NRC Comment 17: DOE-ID needs to determine if the final end-state of residual contamination in grouted tanks, vaults, and auxiliary equipment at the TFF is Class C or greater as defined in 10 CFR 61.55.

Basis: The Ronald W. Reagan National Defense Authorization Act for Fiscal Year 2005 (NDAA) provides criteria for determining whether certain waste resulting from the reprocessing of spent nuclear fuel is not high-level waste (HLW). Criteria 3(A) and 3(B) of Section 3116(a) of the NDAA require that the waste be disposed of in compliance with the performance objectives contained in NRC regulations at 10 CFR 61, Subpart C. The applicability of either 3(A) or 3(B) is dependent upon whether the waste exceeds Class C concentration limits, thus the classification of waste residuals must be determined in order to apply the NDAA criteria.

Path Forward: DOE-ID should consult the interim concentration averaging guidance (70 FR 74846) for additional information regarding acceptable methods of estimating residual concentrations in Tank Farm Facility (TFF) tanks, vaults, and auxiliary equipment. DOE-ID needs to specify the class of residual waste at the TFF, as defined in 10 CFR 61.55. Assumptions used in the calculation of waste concentrations should be clearly stated and justification for these assumptions should be provided.

Response:

1. INTRODUCTION

The draft Section 3116 Determination for the INTEC TFF was transmitted to NRC in September 2005. The draft 3116 Determination provided tables that compared concentrations of individual radionuclides in the stabilized waste against the Class C concentration limits in Tables 1 and 2 as shown in 10 CFR 61.55, including sum of the fractions values, as well as the data and assumptions used to complete the tables. However, DOE did not decide in the draft 3116 Determination whether the radioactive waste exceeded Class C concentration limits or not, and requested further consultation with the NRC. This response concludes that the TFF at closure will be within Class C concentration limits.

Following submittal of the draft 3116 Determination to NRC in September 2005, the NRC released a Federal Register (FR) notice, “Draft Interim Concentration Averaging Guidance for Waste Determinations” (70 FR 74846), for public comment.

Each of the major components of the TFF tank system is described as an individual component (in the draft 3116 Determination) for calculation of waste concentrations using the sum of the fractions approach. The TFF tank system comprises 11 300,000-gal tanks, four 30,000-gal tanks, as well as the tank vaults, piping, structures, and ancillary equipment associated with these tanks. The draft 3116 Determination was prepared to demonstrate that the TFF residual waste and associated ancillary equipment at final closure will meet the Section 3116 criteria. Prior to cleaning and receiving sampling and analysis results of the first tank cleaning, planning documents such as the first HWMA/RCRA closure plan and the TFF PA (DOE-ID 2003) were prepared. These planning documents identified the baseline inventory of radionuclides remaining in the tanks.

This response has been developed for TFF tanks and ancillary equipment to determine whether residual waste concentrations exceed Class C concentration limits. The nature of the acidic waste and stainless steel tanks are unique to the DOE complex. Because the waste remained acidic, significant amounts of stiff, recalcitrant sludge do not remain in cleaned tanks. Methods used in this determination of waste concentrations are not likely to be used in the same manner by other DOE sites because the characteristics of the waste and tanks, and the general characteristics of individual DOE sites, are different, which may lead to a variety of approaches for determination of waste concentrations within the concepts of the NRC draft interim guidance.

The draft interim guidance introduces a concept of ratios of unstabilized-to-stabilized waste. The factor of 10 is an approximation derived from a consideration that most stabilization techniques commonly envisioned use of cementitious materials, and most cementitious waste forms can readily achieve a 10% waste loading. For illustrative purposes, an analysis was performed using a 10:1 ratio of unstabilized-to-stabilized waste mass. Such an analysis results in each of the 300,000-gal tanks exceeding Class C concentration limits. However, the 10:1 ratio is a general goal that should take into account other considerations, including the ability of the solidified waste form to meet the performance of objectives of 10 CFR 61. For other components of the TFF tank system, using examples or extrapolation of examples from the guidance yields concentrations that are within Class C concentration limits as discussed in Sections 2 through 6 of this response. (See Section RAI-17-A-2.1.2 in Appendix RAI-17-A for further discussion.)

In the rest of this response DOE will demonstrate that, by using reasonable assumptions and scenarios, calculations of the sum of the fractions show that the TFF is within Class C concentration limits at closure and disposal.

Several sensitivity evaluations are included in Appendix RAI-17-A to assess the impacts of variability of various parameters on concentration results. The sensitivity analysis varies grout volumes, inventories, and averaging methodologies to provide additional insight into these calculations and support the conclusion of a Class C waste determination.

2. 300,000-GAL TANKS

The waste in the 300,000-gal tanks has been removed to the maximum extent practical and any residuals will be stabilized so that there is reasonable assurance that the performance objectives of 10 CFR 61, Subpart C, can be achieved.[a] The processing and removal included calcination, evaporation of liquid, and tank cleaning to remove as much residual waste as practical. Engineered grout placements are used to provide a final opportunity for waste removal. The

a. There are four tanks remaining to be cleaned; however, as discussed in the draft 3116 Determination, it is assumed these remaining tanks will be cleaned to the same extent as the previously cleaned tanks.

placements are a last step to remove residuals but are not credited for purposes of removal to the maximum extent practical because it is not known how much additional residual waste will be removed by this last step.

As described in the draft 3116 Determination, the engineered grout placement sequence to move remaining solids and liquids toward the removal pumps is estimated to use 85 m^3 of grout. The function of the engineered grout placements is to provide additional assurance that the waste is being removed. The engineered grout placements also aid in the mixing of residuals with the grout. The engineered grout placements also provide a reducing environment. A final encapsulation pour of 140 m^3 of grout is proposed to level the engineering grout placement. A portion of the 140 m^3 (33 m^3) is used to stabilize the residual waste on the grout surface. The total volume of grout for this operation is 225 m^3, which results in a layer of grout about 1.2 m (4 ft) thick from the tank floor; however, the total volume used for calculating whether the waste will exceed Class C concentration limits through concentration averaging is 118 m^3 (see discussion in Section RAI-17-B-2 in Appendix RAI-17-B). The engineered grout placement sequence is described below.

The grout will be introduced through two available risers with specially designed grout masts. The first two placements go in directly below the available risers to a height of 3–4 ft. The purpose of the first two placements is to begin moving residuals toward the steam jet for removal and to provide troughs to direct placements 3 through 5 to the other areas of the tank. In the grout mockup (INEEL 1999), these placements were successful in moving solid and liquid surrogate materials.

Placements 3 and 4 use the same riser access as placements 1 and 2, and displace the residuals between the tank wall and the steam jet. The purpose of placement 5 is to displace the residuals on the opposite side of the tank from the steam jet. These placements flow through the trough to sweep residuals toward the steam jet. Placement 5 may be replaced with two separate placements to allow better residual removal, but the purpose of the placement is the same. Figure RAI-17-1 shows a schematic of the grout placements.

Based upon mockup results, it is anticipated that some portion of remaining residuals will be pushed to the steam jet and removed during grouting. Some of the residuals will likely remain trapped between the tank surfaces and the grout, some will be mixed within the grout, and some will remain on top of the engineered grout placements. A final encapsulation pour will then be used to ensure adequate immobilization of any remaining residuals.

To calculate a waste concentration in these tanks, the estimate of final residual waste inventory at closure is divided by the volume or mass of the final waste form.[b]

b. This approach is consistent with 10 CFR 61.55(a)(8), which states that the radioactivity in the waste may be divided by the volume or mass of the final waste form.

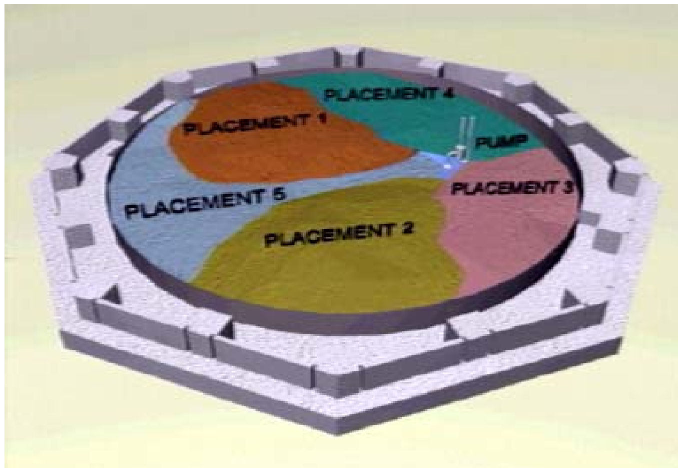

Figure RAI-17-1. Schematic of the grout placement sequence.

2.1 300,000-gal Tank Waste Concentration

To determine the radionuclide concentration of the final waste form in the 300,000-gal tanks, a residual waste inventory of 2,394 Ci and a grout volume of 118 m^3 were used as described in Appendix RAI-17-B. Tables RAI-17-1 and -2 show the calculations of the residual waste inventory at closure for Tank WM-182 averaged over 118 m^3 of grout. The mass of grout is equal to 2.48E+08 g (density of 2.1 g/cc). The Class C concentration limits for long- and short-lived radionuclides (Tables 1 and 2 of 10 CFR 61.55) are shown in Tables RAI-17-1 and -2. To ensure conservatism in the analysis, the mass of tank steel is not used in these calculations.[c] The sum of the fractions is shown for the Tank WM-182 grouted waste form. The other 300,000-gal tanks that have been cleaned have a lower residual waste inventory at closure than Tank WM-182 and are, therefore, bounded by these calculations. The residual waste inventory at closure for the 300,000-gal tanks does not take credit for any additional residuals that may be removed during grouting operations.

Long-lived radionuclides shown in Table 1 of 10 CFR 61.55 are the significant concentration limits for the TFF tanks (as described in Sections 3 through 5) and ancillary equipment. Concentrations of ^{238}Pu and ^{239}Pu contribute significantly to the sum of the fractions. A review of Table RAI-17-2 shows that short-lived radionuclides do not affect the analysis for Class C waste concentration limits as the sum of the fractions is two orders of magnitude lower than the sum of the fractions for long-lived radionuclides.

The sum of the fractions for short-lived radionuclides (Table 2 of 10 CFR 61.55) in the vault is also two orders of magnitude lower than the sum of the fractions for long-lived radionuclides and the sum of the fractions for 30,000-gal tanks and piping are three to four orders of magnitude lower. Tables for short-lived radionuclides are shown in Appendix RAI-17-C of this response.

c. For perspective, the results of calculations that include the mass of the tank steel to a height of steel are shown in Table RAI-17-A-3 as part of a sensitivity evaluation.

Table RAI-17-1. Radionuclide concentrations in the final Tank WM-182 grouted waste form (Table 1 of 10 CFR 61.55).

Radionuclide[a]	Half-Life (yr)	Tank Inventory (Ci)[b]	Ci/m³	nCi/g	Class C Concentration Limit (Ci/m³ or nCi/g)	Fraction of Limit
^{241}Am	4.30E+02	4.20E–01		1.70E+00	100	0.0170
^{14}C	*5.70E+03*	*5.00E–06*	*4.20E–08*		*8*	*0.0000000053*
^{242}Cm	4.50E–01	1.30E–03		5.30E-03	20,000	0.00000027
^{129}I	*1.60E+07*	*7.70E–04*	*6.60E–06*		*0.08*	*0.000082*
^{59}Ni	*7.50E+04*	*2.50E–02*	*2.10E–04*		*220*	*0.00000097*
^{94}Nb	*2.00E+04*	*2.10E–01*	*1.70E–03*		*0.2*	*0.0087*
^{237}Np	2.10E+06	4.70E–02		1.90E–01	100	0.00190
^{238}Pu	8.80E+01	1.10E+01		4.60E+01	100	0.46
^{239}Pu	2.40E+04	3.40E+00		1.40E+01	100	0.137
^{240}Pu	7.00E+03	1.40E+00		5.50E+00	100	0.055
^{241}Pu	1.40E+01	1.90E+01		7.90E+01	3,500	0.022
^{242}Pu	3.80E+05	9.90E–04		4.00E–03	100	0.000040
^{99}Tc	*2.10E+05*	*7.60E–01*	*6.50E–03*		*3*	*0.0022*
Sum of the Fractions						**0.71**

a. Radionuclides shown in italics are compared to Class C concentration limits in units of Ci/m³ ; remaining nuclides are compared to limits in units of nCi/g.
b. Radioactive decay to 2012.

Table RAI-17-2. Radionuclide concentrations in the final Tank WM-182 grouted waste form (Table 2 of 10 CFR 61.55).

Radionuclide	Half-Life (yr)	Tank Inventory (Ci)[a]	Ci/m³	Class C Concentration Limit (Ci/m³)	Fraction of Class C Concentration Limit
^{137}Cs	3.00E+01	1.10E+03	9.70E+00	4,600	0.0021
^{63}Ni	1.00E+02	2.90E+00	2.40E–02	700	0.000035
^{90}Sr	2.90E+01	2.30E+01	2.00E–01	7,000	0.000028
Sum of the Fractions					**0.0022**

a. Radioactive decay to 2012.

The sum of the fractions from Tables RAI-17-1 and -2 is 0.71 and 0.0022, respectively. Based on the results of these tables and a review of the data and assumptions, the residuals in the 300,000-gal tanks would be Class C waste.

2.2 Summary and Conclusions

At closure and disposal, the residual waste in the 300,000-gal tanks would meet Class C concentration limits. The basis for this is the completion of waste concentration tables as described in 10 CFR 61.55.

Additional sensitivity evaluations and operational constraints described in Appendix RAI-17-A provide reasonable scenarios for waste concentration calculations. For perspective, an analysis was also performed using a 10:1 ratio of unstabilized-to-stabilized waste mass, which showed that each of the 300,000-gal tanks exceeds Class C concentration limits. However, as discussed in Section RAI-17-A-2.1.2 of Appendix RAI-17-A, such an approach is not appropriate or reasonable for calculating final waste concentrations at the TFF. The reasonable scenarios that have been developed all have a sum of the fractions of less than 1.

Appendix RAI-17-D provides an evaluation of these data that demonstrates that this concentration averaging analysis is consistent with the fundamental principles presented in the NRC draft interim guidance on concentration averaging (70 FR 74846).

