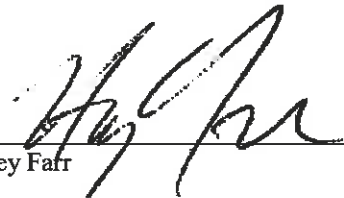



TSD 14-019
Radionuclides of Concern for Soil and Basement
Fill Model Source Terms

Revision 1

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Summary of Changes in this Revision:

- Rev. 1 – Correct typo from TSD 14-031 for Crib House Ni-63 peak concentration in pCi/L and for Spent Fuel Building peak tritium concentration. Updated 0.15 cm soil DCGLs and corrected error in percent dose from using 2013 data.

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1. PURPOSE

This technical support document (TSD) refines the initial selection of radionuclides of concern (ROCs) for decommissioning at the Zion Station Restoration Project (ZSRP) completed in October of 2012. (1) The list of ROCs was evaluated using Containment Building(s) and Auxiliary Building concrete core analysis data to evaluate the dose significance of each radionuclide in the end state model.

2. DISCUSSION

2.1. TSD 11-001 Initial Suite of Potential Radionuclides

The initial suite of potential radionuclides was used to help define sample analysis requirements associated with decommissioning activities including characterization activities and license termination plan (LTP) development. It was expected that as additional samples were collected and analyzed that this initial suite of radionuclides would be updated and would eventually represent those long lived radionuclides with a potential to be present at the time of final status survey (FSS). (1) The TSD developed an initial suite of potential radionuclides based upon a review of Industry Guidance Documents NUREG/CR-3474 (2), NUREG/CR-4289 (3) and WINCO-1191 (4). The review also included evaluation of 19 post-shutdown waste stream analysis results. The positively identified radionuclides in the samples were decay corrected to January 1, 2011. Positively identified radionuclides whose decayed fractions of the total mix were equal to, or greater than, 0.0001 (e.g. 0.01%) were included in the ROCs developed from industry guidance. Radionuclides were eliminated if they were not identified in ZSRP samples or were less than 0.01% of the theoretical concentrations. The final list of ROCs was provided in Table 5-2 of TSD 11-001 and is provided as Table 1 below.

Table 1 - TSD 11-001 Rev. 1 List of Radionuclides of Concern

Radionuclide	Half Life (years)	Radionuclide	Half Life (years)	Radionuclide	Half Life (years)
H-3	1.24E+01	Nb-94	2.03E+04	Eu-154	8.80E+00
C-14	5.73E+03	Tc-99	2.13E+05	Np-237	2.14E+06
Fe-55	2.70E+00	Sb-125	2.77E+00	Pu-238	8.77E+01
Ni-59	7.50E+04	Cs-134	2.06E+00	Pu-239/240	2.41E+04
Co-60	5.27E+00	Cs-137	3.00E+01	Pu-241	1.44E+01
Ni-63	9.60E+01	Pm-147	2.62E+00	Am-241	4.32E+02
Sr-90	2.91E+01	Eu-152	1.33E+01	Am-243	7.38E+03
Note: Half-lives from original TSD 11-001 in 2011				Cm-243/244	2.85E+01

The TSD stated, “Some radionuclides may prove not to have been present, some radionuclides may be removed with the removal of a specific source term, some radionuclides may continue to decay to insignificant activity concentrations, and some radionuclides may be eliminated due to insignificant dose contributions. Eventually an updated suite of radionuclides representative of radionuclides with a potential to be present at the time of final status survey will be prepared.” (1) Additional characterization data has since been obtained through direct sampling of the Unit 1 and Unit 2 Containment Buildings, Auxiliary Building, Turbine Building and Crib House and land area characterization surveys and sampling. In addition, waste stream samples were obtained for the interior surface of reactor coolant piping in September 2011 in Unit 2 and April 2012 in Unit 1.

2.2. Radionuclides Identified in Characterization Data

The radionuclides identified to date in land area surveys or samples have been Cs-137 and Co-60 at concentrations less than 4 pCi/g. Therefore, there has been insufficient source term to date to support analysis for hard-to-detect radionuclides in soil. The results of concrete core samples were evaluated separately for the Reactor Building Containments (5), Auxiliary Building (6) and the Turbine Building. (7). The only ROC positively identified in the Turbine Building concrete cores was Cs-137. Due to the low levels present, all other nuclides were below the minimum detectable activity (MDA). Concrete cores were also obtained in the Crib House, but these were for the purpose of identifying background concentrations in clean, non-contaminated concrete. The potential end state concrete of the Fuel Handling Building has not yet been sampled. Only portions of the Transfer Canal and Spent Fuel Pool below the 588 foot elevation could potentially remain during the end state for the Fuel Handling Building. The remainder is above the 588 foot elevation and will be disposed of as waste. Since the Spent Fuel Pool is still in use, no characterization of end state concrete under the liner has been possible. Similarly, the Waste Water Treatment Facility (WWTF) is still in use and the end state concrete has not yet been characterized.

Concrete core locations in the Auxiliary Building and Containments were chosen based upon contact dose rates and/or visible indication of leakage. This ensured the core samples would be from the most contaminated locations and provide good indications of hard-to-detect (HTD) nuclide source terms. As seen in Attachment A, there were 69 concrete cores from the Containment Building(s), Auxiliary Building, and Turbine Building collected and analyzed on site. As seen in Attachment A, the Containment Building samples included concrete cores from the Under Vessel Incore areas where activated concrete was present. The concrete cores were sectioned into ½ inch slices or pucks and analyzed on the top and bottom of each slice by on-site gamma spectroscopy. Five plant related radionuclides were positively identified; Co-60, Cs-134, Cs-137, Eu-152, and Eu-154. As described in the TSDs, (5), (6), (7) the top and bottom results of each puck were averaged to determine the activity in units of picocuries per gram (pCi/g) at depth. In order to ensure the estimated source terms were bounding and conservative, the MDA was used when no activity was positively identified. The concentrations were decay corrected to January 1, 2013. This provided a worst case depth profile for each core in ½ inch increments in pCi/g. The calculated surface area of the walls and floors of the end state structure (8), (6), (7) was multiplied by ½ inch [1.27 centimeters (cm)] to calculate the volume of concrete equal to a ½ inch thickness for the location sampled. A density of 2.40 grams (5) per cubic centimeter (g/cm^3) was used to calculate the mass equal to the ½ inch thick volume. The estimated masses at each ½ depth were multiplied times the average in-house gamma spectroscopy concentration to determine the total estimated source term in each area based upon the on-site gamma spectroscopy results as shown in Table 2. The Turbine Building estimated source term consists of Cs-137 with no other ROCs above the MDA identified. The Turbine Building source term is insignificant in comparison to the Auxiliary Building and Containment Buildings. (7)

In addition, the top pucks of 27 concrete cores were sent for off-site laboratory analysis that included the Table 3 full suite of 39 radionuclides as opposed to the 22 radionuclides identified in TSD 11-001 Rev. 1 list in Table 1. (1) The pucks sent for analysis tended to be the highest activity ones in order to ensure sufficient source term to quantify HTD nuclide ratios relative to the Table 3 scaling nuclides. Use of low concentration cores artificially reduces the ratio of the HTD nuclide to scaling nuclide due to the low scaling nuclide activity and the MDAs of the HTD nuclides.

Table 2 - Estimated January 1, 2013 Source Terms from On-Site Gamma Spectroscopy Results

Nuclide	Unit 1 CTMT Concrete			Unit 2 CTMT Concrete			Aux Bldg		
	Total 568' Floor Ci	Total 542' Floor & Walls Ci	Overall Total Ci	Total 568' Floor Ci	Total 542' Floor & Walls Ci	Overall Total Ci	Total 542' Floor Ci	Total Contam Wall 542' Ci	Overall Total Ci
Co-60	2.08E-01	1.19E-03	2.09E-01	2.55E-01	1.53E-03	2.57E-01	1.2E-02	3.79E-03	1.57E-02
Cs-134	2.00E-03	5.95E-05	2.06E-03	1.07E-03	6.60E-05	1.13E-03	3.4E-04	2.06E-04	5.47E-04
Cs-137	6.80E+00	3.94E-03	6.80E+00	7.24E-01	8.59E-04	7.25E-01	5.99E-01	1.10E-01	7.09E-01
Eu-152	<i>ND</i>	7.49E-03	2.13E-02	<i>ND</i>	1.27E-02	1.31E-02	<i>ND</i>	<i>ND</i>	<i>ND</i>
Eu-154	<i>ND</i>	4.07E-04	7.33E-03	<i>ND</i>	7.26E-04	9.96E-04	<i>ND</i>	<i>ND</i>	<i>ND</i>

ND = Not Detected Above MDA

Table 3 - Off-Site Laboratory Suite of Radionuclides and Analysis Methods

Radionuclide	Analytical Method
Ac-228	Actinium-228
Am-241	Americium-241
Am-243	Americium-243
Sb-125	Antimony-125
Ba-133	Barium-133
Bi-214	Bismuth-214
C-14	Carbon-14
Cs-134	Cesium-134
Cs-137	Cesium-137
Co-60	Cobalt-60
Cm-243/244	Curium-243/244
Eu-152	Europium-152
Eu-154	Europium-154
Eu-155	Europium-155
Ho-166	Holmium-166m
I-129	Iodine-129
Fe-55	Iron-55
Pb-210	Lead-210
Pb-212	Lead-212
Pb-214	Lead-214
Mn-54	Manganese-54
Np-237	Neptunium-237
Ni-59	Nickel-59
Ni-63	Nickel-63
Nb-94	Niobium-94
Pu-238	Plutonium-238
Pu-239/240	Plutonium-239/240
Pu-241	Plutonium-241

Radionuclide		Analytical Method
K-40	Potassium-40	LANL ER-130 Modified
Pm-145	Promethium-145	LANL ER-130 Modified
Pm-147	Promethium-147	EML Pm-01 Modified
Rn-226	Radium-226	LANL ER-130 Modified
Ag-110m	Silver-108m	LANL ER-130 Modified
Sr-90	Strontium-90	EIChroM SRW01 Modified
Tc-99	Technetium-99	EIChroM TCS01 Modified
Tl-208	Thallium-208	LANL ER-130 Modified
Th-234	Thorium-234	LANL ER-130 Modified
H-3	Tritium	LANL ER-210 Modified
U-235	Uranium-235	LANL ER-130 Modified

The off-site analysis results including MDAs were decay corrected to January 1, 2013 and used to calculate average concentrations and estimate source terms in the first half inch in each building as described above. As is documented in the off-site laboratory reports and in the technical support documents (5) (6), three radionuclides I-129, Pm-145, and Pm-147 were eliminated from the decayed mixes due to false positive results from interference of very high Cs-137 concentrations. The estimated source terms in the first half inch were used to develop scaling factors for each area shown in Table 2. The scaling factors applied were specific to each building end state basement structure based upon the ratio of radionuclides in the concrete cores for that area. Since pucks from only 27 of the 69 concrete cores were sent for off-site analysis, the positively identified HTD radionuclide source terms were estimated by multiplying the scaling factor times the Table 2 source term of the scaling nuclide. (5) (6) The scaling nuclide used for each HTD radionuclide positively identified is shown in Table 4. Co-60 was used to scale metallic activation products, Eu-152 was used for concrete activation products and Cs-137 was used for the remaining radionuclides. The calculated source terms from on-site gamma spectroscopy results were used for Cs-134 and Eu-154.

Table 4 - Hard-to-Detect Radionuclides from Off-Site Analysis and Table 2 Scaling Nuclide

Nuclide	Scaling Nuclide	Nuclide	Scaling Nuclide	Nuclide	Scaling Nuclide
H-3	Cs-137	<i>Ag-108m</i>	Co-60	<i>Eu-155</i>	Eu-152
C-14	Cs-137	Sb-125	Sb-125	Np-237	<i>ND</i>
Fe-55	<i>ND</i>	I-129	<i>ND</i>	Pu-238	Cs-137
Ni-59	<i>ND</i>	Cs-134	Cs-134	Pu-239	Cs-137
Co-60	Co-60	Cs-137	Cs-137	Pu-240	Cs-137
Ni-63	Co-60	Pm-145	<i>ND</i>	Pu-241	<i>ND</i>
Sr-90	Cs-137	Pm-147	<u>Cs-137</u>	Am-241	Cs-137
Nb-94	Co-60	Eu-152	Eu-152	Am-243	Cs-137
Tc-99	Cs-137	Eu-154	Eu-154	Cm-243	Cs-137
				Cm-244	Cs-137

ND = Not Detected due to compromised results. See TSD 13-006 and TSD 14-013

As noted above, Ag-108m and Eu-155 were positively detected in some samples. Based upon this, they were added to the list of radionuclides of concern in Table 1. The source terms [in units of curies (Ci)] estimated by this method as identified in the Containment Building(s) and Auxiliary Building TSDs (5), (6), are provided in Table 5. It is important to note that these are very conservative estimates of the source terms in concrete at the time of characterization. The estimates are conservative because, as seen in the two bottom rows of Table 5, the MDA values were used for each of the Table 2 radionuclides even when it was not positively identified in that puck. More significantly, the locations with the highest contact dose rates and/or visible evidence of leaks were chosen for concrete core sampling, which biased the scaling nuclide (Cs-137 and Co-60) average concentrations and total activities high as the average concentration is applied to the entire surface area. In addition, all concrete interior to the steel liners in the Unit 1 and 2 Containment Buildings is planned to be removed and Auxiliary Building concrete will be remediated to ALARA levels. Thus the Table 5 source terms are extremely conservative and bounding with regard to potential end state source terms embedded in the concrete. The samples from inside the Unit 1 and Unit 2 reactor coolant system (RCS) whose results are provided in Attachment A were decay corrected to January 1, 2013.

