SRNL
SAVANNAH RIVER NATIONAL LABORATORY

SRNL-L6200-2010-00019

June 22, 2010

To: K. H. Rosenberger, 705-1C

From: K. L. Dixon, 773-42A

Re: Sensitivity Simulations for the Saltstone Disposal Facility Radon and Air Pathway Model

In response to comments from the Nuclear Regulatory Commission (NRC), several simulations have been performed to evaluate the sensitivity of the Saltstone Disposal Facility (SDF) Radon and Air Pathway model to input assumptions. The SDF radon and air pathway models are documented by Dixon et al. (2008).

Sensitivity simulations included:
Case 1: Evaluating the sensitivity of the radon pathway model to the assumed emanation factor
Case 2: Evaluating the sensitivity of the radon pathway model to the assumed cover layer saturation values
Case 3: Evaluating the sensitivity of the air pathway model to the assumed cover layer saturation values

Case 1 involved conducting a simulation with the original PA Radon pathway model but with the emanation factor set to the maximum value suggested by RESRAD (0.7). All other properties and inputs remained unchanged. Case 2 investigated the effect of cover layer saturation on the radon and air pathway model results. For the radon pathway, the emanation factor was maintained at the PA value of 0.25 for the Case 2 simulations. The cover layer saturation values were set to the minimum reported by Jones and Phifer (2008). By reducing the cover layer saturation, the air-filled porosity of the cover layers was maximized. Radon diffusion coefficients for the cover layers were also increased due to the decreased saturation of the cover layers. Input properties used in Case 1 and 2 which were different than those used by Dixon et al. (2008) are summarized in Table 1 and Table 2. The simulations results for Case 1 and 2 are presented in Table 3 through Table 7 and in Figure 1 through Figure 10.

Case 3 investigated the sensitivity of the air pathway model to the assumed cover layer saturation values. As with the radon pathway model, the air-filled porosity of the cover layers was maximized (Table 1) based on the minimum saturation values reported by Jones and Phifer (2008). The diffusion coefficients were also increased as a result of the decreased saturation in the cover layers (Table 2). The simulation results are presented in Table 8 through Table 12 and Figure 11 through Figure 15.

cc: M. A. Phifer, 773-42A
H. H. Burns, 773-41A
T. Whiteside (Design Check), 773-42A
J. J. Mayer, 773-42A

References:

Dixon, K. L., G. P. Flach, M. E. Denham, and M. A. Phifer. 2008. Air And Radon Pathway Modeling For The Saltstone Disposal Facility, SRNL-STI-2008-00447, Savannah River National Laboratory, Aiken, SC 29808.

Jones, W. E. and M. A. Phifer. 2008. Saltstone Closure Facility Closure Cap and Concept and Infiltration Estimates, WSRC-STI-2008-00244. Washington Savannah River Company, Aiken, SC 29808.

Table 1. Average and Maximum Air-Filled Porosity Values used for Cover Layers

Cover Layer	Total Porosity (fraction)	Average Air Filled Porosity[1] (fraction)	Maximum Air Filled Porosity[2] (fraction)	Percent Increase (%)
Erosion barrier layer	0.150	0.017	0.027	54.5
Middle backfill layer	0.350	0.012	0.018	46.6
Upper lateral drainage layer	0.417	0.162	0.181	11.6
Foundation layer	0.350	0.048	0.099	105.3
Lower backfill layer	0.350	0.082	0.100	21.1
Lower drainage layer	0.417	0.417	0.417	0.0

[1]Average air-filled porosity used in PA Radon and Air Pathway modeling.
[2]Maximum air-filled porosity used in sensitivity simulations for radon and air pathway modeling.

Table 2. Effective Air-Diffusion Coefficients for Each Radionuclide/Compound for the Closure Cap (Vaults 1, 2, and 4) Assuming Minimum Saturation for the Cover Layers (Case 2)

Radionuclide[1,2]	Lower Drainage Layer (m^2/yr)	Lower Backfill Layer (m^2/yr)	Foundation Layer (m^2/yr)	Upper Lateral Drainage Layer (m^2/yr)	Middle Backfill Layer (m^2/yr)	Erosion Barrier Layer (m^2/yr)
^{222}Rn	3.47E+02	2.67E+00	2.64E+00	4.97E+00	3.20E-01	1.45E+00
^{14}C	7.62E+02	5.86E+00	5.79E+00	1.09E+01	7.03E-01	3.19E+00
^{36}Cl	6.09E+02	4.69E+00	4.63E+00	8.74E+00	5.62E-01	2.55E+00
^{129}I	3.22E+02	2.48E+00	2.45E+00	4.61E+00	2.97E-01	1.35E+00
^{125}Sb	4.62E+02	3.56E+00	3.51E+00	6.63E+00	4.26E-01	1.93E+00
^{126}Sb	4.61E+02	3.54E+00	3.50E+00	6.60E+00	4.25E-01	1.93E+00
^{79}Se	5.82E+02	4.48E+00	4.42E+00	8.34E+00	5.36E-01	2.43E+00
^{126}Sn	4.61E+02	3.54E+00	3.50E+00	6.60E+00	4.25E-01	1.93E+00
$^{3}H_2$	2.11E+03	1.62E+01	1.60E+01	3.03E+01	1.95E+00	8.82E+00
^{99}Tc	5.20E+02	4.00E+00	3.95E+00	7.45E+00	4.79E-01	2.17E+00

[1]The effective diffusion coefficient for ^{222}Rn was used to determine the effective air diffusion coefficient of each radionuclide/compound based on Graham's law.
[2]The effective diffusion coefficients for all three disposal units are the same because the minimum saturation assumed for each cover layer is the same for all three designs.