3. 300,000-GAL TANK VAULTS

As described in the draft 3116 Determination, the 300,000-gal tank vaults that do not contain contaminated sandpads do not have an established inventory. For PA and waste concentration analysis, the residual contamination in the vaults (without contaminated sandpads) is insignificant. The following considerations listed below provide the basis for the 300,000-gal tank vault inventory:

- The responses to NRC Comments 1, 3, and 4 address the reasons a vault inventory is insignificant
- The data presented in the response to NRC Comment 1 strongly indicate the inventory of 3,850 Ci is conservative and likely bounding
- The contaminated sandpads in Tanks WM-185 and WM-187 are those that are used for the vault/sandpad waste concentration calculations
- Tank Vault WM-185 has been cleaned and is used as the example for the waste concentration calculations.
- The inventory developed for the PA uses the same inventory for both contaminated sandpads.[d]

The estimated radioactivity in the vaults is divided by the volume or mass of the final waste form is used in this response to calculate the radionuclide concentration.[e]

Further uncertainty analysis of the sandpad inventory is provided in the responses to NRC Comments 1, 3, and 4. The sandpad and small amount of residuals in the vault will be stabilized using grout, which can be introduced into the vault in

d. Data collected at the time of the back-siphoning events indicate the inventory in Tank Vault WM-187 is less than Vault WM-185 based on the concentration of radionuclides measured in the tank. The concentration of ^{137}Cs in Tank WM-185 was measured at 1.7 Ci/L and the measured concentration in WM-187 was 7.73E–01 Ci/L. This concentration from WM-187 is approximately a factor of 2 less than the concentration in WM-185.

e. This approach is consistent with 10 CFR 61.55(a)(8).

only two places, the risers over the north and south vault sumps. Sufficient grout must be added to fill the vault floor and contain the sandpad.[f]

The calculations for the sum of the fractions in the draft 3116 Determination assume a 1-m grout pour and an inventory of 3,850 Ci. The ratio of long- to short-lived radionuclides in the sandpad inventory is different than in the tank inventory. The scenario described in the draft 3116 Determination assumes the vault has been leveled to a 1-m depth. For purposes of these waste concentration calculations, an alternative is to use a 1-m-deep pour to ensure the grout has been able to flow around the vault and achieve a minimum depth of 1.5 ft at the opposite side of the vault. The volume of grout in this scenario has been calculated to be 32.5 m^3.

The sum of the fractions for this scenario is 0.51 as shown in Table RAI-17-3. This alternative scenario reduces the amount of grout used in encapsulation and provides an alternative to a 1-m-deep grout pour in the vault. This alternative reflects the fact that grout is not self-leveling in the tank vaults, which have a circumference of 157 ft. Additional alternatives to describe the performance of grout in smaller quantities are not shown because 32.5 m^3 is the lowest volume of grout that can be used to ensure the sandpad is encapsulated. Because only two risers are available and the access through these risers is limited, video confirmation of sandpad encapsulation is not possible. Calculated volumes of grout with expected flow characteristics are used rather than video confirmation.

No analysis was performed for the 300,000-gal tank vaults using a 10:1 ratio of unstabilized-to-stabilized waste mass, since analysis of the 300,000-gal tanks using such an approach already results in final waste form concentrations in the TFF greater than Class C concentration limits.

f. The data or assumptions used in the calculations include the following:

1. The volume of grout equals 32.5 m^3 (INEEL 2000).
2. The volume of the sandpad equals 23.6 m^3 (DOE-ID 2003).
3. The mass of grout equals 6.83E+07 g (DOE-ID 2003).
4. The mass of the sandpad equals 4.14E+07 g (DOE-ID 2003).
5. The inventory was estimated using the ORIGEN2 numerical model. A total of 3,850 Ci is in the WM-185 sandpad inventory (DOE-ID 2003).
6. The ^{137}Cs data collected from Tank WM-185 just prior to the back-siphoning events were used in the ORIGEN2/Wenzel ratios. A ^{137}Cs concentration of 1.7 Ci/L was measured in 1962 (Latchum et al. 1962).
7. A grout with a density of 2.1 g/cc was used in the calculation (INEEL 2000).

Table RAI-17-3. Sum of the fractions for 32.5 m^3 of grout in the tank vault (Table 1 of 10 CFR 61.55).

Radionuclide[a]	Half-Life (yr)	Conservative Tank Inventory (Ci)[b]	Conservative Tank Inventory Ci/m^3	nCi/g	Class C Concentration Limit (Ci/m^3 or nCi/g)	Fraction of Limit
^{241}Am	4.30E+02	1.90E+00		1.60E+01	1.00E+02	1.60E–01
^{14}C	*5.70E+03*	*3.90E–07*	*6.96E–09*		*8.00E+00*	*8.70E–10*
^{242}Cm	4.50E–01	1.40E–05		1.17E–04	2.00E+04	5.87E–09
^{129}I	*1.60E+07*	*1.10E–06*	*1.93E–08*		*8.00E–02*	*2.41E–07*
^{94}Nb	*2.00E+04*	*2.30E–02*	*4.09E–04*		*2.00E–01*	*2.04E–03*
^{237}Np	2.10E+06	3.70E–04		3.15E–03	1.00E+02	3.15E–05
^{238}Pu	8.80E+01	2.10E+00		1.75E+01	1.00E+02	1.75E–01
^{239}Pu	2.40E+04	1.60E+00		1.33E+01	1.00E+02	1.33E–01
^{240}Pu	7.00E+03	3.50E–01		3.00E+00	1.00E+02	3.00E–02
^{241}Pu	1.40E+01	2.30E+00		1.93E+01	3.50E+03	5.53E–03
^{242}Pu	3.80E+05	5.70E–05		4.82E–04	1.00E+02	4.82E–06
^{99}Tc	*2.10E+05*	*2.00E–12*	*3.60E–14*		*3.00E+00*	*1.20E–14*
Sum of the Fractions						**0.51**

a. Radionuclides shown in italics are compared to Class C concentration limits in units of Ci/m^3 ; remaining nuclides are compared to limits in units of nCi/g.
b. Radioactive decay to 2012.

3.1 Summary and Conclusions

At closure and disposal, the 300,000-gal tank vaults would not exceed Class C concentration limits. The basis for this is the completion of the waste concentration tables as described in 10 CFR 61.55.

Encapsulation of the sandpad material and any other vault contamination can be performed only by making grout pours in two available risers. The access and operational constraints allow for grout to be introduced, mound in the location directly under the access risers, and flow in the annular space until a level of 0.30–0.46 m is reached in all locations of the vault. This ensures encapsulation of the sandpad contamination. This volume of grout is necessary because video inspection to ensure the grout has reached a minimum depth is not practical because of operational and physical limitations. A calculated volume must be used to ensure the sandpad is encapsulated. Additional grout (not used in the sum-of-the-fractions calculations) will be used to continue to fill the vaults until the level is approximately 1 m deep, and ultimately, completely filled.

Appendix RAI-17-D provides an evaluation of these data that demonstrates that this concentration averaging analysis is consistent with the fundamental principles presented in the NRC draft interim guidance on concentration averaging (70 FR 74846).

4. 30,000-GAL TANKS

At closure and disposal, the 30,000-gal tanks would meet Class C concentration limits. Sampling and characterization indicates the residual waste remaining in each 30,000-gal tank contains approximately 36 Ci. The residual waste inventory at closure for the 30,000-gal tanks assumes that each tank has a 5-mil (0.005-in.) thick film on the lower half of the tanks. The 5-mil (0.005-in.) thickness was used as a conservative estimate since solid samples were not collected because of a lack of material to sample. As described in the draft 3116 Determination, the tanks have not contained acidic waste for at least 20 years, and the heat from the steam valve condensate allowed the development of what appeared to be a biological film on the tanks. However, this film could not be sampled to determine the radionuclide concentrations. Therefore, conservative thickness and radionuclide concentration assumptions are used. For the radionuclide concentrations in this film layer, the analytical results from the solid samples from Tank WM-183 in Ci/kg are applied to this mass of solid material. The residual liquids were sampled and analyzed as discussed in Section 2 of this response. Liquid sampling results averaged are approximately 0.23 Ci in liquids with 36.1 Ci of residual solids.

The sum of the fractions prepared for the draft 3116 Determination used a volume of grout (57 m^3) that half-filled the tank. The sum of the fractions using the mass of steel and grout is 0.020. This is consistent with the "Draft Interim Concentration Averaging Guidance for Waste Determinations" (70 FR 74846) for contaminated tank walls.

An alternative to this is proposed that would simply use the mass of steel for half of the tank. Since the residual contamination is almost entirely associated with the film on the lower half of the tank wall, the mass of steel for half of the tank is the appropriate mass and volume of steel. The stainless steel walls are 11/16 in. thick and the mass of this amount of steel is 2.07E+07 g. Using the mass of steel and no added grout, the sum of the fractions is well below unity. Table RAI-17-4 shows the sum of the fractions for long-lived radionuclides using the mass of steel for half of a 30,000-gal tank.

No analysis was performed for the 30,000-gal tanks using a 10:1 ratio of unstabilized-to-stabilized waste mass, since the calculations of final waste form concentrations did not use any stabilizing material. Only the mass of the tank steel was used in these calculations.

Table RAI-17-4. Sum of the fractions for 30,000-gal tanks using only the mass of steel (Table 1 of 10 CFR 61.55).

Radionuclide[a]	Half-Life (yr)	Conservative vault Inventory (Ci)[b]	Ci/m^3	nCi/g	Class C Concentration Limit (Ci/m^3 or nCi/g)	Fraction of Limit
^{241}Am	4.30E+02	6.40E–03		3.07E–01	1.00E+02	3.07E–03
^{14}C	*5.70E+03*	*1.10E–07*	*4.27E–08*		*8.00E+00*	*5.34E–09*
^{242}Cm	4.50E–01	2.00E–05		9.62E–04	2.00E+04	4.81E–08
^{129}I	*1.60E+07*	*1.20E–05*	*4.54E–06*		*8.00E–02*	*5.68E–05*
^{59}Ni	*7.50E+04*	*3.80E–04*	*1.47E–04*		*2.20E+02*	*6.68E–07*
^{94}Nb	*2.00E+04*	*3.10E–03*	*1.21E–03*		*2.00E–01*	*6.03E–03*
^{237}Np	2.10E+06	7.10E–04		3.43E–02	1.00E+02	3.43E–04
^{238}Pu	8.80E+01	1.70E–01		8.34E+00	1.00E+02	8.34E–02
^{239}Pu	2.40E+04	5.10E–02		2.49E+00	1.00E+02	2.49E–02
^{240}Pu	7.00E+03	2.00E–02		9.86E–01	1.00E+02	9.86E–03
^{241}Pu	1.40E+01	2.90E–01		1.42E+01	3.50E+03	4.07E–03
^{242}Pu	3.80E+05	1.50E–05		7.21E–04	1.00E+02	7.21E–06
^{99}Tc	*2.10E+05*	*1.20E–02*	*4.48E–03*		*3.00E+00*	*1.49E–03*
Sum of the Fractions						**0.13**

a. Radionuclides shown in italics are compared to Class C concentration limits in units of Ci/m^3; remaining nuclides are compared to limits in units of nCi/g.
b. Radioactive decay to 2012.

4.1 Summary and Conclusions

At closure and disposal, the radioactive waste concentration for the 30,000-gal tank waste meets Class C concentration limits. The basis for this is the completion of waste concentration tables as described in 10 CFR 61.55. As shown in the alternative concentration for the 30,000-gal tanks, the tank steel alone provides adequate mass and volume to produce concentrations of radionuclides that are well within the limits for Class C. Encapsulation grout to fill half of the tank is desirable to contain the residual waste that remains.

Appendix RAI-17-D provides an evaluation of these data that demonstrates that this concentration averaging analysis is consistent with the fundamental principles presented in the NRC draft interim guidance on concentration averaging (70 FR 74846).

5. PIPING

At closure and disposal, radioactive waste concentration of the piping meets Class C concentration limits. The sum of the fractions calculations in the draft 3116 Determination are used in this section without alteration. Either using the residual waste in the piping averaged over the volume or mass of grout and piping or simply using the piping presents a very low sum of the fractions. As described in the draft 3116 Determination (Sections 2.4.5 and 6.4), the total estimated inventory for the piping is 30 Ci of residuals. The data used in the calculations include the following:

1. 10,600 linear ft of piping
2. Total mass of steel equals 1.76E+07 g
3. Total volume of steel equals 2.19 m^3.

The sum of the fractions using the mass and volume of the piping only is shown in Table RAI-17-5. The sum of the fractions in Table RAI-17-5 is 0.13. The calculation using the steel of the piping is appropriate for radioactive waste concentration calculations.

No analysis was performed for the TFF piping using a 10:1 ratio of unstabilized-to-stabilized waste mass, since the calculations of final waste form concentrations did not use any stabilizing material. Only the mass of the piping steel was used in these calculations.

Table RAI-17-5. Sum of the fractions for piping steel (Table 1 of 10 CFR 61.55).

Radionuclide[a]	Half-Life (yr)	Piping Inventory (Ci)[b]	Ci/m^3	nCi/g	Class C Concentration Limit (Ci/m^3 or nCi/g)	Fraction of Limit
^{241}Am	4.30E+02	5.30E–03		3.00E–01	100	0.0030
^{14}C	*5.70E+03*	*6.20E–08*	*2.80E–08*		*8*	*0.0000000035*
^{242}Cm	4.50E–01	1.70E–05		9.40E–04	20,000	0.000000047
^{129}I	*1.60E+07*	*9.70E–06*	*4.40E–06*		*0.08*	*0.000055*
^{59}Ni	*7.50E+04*	*3.10E–04*	*1.40E–04*		*220*	*0.00000065*
^{94}Nb	*2.00E+04*	*2.60E–03*	*1.20E–03*		*0.2*	*0.0059*
^{237}Np	2.10E+06	5.90E–04		3.40E–02	100	0.00034
^{238}Pu	8.80E+01	1.40E–01		8.20E+00	100	0.082
^{239}Pu	2.40E+04	4.30E–02		2.40E+00	100	0.024
^{240}Pu	7.00E+03	1.70E–02		9.60E–01	100	0.010
^{241}Pu	1.40E+01	2.40E–01		1.40E+01	3,500	0.0040
^{242}Pu	3.80E+05	1.20E–05		7.00E–04	100	0.0000070
^{99}Tc	*2.10E+05*	*9.60E–03*	*4.40E–03*		*3*	*0.0015*
Sum of the Fractions						**0.13**

a. Radionuclides shown in italics are compared to Class C concentration limits in units of Ci/m^3 ; remaining nuclides are compared to limits in units of nCi/g.
b. Radioactive decay to 2012.

5.1 Summary and Conclusions

At closure and disposal, the radioactive waste concentration for the piping meets Class C concentration limits. The basis is the completion of waste concentration tables as described in 10 CFR 61.55. The sum of the fractions for long-lived radionuclides is 0.13 for piping.

Appendix RAI-17-D provides an evaluation of these data that demonstrates that this concentration averaging analysis is consistent with the fundamental principles presented in the NRC draft interim guidance on concentration averaging (70 FR 74846).