Table 5 - Estimated January 1, 2013 Unit 1 & 2 Reactor Building and Auxiliary Building Source Terms

Nuclide	Unit 1 CTMT Concrete			Unit 2 CTMT Concrete			Aux Bldg		
	Total 568' Floor Ci	Total 542' Floor & Walls Ci	Overall Total Ci	Total 568' Floor Ci	Total 542' Floor & Walls Ci	Overall Total Ci	Total 542' Floor Ci	Total Contam Wall 542' Ci	Overall Total Ci
H-3	7.15E-03	4.69E-04	7.62E-03	1.07E-03	2.2E-04	1.29E-03	1.87E-03	1.22E-04	1.99E-03
C-14	7.46E-04	5.82E-06	7.52E-04	5.34E-05	2.3E-06	5.57E-05	2.88E-04	8.16E-05	3.69E-04
Fe-55	4.88E-03	3.93E-05	4.92E-03	2.11E-02	1.4E-04	2.13E-02	3.25E-03	3.13E-04	3.56E-03
Ni-59	1.03E-03	7.31E-05	1.11E-03	4.43E-03	3.0E-04	4.73E-03	3.83E-03	3.39E-04	4.17E-03
Co-60	2.08E-01	1.19E-03	2.09E-01	2.55E-01	1.5E-03	2.57E-01	1.19E-02	3.79E-03	1.57E-02
Ni-63	1.47E-01	5.21E-04	1.48E-01	8.38E-01	2.5E-03	8.41E-01	1.72E-01	3.19E-02	2.04E-01
Sr-90	3.64E-03	1.23E-06	3.64E-03	7.02E-05	5.7E-07	7.08E-05	2.56E-04	2.31E-04	4.87E-04
Nb-94	9.79E-04	1.06E-05	9.90E-04	5.47E-03	1.1E-05	5.48E-03	9.38E-05	1.27E-05	1.07E-04
Tc-99	9.08E-04	2.16E-06	9.10E-04	1.04E-05	4.1E-07	1.09E-05	1.19E-04	1.53E-05	1.34E-04
Ag-108m	1.78E-03	1.03E-05	1.79E-03	8.57E-03	1.3E-04	8.70E-03	1.34E-04	1.15E-05	1.45E-04
Sb-125	7.43E-03	1.36E-05	7.45E-03	1.27E-03	6.6E-06	1.27E-03	4.68E-04	1.12E-04	5.80E-04
Cs-134	2.00E-03	5.95E-05	2.06E-03	1.07E-03	6.6E-05	1.13E-03	3.41E-04	2.06E-04	5.47E-04
Cs-137	6.80E+00	3.94E-03	6.80E+00	7.24E-01	8.6E-04	7.25E-01	5.99E-01	1.10E-01	7.09E-01
Eu-152	1.38E-02	7.49E-03	2.13E-02	3.92E-04	1.3E-02	1.31E-02	1.47E-04	4.68E-05	1.94E-04
Eu-154	6.92E-03	4.07E-04	7.33E-03	2.70E-04	7.3E-04	9.96E-04	9.46E-05	2.71E-05	1.22E-04
Eu-155	2.42E-03	1.97E-04	2.62E-03	3.82E-04	2.6E-04	6.37E-04	1.18E-04	2.66E-05	1.44E-04
Np-237	9.11E-06	1.32E-07	9.24E-06	5.42E-07	6.4E-08	6.07E-07	2.81E-06	8.43E-07	3.66E-06
Pu-238	6.41E-05	2.35E-07	6.43E-05	9.29E-07	4.8E-08	9.76E-07	1.09E-05	3.66E-07	1.13E-05
Pu-239	2.24E-05	1.05E-07	2.25E-05	4.71E-07	2.1E-08	4.92E-07	4.29E-06	1.78E-07	4.47E-06
Pu-240	2.24E-05	1.05E-07	2.25E-05	4.71E-07	2.1E-08	4.92E-07	4.29E-06	1.78E-07	4.47E-06
Pu-241	7.99E-04	1.03E-05	8.10E-04	6.89E-05	4.8E-06	7.37E-05	2.63E-04	4.48E-05	3.08E-04
Am-241	7.94E-04	3.57E-07	7.94E-04	1.51E-05	5.5E-08	1.52E-05	9.87E-06	8.35E-07	1.07E-05
Am-243	1.50E-05	1.68E-07	1.52E-05	1.53E-06	7.1E-08	1.60E-06	7.12E-06	8.39E-07	7.96E-06
Cm-243	8.01E-05	1.48E-07	8.02E-05	1.66E-06	3.2E-08	1.70E-06	2.64E-06	5.62E-07	3.20E-06

Nuclide	Unit 1 CTMT Concrete			Unit 2 CTMT Concrete			Aux Bldg		
	Total 568' Floor Ci	Total 542' Floor & Walls Ci	Overall Total Ci	Total 568' Floor Ci	Total 542' Floor & Walls Ci	Overall Total Ci	Total 542' Floor Ci	Total Contam Wall 542' Ci	Overall Total Ci
Cm-244	8.00E-05	1.47E-07	8.02E-05	1.66E-06	3.2E-08	1.70E-06	2.63E-06	5.60E-07	3.19E-06
Total	7.21E+00	1.44E-02	7.22E+00	1.86E+00	1.95E-02	1.88E+00	7.94E-01	1.47E-01	9.41E-01
No MDA	7.17E+00	1.43E-02	7.19E+00	1.84E+00	1.90E-02	1.85E+00	7.86E-01	1.46E-01	9.32E-01

NR = Not Reported

The as left, post remediation source terms will be determined by post remediation surveys of the end state structures. Despite the fact that source terms are likely to be substantially lower than these initial estimates, it is unlikely that the radionuclide ratios or profiles will be changed as a result of remediation activities. The radionuclide ratios corresponding to the Table 5 estimated activities are provided in Table 6.

Table 6 – January 1, 2013 Radionuclide Percent of Total Estimated Source Term for Each Area

Nuclide	Unit 1 CTMT Concrete			Unit 2 CTMT Concrete			Aux Bldg		
	Total 568' Floor Percent	Total Incore 542' Floor & Walls Percent	Overall Total Percent	Total 568' Floor Percent	Total 542' Floor & Walls Percent	Overall Total Percent	Total 542' Floor Percent	Total Contam Wall 542' Percent	Overall Total Percent
H-3	0.10%	3.25%	0.11%	0.06%	1.13%	0.07%	0.23%	0.08%	0.21%
C-14	0.01%	0.04%	0.01%	0.00%	0.01%	0.00%	0.04%	0.06%	0.04%
Fe-55	0.07%	0.27%	0.07%	1.14%	0.70%	1.13%	0.41%	0.21%	0.38%
Ni-59	0.01%	0.51%	0.02%	0.24%	1.55%	0.25%	0.48%	0.23%	0.44%
Co-60	2.88%	8.22%	2.89%	13.70%	7.84%	13.64%	1.49%	2.58%	1.66%
Ni-63	2.04%	3.61%	2.05%	45.02%	12.94%	44.69%	21.70%	21.66%	21.69%
Sr-90	0.05%	0.01%	0.05%	0.00%	0.00%	0.00%	0.03%	0.16%	0.05%
Nb-94	0.01%	0.07%	0.01%	0.29%	0.05%	0.29%	0.01%	0.01%	0.01%
Tc-99	0.01%	0.01%	0.01%	0.00%	0.00%	0.00%	0.01%	0.01%	0.01%
Ag-108m	0.02%	0.07%	0.02%	0.46%	0.67%	0.46%	0.02%	0.01%	0.02%
Sb-125	0.10%	0.09%	0.10%	0.07%	0.03%	0.07%	0.06%	0.08%	0.06%
Cs-134	0.03%	0.41%	0.03%	0.06%	0.34%	0.06%	0.04%	0.14%	0.06%
Cs-137	94.30%	27.28%	94.17%	38.90%	4.40%	38.54%	75.38%	74.68%	75.27%
Eu-152	0.19%	51.89%	0.29%	0.02%	65.28%	0.70%	0.02%	0.03%	0.02%
Eu-154	0.10%	2.82%	0.10%	0.01%	3.72%	0.05%	0.01%	0.02%	0.01%
Eu-155	0.03%	1.36%	0.04%	0.02%	1.31%	0.03%	0.01%	0.02%	0.02%
Np-237	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Pu-238	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Pu-239	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Pu-240	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Pu-241	0.01%	0.07%	0.01%	0.00%	0.02%	0.00%	0.03%	0.03%	0.03%
Am-241	0.01%	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Am-243	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Cm-243	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

Nuclide	Unit 1 CTMT Concrete			Unit 2 CTMT Concrete			Aux Bldg		
	Total 568' Floor Percent	Total Incore 542' Floor & Walls Percent	Overall Total Percent	Total 568' Floor Percent	Total 542' Floor & Walls Percent	Overall Total Percent	Total 542' Floor Percent	Total Contam Wall 542' Percent	Overall Total Percent
Cm-244	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Total	100%	100%	100%	100%	100%	100%	100%	100%	100%

NR = Not Reported

The source terms in each area are dominated by Cs-137, Ni-63 and Co-60. Many radionuclides constitute less than 0.01% of the mix.

The earliest potential date at which license termination could be achieved is estimated at July 1, 2018. As seen in Table 7 this resulted in an 11% to 25% reduction in the overall concrete source term due to decay.

Table 7 - Estimated July 1, 2018 Unit 1 & 2 Reactor Building and Auxiliary Building Source Terms

Nuclide	Half-Life years	Unit 1 CTMT Concrete			Unit 2 CTMT Concrete			Aux Bldg		
		Total 568' Floor Ci	Total 542' Floor & Walls Ci	Overall Total Ci	Total 568' Floor Ci	Total 542' Floor & Walls Ci	Overall Total Ci	Total 542' Floor Ci	Total Contam Wall 542' Ci	Overall Total Ci
H-3	1.23E+01	5.25E-03	3.44E-04	5.60E-03	7.86E-04	1.6E-04	9.49E-04	1.37E-03	8.97E-05	1.46E-03
C-14	5.70E+03	7.45E-04	5.81E-06	7.51E-04	5.34E-05	2.3E-06	5.56E-05	2.88E-04	8.16E-05	3.69E-04
Fe-55	2.74E+00	1.21E-03	9.76E-06	1.22E-03	5.25E-03	3.4E-05	5.28E-03	8.07E-04	7.77E-05	8.85E-04
Ni-59	1.01E+05	1.03E-03	7.31E-05	1.11E-03	4.43E-03	3.0E-04	4.73E-03	3.83E-03	3.39E-04	4.17E-03
Co-60	5.27E+00	1.01E-01	5.76E-04	1.01E-01	1.24E-01	7.4E-04	1.25E-01	5.76E-03	1.84E-03	7.60E-03
Ni-63	1.00E+02	1.42E-01	5.02E-04	1.42E-01	8.07E-01	2.4E-03	8.09E-01	1.66E-01	3.07E-02	1.97E-01
Sr-90	2.88E+01	3.19E-03	1.08E-06	3.19E-03	6.15E-05	5.0E-07	6.20E-05	2.24E-04	2.02E-04	4.27E-04
Nb-94	2.03E+04	9.79E-04	1.06E-05	9.90E-04	5.47E-03	1.1E-05	5.48E-03	9.38E-05	1.27E-05	1.07E-04
Tc-99	2.11E+05	9.08E-04	2.16E-06	9.10E-04	1.04E-05	4.1E-07	1.09E-05	1.19E-04	1.53E-05	1.34E-04
Ag-108m	4.18E+02	1.76E-03	1.02E-05	1.77E-03	8.49E-03	1.3E-04	8.62E-03	1.33E-04	1.14E-05	1.44E-04
Sb-125	2.76E+00	1.87E-03	3.42E-06	1.87E-03	3.18E-04	1.7E-06	3.20E-04	1.17E-04	2.82E-05	1.46E-04
Cs-134	2.06E+00	3.16E-04	9.39E-06	3.25E-04	1.69E-04	1.0E-05	1.79E-04	5.38E-05	3.25E-05	8.63E-05
Cs-137	3.02E+01	5.99E+00	3.47E-03	5.99E+00	6.38E-01	7.6E-04	6.39E-01	5.28E-01	9.68E-02	6.25E-01
Eu-152	1.35E+01	1.04E-02	5.65E-03	1.61E-02	2.96E-04	9.6E-03	9.92E-03	1.11E-04	3.53E-05	1.46E-04
Eu-154	8.80E+00	4.49E-03	2.64E-04	4.75E-03	1.75E-04	4.7E-04	6.46E-04	6.13E-05	1.76E-05	7.89E-05
Eu-155	4.76E+00	1.09E-03	8.83E-05	1.18E-03	1.72E-04	1.1E-04	2.86E-04	5.28E-05	1.19E-05	6.48E-05
Np-237	2.14E+06	9.11E-06	1.32E-07	9.24E-06	5.42E-07	6.4E-08	6.07E-07	2.81E-06	8.43E-07	3.66E-06
Pu-238	8.77E+01	6.14E-05	2.25E-07	6.16E-05	8.89E-07	4.6E-08	9.35E-07	1.05E-05	3.51E-07	1.08E-05
Pu-239	2.41E+04	2.24E-05	1.04E-07	2.25E-05	4.71E-07	2.1E-08	4.92E-07	4.29E-06	1.78E-07	4.47E-06
Pu-240	6.56E+03	2.24E-05	1.04E-07	2.25E-05	4.71E-07	2.1E-08	4.92E-07	4.29E-06	1.78E-07	4.47E-06
Pu-241	1.44E+01	6.13E-04	7.89E-06	6.21E-04	5.28E-05	3.7E-06	5.65E-05	2.02E-04	3.43E-05	2.36E-04
Am-241	4.32E+02	7.87E-04	3.54E-07	7.87E-04	1.50E-05	5.5E-08	1.50E-05	9.78E-06	8.28E-07	1.06E-05
Am-243	7.37E+03	1.50E-05	1.68E-07	1.52E-05	1.53E-06	7.1E-08	1.60E-06	7.11E-06	8.38E-07	7.95E-06
Cm-243	2.85E+01	7.01E-05	1.30E-07	7.02E-05	1.46E-06	2.8E-08	1.48E-06	2.31E-06	4.92E-07	2.80E-06

Nuclide	Half-Life years	Unit 1 CTMT Concrete			Unit 2 CTMT Concrete			Aux Bldg		
		Total 568' Floor Ci	Total 542' Floor & Walls Ci	Overall Total Ci	Total 568' Floor Ci	Total 542' Floor & Walls Ci	Overall Total Ci	Total 542' Floor Ci	Total Contam Wall 542' Ci	Overall Total Ci
Cm-244	1.81E+01	6.48E-05	1.19E-07	6.49E-05	1.35E-06	2.6E-08	1.37E-06	2.13E-06	4.54E-07	2.58E-06
	Total	6.27E+00	1.10E-02	6.28E+00	1.59E+00	1.48E-02	1.61E+00	7.07E-01	1.30E-01	8.37E-01
	% Reduction	13%	24%	13%	14%	24%	14%	11%	11%	11%

NR = Not Reported

As seen in Table 8, the decay corrected end state source term continues to be comprised largely of Cs-137, Ni-63 and Co-60. If the Unit 1 and 2 Containment interior concrete is removed to the liner, only trace levels of contamination will remain. Consequently, the Auxiliary Building concrete will contain the bounding end state source term for the end state structures.