Table 3. Simulated Peak Instantaneous Rn-222 Flux over 10,000-Years at the Land Surface for Vault 1 DDA Saltstone

Parent Source (1 Ci/m^2)	Peak Rn-222 Flux - Emanation Factor 0.25 (pCi/m^2/sec) / (Ci/m^2)	Peak Rn-222 Flux - Emanation Factor 0.70 (pCi/m^2/sec) / (Ci/m^2)	Peak Rn-222 Flux – Minimum Saturation for Cover Layers (pCi/m^2/sec) / (Ci/m^2)
Pu-238	3.39E-14	9.51E-14	2.04E-12
U-238	1.15E-12	3.23E-12	6.95E-11
U-234	9.65E-11	2.70E-10	5.81E-09
Th-230	1.31E-09	3.68E-09	7.90E-08
Ra-226	1.43E-09	4.00E-09	8.59E-08

Table 4. Simulated Peak Instantaneous Rn-222 Flux over 10,000-Years at the Land Surface for Vault 1 ARP/MCU Saltstone

Parent Source (1 Ci/m^2)	Peak Rn-222 Flux - Emanation Factor 0.25 (pCi/m^2/sec) / (Ci/m^2)	Peak Rn-222 Flux - Emanation Factor 0.70 (pCi/m^2/sec) / (Ci/m^2)	Peak Rn-222 Flux – Minimum Saturation for Cover Layers (pCi/m^2/sec) / (Ci/m^2)
Pu-238	3.15E-14	8.82E-14	1.90E-12
U-238	1.07E-12	3.00E-12	6.45E-11
U-234	8.96E-11	2.51E-10	5.39E-09
Th-230	1.22E-09	3.42E-09	7.34E-08
Ra-226	1.33E-09	3.71E-09	7.98E-08

Table 5. Simulated Peak Instantaneous Rn-222 Flux over 10,000-Years at the Land Surface for Vault 2 (and future disposal units) SWPF Saltstone

Parent Source (1 Ci/m^2)	Peak Rn-222 Flux - Emanation Factor 0.25 (pCi/m^2/sec) / (Ci/m^2)	Peak Rn-222 Flux - Emanation Factor 0.70 (pCi/m^2/sec) / (Ci/m^2)	Peak Rn-222 Flux – Minimum Saturation for Cover Layers (pCi/m^2/sec) / (Ci/m^2)
Pu-238	1.63E-20	4.56E-20	9.80E-19
U-238	5.55E-19	1.55E-18	3.33E-17
U-234	4.64E-17	1.30E-16	2.79E-15
Th-230	6.31E-16	1.77E-15	3.79E-14
Ra-226	6.86E-16	1.92E-15	4.12E-14

Table 6. Simulated Peak Instantaneous Rn-222 Flux over 10,000-Years at the Land Surface for Vault 4 DDA Saltstone

Parent Source (1 Ci/m^2)	Peak Rn-222 Flux - Emanation Factor 0.25 (pCi/m^2/sec) / (Ci/m^2)	Peak Rn-222 Flux - Emanation Factor 0.70 (pCi/m^2/sec) / (Ci/m^2)	Peak Rn-222 Flux – Minimum Saturation for Cover Layers (pCi/m^2/sec) / (Ci/m^2)
Pu-238	1.41E-16	3.94E-16	8.46E-15
U-238	4.79E-15	1.34E-14	2.88E-13
U-234	4.00E-13	1.12E-12	2.41E-11
Th-230	5.45E-12	1.53E-11	3.28E-10
Ra-226	5.92E-12	1.66E-11	3.56E-10

Table 7. Simulated Peak Instantaneous Rn-222 Flux over 10,000-Years at the Land Surface for Vault 4 ARP/MCU Saltstone

Parent Source (1 Ci/m^2)	Peak Rn-222 Flux - Emanation Factor 0.25 (pCi/m^2/sec) / (Ci/m^2)	Peak Rn-222 Flux - Emanation Factor 0.70 (pCi/m^2/sec) / (Ci/m^2)	Peak Rn-222 Flux – Minimum Saturation for Cover Layers (pCi/m^2/sec) / (Ci/m^2)
Pu-238	1.28E-16	3.58E-16	7.70E-15
U-238	4.35E-15	1.22E-14	2.62E-13
U-234	3.64E-13	1.02E-12	2.19E-11
Th-230	4.96E-12	1.39E-11	2.98E-10
Ra-226	5.39E-12	1.51E-11	3.24E-10

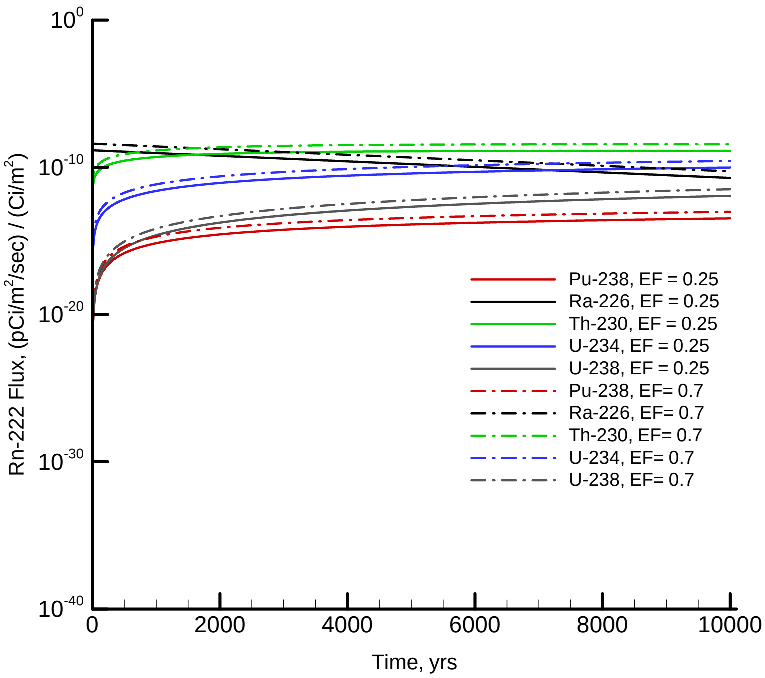

Figure 1. Comparison of Rn-222 Flux at Land Surface Using Emanation Factors of 0.25 (used in PA model) and 0.7 for Vault 1 DDA Saltstone.

