3.45E-25	0.00E+00	5.86E-25	1.11E-24	1.42E-24
Cm-245	1.62E-02	2.81E-35	3.10E-23	0.00E+00	5.27E-23	9.99E-23	1.28E-22
Np-237	1.00E-01	1.59E-30	9.45E-19	0.00E+00	1.61E-18	3.05E-18	3.90E-18
Pu-239	5.19E+00	3.90E-36	4.95E-24	0.00E+00	8.41E-24	1.60E-23	2.04E-23
Pu-241	2.81E+01	2.53E-33	1.92E-21	0.00E+00	3.27E-21	6.20E-21	7.94E-21
Ra-226	5.01E+00	2.11E-98	--	--	--	--	--
U-235	1.63E-02	4.48E-32	4.38E-20	0.00E+00	7.46E-20	1.41E-19	1.81E-19
Sum		1.65E-30	1.00E-18	0.00E+00	1.70E-18	3.23E-18	4.13E-18
SOF		1.10E-31	6.67E-20	0.00E+00	1.13E-19	2.15E-19	2.75E-19
Ratio		1.00	6.05E+11	0.00E+00	1.03E+12	1.95E+12	2.50E+12

Notes:

Ratios highlighted in orange represent the total concentration relative to the total nominal PA concentration.

Largest contributor is highlighted in red.

Entries with "--" represent numbers below single precision.

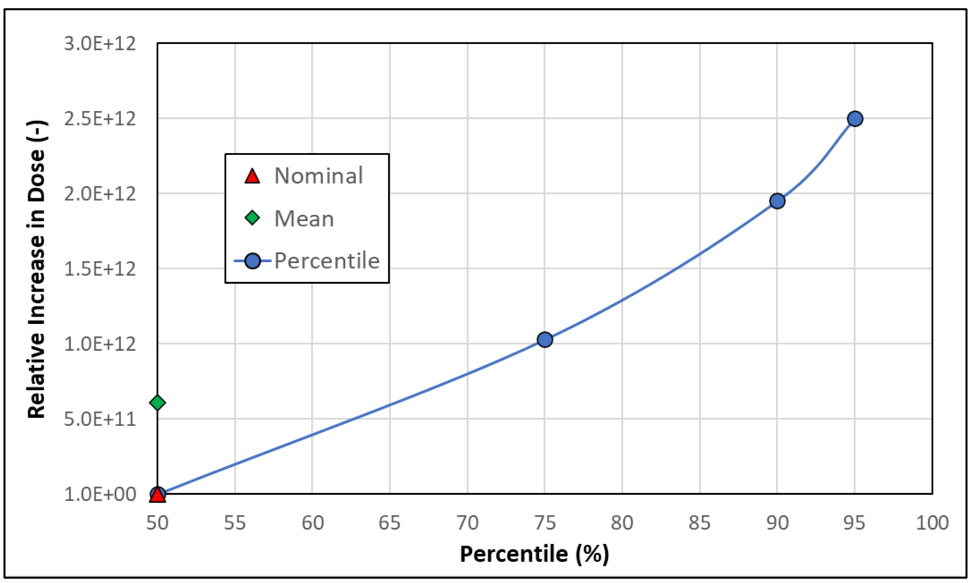


Figure 6-50. Peak Gross-Alpha Relative Concentration for Intermediate-Level Vault

Table 6-115. Peak Uranium Relative Concentration for Intermediate-Level Vault

Radionuclide	Closure Inventory (Ci)	Nominal PA	Mean	50th Percentile	75th Percentile	90th Percentile	95th Percentile
		µg L^{-1}					
Am-241	4.42E+00	4.47E-43	--	--	--	--	--
Cf-249	1.03E-02	9.16E-48	--	--	--	--	--
Cm-245	1.62E-02	1.01E-45	--	--	--	--	--
Np-237	1.00E-01	5.88E-41	--	--	--	--	--
Pu-239	5.19E+00	5.48E-183	--	--	--	--	--
Pu-241	2.81E+01	9.25E-44	--	--	--	--	--
U-235	1.63E-02	8.95E-178	--	--	--	--	--
Sum		5.93E-41	--	--	--	--	--
SOF		1.98E-42	--	--	--	--	--
Ratio		1.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Notes:
Ratios highlighted in orange represent the total concentration relative to the total nominal PA concentration.
Largest contributor is highlighted in red.
Entries with "--" represent numbers below single precision.

6.1.2.3.3. Naval Reactor Component Disposal Areas

Relative dose (or concentration) results for NR07E (Case 3 for welded casks) and NR26E (Case 4 for welded casks; Case 1 for bolted containers) for the four exposure pathways are presented below.

For NR07E (Case 3):

- **All-pathways:** Table 6-116 and Figure 6-51
- **Beta-gamma:** Table 6-117 and Figure 6-52
- **Gross-alpha:** Table 6-118 and Figure 6-53
- **Uranium:** Table 6-119 and Figure 6-54

For NR26E (Case 4):

- **All-pathways:** Table 6-120 and Figure 6-55
- **Beta-gamma:** Table 6-121 and Figure 6-56
- **Gross-alpha:** Table 6-122 and Figure 6-57
- **Uranium:** Table 6-123 and Figure 6-58

For NR26E (Case 1):

- **All-pathways:** Table 6-124 and Figure 6-59
- **Beta-gamma:** Table 6-125 and Figure 6-60
- **Gross-alpha:** Table 6-126 and Figure 6-61
- **Uranium:** Table 6-127 and Figure 6-62

Table 6-116. Peak All-Pathways Relative Dose for NR07E Welded Casks (Case 3)

Radionuclide	Closure Inventory (Ci)	Nominal PA	Mean	50th Percentile	75th Percentile	90th Percentile	95th Percentile
		mrem yr^{-1}					
Am-241S	3.52E-01	1.66E-13	1.88E-09	3.05E-12	3.20E-09	6.08E-09	7.80E-09
Be-10S	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
C-14S	1.39E+02	1.81E-12	4.37E-08	0.00E+00	7.41E-08	1.41E-07	1.80E-07
Cl-36S	1.80E-05	2.10E-11	1.59E-08	5.14E-11	2.68E-08	5.14E-08	6.56E-08
I-129S	1.48E-05	5.32E-06	4.32E-05	4.91E-06	7.45E-05	1.37E-04	1.73E-04
Ni-59S	1.55E+03	1.04E-21	1.16E-13	0.00E+00	1.97E-13	3.73E-13	4.78E-13
Ni-63S	1.80E+05	6.95E-23	8.07E-15	0.00E+00	1.37E-14	2.60E-14	3.33E-14
Np-237S	4.03E-06	1.31E-14	1.48E-10	2.45E-13	2.51E-10	4.76E-10	6.12E-10
Pu-241S	3.40E+01	5.27E-13	5.96E-09	9.60E-12	1.01E-08	1.92E-08	2.47E-08
Tc-99S	1.46E-01	1.82E-02	1.84E-02	1.82E-02	2.58E-02	3.26E-02	3.64E-02
U-235S	2.06E-07	4.89E-17	5.56E-13	7.68E-16	9.45E-13	1.80E-12	2.31E-12
Sum		0.02	0.02	0.02	0.03	0.03	0.04
SOF		0.001	0.001	0.001	0.001	0.001	0.001
Ratio		1.00	1.01	1.00	1.43	1.81	2.02

Notes:

Ratios highlighted in orange represent the total dose relative to the total nominal PA dose.

Largest contributor is highlighted in red.

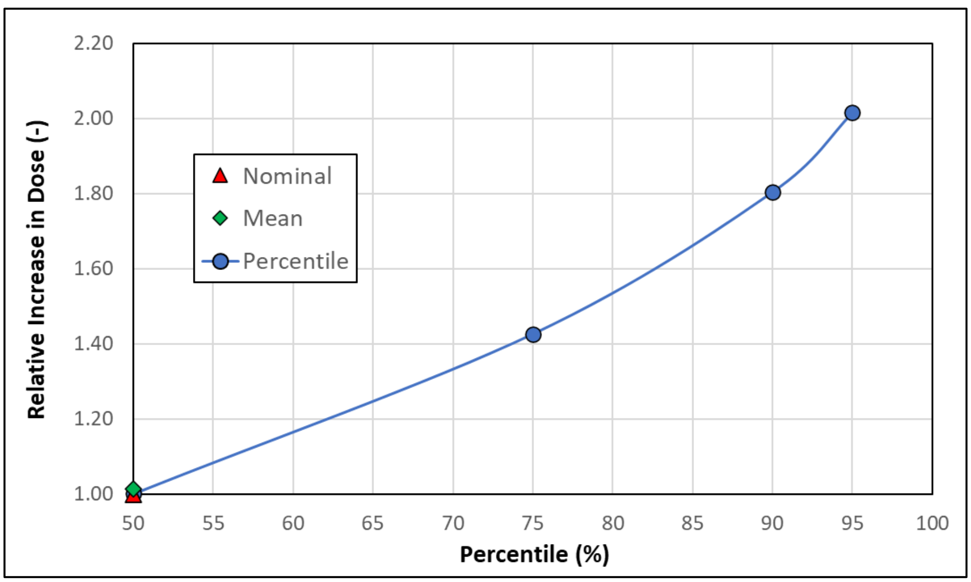


Figure 6-51. Peak All-Pathways Relative Dose for NR07E Welded Casks (Case 3)

Table 6-117. Peak Beta-Gamma Relative Dose for NR07E Welded Casks (Case 3)

Radionuclide	Closure Inventory (Ci)	Nominal PA	Mean	50th Percentile	75th Percentile	90th Percentile	95th Percentile
		mrem yr^{-1}					
Am-241S	3.52E-01	1.11E-14	1.25E-10	2.03E-13	2.13E-10	4.04E-10	5.19E-10
Be-10S	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
C-14S	1.39E+02	1.80E-12	4.35E-08	0.00E+00	7.39E-08	1.40E-07	1.80E-07
Cl-36S	1.80E-05	2.34E-11	1.76E-08	5.71E-11	2.98E-08	5.71E-08	7.30E-08
I-129S	1.48E-05	9.09E-05	7.39E-04	8.40E-05	1.27E-03	2.34E-03	2.96E-03
Ni-59S	1.55E+03	1.00E-19	1.12E-11	0.00E+00	1.90E-11	3.59E-11	4.60E-11
Ni-63S	1.80E+05	1.62E-20	1.88E-12	0.00E+00	3.19E-12	6.05E-12	7.75E-12
Np-237S	4.03E-06	8.73E-16	9.81E-12	1.63E-14	1.67E-11	3.17E-11	4.07E-11
Pu-241S	3.40E+01	3.51E-14	3.96E-10	6.39E-13	6.73E-10	1.28E-09	1.64E-09
Tc-99S	1.46E-01	2.75E-02	2.78E-02	2.75E-02	3.92E-02	4.95E-02	5.52E-02
U-235S	2.06E-07	5.31E-20	6.96E-16	6.67E-19	1.18E-15	2.25E-15	2.89E-15
Sum		0.03	0.03	0.03	0.04	0.05	0.06
SOF		0.01	0.01	0.01	0.01	0.01	0.01
Ratio		1.00	1.04	1.00	1.46	1.88	2.11

Notes:
Ratios highlighted in orange represent the total dose relative to the total nominal PA dose.
Largest contributor is highlighted in red.

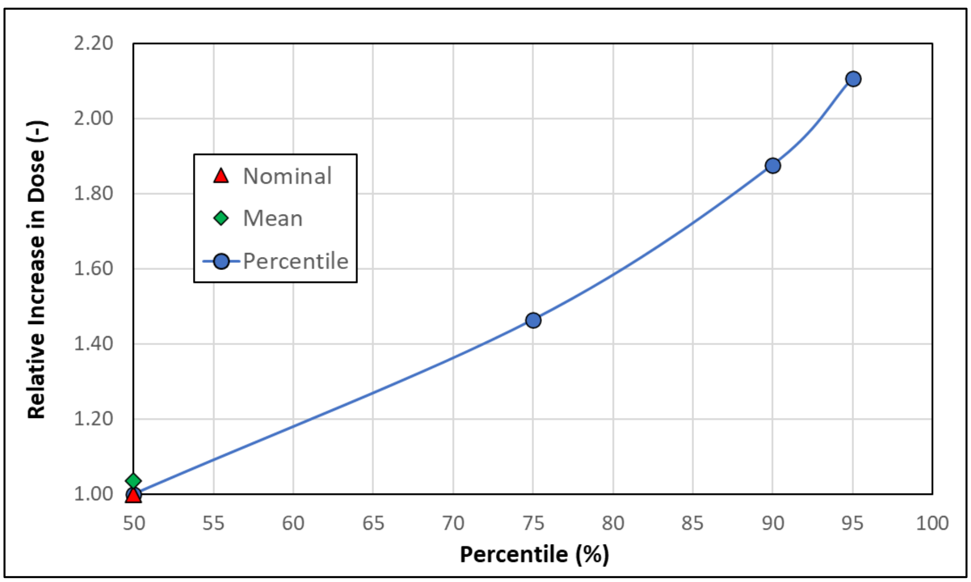


Figure 6-52. Peak Beta-Gamma Relative Dose for NR07E Welded Casks (Case 3)

Table 6-118. Peak Gross-Alpha Relative Concentration for NR07E Welded Casks (Case 3)

Radionuclide	Closure Inventory (Ci)	Nominal PA	Mean	50th Percentile	75th Percentile	90th Percentile	95th Percentile
		pCi L^{-1}					
Am-241S	3.52E-01	8.30E-13	9.39E-09	1.52E-11	1.59E-08	3.03E-08	3.89E-08
Np-237S	4.03E-06	6.55E-14	7.36E-10	1.22E-12	1.25E-09	2.38E-09	3.05E-09
Pu-241S	3.40E+01	2.63E-12	2.97E-08	4.79E-11	5.05E-08	9.60E-08	1.23E-07
U-235S	2.06E-07	5.56E-17	6.34E-13	8.72E-16	1.08E-12	2.05E-12	2.63E-12
Sum		3.52E-12	3.99E-08	6.43E-11	6.77E-08	1.29E-07	1.65E-07
SOF		2.35E-13	2.66E-09	4.29E-12	4.51E-09	8.58E-09	1.10E-08
Ratio		1.00	11307.22	18.25	19201.13	36502.07	46861.50

Notes:

Ratios highlighted in orange represent the total concentration relative to the total nominal PA concentration.

Largest contributor is highlighted in red.

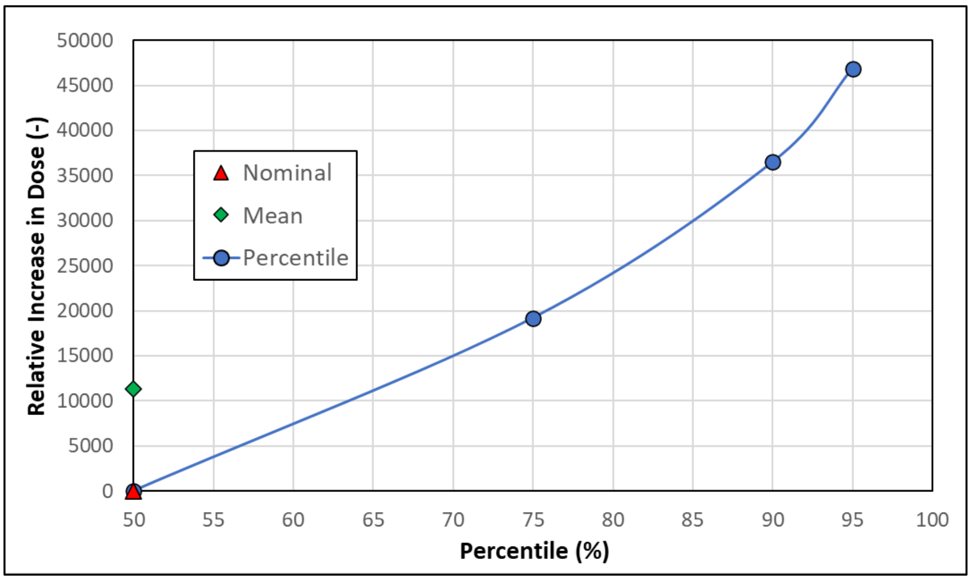


Figure 6-53. Peak Gross-Alpha Relative Concentration for NR07E Welded Casks (Case 3)

Table 6-119. Peak Uranium Relative Concentration for NR07E Welded Casks (Case 3)

Radionuclide	Closure Inventory (Ci)	Nominal PA	Mean	50th Percentile	75th Percentile	90th Percentile	95th Percentile
		µg L^{-1}					
Am-241S	3.52E-01	5.75E-23	7.97E-19	7.54E-22	1.35E-18	2.57E-18	3.30E-18
Np-237S	4.03E-06	4.54E-24	6.26E-20	5.52E-23	1.06E-19	2.02E-19	2.59E-19
Pu-241S	3.40E+01	1.82E-22	2.52E-18	2.39E-21	4.29E-18	8.15E-18	1.05E-17
U-235S	2.06E-07	1.31E-93	--	--	--	--	--
Sum		2.44E-22	3.38E-18	3.20E-21	5.75E-18	1.09E-17	1.40E-17
SOF		8.13E-24	1.13E-19	1.07E-22	1.92E-19	3.64E-19	4.67E-19
Ratio		1.00	13870.76	13.13	23567.54	44770.19	57469.40

Notes:

Ratios highlighted in orange represent the total concentration relative to the total nominal PA concentration.

Largest contributor is highlighted in red.

Entries with "--" represent numbers below single precision.

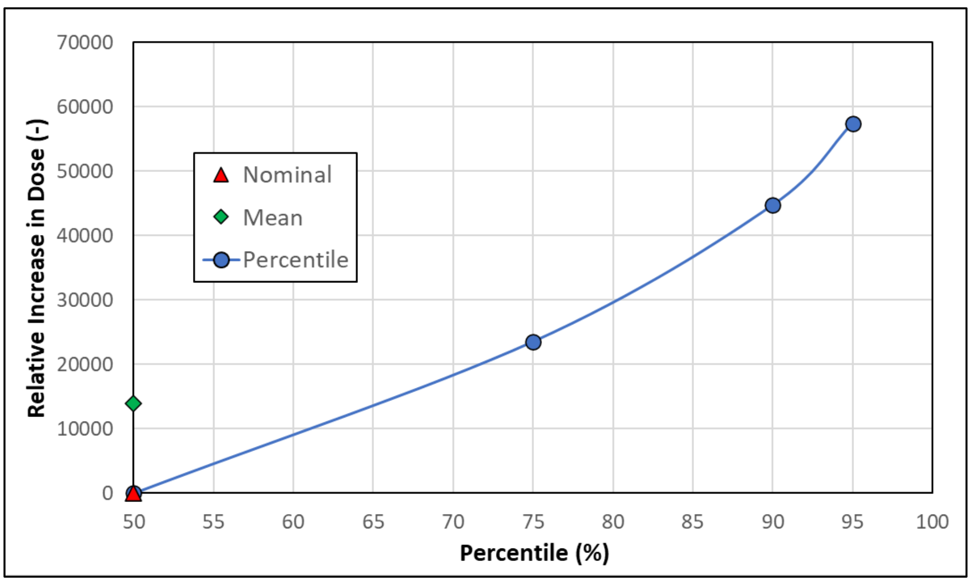


Figure 6-54. Peak Uranium Relative Concentration for NR07E Welded Casks (Case 3)

Table 6-120. Peak All-Pathways Relative Dose for NR26E Welded Casks (Case 4)

Radionuclide	Closure Inventory (Ci)	Nominal PA	Mean	50th Percentile	75th Percentile	90th Percentile	95th Percentile
		mrem yr^{-1}					
Am-241S	2.88E+01	5.39E-14	2.25E-09	0.00E+00	3.81E-09	7.29E-09	9.38E-09
Be-10S	4.67E-03	6.19E-23	1.16E-15	0.00E+00	1.97E-15	3.74E-15	4.78E-15
C-14S	1.90E+04	1.11E-11	2.86E-07	0.00E+00	4.85E-07	9.26E-07	1.20E-06
Cl-36S	2.75E+00	9.74E-08	1.80E-04	0.00E+00	3.17E-04	5.84E-04	7.29E-04
I-129S	2.42E-03	1.29E-05	1.45E-03	1.90E-05	2.55E-03	4.72E-03	5.89E-03
Ni-59S	3.23E+05	9.32E-23	3.73E-14	0.00E+00	6.34E-14	1.20E-13	1.54E-13
Ni-63S	3.76E+07	6.76E-24	2.85E-15	0.00E+00	4.84E-15	9.19E-15	1.18E-14
Np-237S	6.93E-04	8.93E-15	3.71E-10	0.00E+00	6.29E-10	1.20E-09	1.55E-09
Pu-241S	3.48E+03	2.13E-13	8.88E-09	0.00E+00	1.51E-08	2.88E-08	3.71E-08
Tc-99S	3.62E+01	5.71E-02	5.82E-01	5.95E-02	1.03E+00	1.86E+00	2.31E+00
U-235S	1.59E-03	1.48E-15	6.22E-11	0.00E+00	1.05E-10	2.02E-10	2.60E-10
Sum		0.06	0.58	0.06	1.03	1.87	2.32
SOF		0.002	0.02	0.002	0.04	0.07	0.09
Ratio		1.00	10.22	1.04	18.11	32.72	40.60

Notes:

Ratios highlighted in orange represent the total dose relative to the total nominal PA dose.

Largest contributor is highlighted in red.

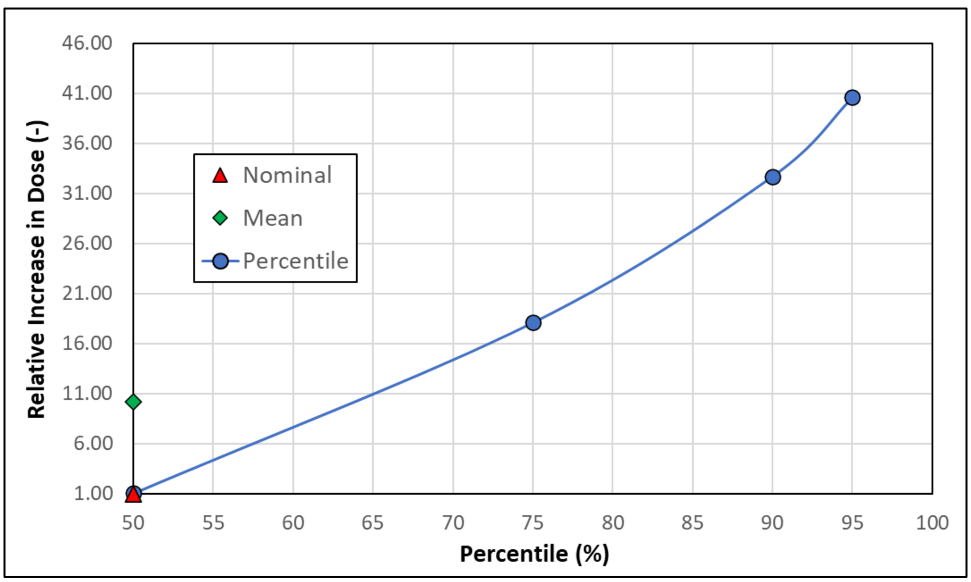


Figure 6-55. Peak All-Pathways Relative Dose for NR26E Welded Casks (Case 4)

Table 6-121. Peak Beta-Gamma Relative Dose for NR26E Welded Casks (Case 4)

Radionuclide	Closure Inventory (Ci)	Nominal PA	Mean	50th Percentile	75th Percentile	90th Percentile	95th Percentile
		mrem yr^{-1}					
Am-241S	2.88E+01	3.58E-15	2.35E-10	0.00E+00	3.99E-10	7.60E-10	9.74E-10
Be-10S	4.67E-03	1.05E-22	3.95E-15	0.00E+00	6.71E-15	1.27E-14	1.63E-14
C-14S	1.90E+04	1.11E-11	5.19E-07	0.00E+00	8.82E-07	1.67E-06	2.15E-06
Cl-36S	2.75E+00	1.08E-07	8.99E-05	2.90E-07	1.52E-04	2.91E-04	3.71E-04
I-129S	2.42E-03	2.21E-04	1.45E-03	2.07E-04	2.50E-03	4.52E-03	5.72E-03
Ni-59S	3.23E+05	8.98E-21	7.19E-12	0.00E+00	1.22E-11	2.32E-11	2.97E-11
Ni-63S	3.76E+07	1.57E-21	1.33E-12	0.00E+00	2.25E-12	4.27E-12	5.47E-12
Np-237S	6.93E-04	5.94E-16	3.88E-11	0.00E+00	6.58E-11	1.25E-10	1.60E-10
Pu-241S	3.48E+03	1.42E-14	9.31E-10	0.00E+00	1.58E-09	3.01E-09	3.85E-09
Tc-99S	3.62E+01	8.65E-02	8.65E-02	8.65E-02	1.04E-01	1.19E-01	1.28E-01
U-235S	1.59E-03	1.49E-18	1.18E-13	0.00E+00	1.99E-13	3.79E-13	4.86E-13
Sum		0.09	0.09	0.09	0.11	0.12	0.13
SOF		0.02	0.02	0.02	0.03	0.03	0.03
Ratio		1.00	1.02	1.00	1.23	1.43	1.54

Notes:
Ratios highlighted in orange represent the total dose relative to the total nominal PA dose.
Largest contributor is highlighted in red.

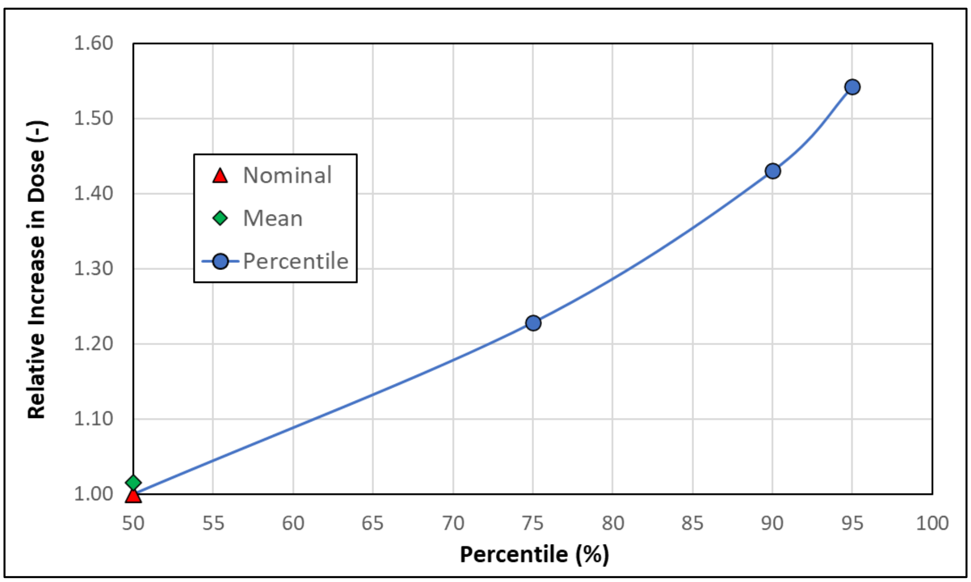


Figure 6-56. Peak Beta-Gamma Relative Dose for NR26E Welded Casks (Case 4)

Table 6-122. Peak Gross-Alpha Relative Concentration for NR26E Welded Casks (Case 4)

Radionuclide	Closure Inventory (Ci)	Nominal PA	Mean	50th Percentile	75th Percentile	90th Percentile	95th Percentile
		pCi L^{-1}					
Am-241S	2.88E+01	3.58E-15	2.35E-10	0.00E+00	3.99E-10	7.60E-10	9.74E-10
Np-237S	6.93E-04	5.94E-16	3.88E-11	0.00E+00	6.58E-11	1.25E-10	1.60E-10
Pu-241S	3.48E+03	1.42E-14	9.31E-10	0.00E+00	1.58E-09	3.01E-09	3.85E-09
U-235S	1.59E-03	1.49E-18	1.18E-13	0.00E+00	1.99E-13	3.79E-13	4.86E-13
Sum		1.83E-14	1.21E-09	0.00E+00	2.05E-09	3.89E-09	4.99E-09
SOF		1.22E-15	8.04E-11	0.00E+00	1.36E-10	2.59E-10	3.32E-10
Ratio		1.00	6.57E+04	0.00E+00	1.12E+05	2.12E+05	2.72E+05

Notes:

Ratios highlighted in orange represent the total concentration relative to the total nominal PA concentration.

Largest contributor is highlighted in red.

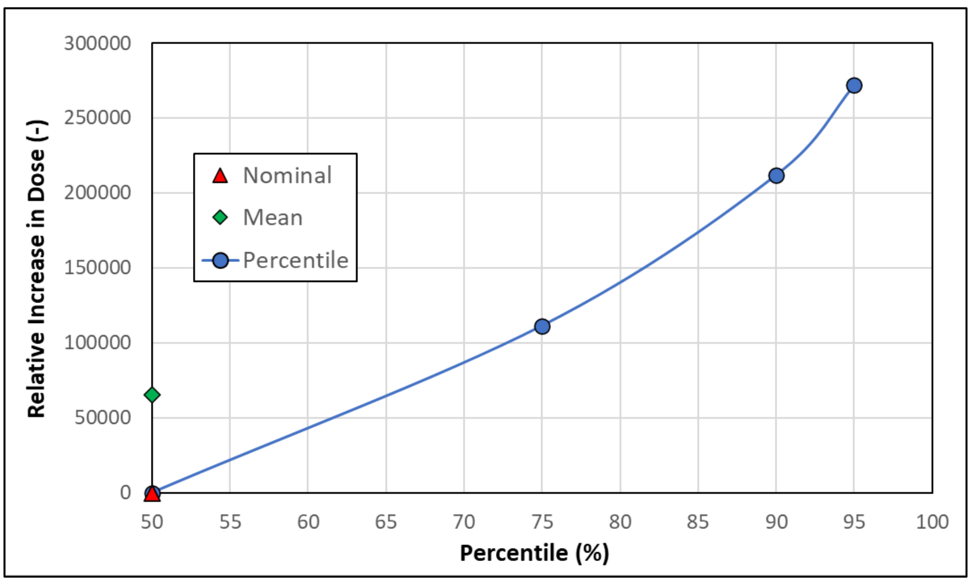


Figure 6-57. Peak Gross-Alpha Relative Concentration for NR26E Welded Casks (Case 4)

Table 6-123. Peak Uranium Relative Concentration for NR26E Welded Casks (Case 4)

Radionuclide	Closure Inventory (Ci)	Nominal PA	Mean	50th Percentile	75th Percentile	90th Percentile	95th Percentile
		µg L^{-1}					
Am-241S	2.88E+01	1.66E-23	1.40E-18	0.00E+00	2.37E-18	4.51E-18	5.78E-18
Np-237S	6.93E-04	2.76E-24	2.31E-19	0.00E+00	3.91E-19	7.45E-19	9.55E-19
Pu-241S	3.48E+03	6.57E-23	5.53E-18	0.00E+00	9.38E-18	1.78E-17	2.29E-17
U-235S	1.59E-03	1.04E-106	--	--	--	--	--
Sum		8.50E-23	7.16E-18	0.00E+00	1.21E-17	2.31E-17	2.96E-17
SOF		2.83E-24	2.39E-19	0.00E+00	4.05E-19	7.70E-19	9.87E-19
Ratio		1.00	8.42E+04	0.00E+00	1.43E+05	2.72E+05	3.48E+05

Notes:

Ratios highlighted in orange represent the total concentration relative to the total nominal PA concentration.

Largest contributor is highlighted in red.

Entries with "--" represent numbers below single precision.

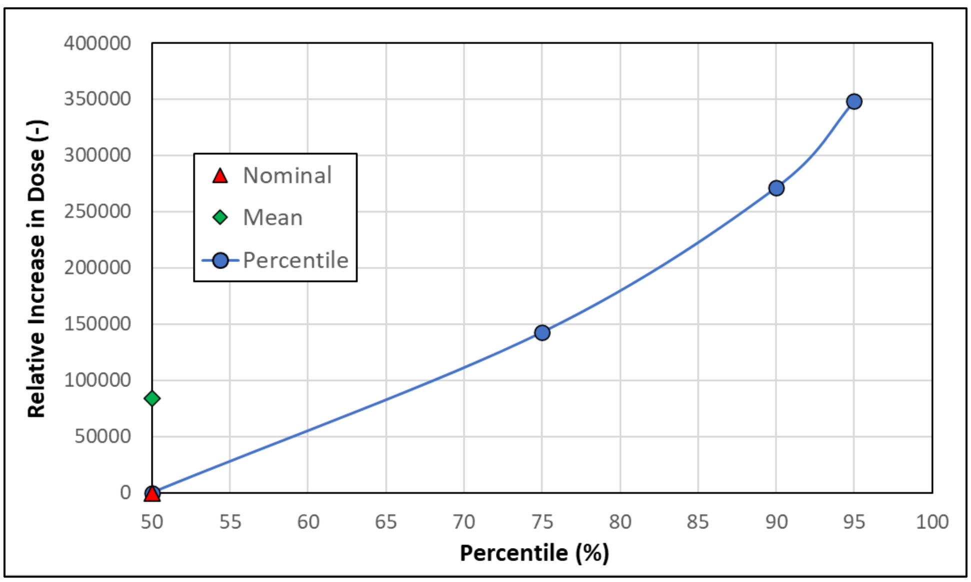


Figure 6-58. Peak Uranium Relative Concentration for NR26E Welded Casks (Case 4)

Table 6-124. Peak All-Pathways Relative Dose for NR26E Bolted Containers (Case 1)

Radionuclide	Closure Inventory (Ci)	Nominal PA	Mean	50th Percentile	75th Percentile	90th Percentile	95th Percentile
		mrem yr^{-1}					
Am-241	7.12E-03	2.83E-08	1.66E-06	2.16E-08	2.84E-06	5.37E-06	6.86E-06
C-14	2.03E+01	2.56E-05	2.01E-02	2.14E-05	3.39E-02	6.51E-02	8.29E-02
Cl-36	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
H-3	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I-129	8.16E-05	3.81E-03	5.32E-03	3.78E-03	9.01E-03	1.37E-02	1.64E-02
Ni-59	6.10E+00	1.02E-13	2.67E-07	1.14E-10	4.54E-07	8.61E-07	1.10E-06
Ni-63	6.07E+02	6.69E-15	1.85E-08	4.84E-12	3.14E-08	5.96E-08	7.64E-08
Np-237	6.10E-08	9.38E-09	4.00E-07	4.88E-09	6.85E-07	1.28E-06	1.64E-06
Pu-241	1.99E-01	2.03E-08	1.30E-06	1.86E-08	2.21E-06	4.20E-06	5.35E-06
Sr-90	8.07E-01	2.97E-18	2.44E-11	0.00E+00	4.16E-11	7.88E-11	1.01E-10
Tc-99	2.03E-02	3.45E-02	3.65E-02	3.44E-02	5.66E-02	7.58E-02	8.57E-02
U-235	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sum		0.04	0.06	0.04	0.10	0.15	0.18
SOF		0.002	0.002	0.002	0.004	0.006	0.007
Ratio		1.00	1.62	1.00	2.60	4.04	4.83

Notes:

Ratios highlighted in orange represent the total dose relative to the total nominal PA dose.

Largest contributor is highlighted in red.

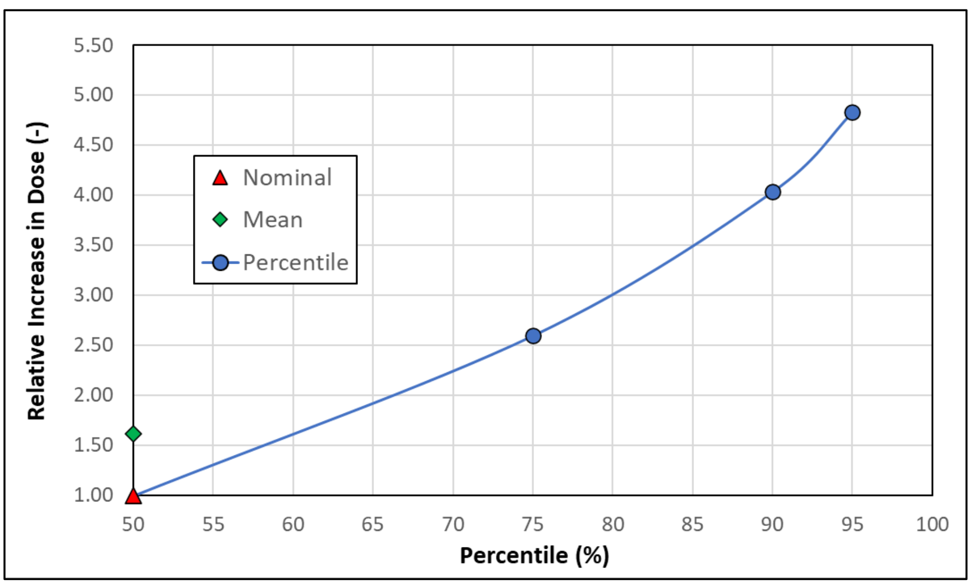


Figure 6-59. Peak All-Pathways Relative Dose for NR26E Bolted Containers (Case 1)

Table 6-125. Peak Beta-Gamma Relative Dose for NR26E Bolted Containers (Case 1)

Radionuclide	Closure Inventory (Ci)	Nominal PA	Mean	50th Percentile	75th Percentile	90th Percentile	95th Percentile
		mrem yr^{-1}					
Am-241	7.12E-03	1.88E-09	1.66E-06	2.16E-08	2.84E-06	5.37E-06	6.86E-06
C-14	2.03E+01	2.56E-05	2.01E-02	2.14E-05	3.39E-02	6.51E-02	8.29E-02
Cl-36	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
H-3	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I-129	8.16E-05	6.51E-02	5.32E-03	3.78E-03	9.01E-03	1.37E-02	1.64E-02
Ni-59	6.10E+00	9.85E-12	2.67E-07	1.14E-10	4.54E-07	8.61E-07	1.10E-06
Ni-63	6.07E+02	1.56E-12	1.85E-08	4.84E-12	3.14E-08	5.96E-08	7.64E-08
Np-237	6.10E-08	6.24E-10	4.00E-07	4.88E-09	6.85E-07	1.28E-06	1.64E-06
Pu-241	1.99E-01	1.35E-09	1.30E-06	1.86E-08	2.21E-06	4.20E-06	5.35E-06
Sr-90	8.07E-01	2.54E-17	2.44E-11	0.00E+00	4.16E-11	7.88E-11	1.01E-10
Tc-99	2.03E-02	5.23E-02	3.65E-02	3.44E-02	5.66E-02	7.58E-02	8.57E-02
U-235	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sum		0.12	0.06	0.04	0.10	0.15	0.18
SOF		0.03	0.02	0.01	0.02	0.04	0.05
Ratio		1.00	0.53	0.33	0.85	1.32	1.58

Notes:

Ratios highlighted in orange represent the total dose relative to the total nominal PA dose.

Largest contributor is highlighted in red.

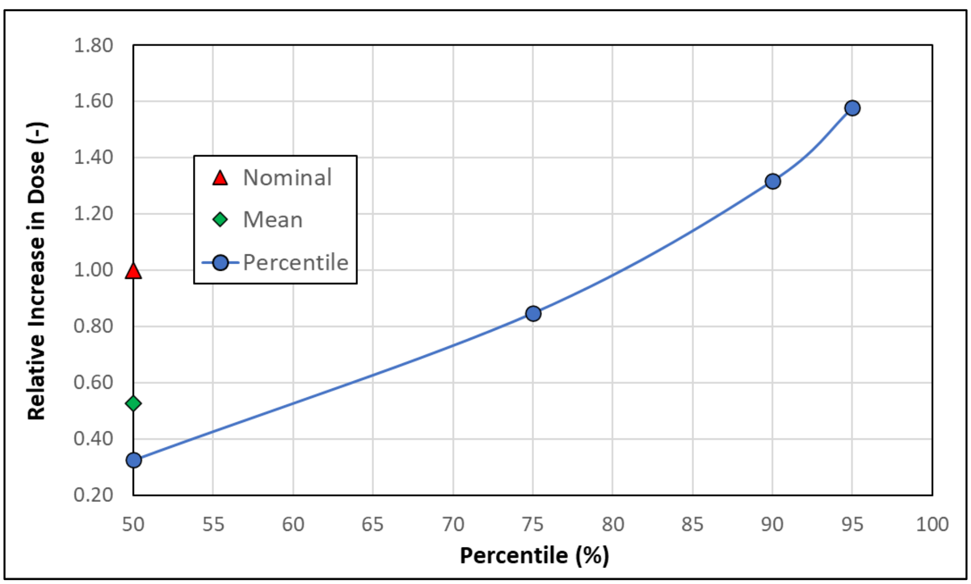


Figure 6-60. Peak Beta-Gamma Relative Dose for NR26E Bolted Containers (Case 1)

Table 6-126. Peak Gross-Alpha Relative Concentration for NR26E Bolted Containers (Case 1)

Radionuclide	Closure Inventory (Ci)	Nominal PA	Mean	50th Percentile	75th Percentile	90th Percentile	95th Percentile
		pCi L^{-1}					
Am-241	7.12E-03	1.41E-07	8.29E-06	1.08E-07	1.42E-05	2.68E-05	3.42E-05
Np-237	6.10E-08	4.68E-08	1.99E-06	2.43E-08	3.41E-06	6.41E-06	8.20E-06
Pu-241	1.99E-01	1.01E-07	6.49E-06	9.30E-08	1.10E-05	2.09E-05	2.67E-05
U-235	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sum		2.89E-07	1.68E-05	2.25E-07	2.86E-05	5.41E-05	6.91E-05
SOF		1.93E-08	1.12E-06	1.50E-08	1.91E-06	3.61E-06	4.61E-06
Ratio		1.00	58.00	0.78	98.96	187.16	239.02

Notes:

Ratios highlighted in orange represent the total concentration relative to the total nominal PA concentration.

Largest contributor is highlighted in red.

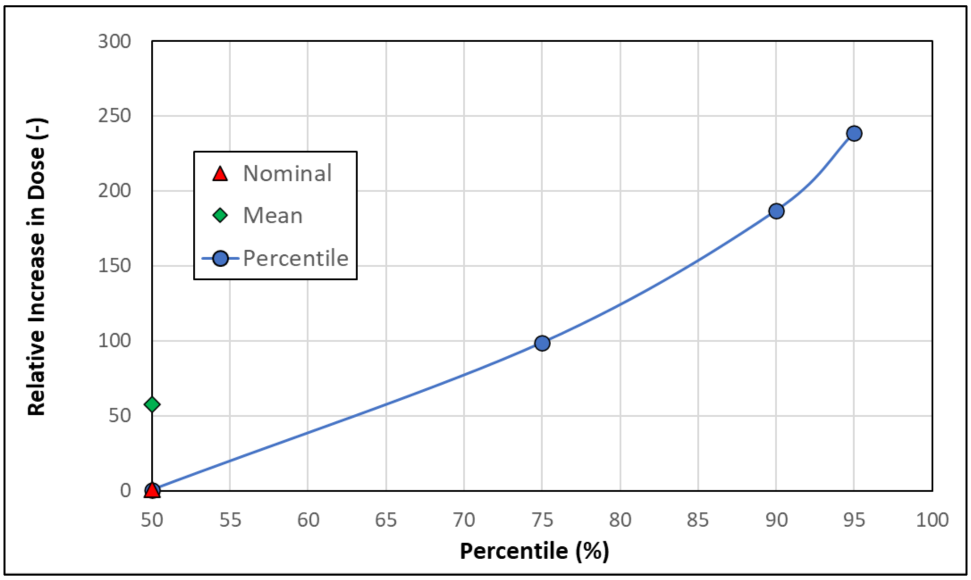


Figure 6-61. Peak Gross-Alpha Relative Concentration for NR26E Bolted Containers (Case 1)

Table 6-127. Peak Uranium Relative Concentration for NR26E Bolted Containers (Case 1)

Radionuclide	Closure Inventory (Ci)	Nominal PA	Mean	50th Percentile	75th Percentile	90th Percentile	95th Percentile
		µg L-1					
Am-241	7.12E-03	2.92E-17	4.05E-15	2.65E-18	6.88E-15	1.31E-14	1.67E-14
Np-237	6.10E-08	9.87E-18	1.15E-15	4.83E-18	1.96E-15	3.70E-15	4.72E-15
Pu-241	1.99E-01	2.08E-17	3.04E-15	0.00E+00	5.17E-15	9.84E-15	1.26E-14
U-235	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sum		5.99E-17	8.24E-15	7.48E-18	1.40E-14	2.66E-14	3.40E-14
SOF		2.00E-18	2.75E-16	2.49E-19	4.67E-16	8.88E-16	1.13E-15
Ratio		1.00	137.66	0.12	234.08	444.81	567.99

Notes:
Ratios highlighted in orange represent the total concentration relative to the total nominal PA concentration.
Largest contributor is highlighted in red.

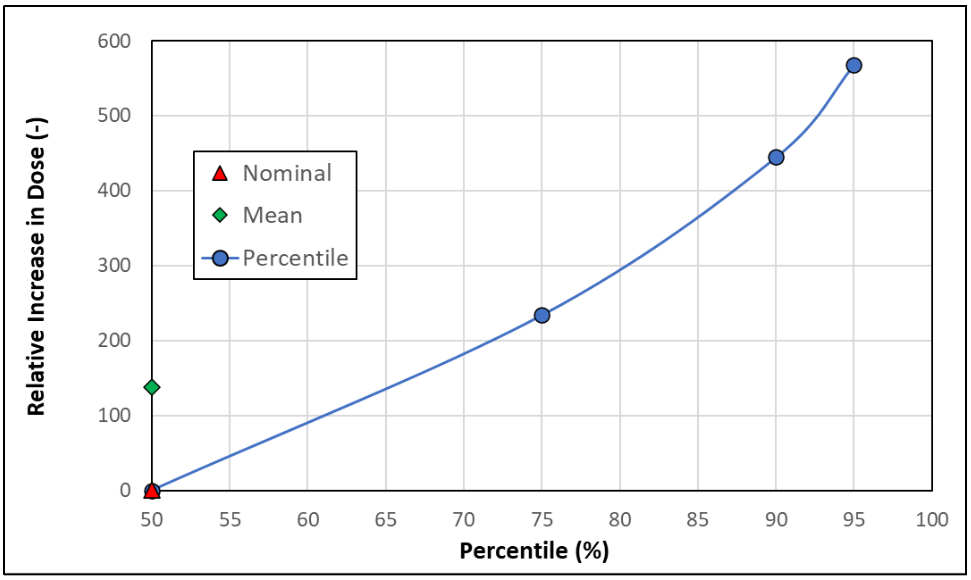


Figure 6-62. Peak Uranium Relative Concentration for NR26E Bolted Containers (Case 1)

6.1.3. Bias in PORFLOW Deterministic Models

Bias in the context of this PA is a "deviation of the expected value of a statistical estimate from the quantity it estimates" or "systematic error introduced into sampling or testing by selecting or encouraging one outcome or answer over others" (Merriam-Webster, 2021). Thus, biases in the PORFLOW models are differences between the predicted and actual maximum dose distributions resulting from choices of models, POA conditions, and parameters.

Infiltration rates serve as a ground surface boundary condition for the GW flow models and are input to the models using tables of infiltration rate as a function of time. Uncertainties in average annual rainfall and in the design parameters of the final closure cap provide opportunities for bias in infiltration. The way in which concrete degradation is modeled as well as the parameters chosen for the degradation model introduce another way for bias to affect outcome.

6.1.3.1. Infiltration Uncertainty and Bias

The two major contributors to uncertainty in intact infiltration rates are uncertainties in closure cap design parameters and uncertainty in annual average rainfall. Detailed Uncertainty Quantification and Sensitivity Analysis (UQSA) discussions of closure cap design parameters and infiltration are found in Section 3.8.4.3.4. While the focus is on STs and ETs (the predominant types of ELLWF DUs), key takeaways apply also to the LAWV, ILV, and NCRDAs. Uncertainty in future SRS rainfall and how it is addressed in the UQSA is explained below.

6.1.3.1.1. Closure Cap Design Parameters

Using HELP modeling, Dyer (2017b) analyzed ten intact infiltration scenarios bracketing the minimum and maximum slope and slope-length design conditions (2% to 4% slope and 150-foot to 600-foot slope length) for the proposed ELLWF final closure cap. Figure 3-109 affirms that a single bounding case of 2% slope and 585-foot slope length represents an upper bound on infiltration rates for the ten intact infiltration scenarios. Shipmon and Dyer (2017) performed a more extensive sensitivity analysis of infiltration through the proposed intact closure cap. Results are summarized in Figure 3-115 and show that saturated hydraulic conductivity for select cap layers, rainfall, surface vegetation type, and geomembrane layer defect density are dominant factors affecting the intact infiltration rate. Dyer (2018a) further considered the impacts of vegetative cover type, geomembrane layer defects, and pine tree intrusion on infiltration rates using the HELP model for five closure-cap scenarios as detailed in Section 3.8.4.3.4. Dyer (2018a) affirmed that a Bahia grass cover with two percent slope and 585-foot slope length gives a reasonable upper bound on intact infiltration rates for the ELLWF final closure cap.

The 2% slope and 585-foot slope length intact case adequately captures reasonably expected uncertainties in the more influential closure cap design parameters and bounds infiltration rates at the upper end of the expected uncertainty ranges for these parameters. In effect, it represents a biased scenario for infiltration rates when only closure cap design parameter uncertainties (and not precipitation uncertainty) are considered (see Figure 3-109 and Figure 3-115). Importantly, best estimate and nominal PA PORFLOW deterministic model simulations of all types of DUs for the intact closure cap scenario are based on these upper bound infiltration rates (Table 3-76). Best estimate infiltration rates (Table 3-79), based on a 3% closure cap slope and 400-foot slope length, are included in the discussion below for comparison; however, they were not used in the PORFLOW simulations of the best estimate, nominal PA, and one-sided sensitivity cases.

6.1.3.1.2. Savannah River Site Precipitation

As described in Section 3.8.4.2, HELP's synthetic weather data generator was employed to create 100 years of synthetic daily precipitation data for Augusta, GA based on SRS-specific mean monthly precipitation and temperature data calculated using the historical monthly precipitation data for calendar years 1961 to 2006 from the 200-F weather station at SRS. The SRS mean monthly precipitation data are listed in Table 3-70. The mean and standard deviation of the resulting 100 years of synthetic annual precipitation data generated by the HELP model synthetic weather data generator are 49.14 in yr^{-1} and 7.69 in yr^{-1}, respectively. This compares well with annual average precipitation of 49.7 in yr^{-1} from H-Area station for the period 2014 to 2018 and 48.2 in yr^{-1} from A-Area station for the period 1952 to 2001 (see Table 2-4). Shipmon and Dyer

(2017) evaluated the sensitivity of infiltration rates to a change of ±0.5 standard deviations in the SRS mean monthly precipitation to account for interannual variability and the potential impacts of climate change. Results are shown in Figure 3-115 and Figure 3-116. A 0.5 standard deviation increase in SRS mean monthly precipitation results in an annual average precipitation rate of 61.68 in yr^{-1}, which is +1.6 standard deviations above the HELP model best estimate mean value of 49.14± 7.69 in yr^{-1}.

The PORFLOW deterministic model cases for the intact closure cap are defined from an infiltration perspective as follows:

- **Best Estimate and Nominal PA Cases:** Bounding cap design (2% slope and 500-foot slope length) and best estimate precipitation rate (49.14 in yr^{-1})
- **One-Sided Pessimistic Sensitivity Case:** Bounding cap design (2% slope and 500-foot slope length) and pessimistic precipitation rate (61.68 in yr^{-1}).

Figure 6-2 (linear-linear plot) and Figure 6-3 (log-linear plot) compare three infiltration curves from the HELP model for STs and ETs to emphasize the infiltration rate bias built into the PORFLOW deterministic model best estimate and nominal PA cases by selection of the bounding cap design over the best estimate cap design.

6.1.3.2. Vault Concrete Degradation Uncertainty and Bias

The largest contributor to uncertainty in concrete degradation is the rate at which concrete will degrade. NUREG-1573 (U.S. NRC, 2000) states that the materials used in engineered barriers, such as concrete vaults, can be assumed to have physically degraded after 500 years. Consequently, the nominal PA (baseline) case assumes that the hydraulic properties of concrete approach those of uncompacted operational soil cover 500 years after the end of IC. However, unlike in previous ELLWF PAs in which the hydraulic properties of concrete were abruptly changed from those of intact concrete to soil after 500 years, degradation in this PA is modeled as a gradual process where concrete hydraulic properties are transformed into those of soil in ten incremental steps over a period of 500 years.

E-Area vault concrete is not expected to degrade to the consistency of soil in 500 years. The best estimate case doubles the length of the degradation process from 500 to 1,000 years and the number of degradation steps from 10 to 20. However, it is unlikely the vault concrete will lose all its integrity even after 1,000 years. This source of pessimistic bias is characterized in this PA by considering relevant one-sided sensitivity cases.