Table 8 – July 1, 2018 Radionuclide Percent of Total Estimated Source Term for Each Area

Nuclide	Unit 1 CTMT Concrete			Unit 2 CTMT Concrete			Aux Bldg		
	Total 568' Floor Percent	Total Incore 542' Floor & Walls Percent	Overall Total Percent	Total 568' Floor Percent	Total 542' Floor & Walls Percent	Overall Total Percent	Total 542' Floor Percent	Total Contam Wall 542' Percent	Overall Total Percent
H-3	0.084%	3.1%	0.089%	0.049%	1.098%	0.059%	0.194%	0.069%	0.174%
C-14	0.012%	0.053%	0.012%	0.003%	0.015%	0.003%	0.041%	0.063%	0.044%
Fe-55	0.019%	0.088%	0.019%	0.329%	0.228%	0.328%	0.114%	0.060%	0.106%
Ni-59	0.017%	0.662%	0.018%	0.278%	2.045%	0.294%	0.542%	0.260%	0.498%
Co-60	1.61%	5.22%	1.61%	7.76%	5.02%	7.74%	0.81%	1.41%	0.91%
Ni-63	2.26%	4.5%	2.27%	50.6%	16.44%	50.3%	23.47%	23.54%	23.48%
Sr-90	0.051%	0.010%	0.051%	0.004%	0.003%	0.004%	0.032%	0.155%	0.051%
Nb-94	0.016%	0.096%	0.0158%	0.343%	0.072%	0.341%	0.013%	0.010%	0.013%
Tc-99	0.014%	0.020%	0.014%	0.0007%	0.003%	0.0007%	0.017%	0.012%	0.016%
Ag-108m	0.028%	0.093%	0.028%	0.533%	0.878%	0.536%	0.019%	0.009%	0.017%
Sb-125	0.030%	0.031%	0.030%	0.020%	0.011%	0.020%	0.017%	0.022%	0.017%
Cs-134	0.005%	0.085%	0.005%	0.011%	0.070%	0.011%	0.008%	0.02%	0.010%
Cs-137	95.6%	31.5%	95.5%	40.0%	5.1%	39.7%	74.7%	74.3%	74.6%
Eu-152	0.166%	51.2%	0.256%	0.019%	65.01%	0.616%	0.016%	0.027%	0.017%
Eu-154	0.072%	2.4%	0.076%	0.011%	3.18%	0.040%	0.009%	0.013%	0.009%
Eu-155	0.017%	0.8%	0.019%	0.011%	0.774%	0.018%	0.007%	0.009%	0.008%
Np-237	0.000%	0.001%	0.000%	0.000%	0.000%	0.000%	0.000%	0.001%	0.000%
Pu-238	0.001%	0.002%	0.001%	0.0001%	0.000%	0.0001%	0.001%	0.000%	0.001%
Pu-239	0.000%	0.001%	0.000%	0.0000%	0.000%	0.0000%	0.001%	0.000%	0.001%
Pu-240	0.000%	0.001%	0.000%	0.0000%	0.000%	0.0000%	0.001%	0.000%	0.001%
Pu-241	0.010%	0.071%	0.010%	0.003%	0.025%	0.004%	0.029%	0.026%	0.028%
Am-241	0.013%	0.003%	0.013%	0.001%	0.000%	0.001%	0.001%	0.001%	0.001%
Am-243	0.000%	0.002%	0.000%	0.0001%	0.000%	0.000%	0.001%	0.001%	0.001%
Cm-243	0.001%	0.001%	0.001%	0.0001%	0.000%	0.0001%	0.000%	0.000%	0.000%

Nuclide	Unit 1 CTMT Concrete			Unit 2 CTMT Concrete			Aux Bldg		
	Total 568' Floor Percent	Total Incore 542' Floor & Walls Percent	Overall Total Percent	Total 568' Floor Percent	Total 542' Floor & Walls Percent	Overall Total Percent	Total 542' Floor Percent	Total Contam Wall 542' Percent	Overall Total Percent
Cm-244	0.001%	0.001%	0.001%	0.0001%	0.000%	0.0001%	0.000%	0.000%	0.000%
Total	100%	100%	100%	100%	100%	100%	100%	100%	100%

NR = Not Reported

The radionuclides Ag-110m and Eu-155 were added to the Table 1 list since they were positively identified in the characterization samples. The list of potential ROCs developed for dose significance evaluations is shown in Table 9.

Table 9 - Radionuclides of Concern Evaluated in Characterization Samples at the Zion Power Plant

Radionuclides	Radionuclides	Radionuclides	Radionuclides	Radionuclides	Radionuclides
H-3	Co-60	Tc-99	Cs-137	<i>Eu-155</i>	Pu-241
C-14	Ni-63	<i>Ag-108m</i>	Pm-147	Np-237	Am-241
Fe-55	Sr-90	Sb-125	Eu-152	Pu-238	Am-243
Ni-59	Nb-94	Cs-134	Eu-154	Pu-239/240	Cm-243/244

The Table 9 list of ROCs were used for fate and transport screening evaluations using DUST MS and RESRAD models.

2.3. Pathway Dose Factors

The fate and transport of the Table 9 ROCs in the Auxiliary Building end state was modeled by Brookhaven National Laboratories (BNL) using the DUST MS code. Although some of the radionuclides were not positively identified, they were retained in the list because they were previously identified in waste streams at ZSRP. The DUST MS results could be used to evaluate their dose significance if they are detected in end state FSSs or samples.

An evaluation for the Auxiliary Building was performed using the DUST MS model to determine the maximum concentration in the basement fill for the ROCs. (9) This evaluation used worst case distribution coefficients for potential basement fill materials. (10) The calculation assumed the future resident farmer well (11) was within each end state basement footprint. The inventory was based on a uniform contamination level of 1 pCi/m² on the wall and floor surfaces. This contamination level was used for modeling convenience only. The Auxiliary Building has 6503 m² of total wall and floor surface area below the 588 foot elevation, resulting in a total of 6503 pCi. This equates to a source term of 6.50E-09 Ci per nuclide used in the DUST-MS model. Other buildings were modeled similarly as described in TSD 14-031. (9)

The model assumed that the basement saturated zone groundwater concentration of each contaminant was initially zero everywhere. The contamination in the Auxiliary Basement is found at depth in the concrete, predominantly in the floor. Diffusion Controlled Release was therefore used to estimate the rate of radionuclide release for the Auxiliary Building basement and Spent Fuel Pool. (9) The results of the DUST MS evaluation (9) and the RESRAD results (12) were used to develop an initial suite of groundwater pathway dose factors (e.g., mrem/yr per mCi) in TSD 14-010 (12). These are provided in Table 10 for each of the Table 9 radionuclides and end state structures. There was a slight change to the Ni-63 Crib House DCF from the one used in revision 0 of this TSD based on a correction to TSD 14-031 that changed the value from 2.69E-04 to 3.44E-04. As noted in TSD 14-010, the Spent Fuel Pool and Transfer Canal floor are at 576' elevation,

leaving only 3 feet to the water table. The ground water pathway is therefore an implausible pathway and there are no groundwater pathway dose factors used for the Fuel Handling Building.

Table 10 – Groundwater Pathway Dose Factors for Initial Suite of Nuclides of Concern

Radionuclide	Aux mrem/year per mCi	Containment mrem/year per mCi	Not Valid Pathway Spent Fuel mrem/year per mCi	Turbine mrem/year per mCi	Crib House mrem/year per mCi	WWTF mrem/year per mCi
Ag-108m	5.47E-03	2.56E-02	7.46E-01	6.39E-03	5.46E-03	1.16E+00
Am-241	2.58E-01	1.15E+00	3.52E+01	2.86E-01	2.45E-01	5.22E+01
Am-243	2.63E-01	1.14E+00	3.59E+01	2.86E-01	2.45E-01	5.21E+01
C-14	6.49E-02	2.84E-01	8.92E+00	7.09E-02	6.08E-02	1.29E+01
Cm-243	2.59E-02	1.55E-01	3.54E+00	3.88E-02	3.33E-02	7.08E+00
Cm-244	1.74E-02	1.24E-01	2.37E+00	3.11E-02	2.67E-02	5.66E+00
Co-60	1.00E-04	1.14E-02	1.36E-02	2.87E-03	2.45E-03	5.21E-01
Cs-134	9.27E-03	1.98E-01	1.27E+00	4.94E-02	4.22E-02	9.03E+00
Cs-137	2.64E-02	1.57E-01	3.62E+00	3.92E-02	3.35E-02	7.17E+00
Eu-152	5.95E-05	3.87E-03	8.12E-03	9.68E-04	8.29E-04	1.76E-01
Eu-154	6.77E-05	5.62E-03	9.23E-03	1.41E-03	1.20E-03	2.56E-01
Eu-155	8.01E-06	8.72E-04	1.09E-03	2.18E-04	1.87E-04	3.98E-02
Fe-55	8.06E-07	1.51E-05	1.11E-04	3.77E-06	3.22E-06	6.85E-04
H-3	6.21E-03	2.72E-02	8.47E-01	6.80E-03	5.80E-03	1.23E+00
Nb-94	2.03E-03	8.84E-03	2.77E-01	2.21E-03	1.89E-03	4.04E-01
Ni-59	1.35E-04	5.87E-04	1.84E-02	1.47E-04	1.26E-04	2.67E-02
Ni-63	2.86E-04	1.61E-03	3.93E-02	4.01E-04	3.44E-04	7.31E-02
Np-237	4.92E+01	2.13E+02	6.70E+03	5.34E+01	4.57E+01	9.73E+03
Pm-147	3.00E-05	5.67E-04	4.10E-03	1.42E-04	1.22E-04	2.59E-02
Pu-238	2.11E-01	1.03E+00	2.87E+01	2.56E-01	2.19E-01	4.66E+01
Pu-239	2.61E-01	1.14E+00	3.56E+01	2.84E-01	2.43E-01	5.18E+01
Pu-240	2.61E-01	1.14E+00	3.56E+01	2.84E-01	2.43E-01	5.18E+01
Pu-241	4.57E-03	3.65E-02	6.25E-01	9.11E-03	7.80E-03	1.66E+00
Sb-125	1.04E-02	1.94E-01	1.42E+00	4.84E-02	4.13E-02	8.78E+00
Sr-90	3.29E-01	4.51E+00	4.50E+01	1.13E+00	9.66E-01	2.06E+02
Tc-99	1.48E-01	6.44E-01	2.02E+01	1.61E-01	1.38E-01	2.93E+01

TSD 14-021 (13) evaluated alternate exposure scenarios and found that the well drilling scenario has the potential to result in significant exposures. Dose factors were developed for drill spoils in TSD 14-021. (13) The drill spoils pathway dose factors are provided in Table 11. There were slight changes to the Ni-63 and Sr-90 drill spoils DCFs as a result of new 0.15 meter soil DCGLs from RESRAD runs made to address NRC requests for additional information. In addition, some very minor changes to the Europium DCGLs as explained above Table 21 resulted in minor changes to the DCFs in Table 11.

Table 11 - Drill Spoils Dose Factors

Nuclide	Aux Building Drill Spoils mrem/yr per mCi	CTMT Drill Spoils mrem per mCi	SFB Drill Spoils mrem/yr per mCi	Turbine Drill Spoils mrem/yr per mCi	Crib House Drill Spoils mrem/yr per mCi	WWTF Drill Spoils mrem/yr per mCi
Ag-108m	1.23E-02	2.05E-02	1.85E-01	6.61E-03	1.23E-02	1.57E-01
Am-241	1.51E-04	3.14E-04	3.06E-03	9.76E-05	1.49E-04	2.91E-03
Am-243	1.58E-03	2.73E-03	2.51E-02	8.75E-04	1.55E-03	2.16E-02
C-14	3.08E-07	4.27E-07	3.72E-06	1.42E-07	3.08E-07	3.11E-06
Cm-243	9.93E-04	1.70E-03	1.56E-02	5.47E-04	9.87E-04	1.34E-02
Cm-244	2.55E-05	6.63E-05	7.09E-04	1.97E-05	2.50E-05	7.21E-04
Co-60	1.07E-02	2.97E-02	1.58E-01	9.58E-03	1.78E-02	2.26E-01
Cs-134	6.29E-03	1.72E-02	9.41E-02	5.54E-03	1.02E-02	1.31E-01
Cs-137	3.22E-03	7.27E-03	4.83E-02	2.35E-03	4.34E-03	5.57E-02
Eu-152	5.02E-03	1.38E-02	7.46E-02	4.45E-03	8.24E-03	1.05E-01
Eu-154	5.57E-03	1.46E-02	8.25E-02	4.73E-03	8.77E-03	1.12E-01
Eu-155	2.83E-04	4.95E-04	4.55E-03	1.58E-04	2.77E-04	3.84E-03
Fe-55	2.97E-09	4.20E-09	3.71E-08	1.39E-09	2.97E-09	3.29E-08
H-3	0.00E+00	0.00E+00	1.45E-09	0.00E+00	0.00E+00	0.00E+00
Nb-94	1.20E-02	1.98E-02	1.79E-01	6.40E-03	1.19E-02	1.52E-01
Ni-59	1.51E-08	2.04E-08	1.77E-07	6.77E-09	1.50E-08	1.52E-07
Ni-63	3.23E-08	5.61E-08	3.78E-07	1.86E-08	4.14E-08	4.16E-07
Np-237	2.91E-03	4.04E-03	3.53E-02	1.34E-03	2.89E-03	3.01E-02
Pm-147	9.32E-08	1.68E-07	1.56E-06	5.35E-08	9.15E-08	1.35E-06
Pu-238	3.97E-05	1.04E-04	1.11E-03	3.08E-05	3.89E-05	1.13E-03
Pu-239	4.41E-05	1.15E-04	1.23E-03	3.40E-05	4.30E-05	1.25E-03
Pu-240	4.38E-05	1.14E-04	1.22E-03	3.38E-05	4.28E-05	1.24E-03
Pu-241	2.97E-06	6.03E-06	5.85E-05	1.88E-06	2.92E-06	5.56E-05
Sb-125	2.75E-03	4.52E-03	4.11E-02	1.46E-03	2.69E-03	3.45E-02
Sr-90	6.26E-05	1.39E-04	7.60E-04	4.61E-05	9.96E-05	1.04E-03
Tc-99	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

The combined dose factors that account for dose from both pathways are provided in Table 12. The revised Ni-63 and Sr-90 soil DCGLs resulted in minor changes to the Table 12 DCFs.