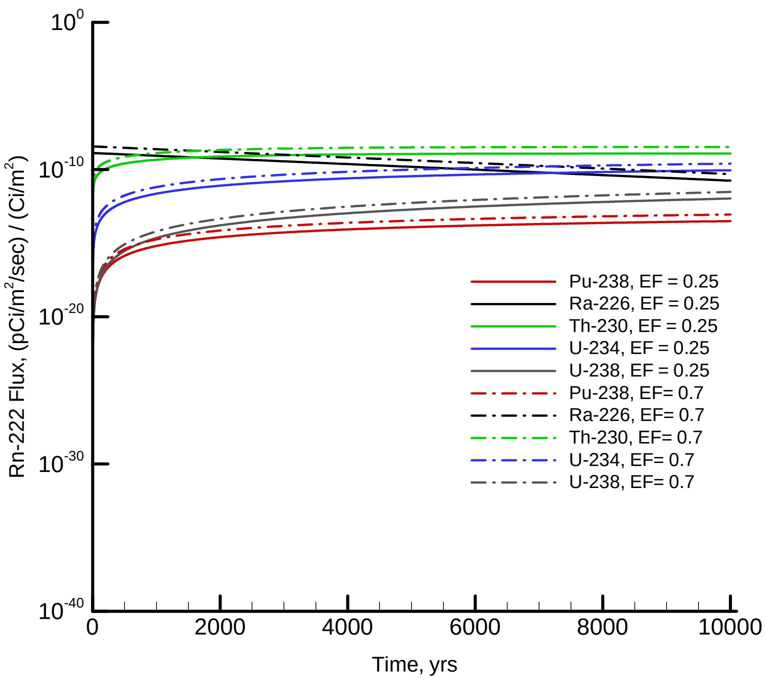

Figure 2. Comparison of Rn-222 Flux at Land Surface Using Emanation Factors of 0.25 (used in PA model) and 0.7 for Vault 1 MCU Saltstone.

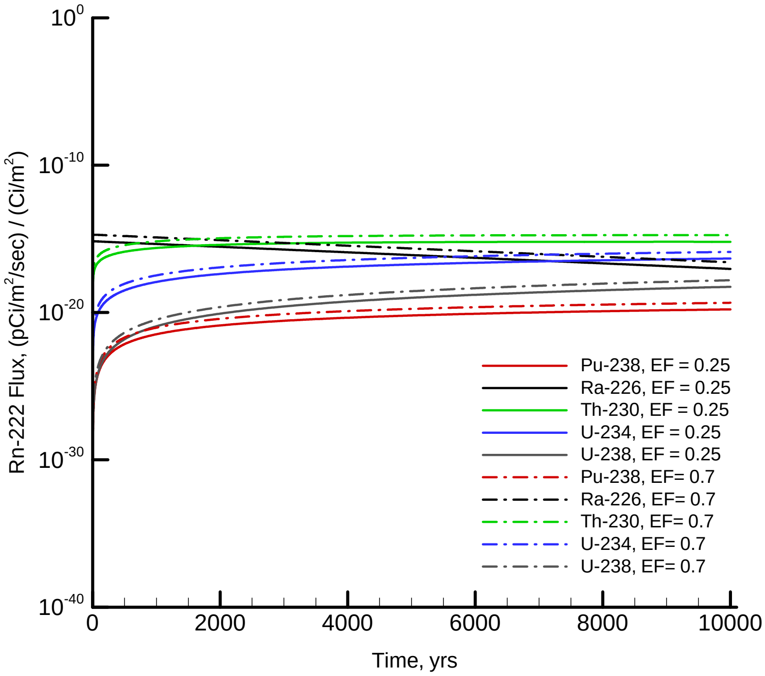

Figure 3. Comparison of Rn-222 Flux at Land Surface Using Emanation Factors of 0.25 (used in PA model) and 0.7 for Vault 2 SWPF Saltstone.

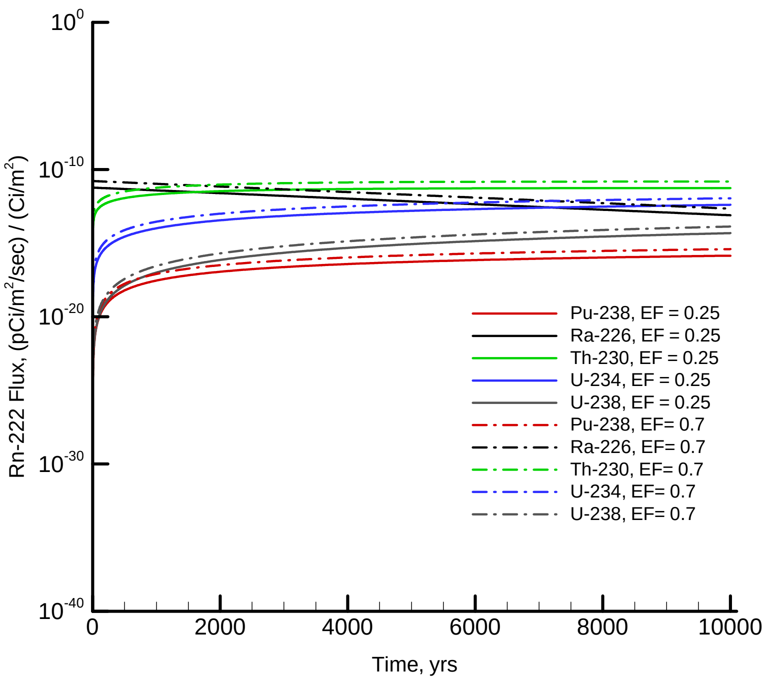

Figure 4. Comparison of Rn-222 Flux at Land Surface Using Emanation Factors of 0.25 (used in PA model) and 0.7 for Vault 4 DDA Saltstone.