6.1.3.2.1. Concrete Cracking

Some cracking of vault roofs and walls is expected when disposal operations end and the final closure cap is installed at the end of the 100-year IC period. Structural analyses performed for the LAWV (Carey, 2005) and ILV (Peregoy, 2006b) indicate that installation of the final closure cap results in cracking that partially penetrates the vault walls and roofs, causing some immediate degradation in concrete hydraulic properties. The nominal PA case models this by changing the hydraulic properties of the vault walls and roofs at the end of IC from those of pure E-Area vault concrete to those of a 90% E-Area vault concrete and 10% gravel mixture. Sensitivity Case 1 doubles the extent of this initial cracking by changing to an 80% E-Area vault concrete and 20% gravel mixture. As seen in Table 6-128 and Table 6-129, this change has a very small impact on peak concentrations at the 100-meter POA. Thus, bias resulting from the estimated initial extent of cracking should be minimal.

Table 6-128. Ratios of Peak Concentrations at 100-meter POA for Low-Activity Waste Vault for Best Estimate Case and Sensitivity Cases 1 Through 3 to the Nominal PA Case Values

Radionuclide		Best Estimate	Sensitivity Case 1	Sensitivity Case 2	Sensitivity Case 3
Parent	Progeny				
Ag-108m	--	0.95	1.00	0.98	3.48
Am-241	Np-237	1.00	1.00	0.98	1.04
Am-241	U-233	0.96	1.00	0.98	0.58
Am-241	Th-229	0.99	1.00	0.99	0.63
C-14	--	0.71	1.00	0.95	0.88
Ca-41	--	0.63	0.99	0.95	0.97
Cl-36	--	0.79	0.98	0.97	0.99
Cm-245	Np-237	0.99	1.00	1.00	0.59
Cm-245	U-233	0.98	0.99	0.99	0.63
Cm-245	Th-229	0.97	0.97	0.97	0.70
Cs-137	--	0.02	1.07	0.15	0.93
H-3	--	2.37	0.82	0.82	1.00
I-129	--	1.08	0.93	1.49	1.00
K-40	--	0.93	0.99	1.01	1.01
Ni-59	--	0.85	0.97	1.03	1.22
Ni-63	--	0.11	1.39	0.32	0.71
Np-237	--	1.01	0.99	0.97	1.09
Np-237	U-233	0.95	0.99	0.97	0.65
Np-237	Th-229	0.99	1.00	0.99	0.63
Pu-239	U-235	1.16	1.08	1.09	1.08
Pu-239	Pa-231	0.98	1.00	1.00	0.93
Pu-241	Np-237	1.00	1.00	0.98	1.04
Pu-241	U-233	0.96	1.00	0.98	0.58
Pu-241	Th-229	0.99	1.00	0.99	0.63
Ra-226	--	0.69	1.00	0.99	1.15
Sr-90	--	0.67	1.06	1.93	12.47
Tc-99	--	1.20	0.96	1.19	6.44
U-235	--	0.99	1.00	1.00	1.00
U-235	Pa-231	0.99	1.00	0.99	0.67

Notes:

Concentrations >10% above nominal PA case value are highlighted in green.

Concentrations >10% below nominal PA case value are highlighted in orange.

Table 6-129. Ratios of Peak Concentrations at 100-meter POA for Intermediate-Level Vault for Best Estimate Case and Sensitivity Cases 1 Through 3 to the Nominal PA Case Values

Radionuclide		Best Estimate	Sensitivity Case 1	Sensitivity Case 2	Sensitivity Case 3
Parent	Progeny				
Ag-108m	--	1.04	1.00	1.00	1.16
Am-241	Np-237	0.99	1.00	1.00	0.89
Am-241	U-233	0.99	1.00	1.00	0.95
Am-241	Th-229	1.00	1.00	1.00	0.96
Ar-39	--	0.42	0.96	0.43	1.00
C-14	--	1.17	1.00	1.00	0.65
Cf-249	Np-237	0.98	1.00	1.00	0.81
Cf-249	U-233	0.99	1.00	1.00	0.89
Cf-249	Th-229	1.00	1.00	1.00	0.90
Cl-36	--	0.84	0.96	0.87	0.96
Cm-245	Np-237	0.98	1.00	1.00	0.82
Cm-245	U-233	0.99	1.00	1.00	0.91
Cm-245	Th-229	1.00	1.00	1.00	0.91
Cs-137	--	0.19	0.91	0.31	0.78
H-3	--	2.06	1.00	1.00	1.00
I-129	--	0.64	0.98	0.93	0.90
K-40	--	0.97	0.97	0.95	0.98
Ni-59	--	1.90	0.99	1.01	2.42
Ni-63	--	0.16	1.11	0.33	0.49
Np-237	--	1.02	1.00	1.00	0.90
Np-237	U-233	0.99	1.00	1.00	0.95
Np-237	Th-229	1.00	1.00	1.00	0.96
Pu-239	U-235	1.02	1.00	1.00	0.99
Pu-239	Pa-231	0.97	1.00	1.00	0.87
Pu-241	Np-237	0.99	1.00	1.00	0.89
Pu-241	U-233	0.99	1.00	1.00	0.95
Pu-241	Th-229	1.00	1.00	1.00	0.96
Ra-226	--	0.95	1.00	1.00	1.45
Sr-90	--	0.07	1.42	0.14	74.09
Tc-99	--	0.89	1.00	0.97	3.19
U-235	--	1.04	1.00	1.00	0.99
U-235	Pa-231	0.97	1.00	1.00	0.84

Notes:

Concentrations >10% above nominal PA case value are highlighted in green.

Concentrations >10% below nominal PA case value are highlighted in orange.

6.1.3.2.2. Concrete Degradation

The best estimate case not only doubles the length of time during which the concrete vaults maintain their integrity but also assumes a more tightly packed waste zone with a porosity only one-third that assumed in the nominal PA case. The latter perturbation has a much bigger impact on radionuclide transport, overwhelming the effect of concrete degradation. Sensitivity Case 2, however, differs from the nominal PA case only in the rate at which concrete deteriorates. Degradation is assumed to progress in twenty 50-year increments until the hydraulic properties of the vault structure are identical to those of uncompacted operational soil cover 1,000 years after the end of IC. Referring to Sensitivity Case 2 in Table 6-128 and Table 6-129, doubling the length of time over which the vault structural components deteriorate does not have a major impact. The shorter-lived radionuclides are the most affected.

The differences between Sensitivity Case 2 and the nominal PA case are more significant than they are for Sensitivity Case 1. This is consistent with the physical situation. In Sensitivity Case 1, the vault walls and roofs sustain twice the amount of cracking at the end of operations as in the nominal PA case but gradually approach the nominal PA case hydraulic parameter values over the next 500 years. In Sensitivity Case 2, all concrete structural components are assigned the same hydraulic parameter values as in the nominal PA case at the end of IC; however, they incrementally approach those for uncompacted soil at half the rate as in the nominal PA case (achieving their maximum difference with the nominal PA case 500 years after the end of IC and matching the nominal PA case 500 years later). Nevertheless, the peak radionuclide concentrations (and consequently the doses) at the 100-meter POA are not greatly impacted by concrete degradation and, to an even lesser extent, concrete cracking. Thus, concrete cracking and concrete degradation are not significant sources of bias in the predicted doses.

6.1.3.2.3. Concrete Aging

K_d values for radionuclides in concrete vary as the concrete ages (Kaplan, 2016b). Aging is related to the number of pore volume exchanges made as water flows through the material. Kaplan (2016b) divides concrete aging into three stages:

- **Stage I (Young):** First 50 pore volume exchanges
- **Stage II (Middle):** Next 450 pore volume exchanges (51 through 500 exchange cycles)
- **Stage III (Aged):** Next 3,500 pore volume exchanges (501 through 4,000 exchange cycles)

K_d values for concrete are assumed to equal those for clayey soil after either 4,000 pore volume exchanges have occurred, or when the vault roof collapses, whichever comes first. Sensitivity Case 3 accelerates concrete aging by shortening Stage I, Stage II, and Stage III to 25; 200; and 1,250 pore volume exchanges, respectively. Depending on the element, K_d values will stay the same or will change by as much as an order of magnitude or more between stages (see Table 5-15).

K_d values for concrete have a greater impact on peak concentrations and, consequently, doses at the 100-meter POA than do either concrete cracking or concrete degradation as displayed in Table 6-128 and Table 6-129. However, looking at the transition times between stages for the ILV, the concrete in only the roof and floor is affected by faster aging during the compliance period. That is, the transition from Stage I to Stage II moves forward from Year 970 for the nominal PA case to Year 820 for Sensitivity Case 3; no further transitions take place until well after Year 1,171. The walls remain in Stage I for the duration of the 1,000-year compliance period. This is reflected in the fact that concrete aging has a minimal impact on dose during the compliance period, as is evidenced by Table 6-128 and Table 6-129.

For LAWV, aging has more of an impact. The concrete in the footer, floor, roof, and roof beams is affected by faster aging during the compliance period: the transition from Stage I to Stage II moves up to Year 721 from Year 771, and from Stage II to Stage III from Years 1,121 to 921 between the nominal PA case and Sensitivity Case 3. The walls remain in Stage I throughout the compliance period for the nominal PA case, while they transition to Stage II after Year 971 for Sensitivity Case 3. Regardless, concrete aging has minimal impact on dose during the compliance period as seen in Table 6-39 and Table 6-41. Consequently, concrete aging is not a significant source of bias in the predicted compliance period doses.

6.1.3.3. Burial Timing Uncertainty and Bias

Waste emplacement occurs throughout the operating life of the ELLWF. Given the transient nature of radioactive decay and the transport processes that carry radionuclides to the 100-meter POA, the timing of emplacement will have an impact on the peak dose at the 100-meter POA. The PORFLOW model simulations considered two extremes. The nominal PA case assumes all the waste inventory is placed in each DU at the start of operations. As presented in Section 6.1, all DUs have also been evaluated for the scenario where the entire waste inventory is placed at the end of operations (timeline sensitivity case, S7). It is assumed that placement at the start of operations is generally pessimistically biased because it allows for increased daughter ingrowth to occur. However, several other factors are also important, such as the half-life of the radionuclides, sorption (K_d) values, the period of uncovered conditions, and the compliance period for specific pathways.

Table 6-130, Table 6-131, and Table 6-132 compare the all-pathways doses calculated during the compliance period for ET06, ST06, and ST09 radionuclides, respectively, for the nominal PA case (Case01: emplacement at the beginning of operations) and the timeline sensitivity case (Case S7: emplacement at the end of operations). Table 6-133, Table 6-134, and Table 6-135 provide the same comparisons for beta-gamma dose.

Table 6-130. Comparison for ET06 of Maximum All-Pathways Dose Factors at 100-meter POA and Times of Maximum for Nominal PA (Case01) and Timeline Sensitivity (S7) Cases

Radionuclide	Nominal PA Case (Case01)		Timeline Sensitivity Case (S7)		Δ(Dose)	Δ(Dose)
	mrem yr^{-1} Ci^{-1}	Year	mrem yr^{-1} Ci^{-1}	Year	mrem yr^{-1} Ci^{-1}	%
C-14	8.76E-03	1,171	1.65E-03	1,171	-7.11E-03	-81.14
H-3	9.84E-07	171	2.80E-06	171	1.81E-06	184.33
I-129	6.76E+01	787	9.11E+01	941	2.34E+01	34.64
Np-237	2.83E+01	1,171	8.57E+00	1,171	-1.98E+01	-69.75
Sr-90	4.75E-14	1,153	4.38E-15	1,171	-4.31E-14	-90.78
Tc-99	3.34E-01	181	1.42E+00	818	1.08E+00	324.90

Notes:
Cells highlighted in green and orange indicate an increase and decrease, respectively, in dose for Case S7 relative to Case01.

Table 6-131. Comparison for ST06 of Maximum All-Pathways Dose Factors at 100-meter POA and Times of Maximum for Nominal PA (Case01) and Timeline Sensitivity (S7) Cases

Radionuclide	Nominal PA Case (Case01)		Timeline Sensitivity Case (S7)		Δ(Dose)	Δ(Dose)
	mrem yr^{-1} Ci^{-1}	Year	mrem yr^{-1} Ci^{-1}	Year	mrem yr^{-1} Ci^{-1}	%
C-14	3.16E-02	1,171	1.48E-02	1,171	-1.68E-02	-53.09
H-3	9.15E-07	171	2.65E-06	171	1.73E-06	189.54
I-129	1.15E+02	827	1.35E+02	955	1.99E+01	17.28
Np-237	2.68E+01	1,171	1.15E+01	1,171	-1.53E+01	-57.23
Sr-90	2.25E-14	1,171	5.57E-15	1,171	-1.69E-14	-75.24
Tc-99	1.41E+00	694	2.08E+00	826	6.69E-01	47.31

Notes:

Cells highlighted in green and orange indicate an increase and decrease, respectively, in dose for Case S7 relative to Case01.

Table 6-132. Comparison for ST09 of Maximum All-Pathways Dose Factors at 100-meter POA and Times of Maximum for Nominal PA (Case01) and Timeline Sensitivity (S7) Cases

Radionuclide	Nominal PA Case (Case01)		Timeline Sensitivity Case (S7)		Δ(Dose)	Δ(Dose)
	mrem yr^{-1} Ci^{-1}	Year	mrem yr^{-1} Ci^{-1}	Year	mrem yr^{-1} Ci^{-1}	%
C-14	8.56E-04	1,171	1.19E-04	1,171	-7.38E-04	-86.14
H-3	1.06E-06	171	1.23E-06	171	1.67E-07	15.74
I-129	1.24E+02	949	1.40E+02	1058	1.60E+01	12.93
Np-237	2.23E+00	1,171	2.12E-01	1,171	-2.02E+00	-90.51
Sr-90	8.92E-18	1,171	4.01E-19	1,171	-8.52E-18	-95.50
Tc-99	1.82E+00	802	2.13E+00	912	3.10E-01	17.05

Notes:

Cells highlighted in green and orange indicate an increase and decrease, respectively, in dose for Case S7 relative to Case01.

Table 6-133. Comparison for ET06 of Maximum Beta-Gamma Dose Factors at 100-meter POA and Times of Maximum for Nominal PA (Case01) and Timeline Sensitivity (S7) Cases

Radionuclide	Nominal PA Case (Case01)		Timeline Sensitivity Case (S7)		Δ(Dose)	Δ(Dose)
	mrem yr^{-1} Ci^{-1}	Year	mrem yr^{-1} Ci^{-1}	Year	mrem yr^{-1} Ci^{-1}	%
C-14	8.74E-03	1,171	1.65E-03	1,171	-7.09E-03	-81.14
H-3	3.94E-01	47	3.65E-05	133	-3.94E-01	-99.99
I-129	1.16E+03	787	1.56E+03	941	4.01E+02	34.64
Np-237	1.88E+00	1,171	5.70E-01	1,171	-1.31E+00	-69.75
Sr-90	4.06E-13	1,153	3.75E-14	1,171	-3.69E-13	-90.78
Tc-99	9.19E-01	107	2.15E+00	818	1.23E+00	133.73

Notes:

Cells highlighted in green and orange indicate an increase and decrease, respectively, in dose for Case S7 relative to Case01.

Table 6-134. Comparison for ST06 of Maximum Beta-Gamma Dose Factors at 100-meter POA and Times of Maximum for Nominal PA (Case01) and Timeline Sensitivity (S7) Cases

Radionuclide	Nominal PA Case (Case01)		Timeline Sensitivity Case (S7)		Δ(Dose)	Δ(Dose)
	mrem yr^{-1} Ci^{-1}	Year	mrem yr^{-1} Ci^{-1}	Year	mrem yr^{-1} Ci^{-1}	%
C-14	3.15E-02	1,171	1.48E-02	1,171	-1.67E-02	-53.09
H-3	6.86E-01	31	2.57E-03	59	-6.83E-01	-99.63
I-129	1.97E+03	827	2.31E+03	955	3.41E+02	17.28
Np-237	1.78E+00	1,171	7.62E-01	1,171	-1.02E+00	-57.23
Sr-90	1.92E-13	1,171	4.76E-14	1,171	-1.45E-13	-75.24
Tc-99	2.14E+00	694	3.16E+00	826	1.01E+00	47.31

Notes:
Cells highlighted in green and orange indicate an increase and decrease, respectively, in dose for Case S7 relative to Case01.

Table 6-135. Comparison for ST09 of Maximum Beta-Gamma Dose Factors at 100-meter POA and Times of Maximum for Nominal PA (Case01) and Timeline Sensitivity (S7) Cases

Radionuclide	Nominal PA Case (Case01)		Timeline Sensitivity Case (S7)		Δ(Dose)	Δ(Dose)
	mrem yr^{-1} Ci^{-1}	Year	mrem yr^{-1} Ci^{-1}	Year	mrem yr^{-1} Ci^{-1}	%
C-14	8.54E-04	1,171	1.18E-04	1,171	-7.36E-04	-86.14
H-3	7.44E-01	35	2.86E-04	97	-7.44E-01	-99.96
I-129	2.11E+03	949	2.39E+03	1058	2.73E+02	12.93
Np-237	1.49E-01	1,171	1.41E-02	1,171	-1.34E-01	-90.51
Sr-90	7.62E-17	1,171	3.43E-18	1,171	-7.28E-17	-95.50
Tc-99	2.75E+00	802	3.22E+00	912	4.69E-01	17.05

Notes:
Cells highlighted in green and orange indicate an increase and decrease, respectively, in dose for Case S7 relative to Case01.

Radionuclides that peak beyond the compliance period (C-14, Np-237, and Sr-90) all display a significant reduction in dose, and the percent reduction is identical for the all-pathways and beta-gamma doses. Two of the radionuclides that peak before the end of the compliance period (I-129 and Tc-99) exhibit a significant increase in dose, which is also consistent with their behavior in the ILV as will be shown below. A possible explanation is that transport rates into the aquifer are lower for the nominal PA case. An interesting difference is seen in the all-pathways and beta-gamma dose cases for Tc-99 in ET06. Specifically, the percent reduction is almost three times larger for the all-pathways dose than for the beta-gamma dose. This is because the peak Tc-99 dose occurs before the start of the compliance period (i.e., beta-gamma peak occurs at Year 107 versus Year 181 for the all-pathways dose), coupled with the fact that beta-gamma dose is calculated from the start of operations while all-pathways dose is calculated for the compliance period only. Finally, H-3 shows a large reduction in beta-gamma dose but an increase in the all-pathways dose. Furthermore, the beta-gamma peak doses for H-3 for the nominal PA case are five or more orders of magnitude higher than the all-pathways peak doses. The increase in the all-pathways dose for H-3 is consistent with the behavior of the two long-lived radionuclides, I-129 and Tc-99. However, the reason for large reductions in beta-gamma dose (two to four orders of magnitude) are unclear. One clue is perhaps in the timing of the peaks. The larger the difference in peak times, the larger the reduction.

In PORFLOW modeling of the vaults, the nominal PA case assumes that all waste ultimately disposed is placed within each DU at the start of operations. The best estimate case (BE) also assumes waste emplacement at the start of operations, although it differs from the nominal PA case in that the integrity of concrete structures is maintained twice as long (1,000 years versus 500 years) and the waste zone porosity is reduced to 0.30. Best Estimate Case 2 (BE2) is identical to the best estimate case except that waste emplacement is assumed to occur entirely at the end of operations. Thus, a comparison of the doses calculated for the two best estimate cases provides a measure of the impact of the timing of waste placement.

Inventory limits (see Chapter 8) are based on the nominal PA case, while the other two best estimate cases are sensitivity cases for assessing the impacts of burial timing. The differential impacts of burial timing to the LAWV versus the nominal PA case are shown in Table 6-136 and Table 6-137 for all-pathways and beta-gamma, respectively. Table 6-138 and Table 6-139 contain the same set of respective analyses for the ILV.

In Table 6-136 through Table 6-139, decreased dose values are highlighted in orange, while increased values are highlighted in green. To assess the actual overall impact a change in dose factors has on dose at the 100-meter POA, estimated inventories of every radionuclide of interest must be considered. For this reason, total dose is computed for the LAWV and ILV based on projected closure inventories presented in Chapter 8. Table 6-140 and Table 6-141 provide the computed individual and total doses for the LAWV and ILV, respectively. As shown in Table 6-140 and Table 6-141, the nominal PA case is the most limiting. A built-in bias exists within the nominal PA case for each vault.

Table 6-136. Comparison of Maximum All-Pathways Dose Factors at 100-meter POA and Times of Maximum for Best Estimate Low-Activity Waste Vault Cases

Radionuclide	Nominal PA Case		Best Estimate Case (BE) [a]		Best Estimate Case 2 (BE2) [a]		Δ(BE – Nominal)	Δ(BE2 – Nominal)
	mrem yr-1 Ci-1	Year	mrem yr-1 Ci-1	Year	mrem yr-1 Ci-1	Year	%	%
I-129	1.75E+03	1,166	4.48E+02	1,171	4.47E+02	1,171	-74.4	-74.4
Tc-99	1.14E-03	1,171	6.09E-06	1,171	6.05E-06	1,171	-99.5	-99.5
Cl-36	7.13E-04	1,171	1.10E-04	1,171	1.08E-04	1,171	-84.5	-84.8
H-3	6.04E-10	71	1.43E-09	71	4.53E-10	175	137.2	-25.0
Np-237	1.43E-21	1,171	3.41E-25	1,171	3.21E-25	1,171	-100.0	-100.0
U-235	8.03E-25	1,171	1.75E-28	1,171	7.47E-29	1,171	-100.0	-100.0
Am-241	1.53E-25	1,171	2.05E-29	1,171	1.61E-31	1,171	-100.0	-100.0
Cm-245	6.53E-26	1,171	3.84E-30	1,171	9.09E-36	1,171	-100.0	-100.0
K-40	5.44E-26	1,171	1.60E-25	1,171	1.46E-25	1,171	194.5	169.0
Ca-41	8.53E-27	1,171	1.58E-27	1,171	1.45E-27	1,171	-81.5	-83.0
Pu-241	4.93E-27	1,171	6.27E-31	1,171	2.51E-47	1,171	-100.0	-100.0
Pu-239	2.20E-31	1,171	2.52E-35	1,171	3.36E-42	1,171	-100.0	-100.0
C-14	4.85E-33	1,171	1.43E-36	1,171	1.33E-36	1,171	-100.0	-100.0
Ni-59	4.27E-39	1,171	4.38E-39	1,171	3.86E-39	1,171	2.6	-9.6
Sr-90	2.70E-41	1,171	3.74E-42	1,171	1.88E-41	1,171	-86.2	-30.3
Ni-63	6.98E-42	1,171	7.28E-42	1,171	1.05E-41	1,171	4.3	50.0
Ag-108m	8.93E-55	1,171	8.79E-54	1,171	6.82E-54	1,171	884.5	663.6
Cs-137	6.84E-59	1,171	1.58E-57	1,171	1.55E-57	1,171	2,203.1	2,170.4
Ra-226	1.69E-110	1,171	1.26E-106	1,171	9.54E-116	1,171	746,986.8	-100.0

Notes:

Cells highlighted in green and orange indicate an increase and decrease, respectively, in dose factors for Cases BE and BE2 relative to the nominal PA case.

[a] Case BE assumes waste emplacement at the start of operations (Year 0), while Case BE2 assumes waste emplacement at the end of operations (Year 71).

Table 6-137. Comparison of Maximum Beta-Gamma Dose Factors at 100-meter POA and Times of Maximum for Best Estimate Low-Activity Waste Vault Cases

Radionuclide	Nominal PA Case		Best Estimate Case (BE) [a]		Best Estimate Case 2 (BE2) [a]		Δ(BE – Nominal)	Δ(BE2 – Nominal)
	mrem yr^{-1} Ci^{-1}	Year	mrem yr^{-1} Ci^{-1}	Year	mrem yr^{-1} Ci^{-1}	Year	%	%
I-129	1.02E+02	1,166	2.62E+01	1,171	2.61E+01	1,171	-74.4	-74.4
Tc-99	7.52E-04	1,171	4.02E-06	1,171	3.99E-06	1,171	-99.5	-99.5
Cl-36	6.41E-04	1,171	9.91E-05	1,171	9.72E-05	1,171	-84.5	-84.8
H-3	2.10E-11	171	4.23E-11	171	1.04E-10	175	101.2	393.0
Np-237	2.15E-20	1,171	5.13E-24	1,171	4.82E-24	1,171	-100.0	-100.0
U-235	1.09E-21	1,171	1.34E-25	1,171	5.81E-26	1,171	-100.0	-100.0
Am-241	2.30E-24	1,171	3.08E-28	1,171	2.42E-30	1,171	-100.0	-100.0
Cm-245	9.82E-25	1,171	5.78E-29	1,171	1.37E-34	1,171	-100.0	-100.0
Pu-241	7.41E-26	1,171	9.43E-30	1,171	3.77E-46	1,171	-100.0	-100.0
K-40	5.23E-26	1,171	1.54E-25	1,171	1.41E-25	1,171	194.5	169.0
Ca-41	1.75E-26	1,171	3.23E-27	1,171	2.97E-27	1,171	-81.5	-83.0
Pu-239	2.99E-28	1,171	1.96E-32	1,171	2.70E-39	1,171	-100.0	-100.0
C-14	4.86E-33	1,171	1.43E-36	1,171	1.34E-36	1,171	-100.0	-100.0
Ni-59	4.44E-41	1,171	4.55E-41	1,171	4.01E-41	1,171	2.6	-9.6
Sr-90	3.16E-42	1,171	4.38E-43	1,171	2.20E-42	1,171	-86.2	-30.3
Ni-63	3.00E-44	1,171	3.13E-44	1,171	4.50E-44	1,171	4.3	50.0
Ag-108m	6.69E-55	1,171	6.59E-54	1,171	5.11E-54	1,171	884.5	663.6
Cs-137	1.02E-58	1,171	2.35E-57	1,171	2.32E-57	1,171	2,203.1	2,170.4
Ra-226	2.17E-108	1,171	9.68E-105	1,171	9.70E-114	1,171	445,951.2	-100.0

Notes:

Cells highlighted in green and orange indicate an increase and decrease, respectively, in dose factors for Cases BE and BE2 relative to the nominal PA case.

[a] Case BE assumes waste emplacement at the start of operations (Year 0), while Case BE2 assumes waste emplacement at the end of operations (Year 71).

Table 6-138. Comparison of Maximum All-Pathways Dose Factors at 100-meter POA and Times of Maximum for Best Estimate Intermediate-Level Vault Cases

Radionuclide	Nominal PA Case		Best Estimate Case (BE) [a]		Best Estimate Case 2 (BE2) [a]		Δ(BE – Nominal)	Δ(BE2 – Nominal)
	mrem yr^{-1} Ci^{-1}	Year	mrem yr^{-1} Ci^{-1}	Year	mrem yr^{-1} Ci^{-1}	Year	%	%
I-129	2.25E+01	1,171	2.73E+00	1,171	5.89E+00	1,171	-87.9	-73.8
Cl-36	4.27E-03	1,171	2.94E-03	1,171	2.20E-03	1,171	-31.3	-48.4
Ar-39	8.71E-06	759	3.65E-06	833	4.24E-06	833	-58.1	-51.4
Tc-99	5.26E-08	1,171	1.06E-10	1,171	1.21E-10	1,171	-99.8	-99.8
H-3	1.67E-09	171	3.31E-09	171	6.13E-09	171	98.2	267.2
K-40	7.82E-26	1,171	5.42E-26	1,171	4.51E-28	1,171	-30.7	-99.4
C-14	4.22E-30	1,171	1.58E-35	1,171	3.98E-35	1,171	-100.0	-100.0
Np-237	3.18E-30	1,171	6.21E-32	1,171	1.67E-31	1,171	-98.0	-94.7
U-235	2.41E-30	1,171	8.60E-32	1,171	2.18E-31	1,171	-96.4	-91.0
Am-241	5.54E-34	1,171	1.23E-35	1,171	3.26E-35	1,171	-97.8	-94.1
Cm-245	3.49E-34	1,171	7.74E-36	1,171	1.87E-35	1,171	-97.8	-94.6
Pu-241	1.81E-35	1,171	4.03E-37	1,171	1.06E-36	1,171	-97.8	-94.1
Cf-249	5.02E-36	1,171	1.08E-37	1,171	2.46E-37	1,171	-97.8	-95.1
Pu-239	6.61E-37	1,171	1.87E-38	1,171	4.14E-38	1,171	-97.2	-93.7
Ni-59	1.72E-46	1,171	1.69E-47	1,171	2.00E-49	1,171	-90.2	-99.9
Ni-63	1.15E-49	1,171	1.19E-50	1,171	1.80E-52	1,171	-89.7	-99.8
Sr-90	9.66E-51	1,171	1.09E-52	1,171	4.86E-52	1,171	-98.9	-95.0
Cs-137	2.01E-53	1,171	1.42E-53	1,171	4.60E-58	1,171	-29.3	-100.0
Ag-108m	3.94E-63	1,171	1.65E-63	1,171	1.34E-67	1,171	-58.1	-100.0
Ra-226	1.06E-99	1,171	3.91E-100	1,171	1.18E-106	1,171	-63.3	-100.0

Notes:

Cells highlighted in green and orange indicate an increase and decrease, respectively, in dose factors for Cases BE and BE2 relative to the nominal PA case.

[a] Case BE assumes waste emplacement at the start of operations (Year 0), while Case BE2 assumes waste emplacement at the end of operations (Year 71).

Table 6-139. Comparison of Maximum Beta-Gamma Dose Factors at 100-meter POA and Times of Maximum for Best Estimate Intermediate-Level Vault Cases

Radionuclide	Nominal PA Case		Best Estimate Case (BE) [a]		Best Estimate Case 2 (BE2) [a]		Δ(BE – Nominal)	Δ(BE2 – Nominal)
	mrem yr^{-1} Ci^{-1}	Year	mrem yr^{-1} Ci^{-1}	Year	mrem yr^{-1} Ci^{-1}	Year	%	%
I-129	3.85E+02	1,171	4.66E+01	1,171	1.01E+02	1,171	-87.9	-73.8
Cl-36	4.75E-03	1,171	3.26E-03	1,171	2.45E-03	1,171	-31.3	-48.4
Tc-99	7.98E-08	1,171	1.61E-10	1,171	1.84E-10	1,171	-99.8	-99.8
H-3	3.70E-08	98	7.63E-08	97	3.69E-08	97	106.2	-0.3
K-40	8.13E-26	1,171	5.63E-26	1,171	4.68E-28	1,171	-30.7	-99.4
C-14	4.21E-30	1,171	1.58E-35	1,171	3.97E-35	1,171	-100.0	-100.0
Np-237	2.11E-31	1,171	4.13E-33	1,171	1.11E-32	1,171	-98.0	-94.7
U-235	1.60E-33	1,171	6.22E-35	1,171	1.57E-34	1,171	-96.1	-90.2
Am-241	3.69E-35	1,171	8.20E-37	1,171	2.17E-36	1,171	-97.8	-94.1
Cm-245	2.32E-35	1,171	5.14E-37	1,171	1.24E-36	1,171	-97.8	-94.6
Pu-241	1.20E-36	1,171	2.68E-38	1,171	7.08E-38	1,171	-97.8	-94.1
Cf-249	3.34E-37	1,171	7.19E-39	1,171	1.64E-38	1,171	-97.8	-95.1
Pu-239	4.33E-40	1,171	1.34E-41	1,171	2.97E-41	1,171	-96.9	-93.2
Ni-59	1.66E-44	1,171	1.63E-45	1,171	1.93E-47	1,171	-90.2	-99.9
Ni-63	2.67E-47	1,171	2.76E-48	1,171	4.18E-50	1,171	-89.7	-99.8
Sr-90	8.25E-50	1,171	9.31E-52	1,171	4.15E-51	1,171	-98.9	-95.0
Cs-137	1.35E-53	1,171	9.55E-54	1,171	3.09E-58	1,171	-29.3	-100.0
Ag-108m	5.26E-63	1,171	2.21E-63	1,171	1.78E-67	1,171	-58.1	-100.0
Ra-226	2.01E-101	1,171	7.23E-102	1,171	1.93E-108	1,171	-63.9	-100.0
Ar-39	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Notes:

Cells highlighted in green and orange indicate an increase and decrease, respectively, in dose factors for Cases BE and BE2 relative to the nominal PA case.

[a] Case BE assumes waste emplacement at the start of operations (Year 0), while Case BE2 assumes waste emplacement at the end of operations (Year 71).

Table 6-140. Comparison of Beta-Gamma and All-Pathways Total Doses at 100-meter POA for the Nominal PA and Best Estimate Low-Activity Waste Vault Cases based on Projected Closure Inventories

Parent Radio-nuclide	Closure Inventory (Ci)	Dose (mrem yr^{-1})											
		Nominal PA Case				Best Estimate Case [a]				Best Estimate Case 2 [a]			
		Beta-Gamma		All-Pathways		Beta-Gamma		All-Pathways		Beta-Gamma		All-Pathways	
		Years 0-700	Years 700-1,171	Years 171-700	Years 700-1,171	Years 0-700	Years 700-1,171	Years 171-700	Years 700-1,171	Years 0-700	Years 700-1,171	Years 171-700	Years 700-1,171
Ag-108m	2.91E-04	1.20E-75	1.03E-57	9.02E-76	7.73E-58	8.72E-75	1.02E-56	6.54E-75	7.61E-57	6.45E-87	7.88E-57	4.83E-87	5.91E-57
Am-241	1.36E+00	1.26E-48	8.28E-25	1.90E-47	1.24E-23	7.01E-47	1.11E-28	1.05E-45	1.67E-27	2.48E-57	8.69E-31	3.73E-56	1.31E-29
C-14	6.35E-01	0.00E+00	0.00E+00	2.85E-55	1.23E-32	0.00E+00	0.00E+00	2.75E-52	3.61E-36	0.00E+00	0.00E+00	1.17E-59	3.37E-36
Ca-41	6.72E-05	2.76E-50	2.28E-30	5.64E-50	4.66E-30	1.92E-48	4.22E-31	3.92E-48	8.62E-31	1.23E-57	3.88E-31	2.51E-57	7.94E-31
Cl-36	6.40E-03	1.64E-15	1.81E-05	1.48E-15	1.63E-05	3.58E-14	2.80E-06	3.22E-14	2.52E-06	5.02E-18	2.75E-06	4.51E-18	2.47E-06
Cm-245	7.53E-03	1.25E-53	1.95E-27	1.88E-52	2.94E-26	1.01E-51	1.15E-31	1.52E-50	1.73E-30	1.42E-65	2.72E-37	2.13E-64	4.09E-36
Cs-137	2.74E+02	8.12E-71	7.44E-56	1.21E-70	1.11E-55	9.46E-70	1.71E-54	1.41E-69	2.55E-54	7.97E-82	1.69E-54	1.19E-81	2.52E-54
H-3	1.39E+06	3.33E-03	4.72E-12	1.16E-04	1.08E-12	7.89E-03	9.98E-13	2.33E-04	2.28E-13	2.50E-03	5.34E-11	5.71E-04	1.22E-11
I-129	5.77E-04	5.02E-08	4.00E+00	2.94E-09	2.34E-01	5.15E-07	1.02E+00	3.01E-08	6.00E-02	3.35E-07	1.02E+00	1.96E-08	5.98E-02
K-40	1.84E-06	1.75E-49	3.96E-31	1.69E-49	3.81E-31	3.25E-47	1.17E-30	3.13E-47	1.12E-30	2.82E-57	1.07E-30	2.71E-57	1.03E-30
Ni-59	5.05E+00	1.79E-57	8.57E-38	1.86E-59	8.90E-40	8.31E-56	8.79E-38	8.63E-58	9.12E-40	4.90E-67	7.75E-38	5.08E-69	8.04E-40
Ni-63	8.64E+02	1.34E-56	2.40E-38	5.75E-59	1.03E-40	6.03E-55	2.50E-38	2.59E-57	1.07E-40	5.68E-66	3.59E-38	2.44E-68	1.55E-40
Np-237	1.39E-01	7.89E-44	7.90E-22	1.19E-42	1.19E-20	3.42E-42	1.89E-25	5.14E-41	2.84E-24	2.53E-48	1.77E-25	3.81E-47	2.67E-24
Pu-239	5.27E+00	5.45E-55	4.61E-30	3.17E-52	6.26E-27	1.98E-53	5.27E-34	1.84E-50	4.10E-31	3.10E-68	7.02E-41	9.40E-65	5.65E-38
Pu-241	3.56E+01	2.21E-49	6.96E-25	3.32E-48	1.05E-23	1.47E-47	8.86E-29	2.21E-46	1.33E-27	6.05E-74	3.54E-45	9.09E-73	5.32E-44
Ra-226	1.28E-01	5.21E-132	8.61E-111	3.08E-130	1.11E-108	1.43E-132	6.43E-107	1.19E-130	4.93E-105	1.67E-152	4.86E-116	2.11E-150	4.94E-114
Sr-90	7.89E+02	5.80E-53	8.47E-38	6.79E-54	9.92E-39	3.71E-51	1.17E-38	4.34E-52	1.37E-39	1.20E-59	5.90E-38	1.40E-60	6.91E-39
Tc-99	4.04E-01	2.17E-24	1.83E-03	1.43E-24	1.21E-03	3.12E-16	9.77E-06	2.06E-16	6.45E-06	2.21E-16	9.70E-06	1.46E-16	6.40E-06
U-235	1.65E-02	3.39E-49	5.26E-26	1.93E-46	7.11E-23	9.73E-48	1.14E-29	8.86E-45	8.81E-27	2.62E-56	4.90E-30	7.74E-53	3.81E-27
Total Dose		0.00	4.00	0.00	0.24	0.01	1.02	0.00	0.06	0.00	1.02	0.00	0.06
Max Total Dose		4.00		0.24		1.02		0.06		1.02		0.06	

Notes:

Cell highlighted in orange represents the limiting pathway and best estimate case.

[a] Case BE assumes waste emplacement at the start of operations (Year 0), while Case BE2 assumes waste emplacement at the end of operations (Year 71).

Table 6-141. Comparison of Beta-Gamma and All-Pathways Total Doses at 100-meter POA for the Nominal PA and Best Estimate Intermediate-Level Vault Cases based on Projected Closure Inventories

Parent Radio-nuclide	Closure Inventory (Ci)	Dose (mrem yr^{-1})											
		Nominal PA Case				Best Estimate Case [a]				Best Estimate Case 2 [a]			
		Beta-Gamma		All-Pathways		Beta-Gamma		All-Pathways		Beta-Gamma		All-Pathways	
		Years 0-400	Years 400-1,171	Years 171-400	Years 400-1,171	Years 0-400	Years 400-1,171	Years 171-400	Years 400-1,171	Years 0-400	Years 400-1,171	Years 171-400	Years 400-1,171
Ag-108m	2.62E-04	3.97E-79	3.53E-66	2.97E-79	2.65E-66	1.42E-79	1.48E-66	1.06E-79	1.11E-66	2.48E-88	1.20E-70	1.86E-88	8.98E-71
Am-241	4.42E+00	3.11E-50	4.17E-34	4.67E-49	6.28E-33	1.15E-50	9.29E-36	1.74E-49	1.40E-34	4.13E-56	2.45E-35	6.21E-55	3.69E-34
Ar-39	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
C-14	3.17E+00	2.02E-52	3.42E-29	2.02E-52	3.43E-29	7.05E-53	1.28E-34	7.07E-53	1.29E-34	1.42E-57	3.23E-34	1.43E-57	3.23E-34
Cf-249	1.03E-02	5.79E-58	8.80E-39	8.70E-57	1.32E-37	2.15E-58	1.90E-40	3.23E-57	2.85E-39	3.47E-64	4.32E-40	5.22E-63	6.49E-39
Cl-36	4.87E-04	1.75E-11	5.92E-06	1.57E-11	5.33E-06	3.74E-11	4.07E-06	3.37E-11	3.66E-06	2.08E-14	3.06E-06	1.87E-14	2.75E-06
Cm-245	1.62E-02	1.01E-54	9.61E-37	1.52E-53	1.44E-35	3.76E-55	2.13E-38	5.66E-54	3.20E-37	8.07E-61	5.15E-38	1.21E-59	7.74E-37
Cs-137	2.42E+03	4.38E-55	8.38E-50	6.53E-55	1.25E-49	2.63E-55	5.93E-50	3.91E-55	8.83E-50	7.37E-64	1.92E-54	1.10E-63	2.86E-54
H-3	8.98E+06	8.50E-01	2.58E-08	3.84E-02	5.90E-09	1.75E+00	5.16E-08	7.61E-02	1.18E-08	8.48E-01	1.10E-07	1.41E-01	2.51E-08
I-129	3.74E-03	5.09E-06	3.68E+00	2.98E-07	2.16E-01	2.15E-06	4.47E-01	1.26E-07	2.61E-02	5.36E-08	9.65E-01	3.14E-09	5.64E-02
K-40	3.63E-02	9.95E-39	7.56E-27	9.58E-39	7.28E-27	5.97E-39	5.24E-27	5.74E-39	5.04E-27	6.33E-46	4.36E-29	6.10E-46	4.20E-29
Ni-59	6.20E+00	1.36E-57	2.63E-43	1.41E-59	2.73E-45	5.08E-58	2.59E-44	5.27E-60	2.68E-46	5.52E-66	3.06E-46	5.73E-68	3.18E-48
Ni-63	7.57E+02	1.02E-55	5.18E-44	4.38E-58	2.23E-46	3.81E-56	5.34E-45	1.64E-58	2.30E-47	3.23E-64	8.10E-47	1.39E-66	3.48E-49
Np-237	1.00E-01	2.04E-47	5.44E-32	3.07E-46	8.18E-31	7.49E-48	1.06E-33	1.13E-46	1.60E-32	3.64E-53	2.86E-33	5.48E-52	4.29E-32
Pu-239	5.19E+00	2.99E-56	5.76E-39	1.49E-53	8.79E-36	1.11E-56	1.79E-40	5.56E-54	2.49E-37	2.68E-62	3.94E-40	1.47E-59	5.50E-37
Pu-241	2.81E+01	2.08E-51	8.65E-35	3.13E-50	1.30E-33	7.73E-52	1.93E-36	1.16E-50	2.90E-35	2.23E-57	5.10E-36	3.36E-56	7.66E-35
Ra-226	5.01E+00	2.70E-116	2.57E-100	2.28E-114	1.36E-98	9.76E-117	9.28E-101	8.25E-115	5.01E-99	1.62E-26	2.48E-107	1.38E-124	1.52E-105
Sr-90	7.27E+02	1.07E-51	1.54E-46	1.26E-52	1.80E-47	3.99E-52	1.73E-48	4.67E-53	2.03E-49	2.14E-59	7.73E-48	2.51E-60	9.04E-49
Tc-99	7.67E-01	8.61E-25	1.57E-07	5.68E-25	1.03E-07	6.39E-25	3.15E-10	4.22E-25	2.08E-10	1.99E-26	3.61E-10	1.32E-26	2.38E-10
U-235	1.63E-02	2.14E-50	6.69E-35	1.07E-47	1.01E-31	7.96E-51	2.60E-36	3.97E-48	3.60E-33	2.59E-56	6.57E-36	1.40E-53	9.10E-33
Total Dose		0.85	3.68	0.04	0.22	1.75	0.45	0.08	0.03	0.85	0.96	0.14	0.06
Max Total Dose		3.68		0.22		1.75		0.08		0.96		0.14	

Notes:

Cell highlighted in orange represents the limiting pathway and best estimate case.

[a] Case BE assumes waste emplacement at the start of operations (Year 0), while Case BE2 assumes waste emplacement at the end of operations (Year 71).

Considering radionuclides with doses greater than 1E-20 mrem $yr^{-1}Ci^{-1}$ parent buried, the differences for the LAWV are small except for H-3 with its short half-life. In general, late emplacement leads to a lower dose with the notable exception of H-3, which shows more than twice the all-pathways dose but less than half the beta-gamma dose for Case BE2 relative to Case BE.

For the ILV, waste emplacement at the end of operations instead of at the start results in higher doses for a slight majority of radionuclides, which differs from the LAWV results. The effect on H-3, which has the shortest half-life, is the opposite of what it is for the LAWV. These differences are attributed to the different vault locations and aquifer transport paths. The ILV aquifer also contains clay, while there is no clay present in the LAWV aquifer.

6.1.4. Technetium-99 Sensitivity to K_d Values

During the LFRG review of PA2008 (DOE LFRG, 2008) one of the two key issues originally declared is as follows:

> *"There is insufficient data in the PA to justify the assumed low Kd value for Tc-99. Use of a Kd value of 0 would change currently estimated disposal limits and the sum of fractions calculations that are used to manage operations of the Slit and Engineered trenches could exceed unity."*

As a follow up, SRNL submitted additional information on measured K_d values and sensitivity runs for consideration. Based on this new information, the LFRG altered their findings as follows:

> *"The Review Team concluded that the two key issues should be down-graded to secondary issues and the Team recommendation changed to approval without conditions. The secondary issues will be tracked through the maintenance plan."*

Below is an update on measured K_d values for technetium, followed by K_d sensitivity results focused on ST06. The nominal PA case (100%) and sensitivity case (50%) K_d values for technetium are supported by experimental data. The transport runs below indicate that a 50% reduction in K_d results in an approximately 30% reduction in inventory limits.

6.1.4.1. Basis for Selection of Technetium K_d Values

This section justifies the selection of the following K_d values for Tc-99 used in the PA2022 transport simulations as recommended by Kaplan (2021):

- 0.6 mL g^{-1} for sandy sediments
- 1.8 mL g^{-1} for clayey sediments

There have been five pertechnetate (TcO_4^-) sorption studies conducted with SRS sediments (Kaplan, 2003; Kaplan et al., 2008; Kaplan and Serkiz, 2006; Oblath, 1982; Routson et al., 1977). Of these five studies, Routson et al. (1977) does not provide insight into the geochemistry of technetium at the SRS because varying levels of dissolved carbonate were added to the aqueous phase. Unlike in western U.S. states where solubility of carbonate minerals supports elevated dissolved carbonate concentrations, appreciably less aqueous carbonate exists in the E-Area GW than was used in the experiments conducted by Routson et al. (1977). Pertinent information regarding the four other experiments, including their measured K_d values, are presented in Table 6-142.

Oblath (1982) reported K_d values for technetium ranging from 0.10 to 1.32 mL g^{-1} (#1 – #10 in Table 6-142). Oblath (1982) concluded that there was a positive correlation between clay content and K_d values for TcO_4^- (the primary form of technetium expected to exist in the SRS aqueous environment). K_d values for TcO_4^- did not change much as a function of the water chemistry or sediment organic carbon content used in the experiments to reflect the range of values expected on the SRS. Oblath (1982) also observed that K_d values measured in column studies tended to be lower than those measured in batch studies. This experimental difference is commonly attributed to the technetium in the flowing spiked solution not coming to steady state with the sediment in the column. Conversely, batch sorption techniques permit complete mixing of the sediment, water, and technetium system, thereby promoting greater sorption than column studies.

Kaplan and Serkiz (2006) used rhenium (as ReO_4^-) as a non-radiological chemical surrogate for TcO_4^- for measuring K_d values of two SRS sediments. Sediment type, pH, and organic carbon concentrations were varied in the study. Consistent with the findings by Oblath (1982), Kaplan and Serkiz (2006) observed that the clayey sediment (#11 – #13 in Table 6-142) adsorbed more ReO_4^- than the sandy sediment (#14 – #16 in Table 6-142). The pH did not influence sorption as expected (i.e., TcO_4^- sorption should increase as pH decreases because of its negative charge) but the concentration of dissolved organic carbon did influence the K_d values.

Kaplan (2003) measured technetium K_d values for two sediments as a function of pH (#17 – #20 in Table 6-142) Both sediments had low clay content (5 – 6 wt%) and adsorbed only trace amounts of technetium at pH levels below background (pH 5.3 for these particular sediments); these sediments sorb no technetium at a pH above their natural pH levels.

Table 6-142. K_d Values for TcO_4^-

ID#	K_d (mL g-1)	Solid	Liquid	Experimental
1	0.23[1]	SRS Old Burial Ground Sediment (PD05): 55 – 56 ft deep, 10% clay + 90% sand	SRS GW	Column
2	0.14[1]	SRS Old Burial Ground Sediment (PD05): 57 - 58 ft deep, 10% clay + 90% sand	SRS GW	Column
3	0.17[1]	SRS Old Burial Ground Sediment (SDS-5), 35 – 37 ft 10% clay, 90% sand	SRS GW	Column
4	0.33[1]	SRS Old Burial Ground Sediment (SDS-5), 64 – 66 ft 30% clay 70% sand	SRS GW	Column
5	0.10[1]	SRS Old Burial Ground Sediment (BG #1) 15% clay/silt + 85% sand	SRS GW	Batch
6	1.16[1]	SRS Old Burial Ground Sediment (BG #3): 50% clay/silt + 49% sand	SRS GW	Batch
7	1.31[1]	SRS Old Burial Ground Sediment (BG #4): 49% clay/silt + 50% sand	SRS GW	Batch
8	1.32[1]	SRS Old Burial Ground Sediment (BG #5): 48% clay/silt + 52% sand	SRS GW	Batch
9	0.16[1]	SRS Old Burial Ground Sediment (PD05): 57 - 58 ft deep, 10% clay + 90% sand	Deionized Water	Batch
10	0.36[1]	SRS Old Burial Ground Sediment (PD05): 57 - 58 ft deep, 10% clay + 90% sand	SRS GW	Batch
11	0.1[2]	SRS sediment: Clayey sediment; Sand / Silt/Clay; 58%/ 30% /12%; pH 3.9	GW with varying amounts of organic C.	Batch: $ReO_4^- \approx TcO_4^-$
12	0.2[2]	SRS sediment: Clayey sediment; Sand / Silt/Clay; 58%/ 30% /12%; pH 5.3 (~background)	GW with varying amounts of organic C.	Batch: $ReO_4^- \approx TcO_4^-$
13	0.0[2]	SRS sediment: Clayey sediment; Sand / Silt/Clay; 58%/ 30% /12%; pH 6.7	GW with varying amounts of organic C.	Batch: $ReO_4^- \approx TcO_4^-$
14	-0.1[b, d]	SRS sediment: Sandy sediment; Sand / Silt/Clay; 96%/ 0% /4%; pH 3.9	GW with varying amounts of organic C.	Batch: $ReO_4^- \approx TcO_4^-$
15	-0.1[b, d]	SRS sediment: Sandy sediment; Sand / Silt/Clay; 96%/ 0% /4%; pH 5.3 (~background)	GW with varying amounts of organic C.	Batch: $ReO_4^- \approx TcO_4^-$
16	0.0[2]	SRS sediment: Sandy sediment; Sand / Silt/Clay; 96%/ 0% /4%; pH 6.7	GW with varying amounts of organic C.	Batch: $ReO_4^- \approx TcO_4^-$
17	<0.11[3]	Loamy Sand SRS wetland sediment: 79%/14%/6% sand/silt/clay, high in organic matter (1,395 ppm organic C) pH 3.7 to 4.3 (natural pH = 4.16)	SRS GW	Batch, varied pH
18	0[3]	Loamy Sand SRS wetland sediment: 79%/14%/6% sand/silt/clay, high in organic matter (1,395 ppm organic C); pH 4.3 to 6.8	SRS GW	Batch, varied pH
19	0 to <0.15[3]	Loamy Sand SRS subsurface upland sediment: 80%/15%/5% sand/ silt/clay, low in organic matter (<200 ppm organic C); pH = 2.4 to 4.0	SRS GW	Batch, varied pH
20	0[3]	Loamy Sand SRS subsurface upland sediment: 80%/15%/5% sand/ silt/clay, low in organic matter (<200 ppm organic C); pH > 4.0	SRS GW	Batch, varied pH

1 Oblath (1982)

2 Kaplan and Serkiz (2006)

3 Kaplan (2003)

4 Negative K_d values may represent anion exclusion; however, for these experiments, they result from analytical variability.