6. SENSITIVITY ANALYSES

In addition to the above analyses, several additional evaluations have been performed to aid in understanding the sensitivity of residual inventory estimates, grout volumes, waste density, and other parameters. These additional evaluations are included in Appendix RAI-17-A and support the conclusion that the TFF tanks, vaults, and piping will meet Class C concentration limits at closure and disposal.

7. CONCLUSIONS

As shown in the preceding sections of this response, the radioactive waste concentrations for the TFF at closure and disposal would meet Class C concentration limits. If, as a result of their review, the NRC believes any of the tanks at the INL Site may be greater than Class C, the TFF would still be in compliance with the performance objectives set out in 10 CFR 61 and DOE would request additional consultation as required under Section 3116(a)(3)(B).

8. REFERENCES

References are included in Appendix RAI-17-E.

APPENDIX RAI-17-A

SENSITIVITY EVALUATIONS

In addition to the previously described analyses, several additional evaluations have been performed to aid in understanding the sensitivity of residual inventory estimates, grout volumes, waste density, and other parameters. These additional evaluations are included in this appendix.

Following submittal of the draft 3116 Determination to NRC in September 2005, the NRC released a FR notice, "Draft Interim Concentration Averaging Guidance for Waste Determinations" (70 FR 74846), for public comment.

The draft interim guidance introduces a concept of ratios of unstabilized-to-stabilized waste. The factor of 10 is an approximation derived from a consideration that most stabilization techniques commonly envisioned use of cementitious materials, and most cementitious waste forms can readily achieve a 10% waste loading. This may be a close approximation for relatively small containers, of which stabilizing material can be easily manipulated without the operational constraints of large underground tanks.[g] However, as the factor of 10 is only guidance, other ratios should be considered, particularly in the case of tank waste and residuals. Additional stabilizing material should be considered as waste in a computation under 10 CFR 61 if it can be demonstrated that such material is stabilizing and containing the waste, but not being added merely for the purpose of diluting waste.

Given the depth of such stabilized waste, it does not appear likely that an individual intruder would be inadvertently exposed to such waste other than by drilling into it. Other inadvertent intruder scenarios, such as excavation for a basement of a house, would be unlikely due to the depth of the waste. In light of the nature of stabilized waste residues in tanks, the 10:1 ratio is unduly conservative.

The analyses in this appendix have been developed considering the specific features of the TFF tanks and ancillary equipment. The nature of the acidic waste and stainless steel tanks is unique to the DOE complex. Because the waste remained acidic, significant amounts of stiff, recalcitrant sludge do not remain in cleaned tanks. Methods used in this determination of waste concentrations are not likely to be used in the same manner by other DOE sites because the characteristics of the waste and tanks, and the general characteristics of individual DOE sites, are different.

To demonstrate a concentration averaging approach to an intruder drilling scenario, a sensitivity analysis is performed in this appendix in which an intruder drills into the stabilized waste. The mass or volume of the drill cuttings to the bottom of the tank is used to prepare a sum of the fractions calculation.

g. It may also be as a result of the view expressed in NUREG-0945, *Final Environmental Impact Statement on 10 CFR 61, "Licensing Requirements for Land Disposal of Radioactive Waste"* (NRC 1982), that when Class C waste is brought to the surface through an excavation scenario the degree of dilution of the disposed waste was estimated to be at least an order of magnitude.

RAI-17-A-1. SENSITIVITY ANALYSES FOR INVENTORY AND SUM OF THE FRACTIONS CALCULATIONS

The following sections provide sensitivity evaluations for the 300,000-gal tanks, tank vaults, and 30,000-gal tanks. These evaluations provide analysis of the radionuclide inventory, volume, and density of grout, and density of residual waste. Additional perspective on the final waste form concentrations is provided below.

RAI-17-A-1.1 Tank Inventory Defensibility

The mass of solids estimated in the cleaned tanks uses a conservative methodology. A discussion of the inventory in this section will be augmented in the response to NRC Comment 2, which will also address sensitivity of the tank inventory. Inventory information is presented here to demonstrate that tank inventory uncertainty is biased toward overestimation of total inventory and long-lived radionuclides, which are important to sum of the fractions calculations. As described in detail below, it is clear when the data for the important contributors to waste concentration are reviewed, the data are more defensible than would appear based on a single sample. The defensibility of the data is strengthened by solid sample data collected from three of the tanks prior to cleaning, which agree remarkably well with data collected after cleaning for relatively insoluble radionuclides. An additional sample was collected from WM-183 after the draft 3116 Determination was prepared. The results of this sample and other tank samples are discussed below and shown in Table RAI-17-A-1.

The draft 3116 Determination inventory at closure and disposal in the TFF tanks is based on the assumptions of the density of residual solids, measurements of interstitial liquid, and the measured concentrations of radionuclides. As described in the draft 3116 Determination, only one sample from the cleaned tank contained solids, and it was used to estimate the residual solids radioactivity in the draft 3116 Determination (as discussed further in the response to NRC Comment 2). Since the draft 3116 Determination was issued, an additional sample was collected from Tank WM-183 in 2005. This sample provides additional confidence in the data and inventory. Long-lived radionuclides, especially ^{238}Pu and ^{239}Pu, contribute significantly to the inventory for waste concentration calculations.

While the inventory in the draft 3116 Determination is based on one sample, the data from samples collected prior to cleaning were used as a foundation for the inventory. The data from all sampling events prior to cleaning, after cleaning, and the sample collected in 2005 are shown in Table RAI-17-A-1. The radionuclides have been decayed to 2012. The values in bold italics show the highest concentration of a radionuclide in any of the samples (either pre- or post-cleaning). The values in bold show the highest concentrations of either of the WM-183 solid samples. Examination of the data for the long-lived radionuclide ^{238}Pu shows the data are normally distributed and the calculated 95% upper confidence limit (UCL) is 1.19E–02 Ci/kg. This value is slightly greater the value used for the inventory. The mean is 8.64E–03, which is less than the inventory concentration of 9.15E–03. The data for ^{239}Pu are normally distributed and the calculated 95% UCL is 2.26E–03. The 95% UCL is slightly lower than the value used in the draft 3116 Determination.

Table RAI-17-A-1. Data collected for solid material in tanks (Ci/kg).

Radionuclide[a]	WM-183 Post-Cleaning Solids (2005)	WM-183 Post-Cleaning Solids	WM-182 Pre-Washed Solids	WM-183 Pre-Washed Solids	WM-188 Pre-Washed Solids	WM-188 Pre-Washed Solids	WM-188 Pre-Washed Solids	WM-188 Pre-Washed Solids
^{241}Am	3.33E–04	**3.34E–04**	*8.31E–04*	2.39E–04	1.48E–04	2.10E–04	2.59E–04	ND
^{60}Co	**5.94E–05**	5.72E–05	2.79E–05	3.79E–05	*1.14E–04*	ND	ND	ND
^{137}Cs	6.33E–01	**9.23E–01**	3.30E–01	6.81E–01	9.26E–01	1.97E+00	1.59E+00	*2.73E+00*
^{154}Eu	**5.16E–05**	3.20E–05	9.34E–05	*2.77E–04*	ND	ND	ND	ND
^{3}H	NA	NA	6.41E–06	*2.07E–05*	ND	ND	ND	ND
^{94}Nb	ND	1.66E–04	ND	ND	8.11E–04	*6.32E–03*	1.98E–03	5.62E–03
^{237}Np	*1.01E–05*	ND	1.66E–06	1.76E–06	4.68E–06	2.24E–06	1.62E–06	ND
^{238}Pu	**9.17E–03**	9.15E–03	*1.77E–02*	3.60E–03	6.24E–03	8.22E–03	6.44E–03	ND
^{239}Pu	*3.17E–03*	2.75E–03	1.47E–03	1.25E–03	3.32E–04	5.27E–04	4.30E–04	ND
^{90}Sr	1.28E–02	**1.87E–02**	1.78E–01	1.41E–01	3.62E+00	*5.82E+00*	2.53E+00	ND
^{99}Tc	1.10E–04	**6.17E–04**	2.63E–03	ND	*5.32E–03*	3.76E–03	4.41E–03	ND
^{234}U	NA	**2.98E–06**	ND	*3.38E–06*	ND	ND	ND	ND
^{129}I	*8.44E–07*	6.24E–07	ND	ND	ND	ND	ND	ND
^{14}C	*2.15E–05*	NA	NA	NA	NA	NA	NA	NA
^{63}Ni	*1.87E–04*	NA	4.14E–05	1.60E–04	NA	NA	NA	NA

NA = Not analyzed.

ND = Not detected.

a. Radionuclides decayed to 2012. The values in underlined italics show the highest concentration of a radionuclide in any of the samples (either pre- or post-cleaning). The values in bold show the highest concentrations of either of the WM-183 solid samples.

Examination of ^{238}Pu and ^{239}Pu data collected from Tank WM-183 after cleaning is important to establishing an inventory and performing the sum of the fractions calculations. It is not possible to use common statistical analysis of sample populations when only two samples have been collected. Statistical methods such as the *t*-test or analysis of variance require at least three degrees of freedom (n–1). As n (number of samples) increases, the confidence in the analysis increases. One degree of freedom is unacceptable for these analyses (EPA 2006a, 2006b). Therefore, a statistical method of assessing differences between radioactivity measurements and determining the significance of those differences is used for these samples. Generally, this method is used to evaluate the statistical difference between duplicate results and sample results. The method is applicable because it evaluates if two sample results are within the analytical error of the instrumentation and it infers that the sub-samples (in this case, samples) have been taken from the same sample. The use of this method is to show that the data from two sampling events are essentially identical.

The method of comparing duplicate analysis for radionuclides uses the mean difference calculation. That is, if a sample is split and duplicates are analyzed, the analysis is deemed to be within an acceptable error if the mean difference is less than 3. The mean difference equation is shown below.

$$MD = \frac{|S - D|}{\sqrt{\sigma_{S^2} + \sigma_{D^2}}} \qquad \text{(RAI-17-A-1)}$$

MD = the mean difference of the duplicate results

S = the original sample result

D = the duplicate sample result

σ_S = the associated total propagated 1σ uncertainty of the original result (as a standard deviation)

σ_D = the associated total propagated 1σ uncertainty of the duplicate result (as a standard deviation).

The mean differences for ^{238}Pu and ^{239}Pu are 0.15 and 0.73, respectively. This is well below the threshold of 3 used in INL data validation methods (GDE-205, 2004). This indicates the samples are quite comparable. This result provides confidence in the data and tends to reduce uncertainty of the inventory for radioactive waste concentration calculations.

RAI-17-A-1.1.1 300,000-gal Tank Inventory Sensitivity

The inventory presented in the PA (DOE-ID 2003) and the draft 3116 Determination used a conservative density and, consequently, a conservative mass of residual solids. The data and assumptions used in calculation of the sum of the fractions in Tables 1 and 2 of 10 CFR 61.55 are listed below.

1. The inventory is based on a sample collected from Tank WM-183. An additional sample was collected in 2005. The inventory and sum of the fractions using the sample collected in 2005 are shown below.

2. The concentrations of radionuclides, which were not detected in the 2003 sample, were estimated using the ORIGEN2 numerical model. Radionuclide concentrations in Table 1 of 10 CFR 61.55, which were estimated based on ORIGEN2, include ^{14}C, ^{242}Cm, ^{59}Ni, ^{237}Np, ^{240}Pu, ^{241}Pu, and ^{242}Pu. ^{14}C and ^{237}Np were detected in the 2005 sample.

3. A ^{137}Cs concentration of 1.8 Ci/kg was used in the ORIGEN2/Wenzel ratios, rather than the ^{137}Cs concentration detected in the Tank WM-183 sample of 0.923 Ci/kg. This is a conservative ratio but has little impact on the sum of the fractions calculations.

4. The concentrations of ^{238}Pu and ^{239}Pu contribute approximately 85% of the sum of the fractions in Table 1 of 10 CFR 61.55.

5. The concentrations of radionuclides, which were not detected in the sample, were estimated using the ORIGEN2 numerical model. Radionuclide

concentrations in Table 1 of 10 CFR 61.55, which were estimated based on ORIGEN2, only include ^{63}Ni.

6. The concentration of ^{137}Cs contributes nearly 100% of the sum of the fractions for Table 2 of 10 CFR 61.55 (short-lived radionuclides). However, the sum of the fractions is 1.10E–03, which is significantly less than unity.

7. 118 m^3 of grout with a density of 2.1 g/cc were used in the calculation. There are 85 m^3 in the engineered grout placements and 33 m^3 in the encapsulation grout pour.

8. A total volume of 118 m^3 and a mass of 2.48E+08 g of grout were used in the calculation.

9. A mass of 1,238 kg of residual solids was used in the calculation.

10. A volume of 4,989 L of residual liquids was used in the calculation.

RAI-17-A-1.1.1.1 Residual Solids Density. This draft 3116 Determination inventory is based on radionuclide concentrations, as previously discussed. The measured and assumed density of residual solids and the measured interstitial liquids associated with the residual solids affect the density of solid residuals. Information on residual solids density, particle size, and interstitial liquids is based on analysis of samples collected prior to tank cleaning. The density of the residual solids is an additional source of uncertainty. The density of residual solids is estimated at 1.4 g/cc for inventory in the draft 3116 Determination and waste concentration calculations. However, measurements from sampling events indicate that the density is likely 1.20 g/cc or as high as 2 g/cc (INEEL 1999). Using a density of 1.2 g/cc equates to a 14% reduction in mass and subsequent reduction in inventory of all radionuclides, while using the density of 2 g/cc results in an increase of 40% in mass and inventory. A density of 2 g/cc is associated with air-dried residual solids (EDF-TST-001, 2000; WSRC 2002).

The data available on the sludge samples were based on the material resulting from air drying the sample, which results in the precipitation of any soluble solids present in the interstitial supernate. Thus, the air-dried sample that was analyzed was a composite of the insoluble and soluble solids. The WM-183 sludge sample had a volume of 2.33 mL and a mass of 2.91 g for a density of 1.25 g/cc. Allowing this sample to air dry resulted in a loss of 1.727 g. This loss has been attributed to water evaporation. The mass of air-dried sludge remaining was 1.179 g. The 1.727 g of water is equivalent to 1.727 mL of water. It follows that 1.727 mL of supernate were present in the 2.33-mL sludge sample (i.e., the volume fraction of the sludge is 75% water and the mass fraction is 59.5% water). Since the density of the supernate is 1.2 g/mL, 1.727 mL contains 0.35 g of soluble solids. This implies that 0.35 g/1.179 g or 30% of the total air-dried solids results from soluble solids deposited during evaporation of the sample. The importance of the air-dried samples is that water was removed by evaporation but the sample was otherwise unchanged (WSRC 2002).