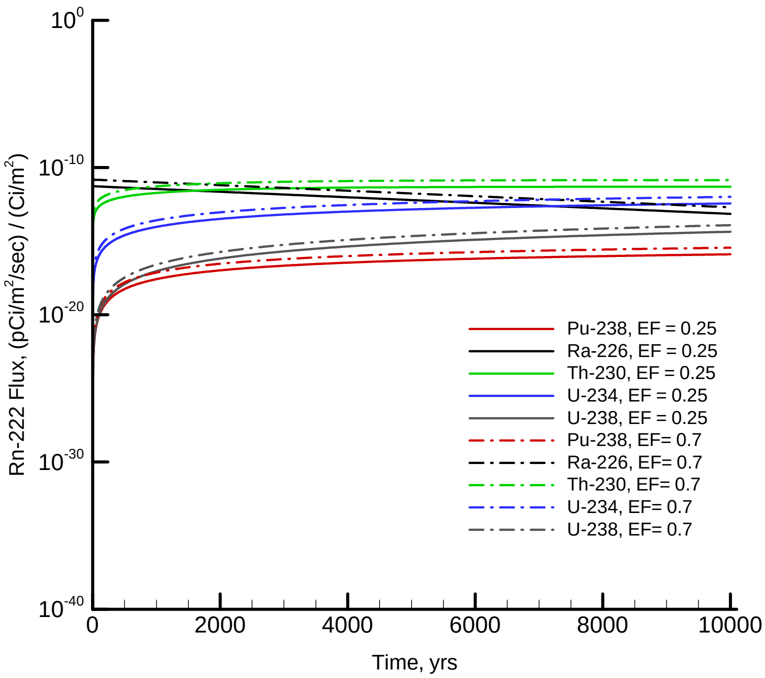

Figure 5. Comparison of Rn-222 Flux at Land Surface Using Emanation Factors of 0.25 (used in PA model) and 0.7 for Vault 4 MCU Saltstone.

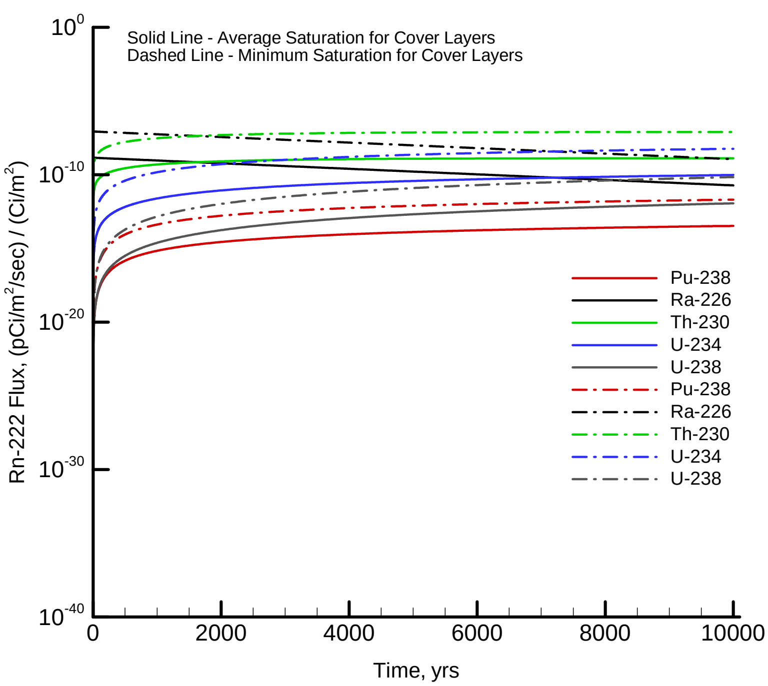

Figure 6. Rn-222 Flux at Land Surface using Average and Minimum Saturation Values for Cover Layers (Vault 1 DDA Saltstone).

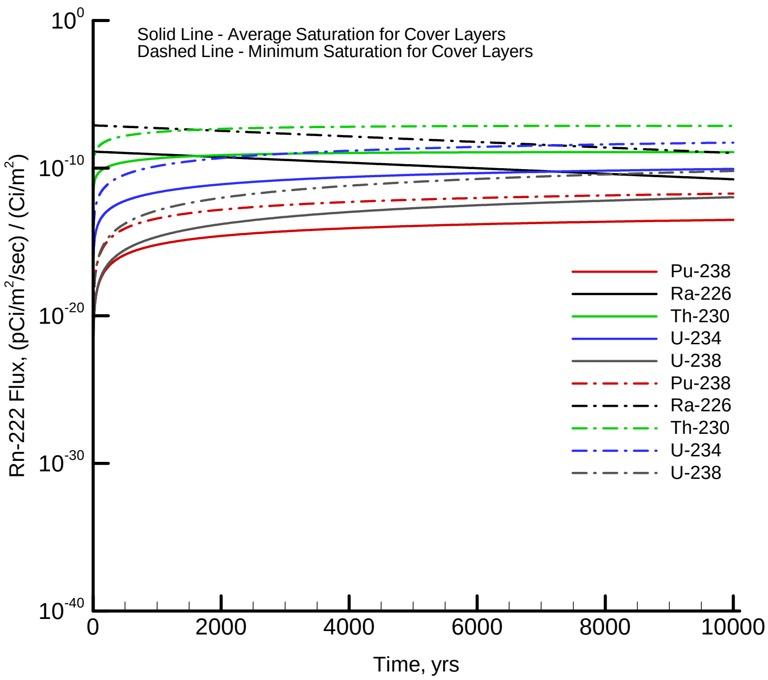

Figure 7. Rn-222 Flux at Land Surface using Average and Minimum Saturation Values for Cover Layers (Vault 1 MCU Saltstone).