Kaplan et al. (2008) measured K_d values for TcO_4^- in 26 sediments collected from a borehole recovered from E-Area (Table 6-143). This data set greatly increases the number of technetium K_d values measured in SRS sediments, but perhaps more importantly for this PA, provides a better estimate for E-Area sediments. The mean K_d value is 3.4 ± 0.5 mL g^{-1} and has a range of -2.9 to 11.2 mL g^{-1} (Table 6-143).[1]

Table 6-143. Summary of K_d Values for Technetium and Sediment Characterization Data for BGO-3A Borehole

Borehole Depth (ft)	K_d for Tc Average +/- Std. Dev. (mL g^{-1})	Cation Exchange Capacity (meq/100g)	Sediment pH	Clay (wt%)	Mn [1] (ppm)	Fe [1] (ppm)
-11	11.2 ± 1.9	2.0	5.1	21.16	2	4,272
-12.5	4.1 ± 0.5	1.6	5.1	19.45	2	2,310
-15	4.3 ± 0.3	2.7	6.0	29.05	11	5,062
-17.5	3.9 ± 0.2	3.3	5.0	49.73	4	10,183
-20	4.0 ± 0.2	1.5	4.9	18.48	11	3,554
-25	-2.6 ± 0.1	3.2	5.8	22.71	1731	24,698
-27	4.0 ± 0.3	1.2	5.0	14.62	18	716
-30	4.3 ± 0.3	1.4	5.3	11.56	27	429
-32	4.0 ± 0.5	1.0	5.3	7.00	7	581
-35	2.9 ± 1.3	1.1	5.4	8.76	9	594
-38	4.1 ± 0.1	1.0	5.2	6.31	12	814
-40	4.5 ± 0.6	1.6	5.3	9.70	6	410
-42	1.9 ± 0.6	1.0	5.2	7.16	34	209
-45	5.2 ± 1.4	1.0	5.2	7.73	3	260
-47	4.3 ± 0.0	1.5	5.2	9.16	3	327
-50	4.3 ± 0.2	1.6	5.0	9.57	3	253
-53	0.7 ± 4.6	1.4	4.9	9.74	3	288
-55	4.2 ± 0.2	1.5	5.1	11.03	9	363
-58	3.5 ± 0.1	1.1	6.0	2.16	11	1,160
-60	3.5 ± 0.2	1.0	6.4	0.31	20	589
-70	3.9 ± 0.1	1.6	5.0	6.60	5	2,223
-75	3.6 ± 0.0	1.6	4.8	3.70	5	3,015
-80	-2.9 ± 0.0	1.2	6.0	2.32	27	13,619
-85	3.7 ± 0.2	1.1	5.8	1.18	14	6,566
-90	1.7 ± 0.1	2.9	5.3	7.94	169	22,696
-95	1.6 ± 0.1	9.3	4.9	21.51	204	10,462

Notes:

The table includes means of duplicated or triplicated measurements (Kaplan et al., 2008).

1 Dithionite-citrate-buffer extractable; an extract that provides a measure of metals on the surface or in the hydroxide coatings of sediment particles but does not measure the metal content within the mineral structure.

Table 6-144 compares a statistical description of the 46 site-specific measured K_d values for technetium reported in Table 6-142 and Table 6-143 to the recommended sandy and clayey

[1] A negative K_d value has physical meaning in surface chemistry. It may represent the phenomenon of anion exclusion, the repulsion of anions from negatively charged mineral surfaces (Kaplan and Serne, 1998). This phenomenon is more likely to occur in soils with basic pH levels that are dominated by permanent charge mineralogy, such as at the Hanford Site (Kaplan and Serne, 1998).

sediment K_d values for Tc reported in the *GeoChem Data Package* used in the PA (Kaplan, 2021). These best values are lower (i.e., pessimistically biased) than the mean measured values to account for uncertainty associated with the plume chemistry and distribution of clayey- versus sandy-textured sediment in the flow path of the hypothetical plume. Furthermore, the 95% confidence level minimum values for both sandy and clayey sediments are also more pessimistically biased than those based solely on the measured values.

Table 6-144. Statistical Description of K_d Values (mL g^{-1}) for Technetium in SRS Sediments Presented in Table 6-142 and Table 6-143

Parameter	Site-Specific Measured K_d for Tc-99	Recommended Best K_d for Tc-99 in Sandy Sediment [1]	Recommended Best K_d for Tc-99 in Clayey Sediment [1]
Mean	2.0	0.6	1.8
Standard Error	0.36		
Median	1.6		
Standard Deviation	2.45		
Sample Variance	6.01		
Minimum	-2.9		
Maximum	11.2		
95% confidence level minimum[2,3]	1.3	0.3	1.1
95% confidence level maximum[2,3]	2.7	1.2	2.6
Confidence Level (95.0%)	0.72		
Count	46		

Notes:

1 "Best" Sandy and Clayey K_d values for Tc reported by Kaplan (2021; p. 89).

2 Sandy Sediment KdMin95% = K_d ÷ 2; Sandy Sediment KdMax95% = K_d × 2

3 Clayey Sediment KdMin95% = K_d × 0.618; Clayey Sediment KdMax95% = K_d ÷ 0.618

6.1.4.2. Impact on Inventory Limits

A variety of operational and transport factors have changed since the PA2008 analyses were performed. A partial listing is provided below.

- DU-specific percentage of non-crushable containers
- Nominal sand and clay K_d values for Tc-99
- Sand and clay particle densities
- Sand and clay total porosities
- DU-specific depth from waste zone to water table
- DU-specific aquifer flow fields
- Surface GW infiltration rates

A new series of sensitivity runs has been completed for Tc-99 buried in ST06; results are compared with the PA2008 results. K_d values considered in this comparative analysis are listed in Table 6-145.

Table 6-145. Listing of K_d Values Considered for Technetium

Case	K_d (mL g^{-1})	
	Sand	Clay
PA2022 (Nominal)	0.6	1.8
PA2022 (Sensitivity)	0.3	0.9
PA2022 (Bounding)	0.0	0.0
PA2008 (CDP off)	0.1	0.2
PA2008 (CDP on)	0.05	0.1

Notes:Cellulose degradation product (CDP)

During the PA2008 analysis, K_d values were assumed to be dependent upon cellulose degradation products as shown in Table 6-145, which are consistent with the K_d values discussed above. Nominal PA case values are presented in Table 6-145. Two sensitivity cases for this PA are listed in Table 6-145: 50% of nominal PA case values (sensitivity case) and 0% of nominal PA case values (bounding case). PORFLOW-predicted aquifer concentrations at the 100-meter POA are shown in Figure 6-63 for the new results. The four case runs are as follows:

- Intact conditions employing the nominal PA case K_d settings (100% K_d)
- Intact conditions employing the sensitivity case K_d settings (50% K_d)
- Intact conditions employing the bounding case K_d settings (0% K_d)
- Subsided (2% non-crushables) case employing the nominal PA case K_d settings (100% K_d)

As Figure 6-63 highlights, two peak concentrations occur for the three non-zero case runs.

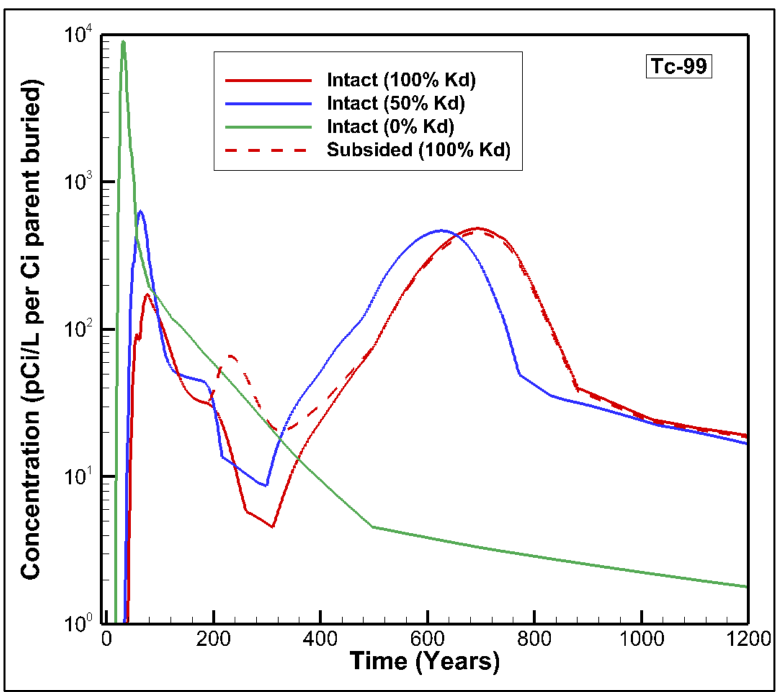


Figure 6-63. Maximum Aquifer Concentrations of Tc-99 in ST06 at 100-meter POA Assuming Variable K_d Values for Tc-99

To see a direct comparison to one of the PA2008 cases (CDP off case), focus is placed on intact closure cap conditions only as shown in Figure 6-64. The PA2008 results (black dashed curve) are based on approximately 17% of nominal PA K_d values and peak earlier than the newer transport runs because of a subset of the parameter changes noted in the bulleted listed at the beginning of the section.

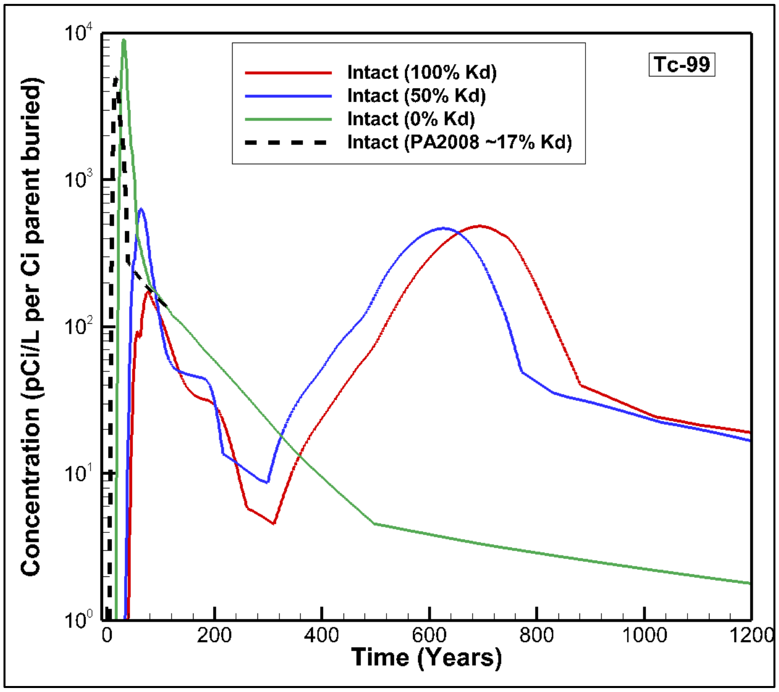


Figure 6-64. Maximum Aquifer Concentrations of Tc-99 in ST06 at 100-meter POA for Intact Closure Cap Conditions Only

A summary plot of peak Tc-99 concentrations for the various transport runs considered for ST06 is provided in Figure 6-65. As the figure indicates, peak Tc-99 concentrations are sensitive to assumed K_d values. Peak Tc-99 concentration ratios (x% of nominal K_d values versus 100%) are 1.32 for 50% of nominal and 18.8 for 0% of nominal.

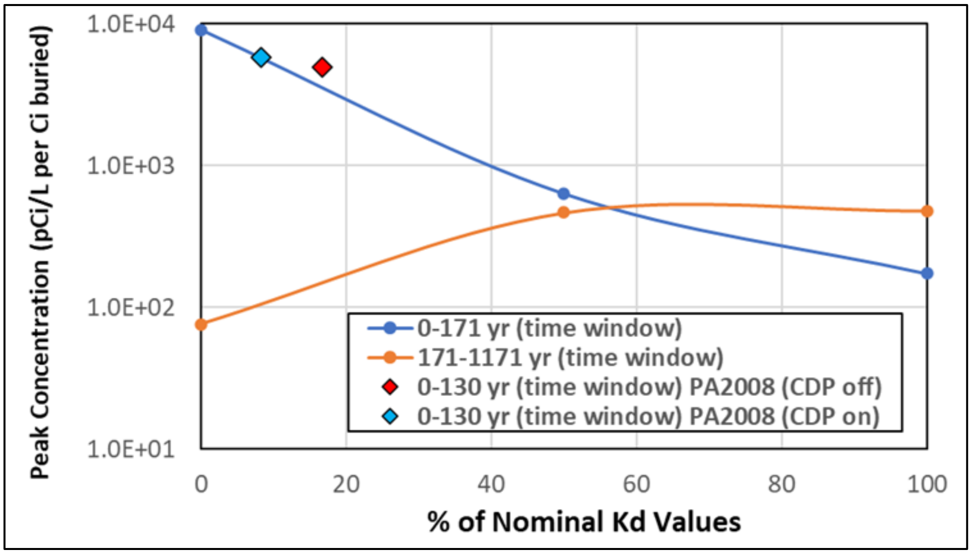


Figure 6-65. Peak Aquifer Concentrations of Tc-99 in ST06 for Various Transport Runs

6.2. GOLDSIM® TRENCH MODELS

Where direct comparisons can be made between PORFLOW and GoldSim® model results, a set of PORFLOW benchmarking and calibration investigations are performed for the three trench DUs (ST06, ST09, and ET06) selected for sensitivity analysis and uncertainty quantification. The PORFLOW models consist of 2-D and 3-D geometries (2-D and 3-D in the VZ and 3-D in the aquifer), while the GoldSim® models for the VZ and aquifer are 1-D simplifications. Assuming the PORFLOW-predicted fate and transport behaviors are accurate representations, a calibration effort is employed to adjust GoldSim® model parameters, where necessary, such that the nominal GoldSim® model predictions produce similar overall behavior. Specifically, calibration focuses on the peak flux at the water table as well as peak concentration value(s) and their timing at the 100-meter POA for parent radionuclides (and their progenies). The GoldSim® model calibration results for the VZ and aquifer are presented in Sections 4.4.10 and 4.4.11, respectively. Note that the GoldSim® model utilizes a unit inventory of 1 gmole of each radionuclide. Additionally, sensitivity and uncertainty analyses are only shown for H-3, C-14, I-129, and Np-237 because the GoldSim® Trench System Model could not be successfully benchmarked to PORFLOW results for Sr-90 and Tc-99 (see Section 4.4.11).

GoldSim® is designed as a stochastic model and provides both deterministic and stochastic (probabilistic) results. The purpose of the GoldSim® fate and transport model for STs and ETs is to generate a distribution of reasonable, potential dose exposures that a MOP may experience in accordance with POs. This distribution in dose exposure is a measure of the uncertainty arising from uncertainty embedded in the input parameters of the model. To capture the uncertainty, the “stochastic element” within GoldSim® is used, which allows the user a means of explicitly accounting for the uncertainty associated with each input parameter as needed. During probabilistic simulation runs, GoldSim® applies the Monte Carlo technique across the set of stochastic elements within the model.

Uncertainty within the GoldSim® Trench System Model is represented using 17 stochastic elements. Each stochastic element ID, along with an associated description, is provided in Table 4-39. The distributions for all 17 stochastic elements reflect symmetrical, independent random variables assuming no covariance effects among them. Their mean values are equal to their 50% percentile values (i.e., median values). Also, the chosen mean values correspond to those values employed in the nominal PA PORFLOW analyses.

6.2.1. GoldSim® Trench System Model Sensitivity Analysis Results

GoldSim® offers the ability to analyze the sensitivity of concentration to stochastically varied model parameters. One of the tools used to understand sensitivity is a Tornado plot that illustrates the degree to which the concentration is sensitive to a particular stochastically varied parameter. In Tornado plots, the thick line represents the 50th-percentile value [all stochastics are at the 50th-percentile value, which is not necessarily the deterministic (i.e., mean) value]. The bars to either side represent the change in concentration from using the upper bound, 95.5% of the stochastic distribution (dark blue), or lower bound, 4.5% of the stochastic distribution (light blue), for the parameter indicated [all other parameters are held at their 50% (median) values].

In addition to the deterministic-based sensitivity analysis where a single simulation is carried out varying one stochastic at a time, probabilistic sensitivity analysis is performed during Monte Carlo simulations. The probabilistic sensitivity analysis quantifies the relative importance of stochastic parameters based on 3,000 realizations, whereas the deterministic sensitivity analysis uses only 15 points along the distribution from the lower bound to the upper bound.

A combined sensitivity analysis using both the PORFLOW and GoldSim® models allows identification of the conceptual model areas of importance, thereby determining which of the many input parameters are most responsible for the resultant concentration profiles.

From a high-level perspective, the following GoldSim® sensitivity results suggest that K_d uncertainties dominate followed by uncertainty in infiltration rates.

6.2.1.1. ET06

6.2.1.1.1. Intact Case

As shown in Figure 6-66, H-3 concentration is most sensitive to changes in VZ water saturation (WaterSat_Distribution), followed by VZ velocity distribution (Velocity_Distribution). VZ water saturation is a stochastic element and multiplier applied to the water saturation time-series elements. A change of 0.36 (lower bound of 0.8183 to upper bound of 1.182 with a 50% of 1.0) produces a 3.62E-05 Ci L^{-1} change in H-3 concentration per gmol H-3 inventory, which is 52% of the deterministic H-3 peak concentration. VZ velocity distribution (Velocity_Distribution) is a stochastic element and multiplier applied to the velocity time-series elements. A change of 0.36 (lower bound of 0.8183 to upper bound of 1.182 with a 50% nominal velocity of 1.0) produces a 1.31E-05 Ci L^{-1} $gmol^{-1}$ change in H-3 concentration, which is 19% of the deterministic H-3 peak concentration. The next two most-impactful stochastic variables are waste porosity before dynamic compaction (Porosity_Waste_PreC_ET) and Darcy velocity distribution for the saturated zone

(SatZoneDarcyVelDist), which is a multiplier applied to the saturated zone velocity element. Waste porosity before dynamic compaction and Darcy velocity distribution for the saturated zone produce a change of 17% and 14% in the deterministic H-3 peak concentration, respectively.

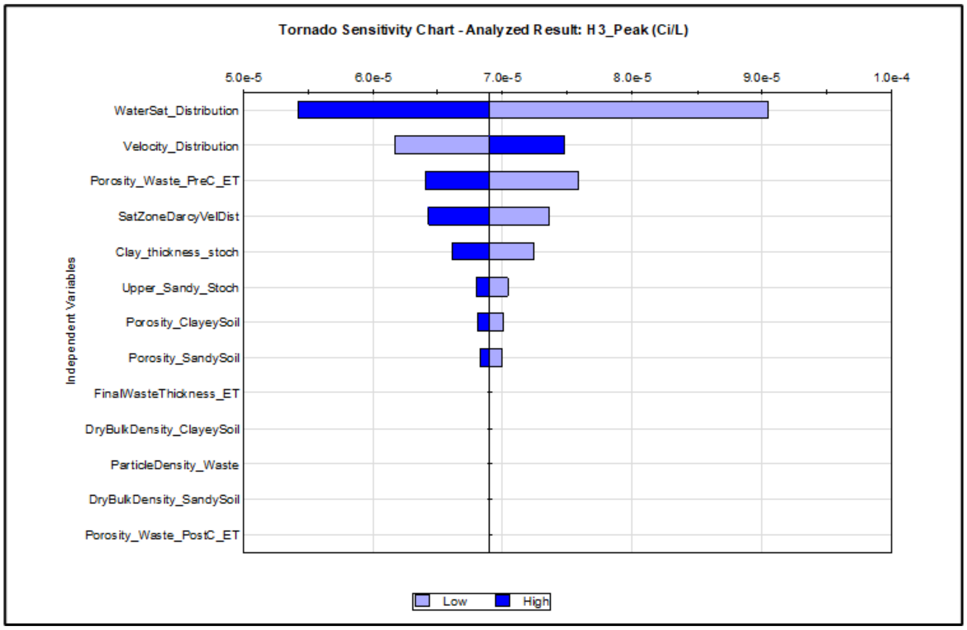


Figure 6-66. H-3 Peak Concentration (Ci L^{-1} per gmole H-3 inventory) at 100-meter POA for ET06 Intact Case

The Tornado plot for the C-14 peak concentration at the 100-meter POA is shown in Figure 6-67. As expected, the most-impactful stochastic parameter is the K_d for C-14 in clayey soils. A change of 24.04 mL g^{-1} (lower bound of 17.98 mL g^{-1} to upper bound of 42.02 mL g^{-1} with a 50% of 30 mL g^{-1}) produces a 2.84E-09 Ci^{-1} L^{-1} $gmol^{-1}$ change in concentration, which is 49% of the deterministic C-14 peak concentration. The second most-impactful stochastic parameter is the Darcy velocity distribution for the saturated zone (SatZoneDarcyVelDist), which is a multiplier applied to the saturated zone velocity element. A change of 0.36 (lower bound multiplier of 0.82 to upper bound multiplier of 1.18 with a 50% value of 1.0 yielding the deterministic nominal value) produces a change in concentration of 2.12E-09 Ci L^{-1} $gmol^{-1}$ or 37% of the deterministic peak concentration. The next two most-impactful stochastic variables are the thickness of the clayey layer in the VZ (Clay_thickness_stoch) and the VZ velocity distribution (Velocity_Distribution), which is also a multiplier applied to the velocity time-series elements. These two variables both produce a change of 16% in the deterministic peak concentration. The K_d for C-14 in sandy soil produces only a 2% change in peak concentration for the range of K_d investigated (0.3992 to 1.601 mL g^{-1}) because of the relatively small absolute value K_d (versus clayey soils where the nominal K_d value is 30 mL g^{-1}).

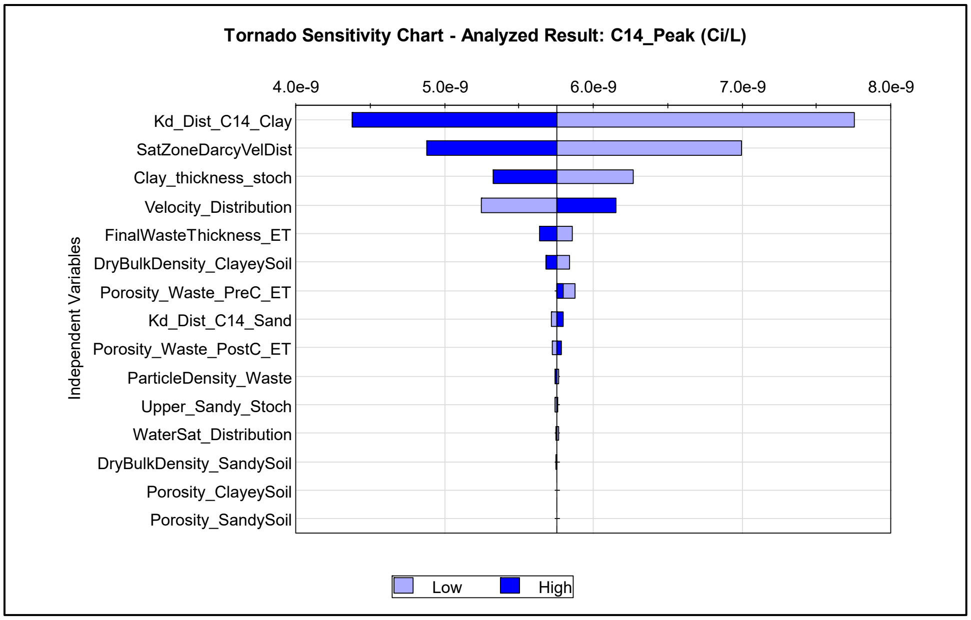


Figure 6-67. C-14 Peak Concentration (Ci L^{-1} per gmole C-14 inventory) at 100-meter POA for ET06 Intact Case

Figure 6-68 illustrates the sensitivity of I-129 concentration to stochastically varied model parameters. The two most-impactful parameters are the K_d values for I-129 in sandy and clayey soils. The impact of K_d on I-129 transport does not display the same linear trend as do the other radionuclides investigated. As seen in Figure 6-69, I-129 peak concentration decreases as K_d increases until a peak minimum is reached when the K_d in sandy soil equals 0.8131 mL g^{-1} (best estimate value is 1.0 mL g^{-1}). Beyond the peak minimum, the peak concentration increases only slightly as K_d continues to increase. In clayey soil, the relationship between I-129 peak concentration and K_d displays an inflection point at a K_d equal to 2.483 mL g^{-1} (best estimate value is 3.0 mL g^{-1}); however, the peak concentration continues to decrease slightly as K_d increases. The lowest values of K_d (0.3992 mL g^{-1} in sandy soil and 1.798 mL g^{-1} in clayey soil) lead to peak I-129 concentrations of 1.69E-11 Ci L^{-1} gmol^{-1} and 1.37E-11 Ci L^{-1} gmol^{-1}, respectively. The minimum I-129 peak concentration corresponds to a K_d in sandy soil of 1.601 mL g^{-1} (5.76E-12 Ci L^{-1} gmol^{-1}) and in clayey soil of 4.202 mL g^{-1} (5.84E-12 Ci L^{-1} gmol^{-1}), which corresponds to a 170% and 120% change in concentration, respectively, relative to the deterministic case.

The next two most-sensitive stochastic variables are the Darcy velocity distribution for the saturated zone (SatZoneDarcyVelDist) and VZ velocity distribution (Velocity_Distribution), which result in changes in the deterministic peak concentration of 23% and 35%, respectively. Like the trend in peak concentration with K_d, I-129 peak concentration decreases with increasing VZ velocity until the multiplier reaches 1.096, at which point the peak concentration sharply begins to rise with increasing velocity.

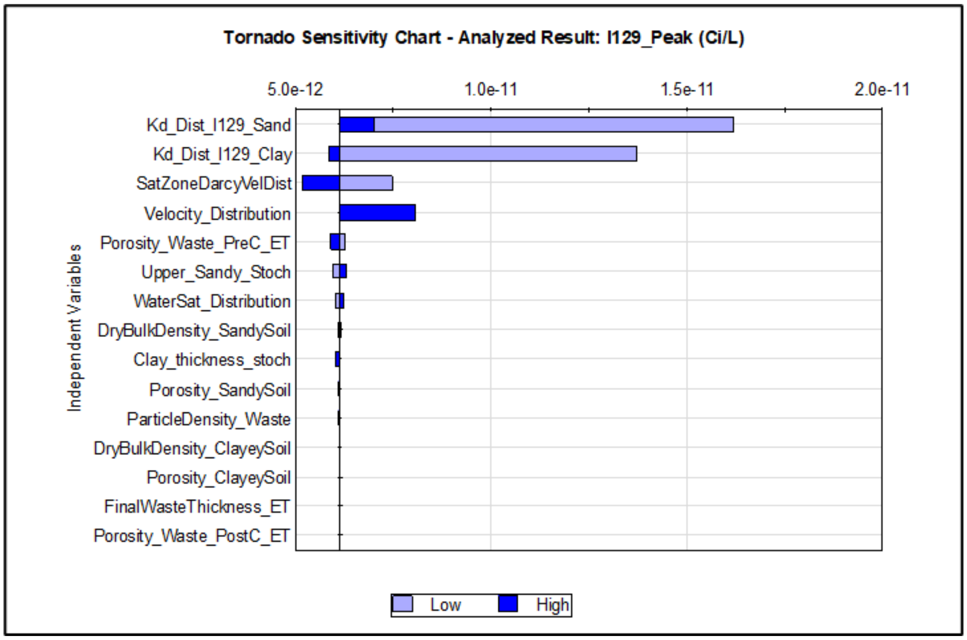


Figure 6-68. I-129 Maximum Concentration (Ci L^{-1} per gmole I-129 inventory) at 100-meter POA for ET06 Intact Case

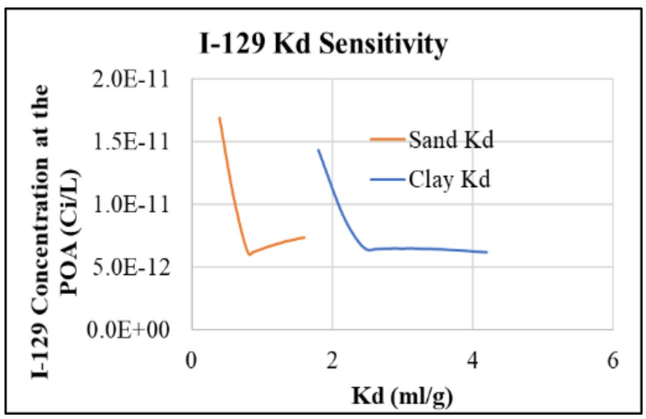


Figure 6-69. Sensitivity of I-129 Concentration (Ci L^{-1} per gmole I-129 inventory) at 100-meter POA to *K_d* for ET06 Intact Case

The Tornado plot for Np-237 peak concentration at the 100-meter POA is shown in Figure 6-70. As expected, the most-impactful stochastic parameter is the K_d for Np-237 in clayey soil. A change of 7.205 mL g^{-1} (lower bound of 5.395 mL g^{-1} to upper bound of 12.6 mL g^{-1} with a 50% value equal to 9 mL g^{-1}) yields a change in peak concentration of 1.79E-11 Ci L^{-1} per gmole Np-237 inventory, which is 47% of the deterministic peak concentration. The second most-impactful stochastic parameter is the Darcy velocity distribution for the saturated zone (SatZoneDarcyVelDist). A change of 0.36 (lower bound multiplier of 0.82 to upper bound multiplier of 1.18, with a 50% value of 1.0 yielding the deterministic nominal PA value) results in a change in concentration of 1.39E-11 Ci L^{-1} gmol^{-1}, which is 37% of the deterministic peak concentration. The next two most-impactful stochastic variables are the thickness of the clayey layer in the VZ (Clay_thickness_stoch) and the VZ velocity distribution (Velocity_Distribution), which result in changes in the Np-237 deterministic peak concentration of 18% and 13%, respectively.

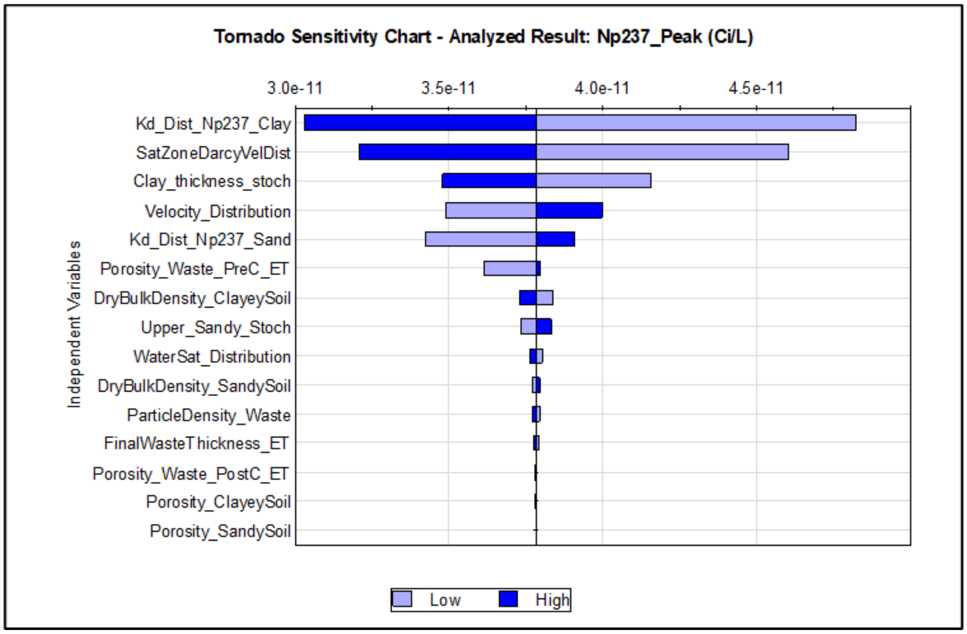


Figure 6-70. Np-237 Peak Concentration (Ci L^{-1} per gmole Np-237 inventory) at 100-meter POA for ET06 Intact Case

6.2.1.1.2. Subsidence Case

The stochastic sensitivity analysis is similar for every case; therefore, only the subsidence case results are discussed below. Additionally, only parameters with a correlation coefficient above an absolute value of 0.15 are shown because, below this value, little to no sensitivity exists. The coefficient of determination (R^2) represents the fraction of the total variance in peak concentration that can be explained based on a linear relationship to the stochastic variables. When R^2 is close to 1.0, the relationship between the result (concentration) and the variables (all stochastic variables) can be explained using a linear model. The lower the value of R^2, the more nonlinear the relationship. Three different values are listed in the stochastic sensitivity analysis: correlation coefficient, standardized regression coefficient, and partial correlation coefficient. The correlation coefficient ranges between –1 and 1 and expresses the extent to which there is a linear relationship between the selected result and the stochastic variable. The standardized regression coefficient ranges between –1 and 1 and provides a normalized measure of the linear relationship between variables and the result. These are the regression coefficients calculated when all the variables (and the result) are transformed and expressed in terms of the number of standard deviations away from their mean. Partial correlation coefficients vary between –1 and 1 and reflect the extent to which there is a linear relationship between the selected result and an input variable, after removing the effects of any linear relationships between the other input variables and both the result and the input variable in question. For systems where some of the input variables may be correlated, the partial correlation coefficients represent the unique contribution of each input to the result.

Table 6-146 presents the stochastic sensitivity analysis for ET06. These results are complementary to the Tornado plots generated by the deterministic sensitivity analysis, and the trends in coefficients are also consistent in most cases. The clayey soil K_d values for C-14, I-129, and Np-237 are the dominant stochastic variables displaying a strong negative relationship with peak concentration (note: K_d values for H-3 are set at a value of "small," which equals 1E-30 mL g^{-1}). The Darcy velocity multiplier coefficient for the saturated zone indicates that when the saturated zone velocity increases, peak concentration decreases. The clay thickness stochastic also displays a strong negative correlation. Clay thickness assumes a triangular distribution with a minimum and maximum of +/- 25% and a most-likely value equal to the best estimate value from PORFLOW. The VZ velocity multiplier shows a strong positive relationship with peak concentration; when the VZ velocity (infiltration rate) increases, the peak concentration increases.

Table 6-146. Stochastic Sensitivity Analysis for ET06

Stochastic Variable	Correlation Coefficient	Standardized Regression Coefficient	Partial Correlation Coefficient
H-3 R^2 = 0.984			
WaterSat_Distribution	-0.854	-0.848	-0.989
Velocity_Distribution	0.316	0.315	0.929
Porosity_Waste_PreC_ET	-0.296	-0.274	-0.909
SatZoneDarcyVelDist	-0.203	-0.23	-0.878
Clay_thickness_stoch	-0.172	-0.154	-0.775
C-14 R^2 = 0.970			
Kd_Dist[C] Clay	-0.727	-0.739	-0.973
SatZoneDarcyVelDist	-0.520	-0.546	-0.953
Clay_thickness_stoch	-0.275	-0.281	-0.85
Velocity_Distribution	0.242	0.26	0.83
I-129 R^2 = 0.515			
Kd_Dist[I] Clay	-0.450	-0.451	-0.541
Kd_Dist[I] Sand	-0.444	-0.440	-0.531
Velocity_Distribution	0.238	0.247	0.332
Clay_thickness_stoch	-0.195	-0.174	-0.241
Np-237 R^2 = 0.964			
Kd_Dist[Np] Clay	-0.689	-0.703	-0.965
SatZoneDarcyVelDist	-0.553	-0.581	-0.950
Clay_thickness_stoch	-0.268	-0.273	-0.820
Velocity_Distribution	0.189	0.210	0.741
Kd_Dist[Np] Sand	0.184	0.192	0.710

The lower value of R^2 for I-129 is indicative of a greater degree of nonlinearity in the relationship between the variables and I-129 concentration. This is likely due to the double peaks in the concentration curves (Figure 6-94). Depending on the distribution utilized during a realization, the peak can occur near Year 100 or Year 700 (the deterministic peak). This also explains the inconsistencies between the order of important variables observed in the tornado plots compared to the stochastic statistical coefficients, which assume a linear model.

The intact and subsidence cases show the same sensitivity trends for H-3 (Figure 6-71), C-14 (Figure 6-72), I-129 (Figure 6-73), and Np-237 (Figure 6-74) peak concentration.

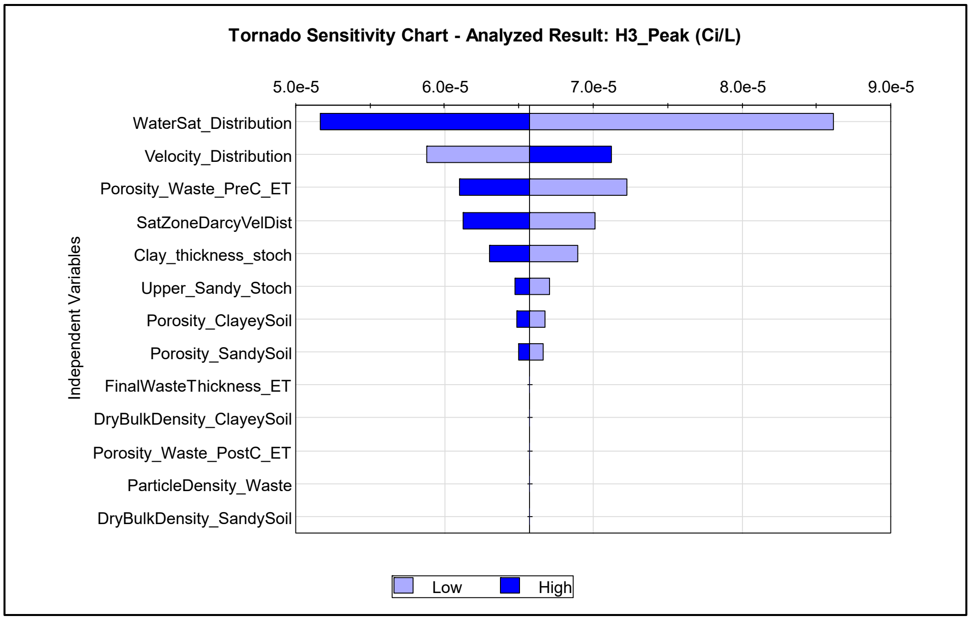


Figure 6-71. H-3 Peak Concentration (Ci L^{-1} per gmole H-3 inventory) at 100-meter POA for ET06 Subsidence Case

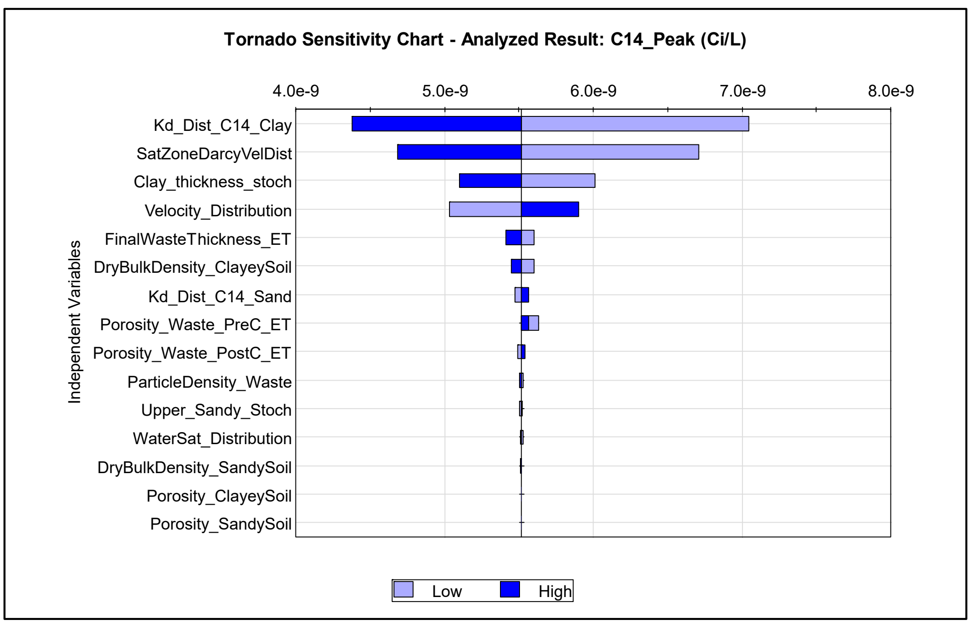


Figure 6-72. C-14 Peak Concentration (Ci L^{-1} per gmole C-14 inventory) at 100-meter POA for ET06 Subsidence Case

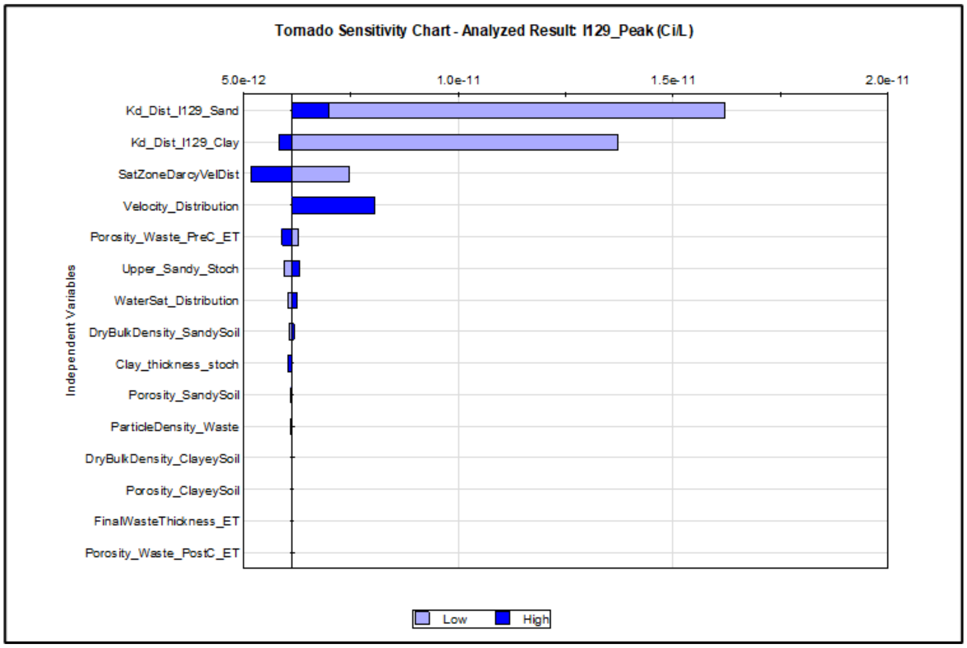


Figure 6-73. I-129 Peak Concentration (Ci L^{-1} per gmole I-129 inventory) at 100-meter POA for ET06 Subsidence Case

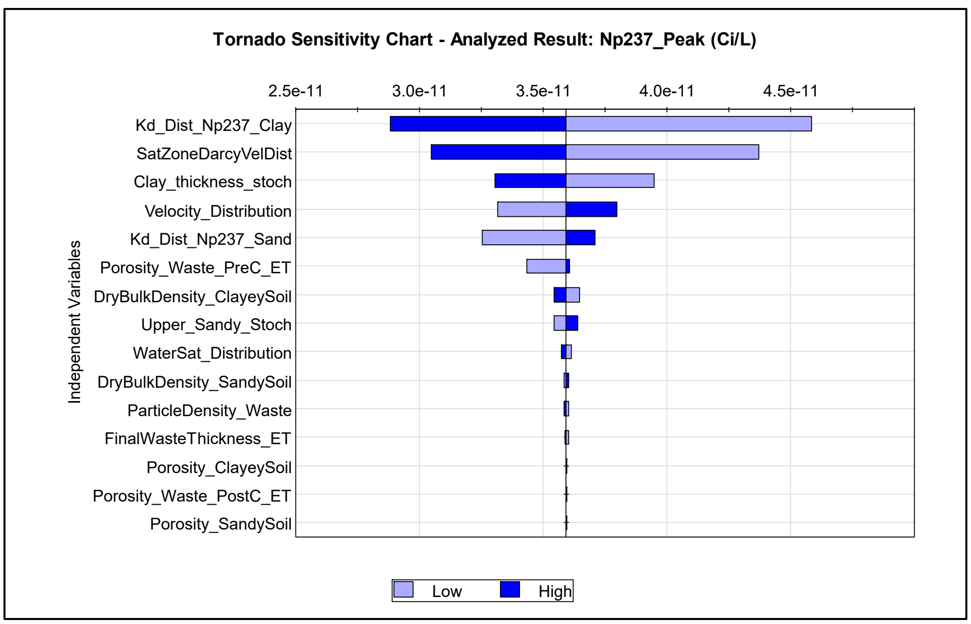


Figure 6-74. Np-237 Peak Concentration (Ci L^{-1} per gmole Np-237 inventory) at 100-meter POA for ET06 Subsidence Case

6.2.1.2. ST06

6.2.1.2.1. Intact Case

As shown in Figure 6-75, H-3 concentration is most sensitive to changes in the VZ velocity distribution (Velocity_Distribution). A change of 0.36 (lower bound of 0.8183 to upper bound of 1.182 with a 50% value of 1.0) produces a change of 2.36E-5 Ci L^{-1} gmol^{-1} in peak concentration, which is 27% of the deterministic peak H-3 concentration. The second most-impactful variable is VZ water saturation (WaterSat_Distribution). A change of 0.36 (lower bound of 0.8183 to upper bound of 1.182 with a 50% value of 1.0, which is the nominal PA velocity) results in a change in peak concentration of 2.22E-5 Ci L^{-1} $gmol^{-1}$, which is 25% of the deterministic peak H-3 concentration. The next two most-impactful stochastic variables are the Darcy velocity distribution for the saturated zone (SatZoneDarcyVelDist) and the stochastic parameter that varies the sandy thickness in the VZ (Upper_Sandy_Stoch). They account for changes in the deterministic peak concentration of 11% and 10%, respectively.

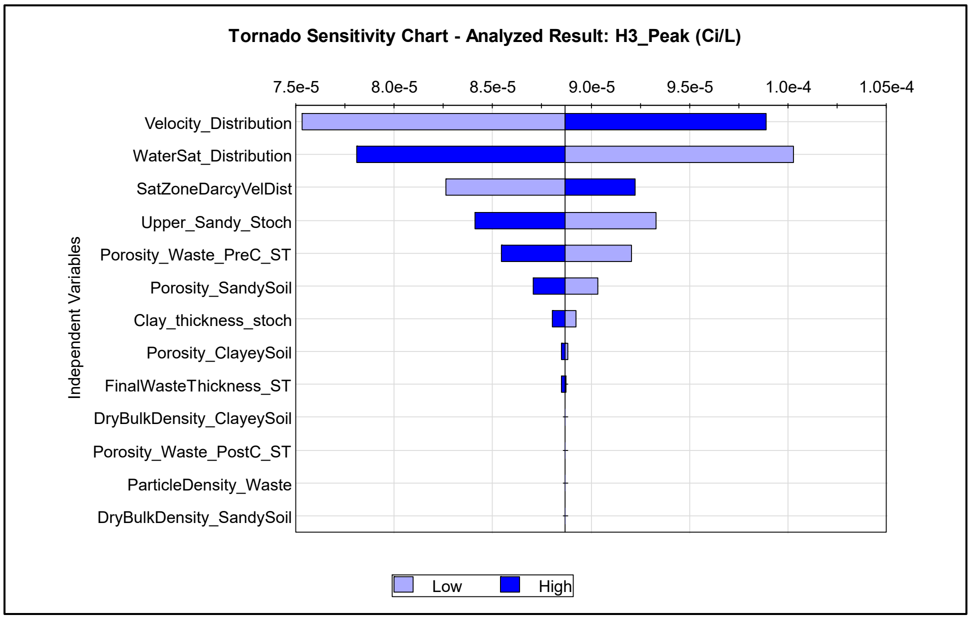


Figure 6-75. H-3 Peak Concentration (Ci L^{-1} per gmole H-3 inventory) at 100-meter POA for ST06 Intact Case

The Tornado plot for C-14 peak concentration at the 100-meter POA is displayed in Figure 6-76. As expected, the most-impactful stochastic parameter is the K_d for C-14 in clayey soils, where a change of 24.04 mL g^{-1} (lower bound of 17.98 mL g^{-1} to upper bound of 42.02 mL g^{-1} with a 50% value of 30 mL g^{-1}) results in a change in C-14 concentration of 4.66E-09 Ci L^{-1} $gmol^{-1}$, which is 68% of the deterministic peak concentration. The second most-impactful stochastic parameter is the Darcy velocity distribution for the saturated zone (SatZoneDarcyVelDist). A change of 0.36 (lower bound multiplier of 0.82 to upper bound multiplier of 1.18 with a 50% value of 1.0, which yields the deterministic nominal PA value) generates a change in peak concentration of 1.97E-09 Ci L^{-1} $gmol^{-1}$, which is 29% of the deterministic peak C-14 concentration. The next two most-impactful stochastic variables are the VZ velocity distribution (Velocity_Distribution), a multiplier applied to the velocity time-series elements, and the waste zone thickness after dynamic compaction (FinalWasteThickness_ST). They result in changes in the deterministic peak C-14 concentration of 20% and 19%, respectively. Variation in the K_d for C-14 in sandy soils produces only a 3% change in peak C-14 concentration for the K_d sensitivity range investigated (0.3992 lower bound to 1.601 mL g^{-1} upper bound). This is because of the relatively small K_d value for C-14 in sandy soil when compared to its K_d value for clayey soils (nominal value of 30 mL g^{-1}), which is the input parameter that peak C-14 concentration is most sensitive to at the 100-meter POA.

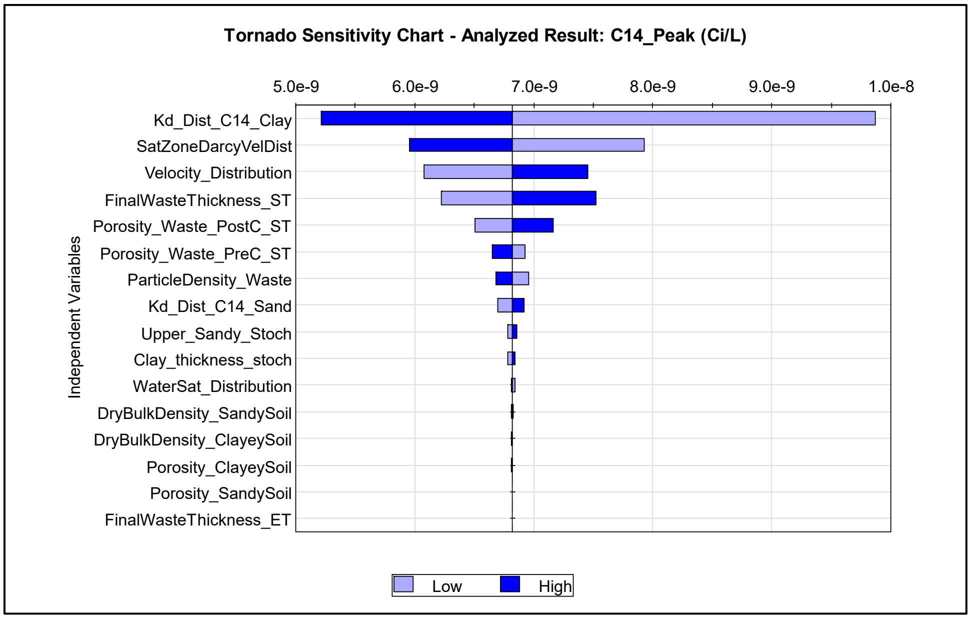


Figure 6-76. C-14 Peak Concentration (Ci L^{-1} per gmole C-14 inventory) at 100-meter POA for ST06 Intact Case

Figure 6-77 illustrates the sensitivity diagram for the peak I-129 concentration at the 100-meter POA. The stochastic multiplier applied to the Darcy velocity (SatZoneDarcyVelDist) for the saturated zone has the most significant impact on peak I-129 concentration. A change of 0.36 (lower bound multiplier of 0.82 to upper bound multiplier of 1.18 with a 50% value of 1.0, which yields the deterministic nominal PA value) produces a change in concentration of 3.91E-12 Ci L^{-1} $gmol^{-1}$, which is 34% of the deterministic peak I-129 concentration. The next two most-impactful stochastic variables are the sandy and clayey soil K_d values for I-129. A change in the sandy soil K_d (Kd_Dist_I129_Sand) of 1.202 mL g^{-1} (lower bound K_d of 0.399 to upper bound K_d of 1.601 mL g^{-1} with a 50% value of 1.0 mL g^{-1}) leads to a change in the peak I-129 concentration of 3.65E-12 Ci L^{-1} $gmol^{-1}$, which is 31% of the deterministic peak concentration. Only slightly less impactful is the K_d for clayey soil where a change of 2.404 mL g^{-1} (lower bound K_d of 1.798 mL g^{-1} to upper bound of 4.202 mL g^{-1} with a 50% value of 3 mL g^{-1}) results in a change in peak I-129 concentration of 3.57E-12 Ci L^{-1} $gmol^{-1}$, which is also 31% of the deterministic peak concentration. The fourth most-impactful parameter is the porosity of the waste before dynamic compaction, which produces a change in peak I-129 concentration that is 13% of the deterministic value.