No equivalent data exist for WM-182. Therefore, it was assumed that the WM-183 drying and density data were also applicable to the WM-182 sludge sample. The hydrogen ion concentrations for the samples are 0.53 *M* for WM-182 and 2.5 *M* for WM-183. The specific gravity values for the two samples are 1.1 g/mL for WM-182 and 1.2 g/mL for WM-183.

The density of air-dried solids (2 g/cc) does not directly relate to the density of residual solids in clean tanks. The relatively small particle size, the flocculent nature of the residual solids, and the higher pH of the liquids have an effect on the actual density of the solids compared to the density that has been measured in the pre-cleaning samples. When using the observation method to map the tank bottoms, the amount of solids observed is likely similar to the density of samples taken prior to cleaning or 1.2–1.4 g/cc not those of air-dried solids. That is, when examining the videotape, observed solids contain interstitial liquids between particles that occupy volume, and the volume of solids to the observer is greater than the actual volume.

RAI-17-A-1.1.1.2 Interstitial Liquids. The supernate, or interstitial liquids in solids, was not introduced in the calculation of mass in the draft 3116 Determination. The residual solids are composed of small particles that have a considerable percentage of interstitial liquids that occupy space between the particles. Due to multiple liquid additions during retrieval and cleaning, the liquids remaining in the tank, including interstitial liquids, are not the liquids that were directly produced during the reprocessing of spent nuclear fuel. Since the volume of interstitial liquids has been measured to be 75% by volume (EDF-015722-041, 2000; WSRC 2002), measurements of supernate in solid samples collected before cleaning were measured at 75%. If a value of 75% interstitial liquids was used in the calculation, it would have a significant reduction in estimated solid mass. If the Tank WM-182 inventory was used as an example, the 2,391 Ci in solids would be reduced to approximately 600 Ci. It is likely the interstitial liquids may be somewhat less than measured in residual solids prior to cleaning, but it is apparent based on particle size and observation of the settling rate that some volume of interstitial liquids remains in the cleaned tanks.

RAI-17-A-1.1.1.3 Solids Removal during Grout Placement. The effectiveness of radionuclide removal by the engineered grout placement also introduces uncertainty of the radionuclide inventory. It is not known how much of the residual solids will be removed; based on the mockup some portion is removed, but a method to quantify the removal was not used. The initial amount of residual solids remaining in each tank and the distribution of residual solids on the bottom will affect the removal achieved by the engineered grout placements. For instance, Tank WM-182 may have a greater total Ci removal than a tank like WM-186, which has a smaller starting inventory.

RAI-17-A-1.1.1.4 Solids Mass Estimates. Conservative estimates of the properties of the residual solids were made. Visual examination and Kriging methods were used to estimate the volume of solids. Each estimate was made to bias high the volume of solids during the examination. While errors are likely, there is not a reasonable way to quantify the uncertainty associated with visual estimation of solids height remaining in the tanks.

RAI-17-A-1.1.1.5 Limited Number of Solid Samples. The limited number of samples and analytical results introduces uncertainty into the inventory. The total activity could increase in Tank WM-182, perhaps by as much as 1,600 Ci (over the Tank WM-182 estimate) based on the average ^{137}Cs concentration detected in Tanks WM-182, WM-183, and WM-188 prior to cleaning. While this is a significant increase in radioactivity, the effect on radioactive waste concentration would not be significant because most of the increase would be due to ^{137}Cs and its daughter ^{137}Ba. These increases of short-lived radionuclides are not significant when a 100-fold increase would be necessary to approach the sum of the fractions calculated for long-lived radionuclides.

RAI-17-A-1.1.1.6 Conclusions. If the data from the 2005 sampling of Tank WM-183 are used in the calculation, the sum of the fractions is 0.73. This value is slightly higher than the base case due to a slight increase in the concentration of ^{239}Pu in the sample concentration detected after the initial cleaning in Tank WM-183. When the 95% UCL around the mean is used from any sample taken either before or after cleaning, the sum of the fractions equals 0.84 due the concentration of ^{238}Pu in Tank WM-182 prior to cleaning. When the lowest concentrations from the 2003 or 2005 sampling events are used, the sum of the fractions is 0.43. The lowest concentrations of all samples collected produce a sum of the fractions of 0.29 due to the lower concentrations of ^{238}Pu and ^{239}Pu in Tank WM-188 (pre-cleaning). Tables showing the sum of the fractions calculations are included in Appendix RAI-17-C of this response.

The sum of the fractions of the example inventories described above demonstrates that the inventory of radionuclides as it pertains to waste concentration limits can be described by the various inventory estimates. Table RAI-17-A-2 shows the sum of the fractions using the various inventory estimates.

If alternative assumptions of volume of grout, density of solids, and 2005 sampling are used, the effect on the sum of the fractions provides more insight into the inventory and the concentration of radioactive waste. Using the measured density of 1.2 g/cc (INEEL 1999) for the residual solids lowers all calculated sum of the fractions by 14%.

Table RAI-17-A-2. Sum of the fractions for alternate inventories and densities of Tank WM-182.

Inventory Description	Sum of the Fractions		
	Density of 1.4 g/cc	Density of 1.2 g/cc	Density of 2 g/cc and interstitial liquids of 75%
95% UCL of all samples	0.84	0.72	0.30
Highest of 2003 and 2005 samples (Tank WM-183)	0.76	0.66	0.27
2005 WM-183 samples	0.73	0.63	0.26
Base case inventory	0.71	0.61	0.25
Lowest of 2003 and 2005 samples	0.43	0.37	0.15
Lowest of all samples	0.29	0.25	0.10

a. Interstitial liquids percentages are applicable to the air-dried density of 2 g/cc.

RAI-17-A-2.1 Variations in Grout Volume

For perspective in understanding the sensitivity of encapsulation grout pour volume, additional analysis is presented below.

RAI-17-A-2.1.1 Reduction of Encapsulation Grout Pour Volume

Use of the engineered grout placements and an encapsulation grout pour totaling 118 m^3 provides a basis for the 300,000-gal tank radioactive waste concentration calculations. This section evaluates the sensitivities of using less than the 118 m^3 in the encapsulation grout pour. The grout designed for the engineered grout placement has properties that enhance the removal of residuals from the tank. Because of the properties of each individual placement, the height of total placement during the mockups was approximately 4 ft. This represents the highest point of the pours as the various sections create an uneven surface with the lowest point being near the location of the steam jet used for removal of residuals. Figure RAI-17-A-3 shows the mounding and the uneven surface of the engineered grout placements.

The contaminated residual, which will be forced upward between pours and toward the steam jet, must be encapsulated. The uneven surface of the engineered grout placement must be covered with grout to encapsulate the remaining residual liquids and solids. The areas along the seams of each placement and the low point near the steam jet are likely locations for residuals to remain. Figures RAI-17-A-1 through -4 show the mixing between placements and the surrogate that has been forced to the surface of the grout. The encapsulation grout volume of 33 m^3 (118 m^3 total) is believed to be the minimum volume necessary to adequately encapsulate residuals exposed from the engineered grout placements. For analysis purposes, other volumes were evaluated as shown in Table RAI-17-A-3. The results of the sum of the fractions calculations are shown for a reduction of the entire grout volume to 100 m^3. This table also shows the sum of the fractions if the mass of tank steel up to a height of 3 ft (the tank bottom is also used) is used in the calculations. Table RAI-17-A-3 shows the results of using less encapsulating grout and using the inventory as described in the draft 3116 Determination.

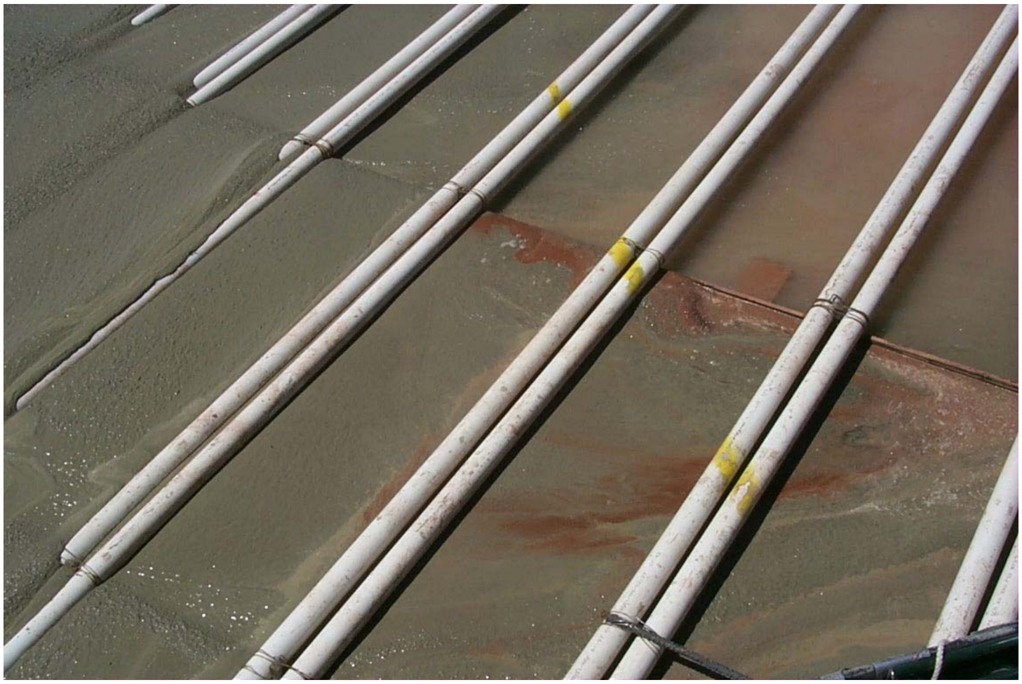

Figure RAI-17-A-1. Vertical mixing during mockup.

Figure RAI-17-A-2. Vertical mixing near the tank wall.

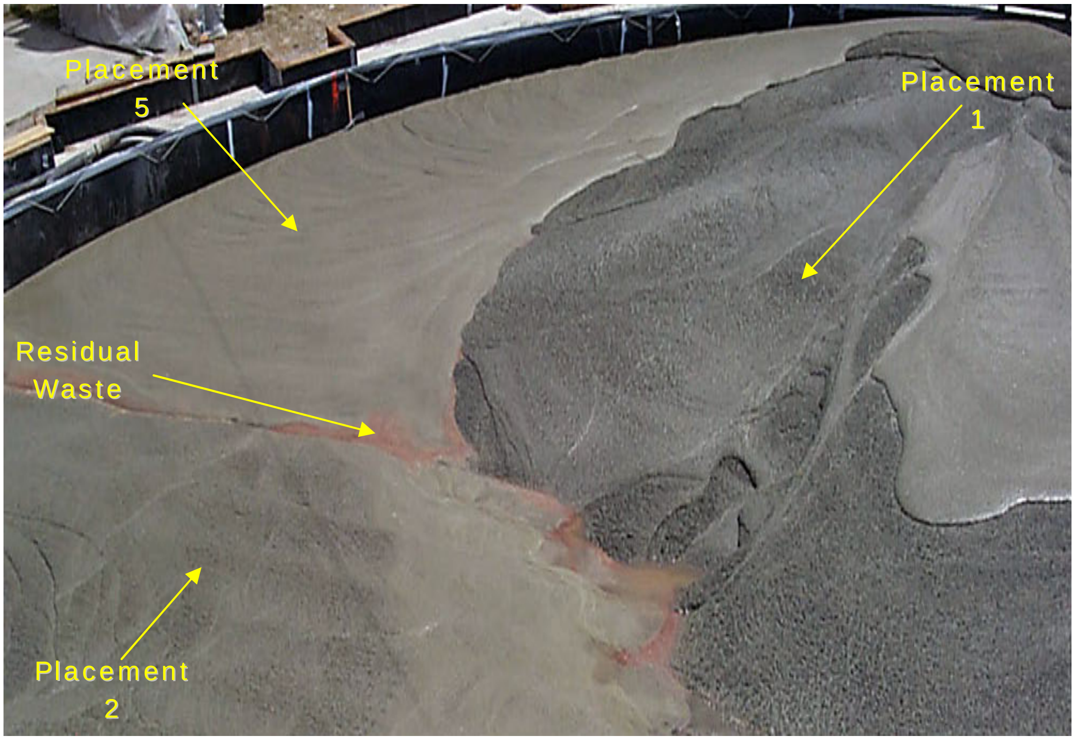

Figure RAI-17-A-3. Mounding of grout placements and vertical mixing.

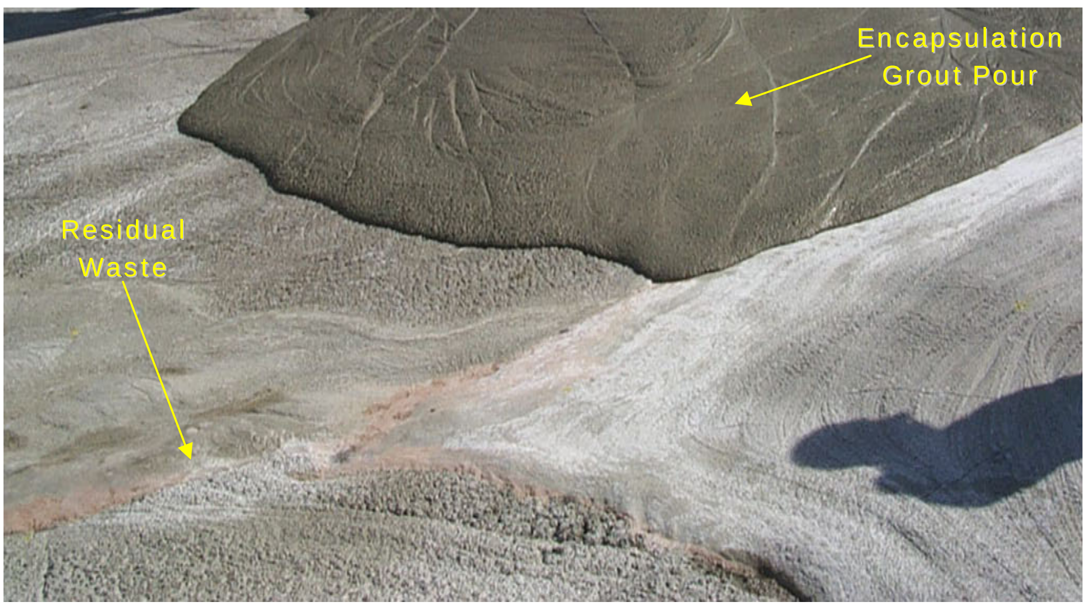

Figure RAI-17-A-4. Encapsulation grout pour covering surrogate that is on the surface.