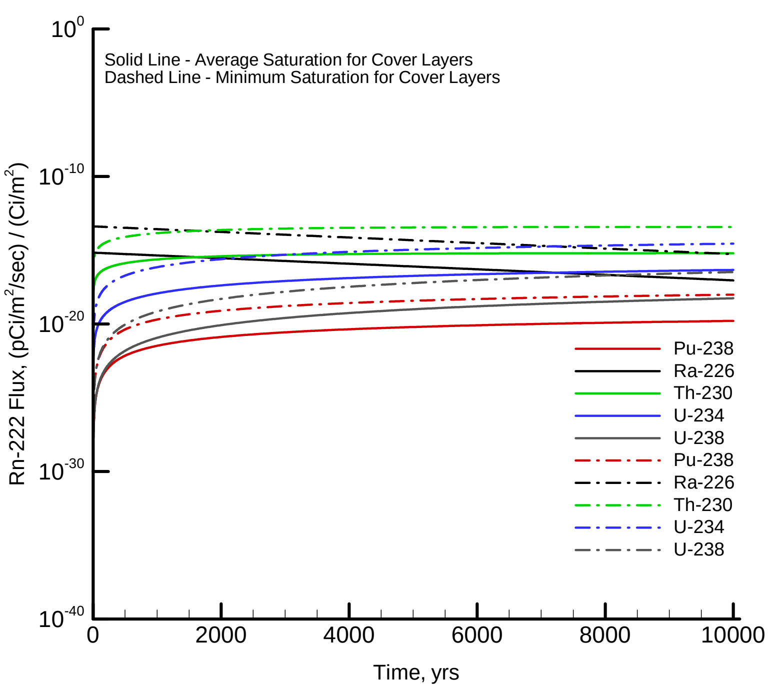

Figure 8. Rn-222 Flux at Land Surface using Average and Minimum Saturation Values for Cover Layers (Vault 2 SWPF Saltstone).

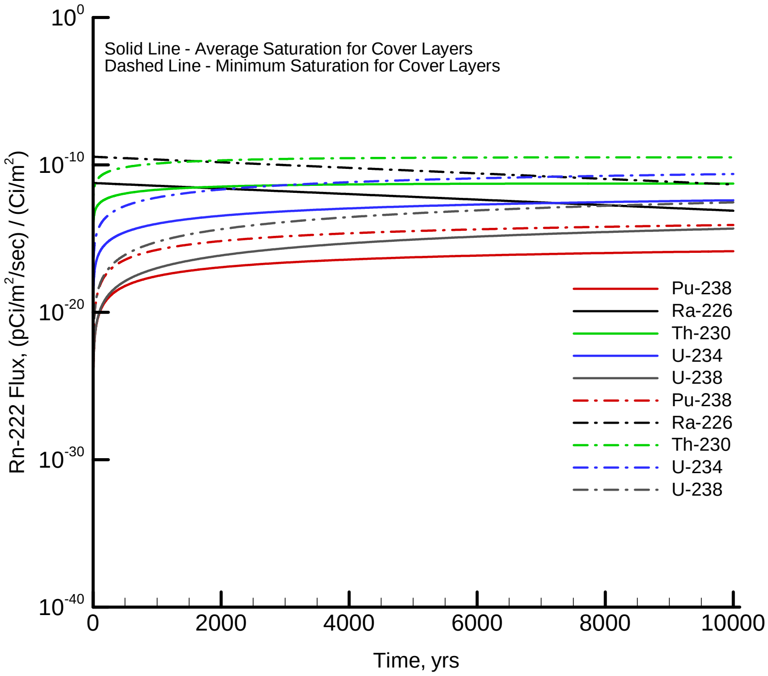

Figure 9. Rn-222 Flux at Land Surface using Average and Minimum Saturation Values for Cover Layers (Vault 4 DDA Saltstone).

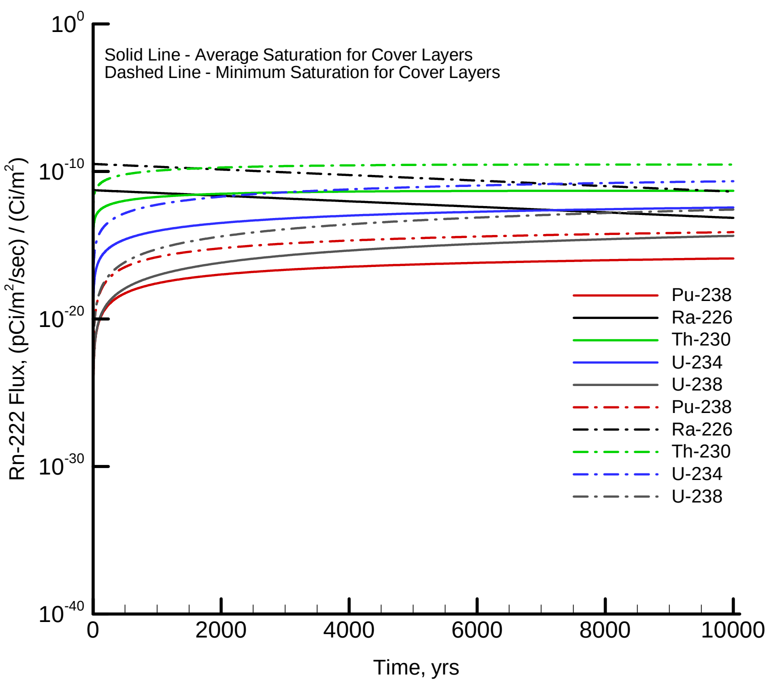

Figure 10. Rn-222 Flux at Land Surface using Average and Minimum Saturation Values for Cover Layers (Vault 4 MCU Saltstone).