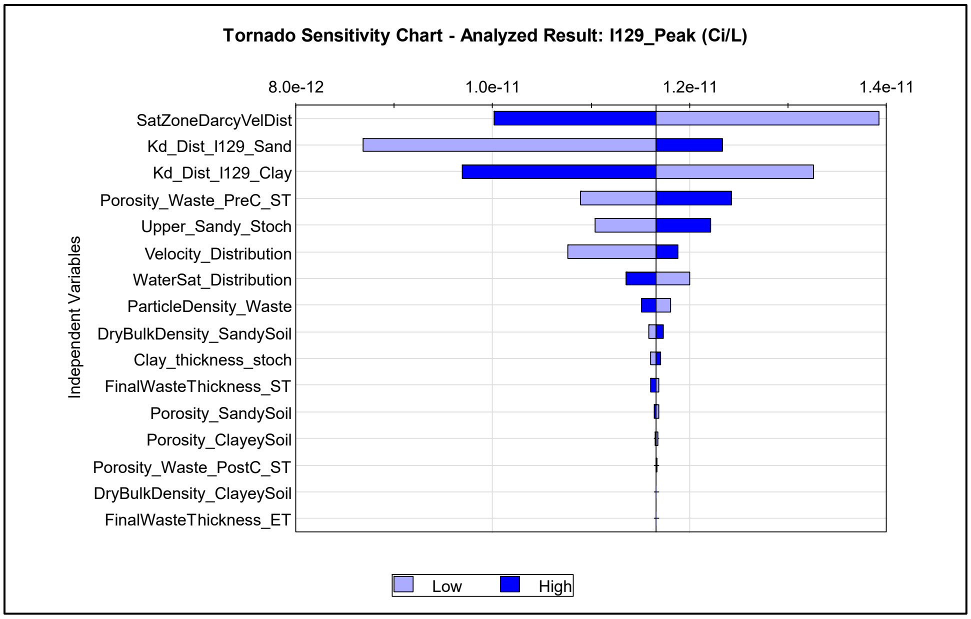


Figure 6-77. I-129 Peak Concentration (Ci L^{-1} per gmole I-129 inventory) at 100-meter POA for ST06 Intact Case

The Tornado plot for Np-237 peak concentration at the 100-meter POA is displayed in Figure 6-78. Again, the most-impactful stochastic parameter is the K_d for Np-237 in clayey soils. A change of 7.205 mL g^{-1} (lower bound of 5.395 mL g^{-1} to upper bound of 12.6 mL g^{-1} with a 50% of 9 mL g^{-1}) results in a change in peak Np-237 concentration of 2.50E-11 Ci L^{-1} $gmol^{-1}$, which is 48% of the deterministic peak concentration. The second most-impactful stochastic parameter is the Darcy velocity distribution for the saturated zone (SatZoneDarcyVelDist). A change of 0.36 (lower bound multiplier of 0.82 to upper bound multiplier of 1.18 with a 50% value of 1.0, which yields the deterministic nominal PA value) produces a change in concentration of 1.54E-11 Ci L^{-1} $gmol^{-1}$, which is 29% of the deterministic peak concentration. The next two most-impactful stochastic variables are the K_d for Np-237 in sandy soil and the VZ velocity distribution (Velocity_Distribution) which lead to changes in the deterministic peak Np-237 concentration of 16% and 14%, respectively.

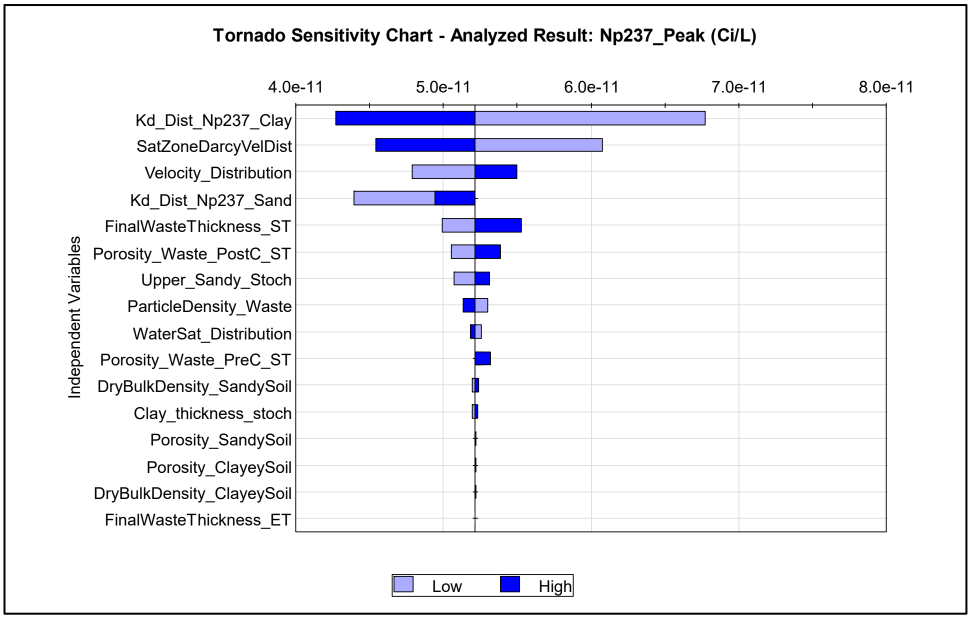


Figure 6-78. Np-237 Peak Concentration (Ci L^{-1} per gmole Np-237 inventory) at 100-meter POA for ST06 Intact Case

6.2.1.2.2. Subsidence Case

The stochastic sensitivity analysis is similar for every case; therefore, only the subsidence case results are discussed below. Again, only parameters with a correlation coefficient above an absolute value of 0.15 are shown because below this value, little to no sensitivity exists. Table 6-147 presents the stochastic sensitivity analysis for ST06. The results are complementary to the Tornado plots generated in the deterministic sensitivity analysis; the trends in coefficients are also consistent. The clayey soil K_d variables are the most dominant stochastic elements with respect to peak concentration, showing a strong negative relationship for C-14 and Np-237. The VZ velocity multiplier has a strong positive relationship (especially with H-3). When the VZ velocity (infiltration rate) increases, the peak concentration increases as well. The Darcy velocity multiplier for the saturated zone displays a strong negative relationship. When the saturated zone velocity increases, the peak concentration decreases. The porosity of the waste zone before dynamic compaction shows a negative relationship for H-3 but a positive relationship for I-129 and Np-237.

The intact and subsidence cases display the same sensitivity trends for the H-3 (Figure 6-79), C-14 (Figure 6-80), I-129 (Figure 6-81), and Np-237 (Figure 6-82) peak concentrations.

Table 6-147. Stochastic Sensitivity Analysis for ST06

Stochastic Variable	Correlation Coefficient	Standardized Regression Coefficient	Partial Correlation Coefficient
H-3 R^2 = 0.983			
Velocity_Distribution	0.654	0.633	0.979
WaterSat_Distribution	-0.63	-0.618	-0.978
SatZoneDarcyVelDist	0.302	0.255	0.888
Upper_Sandy_Stoch	-0.253	-0.263	-0.894
Porosity_Waste_PreC_ST	-0.192	-0.178	-0.803
C-14 R^2 = 0.956			
Kd_Dist[C]_Clay	-0.830	-0.833	-0.969
SatZoneDarcyVelDist	-0.351	-0.372	-0.870
FinalWasteThickness_ST	0.241	0.227	0.733
Velocity_Distribution	0.223	0.248	0.762
I-129 R^2 = 0.514			
Kd_Dist[I] Clay	-0.473	-0.471	-0.557
SatZoneDarcyVelDist	-0.404	-0.41	-0.504
Kd_Dist[I] Sand	0.234	0.228	0.31
Porosity_Waste_PreC_ST	0.175	0.173	0.239
Np-237 R^2 = 0.8965			
Kd_Dist[Np] Clay	-0.764	-0.774	-0.923
SatZoneDarcyVelDist	-0.443	-0.473	-0.825
Velocity_Distribution	0.221	0.24	0.596

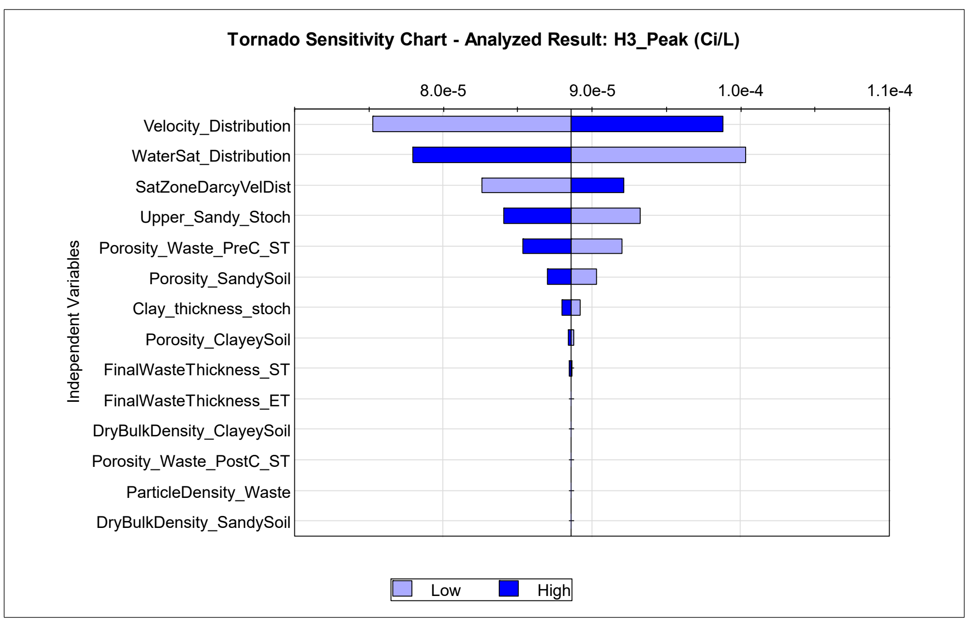


Figure 6-79. H-3 Peak Concentration (Ci L^{-1} per gmole H-3 inventory) at 100-meter POA for ST06 Subsidence Case

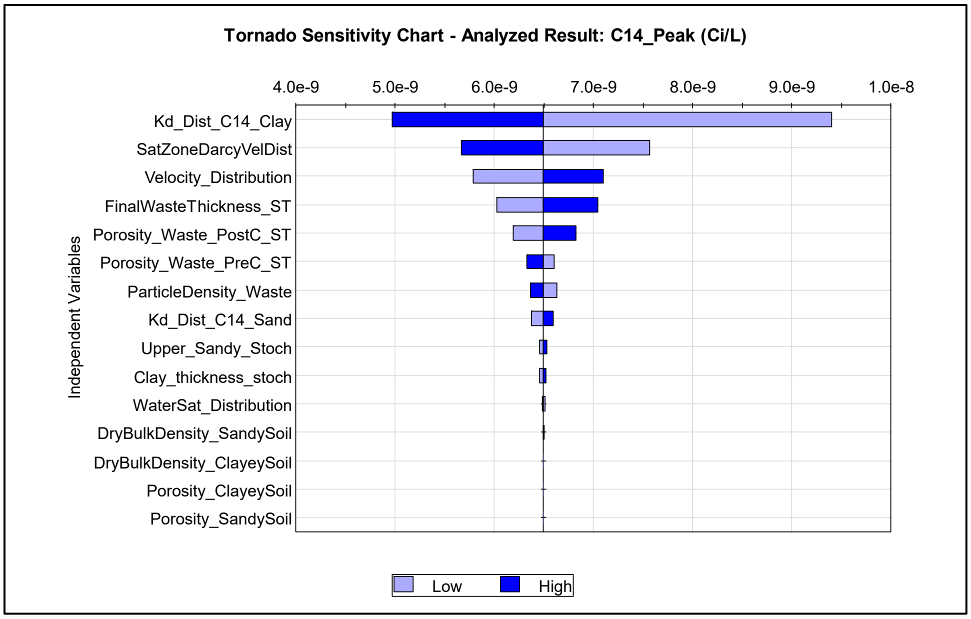


Figure 6-80. C-14 Peak Concentration (Ci L^{-1} per gmole C-14 inventory) at 100-meter POA for ST06 Subsidence Case

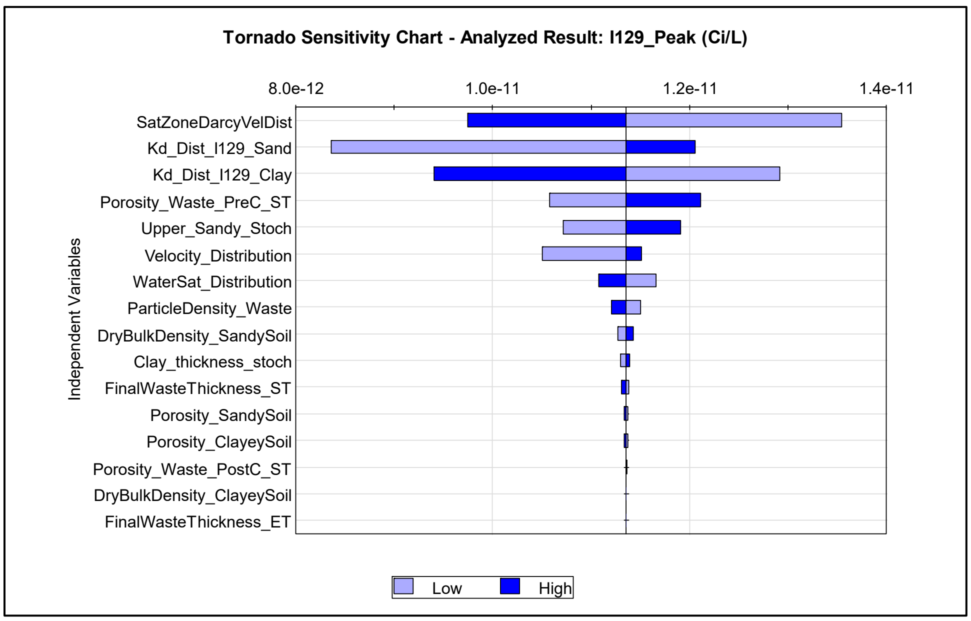


Figure 6-81. I-129 Peak Concentration (Ci L^{-1} per gmole I-129 inventory) at 100-meter POA for ST06 Subsidence Case

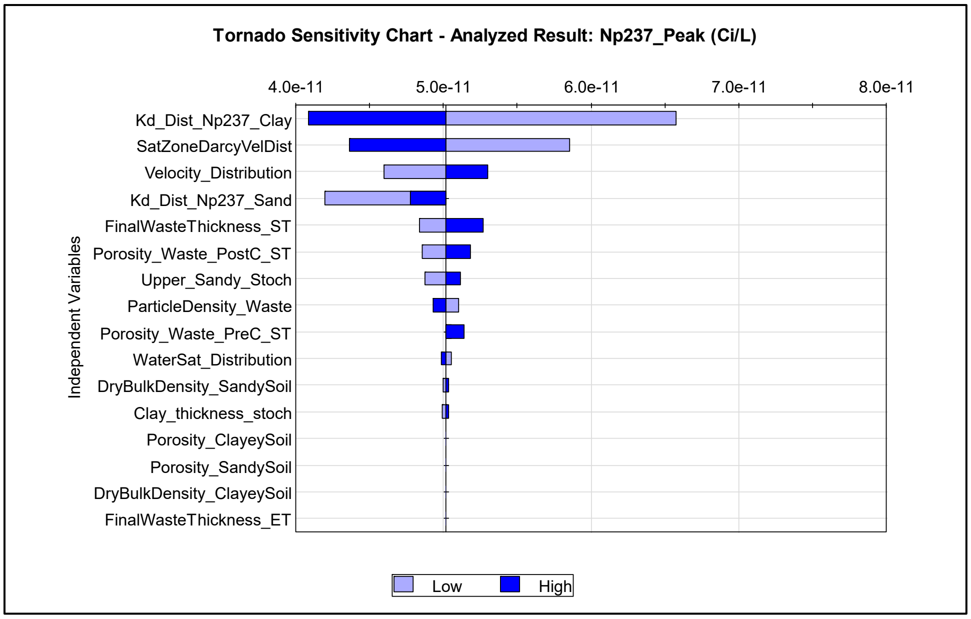


Figure 6-82. Np-237 Peak Concentration (Ci L^{-1} per gmole Np-237 inventory) at 100-meter POA for ST06 Subsidence Case

6.2.1.3. ST09

6.2.1.3.1. Intact Case

As shown in Figure 6-83, H-3 concentration is most sensitive to changes in the VZ velocity distribution (Velocity_Distribution) and the VZ water saturation (WaterSat_Distribution). A change of 0.36 (lower bound of 0.8183 to upper bound of 1.182 with a 50% of 1.0) produces a change in peak concentration of 6.28E-5 Ci L^{-1} $gmol^{-1}$, which is 49% of the deterministic peak H-3 concentration for both stochastic multipliers. The third most-impactful variable is the stochastic parameter that varies the sandy thickness in the VZ (Upper_Sandy_Stoch). A change of 12.62 meters (lower bound of 40.31 meters to upper bound of 27.69 meters with a 50% value of 34 meters, which is the nominal PA value) results in a change in peak concentration of 2.47E-5 Ci L^{-1} $gmol^{-1}$, which is 19% of the deterministic peak H-3 concentration. The next two most-impactful stochastic variables are the Darcy velocity distribution for the saturated zone (SatZoneDarcyVelDist) and the porosity of the waste zone before dynamic compaction (Porosity_Waste_PreC_ST). Variation in these two parameters leads to a change in the deterministic peak concentration of 15% and 11%, respectively.

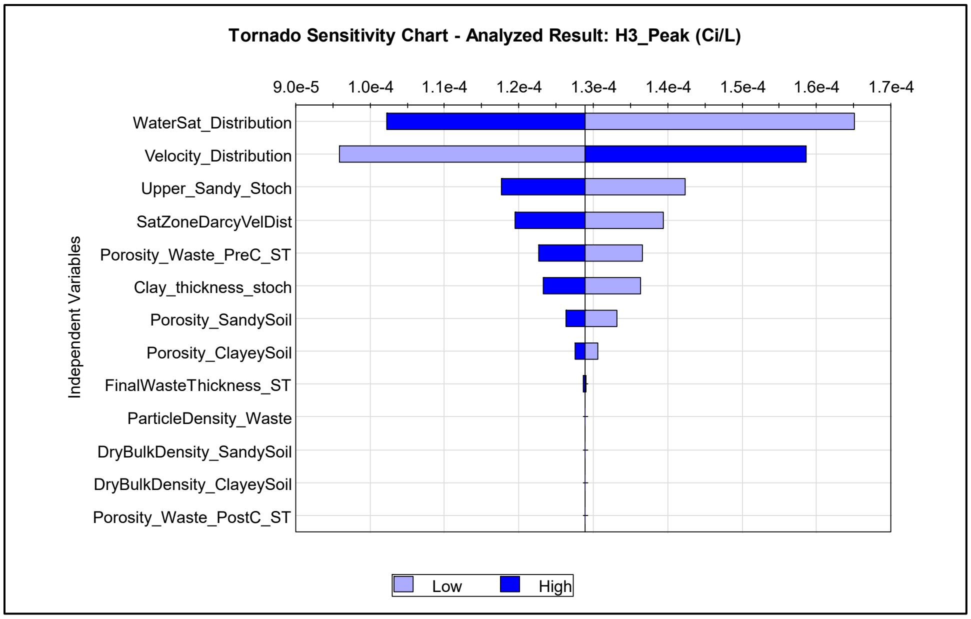


Figure 6-83. H-3 Peak Concentration (Ci L^{-1} per gmole H-3 inventory) at 100-meter POA for ST09 Intact Case

The Tornado chart for C-14 peak concentration at the 100-meter POA is given in Figure 6-84. As for ST06 and ET06, the most-impactful stochastic parameter is the K_d for C-14 in clayey soil. A change of 24.04 mL g^{-1} (lower bound of 17.98 mL g^{-1} to upper bound of 42.02 mL g^{-1} with a 50% value of 30 mL g^{-1}) generates a change in peak concentration of 4.49E-09 Ci L^{-1} $gmol^{-1}$, which is 68% of the deterministic peak concentration. The second most-impactful stochastic parameter is the Darcy velocity distribution for the saturated zone (SatZoneDarcyVelDist). A change of 0.36 (lower bound multiplier of 0.82 to upper bound multiplier of 1.18 with a 50% value of 1.0, which yields the deterministic nominal PA value) results in a change in peak concentration of 2.45E-09 Ci L^{-1} $gmol^{-1}$, which is 37% of the deterministic peak concentration. The next two most-impactful stochastic variables are the VZ velocity distribution (Velocity_Distribution) and the thickness of the clay layer in the vadose zone (Clay_thickness_stoch). Variation in these two parameters leads to a change in the deterministic peak concentration of 27% and 13%, respectively.

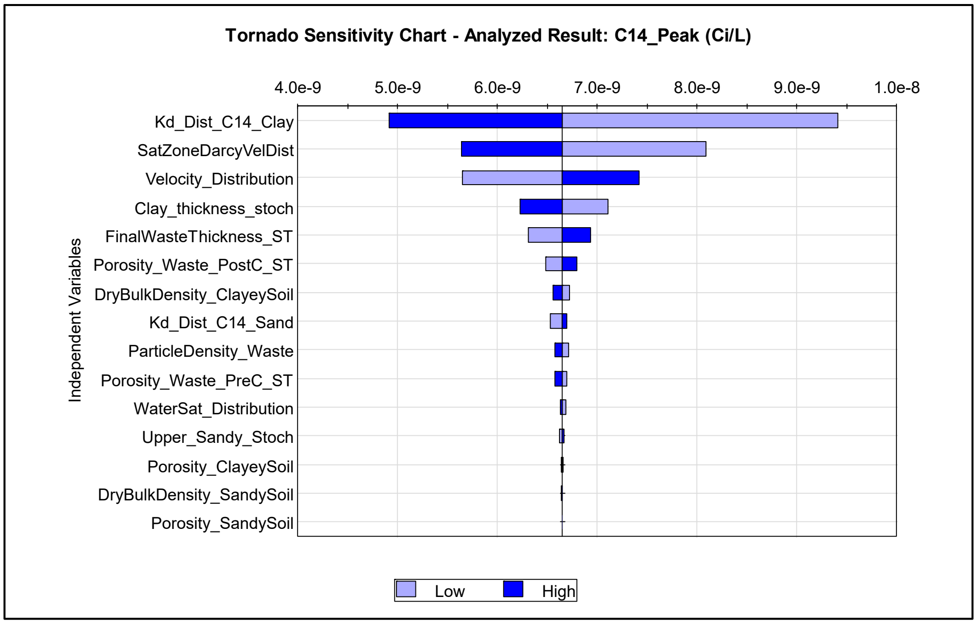


Figure 6-84. C-14 Peak Concentration (Ci L^{-1} per gmole C-14 inventory) at 100-meter POA for ST09 Intact Case

Figure 6-85 illustrates the sensitivity diagram for peak I-129 concentration at the 100-meter POA. The K_d value for I-129 in clayey soil is the most-impactful stochastic parameter. A change of 2.404 mL g^{-1} (lower bound of 1.798 mL g^{-1} to upper bound of 4.202 mL g^{-1} with a 50% value of 3 mL g^{-1}) results in a change in peak I-129 concentration of 4.48E-12 Ci L^{-1} $gmol^{-1}$ which is 38% of the deterministic value. The second most-impactful stochastic value is the multiplier applied to the saturated zone Darcy velocity (SatZoneDarcyVelDist). A change of 0.36 (lower bound multiplier of 0.82 to upper bound multiplier of 1.18 with a 50% value of 1.0, which yields the deterministic nominal PA value) generates a change in concentration of 4.39E-12 Ci L^{-1} $gmol^{-1}$, which is 37% of the deterministic peak concentration. The next two most-impactful stochastic variables are the sandy soil K_d for I-129 and the velocity distribution in the VZ. A change in the sandy soil K_d (Kd_Dist_I129_Sand) of 1.202 mL g^{-1} (lower bound K_d of 0.399 to upper bound K_d of 1.601 mL g^{-1} with a 50% value of 1 mL g^{-1}) leads to a change in peak concentration of 2.30E-12 Ci L^{-1} $gmol^{-1}$, which is 19% of the deterministic peak concentration. Only slightly less impactful is the velocity distribution in the VZ where a change of 0.36 (lower bound multiplier of 0.818 mL g^{-1} to upper bound of 1.182 mL g^{-1} with a 50% value of 1 mL g^{-1}) results in a change in concentration of 2.03E-12 Ci L^{-1} $gmol^{-1}$, which is 17% of the deterministic peak I-129 concentration.

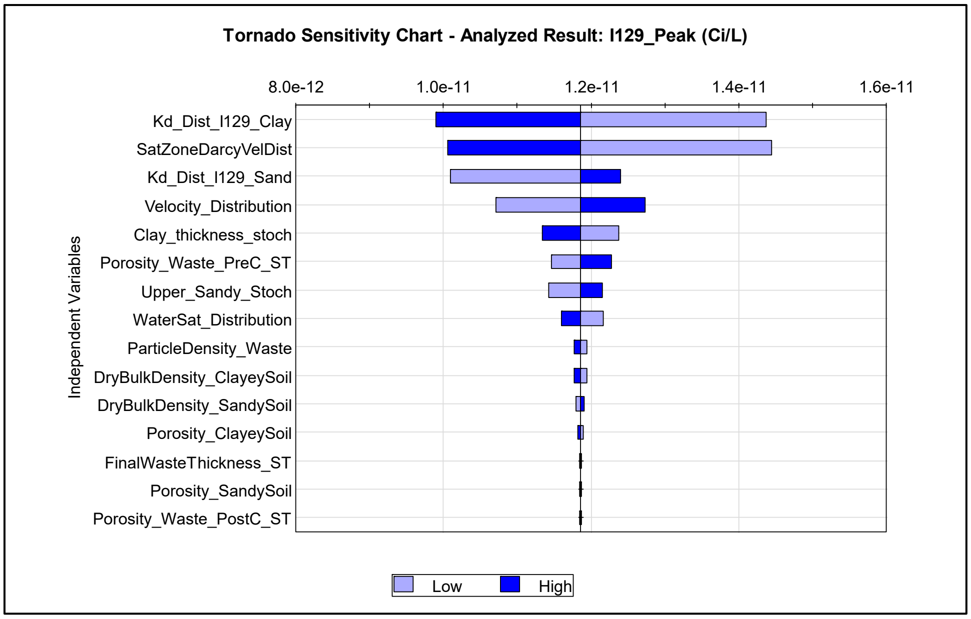


Figure 6-85. I-129 Peak Concentration (Ci L^{-1} per gmole I-129 inventory) at 100-meter POA for ST09 Intact Case

The Tornado plot for Np-237 peak concentration at the 100-meter POA is shown in Figure 6-86. The most-impactful stochastic parameter is the K_d for Np-237 in clayey soil. A change of 7.205 mL g^{-1} (lower bound of 5.395 mL g^{-1} to upper bound of 12.6 mL g^{-1} with a 50% of 9 mL g^{-1}) produces a change in peak concentration of 2.68E-11 Ci L^{-1} $gmol^{-1}$, which is 54% of the deterministic peak concentration. The second most-impactful stochastic parameter is the Darcy velocity distribution for the saturated zone (SatZoneDarcyVelDist). A change of 0.36 (lower bound multiplier of 0.82 to upper bound multiplier of 1.18 with a 50% value of 1.0, which yields the deterministic nominal PA value) results in a change in peak Np-237 concentration of 1.79E-11 Ci L^{-1} $gmol^{-1}$, which is 36% of the deterministic peak concentration. The next two most-impactful stochastic variables are the VZ velocity distribution (Velocity_Distribution) and VZ clayey layer thickness (Clay_thickness_stoch). Variation in these two parameters leads to a change in the deterministic peak concentration of 23% and 11%, respectively.

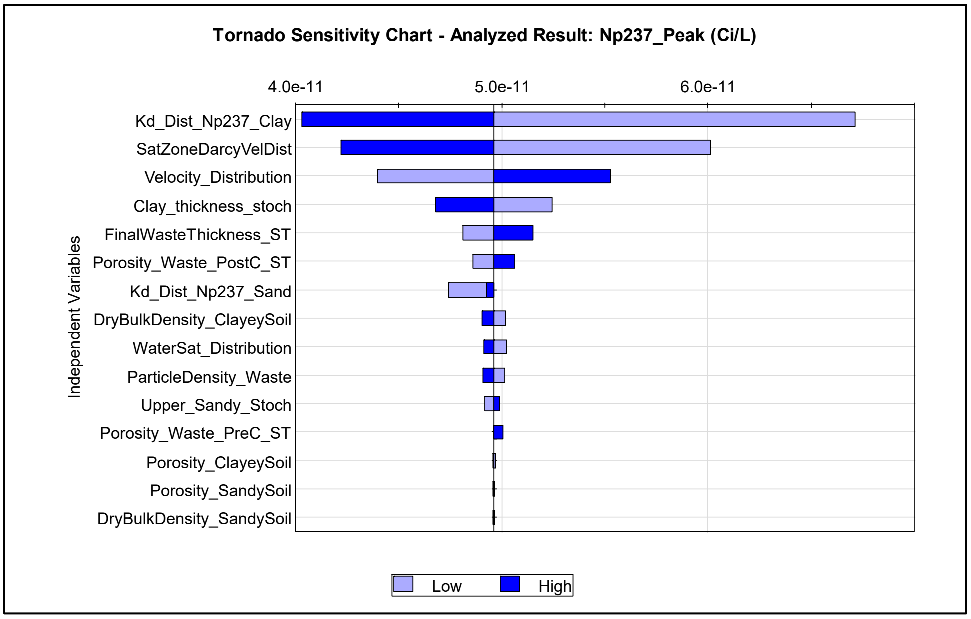


Figure 6-86. Np-237 Peak Concentration (Ci L^{-1} per gmole Np-237 inventory) at 100-meter POA for ST09 Intact Case

6.2.1.3.2. Subsidence Case

The stochastic sensitivity analysis is similar for every case; therefore, only the subsidence case results are discussed. Also, only parameters with a correlation coefficient above an absolute value of 0.15 are shown because below this value, little to no sensitivity exists. Table 6-148 presents the stochastic sensitivity analysis for ST09. The results are complementary to the Tornado charts generated by the deterministic sensitivity analysis. The trends in coefficients are consistent as well. The assumed K_d values for clayey soil are the predominant stochastic parameters for ST09, displaying a strong negative correlation with peak concentration for C-14, I-129, and Np-237 (H-3 K_d values are set at a "small" value, which is 1E-30 mL g^{-1}.). The Darcy velocity multiplier for the saturated zone also indicates a strong negative relationship with peak concentration. When saturated zone velocity increases, peak concentration decreases. The clay thickness stochastic displays a somewhat weaker, negative relationship. Clay thickness assumes a triangular distribution with a minimum and maximum of +/- 25% and a most-likely value that is the best estimate value from PORFLOW. The VZ velocity multiplier has a strong, positive relationship with H-3 peak concentration. When the VZ velocity (infiltration rate) increases, the peak H-3 concentration also increases. In addition, the H-3 peak concentration displays a strong, negative relationship with the VZ water saturation multiplier, where the peak concentration decreases as saturation increases.

The intact and subsidence cases show the same sensitivity trends for the H-3 (Figure 6-87), C-14 (Figure 6-88), I-129 (Figure 6-89), and Np-237 (Figure 6-90) peak concentrations.

Table 6-148. Stochastic Sensitivity Analysis for ST09

Stochastic Variable	Correlation Coefficient	Standardized Regression Coefficient	Partial Correlation Coefficient
H-3 R^2 = 0.994			
WaterSat_Distribution	-0.652	-0.645	-0.993
Velocity_Distribution	0.648	0.656	0.993
Upper_Sandy_Stoch	-0.249	-0.26	-0.959
SatZoneDarcyVelDist	-0.163	-0.212	-0.94
Clay_thickness_stoch	-0.157	-0.137	-0.871
Porosity_Waste_PreC_ST	-0.155	-0.145	-0.883
C-14 R^2 = 0.965			
Kd_Dist[C] Clay	-0.783	-0.79	-0.972
SatZoneDarcyVelDist	-0.413	-0.439	-0.918
Velocity_Distribution	0.317	0.342	0.875
Clay_thickness_stoch	-0.192	-0.183	-0.694
I-129 R^2 = 0.965			
Kd_Dist[I] Clay	-0.618	-0.617	-0.957
SatZoneDarcyVelDist	-0.6	-0.609	-0.956
Kd_Dist[I] Sand	0.334	0.334	0.873
Velocity_Distribution	0.225	0.258	0.81
Np-237 R^2 = 0.949			
Kd_Dist[Np] Clay	-0.741	-0.751	-0.957
SatZoneDarcyVelDist	-0.483	-0.518	-0.916
Velocity_Distribution	0.318	0.336	0.828
Clay_thickness_stoch	-0.156	-0.153	-0.558

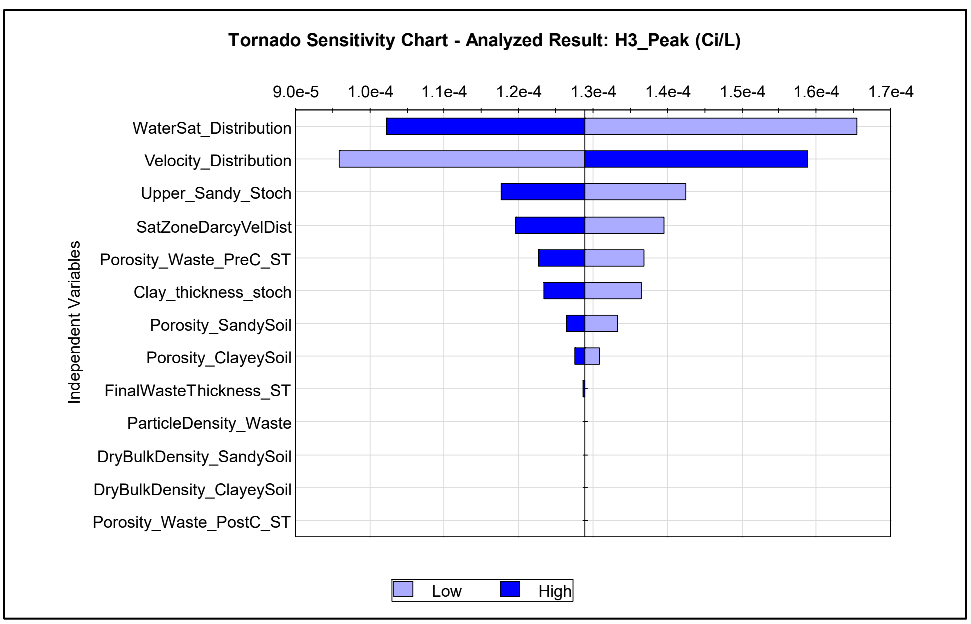


Figure 6-87. H-3 Peak Concentration (Ci L^{-1} per gmole H-3 inventory) at 100-meter POA for ST09 Subsidence Case

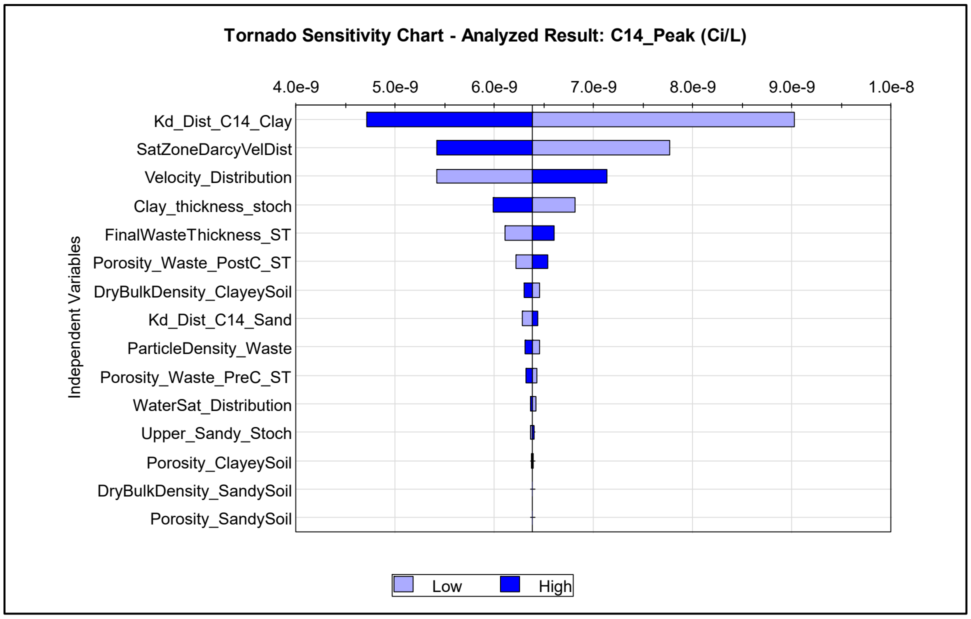


Figure 6-88. C-14 Peak Concentration (Ci L^{-1} per gmole C-14 inventory) at 100-meter POA for ST09 Subsidence Case

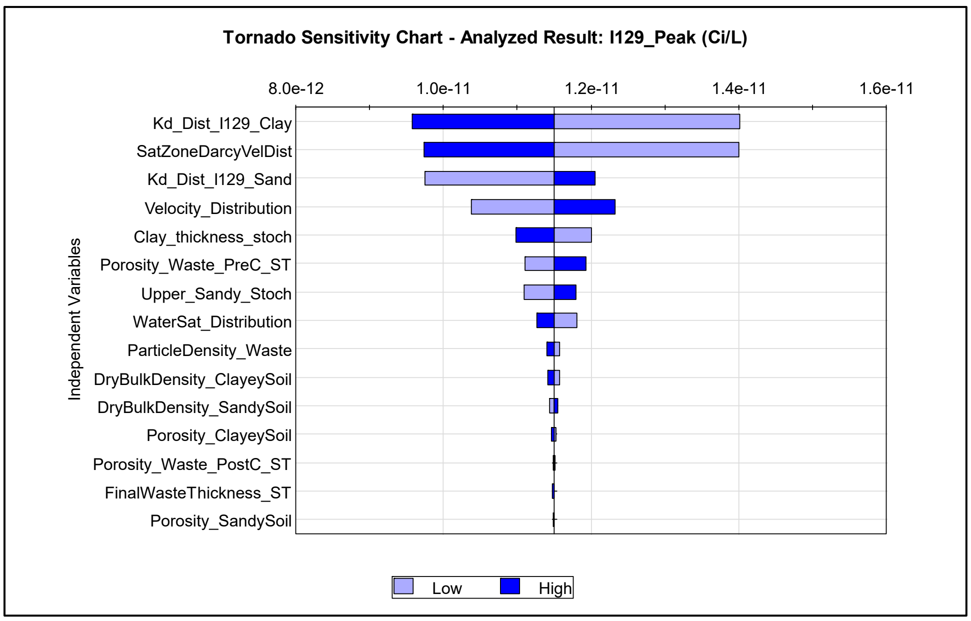


Figure 6-89. I-129 Peak Concentration (Ci L^{-1} per gmole I-129 inventory) at 100-meter POA for ST09 Subsidence Case

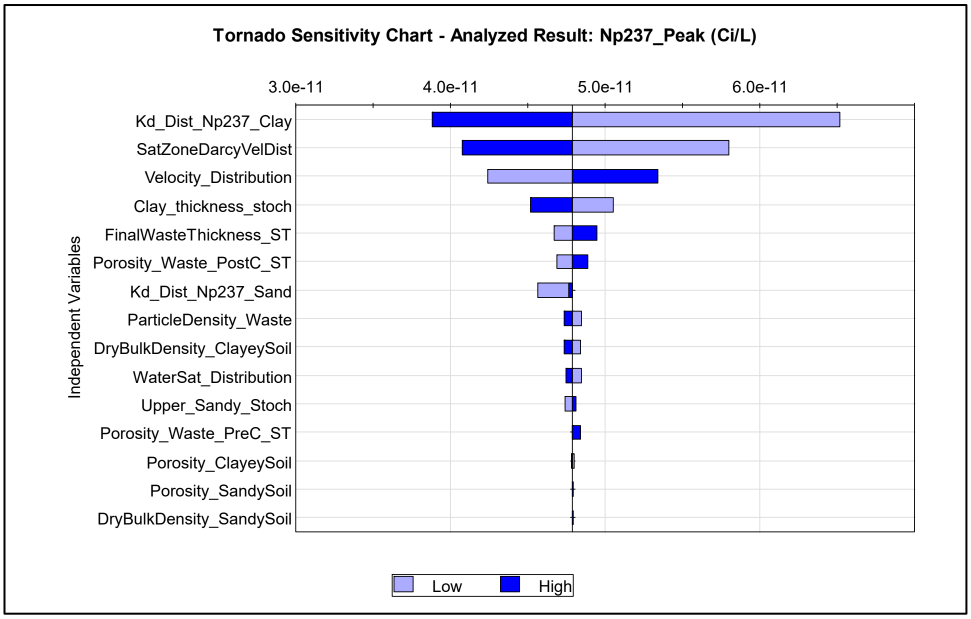


Figure 6-90. Np-237 Peak Concentration (Ci L^{-1} per gmole Np-237 inventory) at 100-meter POA for ST09 Subsidence Case

6.2.2. GoldSim® Trench Model Uncertainty Quantification Analysis

The ultimate objective of GoldSim® modeling is to characterize the uncertainty in radionuclide concentrations at the 100-meter POA by performing Monte Carlo stochastic calculations. Uncertainty analyses with the GoldSim® models is conducted utilizing 3,000 realizations with Latin Hypercube Sampling. This sampling approach discretizes the chosen distribution into 3,000 equally spaced bands. For each stochastic element, its bands are randomly shuffled and a random value within each band is picked. Applying Latin Hypercube Sampling ensures that the probability space is uniformly covered, which effectively minimizes the number of realizations needed.

Probabilistic results for the GoldSim® Trench System Model are employed to capture the overall uncertainty manifested in model input distributions. This analysis is not intended to quantify conceptual model uncertainty or uncertainty induced by model structure. Uncertainty analysis is concerned with how the uncertainty in model input parameters propagates through the model to influence the concentration profiles of the radionuclides that were successfully calibrated to the PORFLOW nominal PA deterministic results. Built-in modeling biases between the multidimensional PORFLOW models and the 1-D GoldSim® models are not explicitly addressed.

6.2.2.1. ET06

Uncertainty quantification results showing the statistics for peak radionuclide concentration are summarized in Table 6-149 for the simulated duration of the model (3,000 years). In addition to the statistical information, the deterministic nominal PA peaks predicted by the PORFLOW and GoldSim® models are provided for comparison. For both cases (intact and subsidence), two separate Monte Carlo simulations are performed: one where geometric parameters relating to hydrostratigraphy (VZ clayey and sandy soil thicknesses) and the final waste thickness after dynamic compaction are stochastically varied, and a second where only material properties and

Darcy velocities are stochastically varied. Although the hydrostratigraphic layer thicknesses and final waste thickness are well-known quantities, including these stochastic parameters in the uncertainty analysis is important because the trenches investigated are meant to be representative of the remaining trenches in the ELLWF. Table 6-149 lists the peak concentrations across the entire simulation period.

Table 6-149. Summary Statistics of Peak Concentrations (Ci L^{-1} per gmole inventory) at 100-meter POA for ET06

Statistic	C-14	H-3	I-129	Np-237
	Ci L^{-1} per gmole inventory			
Intact Case Including Geometric Stochastic Uncertainty				
Mean	4.87E-09	6.55E-05	5.14E-12	2.76E-11
95th Percentile	7.20E-09	8.71E-05	7.58E-12	4.43E-11
Median	5.09E-09	6.63E-05	5.50E-12	2.91E-11
5th Percentile	2.36E-09	4.84E-05	1.95E-12	7.09E-12
75th Percentile	5.93E-09	7.41E-05	6.38E-12	3.55E-11
90th Percentile	6.70E-09	8.25E-05	7.09E-12	4.11E-11
Nominal PA (GoldSim®)	5.87E-09	6.92E-05	6.46E-12	3.79E-11
Nominal PA (PORFLOW)	6.39E-09	5.71E-05	6.58E-12	4.89E-11
Intact Case Not Including Geometric Stochastic Uncertainty				
Mean	5.01E-09	6.57E-05	5.22E-12	2.79E-11
95th Percentile	7.32E-09	8.66E-05	7.58E-12	4.39E-11
Median	5.19E-09	6.63E-05	5.62E-12	2.96E-11
5th Percentile	2.66E-09	4.88E-05	2.11E-12	7.81E-12
75th Percentile	6.01E-09	7.41E-05	6.39E-12	3.56E-11
90th Percentile	6.80E-09	8.23E-05	7.14E-12	4.09E-11
Nominal PA (GoldSim®)	5.87E-09	6.92E-05	6.46E-12	3.79E-11
Nominal PA (PORFLOW)	6.39E-09	5.71E-05	6.58E-12	4.89E-11
Subsidence Case Including Geometric Stochastic Uncertainty				
Mean	4.69E-09	6.24E-05	4.86E-12	2.62E-11
95th Percentile	6.90E-09	8.30E-05	7.20E-12	4.21E-11
Median	4.92E-09	6.32E-05	5.18E-12	2.77E-11
5th Percentile	2.31E-09	4.61E-05	1.91E-12	6.74E-12
75th Percentile	5.67E-09	7.06E-05	6.02E-12	3.38E-11
90th Percentile	6.42E-09	7.86E-05	6.75E-12	3.91E-11
Nominal PA (GoldSim®)	5.61E-09	6.59E-05	6.14E-12	3.60E-11
Nominal PA (PORFLOW)	6.16E-09	5.71E-05	6.19E-12	4.66E-11
Subsidence Case Not Including Geometric Stochastic Uncertainty				
Mean	4.8E-09	6.26E-05	4.96E-12	2.66E-11
95th Percentile	6.97E-09	8.25E-05	7.28E-12	4.17E-11
Median	4.96E-09	6.32E-05	5.34E-12	2.81E-11
5th Percentile	2.58E-09	4.65E-05	2.01E-12	7.42E-12
75th Percentile	5.74E-09	7.06E-05	6.07E-12	3.38E-11
90th Percentile	6.48E-09	7.84E-05	6.78E-12	3.89E-11
Nominal PA (GoldSim®)	5.61E-09	6.59E-05	6.14E-12	3.60E-11
Nominal PA (PORFLOW)	6.16E-09	5.71E-05	6.19E-12	4.66E-11

Notes:

The Nominal PA case results are highlighted in orange to facilitate comparison between the GoldSim® and PORFLOW models.

Table 6-150 gives the percent difference in the 95th-percentile peak concentrations at the 100-meter POA for ET06 compared to the PORFLOW nominal PA results. The table also lists the increase (negative %) or decrease (positive %) in the 95th-percentile peak concentrations relative to the PORFLOW nominal PA peak concentration. Most radionuclides display a 13% to 53% higher (negative % difference) peak concentration at the 95th percentile when compared to the PORFLOW value. The 95th-percentile peak concentration of Np-237, on the other hand, is 8% to 11% lower than the PORFLOW nominal PA peak concentration in both the intact and subsidence cases.

Table 6-150. Percent Difference of 95th-Percentile Peak Concentrations (Ci L^{-1} per gmole inventory) at 100-meter POA for ET06 Compared to PORFLOW Nominal PA Results

Case	C-14	H-3	I-129	Np-237
Intact with Geometric Parameters	-13%	-53%	-15%	9%
Intact without Geometric Parameters	-15%	-52%	-15%	10%
Subsidence with Geometric Parameters	-12%	-45%	-16%	10%
Subsidence without Geometric Parameters	-13%	-44%	-18%	11%

Notes: A negative value indicates an increase in the 95th-percentile peak concentration from GoldSim® relative to the nominal PA peak concentration from the PORFLOW deterministic model. Conversely, a positive value indicates a decrease in the 95th-percentile peak concentration from GoldSim® relative to the nominal PA peak concentration from PORFLOW.

Focusing on GoldSim®-generated results only, a similar metric can be computed for the overall impact associated with model parameter uncertainties. Table 6-151 provides the percent increase in peak concentration for each radionuclide (i.e., the increase from the mean value to the 95th-percentile value). As indicated in Table 6-151, the overall average impact is ~21%.

Table 6-151. Percent Difference of 95th-Percentile Peak Concentrations (Ci L^{-1} per gmole inventory) at 100-meter POA for ET06 Compared to GoldSim® Nominal PA Results

Case	C-14	H-3	I-129	Np-237	Avg
Intact with Geometric Parameters	23%	26%	17%	17%	21%
Intact without Geometric Parameters	25%	25%	17%	16%	22%
Subsidence with Geometric Parameters	23%	26%	17%	17%	21%
Subsidence without Geometric Parameters	24%	25%	19%	16%	22%

6.2.2.1.1. Intact Case

Figure 6-91 and Figure 6-92 present the statistical time histories for radionuclide concentration at the 100-meter POA when not including and including the geometric parameters in the uncertainty analysis, respectively. In addition to the 5th, 25th, mean, 50th (median), 75th, 90th, and 95th percentiles, the deterministic PORFLOW model and stochastic GoldSim® model results used during benchmarking are also shown. For all radionuclides investigated in the uncertainty quantification analysis, the 5th- and 95th-percentile peak concentrations are below and above the mean values, respectively. C-14, H-3, and I-129 display 95th-percentile peaks that are higher than the PORFLOW benchmarking peak. C-14 has a 95th-percentile profile that drops below the PORFLOW concentration profile at approximately 1,900 years, while the Np-237 95th-percentile peak concentration is 8% to 11% lower than the PORFLOW peak because of an initial benchmarking underestimation. In all cases, the mean value is only slightly less than the median.

Including the geometric parameters in the uncertainty analysis results in only slightly lower peak concentrations when compared to not stochastically varying the geometric parameters.