Table RAI-17-A-3. Sum of the fractions for alternate volumes of grout.

Inventory Description	Density of 1.4 g/cc	Density of 1.2 g/cc
33 m^3 (118 m^3 total) [a]	0.65	0.56
33 m^3 (118 m^3 total)	0.71	0.61
15 m^3 (100 m^3 total)	0.83	0.71

a. These values show the results using the tank steel mass to a height of 3 ft and the tank bottom.

RAI-17-A-2.1.2 10:1 Ratio Unstabilized-to-Stabilized Material Encapsulation Pour

In addition to the set of principles discussed in the NRC's draft interim guidance, the guidance also includes statements that suggest *in most cases* the ratio of the unstabilized-to-stabilized radionuclide concentrations would not be significantly greater than a factor of 10 for comparison to Class C concentration limits. To address these statements, this section considers the feasibility of a grouting scenario, which would produce a "waste loading" approaching such a 10:1 ratio.

An encapsulation pour to simply fill the tanks with grout without using the engineered grout placements and the encapsulating grout sequence has been examined. This scenario assumes a 10-in.-deep grout pour (this 10-in.-deep grout pour would be appropriate to produce an approximate 10:1 ratio, with 1 in. of residual liquids in the tank and underlying tank solids). There are several factors that cause this type of grout pour to be unachievable in a large underground tank, including the inability to achieve a 10-in.-deep uniform grout pour where the grout meets minimum criteria. The currently planned pour also intends to remove additional residual material, which a 10-in.-deep pour would not achieve.

With only two available riser locations, a grout pour that is uniformly 10 in. deep across the tank bottom is not achievable. Grout that meets minimum criteria for strength, cracking, and bleed water is not self-leveling over a 50-ft-diameter tank. Grout will mound up in locations where it is placed and result in an uneven surface that may be 10 in. deep in some places but much greater than 10 in. deep in others. To achieve a grout pour near 10 in. of uniform depth, the grout must be very fluid. Adjusting the amount of water in the mixture is a simple method to obtain the desired fluidity. However, grout with additional water to increase fluidity will produce excessive cracking and bleed water. Additives are available to increase flow characteristics, but their effectiveness does not provide the flow characteristics for the grout to self-level in the tank. The grout must meet minimum criteria for low heat generation, low shrinkage, and limited cracking. A grout mixture that would meet the criteria described above would form mounds and, therefore, not meet a 10-in. uniform depth. Figures RAI-17-A-1 through -4 show the type of mounding of grout placements that will occur for currently planned TFF grout pours.

Use of a self-leveling pour in place of a sequenced engineered grout pour introduces many complications into the removal and encapsulation process. A single pour or a series of pours from two tank risers across the entire tank floor will plug the steam jet prematurely and allow liquids to remain in the tank that are not encapsulated in the grout. When the grout moves across the tank bottom, it will displace the residual liquids and put some of the fine solids in suspension. Some liquids and solids will be moved up the tank wall by the grout and deposited on top of the grout. Figure RAI-17-A-5 shows residual liquids and solids being forced up the tank wall. This is a photograph of an engineered grout placement, which allows liquids and suspended solids to flow along the tank wall to be removed by the steam jet. A non-engineered grout pour sequence would produce increased quantities of liquids and solids to be forced up the tank wall and onto the grout surface because the pour will not be sequenced to allow liquid to drain toward the steam jet. Figure RAI-17-A-6 shows that some residuals remain on the engineered grout placements, which require encapsulation by additional grout.

Tanks with cooling coils also provide complications for a simple encapsulation grout pour. The cooling coils tend to slow the flow of grout mixtures. Figure RAI-17-A-6 shows grout flow being restricted by cooling coils. The top of the cooling coils are approximately 7 in. above the tank bottom. The presence of these coils 3 in. from the surface may introduce cracking in a 10-in. grout pour scenario.

For the reasons discussed above, the limitations of a 10-in.-deep grout pour to self-level over a 50-ft-diameter tank create a scenario that would not adequately encapsulate residual waste under actual field conditions.

Figure RAI-17-A-5. Liquids and solids rise along the tank wall as grout is poured.

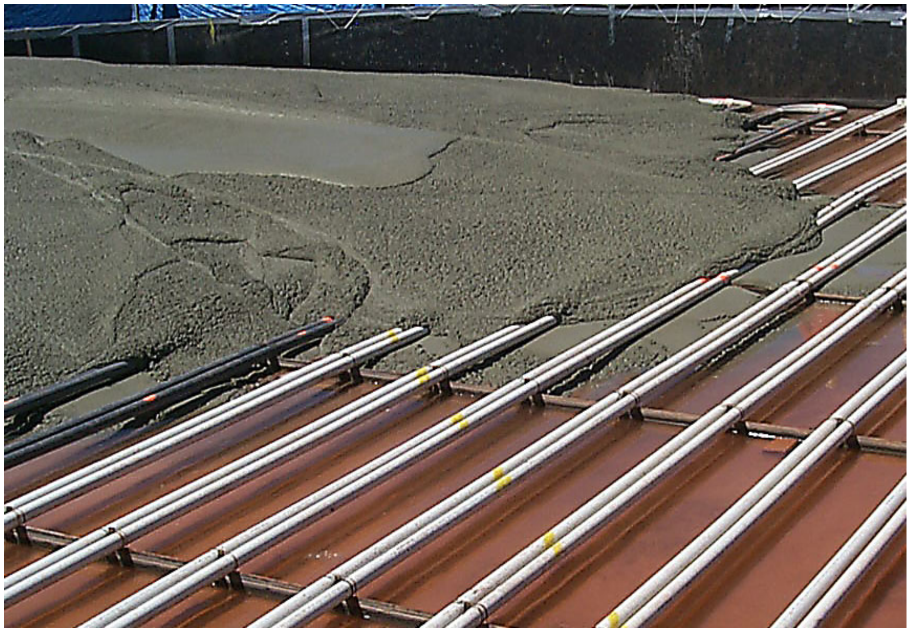

Figure RAI-17-A-6. Grout flow is hampered by cooling coils.

Although statements are made in the NRC draft interim guidance that suggest *in most cases* the ratio of the unstabilized-to-stabilized radionuclide concentrations would not be significantly greater than a factor of 10 for comparison to Class C concentration limits, for the reasons discussed above, it is not judged feasible to achieve a grouting scenario that achieves such a 10:1 ratio. However, for illustrative purposes, an analysis was performed using a 10:1 ratio of unstabilized-to-stabilized waste mass. Final waste form concentrations were calculated by assuming the original radioactivity in the tank achieves a 10% waste loading in the grout. Table RAI-17-A-4 shows that each of the cleaned 300,000-gal tanks would have concentrations of radionuclides above Class C concentration limits in Tables 1 and 2 of 10 CFR 61.55 even with depths of grout less than 1.3 in. However, while the NRC has stated in their draft interim guidance that it is appropriate *in general* to use such a 10:1 ratio as reference point, this evaluation concludes that, based upon analysis of actual site-specific conditions, operational constraints, and technical considerations, as discussed above, it is not appropriate or reasonable for calculating final waste concentrations at the TFF. The results shown in Table RAI-17-A-4 demonstrate that a 10-fold stabilization factor produces identical results in sum of the fractions calculations. Although each tank has differing amounts of residuals, and consequently, differing mass of added grout to achieve a 10:1 ratio, variations in the amount of estimated residual mass in each tank do not alter sum of the fractions values since tank cleaning activities do not reduce the concentration of relatively insoluble radionuclides in the tank solids. No amount of tank washing would result in reduced sum of the fractions values. Therefore, these calculations show that the mass of remaining tank solids is irrelevant to this type of simplified 10:1 analysis, and therefore, all of the 300,000-gal tanks would be calculated at greater than Class C concentration limits.

Table RAI-17-A-4. Sum of the fractions using 10:1 ratio of unstabilized-to-stabilized radionuclide concentrations.

	Tank WM-180	Tank WM-181	Tank WM-182	Tank WM-183	Tank WM-184	Tank WM-185	Tank WM-186
Volume of Grout (m^3)	2.6	1.2	5.9	3.3	2.7	3.4	1.6
Inches of Grout	0.6	0.3	1.3	0.7	0.6	0.7	0.3
Mass of Grout (kg)	5.00E+03	2.00E+03	1.00E+04	7.00E+03	6.00E+03	7.00E+03	3.00E+03
Radionuclide	**Fraction of Limit**	**Fraction of Limit**	**Fraction of Limit**	**Fraction of Limit**	**Fraction of Limit**	**Fraction of Limit**	**Fraction of Limit**
^{241}Am	3.40E–01	3.40E–01	3.40E–01	3.40E–01	3.40E–01	3.40E–01	3.40E–01
^{14}C	8.90E–03	8.90E–03	8.90E–03	8.90E–03	8.90E–03	8.90E–03	8.90E–03
^{242}Cm	5.30E–06	5.30E–06	5.30E–06	5.30E–06	5.30E–06	5.30E–06	5.30E–06
^{129}I	2.80E–03	2.80E–03	2.80E–03	2.80E–03	2.80E–03	2.80E–03	2.80E–03
^{59}Ni	6.00E–07	6.00E–07	6.00E–07	6.00E–07	6.00E–07	6.00E–07	6.00E–07
^{94}Nb	2.10E–02	2.10E–02	2.10E–02	2.10E–02	2.10E–02	2.10E–02	2.10E–02
^{237}Np	3.80E–02	3.80E–02	3.80E–02	3.80E–02	3.80E–02	3.80E–02	3.80E–02
^{238}Pu	9.20E+00	9.20E+00	9.20E+00	9.20E+00	9.20E+00	9.20E+00	9.20E+00
^{239}Pu	2.80E+00	2.80E+00	2.80E+00	2.80E+00	2.80E+00	2.80E+00	2.80E+00
^{240}Pu	1.10E+00	1.10E+00	1.10E+00	1.10E+00	1.10E+00	1.10E+00	1.10E+00
^{241}Pu	4.50E–01	4.50E–01	4.50E–01	4.50E–01	4.50E–01	4.50E–01	4.50E–01
^{242}Pu	8.00E–04	8.00E–04	8.00E–04	8.00E–04	8.00E–04	8.00E–04	8.00E–04
^{99}Tc	5.60E–05	5.60E–05	5.60E–05	5.60E–05	5.60E–05	5.60E–05	5.60E–05
Sum of the Fractions	**14**	**14**	**14**	**14**	**14**	**14**	**14**

Notes:
* The volume/mass and radionuclide concentrations for the residual solids were taken from PEI-EDF-1009, 2005; PEI-EDF-1010, 2005; PEI-EDF-1011, 2005; PEI-EDF-1012, 2005; PEI-EDF-1013, 2005; PEI-EDF-1015, 2005; PEI-EDF-1016, 2006; PEI-EDF-1018, 2006; PEI-EDF-1019, 2005.
* The residual volume/mass estimate in each tank was based only on the remaining solids, without including the volume of remaining liquids. The volume of the remaining liquids was not used because it contained insignificant concentrations of radionuclides.
* The individual grout volume/mass was calculated to produce a 10% waste loading.
* The resulting radionuclide concentrations were compared to values in Table 1 of 10 CFR 61.55.
* The sum of the fractions is identical for these tanks because the inventory concentrations are from the same data set as described in Section RAI-17-A-1.1 of Appendix RAI-17-A.

RAI-17-A-2.1.3 Concentration of Radionuclides in Drill Cuttings

Past guidance for determining concentrations for comparison with Class C concentration limits of 10 CFR 61.55 was based on excavation as the likely pathway to expose an inadvertent member of the public as a result of waste in a commercial burial site. This pathway is not applicable to tanks and their associated waste. The stabilized tank residual waste is much deeper in the ground, and is protected by both a thick surface barrier and a massive grout-filled tank structure, which makes the basement excavation scenario an impractical scenario. A more credible scenario is one in which the inadvertent intruder is drilling a well for groundwater and drills through the tank. During this drilling process the residual waste encountered by the drill is mixed with the other drill cuttings and brought to the surface where the driller and future site users can be exposed to the radioactive waste. Only the volume of tank grout from the drill cutting is used for the sum of the fractions calculations.

The inadvertent intruder places his drill rig on top of the tank surface barrier and drills into the tank using a typical domestic water well diameter drill. The driller drills through the waste heel at its highest point and abandons the hole when the drill reaches the bottom of the tank (worst case). Because of the way the drill cuttings are brought to the surface (by air or water), the residual waste encountered by the drill is mixed with all the other material the drill encounters as it penetrates the tank. The concentration of radionuclides is calculated by averaging the residual waste in the drill hole with the grout column that extends from the top to the bottom of the tank, which is approximately 10 m. To ensure conservatism in the estimate, the mass of the vault type, any overburden, and volume of a closure cap are not included in the calculation. The sum of the fractions is shown in Tables RAI-17-A-5 and -6. Table RAI-17-A-5 shows the results of drilling to the bottom of the tank. Table RAI-17-A-6 shows the results of drilling through the tank and into the contaminated sandpad.

The following data or assumptions were used in the Table RAI-17-A-5 tank calculations:

1. The diameter of the drill is 8 in.

2. The maximum height of waste is 1.22 cm

3. The volume of residual waste is 3.95E–04 m^3

4. The mass of residual waste is 0.83 kg

5. The volume of grout in the borehole is 1.166 m^3.

Table RAI-17-A-5. Sum of the fractions using an intruder scenario—drilling to bottom of tank.

Radionuclide[a]	Half-Life (yr)	Tank Inventory (Ci)[b]	Ci/m^3	nCi/g	Class C Concentration Limit (Ci/m^3 or nCi/g)	Fraction of Limit
^{241}Am	432.2	2.80E–04		1.15E–01	1.00E+02	1.15E–03
^{14}C	*5,730*	3.30E–09	*2.82E–09*		*8.00E+00*	*3.52E–10*
^{242}Cm	0.446	8.80E–07		3.61E–04	2.00E+04	1.80E–08
^{129}I	*15,700,000*	5.20E–07	*4.44E–07*		*8.00E–02*	*5.55E–06*
^{59}Ni	*75,000*	1.70E–05	*1.44E–05*		*2.20E+02*	*6.56E–08*
^{94}Nb	*20,300*	1.40E–04	*1.18E–04*		*2.00E–01*	*5.91E–04*
^{237}Np	2,140,000	3.20E–05		1.29E–02	1.00E+02	1.29E–04
^{237}Pu	87.75	7.70E–03		3.13E+00	1.00E+02	3.13E–02
^{239}Pu	24,131	2.30E–03		9.33E–01	1.00E+02	9.33E–03
^{240}Pu	6,970	9.10E–04		3.70E–01	1.00E+02	3.70E–03
^{241}Pu	14.4	1.30E–02		5.34E+00	3.50E+03	1.53E–03
^{242}Pu	375,800	6.60E–07		2.70E–04	1.00E+02	2.70E–06
^{99}Tc	*213,000*	5.10E–04	*4.39E–04*		*3.00E+00*	*1.46E–04*
Sum of the Fractions						**0.05**

a. Radionuclides shown in italics are compared to Class C concentration limits in units of Ci/m^3; remaining nuclides are compared to limits in units of nCi/g.

b. Radioactive decay to 2012.