Table 8. Peak Fluxes, Time to Peak Fluxes, SRS Boundary Dose Release Factors, and SRS Boundary Dose to the MEI for DDA Saltstone in Vault 1

Radionuclide	Average Saturation for Cover Layers		Minimum Saturation for Cover Layers	
	Peak Flux ($Ci/m^2/yr$) /Ci/m^2)	**Time to Peak Flux (yrs)**	**Peak Flux ($Ci/m^2/yr$) /Ci/m^2)**	**Time to Peak Flux (yrs)**
^{14}C	5.17E-14	136.7	5.69E-14	67.99
^{36}Cl	2.56E-27	281.7	2.79E-27	133.30
^{129}I	1.12E-30	763.8	1.22E-30	354.30
^{125}Sb	4.33E-46	4.4	1.08E-45	3.98
^{79}Se	5.12E-16	291.7	5.58E-16	138.00
^{126}Sn	2.03E-70	350.8	2.22E-70	167.70
$^{3}H_2$	3.85E-13	9.7	6.12E-13	6.52
^{99}Tc	3.36E-77	311.2	3.66E-77	148.00

Table 9. Peak Fluxes, Time to Peak Fluxes, SRS Boundary Dose Release Factors, and SRS Boundary Dose to the MEI for ARP/MCU Saltstone in Vault 1

Radionuclide	Average Saturation for Cover Layers		Minimum Saturation for Cover Layers	
	Peak Flux ($Ci/m^2/yr$) /Ci/m^2)	**Time to Peak Flux (yrs)**	**Peak Flux ($Ci/m^2/yr$) /Ci/m^2)**	**Time to Peak Flux (yrs)**
^{14}C	4.18E-14	136.0	4.61E-14	67.65
^{36}Cl	2.07E-27	283.1	2.26E-27	133.30
^{129}I	9.02E-31	715.8	9.85E-31	333.70
^{125}Sb	3.51E-46	4.4	8.73E-46	3.98
^{79}Se	4.14E-16	291.7	4.52E-16	138.00
^{126}Sn	1.64E-70	350.8	1.80E-70	167.70
$^{3}H_2$	3.12E-13	9.7	4.96E-13	6.52
^{99}Tc	2.72E-77	311.2	2.97E-77	148.00

Table 10. Peak Fluxes, Time to Peak Fluxes, SRS Boundary Dose Release Factors, and SRS Boundary Dose to the MEI for SWPF Saltstone in Vault 2 (and future disposal units)

Radionuclide	Average Saturation for Cover Layers		Minimum Saturation for Cover Layers	
	Peak Flux ($Ci/m^2/yr$) / Ci/m^2)	**Time to Peak Flux (yrs)**	**Peak Flux ($Ci/m^2/yr$) / Ci/m^2)**	**Time to Peak Flux (yrs)**
^{14}C	4.27E-14	147.3	4.48E-14	71.11
^{36}Cl	2.12E-27	305.1	2.20E-27	139.40
^{129}I	9.22E-31	787.0	9.56E-31	352.60
^{125}Sb	2.10E-46	6.1	5.19E-46	5.70
^{79}Se	4.24E-16	317.5	4.40E-16	143.70
^{126}Sn	1.68E-70	379.9	1.74E-70	174.50
$^{3}H_2$	2.97E-13	10.4	4.65E-13	7.06
^{99}Tc	2.77E-77	337.1	2.88E-77	155.60

Table 11. Peak Fluxes, Time to Peak Fluxes, SRS Boundary Dose Release Factors, and SRS Boundary Dose to the MEI for DDA Saltstone in Vault 4

Radionuclide	Average Saturation for Cover Layers		Minimum Saturation for Cover Layers	
	Peak Flux ($Ci/m^2/yr$) / Ci/m^2)	**Time to Peak Flux (yrs)**	**Peak Flux ($Ci/m^2/yr$) / Ci/m^2)**	**Time to Peak Flux (yrs)**
^{14}C	7.24E-14	141.5	7.78E-14	69.36
^{36}Cl	3.59E-27	291.7	3.82E-27	136.00
^{129}I	1.56E-30	787.0	1.66E-30	363.30
^{125}Sb	5.07E-46	5.0	1.26E-45	4.55
^{79}Se	7.18E-16	303.6	7.64E-16	141.50
^{126}Sn	2.84E-70	363.3	3.02E-70	170.20
$^{3}H_2$	5.23E-13	10.0	8.25E-13	6.69
^{99}Tc	4.69E-77	323.9	4.99E-77	151.80

Table 12. Peak Fluxes, Time to Peak Fluxes, SRS Boundary Dose Release Factors, and SRS Boundary Dose to the MEI for ARP/MCU Saltstone in Vault 4