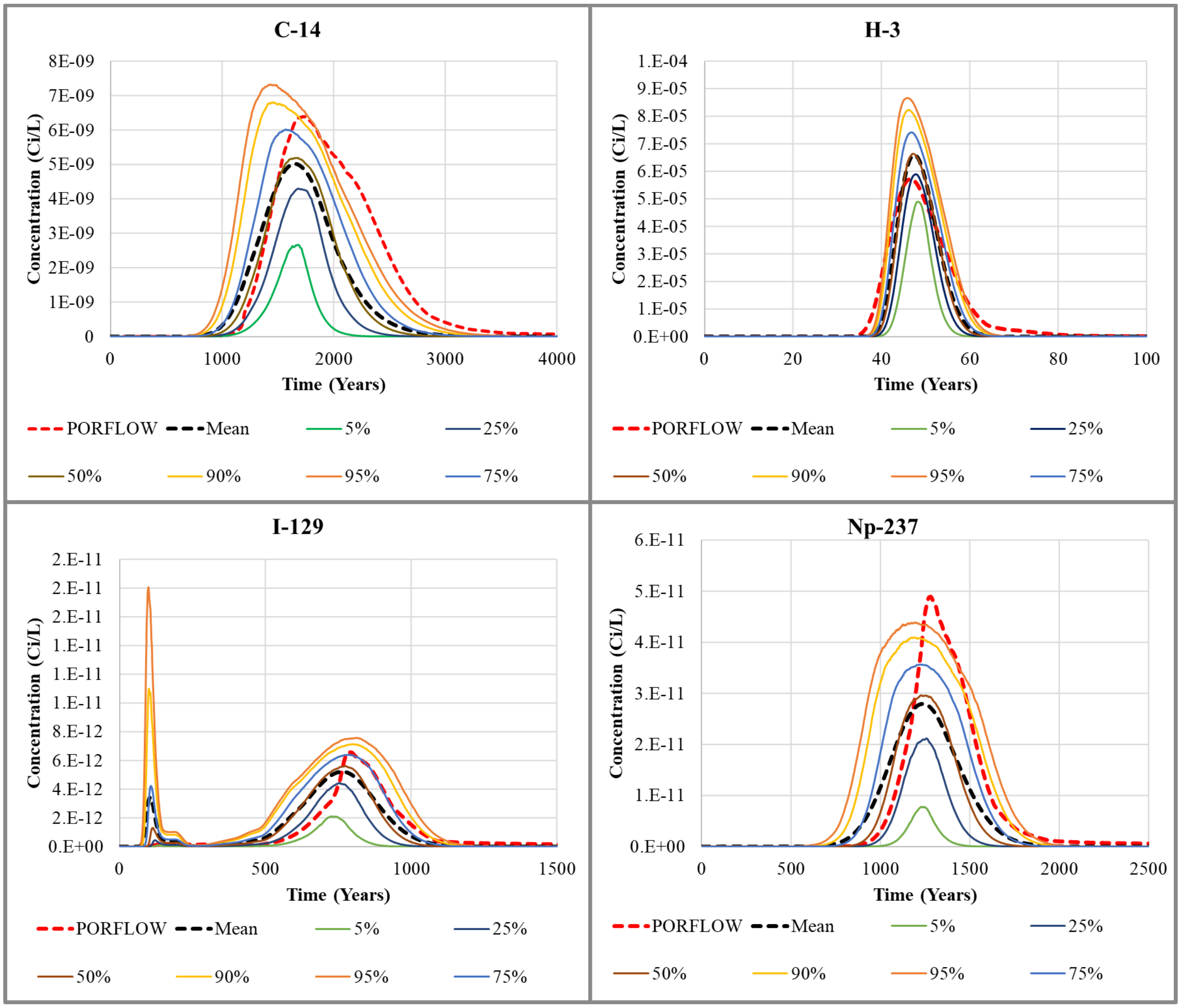


Figure 6-91. Intact Case Uncertainty Statistics for Concentration (Ci L^{-1} per gmole inventory) at 100-meter POA for ET06 (excluding geometric parameter stochastics)

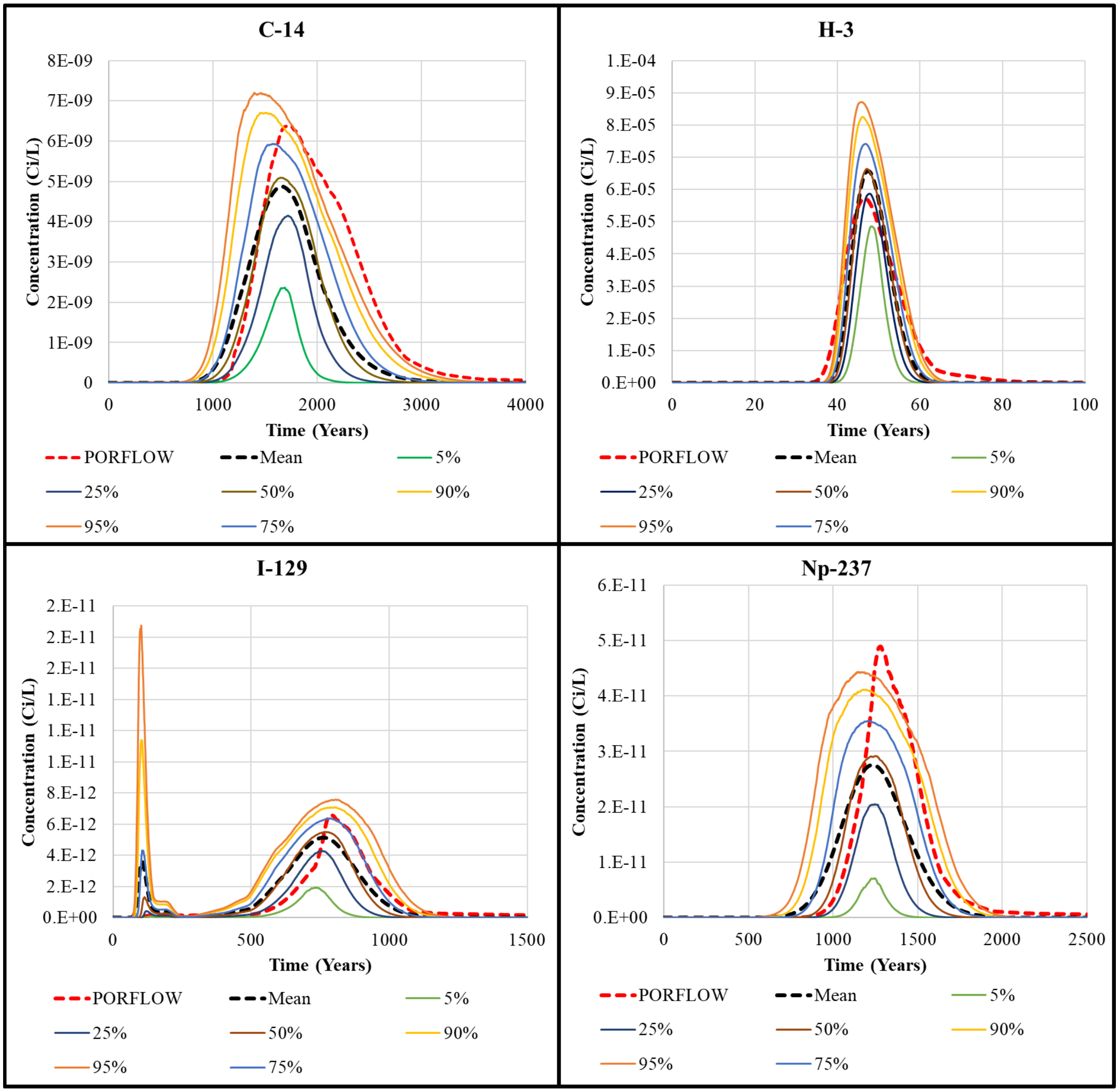


Figure 6-92. Intact Case Uncertainty Statistics for Concentration (Ci L^{-1} per gmole inventory) at 100-meter POA for ET06 (including geometric parameter stochastics)

In all cases, the leading edge within the compliance period is captured and the 95th percentile is always greater than the PORFLOW deterministic concentrations. The initial I-129 peak in the GoldSim® model does not compare adequately to the initial peak in PORFLOW. However, the 95th-percentile concentration profile for the secondary peak lies above the PORFLOW deterministic profile, which is the maximum I-129 peak in the PORFLOW simulations. The initial peak is an artifact of the 1-D to 3-D abstraction and is not used for the limits analysis.

6.2.2.1.2. Subsidence Case

When comparing the intact (Figure 6-91 and Figure 6-92) and subsidence cases (Figure 6-93 and Figure 6-94), as in the sensitivity analysis, no distinct differences in the shape or order of the concentration profiles are found. In all cases, the peak concentrations for the subsidence cases are lower than those for the intact cases.

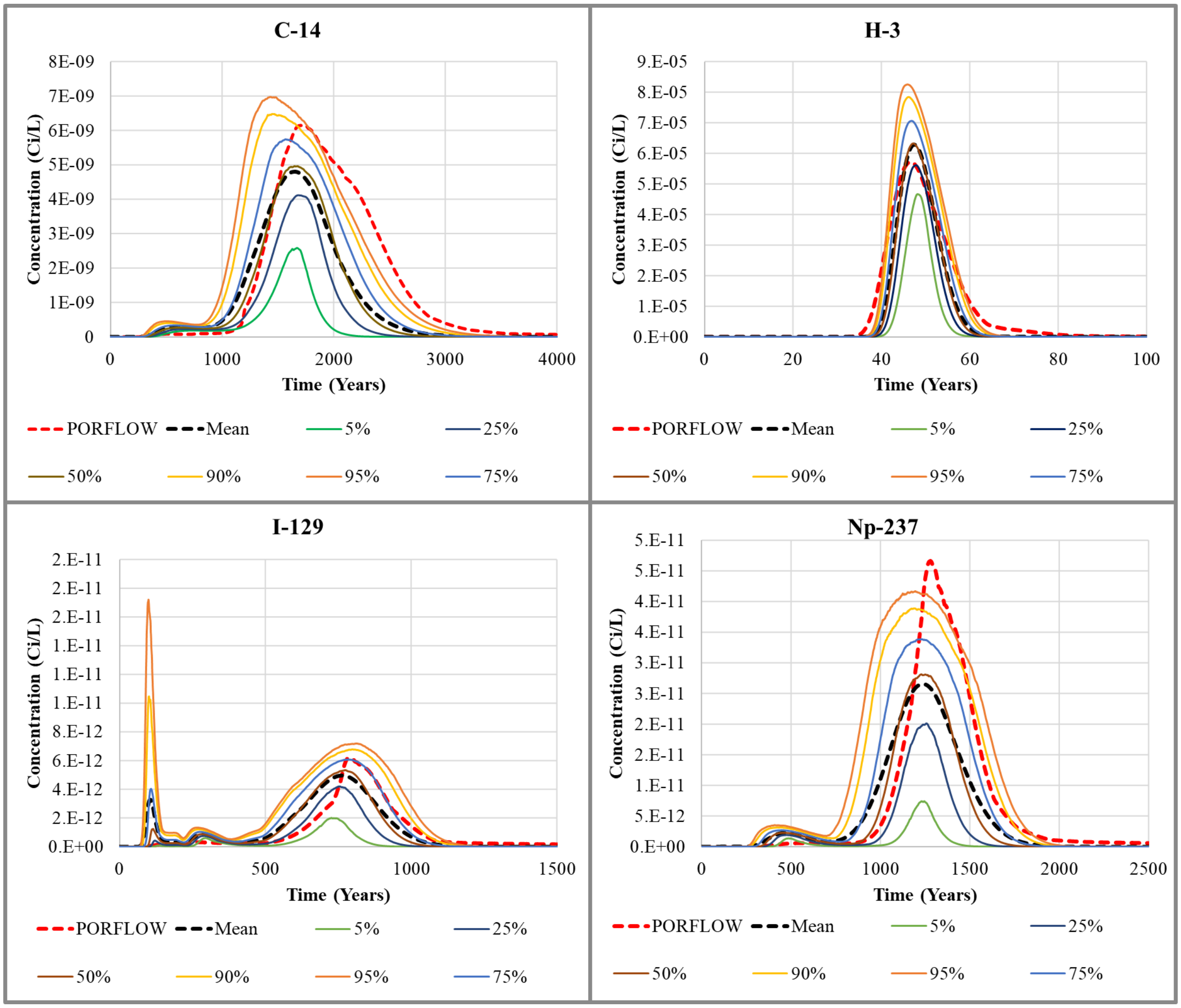


Figure 6-93. Subsidence Case Uncertainty Statistics for Concentration (Ci L^{-1} per gmole inventory) at 100-meter POA for ET06 (excluding geometric parameter stochastics)

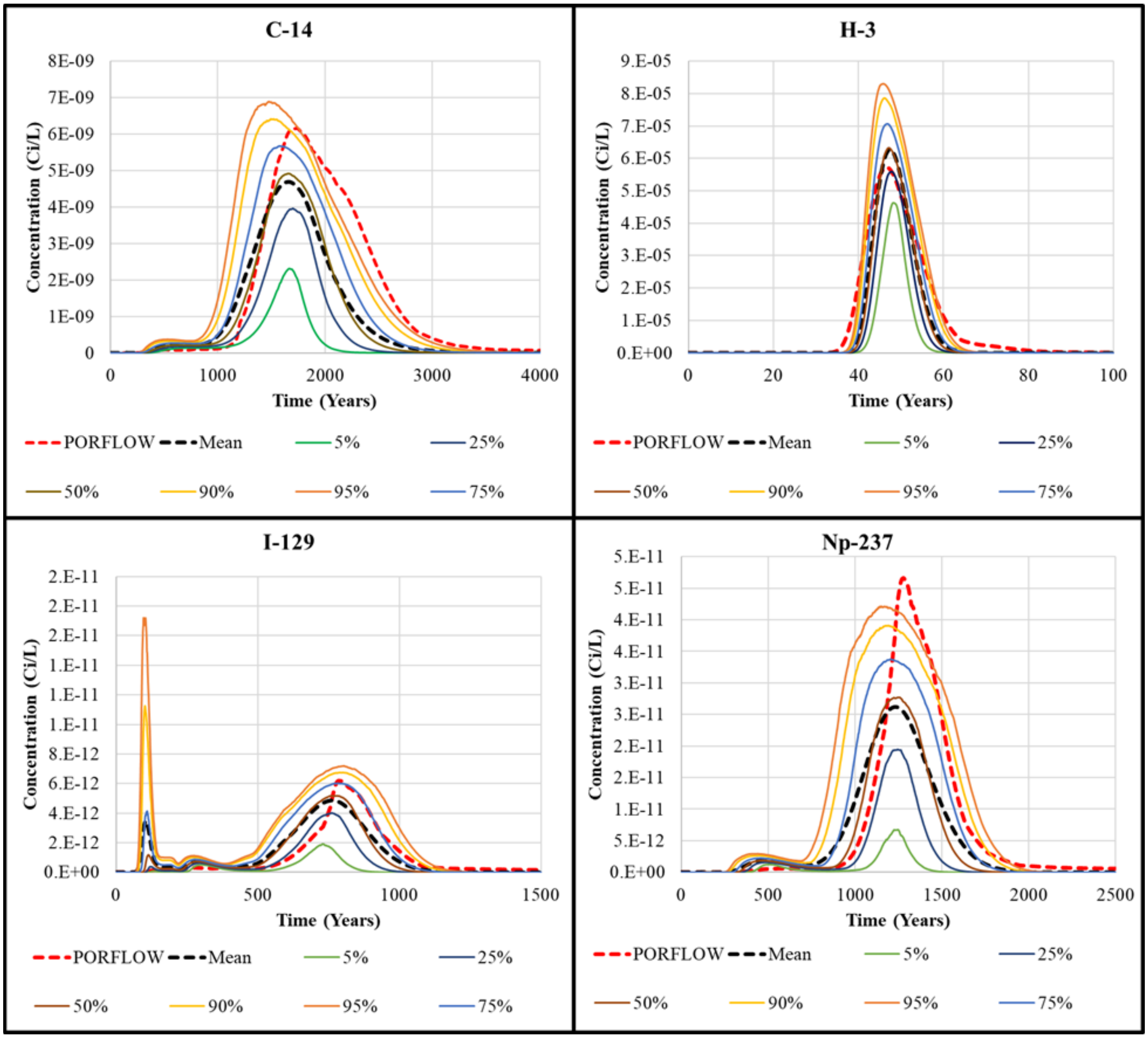


Figure 6-94. Subsidence Case Uncertainty Statistics for Concentration (Ci L^{-1} per gmole inventory) at 100-meter POA for ET06 (including geometric parameter stochastics)

6.2.2.2. ST06

Uncertainty quantification results displaying the statistics for peak radionuclide concentration are summarized in Table 6-152 for the simulated duration of 3,000 years. Section 6.2.2.1 provides a description of the bases for what is included in the table. Table 6-153 lists the increase (negative %) or decrease (positive %) in the 95th-percentile peak concentration relative to the nominal PA peak concentration from the PORFLOW deterministic model. All radionuclides display a 4% to 78% higher (negative percent difference) peak concentration at the 95th percentile compared to PORFLOW. The largest negative percent difference is observed for C-14 because the deterministic concentration in the GoldSim® model is already 15% to 16% higher than the deterministic peak concentration in PORFLOW. H-3, I-129, and Np-237 display a lower negative percent difference because the deterministic concentration in the GoldSim® model is better aligned with the PORFLOW model concentrations.

Table 6-152. Summary Statistics of Peak Concentrations (Ci L^{-1} per gmole inventory) at 100-meter POA for ST06

Statistic	C-14	H-3	I-129	Np-237
	Ci L^{-1} per gmole inventory			
Intact Case Including Geometric Stochastic Uncertainty				
Mean	6.04E-09	8.33E-05	8.10E-12	3.59E-11
95th Percentile	9.54E-09	1.04E-04	1.32E-11	5.99E-11
Median	6.17E-09	8.75E-05	8.74E-12	3.94E-11
5th Percentile	3.27E-09	6.50E-05	1.51E-12	5.35E-12
75th Percentile	7.35E-09	9.48E-05	1.08E-11	4.83E-11
90th Percentile	8.58E-09	1.01E-04	1.24E-11	5.52E-11
Nominal PA (GoldSim®)	6.19E-09	8.87E-05	1.17E-11	4.98E-11
Nominal PA (PORFLOW)	5.37E-09	9.95E-05	1.12E-11	4.64E-11
Intact Case Not Including Geometric Stochastic Uncertainty				
Mean	5.58E-09	8.37E-05	8.16E-12	3.51E-11
95th Percentile	8.55E-09	1.04E-04	1.32E-11	5.87E-11
Median	5.67E-09	8.76E-05	8.83E-12	3.76E-11
5th Percentile	3.30E-09	6.67E-05	1.59E-12	6.40E-12
75th Percentile	6.70E-09	9.46E-05	1.08E-11	4.64E-11
90th Percentile	7.86E-09	1.01E-04	1.23E-11	5.39E-11
Nominal PA (GoldSim®)	6.19E-09	8.87E-05	1.17E-11	4.98E-11
Nominal PA (PORFLOW)	5.37E-09	9.95E-05	1.12E-11	4.64E-11
Subsided Case Including Geometric Stochastic Uncertainty				
Mean	5.78E-09	8.33E-05	7.85E-12	3.46E-11
95th Percentile	9.04E-09	1.04E-04	1.29E-11	5.78E-11
Median	5.90E-09	8.74E-05	8.47E-12	3.79E-11
5th Percentile	3.19E-09	6.49E-05	1.40E-12	5.24E-12
75th Percentile	7.01E-09	9.47E-05	1.05E-11	4.64E-11
90th Percentile	8.19E-09	1.01E-04	1.21E-11	5.33E-11
Nominal PA (GoldSim®)	6.00E-09	8.87E-05	1.14E-11	4.83E-11
Nominal PA (PORFLOW)	5.19E-09	9.95E-05	1.06E-11	4.45E-11
Subsided Case Not Including Geometric Stochastic Uncertainty				
Mean	5.41E-09	8.37E-05	7.91E-12	3.41E-11
95th Percentile	8.29E-09	1.04E-04	1.29E-11	5.71E-11
Median	5.50E-09	8.75E-05	8.56E-12	3.65E-11
5th Percentile	3.21E-09	6.66E-05	1.48E-12	6.17E-12
75th Percentile	6.50E-09	9.46E-05	1.06E-11	4.49E-11
90th Percentile	7.62E-09	1.01E-04	1.21E-11	5.23E-11
Nominal PA (GoldSim®)	6.00E-09	8.87E-05	1.14E-11	4.83E-11
Nominal PA (PORFLOW)	5.19E-09	9.95E-05	1.06E-11	4.45E-11

Notes:

The Nominal PA case results are highlighted in orange to facilitate comparison between the GoldSim® and PORFLOW models.

Table 6-153. Percent Difference of 95th-Percentile Peak Concentrations (Ci L^{-1} per gmole inventory) at 100-meter POA for ST06 Compared to PORFLOW Nominal PA Results

Case	C-14	H-3	I-129	Np-237
Intact with Geometric Parameters	-78%	-5%	-18%	-29%
Intact without Geometric Parameters	-59%	-4%	-17%	-27%
Subsided with Geometric Parameters	-74%	-5%	-22%	-30%
Subsided without Geometric Parameters	-60%	-4%	-22%	-28%

Notes: A negative value indicates an increase in the 95th-percentile peak concentration from GoldSim® relative to the nominal PA peak concentration from the PORFLOW deterministic model. Conversely, a positive value indicates a decrease in the 95th-percentile peak concentration from GoldSim® relative to the nominal PA peak concentration from PORFLOW.

Table 6-154 lists the GoldSim®-based percent increase in peak concentration for each ST06 radionuclide (i.e., the increase from the mean value to the 95th-percentile value). The calculated, overall average impact is ~24%.

Table 6-154. Percent Difference of 95th-Percentile Peak Concentrations (Ci L^{-1} per gmole inventory) at 100-meter POA for ST06 Compared to GoldSim® Nominal PA Results

Case	C-14	H-3	I-129	Np-237	Avg
Intact with Geometric Parameters	54%	17%	13%	20%	26%
Intact without Geometric Parameters	38%	17%	13%	18%	22%
Subsidence with Geometric Parameters	51%	17%	13%	20%	25%
Subsidence without Geometric Parameters	38%	17%	13%	18%	22%

6.2.2.2.1. Intact Case

Figure 6-95 and Figure 6-96 present the statistical time histories for the radionuclide concentration at the 100-meter POA when not including and including, respectively, geometric parameters in the uncertainty analysis. In addition to the 5th, 25th, mean, 50th (median), 75th, 90th, and 95th percentiles, the deterministic PORFLOW model and stochastic GoldSim® model results used during benchmarking are also shown. For all radionuclides investigated in the uncertainty quantification analysis, the 5th- and 95th-percentile peak concentrations lie below and above the mean values, respectively, while the 95th-, 90th-, and 75th-percentile peak concentrations are higher than the PORFLOW model benchmarking peak. In all cases, the mean value is only slightly less than the median. Little difference is observed in the concentration profiles for H-3, I-129, and Np-237 when the geometric parameters are included in the uncertainty analysis; however, peak concentrations are slightly (6% to 10%) higher when compared to peak concentrations observed when the geometric parameters are excluded from the stochastic analysis.

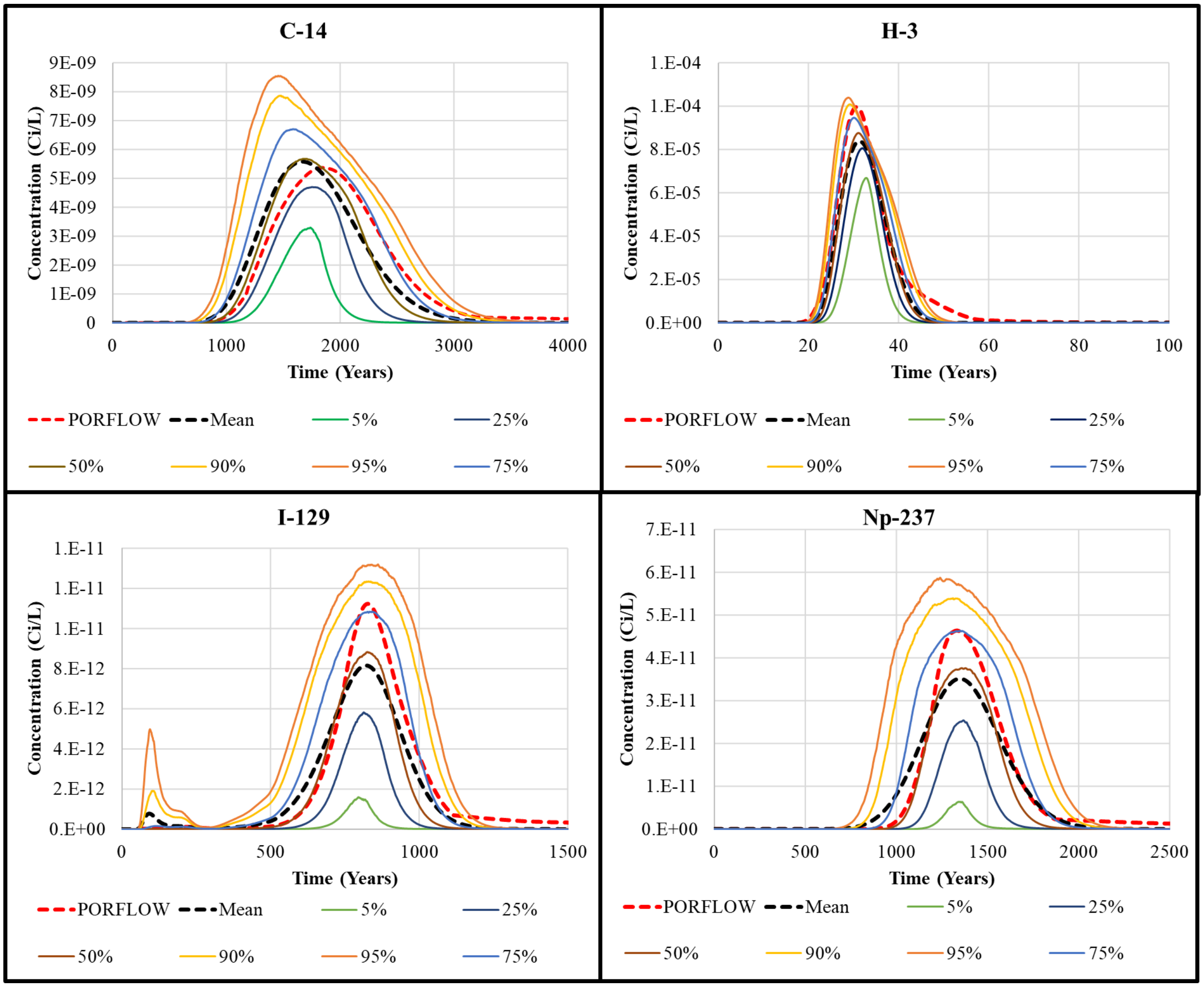


Figure 6-95. Intact Case Uncertainty Statistics for Concentration (Ci L^{-1} per gmole inventory) at 100-meter POA for ST06 (excluding geometric parameter stochastics)

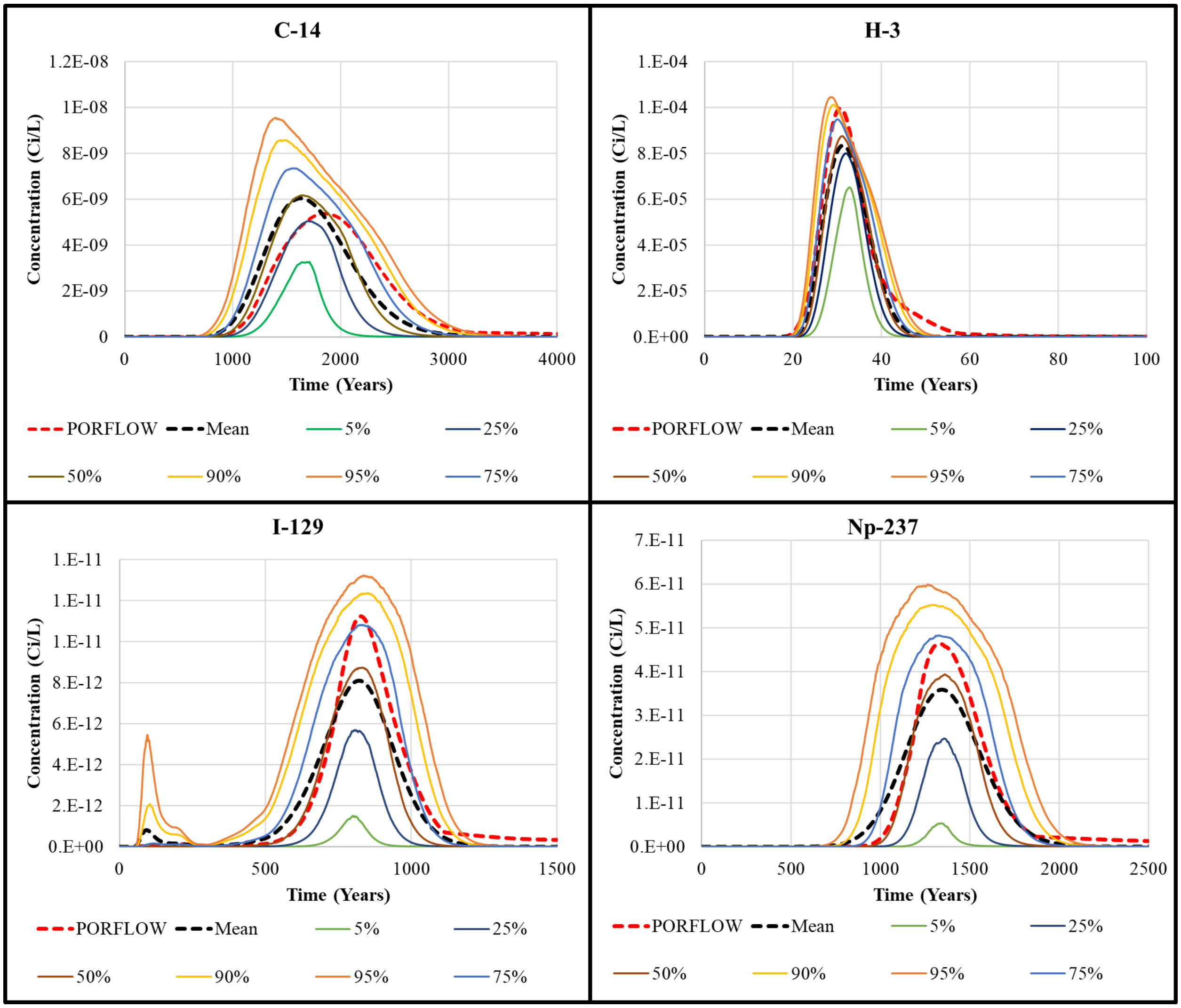


Figure 6-96. Intact Case Uncertainty Statistics for Concentration (Ci L^{-1} per gmole inventory) at 100-meter POA for ST06 (including geometric parameter stochastics)

6.2.2.2.2. Subsidence Case

When comparing the intact (Figure 6-95 and Figure 6-96) and subsidence cases (Figure 6-97 and Figure 6-98), as in the sensitivity analysis, no distinct differences in the shape or order of the concentration profiles are found. In all cases, the peak concentrations for the subsidence cases are lower than those for the intact cases.

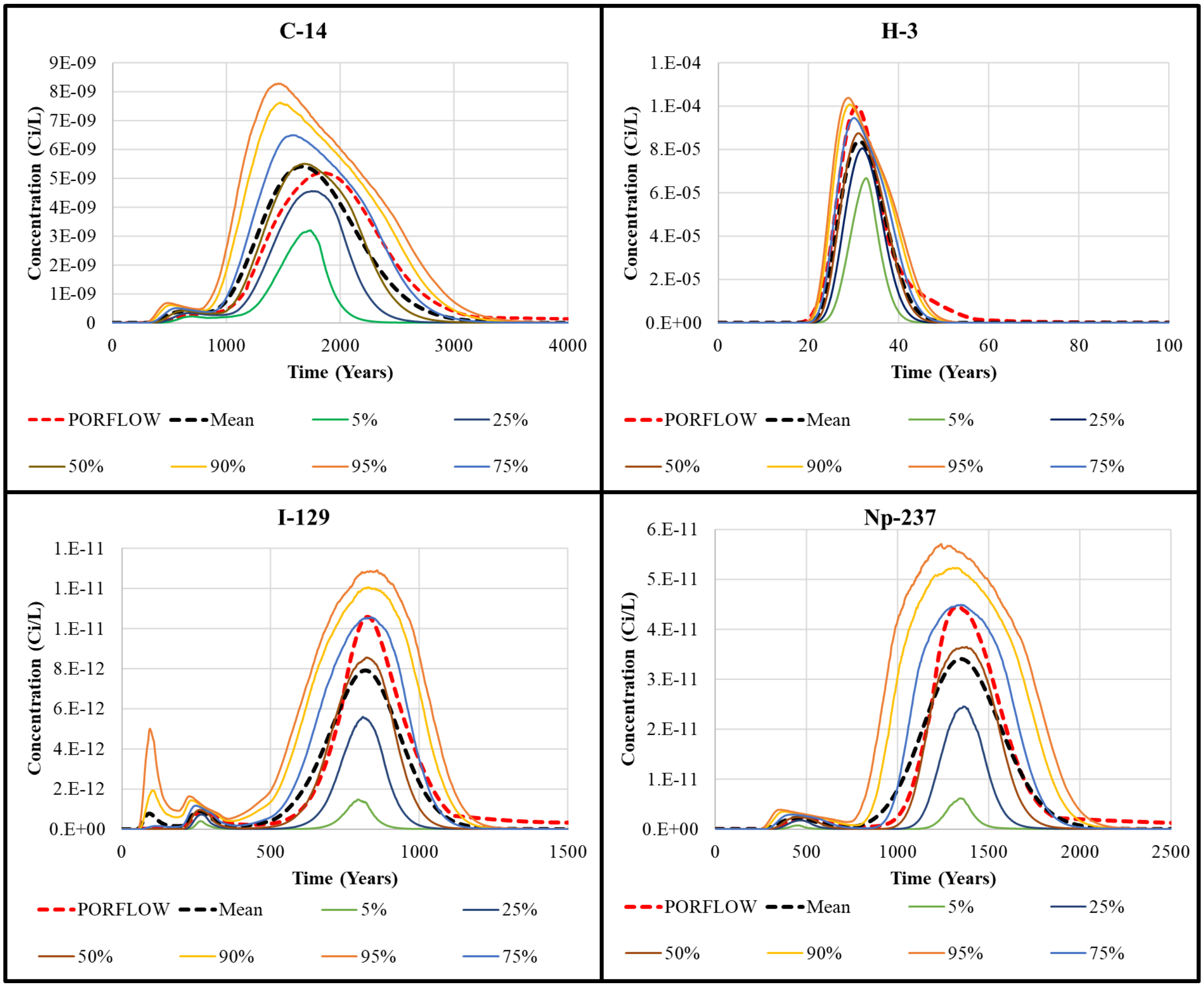


Figure 6-97. Subsidence Case Uncertainty Statistics for Concentration (Ci L^{-1} per gmole inventory) at 100-meter POA for ST06 (excluding geometric parameter stochastics)

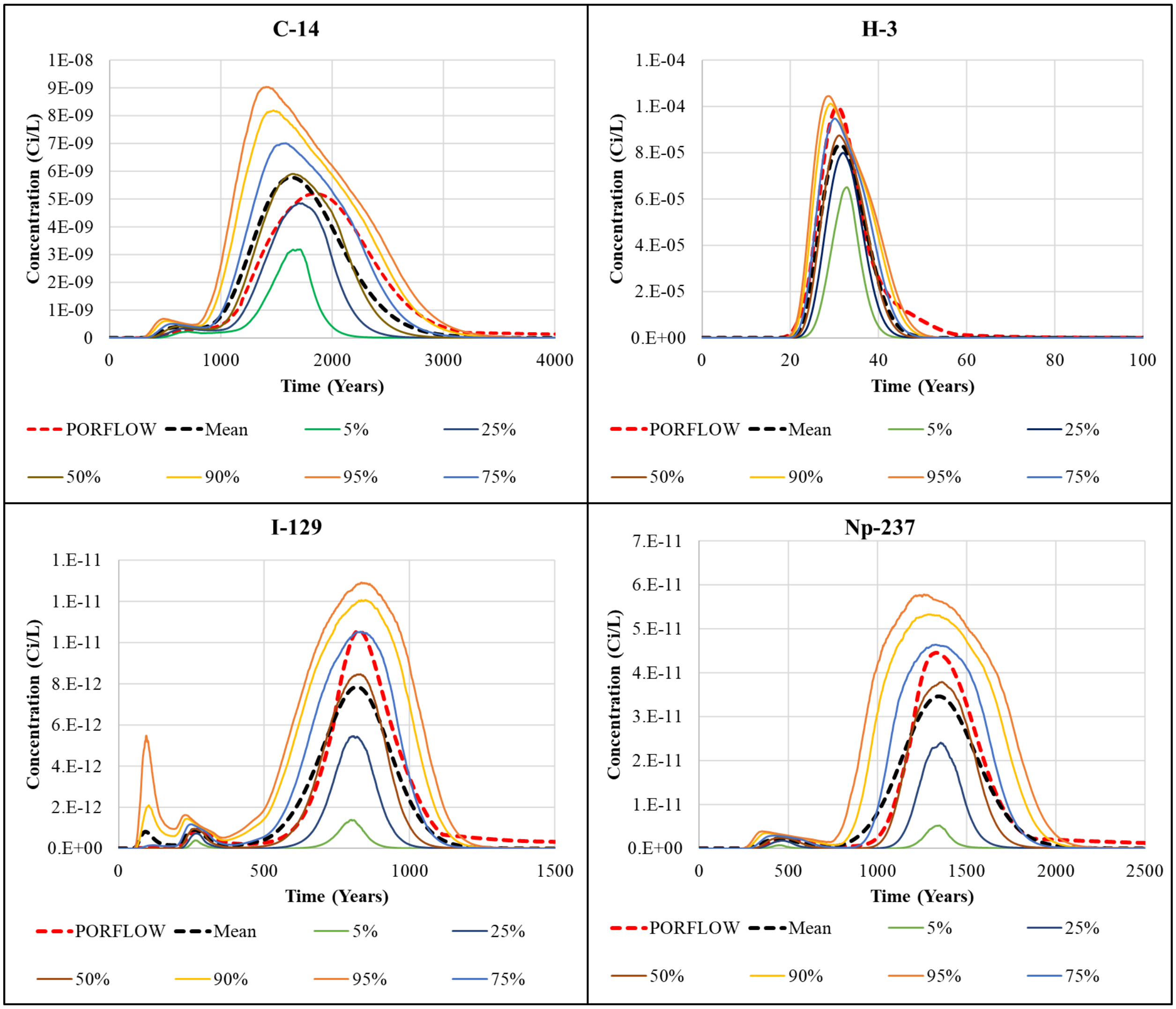


Figure 6-98. Subsidence Case Uncertainty Statistics for Concentration (Ci L^{-1} per gmole inventory) at 100-meter POA for ST06 (including geometric parameter stochastics)

6.2.2.3. ST09

Uncertainty quantification results displaying the statistics for peak radionuclide concentration are summarized in Table 6-155 for the simulated duration of 3,000 years. Section 6.2.2.1 provides a description of the bases for what is included in the table. Table 6-156 lists the increase (negative %) or decrease (positive %) in the 95th-percentile peak concentration relative to the nominal PA peak concentration from the PORFLOW deterministic model. All radionuclides display a 13% to 58% higher (negative percent difference) peak concentration at the 95th percentile compared to PORFLOW.

Table 6-155. Summary Statistics of Peak Concentrations (Ci L^{-1} per gmole inventory) at 100-meter POA for ST09

Statistic	C-14	H-3	I-129	Np-237
	Ci L^{-1} per gmole inventory			
Intact Case Including Geometric Stochastic Uncertainty				
Mean	5.53E-09	1.11E-04	8.28E-12	3.35E-11
95th Percentile	9.09E-09	1.70E-04	1.36E-11	6.04E-11
Median	5.81E-09	1.20E-04	8.90E-12	3.60E-11
5th Percentile	2.40E-09	5.59E-05	1.53E-12	4.36E-12
75th Percentile	7.02E-09	1.43E-04	1.10E-11	4.59E-11
90th Percentile	8.32E-09	1.59E-04	1.26E-11	5.52E-11
Nominal PA (GoldSim®)	6.29E-09	1.29E-04	1.19E-11	4.80E-11
Nominal PA (PORFLOW)	6.56E-09	1.08E-04	1.20E-11	4.24E-11
Intact Case Not Including Geometric Stochastic Uncertainty				
Mean	5.34E-09	1.13E-04	8.41E-12	3.33E-11
95th Percentile	8.67E-09	1.69E-04	1.36E-11	5.87E-11
Median	5.58E-09	1.21E-04	9.04E-12	3.54E-11
5th Percentile	2.57E-09	5.99E-05	1.72E-12	5.43E-12
75th Percentile	6.64E-09	1.42E-04	1.11E-11	4.51E-11
90th Percentile	7.87E-09	1.58E-04	1.27E-11	5.32E-11
Nominal PA (GoldSim®)	6.29E-09	1.29E-04	1.19E-11	4.80E-11
Nominal PA (PORFLOW)	6.56E-09	1.08E-04	1.20E-11	4.24E-11
Subsided Case Including Geometric Stochastic Uncertainty				
Mean	5.32E-09	1.11E-04	8.02E-12	3.24E-11
95th Percentile	8.74E-09	1.70E-04	1.33E-11	5.84E-11
Median	5.59E-09	1.20E-04	8.61E-12	3.48E-11
5th Percentile	2.32E-09	5.64E-05	1.47E-12	4.23E-12
75th Percentile	6.74E-09	1.42E-04	1.07E-11	4.43E-11
90th Percentile	7.96E-09	1.59E-04	1.23E-11	5.33E-11
Nominal PA (GoldSim®)	6.10E-09	1.29E-04	1.15E-11	4.66E-11
Nominal PA (PORFLOW)	6.01E-09	1.08E-04	1.13E-11	4.05E-11
Subsided Case Not Including Geometric Stochastic Uncertainty				
Mean	5.17E-09	1.13E-04	8.15E-12	3.23E-11
95th Percentile	8.41E-09	1.69E-04	1.32E-11	5.69E-11
Median	5.41E-09	1.21E-04	8.76E-12	3.43E-11
5th Percentile	2.51E-09	6.03E-05	1.64E-12	5.29E-12
75th Percentile	6.44E-09	1.42E-04	1.07E-11	4.38E-11
90th Percentile	7.64E-09	1.59E-04	1.23E-11	5.16E-11
Nominal PA (GoldSim®)	6.10E-09	1.29E-04	1.15E-11	4.66E-11
Nominal PA (PORFLOW)	6.01E-09	1.08E-04	1.13E-11	4.05E-11

Notes:

The Nominal PA case results are highlighted in orange to facilitate comparison between the GoldSim® and PORFLOW models.

Table 6-156. Percent Difference of 95th-Percentile Peak Concentrations (Ci L^{-1} per gmole inventory) at 100-meter POA for ST09 Compared to PORFLOW Nominal PA Results

Case	C-14	H-3	I-129	Np-237
Intact with Geometric Parameters	-39%	-57%	-13%	-42%
Intact without Geometric Parameters	-32%	-56%	-13%	-38%
Subsided with Geometric Parameters	-45%	-57%	-18%	-44%
Subsided without Geometric Parameters	-40%	-56%	-17%	-40%

Notes: A negative value indicates an increase in the 95th-percentile peak concentration from GoldSim® relative to the nominal PA peak concentration from the PORFLOW deterministic model. Conversely, a positive value indicates a decrease in the 95th-percentile peak concentration from GoldSim® relative to the nominal PA peak concentration from PORFLOW.

Table 6-157 gives the GoldSim®-based percent increase in peak concentration for each ST09 radionuclide (i.e., the increase from the mean value to the 95th-percentile value). The calculated, overall average impact is ~28%.

Table 6-157. Percent Difference of 95th-Percentile Peak Concentrations (Ci L^{-1} per gmole inventory) at 100-meter POA for ST09 Compared to GoldSim® Nominal PA Results

Case	C-14	H-3	I-129	Np-237	Avg
Intact with Geometric Parameters	45%	32%	14%	26%	29%
Intact without Geometric Parameters	38%	31%	14%	22%	26%
Subsidence with Geometric Parameters	43%	32%	16%	25%	29%
Subsidence without Geometric Parameters	38%	31%	15%	22%	26%

6.2.2.3.1. Intact Case

Figure 6-99 and Figure 6-100 present the statistical time histories for the radionuclide concentration at the 100-meter POA when not including and including the geometric parameters in the uncertainty analysis, respectively. In addition to the 5th, 25th, mean, 50th (median), 75th, 90th, and 95th percentiles, the deterministic PORFLOW model and stochastic GoldSim® model results used during benchmarking are also shown. For all radionuclides investigated in the uncertainty quantification analysis, the 5th- and 95th-percentile peak concentrations lie below and above the mean values, respectively, while the 95th- and 90th-percentile peak concentrations are higher than the PORFLOW model benchmarking peak. In all cases, the mean value is only slightly less than the median. Including geometric parameters in the uncertainty analysis results in only 1% to 5% differences in peak radionuclide concentration when compared to peak concentrations observed when geometric parameters are excluded from the stochastic analysis.

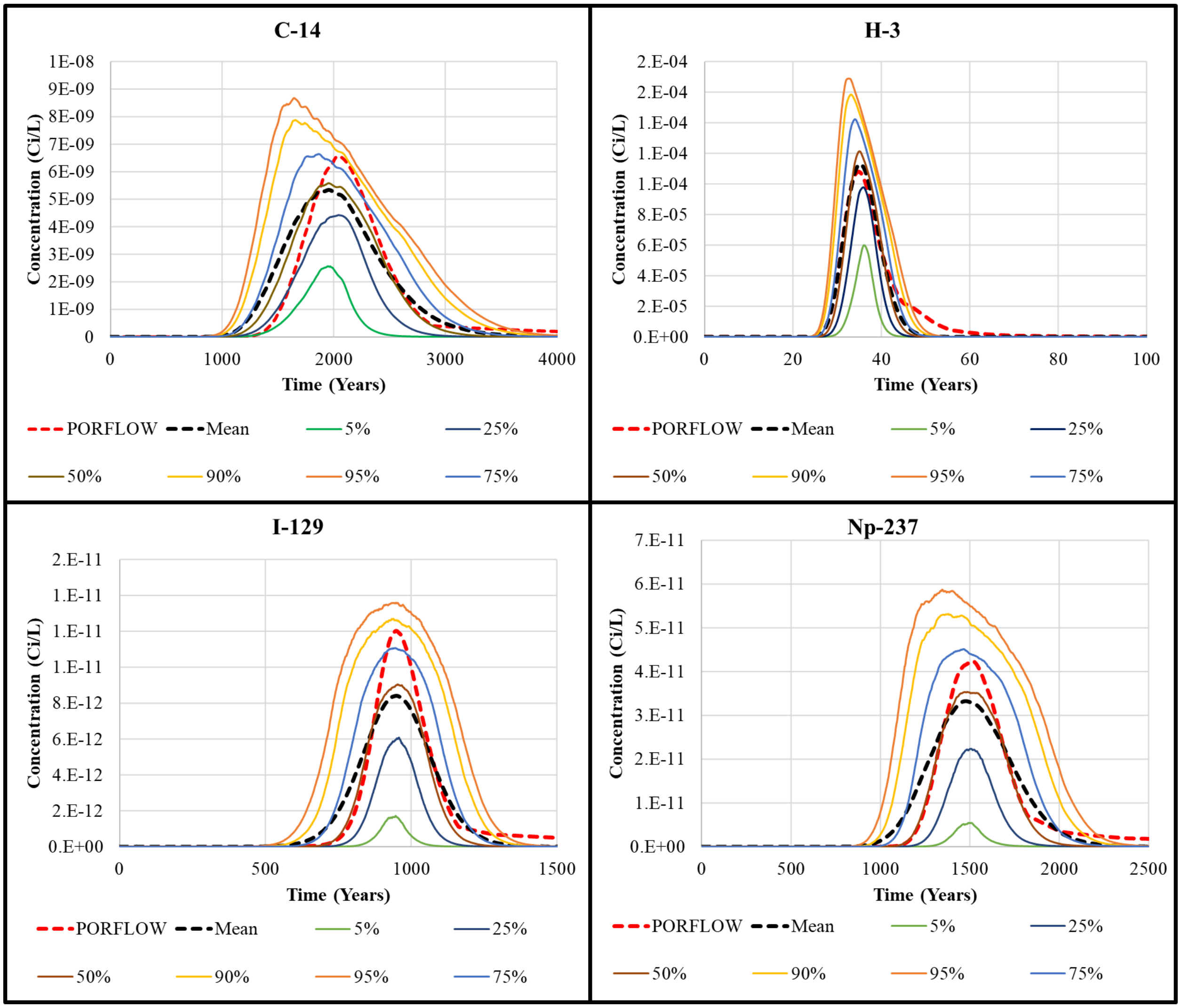


Figure 6-99. Intact Case Uncertainty Statistics for Concentration (Ci L^{-1} per gmole inventory) at 100-meter POA for ST09 (excluding geometric parameter stochastics)

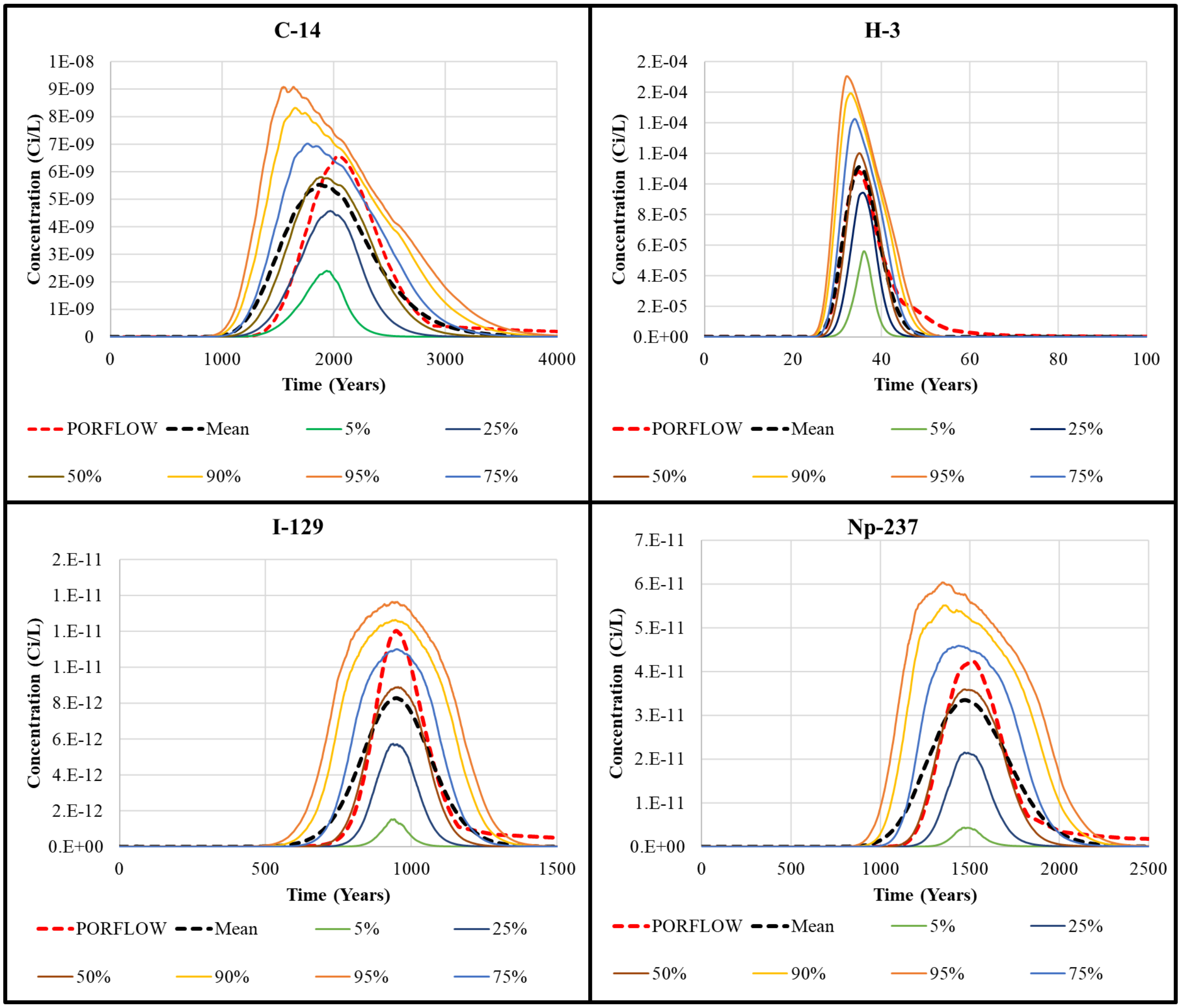


Figure 6-100. Intact Case Uncertainty Statistics for Concentration (Ci L^{-1} per gmole inventory) at 100-meter POA for ST09 (including geometric parameter stochastics)

6.2.2.3.2. Subsidence Case

When comparing the intact (Figure 6-99 and Figure 6-100) and subsidence cases (Figure 6-101 and Figure 6-102), as in the sensitivity analysis, no distinct differences in the shape or order of the concentration profiles are found. In all cases, the peak concentrations for the subsidence cases are lower than those for the intact cases.