The following data or assumptions were used in the Table RAI-17-A-6 tank and sandpad calculations:

1. The diameter of the drill is 8 in.

2. The maximum height of waste is 15.24 cm

3. The volume of residual waste is 2.78E–03 m^3

4. The mass of residual waste is 4.86 kg

5. The volume of grout in the borehole is 1.166 m^3

6. The volume of the sandpad is 23.6 m^3.

Table RAI-17-A-6. Sum of the fractions using an intruder scenario—drilling to bottom of sandpad.

Radionuclide[a]	Half-Life (yr)	Tank Inventory (Ci)[b]	Tank Inventory Ci/m^3	nCi/g	Class C Concentration Limit (Ci/m^3 or nCi/g)	Fraction of Limit
^{241}Am	432.2	3.80E–04		2.75E–01	1.00E+02	2.75E–03
^{14}C	*5,730*	1.90E–09	*2.88E–09*		*8.00E+00*	*3.60E–10*
^{242}Cm	0.446	4.99E–07		3.60E–04	2.00E+04	1.80E–08
^{129}I	*15,700,000*	2.92E–07	*4.43E–07*		*8.00E–02*	*5.53E–06*
^{59}Ni	*75,000*	1.22E–05	*1.85E–05*		*2.00E–01*	*9.23E–05*
^{94}Nb	*20,300*	7.76E–05	*2.88E–09*	5.61E–02	1.00E+02	5.61E–04
^{237}Np	2,140,000	2.60E–04		1.88E–01	1.00E+02	2.00E–03
^{237}Pu	87.75	4.50E–03		3.25E+00	1.00E+02	3.25E–02
^{239}Pu	24,131	1.33E–03		9.58E–01	1.00E+02	9.58E–03
^{240}Pu	6,970	7.77E–04		5.62E–01	3.50E+03	1.60E–04
^{241}Pu	14.4	7.36E–03		5.32E+00	1.00E+02	5.32E–02
^{242}Pu	375,800	3.73E–07		2.75E–01	*3.00E+00*	*1.88E–07*
^{99}Tc	*213,000*	3.80E–04	*5.65E–07*		1.00E+02	2.75E–03
Sum of the Fractions						**0.10**

a. Radionuclides shown in italics are compared to Class C concentration limits in units of Ci/m^3 ; remaining nuclides are compared to limits in units of nCi/g.

b. Radioactive decay to 2012.

RAI-17-A-3. ADDITIONAL SENSITIVITY EVALUATION: TANK AND VAULT VIEWED AS A SINGLE UNIT FOR COMPARISON TO CLASS C CONCENTRATION LIMITS

To aid in understanding the sensitivity of waste form calculations shown above, a tank and vault is shown as a single unit for comparison to Class C concentration limits in this section. A combination of the most contaminated tank and most contaminated sandpad will be used to establish a worst case. Tank WM-185 and its vault contain the greatest amount of residual waste of the cleaned tanks and vaults. Tank WM-185 contains an estimated mass of residual waste of 720 kg (1,391 Ci of residuals) and Tank WM-182 has an estimated mass of residual of 1,238 kg (2,394 Ci of residuals). The contaminated sandpad contains 3,850 Ci of residual waste. Therefore, Tank WM-185 and the sandpad have a total Ci inventory of 5,241 Ci, and Tank WM-182 and a contaminated sandpad would have an inventory of 6,244 Ci. Two scenarios are presented for waste concentrations for the tank and vault system. The first scenario uses Tank WM-185 tank residuals and the contaminated sandpad. As a second sensitivity evaluation, the Tank WM-182 residual waste and a contaminated sandpad (Tank WM-185 sandpad) will be examined.

Tanks WM-185 and WM-187 have contaminated sandpads. Only Tank WM-185 has been cleaned to date. The highest radionuclide inventory of cleaned tanks and vaults is from the contaminated sandpad and Tank WM-185. Therefore, it is reasonable to use this tank and vault for radioactive waste concentration calculations. Data for Tank WM-187 will be reviewed when the tank and vault are cleaned.

The tank and vault system are evaluated together because they are not independent entities. The tank lies within the vault and is separated from the vault contamination by only the tank wall and floor. The closed system will be a grouted monolith separate from other tanks and vaults. The basis of 10 CFR 61.55 Class C concentration limits is the inadvertent intruder scenario (70 FR 74846). The tank system approach is justified because the concentrations would be expected to approach homogeneity with respect to the intruder scenarios, and an important justification for the Class C concentration limits is to provide protection to the inadvertent intruder.

The tank system, which includes the tank and vault grouted monolith, would appear indistinguishable to the inadvertent intruder. The limiting intruder scenario for the TFF is the well-drilling scenario. An inadvertent intruder in the INL Site will drill a well with equipment that would penetrate basalt (basalt flows compose the majority of the subsurface at the INL Site). If the intruder would drill through a reinforced-concrete ceiling, grout above the tank dome, the stainless steel tank dome, and over 30 ft of grout, it is reasonable to assume that drilling would continue through the stainless steel tank bottom to enter the vault area.

As specified below in Section RAI-17-A-3.1, assumptions for calculation of the radioactive waste concentration of the tank system will include the tank walls and tank bottom, vault walls, and a portion of the tank system base mat. In addition, the volume and mass of grout for the engineered grout placements and encapsulation grout pours will be incorporated into the calculation.

Using the vault walls and a portion of the base mat are appropriate for the tank system waste concentration calculations. Also, as described in Section II of the draft interim guidance, the vaults are not defined as separate entities, but the tank and ancillary equipment are defined as one system. As stated in the draft interim guidance (70 FR 74846):

> *The guidance is not intended to address all unique situations at DOE sites. However, the guidance contained herein is generally applicable to the following scenarios:*

1. *Underground waste storage tanks including heels, cooling coils, and residuals adhering to walls and other surfaces,*

2. *Infrastructure used to support underground waste storage tanks such as transfer lines, transfer pumps, and diversion boxes.*

Use of the volume or mass of steel and/or vault material in calculation of the sum of the fractions is appropriate. The tank steel and the vault concrete are both contaminated to a certain degree and are considered to be LLW. The materials would be considered LLW if they were removed from the TFF and are considered LLW when kept in place.

RAI-17-A-3.1 Calculations for WM-185 Tank and Vault

The waste concentration calculations for the tank system are performed using Table 1 of 10 CFR 61.55. As with the individual components, the long-lived radionuclides are most important to waste concentration calculations. Table RAI-17-A-7 shows the sum of the fractions for the tank system using the WM-185 tank and vault.

The data or assumptions for the tank system are listed below.

1. The vault walls (including pillars and panels) are used in the calculations. The height of the pillars and panels used in the calculations is 4.5 ft.

2. 6 in. of the top of the base mat are included.

3. The density of reinforced concrete in the base mat and vault walls is 2.56 g/cc.

4. 118 and 32.5 m^3 of grout are placed in the tank and vault, respectively.

5. The mass of grout and steel is 6.06E+08 g.

6. The sandpad volume of 23.6 m^3 and the volume of the cone (8 m^3) of concrete underlying the sandpad are include in the calculation. The sandpad does not lie on a flat surface but rather a reinforced concrete cone, which is the diameter of the tank and 4 in. at the peak.

7. The volume of pillars and panels, sandpad, base mat, and cone equals 29.2, 23.6, 48, and 8 m^3, respectively. The total volume equals 261 m^3.

Table RAI-17-A-7. Sum of the fractions calculation for the tank system.

Radionuclide[a]	Half-Life (yr)	Tank System Inventory (Ci)[b]	Ci/m³	nCi/g	Class C Concentration Limit (Ci/m^3 or nCi/g)	Fraction of Limit
^{241}Am	4.30E+02	2.10E+00		3.50E+00	100	0.0352
^{14}C	*5.70E+03*	*3.20E–06*	*1.20E–08*		*8*	*0.0000000016*
^{242}Cm	4.50E–01	9.40E–04		1.60E–03	20,000	0.00000008
^{129}I	*1.60E+07*	*4.50E–04*	*1.70E–06*		*0.08*	*0.000022*
^{59}Ni	*7.50E+04*	*1.20E–20*	*4.60E–23*		*220*	*0.00000000*
^{94}Nb	*2.00E+04*	*1.40E–01*	*5.50E–04*		*0.2*	*0.0027*
^{237}Np	2.10E+06	2.80E–02		4.60E–02	100	0.00046
^{238}Pu	8.80E+01	8.70E+00		1.40E+01	100	0.14
^{239}Pu	2.40E+04	3.60E+00		5.90E+00	100	0.059
^{240}Pu	7.00E+03	1.10E+00		1.90E+00	100	0.019
^{241}Pu	1.40E+01	1.40E+01		2.20E+01	3,500	0.006
^{242}Pu	3.80E+05	6.30E–04		1.00E–03	100	0.000010
^{99}Tc	*2.10E+05*	*4.40E–01*	*1.70E–03*		*3*	*0.0006*
Sum of the Fractions						**0.27**

a. Radionuclides shown in italics are compared to Class C concentration limits in units of Ci/m^3 ; remaining nuclides are compared to limits in units of nCi/g.
b. Radioactive decay to 2012.

An alternative scenario, which includes 2.5 ft of the vault walls (2 ft of the tank), a smaller amount of grout in the tank and vaults, and half of the base mat used in the previous calculation (3 in.), yields the sum of the fractions of 0.48 as shown in Table RAI-17-A-8. The total mass of this system is 3.51E+08 g.

The data or assumptions for the tank system alternative are listed below.

1. The vault walls (including pillars and panels) are used in the calculations. The height of the pillars and panels used in the calculations is 2.25 ft.

2. 3 in. of the top of the base mat are included.

3. The density of reinforced concrete in the base mat, pillars, and panels is 2.56 g/cc.

4. 46 and 32.5 m^3 of grout are placed in the tank and vault, respectively.

5. The mass of grout and steel is 3.34E+08 g.

6. The volume of pillars and panels, sandpad, base mat, and cone equal 14.5, 23.6, 24, and 8 m^3, respectively. Total volume equals 150 m^3.

Table RAI-17-A-8. Sum of the fractions calculations for minimum quantities of uncontaminated materials and encapsulating grout.

Radionuclide[a]	Half-Life (yr)	Tank System Inventory (Ci)[b]	Ci/m^3	nCi/g	Class C Concentration Limit (Ci/m^3 or nCi/g)	Fraction of Limit
^{241}Am	4.30E+02	2.10E+00		6.40E+00	100	0.0638
^{14}C	*5.70E+03*	*3.20E–06*	*2.20E–08*		*8*	*0.0000000027*
^{242}Cm	4.50E–01	1.40E–05		4.10E–05	20,000	0.00000000
^{129}I	*1.60E+07*	*4.50E–04*	*3.00E–06*		*0.08*	*0.000038*
^{59}Ni	*7.50E+04*	*1.20E–20*	*8.10E–23*		*220*	*0.00000000*
^{94}Nb	*2.00E+04*	*1.40E–01*	*9.50E–04*		*0.2*	*0.0048*
^{237}Np	2.10E+06	2.80E–02		8.30E–02	100	0.00083
^{238}Pu	8.80E+01	8.70E+00		2.60E+01	100	0.26
^{239}Pu	2.40E+04	3.60E+00		1.10E+01	100	0.106
^{240}Pu	7.00E+03	1.10E+00		3.40E+00	100	0.034
^{241}Pu	1.40E+01	1.40E+01		4.10E+01	3,500	0.012
^{242}Pu	3.80E+05	6.30E–04		1.90E–03	100	0.000019
^{99}Tc	*2.10E+05*	*4.40E–01*	*3.00E–03*		*3*	*0.0010*
Sum of the Fractions						**0.48**

a. Radionuclides shown in italics are compared to Class C concentration limits in units of Ci/m^3 ; remaining nuclides are compared to limits in units of nCi/g.

b. Radioactive decay to 2012.

RAI-17-A-3.2 Calculations for WM-182 Tank and Vault

The inventory for the tank system using the Tank WM-182 inventory and a contaminated sandpad has also been calculated. Tank WM-182 has the highest radionuclide inventory but its tank vault does not contain a contaminated sandpad. Using the inventory of a contaminated sandpad and highest inventory for a tank provides a bounding scenario for waste concentration calculations.

The method of using a sandpad inventory and the highest tank inventory was used in the PA and the draft 3116 Determination for intruder scenarios. Using this approach for the sum of the fractions calculations provides additional insight. The conditions of this scenario do not presently exist at the TFF. The only possible circumstance where this scenario could occur is if Tank WM-187, when cleaned, contains a similar inventory as Tank WM-182. Tank WM-187 may contain the same inventory or greater than WM-182, but the inventory for the WM-187 sandpad is half of the inventory for WM-185. Tables RAI-17-A-9 and -10 show the sum of the fractions calculations for this scenario using the same data or assumptions shown in Table RAI-17-A-7 and-8.

Table RAI-17-A-9. Sum of the fractions calculations for tank system using bounding inventory.

Radionuclide[a]	Half-Life (yr)	Tank System Inventory (Ci)[b]	Ci/m^3	nCi/g	Class C Concentration Limit (Ci/m^3 or nCi/g)	Fraction of Limit
^{241}Am	4.30E+02	2.30E+00		3.80E+00	100	0.0381
^{14}C	*5.70E+03*	*5.30E–06*	*2.00E–08*		*8*	*0.0000000026*
^{242}Cm	4.50E–01	1.30E–03		2.20E–03	20,000	0.00000011
^{129}I	*1.60E+07*	*7.70E–04*	*3.00E–06*		*0.08*	*0.000037*
^{59}Ni	*7.50E+04*	*2.50E–02*	*9.60E–05*		*220*	*0.00000044*
^{94}Nb	*2.00E+04*	*2.30E–01*	*8.80E–04*		*0.2*	*0.0044*
^{237}Np	2.10E+06	4.70E–02		7.80E–02	100	0.00078
^{238}Pu	8.80E+01	1.30E+01		2.20E+01	100	0.22
^{239}Pu	2.40E+04	5.00E+00		8.20E+00	100	0.082
^{240}Pu	7.00E+03	1.70E+00		2.80E+00	100	0.028
^{241}Pu	1.40E+01	2.20E+01		3.60E+01	3,500	0.010
^{242}Pu	3.80E+05	1.00E–03		1.70E–03	100	0.000017
^{99}Tc	*2.10E+05*	*7.60E–01*	*2.90E–03*		*3*	*0.0010*
Sum of the Fractions						**0.39**

a. Radionuclides shown in italics are compared to Class C concentration limits in units of Ci/m^3 ; remaining nuclides are compared to limits in units of nCi/g.

b. Radioactive decay to 2012.