Table 12 - Combined Dose Factor for Groundwater and Drill Spoils

Radionuclide	Aux mrem/year per mCi	Containment mrem/year per mCi	Spent Fuel mrem/year per mCi	Turbine mrem/year per mCi	Crib House mrem/year per mCi	WWTF mrem/year per mCi
Ag-108m	1.78E-02	4.61E-02	1.85E-01	1.30E-02	1.77E-02	1.32E+00
Am-241	2.58E-01	1.15E+00	3.06E-03	2.86E-01	2.45E-01	5.22E+01
Am-243	2.64E-01	1.15E+00	2.51E-02	2.86E-01	2.46E-01	5.22E+01
C-14	6.49E-02	2.84E-01	3.72E-06	7.09E-02	6.08E-02	1.29E+01
Cm-243	2.69E-02	1.57E-01	1.56E-02	3.94E-02	3.43E-02	7.09E+00
Cm-244	1.74E-02	1.24E-01	7.09E-04	3.11E-02	2.67E-02	5.66E+00

Radionuclide	Aux mrem/year per mCi	Containment mrem/year per mCi	Spent Fuel mrem/year per mCi	Turbine mrem/year per mCi	Crib House mrem/year per mCi	WWTF mrem/year per mCi
Co-60	1.08E-02	4.11E-02	1.58E-01	1.25E-02	2.03E-02	7.48E-01
Cs-134	1.56E-02	2.15E-01	9.41E-02	5.49E-02	5.25E-02	9.16E+00
Cs-137	2.96E-02	1.64E-01	4.83E-02	4.16E-02	3.79E-02	7.22E+00
Eu-152	5.08E-03	1.76E-02	7.46E-02	5.41E-03	9.07E-03	2.81E-01
Eu-154	5.63E-03	2.03E-02	8.25E-02	6.13E-03	9.97E-03	3.68E-01
Eu-155	2.91E-04	1.37E-03	4.55E-03	3.77E-04	4.64E-04	4.36E-02
Fe-55	8.09E-07	1.51E-05	3.71E-08	3.78E-06	3.23E-06	6.85E-04
H-3	6.21E-03	2.72E-02	1.45E-09	6.80E-03	5.80E-03	1.23E+00
Nb-94	1.41E-02	2.86E-02	1.79E-01	8.61E-03	1.37E-02	5.55E-01
Ni-59	1.35E-04	5.87E-04	1.77E-07	1.47E-04	1.26E-04	2.67E-02
Ni-63	2.86E-04	1.61E-03	3.78E-07	4.01E-04	3.44E-04	7.31E-02
Np-237	4.92E+01	2.13E+02	3.53E-02	5.34E+01	4.57E+01	9.73E+03
Pm-147	3.01E-05	5.67E-04	1.56E-06	1.42E-04	1.22E-04	2.59E-02
Pu-238	2.11E-01	1.03E+00	1.11E-03	2.56E-01	2.19E-01	4.66E+01
Pu-239	2.61E-01	1.14E+00	1.23E-03	2.84E-01	2.43E-01	5.18E+01
Pu-240	2.61E-01	1.14E+00	1.22E-03	2.84E-01	2.43E-01	5.18E+01
Pu-241	4.58E-03	3.65E-02	5.85E-05	9.11E-03	7.80E-03	1.66E+00
Sb-125	1.32E-02	1.98E-01	4.11E-02	4.99E-02	4.40E-02	8.82E+00
Sr-90	3.29E-01	4.51E+00	7.60E-04	1.13E+00	9.67E-01	2.06E+02
Tc-99	1.48E-01	6.44E-01	0.00E+00	1.61E-01	1.38E-01	2.93E+01

3. CALCULATIONS

3.1. Normalized End State Basement Fill Source Terms

The January 1, 2013 Table 6 source term distributions and Table 8 July 1, 2018 source term distributions can be used to estimate the source term distribution of the basement fill water in pCi/L for positively detected radionuclides using the Table 10 DUST MS screening results. In this evaluation, each column is normalized to a 1 Ci source term as seen in Table 13 and Table 14. The overall source terms were also normalized to one Curie so the values do not equal the sum of the two columns.

Table 13 - January 1, 2013 End State Concrete Source Terms Normalized to One Curie

Nuclide	Unit 1 CTMT Concrete			Unit 2 CTMT Concrete			Aux Bldg		
	Total 568' Floor Ci	Total 542' Floor & Walls Ci	Overall Total Ci	Total 568' Floor Ci	Total 542' Floor & Walls Ci	Overall Total Ci	Total 542' Floor Ci	Total Contam Wall 542' Ci	Overall Total Ci
H-3	9.93E-04	3.25E-02	1.06E-03	5.75E-04	1.1E-02	6.87E-04	2.35E-03	8.32E-04	2.11E-03
C-14	1.03E-04	4.03E-04	1.04E-04	2.87E-05	1.2E-04	2.96E-05	3.62E-04	5.55E-04	3.92E-04
Fe-55	6.77E-04	2.72E-03	6.81E-04	1.14E-02	7.0E-03	1.13E-02	4.09E-03	2.13E-03	3.78E-03
Ni-59	1.44E-04	5.06E-03	1.53E-04	2.38E-03	1.5E-02	2.52E-03	4.82E-03	2.31E-03	4.43E-03
Co-60	2.88E-02	8.22E-02	2.89E-02	1.37E-01	7.8E-02	1.36E-01	1.49E-02	2.58E-02	1.66E-02

Nuclide	Unit 1 CTMT Concrete			Unit 2 CTMT Concrete			Aux Bldg		
	Total 568' Floor Ci	Total 542' Floor & Walls Ci	Overall Total Ci	Total 568' Floor Ci	Total 542' Floor & Walls Ci	Overall Total Ci	Total 542' Floor Ci	Total Contam Wall 542' Ci	Overall Total Ci
Ni-63	2.04E-02	3.61E-02	2.05E-02	4.50E-01	1.3E-01	4.47E-01	2.17E-01	2.17E-01	2.17E-01
Sr-90	5.05E-04	8.55E-05	5.05E-04	3.77E-05	2.9E-05	3.76E-05	3.22E-04	1.57E-03	5.17E-04
Nb-94	1.36E-04	7.32E-04	1.37E-04	2.94E-03	5.5E-04	2.91E-03	1.18E-04	8.66E-05	1.13E-04
Tc-99	1.26E-04	1.49E-04	1.26E-04	5.61E-06	2.1E-05	5.77E-06	1.49E-04	1.04E-04	1.42E-04
Ag-108m	2.46E-04	7.15E-04	2.47E-04	4.60E-03	6.7E-03	4.63E-03	1.69E-04	7.85E-05	1.55E-04
Sb-125	1.03E-03	9.42E-04	1.03E-03	6.81E-04	3.4E-04	6.78E-04	5.89E-04	7.62E-04	6.16E-04
Cs-134	2.78E-04	4.12E-03	2.85E-04	5.73E-04	3.4E-03	6.03E-04	4.29E-04	1.40E-03	5.81E-04
Cs-137	9.43E-01	2.73E-01	9.42E-01	3.89E-01	4.4E-02	3.85E-01	7.54E-01	7.47E-01	7.53E-01
Eu-152	1.91E-03	5.19E-01	2.95E-03	2.11E-04	6.5E-01	6.98E-03	1.85E-04	3.18E-04	2.06E-04
Eu-154	9.60E-04	2.82E-02	1.01E-03	1.45E-04	3.7E-02	5.30E-04	1.19E-04	1.84E-04	1.29E-04
Eu-155	3.36E-04	1.36E-02	3.63E-04	2.05E-04	1.3E-02	3.39E-04	1.48E-04	1.81E-04	1.53E-04
Np-237	1.26E-06	9.16E-06	1.28E-06	2.91E-07	3.3E-06	3.22E-07	3.54E-06	5.73E-06	3.88E-06
Pu-238	8.89E-06	1.63E-05	8.91E-06	4.99E-07	2.4E-06	5.19E-07	1.37E-05	2.49E-06	1.20E-05
Pu-239	3.11E-06	7.24E-06	3.12E-06	2.53E-07	1.1E-06	2.62E-07	5.40E-06	1.21E-06	4.75E-06
Pu-240	3.11E-06	7.24E-06	3.12E-06	2.53E-07	1.1E-06	2.62E-07	5.40E-06	1.21E-06	4.75E-06
Pu-241	1.11E-04	7.12E-04	1.12E-04	3.70E-05	2.5E-04	3.92E-05	3.31E-04	3.04E-04	3.27E-04
Am-241	1.10E-04	2.47E-05	1.10E-04	8.12E-06	2.8E-06	8.06E-06	1.24E-05	5.68E-06	1.14E-05
Am-243	2.09E-06	1.16E-05	2.11E-06	8.20E-07	3.6E-06	8.49E-07	8.96E-06	5.70E-06	8.45E-06
Cm-243	1.11E-05	1.03E-05	1.11E-05	8.94E-07	1.6E-06	9.02E-07	3.32E-06	3.82E-06	3.40E-06
Cm-244	1.11E-05	1.02E-05	1.11E-05	8.94E-07	1.6E-06	9.02E-07	3.31E-06	3.81E-06	3.39E-06
Total	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00

NR = Not Reported

Table 14- July 1, 2018 Concrete Source Terms Normalized to One Curie

Nuclide	Unit 1 CTMT Concrete			Unit 2 CTMT Concrete			Aux Bldg		
	Total 568' Floor Ci	Total 542' Floor & Walls Ci	Overall Total Ci	Total 568' Floor Ci	Total 542' Floor & Walls Ci	Overall Total Ci	Total 542' Floor Ci	Total Contam Wall 542' Ci	Overall Total Ci
H-3	8.38E-04	3.12E-02	8.91E-04	4.93E-04	1.1E-02	5.90E-04	1.94E-03	6.89E-04	1.74E-03
C-14	1.19E-04	5.27E-04	1.20E-04	3.35E-05	1.5E-04	3.46E-05	4.07E-04	6.26E-04	4.41E-04
Fe-55	1.93E-04	8.84E-04	1.95E-04	3.29E-03	2.3E-03	3.28E-03	1.14E-03	5.97E-04	1.06E-03
Ni-59	1.65E-04	6.62E-03	1.76E-04	2.78E-03	2.0E-02	2.94E-03	5.42E-03	2.60E-03	4.98E-03
Co-60	1.61E-02	5.22E-02	1.61E-02	7.76E-02	5.0E-02	7.74E-02	8.15E-03	1.41E-02	9.08E-03
Ni-63	2.26E-02	4.55E-02	2.27E-02	5.06E-01	1.6E-01	5.03E-01	2.35E-01	2.35E-01	2.35E-01
Sr-90	5.09E-04	9.80E-05	5.08E-04	3.86E-05	3.4E-05	3.85E-05	3.17E-04	1.55E-03	5.10E-04
Nb-94	1.56E-04	9.58E-04	1.58E-04	3.43E-03	7.2E-04	3.41E-03	1.33E-04	9.78E-05	1.27E-04
Tc-99	1.45E-04	1.95E-04	1.45E-04	6.55E-06	2.8E-05	6.74E-06	1.68E-04	1.18E-04	1.60E-04
Ag-108m	2.81E-04	9.28E-04	2.82E-04	5.33E-03	8.8E-03	5.36E-03	1.88E-04	8.78E-05	1.72E-04
Sb-125	2.98E-04	3.10E-04	2.98E-04	2.00E-04	1.1E-04	1.99E-04	1.66E-04	2.16E-04	1.74E-04

Nuclide	Unit 1 CTMT Concrete			Unit 2 CTMT Concrete			Aux Bldg		
	Total 568' Floor Ci	Total 542' Floor & Walls Ci	Overall Total Ci	Total 568' Floor Ci	Total 542' Floor & Walls Ci	Overall Total Ci	Total 542' Floor Ci	Total Contam Wall 542' Ci	Overall Total Ci
Cs-134	5.04E-05	8.51E-04	5.18E-05	1.06E-04	7.0E-04	1.11E-04	7.62E-05	2.49E-04	1.03E-04
Cs-137	9.56E-01	3.15E-01	9.55E-01	4.00E-01	5.1E-02	3.97E-01	7.47E-01	7.43E-01	7.46E-01
Eu-152	1.66E-03	5.12E-01	2.56E-03	1.86E-04	6.5E-01	6.16E-03	1.57E-04	2.71E-04	1.75E-04
Eu-154	7.16E-04	2.39E-02	7.57E-04	1.10E-04	3.2E-02	4.01E-04	8.68E-05	1.35E-04	9.43E-05
Eu-155	1.74E-04	8.01E-03	1.87E-04	1.08E-04	7.7E-03	1.78E-04	7.47E-05	9.16E-05	7.74E-05
Np-237	1.45E-06	1.20E-05	1.47E-06	3.40E-07	4.4E-06	3.77E-07	3.98E-06	6.47E-06	4.37E-06
Pu-238	9.79E-06	2.04E-05	9.81E-06	5.58E-07	3.1E-06	5.81E-07	1.48E-05	2.69E-06	1.29E-05
Pu-239	3.58E-06	9.47E-06	3.59E-06	2.96E-07	1.4E-06	3.06E-07	6.07E-06	1.37E-06	5.34E-06
Pu-240	3.58E-06	9.47E-06	3.59E-06	2.95E-07	1.4E-06	3.06E-07	6.06E-06	1.37E-06	5.33E-06
Pu-241	9.78E-05	7.15E-04	9.89E-05	3.31E-05	2.5E-04	3.51E-05	2.86E-04	2.63E-04	2.82E-04
Am-241	1.26E-04	3.21E-05	1.25E-04	9.39E-06	3.7E-06	9.34E-06	1.38E-05	6.35E-06	1.27E-05
Am-243	2.40E-06	1.52E-05	2.42E-06	9.57E-07	4.8E-06	9.92E-07	1.01E-05	6.43E-06	9.50E-06
Cm-243	1.12E-05	1.17E-05	1.12E-05	9.13E-07	1.9E-06	9.22E-07	3.27E-06	3.78E-06	3.35E-06
Cm-244	1.03E-05	1.08E-05	1.03E-05	8.46E-07	1.7E-06	8.54E-07	3.01E-06	3.48E-06	3.09E-06
Total	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

NR = Not Reported

These source terms are much higher than the probable end state source terms, due to the fact that the concrete in the Containments will be removed to the liner and the concrete surfaces in the Auxiliary Building basement will be remediated to accommodate open air demolition. However, they allow the predicted worst case groundwater concentrations and resulting maximum doses to be evaluated for the variations in the mixes on a uniform basis.