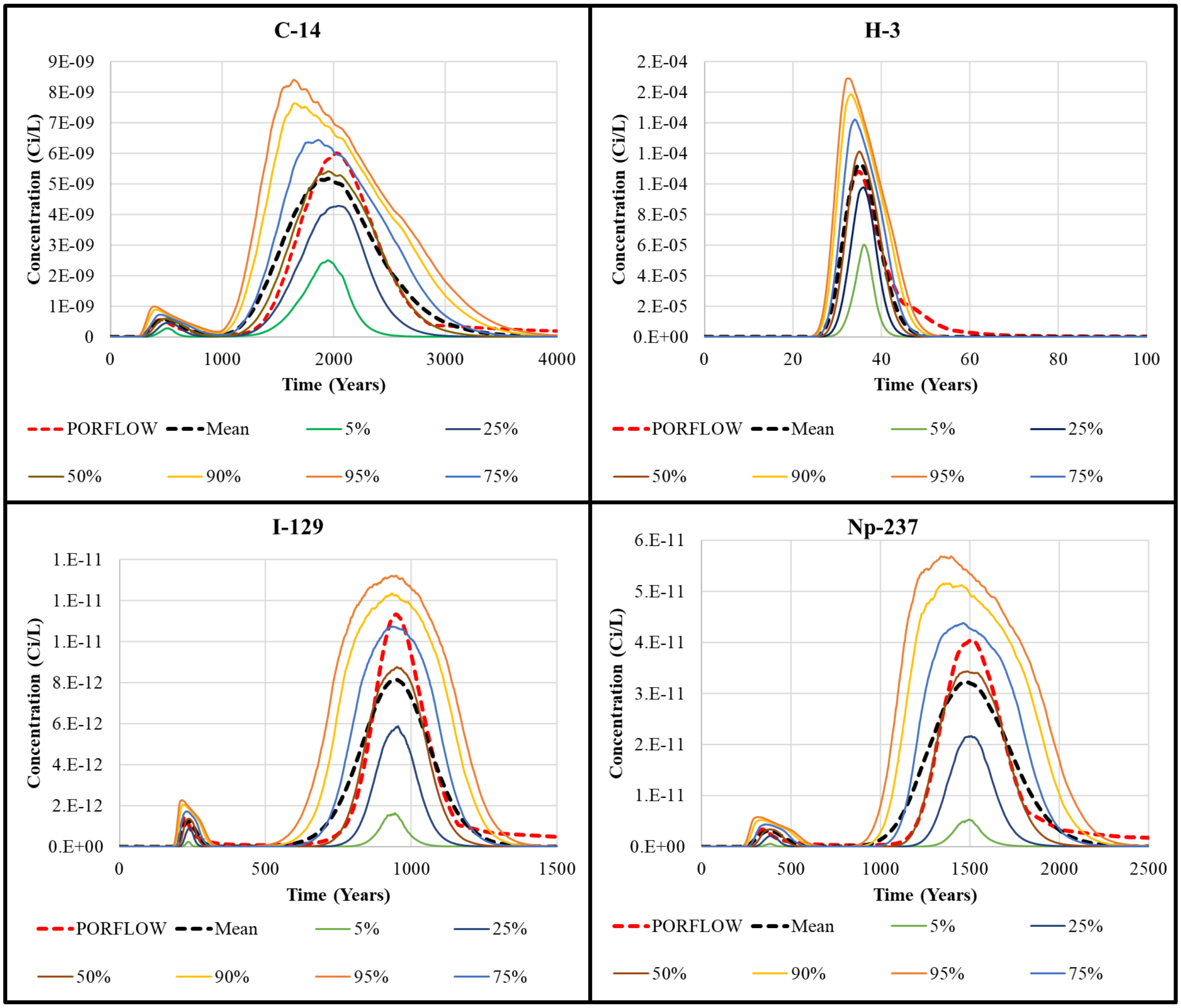


Figure 6-101. Subsidence Case Uncertainty Statistics for Concentration (Ci L^{-1} per gmole inventory) at 100-meter POA for ST09 (excluding geometric parameter stochastics)

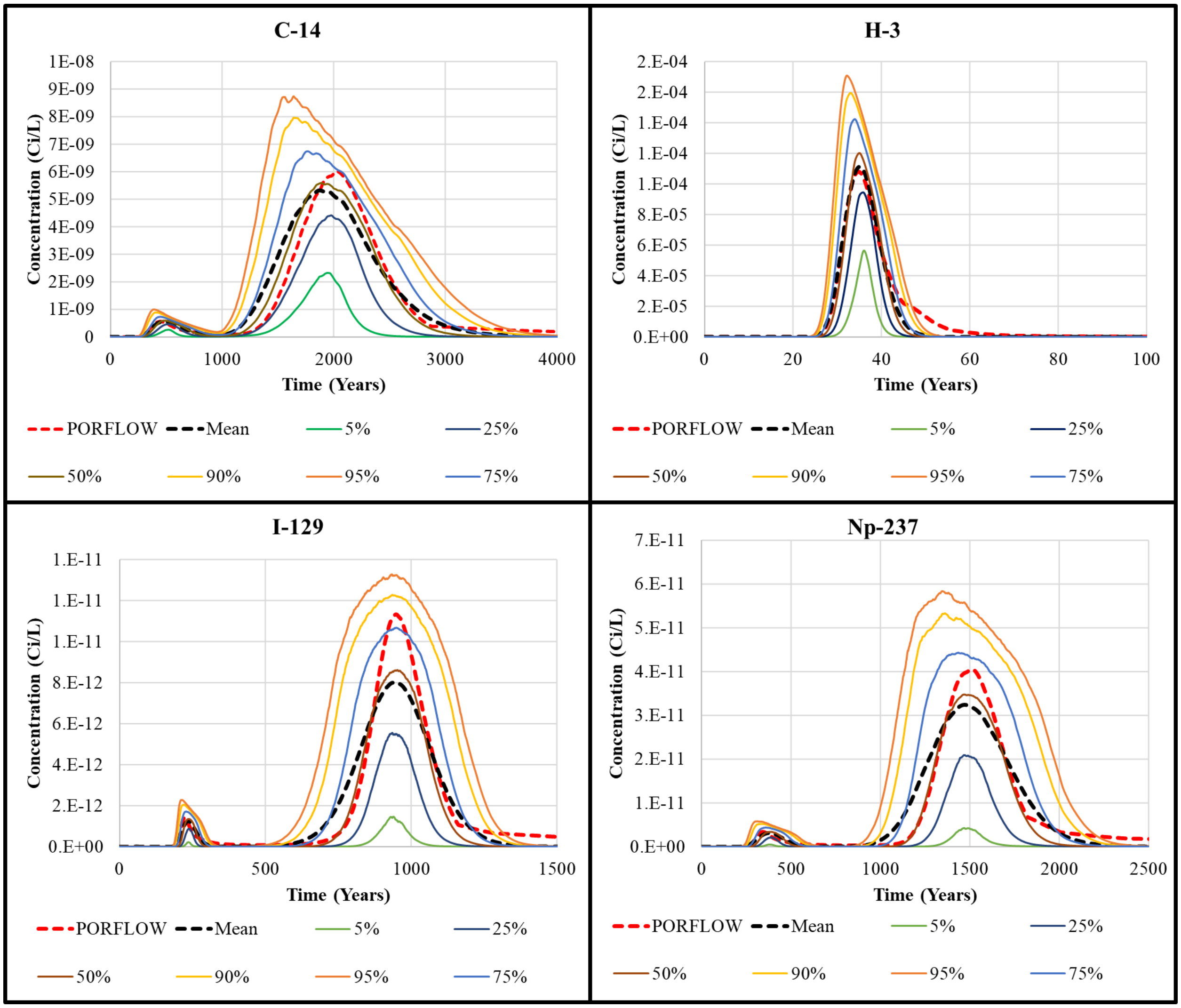


Figure 6-102. Subsidence Case Uncertainty Statistics for Concentration (Ci L^{-1} per gmole inventory) at 100-meter POA for ST09 (including geometric parameter stochastics)

6.2.3. Comparison of GoldSim® and Response Surface Uncertainty Results

Two methods have been presented as follows for quantifying uncertainty in the nominal PA PORFLOW calculations:

- Section 6.1.2 presents the results of using a response surface calculation to estimate the uncertainty in the peak dose factor at the 100-meter POA for all DUs and a limited number of radionuclides. These peak dose factors are analyzed during the compliance period. This method utilizes results from PORFLOW sensitivity calculations to create the response surface.
- Section 6.2.1 summarizes results from the GoldSim® 1-D Trench System Model used to quantify uncertainty in peak radionuclide concentrations at the 100-meter POA for a limited number of radionuclides in three trench DUs. Peak concentrations occurring at any time in the simulation (0 to 3,000 years) are analyzed. This method relies on benchmarking

the 1-D GoldSim® model to the 3-D PORFLOW flow and transport model for STs and ETs.

To compare these two approaches for quantifying uncertainty in the nominal PA PORFLOW results, the response surface method is modified to calculate the uncertainty in peak concentration at the 100-meter POA at any time during the simulation. Calculations are performed for six radionuclides (C-14, H-3, I-129, Np-237, Sr-90 and Tc-99) and the same three trenches (ET06, ST06, and ST09) used in the PORFLOW sensitivity analysis and uncertainty quantification simulations (Sections 6.1.1.1 and 6.1.2.2.1, respectively). PORFLOW sensitivity calculations are available for the intact closure cap scenario only (no subsidence). Sr-90 has a very low concentration and is not well represented in either uncertainty calculation. Tc-99 displays a sharp release that peaks early in the transient, which is difficult for the GoldSim® model to capture in conjunction with the behavior of the other radionuclides. Geometric uncertainties incorporated into the GoldSim® model are not part of the response surface uncertainty calculation. Consequently, there are only 12 cases where a comparison between the two uncertainty calculations are made: specifically, peak concentrations of C-14, H-3, I-129, and Np-237 at the 100-meter POA for intact trenches ET06, ST06, and ST09 with no geometric uncertainty.

Results from the response surface uncertainty calculation are shown in Table 6-158, which lists peak concentrations of five radionuclides at the 100-meter POA from the PORFLOW nominal PA calculation as well as the mean, median, 75th-, 90th-, and 95th-percentile concentrations calculated using the response surface analysis. The peak concentrations listed are computed based on transient results spanning approximately a 4,000-year time window. As noted in Section 6.1.2.2, symmetric distributions are used in the analysis. Under this assumption, the mean and median values from the uncertainty analysis are expected to be equal to the nominal PA values. The results included in Table 6-158 confirm this expectation and provide some verification that the calculations are done correctly. The only case in Table 6-158 where the mean exceeds the median is Tc-99 in ET06. Given the long transport path from ET06 to the 100-meter POA, large K_d values (and/or low infiltration rates) result in a significant number of Monte Carlo realizations yielding zero concentrations.

The calculation does not require them, but symmetric distributions typically satisfactorily represent the uncertainty parameters. In fact, little difference is observed in the results when using a normal versus log-normal distribution to represent variations in K_d.

Table 6-158. Statistics from Response Surface Uncertainty Calculations for Peak Concentrations per Ci Buried at the 100-meter POA

Radionuclide	Nominal PA	Mean		Median		75th Percentile		90th Percentile		95th Percentile	
	pCi L^{-1} Ci^{-1} parent	pCi L^{-1} Ci^{-1} parent	Ratio	pCi L^{-1} Ci^{-1} parent	Ratio	pCi L^{-1} Ci^{-1} parent	Ratio	pCi L^{-1} Ci^{-1} parent	Ratio	pCi L^{-1} Ci^{-1} parent	Ratio
ET06											
C-14	1.02E+02	1.02E+02	1.00	1.02E+02	1.00	1.22E+02	1.20	1.40E+02	1.38	1.51E+02	1.48
H-3	1.97E+03	1.97E+03	1.00	1.96E+03	1.00	2.37E+03	1.21	2.72E+03	1.38	2.90E+03	1.47
I-129	2.89E+02	2.89E+02	1.00	2.89E+02	1.00	3.57E+02	1.23	4.17E+02	1.44	4.51E+02	1.56
Np-237	2.93E+02	2.93E+02	1.00	2.93E+02	1.00	3.35E+02	1.14	3.70E+02	1.26	3.91E+02	1.33
Tc-99	2.07E+02	5.59E+02	2.70	2.10E+02	1.02	9.71E+02	4.69	1.64E+03	7.93	2.04E+03	9.87
ST06											
C-14	8.56E+01	8.56E+01	1.00	8.57E+01	1.00	1.07E+02	1.25	1.26E+02	1.47	1.37E+02	1.60
H-3	3.43E+03	3.43E+03	1.00	3.43E+03	1.00	3.95E+03	1.15	4.39E+03	1.28	4.63E+03	1.35
I-129	4.93E+02	4.93E+02	1.00	4.93E+02	1.00	5.03E+02	1.02	5.11E+02	1.04	5.16E+02	1.05
Np-237	2.78E+02	2.78E+02	1.00	2.78E+02	1.00	3.09E+02	1.11	3.38E+02	1.21	3.54E+02	1.27
Tc-99	4.82E+02	4.82E+02	1.00	4.81E+02	1.00	8.51E+02	1.76	1.16E+03	2.41	1.33E+03	2.76
ST09											
C-14	9.96E+01	9.96E+01	1.00	9.95E+01	1.00	1.15E+02	1.15	1.28E+02	1.28	1.36E+02	1.36
H-3	3.72E+03	3.72E+03	1.00	3.73E+03	1.00	4.72E+03	1.27	5.57E+03	1.50	6.05E+03	1.63
I-129	5.28E+02	5.28E+02	1.00	5.29E+02	1.00	5.88E+02	1.11	6.40E+02	1.21	6.67E+02	1.26
Np-237	2.55E+02	2.55E+02	1.00	2.55E+02	1.00	3.02E+02	1.19	3.45E+02	1.36	3.69E+02	1.45
Tc-99	6.20E+02	6.20E+02	1.00	6.20E+02	1.00	6.37E+02	1.03	6.53E+02	1.05	6.62E+02	1.07

Table 6-159 compares the ratio of peak concentrations to nominal PA values for the two uncertainty calculation methods (response surface and GoldSim®) at the 95th-percentile confidence interval for ET06, ST06, and ST09. The GoldSim® Trench System Model values are extracted from Table 6-149, Table 6-152, and Table 6-155 for ET06, ST06, and ST09, respectively. The GoldSim® model uses concentration units of Ci L^{-1} per gmol of parent buried, whereas the response surface calculation employs concentration units of pCi L^{-1} per Ci of parent buried. This difference in concentration units has no effect on the reported ratios. On average, the response surface results exceed the GoldSim® stochastic model results by approximately 6%. Considering that the two uncertainty calculations are based on entirely different and independent methodologies, agreement between the results is satisfactory and provides some verification that both methods give reasonable results.

Table 6-159. Comparison of 95th-Percentile Peak Concentrations Ratioed to Nominal PA Values for the GoldSim® Trench System Model and the Response Surface Uncertainty Calculations

Radionuclide	Nominal PA Value (pCi L^{-1} Ci^{-1} parent buried)	Ratio Based on 95th-Percentile Values	
		GoldSim® [1]	Response Surface
ET06			
C-14	1.02E+02	1.25	1.48
H-3	1.97E+03	1.25	1.47
I-129	2.89E+02	2.80	1.56
Np-237	2.93E+02	1.16	1.33
ST06			
C-14	8.56E+01	1.49	1.60
H-3	3.43E+03	1.18	1.35
I-129	4.93E+02	1.13	1.05
Np-237	2.78E+02	1.21	1.27
ST09			
C-14	9.96E+01	1.48	1.36
H-3	3.72E+03	1.30	1.63
I-129	5.28E+02	1.14	1.26
Np-237	2.55E+02	1.25	1.45

Notes:

1 GoldSim® ratios are evaluated relative to the predicted peak dose calculated by the GoldSim® Trench System Model.

Table 6-160 summarizes the advantages and disadvantages of both methods of uncertainty quantification.

Table 6-160. Comparison of GoldSim® Model to Response Surface Uncertainty Calculations

Uncertainty Calculation Method	Advantages	Disadvantages
GoldSim® Model	• Widely accepted method for estimating model uncertainty • Able to assess many different uncertainty distributions simultaneously • Automated results analysis and plotting capabilities	• Requires model development and benchmarking • 1-D model does not fully capture 2-D and 3-D PORFLOW model behavior
Response Surface	• Based directly on PORFLOW results • Simple method that can be easily and quickly applied (20,000 evaluations using GoldSim® took less than 1 minute)	• Requires PORFLOW sensitivity calculations • Assumption of a linear response surface may not be valid for all sensitivity parameters

When the focus is on ST and ET behavior, the PORFLOW-based response surface analyses and GoldSim®-based Trench Model analyses lead to the following observations:

- GoldSim® Trench Model stochastic results indicate that a nonlinear response exists to some degree when predicting peak radionuclide concentrations at the 100-meter POA. This nonlinear response is also observed in the response surface analyses where, in some cases, negative concentrations are computed for various realizations.
- During the GoldSim® Trench Model calibration process, where the PORFLOW results are assumed to be accurate and its benchmark cases, difficulties are encountered with some scenarios and/or radionuclides, which indicates that the 1-D representation has limitations.
- The above two observations suggest for each method that as the sensitivity variables begin to approach their extreme values, a diminishing value is computed for the predicted responses.

Even though both uncertainty methods have their own weaknesses, a consistent picture does emerge when a comparison is made based on overall behavior. For example, Figure 6-103 compares both uncertainty methods where the relative increase in predicted concentration (i.e., concentration at a given percentile divided by its predicted mean value) is plotted for increasing percentile level. The results shown are averaged across all radionuclides and the three DUs considered. Given the above-mentioned weaknesses and unique method differences, the similarity in average results suggests that these weaknesses have only marginal impacts.

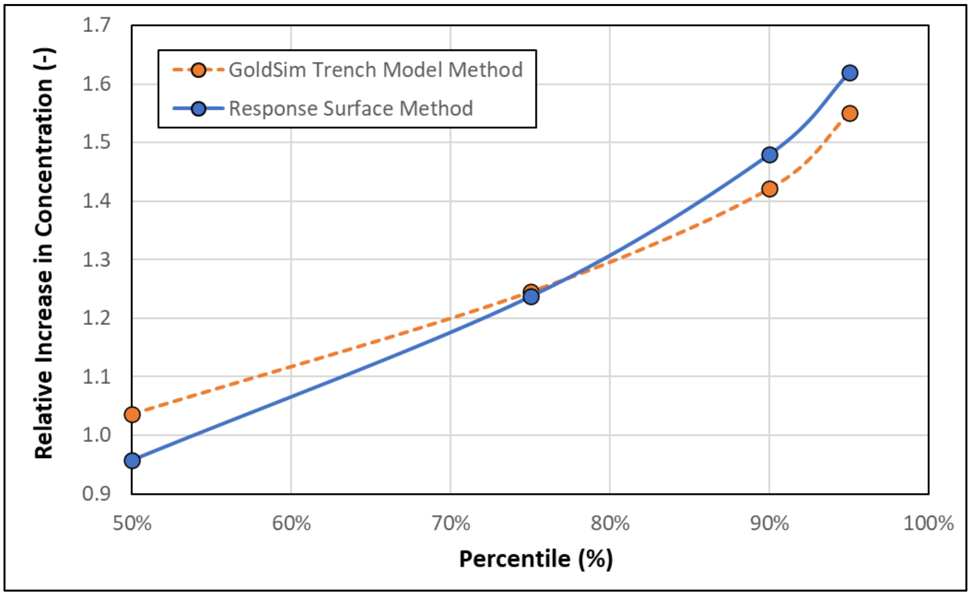


Figure 6-103. Comparison of Averaged Relative Increase in Predicted Concentration for Varying Percentiles for GoldSim® Trench Model versus Response Surfaces Methods

6.3. AIR AND RADON PATHWAYS

Sensitivity simulations for the air and radon pathways are performed using the ARM model described in Section 3.6 and Sections 5.1.5, 5.2.3, 5.3.3, and 5.4.3 for STs and ETs, LAWV, ILV, and NRCDAs, respectively. Model parameters are varied and the resultant doses and/or fluxes from an individual DU are compared. Four categories of sensitivity effects are investigated:

1) **Water Saturation of Materials:** Material-specific values are used as the best estimate or nominal PA cases. The water saturation values are generally biased low to be conservative (pessimistic) relative to transport time to the surface. For the worst-case scenario, water saturation of every material is set to 1E-05 within the entire model. Additional sensitivity runs included 50% and 90% water saturation of all materials relative to the best estimate case. ST and ET waste and final closure cap materials are also separately desaturated (value set to 1E-05).

2) **Final Closure Cap Thickness/Presence:** A scenario is modeled where the thickness of each layer of the closure cap is multiplied by 1E-8, effectively removing the closure cap.

3) **Diffusion Coefficients:** Within the ARM, Graham's Law describes diffusion through air where the effective diffusion coefficient, D_e, is given as the effective diffusion coefficient for Rn-222 times the square root of the molecular weight ratio between Rn-222 and the radionuclide of interest, s:

$$D_e = D_e^{Rn-222}\sqrt{\frac{MW_{Rn-222}}{MW_s}} \qquad \text{Eq. (6-10)}$$

where:

D_e	Effective diffusion coefficient for radionuclide of interest, s (m^2 s^{-1})
D_e^{Rn-222}	Effective diffusion coefficient for Rn-222 (m^2 s^{-1})
$MW_{Rn\text{-}222}$	Molecular weight of Rn-222 (g mol^{-1})
MW_s	Molecular weight of radionuclide of interest, s (g mol^{-1})

Two options are provided in the ARM to calculate D_e^{Rn-222}. The first, given by Rogers and Nielson (1991), is as follows:

$$D = D_o \times A_o \times \eta_a^{b_o} \qquad \text{Eq. (6-11)}$$

where:

D	D_e^{Rn-222} (m^2 s^{-1})
D_o	Diffusion coefficient for Rn-222 in air (m^2 s^{-1})
A_o, b_o	Empirical functions of porosity or dimensionless constants (0.74 and 2.2, respectively)
η_a	Air-filled porosity (m^3 m^{-3}, unitless) which equals [$\eta(1 - S)$]
S	Volume fraction of water saturation (m^3 m^{-3}, unitless)

The second option, also given by (Rogers and Nielson, 1991), is an updated diffusion correlation based upon a larger database:

$$D_c = D_o\eta \times \exp\left(-6S\eta - 6S^{14\eta}\right) \qquad \text{Eq. (6-12)}$$

where:

D_c	D_e^{Rn-222} (m^2 s^{-1})
η	Total porosity [in contrast to air-filled porosity, η_a, used in Eq. (6-11)] (m^3 m^{-3}, unitless)

Both Eq. (6-11) and Eq. (6-12) are incorporated in the ARM; however, because Eq. (6-12) is based upon a larger database, it is used as the best estimate case in the ARM simulations for this PA.

Sensitivity analysis is performed on diffusion coefficient by first doubling D_o. The second analysis uses Eq. (6-11) to calculate D_e^{Rn-222}. Eq. (6-11) resulted in lower D_e^{Rn-222} values that are similar to those utilized in PA2008 (WSRC, 2008).

4) **Henry's Law Constant**: The base-case scenario includes lower Henry's Law constants for cementitious materials and cementitious waste zones in the LAWV, ILV, and CIG trench segments (NRCDAs excepted) because of the alkaline porewater (pH 8.23; Section 3.6.1.7). However, a sensitivity case is also run where the alkaline pH associated with cementitious materials is not assumed. Instead, all Henry's Law constants are defined based on a soil pH of 5.4 (Section 3.6.1.7). This sensitivity case applies only to C-14 in the

air pathway analysis because Rn-222, H-3, and Kr-85 are assigned identical Henry's Law constants for cementitious and soil materials in the ARM (Section 3.6.1.7).

For the air pathway, sensitivity analysis is performed assuming 1 Ci parent buried from the set of radionuclides requiring disposal limits for each reference DU-type as determined in the multitiered radionuclide screening process detailed in Section 2.3.8.1. One to three parent radionuclides from the set of C-14, H-3, and Kr-85 are included in the air pathway analysis for each reference DU-type as listed in Table 2-32.

For the radon pathway, sensitivity analysis is performed assuming 1 Ci parent buried (0.25 Ci after emanation factor is applied) for three parent radionuclides: Ra-226, Th-230, and U-234. These parents provide the largest Rn-222 flux at the surface. Ra-226 is a required disposal limit for most ELLWF DUs based upon the results of the multitiered radionuclide screening process described in Section 2.3.8.2 and summarized in Table 2-35. U-234 and Th-230 are two other parent radionuclides that require disposal limits (Table 2-35). U-234 decays to Th-230, which then decays to Ra-226 and Rn-222. This decay process takes time to build to a steady-state flux of Rn-222 due to the long half-lives of U-234 (2.46E05 yr) and Th-230 (7.54E04 yr). U-234 produces vastly different and delayed fluxes relative to Ra-226. U-234 is also the convergence point of all decay chains that generate Rn-222. Therefore, U-234 provides a measure to capture how variations in ARM input parameters will impact other parents further up the decay chains.

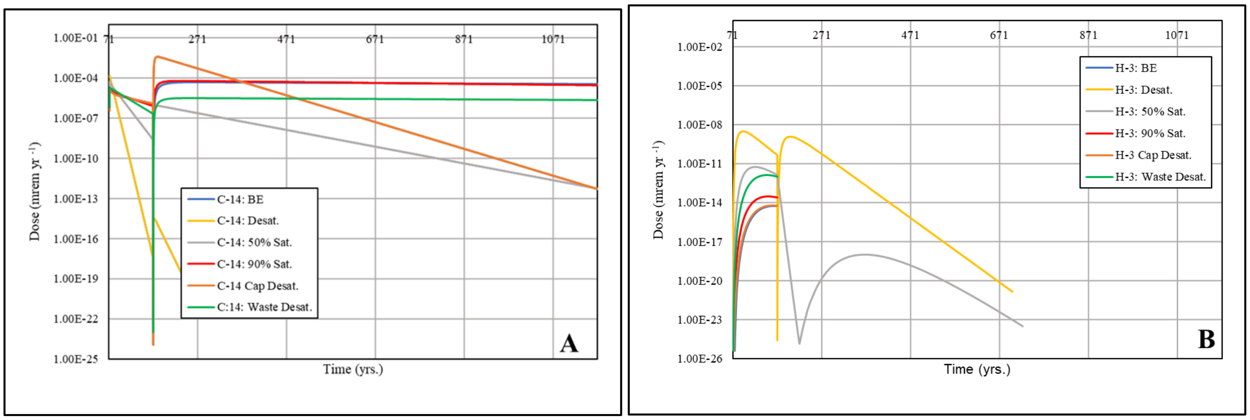
By nature, changes to input parameter values in the ARM influence the transport of Rn-222 only, not its production, which is based on established half-lives of the decay-chain radionuclides. Therefore, variation in peak flux arising from parameter changes within the ARM will be constant between parents if the peak fluxes fall within the same time window (Years 71 to 171 or Years 171 to 1,171). However, a change in flux will not be constant for peaks that do not fall within the same time window because some properties do not apply to all time windows (e.g., closure cap properties apply only after Year 171 when the final closure cap is installed). This is especially pertinent for parent radionuclides that have not reached a maximum flux of Rn-222 within the compliance period. As such, the relative change in peak Rn-222 flux from parents Ra-226, Th-230, and U-234 does not scale directly for all Rn-222-producing parents but does provide apt representation of all Rn-222-producing parents.

6.3.1. Slit and Engineered Trenches

6.3.1.1. Air Pathway Sensitivity to Water Saturation

6.3.1.1.1. Generic Waste Form

Air pathway dose factors for C-14 and H-3 emanating from a generic waste form in a ST or ET are highly dependent on water saturation of the materials. Water saturation impacts two major factors in diffusive transport through the air phase: (1) partitioning of a radionuclide and (2) air-filled porosity of a material. The partitioning defines the fraction of the radionuclide that is available for transport. Air-filled porosity determines the diffusive conductance in the model, which increases at lower saturation because of the larger diffusive connection between material layers. Therefore, mass transport is faster, leading to increased peak dose. This is especially evident at complete desaturation (all materials desaturated) and 50% saturation (Figure 6-104 and Table 6-161), where an orders-of-magnitude increase in peak dose factor is observed relative to the best estimate case. The water saturation values used in the best estimate case are biased low (see Section 5.1.5). A small change in water saturation has a less significant impact on peak dose factor as observed in Table 6-161 for peak dose factors at 90% saturation, which are within an order of magnitude of the best estimate case.



Note: Values below 1E-26 are not shown.

Figure 6-104. Dose Factor Time Histories for 1 Ci of C-14 (A) and H-3 (B) Buried in Slit and Engineered Trenches for Air Pathway Water Saturation Sensitivity Cases

Table 6-161. Peak Dose Factor and Time of Peak for 1 Ci Parent Buried in Slit and Engineered Trenches for Air Pathway Water Saturation Sensitivity Cases

Radio-nuclide	Best Estimate Case		All Materials Desaturated			50% Saturation		
	Peak Dose Factor (mrem yr^{-1} Ci^{-1})	Time of Peak (Year)	Peak Dose Factor (mrem yr^{-1} Ci^{-1})	Time of Peak (Year)	ΔDose Fraction	Peak Dose Factor (mrem yr^{-1} Ci^{-1})	Time of Peak (Year)	ΔDose Fraction
C-14	4.79E-05	266	1.47E-04	73.04	2.07E+00	5.51E-05	73.08	1.51E-01
H-3	5.50E-15	162	2.76E-09	97	5.02E+05	4.98E-12	123	9.05E+02
Radio-nuclide	Best Estimate Case		90% Saturation			Desaturated Closure Cap Only		
	Peak Dose Factor (mrem yr^{-1} Ci^{-1})	Time of Peak (Year)	Peak Dose Factor (mrem yr^{-1} Ci^{-1})	Time of Peak (Year)	ΔDose Fraction	Peak Dose Factor (mrem yr^{-1} Ci^{-1})	Time of Peak (Year)	ΔDose Fraction
C-14	4.79E-05	266	5.99E-05	230	2.51E-01	3.85E-03	181	7.94E+01
H-3	5.50E-15	162	2.71E-14	153	3.93E+00	5.50E-15	162	0.00E+00
Radio-nuclide	Best Estimate Case		Desaturated Waste Zone Only			--		
	Peak Dose Factor (mrem yr^{-1} Ci^{-1})	Time of Peak (Year)	Peak Dose Factor (mrem yr^{-1} Ci^{-1})	Time of Peak (Year)	ΔDose Fraction	--	--	--
C-14	4.79E-05	266	1.87E-05	73.3	-6.10E-01	--	--	--
H-3	5.50E-15	162	1.19E-12	150	2.15E+02	--	--	--

Notes:

ΔDose Fraction = (Sensitivity Case Dose Factor − Best Estimate Case Dose Factor) ÷ Best Estimate Case Dose Factor

Changes in water saturation influence the peak dose factor of H-3 more so than C-14. The time of peak for H-3 is always before the final closure cap is installed in Year 171, when the POA moves from the SRS site boundary to the 100-meter POA. The time of peak for C-14 occurs well after Year 171 in the best estimate case well before Year 171 in the three desaturation cases. C-14 is transported more quickly under desaturation conditions. Before Year 171, smaller site-boundary DRFs apply in the model thereby reducing peak dose factors.

Desaturation of the trench waste zone results in a lower peak dose factor for C-14 because desaturation increases the mass of C-14 released before closure cap placement at Year 171. Hence, less residual C-14 mass is available for mass transport beyond Year 171 when a second, lower C-14 peak dose occurs. This effect is not seen with H-3 because it decays before the final closure cap is placed; all H-3 peaks occur before Year 171.

6.3.1.1.2. Components-in-Grout Special Waste Form

Air pathway dose factors for C-14 and H-3 emanating from the CIG trench segment SWFs is highly dependent on water saturation of the materials. Diffusive conductance increases at lower water saturation because of the larger diffusive connection between material layers. Therefore, transport is faster, which leads to increased peak dose factor. The sensitivity cases for water saturation (Table 6-162 and Figure 6-105) display an orders-of-magnitude increase in peak dose factor compared to the best estimate case. Desaturation of concrete significantly impacts mass transport in the air phase. Interestingly, the 50% saturation case displays the highest peak dose factor for C-14. Water saturation in the closure cap helps retain C-14, which is then instantaneously released upon collapse of the closure cap and grout at Year 371. Because less C-14 mass is retained in the closure cap layers in the desaturated closure cap only case, this peak is less pronounced (Figure 6-105).

Table 6-162. Peak Dose Factor and Time of Peak for 1 Ci Parent Buried in CIG Special Waste Forms for Air Pathway Water Saturation Sensitivity Cases

Radio-nuclide	Best Estimate Case		All Materials Desaturated			50% Saturation		
	Peak Dose Factor (mrem yr^{-1} Ci^{-1})	Time of Peak (Year)	Peak Dose Factor (mrem yr^{-1} Ci^{-1})	Time of Peak (Year)	ΔDose Fraction	Peak Dose Factor (mrem yr^{-1} Ci^{-1})	Time of Peak (Year)	ΔDose Fraction
C-14	8.58E-08	371.04	2.23E-05	371	2.59E+02	3.23E-05	371.01	3.75E+02
H-3	4.82E-15	168.84	5.40E-09	179	1.12E+06	8.75E-11	122	1.82E+04
Radio-nuclide	Best Estimate Case		90% Saturation			Desaturated Closure Cap Only		
	Peak Dose Factor (mrem yr^{-1} Ci^{-1})	Time of Peak (Year)	Peak Dose Factor (mrem yr^{-1} Ci^{-1})	Time of Peak (Year)	ΔDose Fraction	Peak Dose Factor (mrem yr^{-1} Ci^{-1})	Time of Peak (Year)	ΔDose Fraction
C-14	8.58E-08	371.04	1.46E-06	371.03	1.61E+01	5.02E-08	1,070	-4.15E-01
H-3	4.82E-15	168.84	9.45E-14	156	1.86E+01	2.66E-12	116	5.50E+02

Notes:

ΔDose Fraction = (Sensitivity Case Dose Factor − Best Estimate Case Dose Factor) ÷ Best Estimate Case Dose Factor

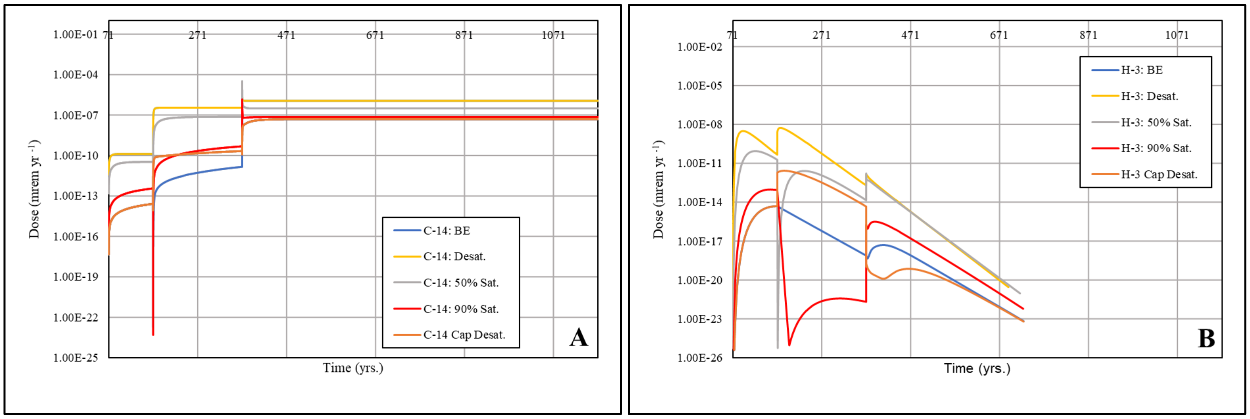


Figure 6-105. Dose Factor Time Histories for 1 Ci of C-14 (A) and H-3 (B) Buried in CIG Special Waste Forms for Air Pathway Water Saturation Sensitivity Cases

6.3.1.2. Radon Flux Sensitivity to Water Saturation

6.3.1.2.1. Generic Waste Form

Water saturation of materials does not strongly impact Rn-222 surface flux originating from the decay of Ra-226, Th-230, and U-234 buried as a generic waste form in STs or ETs (Table 6-163). Water saturation impacts Rn-222 diffusive transport because it defines the air-filled porosity of a material, which in part determines the diffusive conductance in the model. Diffusive conductance increases with decreased water saturation because of the larger diffusive connection between material layers. Mass transport of Rn-222 is therefore faster, which increases radon flux at the surface as less Rn-222 decay occurs. Well after the peak radon flux occurs, the effect of water saturation is more pronounced (Figure 6-106).

Table 6-163. Peak Rn-222 Flux Factor and Time of Peak for 1 Ci Parent Buried in Slit and Engineered Trenches for Radon Pathway Water Saturation Sensitivity Cases

Radio-nuclide	Best Estimate Case		All Materials Desaturated			50% Saturation		
	Peak Flux Factor (pCi m^{-2} s^{-1} Ci^{-1})	Time of Peak (Year)	Peak Flux Factor (pCi m^{-2} s^{-1} Ci^{-1})	Time of Peak (Year)	ΔFlux Fraction	Peak Flux Factor (pCi m^{-2} s^{-1} Ci^{-1})	Time of Peak (Year)	ΔFlux Fraction
Ra-226	2.19E+03	72	3.14E+04	72	1.33E+01	1.24E+04	72	4.67E+00
Th-230	1.61E+02	170.99	2.31E+03	170.99	1.33E+01	9.14E+02	170.99	4.67E+00
U-234	1.28E-01	170.99	3.68E+00	1,171	2.77E+01	7.28E-01	170.99	4.67E+00
Radio-nuclide	Best Estimate Case		90% Saturation			Desaturated Closure Cap Only		
	Peak Flux Factor (pCi m^{-2} s^{-1} Ci^{-1})	Time of Peak (Year)	Peak Flux Factor (pCi m^{-2} s^{-1} Ci^{-1})	Time of Peak (Year)	ΔFlux Fraction	Peak Flux Factor (pCi m^{-2} s^{-1} Ci^{-1})	Time of Peak (Year)	ΔFlux Fraction
Ra-226	2.19E+03	72	3.38E+03	72	5.43E-01	2.19E+03	72	0.00E+00
Th-230	1.61E+02	170.99	2.49E+02	170.99	5.43E-01	1.61E+02	170.99	0.00E+00
U-234	1.28E-01	170.99	1.98E-01	170.99	5.43E-01	1.28E-01	170.99	0.00E+00
Radio-nuclide	Best Estimate Case		Desaturated Waste Zone Only			--		
	Peak Flux Factor (pCi m^{-2} s^{-1} Ci^{-1})	Time of Peak (Year)	Peak Flux Factor (pCi m^{-2} s^{-1} Ci^{-1})	Time of Peak (Year)	ΔFlux Fraction	--	--	--
Ra-226	2.19E+03	72	1.84E+03	72	-1.59E-01	--	--	--
Th-230	1.61E+02	170.99	1.36E+02	170.99	-1.59E-01	--	--	--
U-234	1.28E-01	170.99	1.08E-01	170.99	-1.59E-01	--	--	--

Notes:

ΔFlux Fraction = (Sensitivity Case Flux Factor − Best Estimate Case Flux Factor) ÷ Best Estimate Case Flux Factor

The change in Δflux fraction is the same for radionuclides that peak in the same time window as each other and the best estimate case.

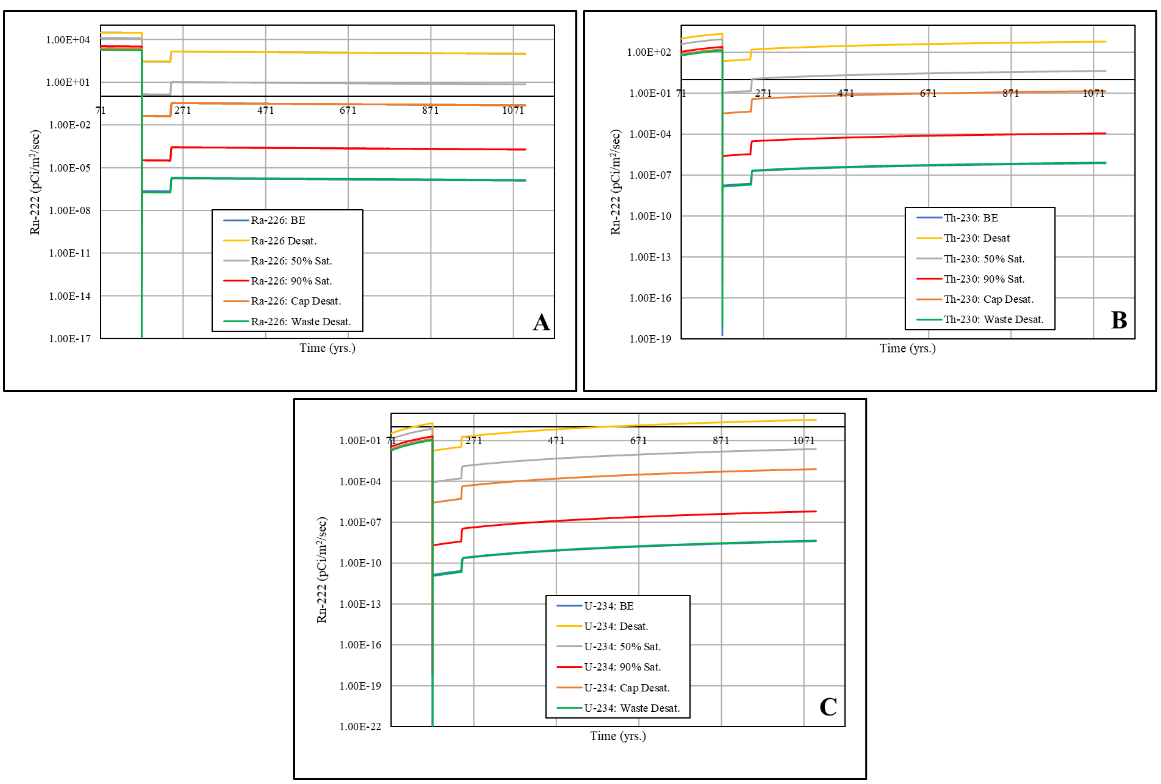


Figure 6-106. Flux Factor Time Histories from 1 Ci of Ra-226 (A), Th-230 (B), and U-234 (C) Buried in Slit and Engineered Trenches for Radon Pathway Water Saturation Sensitivity Cases

Desaturation of the trench waste zone results in a slight decrease in peak flux factor from the three Rn-222 parents. Rn-222 diffusion is primarily a function of the diffusive conductance and the concentration gradient across cells. The overall gradient is defined by waste zone concentration and the surface boundary concentration, which set at 0.0 pCi L^{-1}. Increasing water saturation increases the concentration of Rn-222 in the waste zone by decreasing the volume of air. The increased waste zone concentration increases the overall gradient. Rn-222 mass is at a steady state because it is continuously produced by Ra-226. Conversely, diffusive conductance decreases with increasing water saturation because of the smaller area of the diffusive connection. Thus, the change in flux is a balance between the larger concentration gradient and lower diffusive conductance as the water saturation of the waste zone changes. As a result, an inflection point exists where increasing water saturation no longer increases the radon surface flux. To illustrate this point, Figure 6-107 displays a Tornado chart for Rn-222 surface flux originating from the decay of a Ra-226 parent with a dry waste zone at the low end, a 35% water-saturated waste zone as the central value (dark line at about 2,210 pCi m^{-2} s^{-1}), and a 70% water-saturated waste zone at the upper end. The case displaying the highest flux factor is the central value, which supports the notion of a balance between the concentration gradient and diffusive conductance as well as the presence of an inflection point.

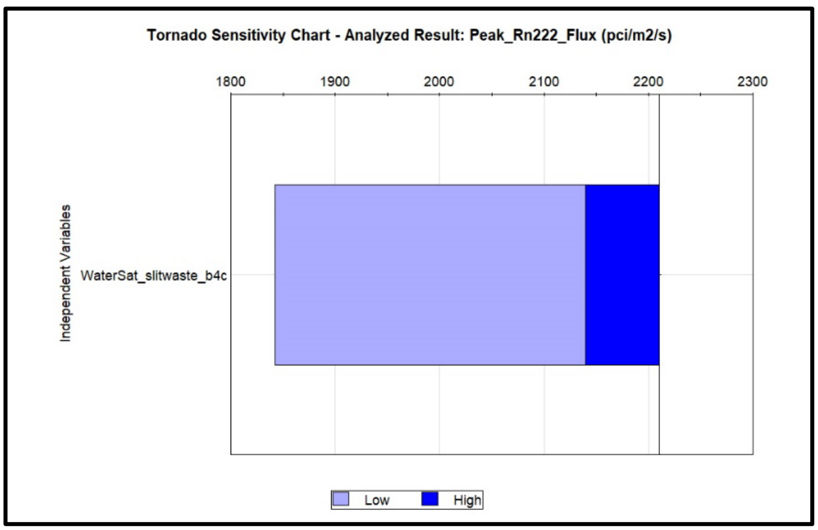


Figure 6-107. Effect of Water Saturation of Slit and Engineered Trench Generic Waste Form on Rn-222 Surface Flux Assuming 1 Ci of Ra-226 Parent

6.3.1.2.2. Components-in-Grout Special Waste Form

Water saturation of materials has a strong impact on Rn-222 surface flux factor originating from the decay of Ra-226, Th-230, and U-234 buried in a CIG trench segment SWF (Table 6-164). Water saturation affects Rn-222 diffusive transport because it defines the air-filled porosity of a material, which in part determines the diffusive conductance in the model. Desaturation of the grout material and soil fill overlaying the trench seemingly has the largest effect on radon flux. An increase in radon flux factor is seen ahead of closure cap placement in Year 171 as well as after the subsequent collapse of the grout material and closure cap in Year 371 (Figure 6-108).

Table 6-164. Peak Rn-222 Flux Factor and Time of Peak for 1 Ci Parent Buried in Components-in-Grout Special Waste Forms for Radon Pathway Water Saturation Sensitivity Cases

Radio-nuclide	Best Estimate Case		All Materials Desaturated			50% Saturation		
	Peak Flux Factor (pCi m^{-2} s^{-1} Ci^{-1})	Time of Peak (Year)	Peak Flux Factor (pCi m^{-2} s^{-1} Ci^{-1})	Time of Peak (Year)	ΔFlux Fraction	Peak Flux Factor (pCi m^{-2} s^{-1} Ci^{-1})	Time of Peak (Year)	ΔFlux Fraction
Ra-226	1.97E+02	371.21	3.62E+04	371.03	1.83E+02	9.05E+03	72	4.48E+01
Th-230	9.17E+01	1,171	1.66E+04	1,171	1.80E+02	3.55E+03	1,171	3.77E+01
U-234	5.35E-01	1,171	9.65E+01	1,171	1.79E+02	2.07E+01	1,171	3.76E+01

Radio-nuclide	Best Estimate Case		90% Saturation			Desaturated Closure Cap Only		
	Peak Flux Factor (pCi m^{-2} s^{-1} Ci^{-1})	Time of Peak (Year)	Peak Flux Factor (pCi m^{-2} s^{-1} Ci^{-1})	Time of Peak (Year)	ΔFlux Fraction	Peak Flux Factor (pCi m^{-2} s^{-1} Ci^{-1})	Time of Peak (Year)	ΔFlux Fraction
Ra-226	1.97E+02	371.21	5.05E+02	371.19	1.56E+00	1.98E+02	371.21	1.30E-03
Th-230	9.17E+01	1,171	2.35E+02	1,171	1.56E+00	9.18E+01	1,171	1.30E-03
U-234	5.35E-01	1,171	1.37E+00	1,171	1.56E+00	5.36E-01	1,171	1.30E-03

Notes:

ΔFlux Fraction = (Sensitivity Case Flux Factor − Best Estimate Case Flux Factor) ÷ Best Estimate Case Flux Factor

The change in Δflux fraction is the same for radionuclides that peak in the same time window as each other and the best estimate case.

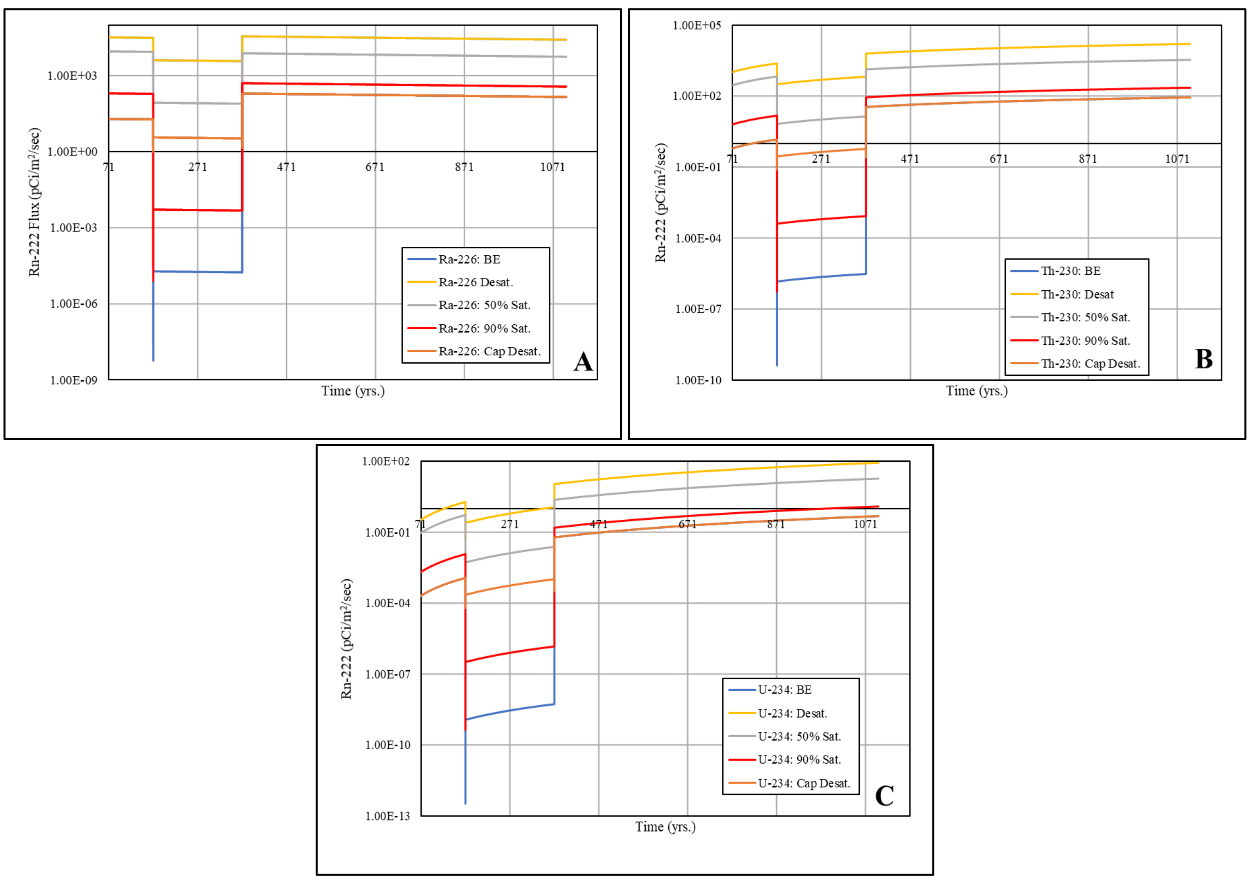


Figure 6-108. Dose Factor Time Histories from 1 Ci of Ra-226 (A), Th-230 (B), and U-234 (C) Buried in Components-in-Grout Special Waste Forms for Radon Pathway Water Saturation Sensitivity Cases

6.3.1.3. Air Pathway Sensitivity to Closure Cap Presence and Diffusion Coefficient

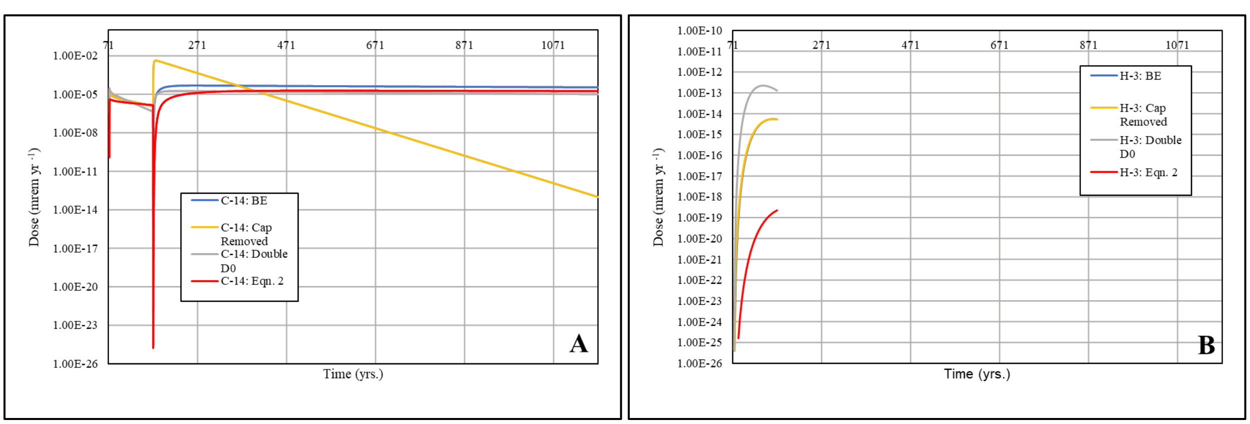
6.3.1.3.1. Generic Waste Form

The absence of a final closure cap over STs and ETs impacts the dose factor for C-14 but not for H-3 as indicated in Table 6-165. The peak dose factor for C-14 occurs following placement of the final closure cap at Year 171 when the DRFs are calculated for the 100-meter POA (Figure 6-109). The absence of a final closure cap facilitates C-14 release directly to the atmosphere, increasing the peak dose. The dose factor for H-3, on the other hand, which peaks before Year 171, is unaffected. Doubling D_o accelerates C-14 and H-3 transport as indicated in Table 6-165 by the earlier time of peak. For H-3, this results in a higher peak dose factor, while for C-14, the peak dose factor decreases and occurs before the switch in DRF at Year 171 as shown in Figure 6-109. Employing Eq. (6-11) in place of Eq. (6-12) in the model to calculate $D_e^{Rn\text{-}222}$ decreases the effective diffusion coefficient, D_e, for each material thereby decreasing the overall dose factor and delaying the time of peak dose, particularly for C-14.

Table 6-165. Peak Dose Factor and Time of Peak for 1 Ci Parent Buried in Slit and Engineered Trenches for Air Pathway Closure Cap Presence and Diffusion Coefficient Sensitivity Cases

Radio-nuclide	Best Estimate Case		Closure Cap Removed			Double D_o		
	Peak Dose Factor (mrem yr^{-1} Ci^{-1})	Time of Peak (Year)	Peak Dose Factor (mrem yr^{-1} Ci^{-1})	Time of Peak (Year)	ΔDose Fraction	Peak Dose Factor (mrem yr^{-1} Ci^{-1})	Time of Peak (Year)	ΔDose Fraction
C-14	4.79E-05	266	4.26E-03	178	8.80E+01	2.94E-05	73.12	-3.87E-01
H-3	5.50E-15	162	5.50E-15	162	0.00E+00	2.22E-13	139	3.93E+01
Radio-nuclide	Best Estimate Case		Diffusion Eq. (6-11)			--		
	Peak Dose Factor (mrem yr^{-1} Ci^{-1})	Time of Peak (Year)	Peak Dose Factor (mrem yr^{-1} Ci^{-1})	Time of Peak (Year)	ΔDose Fraction	--	--	--
C-14	4.79E-05	266	1.93E-05	542	-5.96E-01	--	--	--
H-3	5.50E-15	162	2.25E-19	170.99	-1.00E+00	--	--	--

Notes:
ΔDose Fraction = (Sensitivity Case Dose Factor − Best Estimate Case Dose Factor) ÷ Best Estimate Case Dose Factor



Notes: C-14 Eqn. 2 and H-3 Eqn. 2 in the plot legends refers to Eq. (6-11) in the text. Values below 1E-26 mrem yr^{-1} are not shown.