Table RAI-17-A-10. Sum of the fractions calculations for minimum quantities of uncontaminated materials and encapsulating grout and bounding inventory.

Radionuclide[a]	Half-Life (yr)	Tank System Inventory (Ci)[b]	Ci/m^3	nCi/g	Class C Concentration Limit (Ci/m^3 or nCi/g)	Fraction of Limit
^{241}Am	4.30E+02	2.30E+00		6.60E+00	100	0.0658
^{14}C	*5.70E+03*	*5.30E–06*	*3.60E–08*		*8*	*0.0000000045*
^{242}Cm	4.50E–01	1.40E–05		3.90E–05	20,000	0.00000000
^{129}I	*1.60E+07*	*7.70E–04*	*5.20E–06*		*0.08*	*0.000065*
^{59}Ni	*7.50E+04*	*1.20E–20*	*8.00E–23*		*220*	*0.00000000*
^{94}Nb	*2.00E+04*	*2.30E–01*	*1.50E–03*		*0.2*	*0.0076*
^{237}Np	2.10E+06	4.70E–02		1.40E–01	100	0.00135
^{238}Pu	8.80E+01	1.30E+01		3.80E+01	100	0.38
^{239}Pu	2.40E+04	5.00E+00		1.40E+01	100	0.142
^{240}Pu	7.00E+03	1.70E+00		4.90E+00	100	0.049
^{241}Pu	1.40E+01	2.20E+01		6.20E+01	3,500	0.018
^{242}Pu	3.80E+05	1.00E–03		3.00E–03	100	0.000030
^{99}Tc	*2.10E+05*	*7.60E–01*	*5.1E–03*		*3*	*0.0017*
Sum of the Fractions						**0.67**

a. Radionuclides shown in italics are compared to Class C concentration limits in units of Ci/m^3; remaining nuclides are compared to limits in units of nCi/g.

b. Radioactive decay to 2012.

RAI-17-A-3.3 Summary and Conclusions

Under this sensitivity evaluation, at closure and disposal, the radioactive waste concentration for the 300,000-gal tank and vault system would be below Class C concentration limits. The basis for this is the intruder analysis in the PA (DOE-ID 2003), intruder calculations in the draft 3116 Determination, and the completion of waste concentration tables as described in 10 CFR 61.55. The tank system, which includes the tank and vault grouted monolith, would appear indistinguishable to the inadvertent intruder. The various calculations performed and operational constraints described provide reasonable scenarios to be presented for comparison to Class C concentration limits.

Using inventory from Tank WM-182 provides assurance that the tank system inventory is estimated conservatively. Tank WM-187 remains to be cleaned. Assuming the tank with the highest inventory and a sandpad provides a reasonable worst-case estimation of the Tank WM-187 system. The tank system calculations, using a minimum of grout and uncontaminated materials, also provide assurance that the radionuclide concentration is reasonable.

RAI-17-A-4. REFERENCES

References are included in Appendix RAI-17-E.

APPENDIX RAI-17-B

RESIDUAL WASTE INVENTORY AND GROUT VOLUME USED IN FINAL 300,000-GAL TANK CONCENTRATION CALCULATIONS

RAI-17-B-1. ESTIMATE OF FINAL RESIDUAL WASTE INVENTORY AT CLOSURE

For purposes of determining radionuclide concentrations, the inventory for Tank WM-182 (shown in Table RAI-17-B-1) is used because this tank contains the largest amount of residual radioactivity of the cleaned tanks. The residual waste inventory at closure and disposal is based on an assumption that at least the same degree of radionuclide removal will be achieved in the tanks remaining to be cleaned. The residual waste inventory at closure and disposal is approximately 2,394 Ci in Tank WM-182, of which approximately 3 Ci remain in liquid. The mass of solid residual is estimated to be 1,238 kg. The volume of liquid (1-in. depth) estimated to be remaining is approximately 5,000 L.

Videos and photographs of the tank walls show staining and discoloration, but no discernible buildup of residual waste. Therefore, no inventory for the tank walls was included in the tank inventory as discussed in Section 2 of the draft 3116 Determination. The residual waste for determination of concentrations includes the residual liquids and solids located at the bottom of the tank.

Table RAI-17-B-1. Residual waste inventory at closure and disposal for Tank WM-182.

Radionuclide	Residual Liquids (Ci)	Residual Solids (Ci)	Total Residuals (Ci)
^{241}Am	5.30E–04	5.43E+00	5.43E+00
^{137m}Ba	1.11E+00	1.14E+03	1.14E+03
^{242}Cm	6.58E–07	1.32E–03	1.32E–03
^{137}Cs	1.11E+00	1.14E+03	1.14E+03
^{14}C	5.39E–08	4.90E–06	4.96E–06
^{129}I	1.12E–06	7.73E–04	7.74E–04
^{3}H	1.66E–05	7.17E–01	7.17E–01
^{94}Nb	4.03E–05	2.06E–01	2.06E–01
^{59}Ni	1.25E–05	2.51E–02	2.51E–02
^{63}Ni	1.43E–03	2.86E+00	2.86E+00
^{237}Np	2.71E–07	4.70E–02	4.70E–02
^{238}Pu	2.47E–03	1.14E+01	1.14E+01
^{239}Pu	2.44E–04	3.40E+00	3.40E+00
^{240}Pu	6.74E–04	1.35E+00	1.35E+00
^{241}Pu	5.89E–04	1.95E+01	1.95E+01
^{242}Pu	4.93E–07	9.87E–04	9.88E–04
^{90}Sr	2.41E–01	2.32E+01	2.34E+01
^{99}Tc	4.54E–05	7.64E–01	7.64E–01
^{90}Y	2.41E–01	2.32E+01	2.34E+01
Total Ci (all radionuclides)	3	2,391	2,394

RAI-17-B-2. VOLUME OR MASS OF THE FINAL WASTE FORM

The grout added after the engineered grout placement is expected to stabilize the remaining residual waste by capping the engineered grout placements and the residual waste on the surface. The engineered grout placements and residual waste comprise 85 m^3 of material. A pour of 140 m^3 is planned to cover the engineered grout placements and ensure any remaining residuals are adequately stabilized. Visual inspection from the 1999 mockup indicates some unquantifiable volume of residual contamination that is not mixed with the engineered grout remains on top of the placements (INEEL 1999). This material will be stabilized using the encapsulation grout pour. For purposes of final waste form concentration calculations, as explained below, only a fraction of the 140 m^3 has been assumed to be necessary to stabilize the residuals remaining after the engineered grout placements.

A review of the full-scale mockup photographs allowed calculation of a minimum volume necessary to encapsulate the residual waste on top of the engineered grout placements.

The first two engineered grout placements create very high mounds. The remaining three placements do not create high mounds and the area of residuals is widely distributed on the surface. Approximately three-fifths of the tank area requires some amount of grout to encapsulate the residual waste. The first two engineered grout placements create mounds that occupy approximately two-fifths of the area of the tank. The remaining three-fifths of the tank contain some amount of waste residual (solid or liquid). The area near the steam jet is the low point of the engineered grout placements and requires over 2 ft of grout to stabilize the liquids and solids remaining. Therefore, an estimate of three-fifths of the tank area at an average depth of 1 ft is required to stabilize the residual waste on the surface of the engineered grout placements. This results in a volume of 33 m^3 of grout.

The engineered grout placement has a volume of 85 m^3. Because of the enhanced waste mixing and the important residual waste removal function, a reduction of this volume of the engineered grout placement is not practical.

Therefore, in the final waste form calculations, the volume of grout used is comprised of 85 m^3 in the engineered grout placements, plus 33 m^3 of grout in the encapsulation pour, for a total grout volume of 118 m^3. This is equivalent to a level pour of approximately 2 ft of grout.

RAI-17-B-3. REFERENCES

References are included in Appendix RAI-17-E.

APPENDIX RAI-17-C

TABLES FOR SUM OF THE FRACTIONS CALCULATIONS DISCUSSED IN SENSITIVITY EVALUATIONS

The tables in this appendix show various calculations of the sum of the fractions using inventories prepared with sample data that have been collected directly from the TFF tanks. Until 1999, any solid samples associated with tanks were collected after a liquids transfer to a collection tank at the Waste Calcining Facility or the New Waste Calcining Facility. These samples include Tanks WM-188, WM-183, and WM-182. Samples were collected before cleaning was started and two samples from WM-183 were collected after cleaning was complete.

Table RAI-17-C-1 shows the tank inventory and the sum of the fractions for long-lived radionuclides using data collected from Tank WM-183 in 2005. This table and the others in this appendix use the WM-182 tank mass and inventory for radionuclides. Tank WM-182 is used because it had the greatest inventory of all the cleaned tanks. This sample was collected after the tanks were cleaned, after a valve was not closed completely, and approximately 200 gal of sodium-bearing waste entered the tank. Solid and liquid samples were collected from the second tank cleaning. It is assumed the redistribution of residual solids allowed the solids sample to be collected. Tables RAI-17-C-1 through -5 use a volume of grout of 118 m^3 and no tank steel.

Table RAI-17-C-1. Calculation of the sum of the fractions using 2005 data from Tank WM-183.

Radionuclide[a]	Half-Life (yr)	Tank Inventory (Ci)[b]	Tank Inventory Ci/m^3	nCi/g	Class C Concentration Limit (Ci/m^3 or nCi/g)	Fraction of Limit
^{241}Am	4.30E+02	4.10E–01		1.70E+00	100	0.0167
^{14}C	*5.70E+03*	*2.70E–02*	*2.30E–04*		*8*	*0.0000281965*
^{242}Cm	4.50E–01	1.30E–03		5.30E–03	20,000	0.00000027
^{129}I	*1.60E+07*	*1.00E–03*	*8.90E–06*		*0.08*	*0.000111*
^{59}Ni	*7.50E+04*	*2.50E–02*	*2.10E–04*		*220*	*0.00000097*
^{94}Nb	*2.00E+04*	*2.50E–02*	*2.10E–04*		*0.2*	*0.0011*
^{237}Np	2.10E+06	4.20E–01		1.70E+00	100	0.01676
^{238}Pu	8.80E+01	1.10E+01		4.60E+01	100	0.46
^{239}Pu	2.40E+04	3.90E+00		1.60E+01	100	0.158
^{240}Pu	7.00E+03	1.40E+00		5.50E+00	100	0.055
^{241}Pu	1.40E+01	1.90E+01		7.90E+01	3,500	0.022
^{242}Pu	3.80E+05	9.90E–04		4.00E–03	100	0.000040
^{99}Tc	*2.10E+05*	*1.40E–01*	*1.20E–03*		*3*	*0.0004*
Sum of the Fractions						**0.73**

a. Radionuclides shown in italics are compared to Class C concentration limits in units of Ci/m^3 ; remaining nuclides are compared to limits in units of nCi/g.

b. Radioactive decay to 2012.

Table RAI-17-C-2 shows the calculation of sum of the fractions for long-lived radionuclides (Tank WM-182 inventory) using the highest concentration from either of the Tank WM-183 post-cleaning samples. If only one of the sampling events had a detection for a radionuclide, that sample was used in the calculation.

Table RAI-17-C-2. Calculation of the sum of the fractions using Tank WM-183 post-cleaning data (highest concentration).

Radionuclide[a]	Half-Life (yr)	Tank Inventory (Ci)[b]	Tank Inventory Ci/m^3	nCi/g	Class C Concentration Limit (Ci/m^3 or nCi/g)	Fraction of Limit
^{241}Am	432.2	4.10E–01		1.66E+00	1.00E+02	1.66E–02
^{14}C	*5,730*	*4.96E–06*	*4.20E–08*		*8.00E+00*	*5.25E–09*
^{242}Cm	0.446	1.32E–03		5.32E–03	2.00E+04	2.66E–07
^{129}I	*15,700,000*	*7.74E–04*	*8.86E–06*		*8.00E–02*	*1.11E–04*
^{59}Ni	*75,000*	*2.51E–02*	*2.13E–04*		*2.20E+02*	*9.68E–07*
^{94}Nb	*20,300*	*2.06E–01*	*1.74E–03*		*2.00E–01*	*8.71E–03*
^{237}Np	2,140,000	1.25E–02		5.05E–02	1.00E+02	5.05E–04
^{238}Pu	87.75	1.24E+01		4.99E+01	1.00E+02	4.99E–01
^{239}Pu	24,131	3.92E+00		1.58E+01	1.00E+02	1.58E–01
^{240}Pu	6,970	1.35E+00		5.45E+00	1.00E+02	5.45E–02
^{241}Pu	14.4	1.95E+01		7.87E+01	3.50E+03	2.25E–02
^{242}Pu	375,800	9.88E–04		3.99E–03	1.00E+02	3.99E–05
^{99}Tc	*213,000*	*7.64E–01*	*6.47E–03*		*3.00E+00*	*2.16E–03*
Sum of the Fractions						**0.76**

a. Radionuclides shown in italics are compared to Class C concentration limits in units of Ci/m^3 ; remaining nuclides are compared to limits in units of nCi/g.

b. Radioactive decay to 2012.

Table RAI-17-C-3 shows the calculation of the sum of the fractions for long-lived radionuclides (Tank WM-182 inventory) using the lowest concentration from either of the Tank WM-183 post-cleaning samples. If only one of the samples events had a detection for a radionuclide, that sample was used in the calculation.

Table RAI-17-C-3. Calculation of the sum of the fractions using Tank WM-183 post-cleaning data (lowest concentration).