	Average Saturation for Cover Layers		Minimum Saturation for Cover Layers	
Radionuclide	**Peak Flux ($Ci/m^2/yr$) /Ci/m^2)**	**Time to Peak Flux (yrs)**	**Peak Flux ($Ci/m^2/yr$) /Ci/m^2)**	**Time to Peak Flux (yrs)**
^{14}C	4.10E-15	152.5	4.23E-15	72.18
^{36}Cl	2.04E-28	315.9	2.07E-28	142.20
^{129}I	8.86E-32	819.0	9.01E-32	361.50
^{125}Sb	1.84E-47	6.2	4.53E-47	5.76
^{79}Se	4.08E-17	328.8	4.15E-17	147.30
^{126}Sn	1.61E-71	391.5	1.64E-71	178.00
$^{3}H_2$	2.79E-14	10.6	4.33E-14	7.20
^{99}Tc	2.66E-78	350.8	2.71E-78	157.90

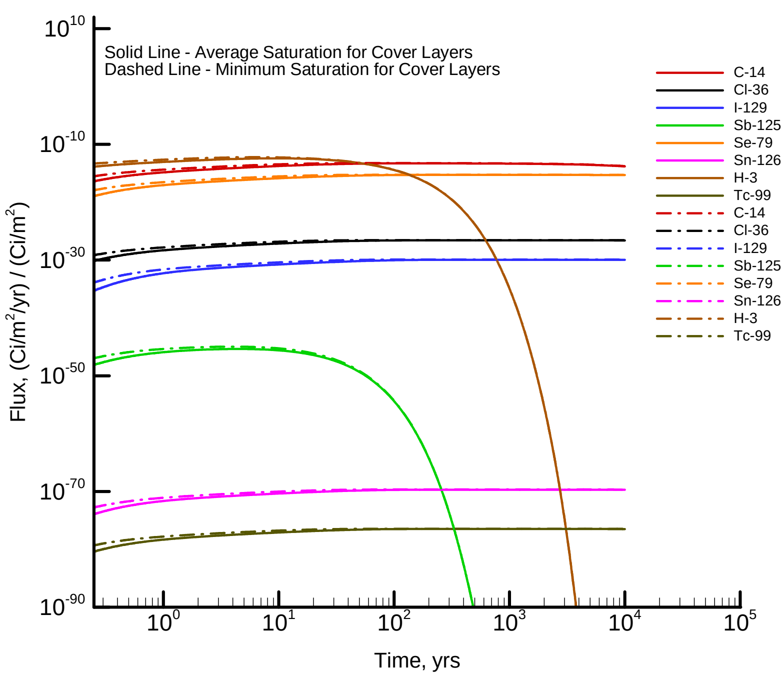

Figure 11. Flux at Land Surface for C-14, Cl-36, I-129, Sb-125, Se-79, Sn-126, H-3, and Tc-99 per Ci of Radionuclide in Vault 1 for DDA Saltstone.

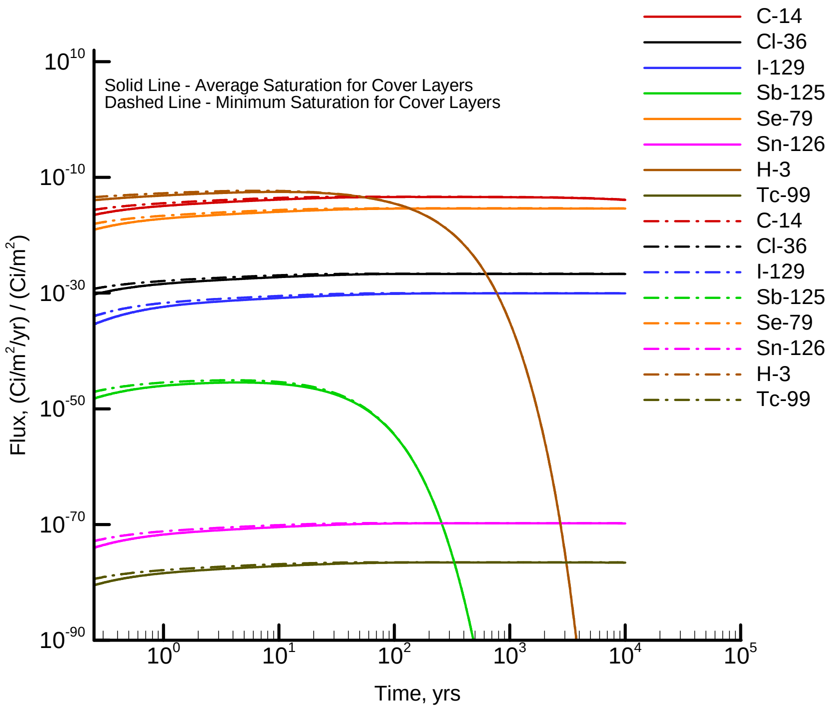

Figure 12. Flux at Land Surface for C-14, Cl-36, I-129, Sb-125, Se-79, Sn-126, H-3, and Tc-99 per Ci of Radionuclide in Vault 1 for ARP/MCU Saltstone.