3.2. Basement Fill Doses for Normalized Source Terms

The Table 12 dose factors can be used to estimate the relative dose contribution of the nuclides in the normalized source terms by multiplying the dose factors times the source term in Table 13. The dose calculation results for the Containment Buildings and Auxiliary Building are provided in Table 15 and Table 16. The results show that in both the January 1, 2013 and July 1, 2018, the normalized source terms for Co-60, Ni-63, Sr-90, Cs-134 and Cs-137 account for greater than 99.5% of the dose. Therefore, the insignificant dose consequences from eliminating the other nuclides is less than 0.5% as seen in the last row of each table.

It should also be noted that since the source term is approximately fifty feet below grade (e.g., grade is the 592' elevation and the Auxiliary Building basement floor is at the 542' elevation) there is no inhalation or direct radiation component with corresponding minor doses consequences. The total dose for each building ranges from ten to hundreds of millirem a year for a Curie of source term which greatly exceeds the estimated source terms (5) (6) and any potential remaining post remediation source term.

There is a slight change to the Auxiliary Building missed dose totals due to the DCF changes described above and use of updated half-lives in Version 3 of NRC Radiological Toolbox. (14) These changes were very minor resulting a change in the missed dose in the Aux Building changing from 2.88E-01 to 3.00E-01 and the percent of missed dose changing from 1.266% to 1.320%. The rest of the values were unchanged.

As seen in Table 15 and Table 16, the activated concrete in the Unit 1 and 2 542' elevation Incore Areas have the highest dose contributions from radionuclides other than the yellow and purple highlighted radionuclides. Excluding the theoretical dose from Np-237, which was not detected above the MDA in any samples, lowers the potential missed dose to less than 3% for all radionuclide mixes.

Table 17 shows each radionuclide percent contribution to the total dose of each radionuclide mix for the July 1, 2018 decayed data. Radionuclides that contribute greater than 0.5% of the dose within a mix are highlighted in yellow cells.

Table 17 shows that only a few radionuclides contribute greater than a half of one percent (i.e. 0.5%) to the total dose. It also shows that the percentage of dose contributed by transuranics (e.g., Np-237) in the Containment source terms is consistently higher in the activated Incore areas than in the 568 foot elevation concrete. This is because the overall source term and concentration levels in the Incore areas are much lower and therefore the MDAs of the transuranics contribute a higher percentage of the overall dose. The overall mix source terms are therefore more representative of the transuranic ratios that will be present in the final mix and the

composite of the Unit 1 and Unit 2 Overall normalized mix should be used for the Containment source term. This results in an insignificant dose fraction that is conservative compared to the 568' and overall total insignificant doses in Table 16, but is not disproportionately biased by the transuranic MDAs as is the case for the Incore Area 542 foot elevation activated source terms.

Table 15 - January 1, 2013 Calculated Dose for Normalized 1 Ci Source Term

Nuclide	Unit 1 CTMT Concrete			Unit 2 CTMT Concrete			Aux Bldg		
	Total 568' Floor mrem/yr	Total 542' Floor & Walls mrem/yr	Overall Total mrem/yr	Total 568' Floor mrem/yr	Total 542' Floor & Walls mrem/yr	Overall Total mrem/yr	Total 542' Floor mrem/yr	Total Contam Wall 542' mrem/yr	Overall Total mrem/yr
H-3	2.70E-02	8.83E-01	2.87E-02	1.56E-02	3.1E-01	1.87E-02	1.46E-02	5.16E-03	1.31E-02
C-14	2.94E-02	1.14E-01	2.95E-02	8.14E-03	3.3E-02	8.40E-03	2.35E-02	3.60E-02	2.55E-02
Fe-55	1.02E-05	4.10E-05	1.03E-05	1.71E-04	1.0E-04	1.70E-04	3.31E-06	1.72E-06	3.06E-06
Ni-59	8.42E-05	2.97E-03	9.00E-05	1.40E-03	9.1E-03	1.48E-03	6.50E-04	3.11E-04	5.97E-04
Co-60	1.18E+00	3.38E+00	1.19E+00	5.63E+00	3.2E+00	5.61E+00	1.62E-01	2.79E-01	1.80E-01
Ni-63	3.28E-02	5.80E-02	3.29E-02	7.23E-01	2.1E-01	7.18E-01	6.20E-02	6.19E-02	6.20E-02
Sr-90	2.28E+00	3.86E-01	2.28E+00	1.70E-01	1.3E-01	1.70E-01	1.06E-01	5.17E-01	1.70E-01
Nb-94	3.89E-03	2.10E-02	3.93E-03	8.42E-02	1.6E-02	8.35E-02	1.66E-03	1.22E-03	1.59E-03
Tc-99	8.11E-02	9.62E-02	8.12E-02	3.61E-03	1.4E-02	3.71E-03	2.21E-02	1.54E-02	2.10E-02
Ag-108m	1.14E-02	3.30E-02	1.14E-02	2.12E-01	3.1E-01	2.13E-01	3.00E-03	1.40E-03	2.75E-03
Sb-125	2.04E-01	1.87E-01	2.04E-01	1.35E-01	6.7E-02	1.34E-01	7.76E-03	1.00E-02	8.11E-03
Cs-134	5.96E-02	8.84E-01	6.12E-02	1.23E-01	7.3E-01	1.29E-01	6.68E-03	2.18E-02	9.04E-03
Cs-137	1.55E+02	4.48E+01	1.55E+02	6.38E+01	7.2E+00	6.32E+01	2.23E+01	2.21E+01	2.23E+01
Eu-152	3.37E-02	9.15E+00	5.20E-02	3.72E-03	1.2E+01	1.23E-01	9.40E-04	1.62E-03	1.05E-03
Eu-154	1.95E-02	5.71E-01	2.06E-02	2.94E-03	7.5E-01	1.07E-02	6.71E-04	1.04E-03	7.28E-04
Eu-155	4.60E-04	1.86E-02	4.96E-04	2.81E-04	1.8E-02	4.63E-04	4.31E-05	5.25E-05	4.45E-05
Np-237	2.70E-01	1.95E+00	2.73E-01	6.21E-02	7.0E-01	6.87E-02	1.74E-01	2.82E-01	1.91E-01
Pu-238	9.12E-03	1.67E-02	9.14E-03	5.12E-04	2.5E-03	5.33E-04	2.90E-03	5.25E-04	2.53E-03
Pu-239	3.55E-03	8.25E-03	3.56E-03	2.88E-04	1.2E-03	2.98E-04	1.41E-03	3.16E-04	1.24E-03
Pu-240	3.55E-03	8.25E-03	3.56E-03	2.88E-04	1.2E-03	2.98E-04	1.41E-03	3.16E-04	1.24E-03
Pu-241	4.05E-03	2.60E-02	4.10E-03	1.35E-03	9.1E-03	1.43E-03	1.52E-03	1.39E-03	1.50E-03
Am-241	1.26E-01	2.84E-02	1.26E-01	9.31E-03	3.2E-03	9.25E-03	3.20E-03	1.46E-03	2.93E-03
Am-243	2.40E-03	1.33E-02	2.42E-03	9.41E-04	4.2E-03	9.74E-04	2.37E-03	1.51E-03	2.23E-03
Cm-243	1.74E-03	1.61E-03	1.74E-03	1.40E-04	2.5E-04	1.42E-04	8.95E-05	1.03E-04	9.16E-05

Nuclide	Unit 1 CTMT Concrete			Unit 2 CTMT Concrete			Aux Bldg		
	Total 568' Floor mrem/yr	Total 542' Floor & Walls mrem/yr	Overall Total mrem/yr	Total 568' Floor mrem/yr	Total 542' Floor & Walls mrem/yr	Overall Total mrem/yr	Total 542' Floor mrem/yr	Total Contam Wall 542' mrem/yr	Overall Total mrem/yr
Cm-244	1.38E-03	1.27E-03	1.38E-03	1.11E-04	2.0E-04	1.12E-04	5.77E-05	6.64E-05	5.90E-05
Total	1.59E+02	6.26E+01	1.59E+02	7.10E+01	2.53E+01	7.05E+01	2.29E+01	2.33E+01	2.30E+01
Missed Dose	7.52E-01	2.53E+00	7.56E-01	5.20E-01	1.19E+00	5.27E-01	2.62E-01	3.60E-01	2.77E-01
% Missed	0.473%	4.039%	0.476%	0.733%	4.715%	0.747%	1.143%	1.542%	1.207%
No Np-237	0.304%	0.951%	0.305%	0.646%	1.989%	0.651%	0.386%	0.338%	0.379%

= Included in ROCs when Activated Concrete is Present

Bold Italic = MDA

= Basement Fill ROCs

Table 16 - July 1, 2018 Calculated Dose for Normalized 1 Ci Source Term

Nuclide	Unit 1 CTMT Concrete			Unit 2 CTMT Concrete			Aux Bldg		
	Total 568' Floor mrem/yr	Total 542' Floor & Walls mrem/yr	Overall Total mrem/yr	Total 568' Floor mrem/yr	Total 542' Floor & Walls mrem/yr	Overall Total mrem/yr	Total 542' Floor mrem/yr	Total Contam Wall 542' mrem/yr	Overall Total mrem/yr
H-3	2.28E-02	8.48E-01	2.42E-02	1.34E-02	3.0E-01	1.60E-02	1.20E-02	4.27E-03	1.08E-02
C-14	3.37E-02	1.49E-01	3.40E-02	9.50E-03	4.4E-02	9.81E-03	2.64E-02	4.06E-02	2.86E-02
Fe-55	2.91E-06	1.33E-05	2.93E-06	4.96E-05	3.4E-05	4.94E-05	9.24E-07	4.83E-07	8.56E-07
Ni-59	9.68E-05	3.89E-03	1.04E-04	1.63E-03	1.2E-02	1.73E-03	7.30E-04	3.51E-04	6.71E-04
Co-60	6.61E-01	2.15E+00	6.63E-01	3.19E+00	2.1E+00	3.18E+00	8.82E-02	1.53E-01	9.82E-02
Ni-63	3.64E-02	7.30E-02	3.64E-02	8.13E-01	2.6E-01	8.08E-01	6.71E-02	6.73E-02	6.71E-02
Sr-90	2.30E+00	4.42E-01	2.29E+00	1.74E-01	1.5E-01	1.74E-01	1.05E-01	5.11E-01	1.68E-01
Nb-94	4.47E-03	2.74E-02	4.51E-03	9.83E-02	2.1E-02	9.76E-02	1.87E-03	1.38E-03	1.79E-03
Tc-99	9.33E-02	1.26E-01	9.34E-02	4.22E-03	1.8E-02	4.34E-03	2.48E-02	1.74E-02	2.37E-02
Ag-108m	1.30E-02	4.28E-02	1.30E-02	2.46E-01	4.1E-01	2.47E-01	3.34E-03	1.56E-03	3.07E-03
Sb-125	5.91E-02	6.14E-02	5.91E-02	3.96E-02	2.2E-02	3.94E-02	2.19E-03	2.85E-03	2.29E-03
Cs-134	1.08E-02	1.83E-01	1.11E-02	2.27E-02	1.5E-01	2.39E-02	1.18E-03	3.88E-03	1.60E-03
Cs-137	1.57E+02	5.16E+01	1.57E+02	6.57E+01	8.4E+00	6.51E+01	2.21E+01	2.20E+01	2.21E+01