Figure 6-109. Dose Factor Time Histories for 1 Ci of C-14 (A) and H-3 (B) Buried in Slit and Engineered Trenches for Air Pathway Closure Cap Presence and Diffusion Coefficient Sensitivity Cases

6.3.1.3.2. Components-in-Grout Special Waste Form

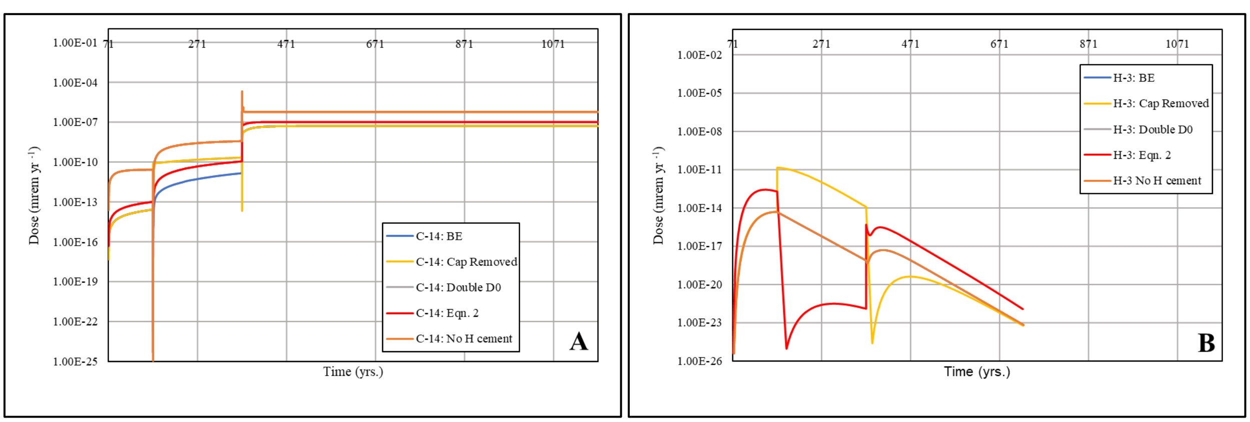
The absence of a final closure cap over the CIG trench segment SWFs impacts the dose factor for C-14 but not for H-3 as indicated in Table 6-166. The peak dose factor for C-14 occurs at the time of collapse of both the grout and overlying closure cap (Figure 6-110). The absence of a final closure cap lowers the C-14 dose factor during collapse. Dose from H-3, on the other hand, increases without a closure cap because the time of peak shifts to beyond Year 171 when the DRFs increase. Doubling D_o accelerates C-14 and H-3 transport and results in higher peak dose factors for both radionuclides. Utilizing Eq. (6-11) instead of Eq. (6-12) in the model to calculate $D_e^{Rn\text{-}222}$ decreases the effective diffusion coefficient, D_e, for each material thereby decreasing overall dose factor and delaying the time of peak dose. Finally, not using the decreased Henry's Law constants within cementitious material results in a higher peak dose factor for C-14. H-3 is unaffected as the same Henry's Law constant is assigned for both soil and cementitious material.

Table 6-166. Dose Factor Time Histories for 1 Ci of C-14 (A) and H-3 (B) Buried in Components-in-Grout Special Waste Forms for Air Pathway Closure Cap Presence and Diffusion Coefficient Sensitivity Cases

Radio-nuclide	Best Estimate Case		Closure Cap Removed			Double D_o		
	Peak Dose Factor (mrem yr^{-1} Ci^{-1})	Time of Peak (Year)	Peak Dose Factor (mrem yr^{-1} Ci^{-1})	Time of Peak (Year)	ΔDose Fraction	Peak Dose Factor (mrem yr^{-1} Ci^{-1})	Time of Peak (Year)	ΔDose Fraction
C-14	8.58E-08	371.04	5.02E-08	1,138	-4.15E-01	6.30E-07	371.02	6.35E+00
H-3	4.82E-15	168.84	1.44E-11	171	2.98E+03	2.68E-13	145	5.46E+01
Radio-nuclide	Best Estimate Case		Diffusion Eq. (6-11)			No Change in Henry's Law Constant for Cementitious Material		
	Peak Dose Factor (mrem yr^{-1} Ci^{-1})	Time of Peak (Year)	Peak Dose Factor (mrem yr^{-1} Ci^{-1})	Time of Peak (Year)	ΔDose Fraction	Peak Dose Factor (mrem yr^{-1} Ci^{-1})	Time of Peak (Year)	ΔDose Fraction
C-14	8.58E-08	371.04	1.24E-08	1,171	-8.56E-01	2.08E-05	371.03	2.42E+02
H-3	4.82E-15	168.84	2.81E-20	170.99	-1.00E+00	4.82E-15	168.84	0.00E+00

Notes:

ΔDose Fraction = (Sensitivity Case Dose Factor − Best Estimate Case Dose Factor) ÷ Best Estimate Case Dose Factor



Notes: C-14 Eqn. 2 and H-3 Eqn. 2 in the plot legends refers to Eq. (6-11) in the text. Values below 1E-26 mrem yr^{-1} are not shown.

Figure 6-110. Dose Factor Time Histories for 1 Ci of C-14 (A) and H-3 (B) Buried in Components-in-Grout Special Waste Forms for Air Pathway Closure Cap Presence and Diffusion Coefficient Sensitivity Cases

6.3.1.4. Radon Pathway Sensitivity to Closure Cap Presence and Diffusion Coefficient

6.3.1.4.1. Generic Waste Form

The presence of the final closure cap does not influence the Rn-222 peak flux factor at the surface of slit and engineered trenches because Rn-222 originating from the decay of all three parent radionuclides reaches its maximum before cap placement in Year 171 (Table 6-167 and Figure 6-111). Removal of the closure cap after Year 171 increases the Rn-222 surface flux factor compared to the best estimate case; however, the absence of a closure cap is somewhat offset by dynamic compaction and application of clean fill to the trenches during final closure. Doubling the Rn-222 diffusion coefficient in air results in higher peaks and flux overall. Employing Eq. (6-11) in place of Eq. (6-12) in the model to calculate $D_e^{Rn\text{-}222}$ decreases the effective diffusion coefficients, D_e, thereby lowering fluxes across the board. The Eq. (6-11) diffusion coefficients are comparable to the values used in PA2008 (WSRC, 2008). Overall, peak radon flux factors are more sensitive to changes in water saturation than to changes in diffusion coefficients or the presence or absence of the closure cap.

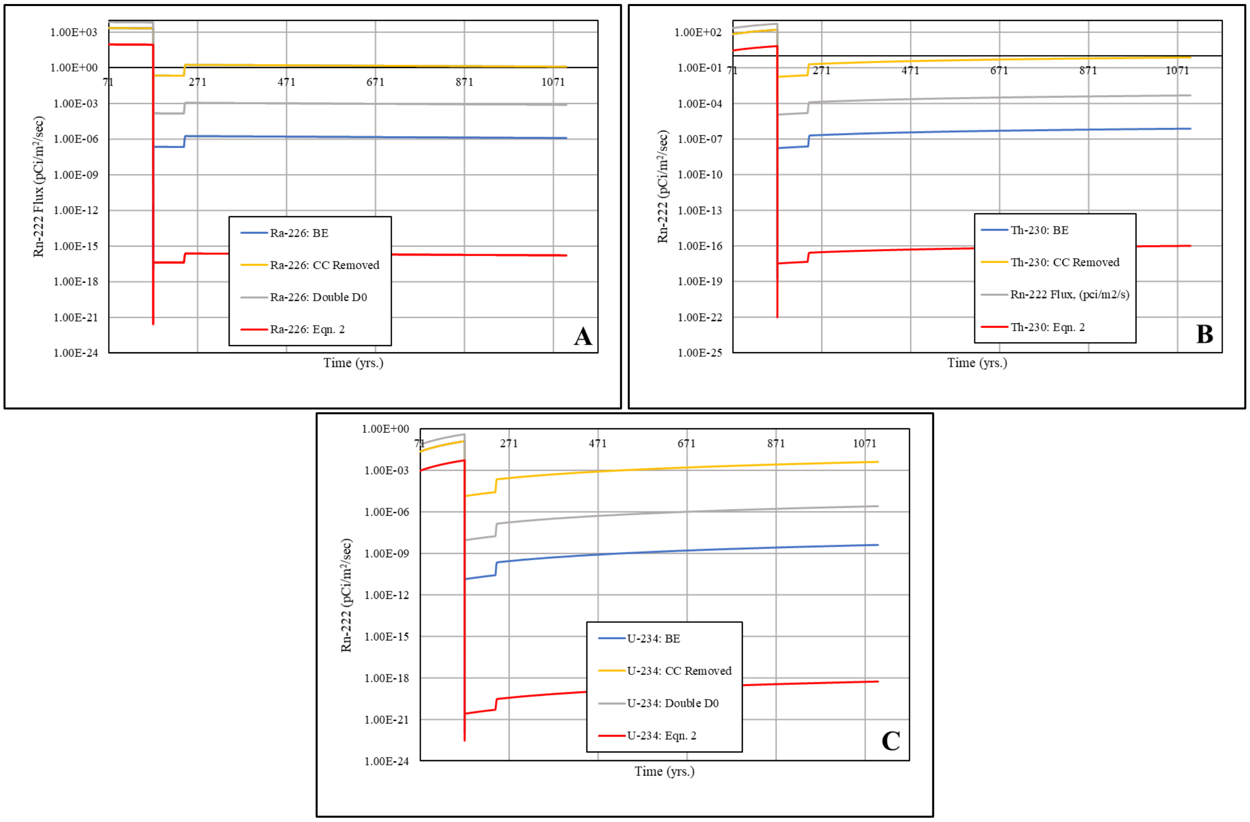
Table 6-167. Peak Rn-222 Flux Factor and Time of Peak for 1 Ci Parent Buried in Slit and Engineered Trenches for Radon Pathway Closure Cap Presence and Diffusion Coefficient Sensitivity Cases

Radio-nuclide	Best Estimate Case		Closure Cap Removed			Double D_o		
	Peak Flux Factor (pCi m^{-2} s^{-1} Ci^{-1})	Time of Peak (Year)	Peak Flux Factor (pCi m^{-2} s^{-1} Ci^{-1})	Time of Peak (Year)	ΔFlux Fraction	Peak Flux Factor (pCi m^{-2} s^{-1} Ci^{-1})	Time of Peak (Year)	ΔFlux Fraction
Ra-226	2.19E+03	72	2.19E+03	72	0.00E+00	6.97E+03	72	2.18E+00
Th-230	1.61E+02	170.99	1.61E+02	170.99	0.00E+00	5.13E+02	170.99	2.18E+00
U-234	1.28E-01	170.99	1.28E-01	170.99	0.00E+00	4.09E-01	170.99	2.18E+00
Radio-nuclide	Best Estimate Case		Diffusion Equation Eq. (6-11)			--		
	Peak Flux Factor (pCi m^{-2} s^{-1} Ci^{-1})	Time of Peak (Year)	Peak Flux Factor (pCi m^{-2} s^{-1} Ci^{-1})	Time of Peak (Year)	ΔFlux Fraction	--	--	--
Ra-226	2.19E+03	72	9.09E+01	72	-9.59E-01	--	--	--
Th-230	1.61E+02	170.99	6.69E+00	170.99	-9.59E-01	--	--	--
U-234	1.28E-01	170.99	5.33E-03	170.99	-9.59E-01	--	--	--

Notes:

ΔFlux Fraction = (Sensitivity Case Flux Factor − Best Estimate Case Flux Factor) ÷ Best Estimate Case Flux Factor

The change in Δflux fraction is the same for radionuclides that peak in the same time window as each other and the best estimate case.

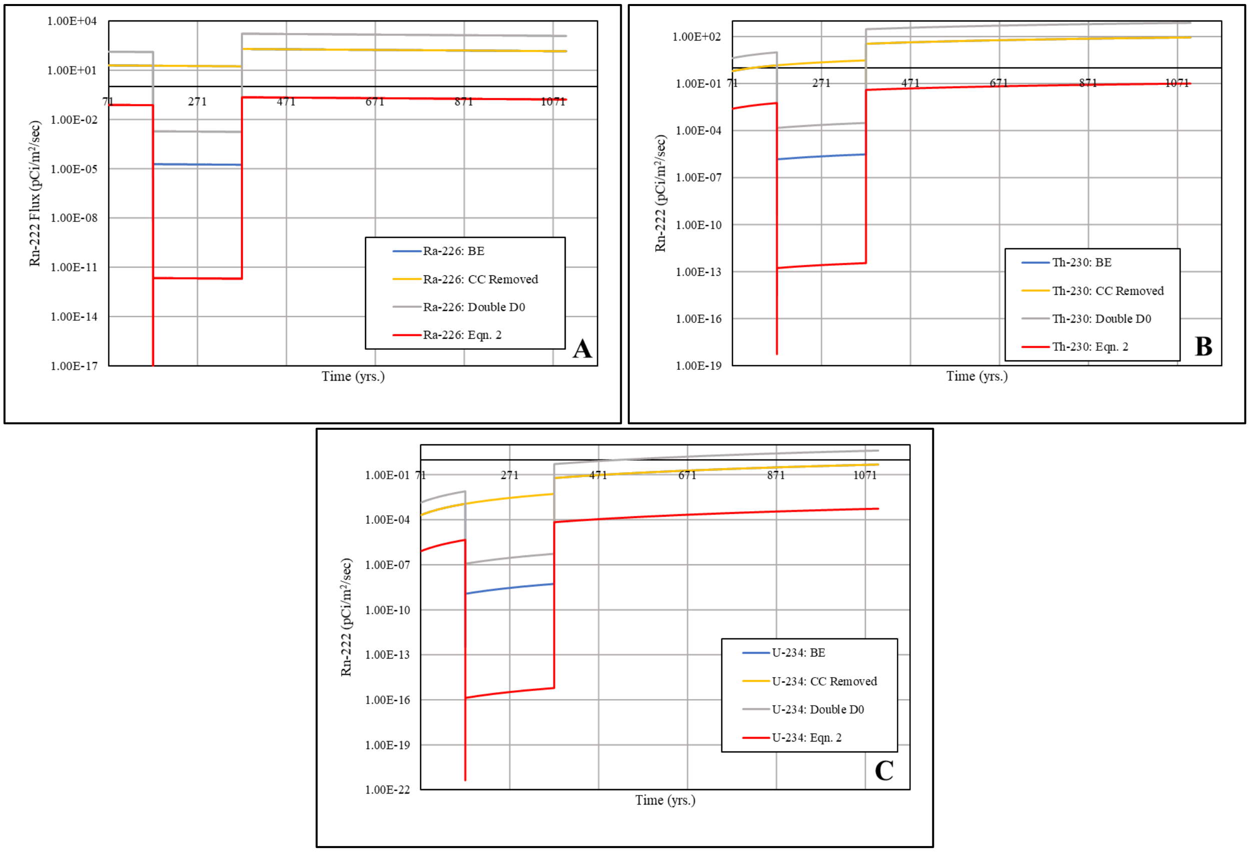


Note: Ra-226 Eqn. 2, Th-230 Eqn. 2, and U-234 Eqn. 2 in the plot legends refers to Eq. (6-11) in the text.

Figure 6-111. Flux Factor Time Histories from 1 Ci of Ra-226 (A), Th-230 (B), and U-234 (C) Buried in Slit and Engineered Trenches for Radon Pathway Closure Cap Presence and Diffusion Coefficient Sensitivity Cases

6.3.1.4.2. Components-in-Grout Special Waste Form

The presence of the final closure cap has a minimal impact on Rn-222 peak flux at the surface of the CIG trench segments because Rn-222 originating from the decay of all three parent radionuclides reaches its maximum after the closure cap is compromised during grout failure in Year 371 (Figure 6-112 and Table 6-168). Removal of the final closure cap increases radon flux relative to the best estimate case between Year 171 and Year 371; however, this does not impact the peak dose (Figure 6-112). Doubling the Rn-222 diffusion coefficient in air results in higher peak flux and overall flux; the increases are less than an order of magnitude. Utilizing Eq. (6-11) instead of Eq. (6-12) in the model to calculate $D_e^{Rn\text{-}222}$ decreases the effective diffusion coefficient, D_e, for each material thereby decreasing overall flux. The Eq. (6-11) diffusion coefficients are comparable to the values used in PA2008 (WSRC, 2008). Overall, peak radon fluxes are more sensitive to changes in water saturation than to changes in the diffusion coefficients or the presence or absence of the final closure cap.



Note: Ra-226 Eqn. 2, Th-230 Eqn. 2, and U-234 Eqn. 2 in the plot legends refers to Eq. (6-11) in the text.

Figure 6-112. Flux Factor Time Histories from 1 Ci of Ra-226 (A), Th-230 (B), and U-234 (C) Buried in Components-in-Grout Special Waste Forms for Radon Pathway Closure Cap Presence and Diffusion Coefficient Sensitivity Cases

Table 6-168. Peak Rn-222 Flux Factor and Time of Peak for 1 Ci Parent Buried in Components-in-Grout Special Waste Forms for Radon Pathway Closure Cap Presence and Diffusion Coefficient Sensitivity Cases

Radio-nuclide	Best Estimate Case		Closure Cap Removed			Double D_o		
	Peak Flux Factor (pCi m^{-2} s^{-1} Ci^{-1})	Time of Peak (Year)	Peak Flux Factor (pCi m^{-2} s^{-1} Ci^{-1})	Time of Peak (Year)	ΔFlux Fraction	Peak Flux Factor (pCi m^{-2} s^{-1} Ci^{-1})	Time of Peak (Year)	ΔFlux Fraction
Ra-226	1.97E+02	371.21	1.98E+02	371.21	1.93E-03	1.68E+03	371.15	7.53E+00
Th-230	9.17E+01	1,171	9.18E+01	1,171	1.93E-03	7.82E+02	1,171	7.53E+00
U-234	5.35E-01	1,171	5.36E-01	1,171	1.93E-03	4.56E+00	1,171	7.53E+00
Radio-nuclide	Best Estimate Case		Diffusion Eq. (6-11)			--		
	Peak Flux Factor (pCi m^{-2} s^{-1} Ci^{-1})	Time of Peak (Year)	Peak Flux Factor (pCi m^{-2} s^{-1} Ci^{-1})	Time of Peak (Year)	ΔFlux Fraction	--	--	--
Ra-226	1.97E+02	371.21	2.26E-01	371.29	-9.99E-01	--	--	--
Th-230	9.17E+01	1,171	1.05E-01	1,171	-9.99E-01	--	--	--
U-234	5.35E-01	1,171	6.12E-04	1,171	-9.99E-01	--	--	--

Notes:

ΔFlux Fraction = (Sensitivity Case Flux Factor − Best Estimate Case Flux Factor) ÷ Best Estimate Case Flux Factor

The change in Δflux fraction is the same for radionuclides that peak in the same time window as each other and the best estimate case.

6.3.2. Low-Activity Waste Vault

6.3.2.1. Air Pathway Sensitivity to Water Saturation

Air pathway dose factors for C-14 and H-3 emanating from the LAWV are highly dependent on water saturation of the materials (see Section 6.3.1.1.1 for ST and ET generic waste forms). Peak dose factors for water saturation sensitivity cases (Table 6-169 and Figure 6-113) display orders-of-magnitude increases versus the best estimate case. Desaturation of concrete and closure cap materials, both unlikely scenarios, also has a substantial impact on air-phase mass transport.

Table 6-169. Peak Dose Factor and Time of Peak for 1 Ci Parent Buried in Low-Activity Waste Vault for Air Pathway Water Saturation Sensitivity Cases

Radio-nuclide	Best Estimate Case		All Materials Desaturated			50% Saturation		
	Peak Dose Factor (mrem yr^{-1} Ci^{-1})	Time of Peak (Year)	Peak Dose Factor (mrem yr^{-1} Ci^{-1})	Time of Peak (Year)	ΔDose Fraction	Peak Dose Factor (mrem yr^{-1} Ci^{-1})	Time of Peak (Year)	ΔDose Fraction
C-14	8.27E-14	1,171	1.63E-07	446.74	1.97E+06	2.63E-08	1,171	3.18E+05
H-3	2.95E-19	171.99	1.41E-05	71.02	4.79E+13	1.71E-08	84	5.81E+10
Radio-nuclide	**Best Estimate Case**		**90% Saturation**			**Desaturated Closure Cap Only**		
	Peak Dose Factor (mrem yr^{-1} Ci^{-1})	**Time of Peak (Year)**	**Peak Dose Factor (mrem yr^{-1} Ci^{-1})**	**Time of Peak (Year)**	**ΔDose Fraction**	**Peak Dose Factor (mrem yr^{-1} Ci^{-1})**	**Time of Peak (Year)**	**ΔDose Fraction**
C-14	8.27E-14	1,171	6.86E-11	1,171	8.29E+02	1.22E-12	1,171	1.38E+01
H-3	2.95E-19	171.99	7.43E-15	166	2.52E+04	9.38E-16	193	3.18E+03

Notes: ΔDose Fraction = (Sensitivity Case Dose Factor − Best Estimate Case Dose Factor) ÷ Best Estimate Case Dose Factor

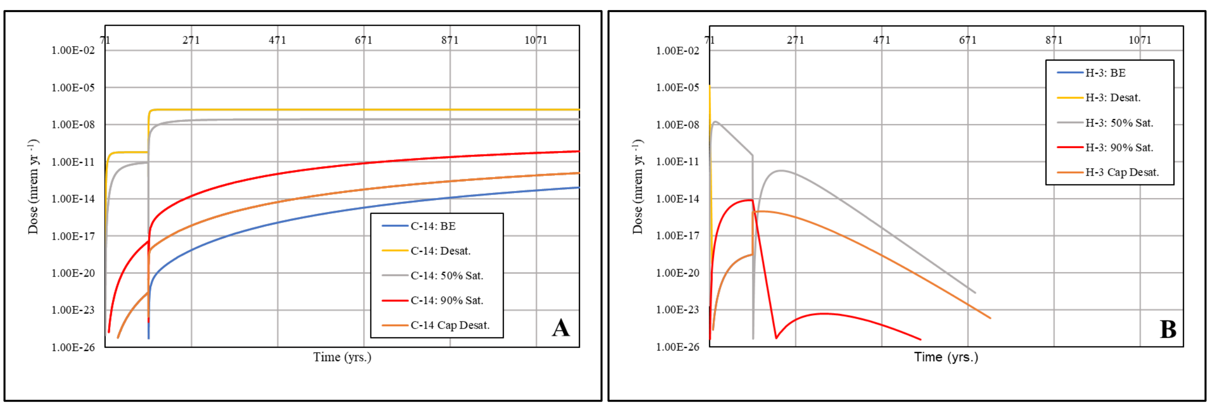


Figure 6-113. Dose Factor Time Histories for 1 Ci of C-14 (A) and H-3 (B) Buried in Low-Activity Waste Vault for Air Pathway Water Saturation Sensitivity Cases

6.3.2.2. Radon Flux Sensitivity to Water Saturation

Water saturation of materials has a strong impact on the surface flux factor of Rn-222 originating from the decay of Ra-226, Th-230, and U-234 in the LAWV as explained in Section 6.3.1.2.1 for ST and ET generic waste forms. This is especially evident in the complete desaturation cases (Table 6-170 and Figure 6-114) where a multiple orders-of-magnitude increase in peak flux factor is observed relative to the best estimate case. For the LAWV, desaturation of concrete seemingly produces much higher fluxes because LAWV waste is already considered dry. Further along in time and well after the time of peak flux, the effect of water saturation is more pronounced

(Figure 6-114) as was the case for STs and ETs also. For U-234 in the two desaturated cases, the slow production of Rn-222 results in a time of peak that occurs after application of the final closure cap, which causes the Rn-222 flux factor to be more readily impacted by the desaturation of the closure cap. As expected, the Δflux fraction is the same for radionuclides that peak in the same time window as each other and the best estimate case.

Table 6-170. Peak Rn-222 Flux Factor and Time of Peak for 1 Ci Parent Buried in Low-Activity Waste Vault for Radon Pathway Water Saturation Sensitivity Cases

Radio-nuclide	Best Estimate Case		All Materials Desaturated			50% Saturation		
	Peak Flux Factor (pCi m^{-2} s^{-1} Ci^{-1})	Time of Peak (Year)	Peak Flux Factor (pCi m^{-2} s^{-1} Ci^{-1})	Time of Peak (Year)	ΔFlux Fraction	Peak Flux Factor (pCi m^{-2} s^{-1} Ci^{-1})	Time of Peak (Year)	ΔFlux Fraction
Ra-226	7.89E-01	72	1.98E+04	72	2.51E+04	3.55E+03	72	4.50E+03
Th-230	5.76E-02	170.99	1.45E+03	170.99	2.52E+04	2.60E+02	170.99	4.51E+03
U-234	4.59E-05	170.99	4.62E+00	1,171	1.01E+05	2.07E-01	170.99	4.52E+03
Radio-nuclide	**Best Estimate Case**		**90% Saturation**			**Desaturated Closure Cap Only**		
	Peak Flux Factor (pCi m^{-2} s^{-1} Ci^{-1})	**Time of Peak (Year)**	**Peak Flux Factor (pCi m^{-2} s^{-1} Ci^{-1})**	**Time of Peak (Year)**	**ΔFlux Fraction**	**Peak Flux Factor (pCi m^{-2} s^{-1} Ci^{-1})**	**Time of Peak (Year)**	**ΔFlux Fraction**
Ra-226	7.89E-01	72	2.45E+01	72	3.01E+01	7.89E-01	72	0.00E+00
Th-230	5.76E-02	170.99	1.79E+00	170.99	3.01E+01	5.76E-02	170.99	0.00E+00
U-234	4.59E-05	170.99	1.43E-03	170.99	3.01E+01	3.15E-04	1,171	5.86E+00

Notes: ΔFlux Fraction = (Sensitivity Case Flux Factor − Best Estimate Case Flux Factor) ÷ Best Estimate Case Flux Factor

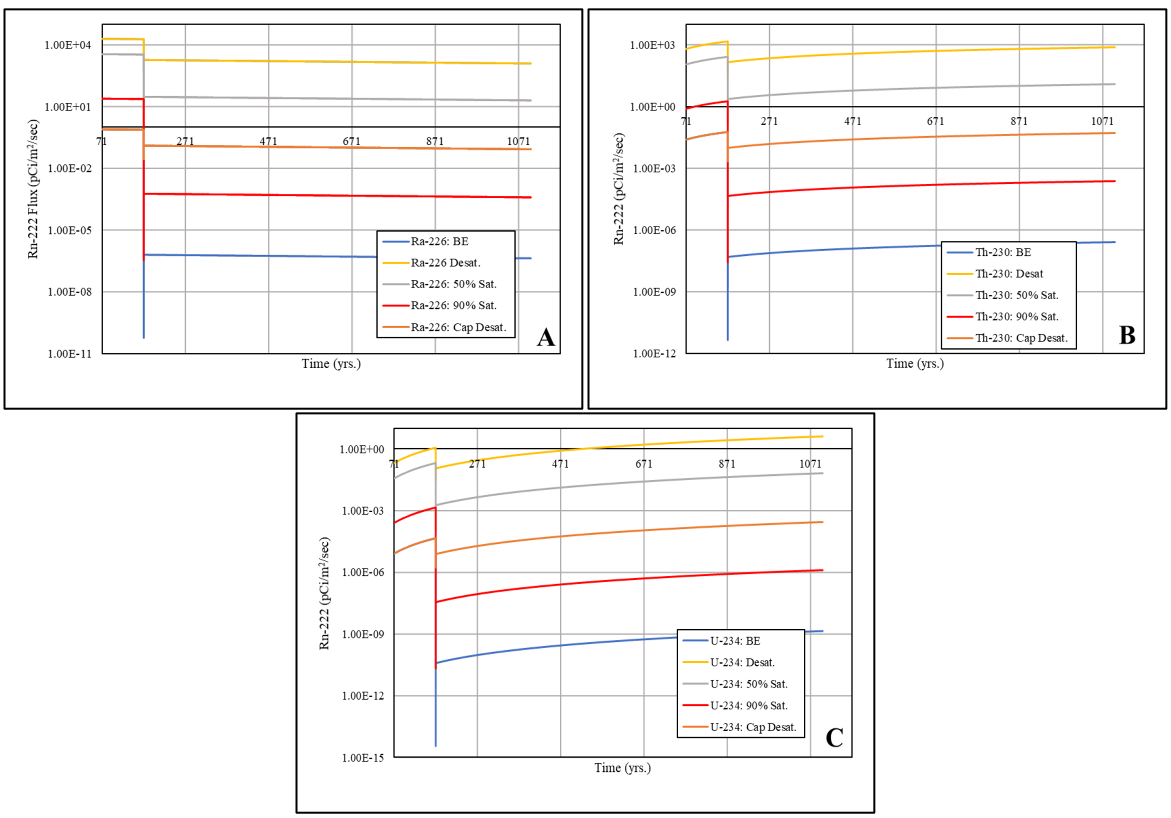


Figure 6-114. Flux Factor Time Histories from 1 Ci of Ra-226 (A), Th-230 (B), and U-234 (C) Buried in Low-Activity Waste Vault for Radon Pathway Water Saturation Sensitivity Cases

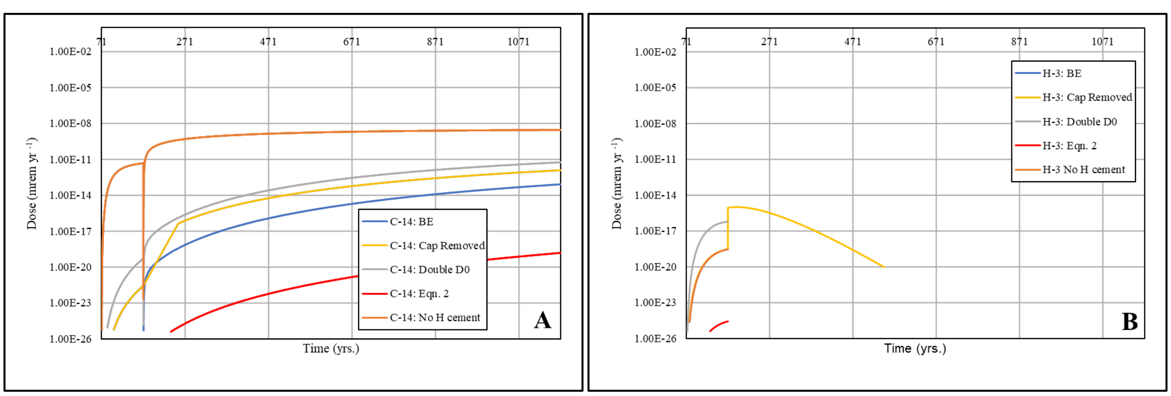
6.3.2.3. Air Pathway Sensitivity to Henry's Law Constant, Closure Cap Presence, and Diffusion Coefficient

Removal of the final closure cap over the LAWV increases the peak dose factors for C-14 and, in particular, H-3 (Table 6-171). The C-14 peak dose occurs 1,000 years after installation of the final closure cap at Year 1,171; therefore, if the closure cap is absent, the C-14 dose factor is higher compared to the best estimate case because of the shorter diffusional path to the surface (Figure 6-115). With H-3, the absence of the closure cap increases mass flux from the surface following the change in the POA and DRF at Year 171. Doubling D_o accelerates the mass transport of both C-14 and H-3, which results in higher peak dose factors. Employing Eq. (6-11) in place of Eq. (6-12) in the model to calculate $D_e^{Rn\text{-}222}$ decreases the effective diffusion coefficient, D_e, for each material thereby decreasing overall dose. Finally, not accounting for the decreased Henry's Law constants within cementitious material leads to a higher peak dose factor for C-14. The H-3 dose factor is unaffected because the Henry's Law constant assigned to the ARM is the same for both soil and cementitious material.

Table 6-171. Peak Dose Factor and Time of Peak for 1 Ci Parent Buried in Low-Activity Waste Vault for Air Pathway Henry's Law Constant, Closure Cap Presence, and Diffusion Coefficient Sensitivity Cases

Radio-nuclide	Best Estimate Case		Closure Cap Removed			Double D_o		
	Peak Dose Factor (mrem yr^{-1} Ci^{-1})	Time of Peak (Year)	Peak Dose Factor (mrem yr^{-1} Ci^{-1})	Time of Peak (Year)	ΔDose Fraction	Peak Dose Factor (mrem yr^{-1} Ci^{-1})	Time of Peak (Year)	ΔDose Fraction
C-14	8.27E-14	1,171	1.24E-12	1,171	1.40E+01	5.70E-12	1,171	6.79E+01
H-3	2.95E-19	170.99	1.01E-15	193	3.43E+03	6.07E-17	170.99	2.05E+02
Radio-nuclide	Best Estimate Case		Diffusion Eq. (6-11)			No Change in Henry's Law Constant for Cementitious Material		
	Peak Dose Factor (mrem yr^{-1} Ci^{-1})	Time of Peak (Year)	Peak Dose Factor (mrem yr^{-1} Ci^{-1})	Time of Peak (Year)	ΔDose Fraction	Peak Dose Factor (mrem yr^{-1} Ci^{-1})	Time of Peak (Year)	ΔDose Fraction
C-14	8.27E-14	1,171	1.55E-19	1,171	-1.00E+00	2.92E-09	1,171	3.54E+04
H-3	2.95E-19	170.99	2.72E-25	170.99	-1.00E+00	2.95E-19	170.99	0.00E+00

Notes: ΔDose Fraction = (Sensitivity Case Dose Factor − Best Estimate Case Dose Factor) ÷ Best Estimate Case Dose Factor

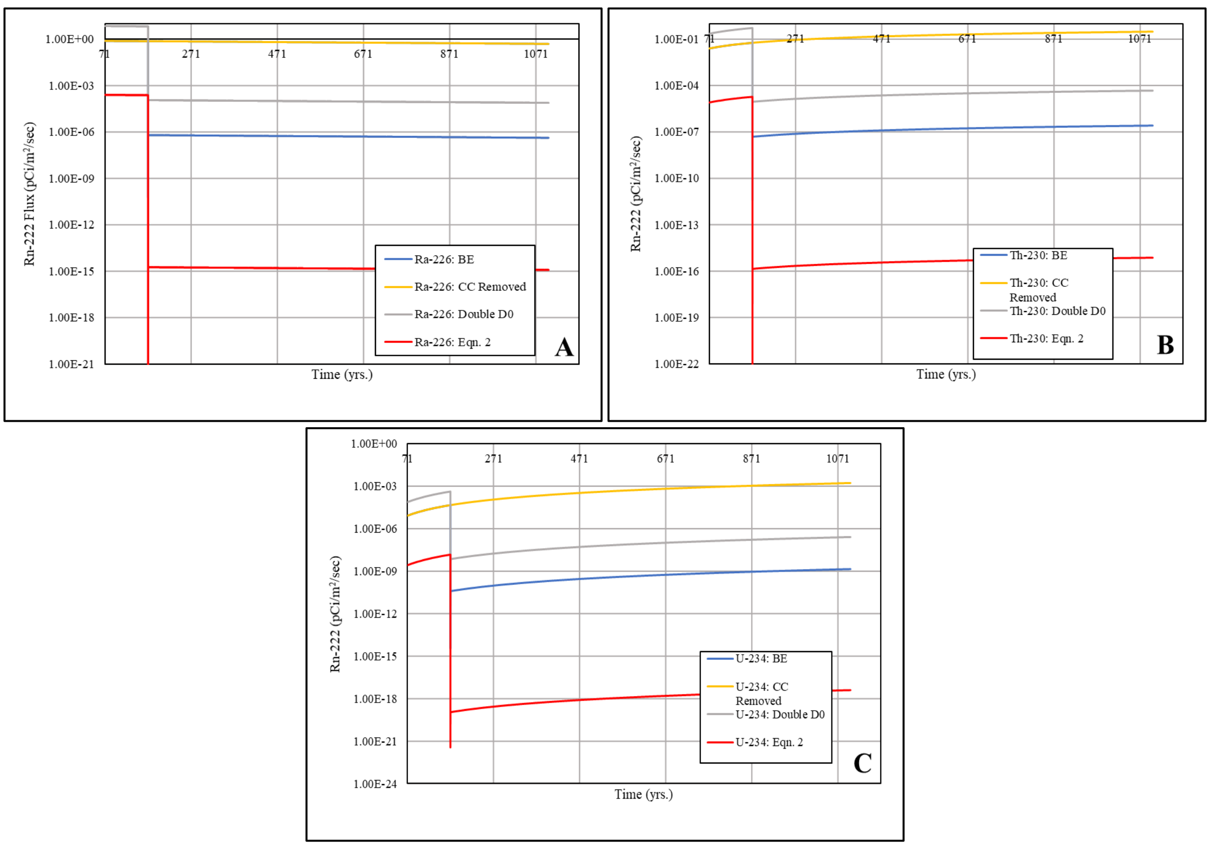


Notes: C-14 Eqn. 2 and H-3 Eqn. 2 in the plot legends refers to Eq. (6-11) in the text. Values below 1E-26 mrem yr^{-1} are not shown.

Figure 6-115. Dose Factor Time Histories for 1 Ci of C-14 (A) and H-3 (B) Buried in Low-Activity Waste Vault for Air Pathway Henry's Law Constant, Closure Cap Presence, and Diffusion Coefficient Sensitivity Cases

6.3.2.4. Radon Pathway Sensitivity to Closure Cap Presence and Diffusion Coefficient

For the LAWV, the presence of the final closure cap has no influence on the peak flux factor for Rn-222 at the surface when it originates from the decay of Ra-226; however, closure cap presence does impact the peak Rn-222 flux factor resulting from the decay of Th-230 and U-234 because their peaks occur after the closure cap is installed in Year 171 (Figure 6-116 and Table 6-172). Removal of the final closure cap permits more rapid transport of Rn-222 to the surface and higher flux relative to cases when the cap is in place. Doubling of the air-phase diffusion coefficient, D_o, for Rn-222 leads to an increased peak flux factor and overall flux. These increases are within an order of magnitude. Employing Eq. (6-11) in place of Eq. (6-12) in the model to calculate $D_e^{Rn\text{-}222}$ decreases the effective diffusion coefficients, D_e, thereby lowering flux factors. The Eq. (6-11) diffusion coefficients are comparable to the values used in PA2008 (WSRC, 2008). As expected, the Δflux fraction is the same for radionuclides that peak in the same time window as each other and the best estimate case. Overall, peak radon flux factors are more sensitive to changes in water saturation than to changes in the diffusion coefficients or the presence or absence of the final closure cap.



Note: Ra-226 Eqn. 2, Th-230 Eqn. 2, and U-234 Eqn. 2 in the plot legends refers to Eq. (6-11) in the text.

Figure 6-116. Flux Factor Time Histories from 1 Ci of Ra-226 (A), Th-230 (B), and U-234 (C) Buried in Low-Activity Waste Vault for Radon Pathway Closure Cap Presence and Diffusion Coefficient Sensitivity Cases

Table 6-172. Peak Rn-222 Flux Factor and Time of Peak for 1 Ci Parent Buried in Low-Activity Waste Vault for Radon Pathway Closure Cap Presence and Diffusion Coefficient Sensitivity Cases

Radio-nuclide	Best Estimate Case		Closure Cap Removed			Double D_o		
	Peak Flux Factor (pCi m^{-2} s^{-1} Ci^{-1})	Time of Peak (Year)	Peak Flux Factor (pCi m^{-2} s^{-1} Ci^{-1})	Time of Peak (Year)	ΔFlux Fraction	Peak Flux Factor (pCi m^{-2} s^{-1} Ci^{-1})	Time of Peak (Year)	ΔFlux Fraction
Ra-226	7.89E-01	72	7.89E-01	72	0.00E+00	7.19E+00	72	8.11E+00
Th-230	5.76E-02	170.99	3.20E-01	1,171	4.55E+00	5.25E-01	170.99	8.11E+00
U-234	4.59E-05	170.99	1.87E-03	1,171	3.97E+01	4.18E-04	170.99	8.11E+00
Radio-nuclide	Best Estimate Case		Diffusion Eq. (6-11)			--		
	Peak Flux Factor (pCi m^{-2} s^{-1} Ci^{-1})	Time of Peak (Year)	Peak Flux Factor (pCi m^{-2} s^{-1} Ci^{-1})	Time of Peak (Year)	ΔFlux Fraction	--	--	--
Ra-226	7.89E-01	72	2.53E-04	72	-1.00E+00	--	--	--
Th-230	5.76E-02	170.99	1.85E-05	170.99	-1.00E+00	--	--	--
U-234	4.59E-05	170.99	1.48E-08	170.99	-1.00E+00	--	--	--

Notes:

ΔFlux Fraction = (Sensitivity Case Flux Factor − Best Estimate Case Flux Factor) ÷ Best Estimate Case Flux Factor

6.3.3. Intermediate-Level Vault

6.3.3.1. Air Pathway Sensitivity to Water Saturation

Like the LAWV (Section 6.3.2.1), the air pathway dose factors for C-14, H-3, and Kr-85 emanating from the ILV are dependent on water saturation of the materials. At lower water saturation, peak radionuclide dose factors increase and occur sooner when compared to the best estimate cases (see Section 6.3.1.1.1 for ST and ET generic waste). In some cases, the time of peak dose shifts from later than to earlier than Year 171, in which case the POA changes from the 100-meter POA to the SRS site boundary with its lower DRFs (Figure 6-117 and Table 6-173). Decreased saturation of the ILV concrete materials and roof has a significant impact on air-phase mass transport.

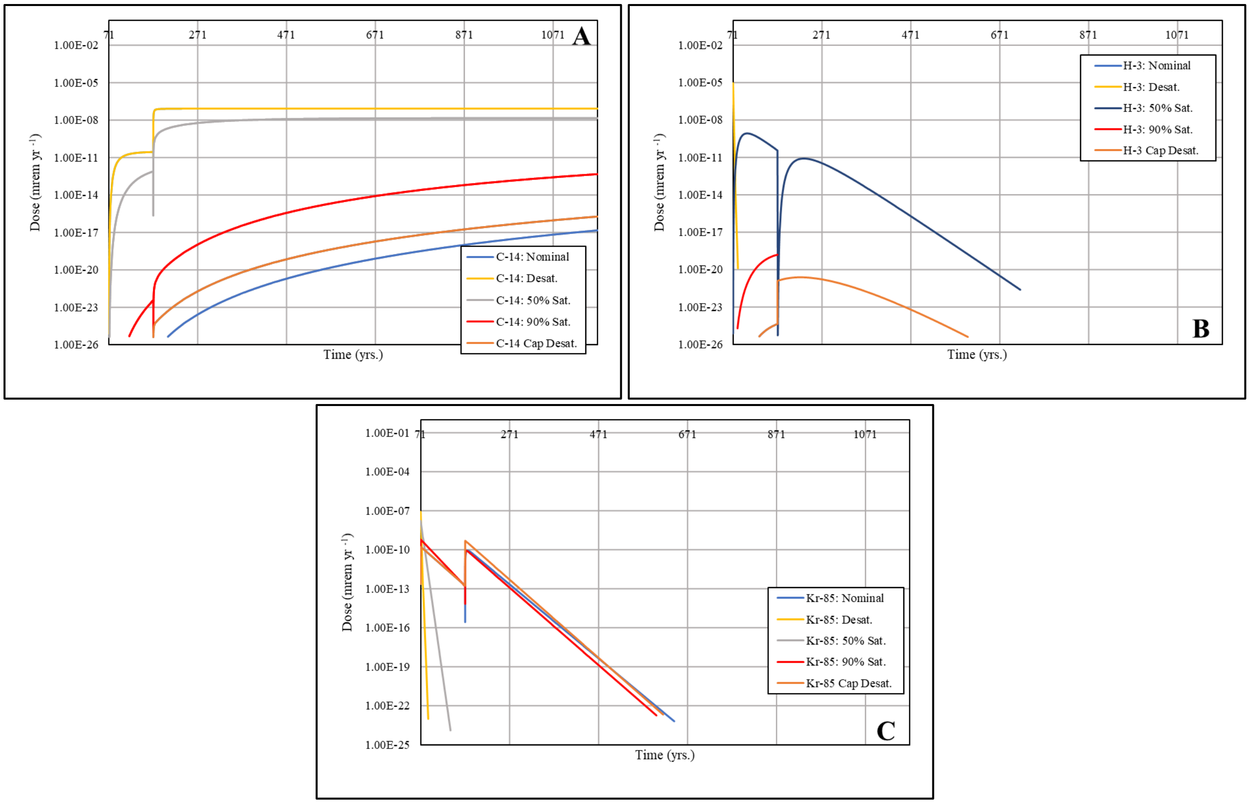


Figure 6-117. Dose Factor Time Histories for 1 Ci of C-14 (A), H-3 (B), and Kr-85 (C) Buried in Intermediate-Level Vault for Air Pathway Water Saturation Sensitivity Cases

Table 6-173. Peak Dose Factor and Time of Peak for 1 Ci Parent Buried in Intermediate-Level Vault for Air Pathway Water Saturation Sensitivity Cases

Radio-nuclide	Best Estimate Case		All Materials Desaturated			50% Saturation		
	Peak Dose Factor (mrem yr^{-1} Ci^{-1})	Time of Peak (Year)	Peak Dose Factor (mrem yr^{-1} Ci^{-1})	Time of Peak (Year)	ΔDose Fraction	Peak Dose Factor (mrem yr^{-1} Ci^{-1})	Time of Peak (Year)	ΔDose Fraction
C-14	1.46018E-17	1,171	8.34E-08	1063	5.71E+09	1.43E-08	1063	9.79E+08
H-3	4.3363E-25	171	8.99E-06	71.02	2.07E+19	8.40E-10	71.02	1.94E+15
Kr-85	1.643E-10	71.47	8.20E-08	71.02	4.98E+02	1.65E-08	71.02	9.97E+01
Radio-nuclide	Best Estimate Case		90% Saturation			Desaturated Closure Cap Only		
	Peak Dose Factor (mrem yr^{-1} Ci^{-1})	Time of Peak (Year)	Peak Dose Factor (mrem yr^{-1} Ci^{-1})	Time of Peak (Year)	ΔDose Fraction	Peak Dose Factor (mrem yr^{-1} Ci^{-1})	Time of Peak (Year)	ΔDose Fraction
C-14	1.46018E-17	1,171	4.66E-13	1,063	3.19E+04	1.86E-16	1,171	1.18E+01
H-3	4.3363E-25	171	1.56E-19	71.02	3.59E+05	2.40E-21	222	5.53E+03
Kr-85	1.643E-10	71.47	5.96E-10	71.02	2.63E+00	4.89E-10	171.16	1.98E+00

Notes:

ΔDose Fraction = (Sensitivity Case Dose Factor − Best Estimate Case Dose Factor) ÷ Best Estimate Case Dose Factor

6.3.3.2. Radon Flux Sensitivity to Water Saturation

Like the LAWV, water saturation of ILV materials has a strong impact on the Rn-222 flux factor originating from the decay of Ra-226, Th-230, and U-234. Results for the ILV are summarized in

Table 6-174 and Figure 6-118. Refer to Section 6.3.2.2 for an explanation of the sensitivity case results.

Table 6-174. Peak Rn-222 Flux Factor and Time of Peak for 1 Ci Parent Buried in Intermediate-Level Vault for Radon Pathway Water Saturation Sensitivity Cases

Radio-nuclide	Best Estimate Case		All Materials Desaturated			50% Saturation		
	Peak Flux Factor (pCi m^{-2} s^{-1} Ci^{-1})	Time of Peak (Year)	Peak Flux Factor (pCi m^{-2} s^{-1} Ci^{-1})	Time of Peak (Year)	ΔFlux Fraction	Peak Flux Factor (pCi m^{-2} s^{-1} Ci^{-1})	Time of Peak (Year)	ΔFlux Fraction
Ra-226	1.06E-02	72	1.12E+04	72	1.06E+06	1.70E+03	72	1.60E+05
Th-230	7.78E-04	170.99	8.24E+02	170.99	1.06E+06	1.24E+02	170.99	1.60E+05
U-234	6.20E-07	170.99	4.24E+00	1,171	6.84E+06	9.91E-02	170.99	1.60E+05
Radio-nuclide	Best Estimate Case		90% Saturation			Desaturated Closure Cap Only		
	Peak Flux Factor (pCi m^{-2} s^{-1} Ci^{-1})	Time of Peak (Year)	Peak Flux Factor (pCi m^{-2} s^{-1} Ci^{-1})	Time of Peak (Year)	ΔFlux Fraction	Peak Flux Factor (pCi m^{-2} s^{-1} Ci^{-1})	Time of Peak (Year)	ΔFlux Fraction
Ra-226	1.06E-02	72	1.83E+00	72	1.71E+02	1.06E-02	72	0.00E+00
Th-230	7.78E-04	170.99	1.33E-01	170.99	1.70E+02	1.06E-03	170.99	3.65E-01
U-234	6.20E-07	170.99	1.06E-04	170.99	1.71E+02	6.20E-06	170.99	9.01E+00

Notes:
ΔFlux Fraction = (Sensitivity Case Flux Factor − Best Estimate Case Flux Factor) ÷ Best Estimate Case Flux Factor
The change in Δflux fraction is the same for radionuclides that peak in the same time window as each other and the best estimate case.