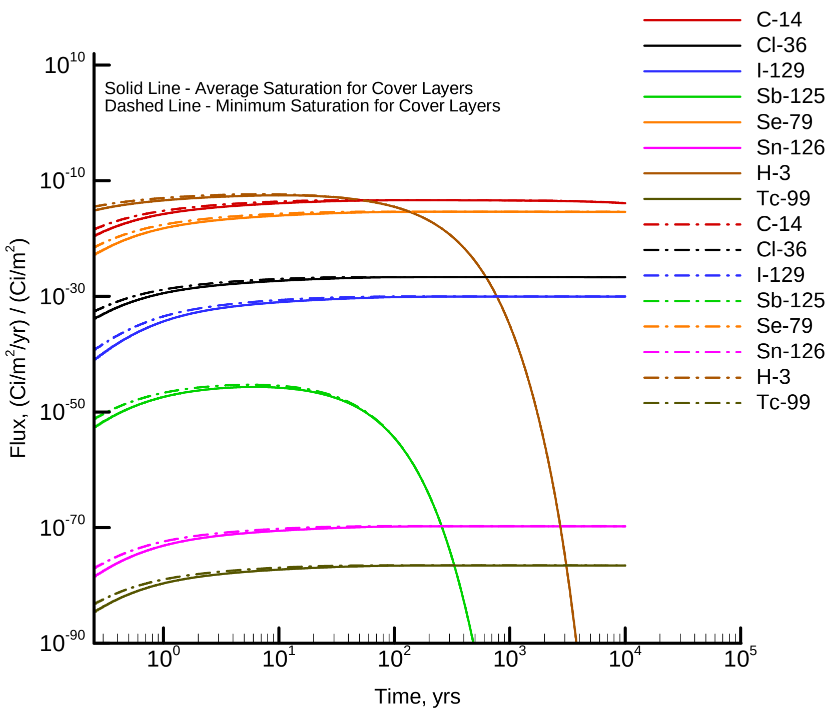

Figure 13. Flux at Land Surface for C-14, Cl-36, I-129, Sb-125, Se-79, Sn-126, H-3, and Tc-99 per Ci of Radionuclide in Vault 2 (and future disposal units) for SWPF Saltstone.

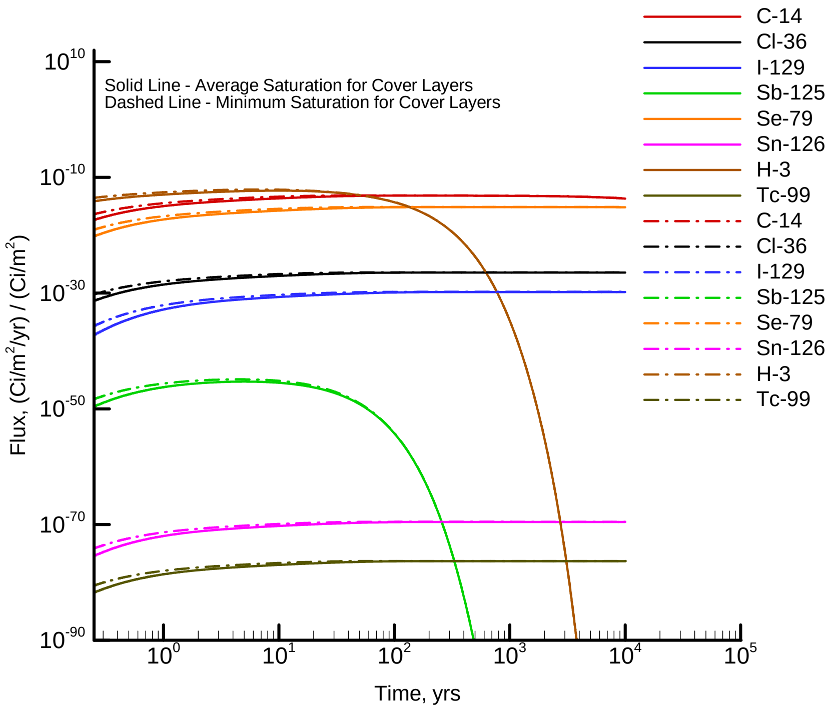

Figure 14. Flux at Land Surface for C-14, Cl-36, I-129, Sb-125, Se-79, Sn-126, H-3, and Tc-99 per Ci of Radionuclide in Vault 4 for DDA Saltstone.

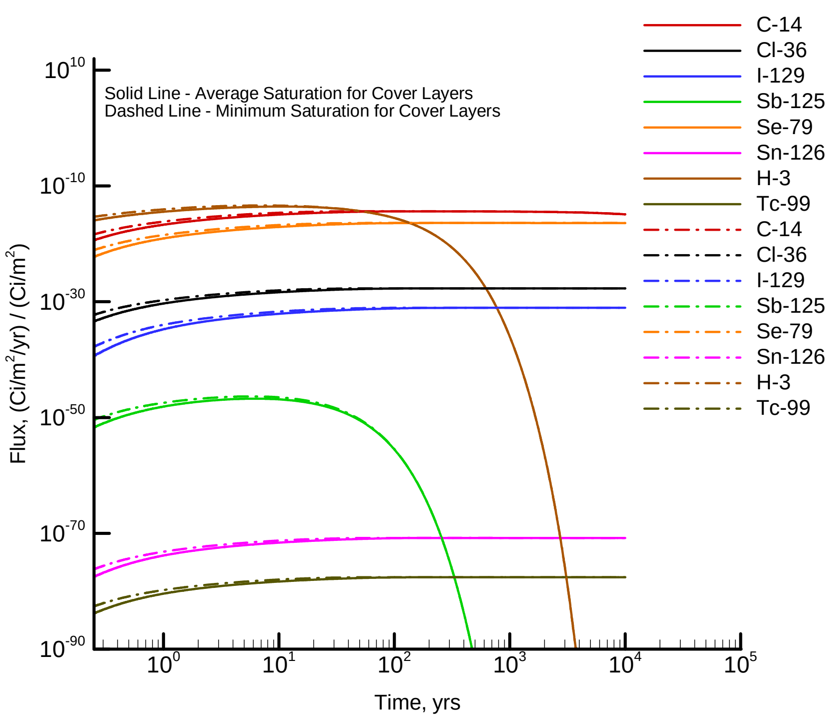

Figure 15. Flux at Land Surface for C-14, Cl-36, I-129, Sb-125, Se-79, Sn-126, H-3, and Tc-99 per Ci of Radionuclide in Vault 4 for ARP/MCU Saltstone.