Nuclide	Unit 1 CTMT Concrete			Unit 2 CTMT Concrete			Aux Bldg		
	Total 568' Floor mrem/yr	Total 542' Floor & Walls mrem/yr	Overall Total mrem/yr	Total 568' Floor mrem/yr	Total 542' Floor & Walls mrem/yr	Overall Total mrem/yr	Total 542' Floor mrem/yr	Total Contam Wall 542' mrem/yr	Overall Total mrem/yr
Eu-152	<i>2.93E-02</i>	9.04E+00	4.51E-02	3.27E-03	1.1E+01	1.09E-01	<i>7.97E-04</i>	<i>1.38E-03</i>	<i>8.88E-04</i>
Eu-154	<i>1.45E-02</i>	4.84E-01	1.53E-02	2.23E-03	6.4E-01	8.13E-03	<i>4.89E-04</i>	<i>7.60E-04</i>	<i>5.31E-04</i>
Eu-155	2.38E-04	1.09E-02	2.56E-04	<i>1.47E-04</i>	1.1E-02	2.43E-04	<i>2.17E-05</i>	<i>2.66E-05</i>	<i>2.25E-05</i>
Np-237	<i>3.10E-01</i>	<i>2.55E+00</i>	3.14E-01	<i>7.25E-02</i>	<i>9.3E-01</i>	8.04E-02	<i>1.96E-01</i>	<i>3.18E-01</i>	<i>2.15E-01</i>
Pu-238	1.00E-02	2.09E-02	1.01E-02	5.72E-04	<i>3.2E-03</i>	5.96E-04	<i>3.12E-03</i>	<i>5.67E-04</i>	<i>2.72E-03</i>
Pu-239	4.08E-03	1.08E-02	4.09E-03	3.37E-04	<i>1.6E-03</i>	3.48E-04	<i>1.58E-03</i>	<i>3.57E-04</i>	<i>1.39E-03</i>
Pu-240	4.08E-03	1.08E-02	4.09E-03	3.37E-04	<i>1.6E-03</i>	3.48E-04	<i>1.58E-03</i>	<i>3.56E-04</i>	<i>1.39E-03</i>
Pu-241	3.57E-03	<i>2.61E-02</i>	3.61E-03	<i>1.21E-03</i>	<i>9.2E-03</i>	1.28E-03	<i>1.31E-03</i>	<i>1.21E-03</i>	<i>1.29E-03</i>
Am-241	1.44E-01	3.68E-02	1.44E-01	1.08E-02	<i>4.3E-03</i>	1.07E-02	<i>3.57E-03</i>	<i>1.64E-03</i>	<i>3.27E-03</i>
Am-243	2.75E-03	<i>1.75E-02</i>	2.78E-03	1.10E-03	<i>5.5E-03</i>	1.14E-03	2.66E-03	1.70E-03	2.51E-03
Cm-243	1.75E-03	1.84E-03	1.76E-03	1.43E-04	<i>2.9E-04</i>	1.45E-04	<i>8.80E-05</i>	<i>1.02E-04</i>	<i>9.01E-05</i>
Cm-244	1.29E-03	1.34E-03	1.29E-03	1.05E-04	<i>2.2E-04</i>	1.06E-04	<i>5.25E-05</i>	<i>6.07E-05</i>	<i>5.38E-05</i>
Total	1.61E+02	6.79E+01	1.60E+02	7.04E+01	2.49E+01	7.00E+01	2.26E+01	2.31E+01	2.27E+01
Missed Dose	6.85E-01	3.10E+00	6.90E-01	4.86E-01	1.49E+00	4.95E-01	2.82E-01	3.95E-01	3.00E-01
% Missed	0.427%	4.566%	0.430%	0.691%	5.963%	0.708%	1.247%	1.708%	1.320%
No Np-237	0.234%	0.838%	0.235%	0.588%	2.327%	0.594%	0.386%	0.336%	0.378%

= Included in ROCs when Activated Concrete is Present

Bold Italic = MDA

= Basement Fill ROCs

Table 17 – Basement July1, 2018 Mix Individual Nuclide Percent of Total Dose

Nuclide	Unit 1 CTMT Concrete			Unit 2 CTMT Concrete			Aux Bldg		
	Total 568' Floor Percent	Total Incore 542' Floor & Walls Percent	Overall Total Percent	Total 568' Floor Percent	Total 542' Floor & Walls Percent	Overall Total Percent	Total 542' Floor Percent	Total Contam Wall 542' Percent	Overall Total Percent
H-3	0.014%	1.248%	0.015%	0.019%	1.198%	0.023%	0.053%	0.018%	0.048%
C-14	0.021%	0.220%	0.021%	0.013%	0.175%	0.014%	0.117%	0.176%	0.126%
Fe-55	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Ni-59	0.000%	0.006%	0.000%	0.002%	0.048%	0.002%	0.003%	0.002%	0.003%
Co-60	0.411%	3.158%	0.413%	4.534%	8.282%	4.547%	0.389%	0.661%	0.432%
Ni-63	0.023%	0.107%	0.023%	1.155%	1.060%	1.155%	0.296%	0.291%	0.296%
Sr-90	1.431%	0.651%	1.431%	0.247%	0.612%	0.249%	0.462%	2.212%	0.739%
Nb-94	0.003%	0.040%	0.003%	0.140%	0.083%	0.139%	0.008%	0.006%	0.008%
Tc-99	0.058%	0.185%	0.058%	0.006%	0.072%	0.006%	0.110%	0.075%	0.104%
Ag-108m	0.008%	0.063%	0.008%	0.349%	1.626%	0.353%	0.015%	0.007%	0.014%
Sb-125	0.037%	0.090%	0.037%	0.056%	0.090%	0.056%	0.010%	0.012%	0.010%
Cs-134	0.007%	0.269%	0.007%	0.032%	0.607%	0.034%	0.005%	0.017%	0.007%
Cs-137	97.660%	75.987%	97.644%	93.313%	33.675%	93.118%	97.600%	95.112%	97.206%
Eu-152	0.018%	13.301%	0.028%	0.005%	46.017%	0.155%	0.004%	0.006%	0.004%
Eu-154	0.009%	0.713%	0.010%	0.003%	2.586%	0.012%	0.002%	0.003%	0.002%
Eu-155	0.000%	0.016%	0.000%	0.000%	0.042%	0.000%	0.000%	0.000%	0.000%
Np-237	0.193%	3.759%	0.196%	0.103%	3.723%	0.115%	0.864%	1.377%	0.945%
Pu-238	0.006%	0.031%	0.006%	0.001%	0.013%	0.001%	0.014%	0.002%	0.012%
Pu-239	0.003%	0.016%	0.003%	0.000%	0.006%	0.000%	0.007%	0.002%	0.006%
Pu-240	0.003%	0.016%	0.003%	0.000%	0.006%	0.000%	0.007%	0.002%	0.006%
Pu-241	0.002%	0.038%	0.002%	0.002%	0.037%	0.002%	0.006%	0.005%	0.006%
Am-241	0.090%	0.054%	0.090%	0.015%	0.017%	0.015%	0.016%	0.007%	0.014%
Am-243	0.002%	0.026%	0.002%	0.002%	0.022%	0.002%	0.012%	0.007%	0.011%
Cm-243	0.001%	0.003%	0.001%	0.000%	0.001%	0.000%	0.000%	0.000%	0.000%
Cm-244	0.001%	0.002%	0.001%	0.000%	0.001%	0.000%	0.000%	0.000%	0.000%
Total	100%	100%	100%	100%	100%	100%	100%	100%	100%

= Greater than 0.5% dose contribution

Table 18 – July 1, 2018 Unit 1 and Unit 2 Containment Normalized Composite Mixes

Nuclide	Composite 568' Ci	Composite Incore Ci	Overall Composite Ci	Overall Composite mrem/yr	Overall Composite % Dose
H-3	6.65E-04	2.11E-02	7.40E-04	2.01E-05	0.017%
C-14	7.62E-05	3.40E-04	7.71E-05	2.19E-05	0.019%
Fe-55	1.74E-03	1.58E-03	1.74E-03	2.62E-08	0.000%
Ni-59	1.47E-03	1.35E-02	1.56E-03	9.15E-07	0.001%
Co-60	4.68E-02	5.12E-02	4.68E-02	1.92E-03	1.669%
Ni-63	2.64E-01	1.05E-01	2.63E-01	4.22E-04	0.366%
Sr-90	2.74E-04	6.59E-05	2.73E-04	1.23E-03	1.072%
Nb-94	1.79E-03	8.41E-04	1.78E-03	5.10E-05	0.044%
Tc-99	7.57E-05	1.12E-04	7.59E-05	4.89E-05	0.042%
Ag-108m	2.80E-03	4.86E-03	2.82E-03	1.30E-04	0.113%
Sb-125	2.49E-04	2.11E-04	2.48E-04	4.92E-05	0.043%
Cs-134	7.80E-05	7.78E-04	8.15E-05	1.75E-05	0.015%
Cs-137	6.78E-01	1.83E-01	6.76E-01	1.11E-01	96.269%
Eu-152	9.23E-04	5.81E-01	4.36E-03	7.69E-05	0.067%
Eu-154	4.13E-04	2.79E-02	5.79E-04	1.17E-05	0.0102%
Eu-155	1.41E-04	7.87E-03	1.83E-04	2.50E-07	0.000%
Np-237	8.97E-07	8.17E-06	9.25E-07	1.97E-04	0.171%
Pu-238	5.17E-06	1.17E-05	5.19E-06	5.33E-06	0.005%
Pu-239	1.94E-06	5.44E-06	1.95E-06	2.22E-06	0.002%
Pu-240	1.94E-06	5.43E-06	1.95E-06	2.22E-06	0.002%
Pu-241	6.55E-05	4.83E-04	6.70E-05	2.45E-06	0.002%
Am-241	6.75E-05	1.79E-05	6.73E-05	7.73E-05	0.067%
Am-243	1.68E-06	1.00E-05	1.71E-06	1.96E-06	0.002%
Cm-243	6.05E-06	6.80E-06	6.05E-06	9.50E-07	0.001%
Cm-244	5.59E-06	6.27E-06	5.60E-06	6.96E-07	0.001%
Total	1.00E+00	1.00E+00	1.00E+00	1.15E-01	100.000%
	=ROCs All Basements			Missed Dose	5.93E-04
	=Additional ROCs for Containments			% Missed	0.514%
				No Np-237	0.344%

3.3. End State Basement Fill Radionuclide Mixes

Based upon the above analysis, the radionuclides of concern for the Containment basement fill end state mix are H-3, Co-60, Ni-63, Sr-90, Cs-134, Cs-137, Eu-152, Eu-154. The radionuclides of concern for the Auxiliary Building are Co-60, Ni-63, Sr-90, Cs-134, and Cs-137. Since the source terms in the Turbine Building, Crib House, Waste Water Treatment Facility, etc. will be too low to obtain good radionuclide mix data, the Auxiliary Building mix should be used for all other basement fill end state buildings, except the Spent Fuel Building. The Transfer Canal and Spent

Fuel Pool mixes will require characterization when access becomes available. The July 1, 2018 Containment and Auxiliary Building radionuclide mixtures are provided in Table 19.

Table 19 - Basement Fill End State July 1, 2018 Radionuclide Mixes for FSS

Nuclide	CTMT			AUX		
	Activity Ci	Percent Activity	Percent Annual Dose	Activity Ci	Percent Activity	Percent Annual Dose
H-3	7.40E-04	0.074%	0.017%	1.74E-03	0.174%	0.048%
C-14	7.71E-05	0.008%	0.019%	4.41E-04	0.044%	0.126%
Fe-55	1.74E-03	0.174%	0.000%	1.06E-03	0.106%	0.000%
Ni-59	1.56E-03	0.156%	0.001%	4.98E-03	0.498%	0.003%
Co-60	4.68E-02	4.675%	1.669%	9.08E-03	0.908%	0.432%
Ni-63	2.63E-01	26.275%	0.366%	2.35E-01	23.480%	0.296%
Sr-90	2.73E-04	0.027%	1.072%	5.10E-04	0.051%	0.739%
Nb-94	1.78E-03	0.178%	0.044%	1.27E-04	0.013%	0.008%
Tc-99	7.59E-05	0.008%	0.042%	1.60E-04	0.016%	0.104%
Ag-108m	2.82E-03	0.282%	0.113%	1.72E-04	0.017%	0.014%
Sb-125	2.48E-04	0.025%	0.043%	1.74E-04	0.017%	0.010%
Cs-134	8.15E-05	0.008%	0.015%	1.03E-04	0.010%	0.007%
Cs-137	6.76E-01	67.582%	96.269%	7.46E-01	74.597%	97.206%
Eu-152	4.36E-03	0.436%	0.067%	1.75E-04	0.017%	0.0039%
Eu-154	5.79E-04	0.058%	0.010%	9.43E-05	0.009%	0.0023%
Eu-155	1.83E-04	0.018%	0.000%	7.74E-05	0.008%	0.0001%
Np-237	9.25E-07	0.000%	0.171%	4.37E-06	0.0004%	0.9453%
Pu-238	5.19E-06	0.001%	0.005%	1.29E-05	0.001%	0.0120%
Pu-239	1.95E-06	0.000%	0.002%	5.34E-06	0.0005%	0.0061%
Pu-240	1.95E-06	0.000%	0.002%	5.33E-06	0.001%	0.0061%
Pu-241	6.70E-05	0.007%	0.002%	2.82E-04	0.028%	0.0057%
Am-241	6.73E-05	0.007%	0.067%	1.27E-05	0.001%	0.0144%
Am-243	1.71E-06	0.000%	0.002%	9.50E-06	0.001%	0.0111%
Cm-243	6.05E-06	0.001%	0.001%	3.35E-06	0.0003%	0.0004%
Cm-244	5.60E-06	0.001%	0.001%	3.09E-06	0.0003%	0.0002%
Total	1.00E+00	100%	100%	1.00E+00	100%	100%
Insignificant	8.64E-03	0.864%	0.514%	9.54E-03	0.954%	1.32%
	=ROCs All Basements					
	=Additional ROCs for Containments					

There is a slight change to the Auxiliary Building percent annual dose values in the last column of Table 19 due to an error in the Rev. 0 spreadsheet that was referencing the January 1, 2013 % dose values instead of the July 18, 2018 values. This resulted in the insignificant dose increasing slightly from 1.207% to 1.32%.

The source term and dose fractions with only the ROCs are as shown Table 20 below. The Auxiliary Building mix applies to all buildings except for the Containments and the Fuel Handling Building, which has yet to be characterized.

Table 20 – ROCs Only Basement Fill End State July 1, 2018 Radionuclide Mixes for FSS

Nuclide	CTMT			AUX		
	Activity Ci	Percent Activity	Percent Annual Dose	Activity Ci	Percent Activity	Percent Annual Dose
H-3	7.40E-04	0.074%	0.017%	Insig	Insig	Insig
Co-60	4.68E-02	4.675%	1.669%	9.08E-03	0.908%	0.432%
Ni-63	2.63E-01	26.275%	0.366%	2.35E-01	23.480%	0.296%
Sr-90	2.73E-04	0.027%	1.072%	5.10E-04	0.051%	0.739%
Cs-134	8.15E-05	0.008%	0.015%	1.03E-04	0.010%	0.007%
Cs-137	6.76E-01	67.582%	96.269%	7.46E-01	74.597%	97.206%
Eu-152	4.36E-03	0.436%	0.067%	Insig	Insig	Insig
Eu-154	5.79E-04	0.058%	0.010%	Insig	Insig	Insig
Insignificant	8.64E-03	0.864%	0.514%	9.54E-03	0.954%	1.32%
Total	1.00E+00	100%	100%	1.00E+00	100%	100%
	=ROCs All Basements					
	=Additional ROCs for Containments					

3.4. Soil Radionuclides of Concern

The Zion Restoration Project RESRAD model was used to develop the soil DCGLs equal to a peak dose of 25 mrem/year provided in Table 21. As described for Table 11, there were minor changes to the Rev. 0 DCGLs. The Rev 0. DCGLs were Eu-152, 1.073E+01, Eu-154, 9.963E+00, and Eu-155, 3.896E+02. The revised RESRAD runs described changed the Ni-63 and Sr-90 DCGLs from Ni-63, 3.996E+03 and Sr-90, 1.439E+01 to the values in Table 21.