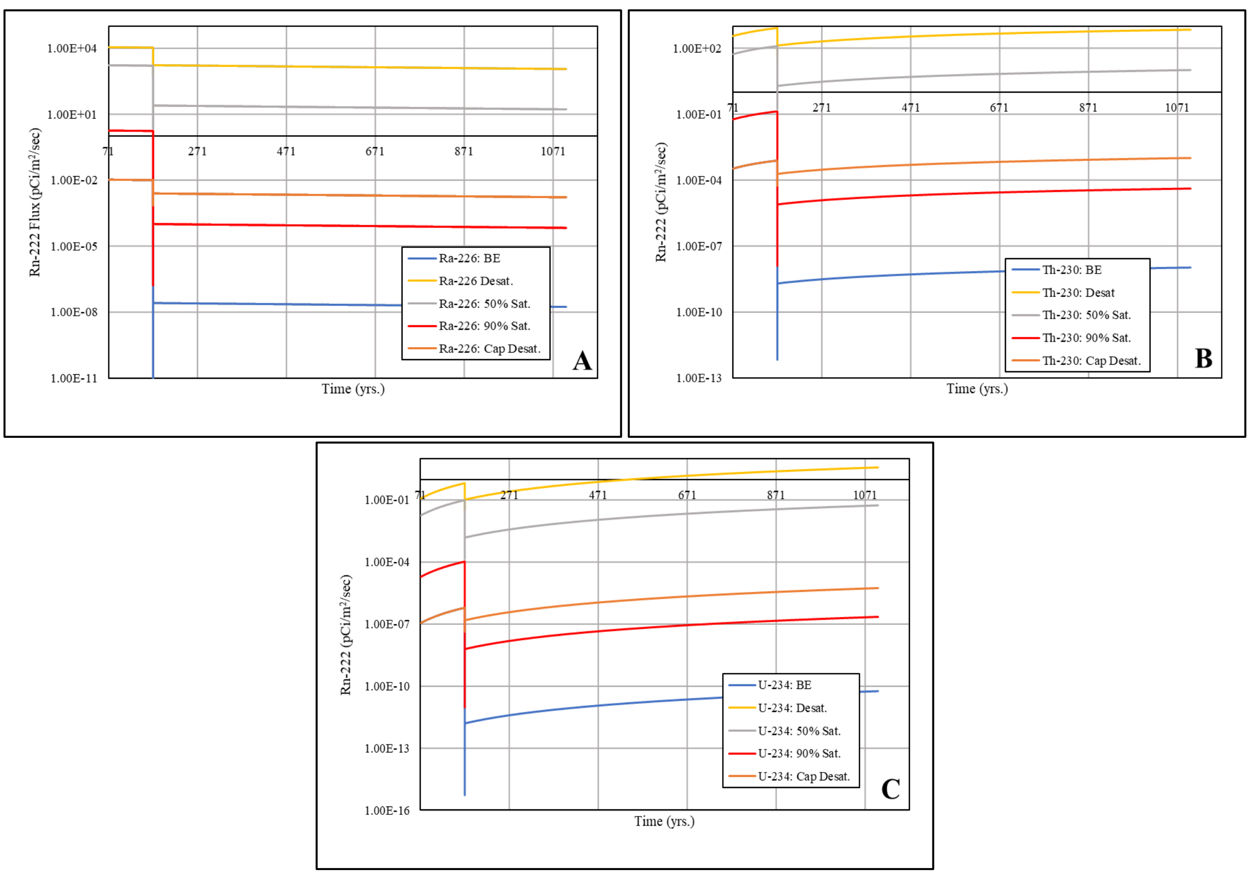


Figure 6-118. Flux Factor Time Histories from 1 Ci of Ra-226 (A), Th-230 (B), and U-234 (C) Buried in Intermediate-Level Vault for Radon Pathway Water Saturation Sensitivity Cases

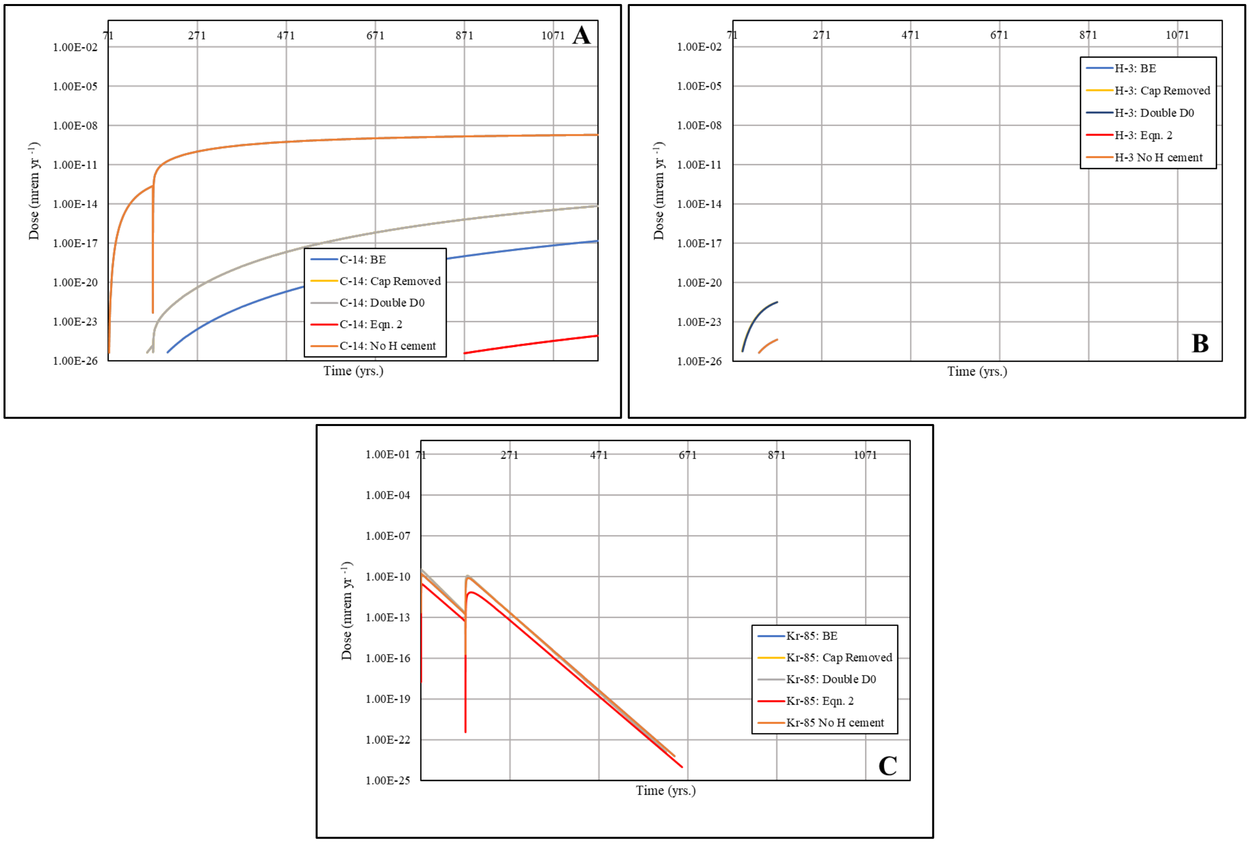
6.3.3.3. Air Pathway Sensitivity to Henry's Law Constant, Closure Cap Presence and Diffusion Coefficient

Removal of the final closure cap from the ILV increases the peak dose factors for C-14 and Kr-85 (Table 6-175 and Figure 6-119) relative to the best estimate case. The H-3 dose factor, on the other hand, is orders of magnitude lower, and sensitivity to closure cap removal is negligible. As displayed in Figure 6-119, the C-14 dose factor is higher compared to the best estimate case because of the shorter diffusional path to the surface (see Section 6.3.2.3 for LAWV). For Kr-85, the absence of the final closure cap leads to an increase in peak dose factor beyond Year 171 when the DRF increases because of the switch to the 100-meter POA from the site boundary. An explanation of the results for the other sensitivity cases can be found in Section 6.3.2.3 for the LAWV.

Table 6-175. Peak Dose Factor and Time of Peak for 1 Ci Parent Buried in Intermediate-Level Vault for Air Pathway Henry's Law Constant, Closure Cap Presence, and Diffusion Coefficient Sensitivity Cases

Radio-nuclide	Best Estimate Case		Closure Cap Removed			Double D_o		
	Peak Dose Factor (mrem yr^{-1} Ci^{-1})	Time of Peak (Year)	Peak Dose Factor (mrem yr^{-1} Ci^{-1})	Time of Peak (Year)	ΔDose Fraction	Peak Dose Factor (mrem yr^{-1} Ci^{-1})	Time of Peak (Year)	ΔDose Fraction
C-14	1.46E-17	1,171	1.89E-16	1,171	1.19E+01	6.79E-15	1,171	4.64E+02
H-3	4.34E-25	170.99	4.34E-25	170.99	0.00E+00	3.16E-22	170.99	7.27E+02
Kr-85	1.64E-10	71.47	4.97E-10	171	2.03E+00	3.34E-10	71.27	1.03E+00
Radio-nuclide	Best Estimate Case		Diffusion Eq. (6-11)			No Change in Henry's Law Constant for Cementitious Material		
	Peak Dose Factor (mrem yr^{-1} Ci^{-1})	Time of Peak (Year)	Peak Dose Factor (mrem yr^{-1} Ci^{-1})	Time of Peak (Year)	ΔDose Fraction	Peak Dose Factor (mrem yr^{-1} Ci^{-1})	Time of Peak (Year)	ΔDose Fraction
C-14	1.46E-17	1,171	8.27E-25	1,171	-1.00E+00	1.88E-09	1,171	1.29E+08
H-3	4.34E-25	170.99	4.94E-32	170.99	-1.00E+00	4.34E-25	170.99	0.00E+00
Kr-85	1.64E-10	71.47	2.87E-11	72.75	-8.25E-01	1.64E-10	71.47	0.00E+00

Notes:
ΔDose Fraction = (Sensitivity Case Dose Factor − Best Estimate Case Dose Factor) ÷ Best Estimate Case Dose Factor

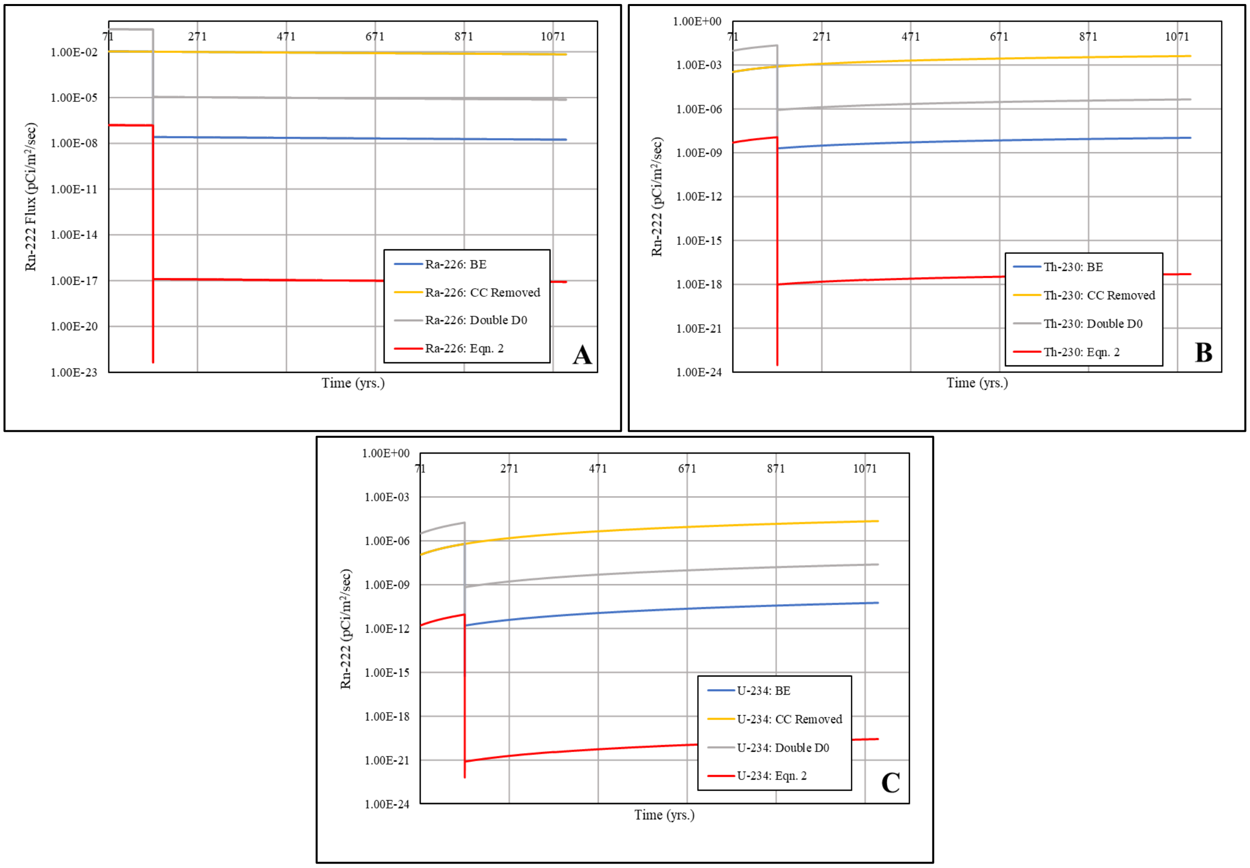


Notes: C-14 Eqn. 2, H-3 Eqn. 2, and Kr-85 Eqn. 2 in plot legends refers to Eq. (6-11) in the text. Values below 1E-26 mrem yr^{-1} are not shown.

Figure 6-119. Dose Factor Time Histories for 1 Ci of C-14 (A), H-3 (B), and Kr-85 (C) Buried in Intermediate-Level Vault for Air Pathway Henry's Law Constant, Closure Cap Presence, and Diffusion Coefficient Sensitivity Cases

6.3.3.4. Radon Pathway Sensitivity to Closure Cap Presence and Diffusion Coefficient

Sensitivity analysis results for the ILV are summarized in Figure 6-120 and Table 6-176. The sensitivity of peak Rn-222 flux factor at the surface of the ILV to the presence or absence of the final closure cap or to changes in the effective diffusion coefficients is consistent with results for the LAWV (Section 6.3.2.4).



Note: Ra-226 Eqn. 2, Th-230 Eqn. 2, and U-234 Eqn. 2 in the plot legends refers to Eq. (6-11) in the text.

Figure 6-120. Flux Factor Time Histories from 1 Ci of Ra-226 (A), Th-230 (B), and U-234 (C) Buried in Intermediate-Level Vault for Radon Pathway Closure Cap Presence and Diffusion Coefficient Sensitivity Cases

Table 6-176. Peak Rn-222 Flux Factor and Time of Peak for 1 Ci Parent Buried in Intermediate-Level Vault for Radon Pathway Closure Cap Presence and Diffusion Coefficient Sensitivity Cases

Radio-nuclide	Best Estimate Case		Closure Cap Removed			Double D_o		
	Peak Flux (pCi m^{-2} s^{-1} Ci^{-1})	Time of Peak (Year)	Peak Flux (pCi m^{-2} s^{-1} Ci^{-1})	Time of Peak (Year)	ΔFlux Fraction	Peak Flux (pCi m^{-2} s^{-1} Ci^{-1})	Time of Peak (Year)	ΔFlux Fraction
Ra-226	1.06E-02	72	1.06E-02	72	0.00E+00	3.04E-01	72	2.76E+01
Th-230	7.78E-04	170.99	4.31E-03	1,171	4.54E+00	2.22E-02	170.99	2.76E+01
U-234	6.20E-07	170.99	2.52E-05	1,171	3.97E+01	1.77E-05	170.99	2.76E+01
Radio-nuclide	Best Estimate Case		Diffusion Eq. (6-11)			--		
	Peak Flux (pCi m^{-2} s^{-1} Ci^{-1})	Time of Peak (Year)	Peak Flux (pCi m^{-2} s^{-1} Ci^{-1})	Time of Peak (Year)	ΔFlux Fraction	--	--	--
Ra-226	1.06E-02	72	1.56E-07	72	-1.00E+00	--	--	--
Th-230	7.78E-04	170.99	1.15E-08	170.99	-1.00E+00	--	--	--
U-234	6.20E-07	170.99	9.13E-12	170.99	-1.00E+00	--	--	--

Notes:

ΔFlux Fraction = (Sensitivity Case Flux Factor − Best Estimate Case Flux Factor) ÷ Best Estimate Case Flux Factor

The change in Δflux fraction is the same for radionuclides that peak in the same time window as each other and the best estimate case.

6.3.4. Naval Reactor Component Disposal Areas

6.3.4.1. Air Pathway Sensitivity to Water Saturation

6.3.4.1.1. Generic Waste Form

Interestingly, C-14 emanating from NRCDA generic waste forms (bolted containers) does not display as large of an increase in dose factor with decreasing water saturation as it does from other types of DUs. This likely arises because faster mass transport causes more C-14 mass to exit the DU before the POA shifts from the site boundary to the 100-meter POA (Table 6-177 and Figure 6-121).

Table 6-177. Peak Dose Factor and Time of Peak for 1 Ci Parent Buried in Naval Reactor Component Disposal Area Generic Waste Form for Air Pathway Water Saturation Sensitivity Cases

Radio-nuclide	Best Estimate Case		All Materials Desaturated			50% Saturation		
	Peak Dose Factor (mrem yr^{-1} Ci^{-1})	Time of Peak (Year)	Peak Dose Factor (mrem yr^{-1} Ci^{-1})	Time of Peak (Year)	ΔDose Fraction	Peak Dose Factor (mrem yr^{-1} Ci^{-1})	Time of Peak (Year)	ΔDose Fraction
C-14	2.25E-05	71.51	1.82E-04	71.07	7.07E+00	7.47E-05	71.17	2.32E+00
	Best Estimate Case		90% Saturation			Desaturated Closure Cap Only		
	Peak Dose Factor (mrem yr^{-1} Ci^{-1})	Time of Peak (Year)	Peak Dose Factor (mrem yr^{-1} Ci^{-1})	Time of Peak (Year)	ΔDose Fraction	Peak Dose Factor (mrem yr^{-1} Ci^{-1})	Time of Peak (Year)	ΔDose Fraction
	2.25E-05	71.51	2.88E-05	71.4	2.80E-01	1.69E-04	175.2	6.52E+00

Notes:

ΔDose Fraction = (Sensitivity Case Dose Factor − Best Estimate Case Dose Factor) ÷ Best Estimate Case Dose Factor

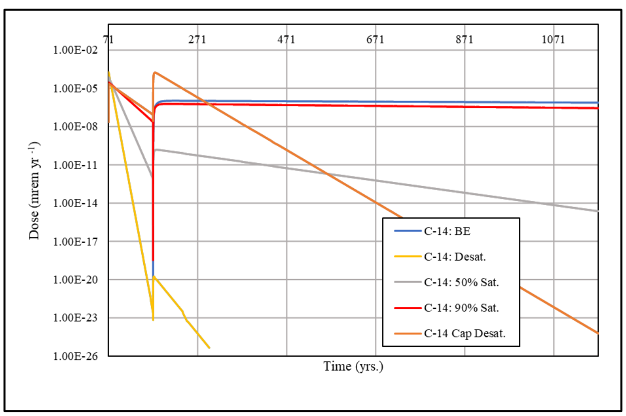


Figure 6-121. Dose Factor Time Histories for 1 Ci of C-14 Buried in Naval Reactor Component Disposal Area Generic Waste Form for Air Pathway Water Saturation Sensitivity Cases

6.3.4.1.2. Special Waste Form

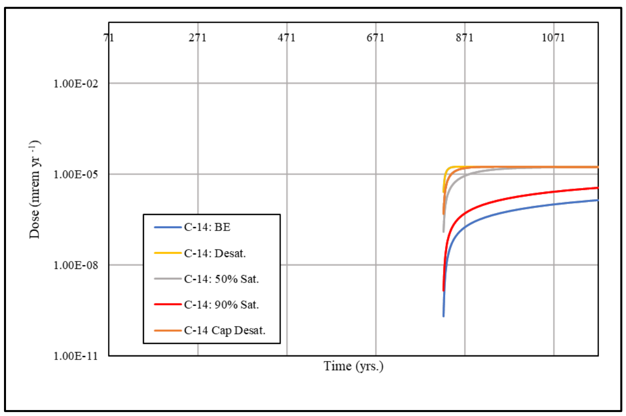
The air pathway dose factor for C-14 emanating from NRCDA SWFs (steel casks) is not overly sensitive to water saturation of materials. C-14 release is largely dependent on the breach of the NRCDA SWF casks at Year 750 and the corrosion of the activation products. (Table 6-178 and Figure 6-122). H-3 is not shown because it decays before being released from the casks.

Table 6-178. Peak Dose Factor and Time of Peak for 1 Ci Parent Buried in Naval Reactor Component Disposal Area Special Waste Form for Air Pathway Water Saturation Sensitivity Cases

Radio-nuclide	Best Estimate Case		All Materials Desaturated			50% Saturation		
	Peak Dose Factor (mrem yr^{-1} Ci^{-1})	Time of Peak (Year)	Peak Dose Factor (mrem yr^{-1} Ci^{-1})	Time of Peak (Year)	ΔDose Fraction	Peak Dose Factor (mrem yr^{-1} Ci^{-1})	Time of Peak (Year)	ΔDose Fraction
C-14	1.38E-06	1,171	1.76E-05	868	1.17E+01	1.68E-05	1,152	1.12E+01
	Best Estimate Case		**90% Saturation**			**Desaturated Closure Cap Only**		
	Peak Dose Factor (mrem yr^{-1} Ci^{-1})	**Time of Peak (Year)**	**Peak Dose Factor (mrem yr^{-1} Ci^{-1})**	**Time of Peak (Year)**	**ΔDose Fraction**	**Peak Dose Factor (mrem yr^{-1} Ci^{-1})**	**Time of Peak (Year)**	**ΔDose Fraction**
	1.38E-06	1,171	3.52E-06	1,171	1.55E+00	1.74E-05	949	1.16E+01

Notes:

ΔDose Fraction = (Sensitivity Case Dose Factor − Best Estimate Case Dose Factor) ÷ Best Estimate Case Dose Factor



Note: H-3 time histories could not be generated because dose is below model output of 1E-26 mrem yr^{-1}.

Figure 6-122. Dose Factor Time Histories for 1 Ci of C-14 Buried in Naval Reactor Component Disposal Area Special Waste Form for Air Pathway Water Saturation Sensitivity Cases

6.3.4.2. Radon Flux Sensitivity to Water Saturation

6.3.4.2.1. Generic Waste Form

Water saturation of NRCDA generic waste form (bolted container) materials has a strong impact on the surface flux factor for Rn-222 originating from the decay of Ra-226, Th-230, and U-234 (Figure 6-123 and Table 6-179). Complete desaturation of materials results in an increase in the Rn-222 flux factor compared to the best estimate case for all three parents. However, the increase for U-234 is more substantial because its time of peak flux shifts from Year 170.99 (site boundary POA) to Year 1,171 (100-meter POA) where a higher DRF is assumed. Desaturation of the final closure cap has a smaller impact on Rn-222 surface flux than complete desaturation; flux factors are within an order of magnitude of the best estimate case.

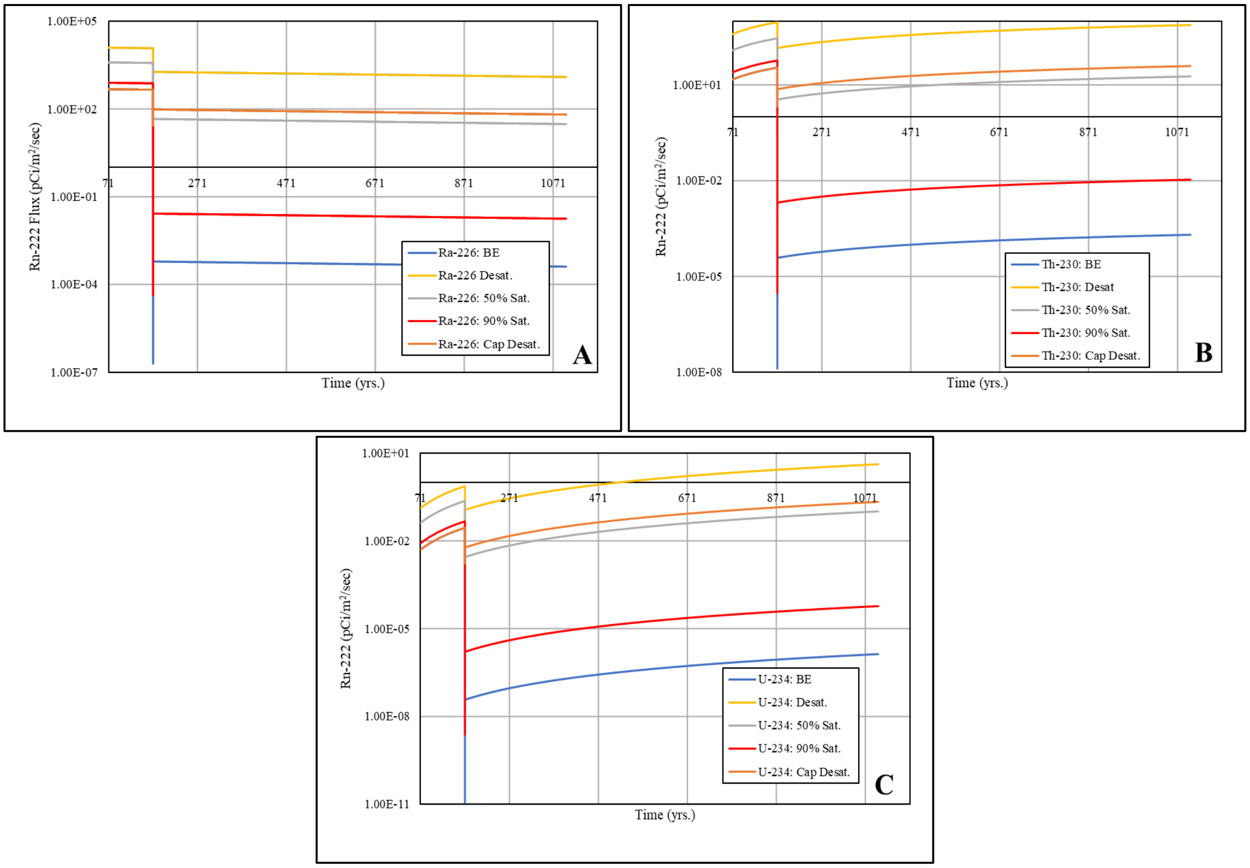


Figure 6-123. Flux Factor Time Histories from 1 Ci of Ra-226 (A), Th-230 (B), and U-234 (C) Buried in Naval Reactor Component Disposal Area Generic Waste Form for Radon Pathway Water Saturation Sensitivity Cases

Table 6-179. Peak Rn-222 Flux Factor and Time of Peak for 1 Ci Parent Buried in Naval Reactor Component Disposal Area Generic Waste Form for Radon Pathway Water Saturation Sensitivity Cases

Radio-nuclide	Best Estimate Case		All Materials Desaturated			50% Saturation		
	Peak Flux Factor (pCi m⁻² s⁻¹ Ci⁻¹)	Time of Peak (Year)	Peak Flux Factor (pCi m⁻² s⁻¹ Ci⁻¹)	Time of Peak (Year)	ΔFlux Fraction	Peak Flux Factor (pCi m⁻² s⁻¹ Ci⁻¹)	Time of Peak (Year)	ΔFlux Fraction
Ra-226	4.74E+02	72	1.25E+04	72	2.53E+01	3.92E+03	72	7.25E+00
Th-230	3.49E+01	170.99	9.18E+02	170.99	2.53E+01	2.88E+02	170.99	7.25E+00
U-234	2.78E-02	170.99	4.62E+00	1,171	1.65E+02	2.30E-01	170.99	7.25E+00
Radio-nuclide	Best Estimate Case		90% Saturation			Desaturated Closure Cap Only		
	Peak Flux Factor (pCi m⁻² s⁻¹ Ci⁻¹)	Time of Peak (Year)	Peak Flux Factor (pCi m⁻² s⁻¹ Ci⁻¹)	Time of Peak (Year)	ΔFlux Fraction	Peak Flux Factor (pCi m⁻² s⁻¹ Ci⁻¹)	Time of Peak (Year)	ΔFlux Fraction
Ra-226	4.74E+02	72	7.87E+02	72	6.59E-01	4.74E+02	72	0.00E+00
Th-230	3.49E+01	170.99	5.79E+01	170.99	6.59E-01	4.11E+01	1,171	1.76E-01
U-234	2.78E-02	170.99	4.62E-02	170.99	6.59E-01	2.40E-01	1,171	7.62E+00

Notes:

ΔFlux Fraction = (Sensitivity Case Flux Factor − Best Estimate Case Flux Factor) ÷ Best Estimate Case Flux Factor

The change in Δflux fraction is the same for radionuclides that peak in the same time window as each other and the best estimate case.

6.3.4.2.2. Special Waste Form

Compared to the NRCDA generic waste form, the Rn-222 surface flux factor from NRCDA SWFs (steel casks) is even more dramatically impacted by water saturation as shown in Table 6-180 and Figure 6-124. Time of peak flux is Year 1,171 for all parents in all cases.

Table 6-180. Peak Rn-222 Flux Factor and Time of Peak for 1 Ci Parent Buried in Naval Reactor Component Disposal Area Special Waste Form for Radon Pathway Water Saturation Sensitivity Cases

Radio-nuclide	Best Estimate Case		All Materials Desaturated			50% Saturation		
	Peak Flux Factor (pCi m^{-2} s^{-1} Ci^{-1})	Time of Peak (Year)	Peak Flux Factor (pCi m^{-2} s^{-1} Ci^{-1})	Time of Peak (Year)	ΔFlux Fraction	Peak Flux Factor (pCi m^{-2} s^{-1} Ci^{-1})	Time of Peak (Year)	ΔFlux Fraction
Ra-226	8.73E-06	1,171	2.67E+01	1,171	3.06E+06	6.54E-01	1,171	7.49E+04
Th-230	5.73E-06	1,171	1.75E+01	1,171	3.06E+06	4.29E-01	1,171	7.49E+04
U-234	3.35E-08	1,171	1.02E-01	1,171	3.06E+06	2.51E-03	1,171	7.49E+04
Radio-nuclide	Best Estimate Case		90% Saturation			Desaturated Closure Cap Only		
	Peak Flux Factor (pCi m^{-2} s^{-1} Ci^{-1})	Time of Peak (Year)	Peak Flux Factor (pCi m^{-2} s^{-1} Ci^{-1})	Time of Peak (Year)	ΔFlux Fraction	Peak Flux Factor (pCi m^{-2} s^{-1} Ci^{-1})	Time of Peak (Year)	ΔFlux Fraction
Ra-226	8.73E-06	1,171	3.80E-04	1,171	4.25E+01	1.38E+00	1,171	1.58E+05
Th-230	5.73E-06	1,171	2.49E-04	1,171	4.25E+01	9.08E-01	1,171	1.58E+05
U-234	3.35E-08	1,171	1.46E-06	1,171	4.25E+01	5.30E-03	1,171	1.58E+05

Notes:

ΔFlux Fraction = (Sensitivity Case Flux Factor − Best Estimate Case Flux Factor) ÷ Best Estimate Case Flux Factor

The change in Δflux fraction is the same for radionuclides that peak in the same time window as each other and the best estimate case.

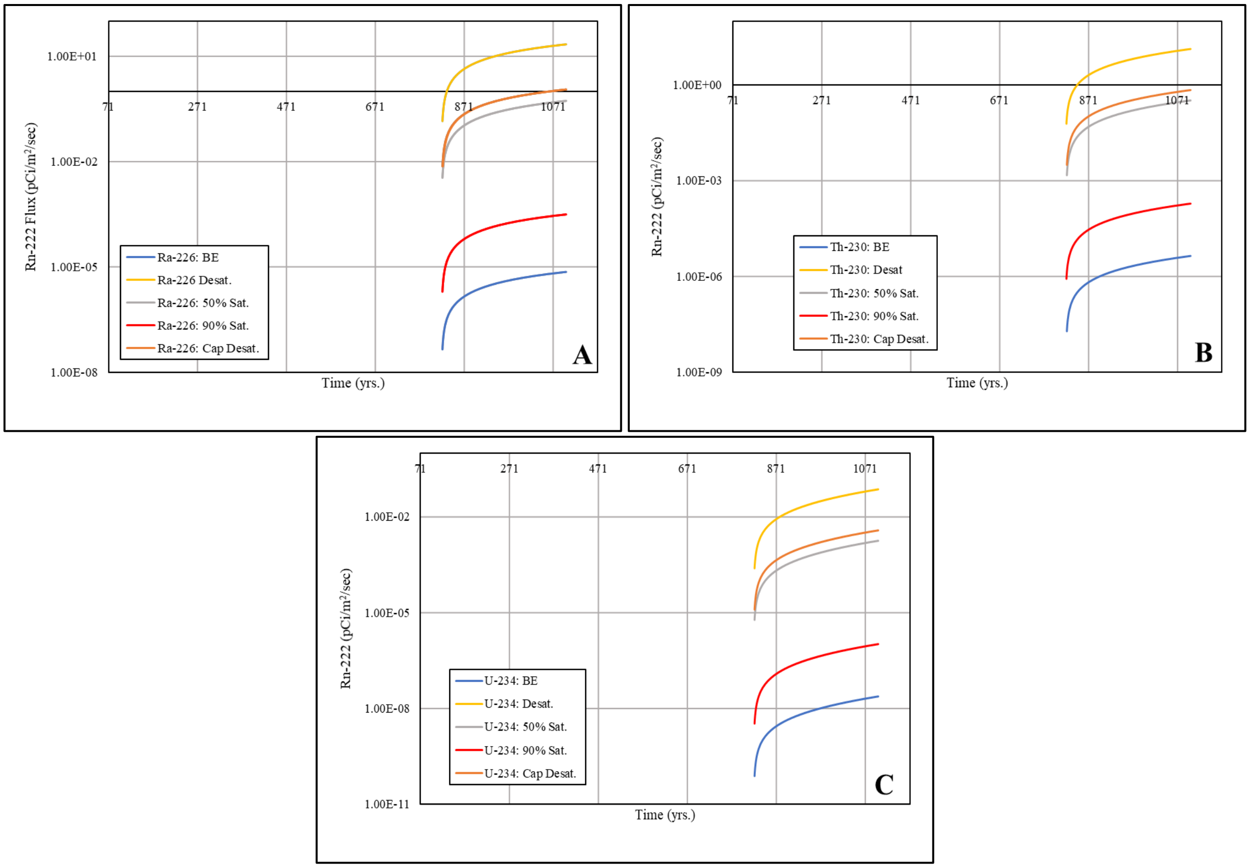


Figure 6-124. Flux Factor Time Histories from 1 Ci of Ra-226 (A), Th-230 (B), and U-234 (C) Buried in Naval Reactor Component Disposal Area Special Waste Form for Radon Pathway Water Saturation Sensitivity Cases

6.3.4.3. Air Pathway Sensitivity to Closure Cap Presence and Diffusion Coefficient

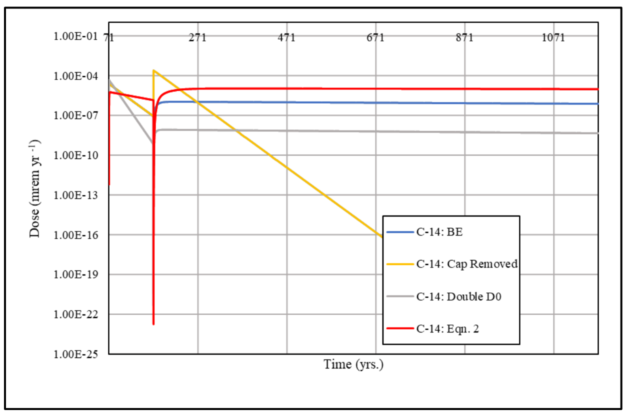
6.3.4.3.1. Generic Waste Form

The removal of the final closure cap for the NRCDA generic waste form (bolted containers) increases the peak dose factor for C-14 by almost an order of magnitude. In the best estimate case, the time of peak dose occurs before the placement of the closure cap in Year 71.51 (Table 6-181); however, if the closure cap is removed, the time of peak shifts to Year 171 (DRF of C-14 increases as POA shifts from site boundary to 100-meter POA). In the closure cap removal case, the C-14 dose factor quickly peaks then declines as mass leaves the system (Figure 6-125). Doubling D_o accelerates C-14 mass transport and doubles the peak dose factor. Employing Eq. (6-11) in place of Eq. (6-12) in the model to calculate $D_e^{Rn\text{-}222}$ decreases the effective diffusion coefficient, D_e, for each material thereby decreasing the overall dose factor.

Table 6-181. Peak Dose Factor and Time of Peak for 1 Ci Parent Buried in Naval Reactor Component Disposal Area Generic Waste Form for Air Pathway Closure Cap Presence, and Diffusion Coefficient Sensitivity Cases

Radio-nuclide	Best Estimate Case		Closure Cap Removed			Double D_o		
	Peak Dose Factor (mrem yr^{-1} Ci^{-1})	Time of Peak (Year)	Peak Dose Factor (mrem yr^{-1} Ci^{-1})	Time of Peak (Year)	ΔDose Fraction	Peak Dose Factor (mrem yr^{-1} Ci^{-1})	Time of Peak (Year)	ΔDose Fraction
C-14	2.25E-05	71.51	2.44E-04	171	9.86E+00	4.50E-05	71.26	9.99E-01
	Best Estimate Case		Diffusion Eq. (6-11)			--		
	Peak Dose Factor (mrem yr^{-1} Ci^{-1})	Time of Peak (Year)	Peak Dose Factor (mrem yr^{-1} Ci^{-1})	Time of Peak (Year)	ΔDose Fraction	--	--	--
	2.25E-05	71.51	1.07E-05	355	-5.24E-01	--	--	--

Notes:
ΔDose Fraction = (Sensitivity Case Dose Factor − Best Estimate Case Dose Factor) ÷ Best Estimate Case Dose Factor



Notes: C-14 Eqn. 2 in the plot legend refers to Eq. (6-11) in the text.
Values below 1E-26 are not shown.

Figure 6-125. Dose Factor Time Histories for 1 Ci of C-14 Buried in Naval Reactor Component Disposal Area Generic Waste Form for Air Pathway Closure Cap Presence and Diffusion Coefficient Sensitivity Cases

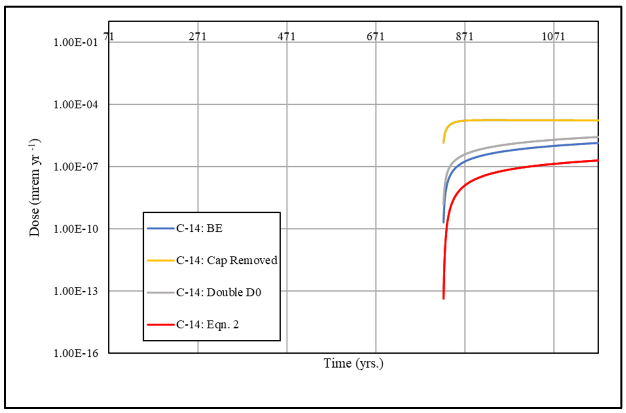
6.3.4.3.2. Special Waste Form

The removal of the final closure cap for NRCDA SWF (steel casks) increases the peak dose factor for C-14 by more than an order of magnitude as displayed in Table 6-182 and Figure 6-126. The time of C-14 peak dose occurs well after final closure in Year 931. Doubling D_o accelerates C-14 mass transport and almost doubles the peak dose factor. Employing Eq. (6-11) in place of Eq. (6-12) in the model to calculate $D_e^{Rn\text{-}222}$ decreases the effective diffusion coefficient, D_e, for each material thereby decreasing the overall dose factor.

Table 6-182. Peak Dose Factor and Time of Peak for 1 Ci Parent Buried in Naval Reactor Component Disposal Area Special Waste Form for Air Pathway Closure Cap Presence, and Diffusion Coefficient Sensitivity Cases

Radio-nuclide	Best Estimate Case		Closure Cap Removed			Double D_o		
	Peak Dose Factor (mrem yr^{-1} Ci^{-1})	Time of Peak (Year)	Peak Dose Factor (mrem yr^{-1} Ci^{-1})	Time of Peak (Year)	ΔDose Fraction	Peak Dose Factor (mrem yr^{-1} Ci^{-1})	Time of Peak (Year)	ΔDose Fraction
C-14	1.38E-06	1,171	1.74E-05	931	1.16E+01	2.68E-06	1,171	9.42E-01
	Best Estimate Case		Diffusion Eq. (6-11)			--		
	Peak Dose Factor (mrem yr^{-1} Ci^{-1})	Time of Peak (Year)	Peak Dose Factor (mrem yr^{-1} Ci^{-1})	Time of Peak (Year)	ΔDose Fraction	--	--	--
	1.38E-06	1,171	1.98E-07	1,171	-8.57E-01	--	--	--

Notes:
ΔDose Fraction = (Sensitivity Case Dose Factor − Best Estimate Case Dose Factor) ÷ Best Estimate Case Dose Factor



Notes: C-14 Eqn. 2 in the plot legend refers to Eq. (6-11) in the text.
Values below 1E-26 mrem yr^{-1} are not shown.

Figure 6-126. Dose Factor Time Histories for 1 Ci of C-14 Buried in Naval Reactor Component Disposal Area Special Waste Form for Air Pathway Closure Cap Presence and Diffusion Coefficient Sensitivity Cases

6.3.4.4. Radon Pathway Sensitivity to Closure Cap Presence and Diffusion Coefficient

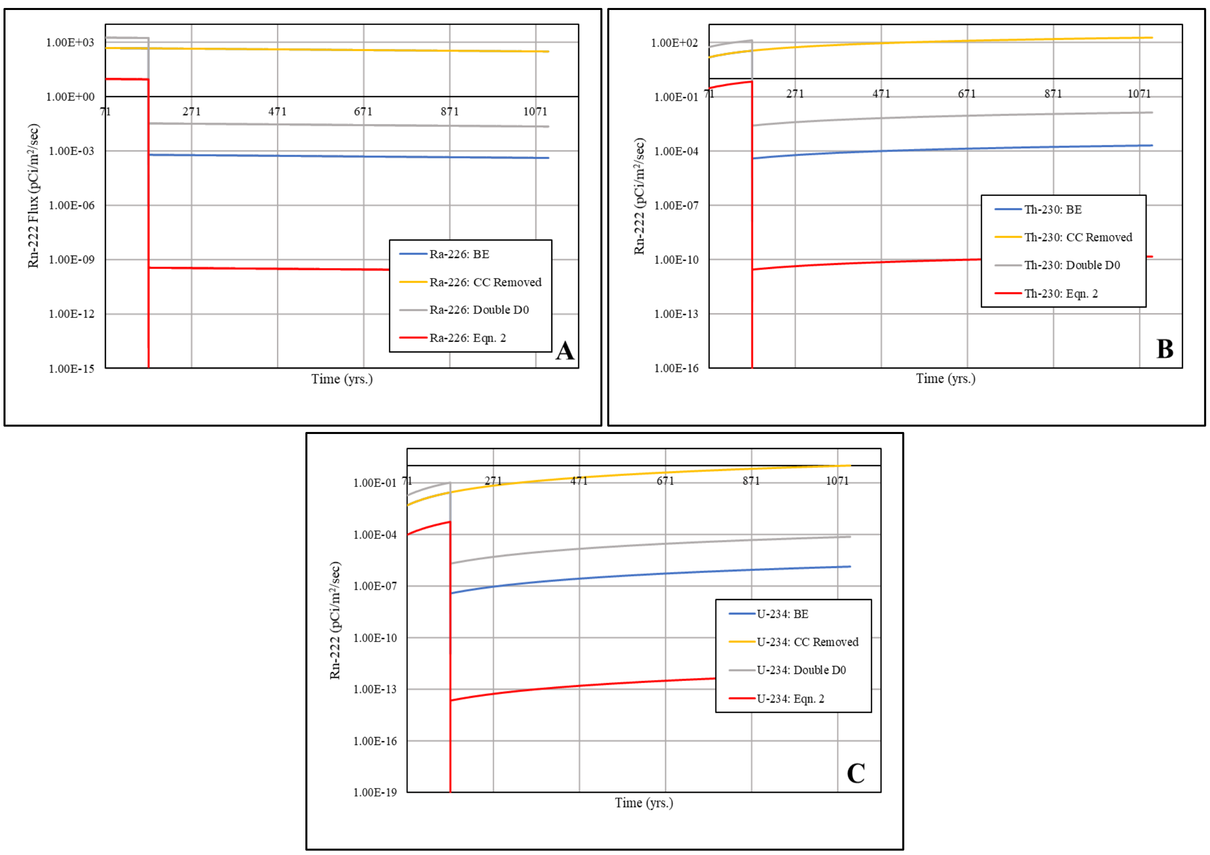
6.3.4.4.1. Generic Waste Form

Removal of the final closure cap strongly impacts the Rn-222 surface flux factor from the NRCDA generic waste form (bolted containers) as shown in Table 6-183 and Figure 6-127. Doubling of the air-phase diffusion coefficient, D_o, for Rn-222 leads to an increased peak flux factor and overall flux, which is similar to the behavior for other types of DUs and waste forms. Employing Eq. (6-11) in place of Eq. (6-12) in the model to calculate $D_e^{Rn\text{-}222}$ decreases the effective diffusion coefficient, D_e, for each material thereby decreasing overall flux. In general, peak flux factors are less sensitive to diffusion and closure cap presence than to water saturation.

Table 6-183. Peak Rn-222 Flux Factor and Time of Peak for 1 Ci Parent Buried in Naval Reactor Component Disposal Area Generic Waste Form for Radon Pathway Closure Cap Presence and Diffusion Coefficient Sensitivity Cases

Radionuclide	Best Estimate Case		Closure Cap Removed			Double D_o		
	Peak Flux Factor (pCi m^{-2} s^{-1} Ci^{-1})	Time of Peak (Year)	Peak Flux Factor (pCi m^{-2} s^{-1} Ci^{-1})	Time of Peak (Year)	ΔFlux Fraction	Peak Flux Factor (pCi m^{-2} s^{-1} Ci^{-1})	Time of Peak (Year)	ΔFlux Fraction
Ra-226	4.74E+02	170.99	4.74E+02	72	0.00E+00	1.77E+03	72	2.73E+00
Th-230	3.49E+01	170.99	1.94E+02	1,171	4.54E+00	1.30E+02	170.99	2.73E+00
U-234	2.78E-02	170.99	1.13E+00	1,171	3.96E+01	1.04E-01	170.99	2.73E+00
Radionuclide	Best Estimate Case		Diffusion Eq. (6-11)			--		
	Peak Flux Factor (pCi m^{-2} s^{-1} Ci^{-1})	Time of Peak (Year)	Peak Flux Factor (pCi m^{-2} s^{-1} Ci^{-1})	Time of Peak (Year)	ΔFlux Fraction	--	--	--
Ra-226	4.74E+02	170.99	9.26E+00	72	-9.80E-01	--	--	--
Th-230	3.49E+01	170.99	6.81E-01	170.99	-9.80E-01	--	--	--
U-234	2.78E-02	170.99	5.43E-04	170.99	-9.80E-01	--	--	--

Notes:
ΔFlux Fraction = (Sensitivity Case Flux Factor − Best Estimate Case Flux Factor) ÷ Best Estimate Case Flux Factor
The change in Δflux fraction is the same for radionuclides that peak in the same time window as each other and the best estimate case.

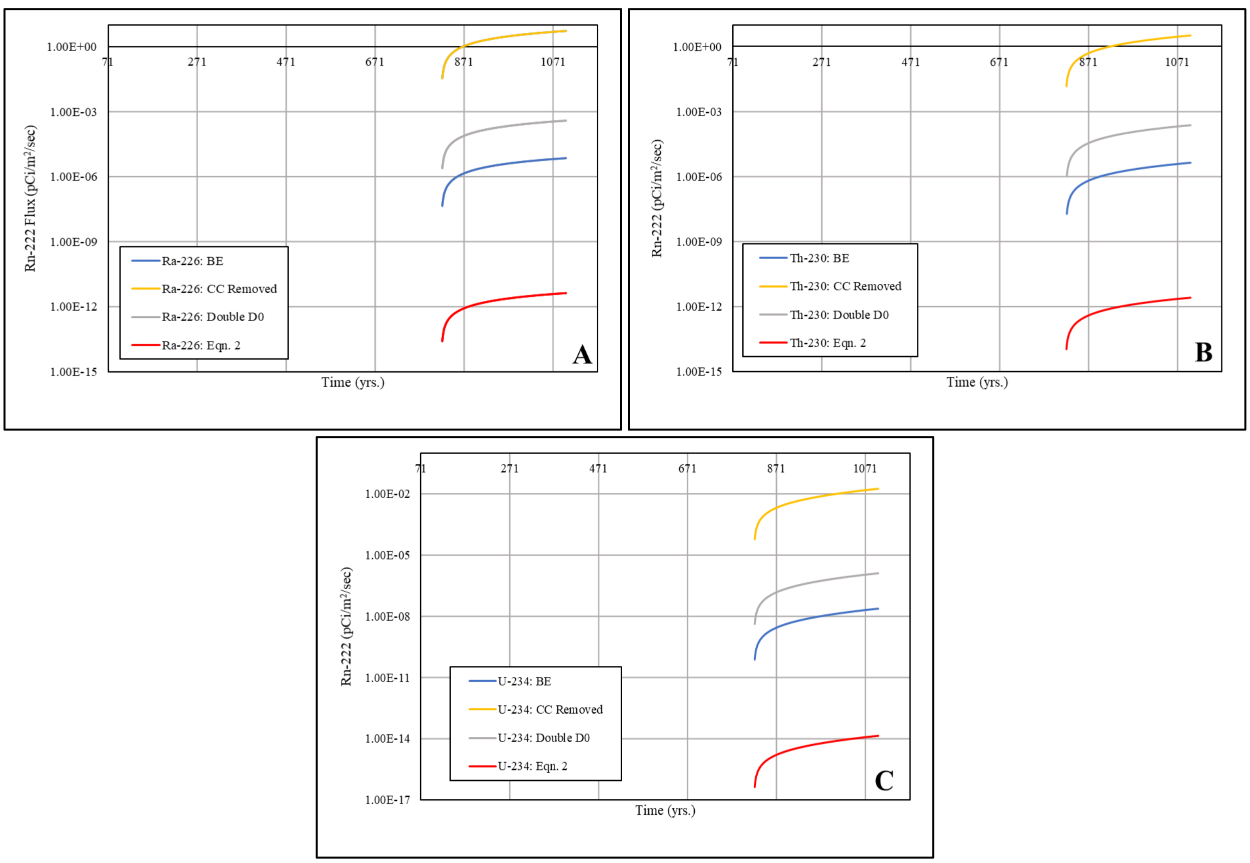


Note: Ra-226 Eqn. 2, Th-230 Eqn. 2, and U-234 Eqn. 2 in the plot legends refers to Eq. (6-11) in the text.

Figure 6-127. Flux Factor Time Histories from 1 Ci of Ra-226 (A), Th-230 (B), and U-234 (C) Buried in Naval Reactor Component Disposal Area Generic Waste Form for Radon Pathway Closure Cap Presence and Diffusion Coefficient Sensitivity Cases

6.3.4.4.2. Special Waste Form

Compared to the NRCDA generic waste form, the Rn-222 flux factor at the surface for NRCDA SWFs (steel casks) is even more strongly impacted by the presence of the final closure cap as indicated in Figure 6-128 and Table 6-184. Removal of the final closure cap accelerates Rn-222 transport, leading to a much higher flux factor. Doubling the air-phase diffusion coefficient, D_o, for Rn-222 leads to an increased peak flux factor and overall flux. The increase is even more pronounced for the NRCDA SWF because changes in diffusion rates within the closure cap have a greater effect on flux than they do for DUs that experience collapse and dynamic compaction events (i.e., STs, ETs, LAWV, and ILV). On the contrary, NRCDA SWFs have markedly lower peak flux factors compared to other DUs. Utilizing Eq. (6-11) in place of Eq. (6-12) in the model to calculate $D_e^{Rn\text{-}222}$ decreases the effective diffusion coefficient, D_e, for each material thereby decreasing overall flux. In general, peak fluxes are less sensitive to diffusion and closure cap presence than to water saturation as was the case for the NRCDA generic waste form. Time of peak flux is Year 1,171 for all parents in all cases.



Note: Ra-226 Eqn. 2, Th-230 Eqn. 2, and U-234 Eqn. 2 in the plot legends refers to Eq. (6-11) in the text.

Figure 6-128. Flux Factor Time Histories from 1 Ci of Ra-226 (A), Th-230 (B), and U-234 (C) Buried in Naval Reactor Component Disposal Area Special Waste Form for Radon Pathway Closure Cap Presence and Diffusion Coefficient Sensitivity Cases

Table 6-184. Peak Rn-222 Flux Factor and Time of Peak for 1 Ci Parent Buried in Naval Reactor Component Disposal Area Special Waste Form for Radon Pathway Closure Cap Presence and Diffusion Coefficient Sensitivity Cases

Radio-nuclide	Best Estimate Case		Closure Cap Removed			Double D_o		
	Peak Flux Factor (pCi m^{-2} s^{-1} Ci^{-1})	Time of Peak (Year)	Peak Flux Factor (pCi m^{-2} s^{-1} Ci^{-1})	Time of Peak (Year)	ΔFlux Fraction	Peak Flux Factor (pCi m^{-2} s^{-1} Ci^{-1})	Time of Peak (Year)	ΔFlux Fraction
Ra-226	8.73E-06	1,171	6.52E+00	1,171	7.47E+05	4.72E-04	1,171	5.30E+01
Th-230	5.73E-06	1,171	4.28E+00	1,171	7.47E+05	3.10E-04	1,171	5.30E+01
U-234	3.35E-08	1,171	2.50E-02	1,171	7.47E+05	1.81E-06	1,171	5.30E+01
Radio-nuclide	Best Estimate Case		Diffusion Eq. (6-11)			--		
	Peak Flux Factor (pCi m^{-2} s^{-1} Ci^{-1})	Time of Peak (Year)	Peak Flux Factor (pCi m^{-2} s^{-1} Ci^{-1})	Time of Peak (Year)	ΔFlux Fraction	--	--	--
Ra-226	8.73E-06	1,171	5.13E-12	1,171	-1.00E+00	--	--	--
Th-230	5.73E-06	1,171	3.37E-12	1,171	-1.00E+00	--	--	--
U-234	3.35E-08	1,171	1.97E-14	1,171	-1.00E+00	--	--	--

Notes:

ΔFlux Fraction = (Sensitivity Case Flux Factor − Best Estimate Case Flux Factor) ÷ Best Estimate Case Flux Factor

The change in Δflux fraction is the same for radionuclides that peak in the same time window as each other and the best estimate case.

6.3.5. Insights Gained

Overall, the air pathway dose factor and radon flux factor results are sensitive to saturation and display mixed responses to the variation of other key parameters in the ARM. Of note is the interplay between the POA or DRFs and transport time for the air pathway where mass released more quickly may result in smaller peak dose factors. To further complicate this insight, the ARM assumes that radionuclides are confined to the waste zone until Year 71. This assumption results in overly sensitive peak dose factors and Rn-222 flux factors in some sensitivity runs where, in reality, mass would escape the system before the PO applies. The cases with the most sensitivity (i.e., the largest change in dose or flux factors due to changes in the sensitivity parameter) are for DUs with extremely low flux rates or dose factors (e.g., NRCDA SWF). As such, the sensitivity analyses for both the air pathway dose factors and radon flux factors support the use of the best estimate peak dose and flux factors in limits determination.

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