Table 21 - ZSRP 0.15 Meter Soil DCGLs

Nuclide	DCGL pCi/g	Nuclide	DCGL pCi/g
Ag-108m	7.400E+00	H-3	4.581E+03
Am-241	1.336E+02	Nb-94	7.507E+00
Am-243	4.979E+01	Ni-59	1.094E+04
C-14	8.959E+01	Ni-63	3.969E+03
Cm-243	7.606E+01	Np-237	8.006E-01
Cm-244	2.708E+02	Pu-238	1.617E+02
Co-60	4.734E+00	Pu-239	1.456E+02
Cs-134	7.524E+00	Pu-240	1.457E+02
Cs-137	1.576E+01	Pu-241	6.519E+03
Eu-152	1.074E+01	Sb-125	3.360E+01
Eu-154	9.969E+00	Sr-90	1.343E+01
Eu-155	3.909E+02	Tc-99	1.277E+02
Fe-55	3.374E+04		

If the July 1, 2018 normalized concrete and RCS piping mixes in Table 14 are considered to be in pCi/g rather than Ci, the value divided by the DCGL and multiplied by 25 mrem/year equals the dose associated with each mix as seen in Table 22. The changes in the DCGLs described for Table 21 and changes in half-lives used resulted in changes to the Rev. 0 missed doses calculated of 0.7% or less. These were so minor they did not change the values of the insignificant doses reported in the Rev. 0 summary tables Table 24, Table 25, or Table 26 below.

As seen in

Table 23, Co-60 and Cs-137 account for over 99% of the dose except in the activated concrete mix and the RCS pipe mixes.

It is highly unlikely that there would be any significant activated concrete in contaminated soil. The AUX mixture in Table 19 results in less than 1% insignificant dose when only Co-60, Cs-134 and Cs-137 are the radionuclides of concern in soil.

Table 22 - July 1, 2018 Normalized Concrete and RCS Pipe Mix Soil Doses

Nuclide	Unit 1 CTMT Concrete			Unit 2 CTMT Concrete			Aux Bldg			L50297 U1 RCS 2012 mrem/yr	L48320-1 U2 RCS Inside Piping Smears mrem/yr
	Total 568' Floor mrem/yr	Total 542' Floor & Walls mrem/yr	Overall Total mrem/yr	Total 568' Floor mrem/yr	Total 542' Floor & Walls mrem/yr	Overall Total mrem/yr	Total 542' Floor mrem/yr	Total Contam Wall 542' mrem/yr	Overall Total mrem/yr		
H-3	4.57E-06	1.70E-04	4.86E-06	2.69E-06	6.0E-05	3.22E-06	1.06E-05	3.76E-06	9.51E-06	5.87E-06	1.96E-06
C-14	3.32E-05	1.47E-04	3.34E-05	9.34E-06	4.3E-05	9.65E-06	1.14E-04	1.75E-04	1.23E-04	6.98E-05	1.52E-04
Fe-55	1.43E-07	6.55E-07	1.44E-07	2.44E-06	1.7E-06	2.43E-06	8.46E-07	4.42E-07	7.83E-07	9.78E-06	4.19E-05
Ni-59	3.77E-07	1.51E-05	4.03E-07	6.35E-06	4.7E-05	6.72E-06	1.24E-05	5.95E-06	1.14E-05	7.78E-06	1.08E-05
Co-60	8.49E-02	2.76E-01	8.52E-02	4.10E-01	2.7E-01	4.09E-01	4.30E-02	7.45E-02	4.79E-02	3.08E+00	1.37E+00
Ni-63	1.43E-04	2.86E-04	1.43E-04	3.19E-03	1.0E-03	3.17E-03	1.48E-03	1.48E-03	1.48E-03	2.22E-03	1.99E-03
Sr-90	9.48E-04	1.82E-04	9.46E-04	7.18E-05	6.3E-05	7.17E-05	5.91E-04	2.89E-03	9.49E-04	4.88E-03	9.80E-04
Nb-94	5.20E-04	3.19E-03	5.25E-04	1.14E-02	2.4E-03	1.13E-02	4.42E-04	3.26E-04	4.24E-04	7.67E-03	6.26E-03
Tc-99	2.84E-05	3.83E-05	2.84E-05	1.28E-06	5.4E-06	1.32E-06	3.28E-05	2.30E-05	3.13E-05	3.43E-04	2.95E-04
Ag-108m	9.49E-04	3.13E-03	9.53E-04	1.80E-02	3.0E-02	1.81E-02	6.34E-04	2.97E-04	5.82E-04	8.47E-03	3.70E-03
Sb-125	2.22E-04	2.30E-04	2.22E-04	1.49E-04	8.4E-05	1.48E-04	1.24E-04	1.61E-04	1.29E-04	8.97E-04	2.60E-03
Cs-134	1.67E-04	2.83E-03	1.72E-04	3.51E-04	2.3E-03	3.69E-04	2.53E-04	8.29E-04	3.43E-04	8.19E-04	4.87E-04
Cs-137	1.52E+00	4.99E-01	1.51E+00	6.35E-01	8.1E-02	6.30E-01	1.18E+00	1.18E+00	1.18E+00	4.07E-02	5.55E-01
Eu-152	3.86E-03	1.19E+00	5.95E-03	4.32E-04	1.5E+00	1.43E-02	3.65E-04	6.31E-04	4.07E-04	0	0
Eu-154	1.80E-03	5.99E-02	1.90E-03	2.76E-04	8.0E-02	1.01E-03	2.18E-04	3.38E-04	2.36E-04	6.00E-03	3.08E-03
Eu-155	1.11E-05	5.12E-04	1.20E-05	6.88E-06	5.0E-04	1.14E-05	4.78E-06	5.86E-06	4.95E-06	0	0
Np-237	4.54E-05	3.74E-04	4.60E-05	1.06E-05	1.4E-04	1.18E-05	1.24E-04	2.02E-04	1.36E-04	9.57E-02	4.75E-02
Pu-238	1.51E-06	3.15E-06	1.52E-06	8.62E-08	4.8E-07	8.98E-08	2.29E-06	4.16E-07	2.00E-06	2.83E-05	1.26E-05
Pu-239	6.15E-07	1.63E-06	6.17E-07	5.07E-08	2.4E-07	5.25E-08	1.04E-06	2.35E-07	9.16E-07	3.29E-06	2.76E-06
Pu-240	6.14E-07	1.62E-06	6.16E-07	5.07E-08	2.4E-07	5.24E-08	1.04E-06	2.34E-07	9.15E-07	3.29E-06	2.75E-06
Pu-241	3.75E-07	2.74E-06	3.79E-07	1.27E-07	9.6E-07	1.35E-07	1.10E-06	1.01E-06	1.08E-06	1.54E-05	1.29E-06
Am-241	2.35E-05	6.00E-06	2.35E-05	1.76E-06	6.9E-07	1.75E-06	2.59E-06	1.19E-06	2.37E-06	3.60E-05	1.67E-05
Am-243	1.20E-06	7.64E-06	1.22E-06	4.80E-07	2.4E-06	4.98E-07	5.05E-06	3.23E-06	4.77E-06	0	0

Nuclide	Unit 1 CTMT Concrete			Unit 2 CTMT Concrete			Aux Bldg			L50297 U1 RCS 2012 mrem/yr	L48320-1 U2 RCS Inside Piping Smears mrem/yr
	Total 568' Floor mrem/yr	Total 542' Floor & Walls mrem/yr	Overall Total mrem/yr	Total 568' Floor mrem/yr	Total 542' Floor & Walls mrem/yr	Overall Total mrem/yr	Total 542' Floor mrem/yr	Total Contam Wall 542' mrem/yr	Overall Total mrem/yr		
Cm-243	3.67E-06	3.86E-06	3.67E-06	3.00E-07	<i>6.1E-07</i>	3.03E-07	<i>1.07E-06</i>	<i>1.24E-06</i>	<i>1.10E-06</i>	4.77E-06	4.30E-06
Cm-244	9.55E-07	9.99E-07	9.55E-07	7.81E-08	<i>1.6E-07</i>	7.88E-08	<i>2.78E-07</i>	<i>3.22E-07</i>	<i>2.85E-07</i>	1.24E-06	1.12E-06
Total	1.61E+00	2.04E+00	<i>1.61E+00</i>	1.08E+00	1.98E+00	<i>1.09E+00</i>	1.23E+00	1.26E+00	<i>1.24E+00</i>	<i>3.25E+00</i>	<i>2.00E+00</i>
Missed Dose	8.76E-03	1.26E+00	1.10E-02	3.39E-02	1.63E+00	4.86E-02	4.42E-03	7.38E-03	4.88E-03	1.27E-01	6.71E-02
% Missed	0.544%	61.994%	0.681%	3.145%	82.475%	4.471%	0.359%	0.585%	0.395%	3.917%	3.360%
No Np-237	0.542%	61.987%	0.678%	3.144%	82.474%	4.470%	0.349%	0.569%	0.384%	0.999%	1.007%
ROC Missed Dose	1.84E-03	7.67E-03	1.85E-03	2.96E-02	3.29E-02	2.96E-02	2.10E-03	2.18E-03	2.11E-03	1.19E-01	6.36E-02

= Co-60 & Cs-137 Only All Others Missed Dose

= Included in ROCs when Activated Concrete is Present

= Basement Fill ROCs

Bold Italic = MDA

Bold Italic

= MDA

Table 23 - Soil July 1, 2018 Mix Individual Nuclide Percent of Total Dose

Nuclide	Unit 1 CTMT Concrete			Unit 2 CTMT Concrete			Aux Bldg			L50297 U1 RCS 2012 Percent	L48320 -1 U2 RCS Inside Piping Smears Percent
	Total 568' Floor Percent	Total Incore 542' Floor & Walls Percent	Overall Total Percent	Total 568' Floor Percent	Total 542' Floor & Walls Percent	Overall Total Percent	Total 542' Floor Percent	Total Contam Wall 542' Percent	Overall Total Percent		
H-3	0.000%	0.008%	0.000%	0.000%	0.003%	0.000%	0.001%	0.000%	0.001%	0.000%	0.000%
C-14	0.002%	0.007%	0.002%	0.001%	0.002%	0.001%	0.009%	0.014%	0.010%	0.002%	0.008%
Fe-55	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.002%
Ni-59	0.000%	0.001%	0.000%	0.001%	0.002%	0.001%	0.001%	0.000%	0.001%	0.000%	0.001%
Co-60	5.272%	13.520%	5.290%	38.000%	13.419%	37.589%	3.493%	5.915%	3.878%	94.830%	68.862%
Ni-63	0.009%	0.014%	0.009%	0.295%	0.052%	0.291%	0.120%	0.118%	0.120%	0.068%	0.100%
Sr-90	0.059%	0.009%	0.059%	0.007%	0.003%	0.007%	0.048%	0.229%	0.077%	0.150%	0.049%
Nb-94	0.032%	0.157%	0.033%	1.059%	0.122%	1.043%	0.036%	0.026%	0.034%	0.236%	0.313%
Tc-99	0.002%	0.002%	0.002%	0.000%	0.000%	0.000%	0.003%	0.002%	0.003%	0.011%	0.015%
Ag-108m	0.059%	0.154%	0.059%	1.668%	1.502%	1.665%	0.051%	0.024%	0.047%	0.261%	0.185%
Sb-125	0.014%	0.011%	0.014%	0.014%	0.004%	0.014%	0.010%	0.013%	0.010%	0.028%	0.130%
Cs-134	0.010%	0.139%	0.011%	0.033%	0.119%	0.034%	0.021%	0.066%	0.028%	0.025%	0.024%
Cs-137	94.184%	24.485%	94.029%	58.855%	4.106%	57.940%	96.148%	93.500%	95.728%	1.253%	27.778%
Eu-152	0.240%	58.507%	0.370%	0.040%	76.595%	1.319%	0.030%	0.050%	0.033%		
Eu-154	0.112%	2.941%	0.118%	0.026%	4.037%	0.093%	0.018%	0.027%	0.019%	0.185%	0.154%
Eu-155	0.001%	0.025%	0.001%	0.001%	0.025%	0.001%	0.000%	0.000%	0.000%		
Np-237	0.003%	0.018%	0.003%	0.001%	0.007%	0.001%	0.010%	0.016%	0.011%	2.947%	2.377%
Pu-238	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.001%	0.001%
Pu-239	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Pu-240	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Pu-241	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Am-241	0.001%	0.000%	0.001%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.001%	0.001%

Nuclide	Unit 1 CTMT Concrete			Unit 2 CTMT Concrete			Aux Bldg			L50297 U1 RCS 2012 Percent	L48320 -1 U2 RCS Inside Piping Smears Percent
	Total 568' Floor Percent	Total Incore 542' Floor & Walls Percent	Overall Total Percent	Total 568' Floor Percent	Total 542' Floor & Walls Percent	Overall Total Percent	Total 542' Floor Percent	Total Conta m Wall 542' Percent	Overall Total Percent		
Am-243	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%		
Cm-243	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Cm-244	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Total	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Co-60 & Cs-137	99.456%	38.006%	99.319%	96.855%	17.525%	95.529%	99.641%	99.415%	99.605%	96.083%	96.640%
ROC Total	99.886%	99.624%	99.885%	97.256%	98.335%	97.274%	99.830%	99.827%	99.829%	96.327%	96.813%

Note – Yellow cells are greater than 0.5%

Table 24 - Soil Radionuclides of Concern and Insignificant Dose

Nuclide	Dose mrem/year	Nuclide	Dose mrem/year
H-3	9.51E-06	Eu-154	2.36E-04
C-14	1.23E-04	Eu-155	4.95E-06
Fe-55	7.83E-07	Np-237	1.36E-04
Ni-59	1.14E-05	Pu-238	2.00E-06
Co-60	4.79E-02	Pu-239	9.16E-07
Ni-63	1.48E-03	Pu-240	9.15E-07
Sr-90	9.49E-04	Pu-241	1.08E-06
Nb-94	4.24E-04	Am-241	2.37E-06
Tc-99	3.13E-05	Am-243	4.77E-06
Ag-108m	5.82E-04	Cm-243	1.10E-06
Sb-125	1.29E-04	Cm-244	2.85E-07
Cs-134	3.43E-04	Total	1.24E+00
Cs-137	1.18E+00	Insignificant	2.11E-03
Eu-152	4.07E-04		=ROCs Soils

Table 25 summarizes the activity and dose contribution for the AUX mixture.

Table 25 - Basement Fill End State July 1, 2018 Radionuclide Mixes for Soil FSS

Nuclide	Dose mrem/year	Activity Ci	Percent Activity	Percent Annual Dose
H-3	9.51E-06	1.74E-03	0.1743%	0.0008%
C-14	1.23E-04	4.41E-04	0.0441%	0.0100%
Fe-55	7.83E-07	1.06E-03	0.1057%	0.0001%
Ni-59	1.14E-05	4.98E-03	0.4982%	0.0009%
Co-60	4.79E-02	9.08E-03	0.9076%	3.8775%
Ni-63	1.48E-03	2.35E-01	23.4804%	0.1196%
Sr-90	9.49E-04	5.10E-04	0.0510%	0.0767%
Nb-94	4.24E-04	1.27E-04	0.0127%	0.0343%
Tc-99	3.13E-05	1.60E-04	0.0160%	0.0025%
Ag-108m	5.82E-04	1.72E-04	0.0172%	0.0471%
Sb-125	1.29E-04	1.74E-04	0.0174%	0.0105%
Cs-134	3.43E-04	1.03E-04	0.0103%	0.0277%
Cs-137	1.18E+00	7.46E-01	74.5965%	95.7278%
Eu-152	4.07E-04	1.75E-04	0.0175%	0.0329%
Eu-154	2.36E-04	9.43E-05	0.0094%	0.0191%
Eu-155	4.95E-06	7.74E-05	0.0077%	0.0004%
Np-237	1.36E-04	4.37E-06	0.0004%	0.0110%
Pu-238	2.00E-06	1.29E-05	0.0013%	0.0002%

Pu-239	9.16E-07	5.34E-06	0.0005%	0.0001%
Pu-240	9.15E-07	5.33E-06	0.0005%	0.0001%
Pu-241	1.08E-06	2.82E-04	0.0282%	0.0001%
Am-241	2.37E-06	1.27E-05	0.0013%	0.0002%
Am-243	4.77E-06	9.50E-06	0.0009%	0.0004%
Cm-243	1.10E-06	3.35E-06	0.0003%	0.0001%
Cm-244	2.85E-07	3.09E-06	0.0003%	0.0000%
Total	1.24E+00	1.00E+00	1.00E+00	1.00E+00
Insignificant	2.11E-03	9.54E-03	9.54E-03	1.71E-03
	=ROCs Soils			

Table 26 shows the percentages with only the dose significant ROCs.

Table 26 - ROCs Only Soils July 1, 2018 Radionuclide Mixes for FSS

Nuclide	Dose mrem/year	Activity Ci	Percent Activity	Percent Annual Dose
Co-60	4.79E-02	9.08E-03	0.91%	3.878%
Ni-63	1.48E-03	2.35E-01	23.48%	0.120%
Sr-90	9.49E-04	5.10E-04	0.05%	0.077%
Cs-134	3.43E-04	1.03E-04	0.01%	0.028%
Cs-137	1.18E+00	7.46E-01	74.60%	95.728%
Insignificant	2.11E-03	9.54E-03	0.95%	0.171%
Total	1.24E+00	1.00E+00	100%	100%
	=ROCs Soils			

Thus the ROCs for soils are the same as those for all end state buildings except the Containments.

4. CONCLUSION

Extensive concrete core samples of potential end state concrete were obtained from the Unit 1 and 2 Containment Buildings and the Auxiliary Building. (5) (6) These cores were obtained at locations with high contact dose rates and/or evidence of leaks/spills. They are therefore heavily biased toward locations with high concentrations or radionuclides in the concrete. The end state Fuel Handling Building is below the Spent Fuel Pool liner and will need to be evaluated once the fuel pool is drained. The other potentially contaminated structures, such as the Turbine Building and Main Steam Tunnel end states, are bounded by the source terms in these structures. Each concrete core section was analyzed by on-site gamma spectroscopy identifying Eu-152, Eu-154 in Containment Incore Area activated concrete cores and Co-60, Cs-137 and Cs-134 in Auxiliary Building and Containment cores. Conservatism was added to the estimated source terms by using MDAs for these nuclides along with positively identified concentrations for these radionuclides. The calculated source terms from these nuclides were used to scale the activities of additional radionuclides positively identified in off-site analysis of cores from an area. Based upon the off-site laboratory results, Ag-110m and Eu-155 were added to the list of potential ROCs. Both the end state DUST MS model (9) and the RESRAD model (12) used the full suite of radionuclides, even

though some were not positively identified in the concrete characterization data. This was done to ensure data was available to calculate basement fill water concentrations and annual doses if they were detected during FSS or sampling.

The DUST MS estimates of basement fill water concentrations per unit of activity were very conservative. The models used distribution coefficients that were the lowest site specific values determined for potential fill materials, or were the lowest 25th percentile values calculated from the RESRAD cumulative probability distribution or from the literature. In addition, a very low total porosity value was used, minimizing the water available for dilution of the source term in the fill material. (9) Similarly sensitive parameters for the RESRAD model were assigned 25th percentile values of the probability density function. (12) The calculated concentrations and doses from the normalized source terms are therefore extremely conservative and represent worst case end state conditions.

Based upon this analysis it was determined that Co-60, Ni-63, Sr-90, Cs-134 and Cs-137 accounted for 99.6% of all dose in the contaminated concrete mixes. For activated concrete, H-3, Eu-152, and Eu-154, in addition to the five aforementioned nuclides, accounted for 99% of the dose. The Containment composite mix in Table 19 can be used for the Unit 1 and Unit 2 Containment Building basement fill end states. The Auxiliary Building mix in the table can be used for all other buildings and soil.

5. REFERENCES

1. TSD 11-001 Rev. 1, Potential Radionuclides of Concern During the Decommissioning of the Zion Station, October 2012.
2. NUREG/CR-3474, Long-Lived Activation Products in Reactor Materials, Pacific Northwest Laboratory, 1984.
3. NUREG/CR-4289, Residual Radionuclide Concentration Within and Around Commercial Nuclear Power Plants; Origin, Distribution, Inventory, and Decommissioning Assessment, Pacific Northwest Laboratory, 1985.
4. WINCO-1191, Radionuclides in United States Commercial Nuclear Power Reactors, Westinghouse Idaho Nuclear Company, Inc., 1994.
5. TSD 13-006 Reactor Building Units 1 and 2 End State Concrete and Liner Initial Characterization Source Terms and Distributions.
6. TSD 14-013 Zion Auxiliary Building End State Estimated Concrete Volumes, Surface Areas, and Source Terms.
7. TSD 14-014 End State Surface Areas, Volumes, and Source Terms of Ancillary Buildings.
8. TSD 13-005 Unit 1 & 2 Reactor Building Estimated End State Concrete and Liner Volumes and Surface Areas.
9. TSD 14-031 BNL Report: Basement Fill Model Evaluation of Maximum Radionuclide Concentrations for Initial Suite of Radionuclides.
10. TSD -14-004 BNL Report: Recommended Values for the Distribution Coefficient (KD) to be Used in Dose Assessments for Decommissioning the Zion Nuclear Power Plant.

11. TSD 14-008 Future Land Use and Conceptual Site Model for Compliance.
12. TSD 14-010 RESRAD Dose Modeling for Basement Fill Model and Soil DCGL and Calculation of Basement Fill Model Dose Factors.
13. TSD 14-021 BFM Drilling Spoils and Alternate Exposure Scenarios.
14. NUREG/CR-7166, Radiological Toolbox User's Guide, May 2013.

6. ATTACHMENTS

- 6.1. Attachment A - Concrete Characterization Core Sample, Locations, and Analyses

Attachment A
Concrete Characterization Core Samples, Locations, and Analyses

TSD 14-019
Revision 1

Survey Unit	Characterization Survey Package Identification	Survey Unit Description	Number of Cores	In-House Gamma Spec	Off-Site Analysis	
Reactor Building Unit 1						
1101	B101101C-U1 CTMT Bioshield	Vessel Bioshield U1 CTMT	1	1	0	
1102	B101102C-U1 CTMT A Loop IMB 568	Inside Missile Barrier – “A” Loop 568 Ft U1 CTMT	2	2	1	
1103	B101103C-U1 CTMT B Loop IMB 568	Inside Missile Barrier – “B” Loop 568 Ft U1 CTMT	2	2	1	
1104	B101104C-U1 CTMT C Loop IMB 568	Inside Missile Barrier – “C” Loop 568 Ft U1 CTMT	2	2	1	
1105	B101105C-U1 CTMT D Loop IMB 568	Inside Missile Barrier – “D” Loop 568 Ft U1 CTMT	2	2	2	
1106	B101106C-U1 CTMT A Loop OMB 568	Outside Missile Barrier – “A” Loop 568 Ft U1 CTMT	2	2	1	
1107	B101107C-U1 CTMT B Loop OMB 568	Outside Missile Barrier – “B” Loop 568 Ft U1 CTMT	2	2	1	
1108	B101108C-U1 CTMT C Loop OMB 568	Outside Missile Barrier – “C” Loop 568 Ft U1 CTMT	2	2	1	
1109	B101109C-U1 CTMT D Loop OMB 568	Outside Missile Barrier – “D” Loop 568 Ft U1 CTMT	2	2	1	
1110	B101110C-U1 CTMT Undervessel 543	Incore Area 543 Ft Elevation U1 CTMT	3	3	2	
			Total Cores	20	20	11
Reactor Building Unit 2						
2102	B102102C-U2 CTMT A Loop IMB 568	Inside Missile Barrier – “A” Loop 568 Ft U2 CTMT	2	2	1	
2103	B102103C-U2 CTMT B Loop IMB 568	Inside Missile Barrier – “B” Loop 568 Ft U2 CTMT	2	2	2	
2104	B102104C-U2 CTMT C Loop IMB 568	Inside Missile Barrier – “C” Loop 568 Ft U2 CTMT	2	2	0	
2105	B102105C-U2 CTMT D Loop IMB 568	Inside Missile Barrier – “D” Loop 568 Ft U2 CTMT	2	2	2	
2106	B102106C-U2 CTMT A Loop OMB 568	Outside Missile Barrier – “A” Loop 568 Ft U2 CTMT	2	2	2	
2107	B102107C-U2 CTMT B Loop OMB 568	Outside Missile Barrier – “B” Loop 568 Ft U2 CTMT	2	2	1	
2108	B102108C-U2 CTMT C Loop OMB 568	Outside Missile Barrier – “C” Loop 568 Ft U2 CTMT	2	2	0	
2109	B102109C-U2 CTMT D Loop OMB 568	Outside Missile Barrier – “D” Loop 568 Ft U2 CTMT	2	2	0	
2110	B102110C-U2 CTMT Undervessel 543	Incore Area 543 Ft Elevation U2 CTMT	3	3	2	
			Total Cores	19	19	10
Auxiliary Building						
05101	B105101C-Aux 542 1A RHR Pmp	Unit 1 A RHR Pump Room 542 Ft Auxiliary Building	1	1	1	
05102	B105102C-Aux 542 1B RHR Pmp	Unit 1 B RHR Pump Room 542 Ft Auxiliary Building				
05103	B105103C-Aux 542 2A RHR Pmp	Unit 2A RHR Pump Room 542 Ft Auxiliary Building	1	1	1	

**Attachment A
Concrete Characterization Core Samples, Locations, and Analyses**

TSD 14-019
Revision 1

Survey Unit	Characterization Survey Package Identification	Survey Unit Description	Number of Cores	In-House Gamma Spec	Off-Site Analysis
05104	B105104C-Aux 542 2B RHR Pmp	Unit 2B RHR Pump Room 542 Ft Auxiliary Building	1	1	1
05105	B105105C-Aux 542 U1 Pipe Tunnel	Unit 1 Pipe Chase 542 Ft Auxiliary Building	1	1	
05106	B105106C-Aux 542 U2 Pipe Tunnel	Unit 2 Pipe Chase 542 Ft Auxiliary Building	2	2	
05107	B105107C-Aux 542 HUT Cubicles	Hold Up Tanks 542 Ft Auxiliary Building	1	1	
05108	B105108C-Aux 542 Central Area	Central Area 542 Ft Auxiliary Building	4	4	2
05109	B105109C-Aux 542 South Area	South Area 542 Ft Auxiliary Building	1	1	
05110	B105110C-Aux 542 North Area	North Area 542 Ft Auxiliary Building	2	2	
05111	B105111C-Aux 542 East Area	West Area 542 Ft Auxiliary Building	2	2	
05112	B105112C-Aux 542 Gas Decay Tks	Gas Decay Tanks 542 Ft Auxiliary Building			
05113	B105113C-Aux 542 U1 EDCT Rm	Unit 1 Equipment Drain Collection Tank 542 Ft Auxiliary Building	3	3	1
05114	B105114C-Aux 542 U2 EDCT Rm	Unit 2 Equipment Drain Collection Tank 542 Ft Auxiliary Building	1	1	
05115	B105115C-Aux 542 HUT Recirc BAE Feed	HUT Recirculation and BAE Feed Pumps 542 Ft Auxiliary Building			
05116	B105116C-Aux 542 EDT	Aux Building Equipment Drain Tank and Pumps 542 Ft Auxiliary Building			
05117	B105117C-Aux 542 A Sump	Aux Building Sump A 542 Ft Auxiliary Building			
05118	B105118C-Aux 542 B Sump	Aux Building Sump B 542 Ft Auxiliary Building			
Total Cores			20	20	6
Turbine Building					
06104	B206104 - North Area	Turbine Building 560 Ft. Unit 1 North Area	3	3	0
06207	B206207 - Unit 1 Steam Pipe Tunnel	Turbine Building 570 Ft. Unit 1 Steam Pipe Tunnel	5	5	0
06208	B206208 - Unit 2 Steam Pipe Tunnel	Turbine Building 570 Ft. Unit 2 Steam Pipe Tunnel	2	2	0
Total Cores			10	10	0
Overall Totals			69	69	27