Radionuclide[a]	Half-Life (yr)	Tank Inventory (Ci)[b]	Ci/m^3	nCi/g	Class C Concentration Limit (Ci/m^3 or nCi/g)	Fraction of Limit
^{241}Am	432.2	4.10E–01		1.66E+00	1.00E+02	1.66E–02
^{14}C	*5,730*	*2.66E–02*	*2.26E–04*		*8.00E+00*	*2.82E–05*
^{242}Cm	0.446	1.32E–03		5.32E–03	2.00E+04	2.66E–07
^{129}I	*15,700,000*	*7.74E–04*	*6.56E–06*		*8.00E–02*	*8.20E–05*
^{59}Ni	*75,000*	*2.51E–02*	*2.13E–04*		*2.20E+02*	*9.68E–07*
^{94}Nb	*20,300*	*2.06E–01*	*1.74E–03*		*2.00E–01*	*8.71E–03*
^{237}Np	2,140,000	1.25E–02		5.05E–02	1.00E+02	5.05E–04
^{238}Pu	87.75	4.58E+00		1.85E+01	1.00E+02	1.85E–01
^{239}Pu	24,131	3.40E+00		1.37E+01	1.00E+02	1.37E–01
^{240}Pu	6,970	1.35E+00		5.45E+00	1.00E+02	5.45E–02
^{241}Pu	14.4	1.95E+01		7.87E+01	3.50E+03	2.25E–02
^{242}Pu	375,800	9.88E–04		3.99E–03	1.00E+02	3.99E–05
^{99}Tc	*213,000*	*1.36E–01*	*1.15E–03*		*3.00E+00*	*3.85E–04*
Sum of the Fractions						**0.43**

a. Radionuclides shown in italics are compared to Class C concentration limits in units of Ci/m^3 ; remaining nuclides are compared to limits in units of nCi/g.

b. Radioactive decay to 2012.

Table RAI-17-C-4 shows the sum of the fractions calculations for long-lived radionuclides from the inventory developed using the lowest concentration from any of the samples collected directly from the tanks. These samples include the WM-188, WM-182, and WM-183 samples collected prior to cleaning and samples from WM-183 post-cleaning.

Table RAI-17-C-4. Calculation of the sum of the fractions using lowest concentrations detected in any tank sample.

Radionuclide[a]	Half-Life (yr)	Tank Inventory (Ci)[b]	Ci/m^3	nCi/g	Class C Concentration Limit (Ci/m^3 or nCi/g)	Fraction of Limit
^{241}Am	4.30E+02	1.80E–01		7.40E–01	100	0.0074
^{14}C	*5.70E+03*	2.70E–02	*2.30E–04*		*8*	*0.0000281965*
^{242}Cm	4.50E–01	1.30E–03		5.30E–03	20,000	0.00000027
^{129}I	*1.60E+07*	7.70E–04	*6.60E–06*		*0.08*	*0.000082*
^{59}Ni	*7.50E+04*	2.50E–02	*2.10E–04*		*220*	*0.00000097*
^{94}Nb	*2.00E+04*	2.10E–01	*1.70E–03*		*0.2*	*0.0087*
^{237}Np	2.10E+06	2.00E–03		8.10E–03	100	0.0001
^{238}Pu	8.80E+01	4.50E+00		1.80E+01	100	0.18
^{239}Pu	2.40E+04	4.10E–01		1.70E+00	100	0.017
^{240}Pu	7.00E+03	1.40E+00		5.50E+00	100	0.055
^{241}Pu	1.40E+01	1.90E+01		7.90E+01	3,500	0.022
^{242}Pu	3.80E+05	9.90E–04		4.00E–03	100	0.000040
^{99}Tc	*2.10E+05*	1.40E–01	*1.20E–03*		*3*	*0.0004*
Sum of the Fractions						**0.29**

a. Radionuclides shown in italics are compared to Class C concentration limits in units of Ci/m^3 ; remaining nuclides are compared to limits in units of nCi/g.

b. Radioactive decay to 2012.

Table RAI-17-C-5 shows the sum of the fractions calculations for long-lived radionuclides from the inventory developed using the 95% UCL around the mean from any of the samples collected directly from the tanks. These samples include the WM-188, WM-182, and WM-183 samples collected prior to cleaning and samples from WM-183 post-cleaning.

Table RAI-17-C-5. Calculation of the sum of the fractions using 95% UCL of all tank samples.

Radionuclide[a]	Half-Life (yr)	Tank Inventory (Ci)[b]	Ci/m^3	nCi/g	Class C Concentration Limit (Ci/m^3 or nCi/g)	Fraction of Limit
^{241}Am	432.2	6.70E–01		2.70E+00	100	0.0272
^{14}C	*5,730*	*4.90E–06*	*4.20E–08*		*8*	*0.0000000052*
^{242}Cm	0.446	1.30E–03		5.30E–03	20,000	0.00000027
^{129}I	*15,700,000*	1.00E–03	*8.90E–06*		*0.08*	*0.000111*
^{59}Ni	*75,000*	*2.50E–02*	*2.10E–04*		*220*	*0.00000097*
^{94}Nb	*20,300*	*2.10E–01*	*1.70E–03*		*0.2*	*0.0087*
^{237}Np	2,140,000	9.90E–03		4.00E–02	100	0.0004
^{238}Pu	87.75	1.50E+01		6.00E+01	100	0.60
^{239}Pu	24,131	2.80E+00		1.10E+01	100	0.113
^{240}Pu	6,970	1.40E+00		5.50E+00	100	0.055
^{241}Pu	14.4	1.90E+01		7.90E+01	3,500	0.022
^{242}Pu	375,800	9.90E–04		4.00E–03	100	0.000040
^{99}Tc	*213,000*	*5.60E+00*	*4.80E–02*		*3*	*0.0158*
Sum of the Fractions						**0.84**

a. Radionuclides shown in italics are compared to Class C concentration limits in units of Ci/m^3 ; remaining nuclides are compared to limits in units of nCi/g.

b. Radioactive decay to 2012.

Table RAI-17-C-6 shows the sum of the fractions for the tank vaults using 32.5 m^3 of grout. This table is the companion of the sum of the fractions table in Section 4 of this document.

Table RAI-17-C-6. Calculation of the sum of the fractions for short-lived radionuclides (Table 2 of 10 CFR 61.55) for the tank vault.

Radionuclide	Half-Life (yr)	Tank Inventory (Ci)[a]	Ci/m^3	Class C Concentration Limit (Ci/m^3)	Fraction of Limit
^{137}Cs	3.00E+01	1.60E+03	5.10E+01	4,600	0.01103
^{63}Ni	1.00E+02	1.70E–10	5.20E–12	700	7.41E–15
^{90}Sr	2.90E+01	2.50E+02	7.70E+00	7,000	0.001094
Sum of the Fractions					**0.01**

a. Radioactive decay to 2012.

Table RAI-17-C-7 shows the sum of the fractions for the 30,000-gal tanks averaged of the mass and volume of the tank steel. This table is the companion of the sum of the fractions table in Section 5 of this document.

Table RAI-17-C-7. Calculation of the sum of the fractions for short-lived radionuclides (Table 2 of 10 CFR 61.55) for the 30,000-gal tanks.

Radionuclide	Half-Life (yr)	Tank Inventory (Ci)[a]	Ci/m^3	Class C Concentration Limit (Ci/m^3)	Fraction of Limit
^{137}Cs	3.00E+01	1.70E+01	1.30E+01	4,600	0.00290
^{63}Ni	1.00E+02	4.30E–02	3.40E–02	700	0.0000479
^{90}Sr	2.90E+01	4.50E–01	3.50E–01	7,000	0.0000502
Sum of the Fractions					**0.002999**

a. Radioactive decay to 2012.

Table RAI-17-C-8 shows the sum of the fractions for the piping averaged of the mass and volume of the piping steel. This table is the companion of the sum of the fractions table in Section 6 of this document.

Table RAI-17-C-8. Calculation of the sum of the fractions for short-lived radionuclides (Table 2 of 10 CFR 61.55) for the piping.

Radionuclide	Half-Life (yr)	Tank Inventory (Ci)[a]	Ci/m^3	Class C Concentration Limit (Ci/m^3)	Fraction of Limit
^{137}Cs	3.00E+01	1.40E+01	6.50E+00	4,600	0.0014
^{63}Ni	1.00E+02	3.60E–02	1.60E–02	700	0.000023
^{90}Sr	2.90E+01	2.90E–01	1.30E–01	7,000	0.000019
Sum of the Fractions					**0.0015**

a. Radioactive decay to 2012.

REFERENCES

References are included in Appendix RAI-17-E.

APPENDIX RAI-17-D

COMPARISON OF FINAL WASTE FORM CALCULATION METHODOLOGY TO FUNDAMENTAL PRINCIPLES ON CONCENTRATION AVERAGING IN THE NRC DRAFT INTERIM GUIDANCE

RAI-17-D-1. 300,000-GAL TANKS METHODOLOGY

The methods discussed in the NRC draft interim guidance on concentration averaging are based on the following fundamental principles:

> *Measures are not to be undertaken to average extreme quantities of uncontaminated materials with residual waste solely for the purpose of waste classification.* [emphasis added]

The residuals in the TFF have not been averaged with extreme quantities of uncontaminated materials solely for the purpose of comparison to Class C concentration limits. The approach for the TFF tanks uses engineered grout placements as a final opportunity for removal of waste and uses a small portion of an encapsulation grout pour to stabilize and encapsulate residuals. This volume of grout is used in the final waste form concentration calculation. This volume represents approximately 8% of the entire tank volume of 1,500 m^3.

> *Mixtures of residual waste and materials can use a volume or mass-based average concentration if it can be demonstrated that the mixture is reasonably well mixed.*

The residual material is well-mixed in the tank prior to grouting due to cleaning activities and the engineered grout placements provide vertical (and some horizontal) mixing in addition to moving some of the residual solids to the steam jet for removal.

The residual waste is considered to be well-mixed and homogeneous relative to the inadvertent intruder scenario. As described in the draft interim guidance, the “technical basis should be provided (e.g., sampling results, engineering experience, operational constraints) to demonstrate that the waste is reasonably well-mixed.” Engineering experience gained during the mockup and operational constraints are important components of the ability to demonstrate the residuals are well-mixed.

Because of the repeated mixing during tank washing, the residual solids before adding the engineered grout placements are considered well-mixed. The engineered grout placements are not strictly considered encapsulation activities; however, some waste encapsulation occurs during the grout placement. The engineered grout placements have been primarily designed to provide an opportunity for additional radionuclide removal.

The initial grout placement pushes waste toward the steam jet. The next placements tend to push waste toward the steam jet, yet the grout and residual waste flow up the sides and over the edges of the initial grout placement. As each of the specified placements is made, the vertical mixing of residual waste is increased. The fifth placement, which moves waste around the edges of the tank and toward the steam jet, provides further opportunity for cleaning and, as a secondary effect, increases mixing of residual waste with grout. It may be necessary to include a sixth placement (a division of placement 5 into two separate placements). The placements create an increased mixing height of residual waste with grout in the tank. The mixing of the surrogate waste with the grout during mockup testing is documented by photographic evidence.

Figures RAI-17-D-1 through -4 show the grout placement mockup and the vertical mixing that occurs between grout placements. The surrogate used for the mockup was kaolin clay; iron oxide was added to give the surrogate a red color. The red color in these and all other photographs indicates contaminated residual. The mixing height was not measured during the mockup because the purpose was to determine the efficacy of the engineered grout placement to enhance removal of residual solids and liquids. A vertical mixing height of approximately 0.8 m or more could be expected based on the observations made during the mockup (INEEL 1999).

Figure RAI-17-D-1 shows the mixing between grout placements. The red material is solid surrogate that has been mixed between the grout placements. The liquids in the mockup were water; therefore, any red-colored materials that are observed are surrogate solids. Figure RAI-17-D-2 shows the mixing between the tank wall and the grout placements. Figure RAI-17-D-3 shows the mounding of the grout placements and the mixing between placements of the surrogate material. A small quantity of liquid is trapped between placements. The quantity of liquid is limited because the placements are introduced sequentially and the placements slope toward the steam jets.

Figure RAI-17-D-4 shows the encapsulation grout pour, which is covering a surrogate that has been forced to the surface of the grout placements. The engineered grout placements remove surrogate, mix the surrogate vertically, and deposit surrogate on the surface of the placements.

> *Credit can be taken for stabilizing materials added for the purpose of immobilizing the waste (not for stabilizing the contaminated structure) even if it can not be demonstrated that the waste and stabilizing materials are reasonably well-mixed, when the radionuclide concentrations are likely to approach uniformity in the context of applicable intruder scenarios.*

An encapsulation grout pour will be completed to stabilize the tank residuals after the engineered grout placement. As previously described, radionuclide concentrations should approach homogeneity in the context of intruder scenarios. The technical basis for the above statement includes sampling results from cleaned tanks and engineering experience gained during mockup.

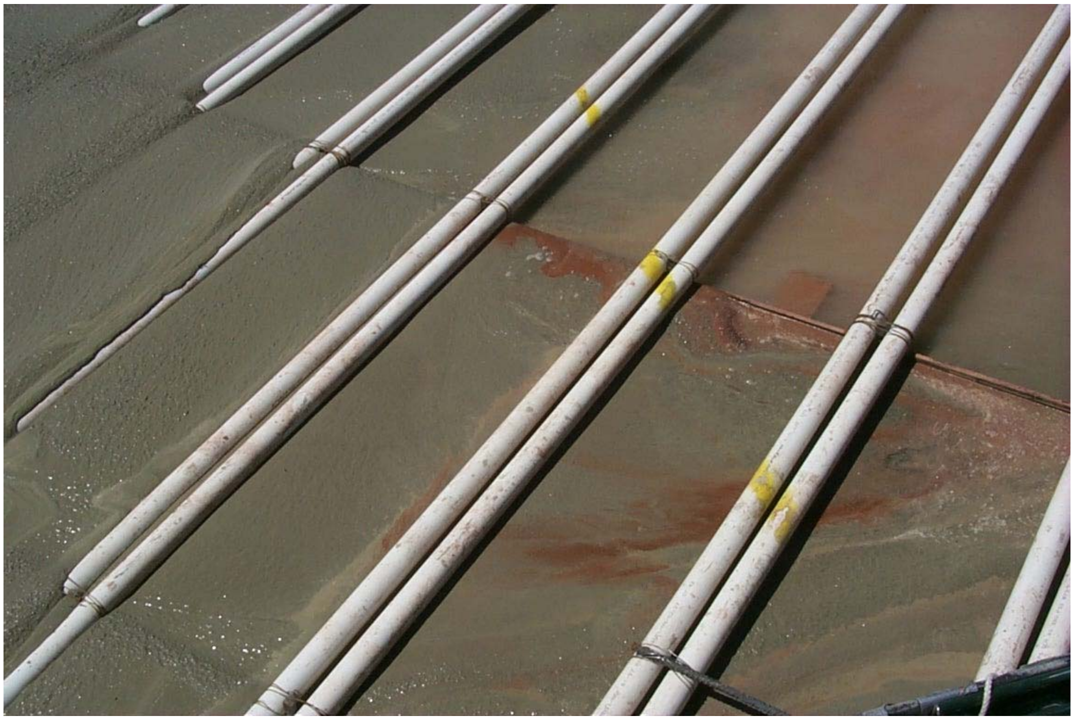

Figure RAI-17-D-1. Vertical mixing during mockup.

Figure RAI-17-D-2. Vertical mixing near the tank wall.

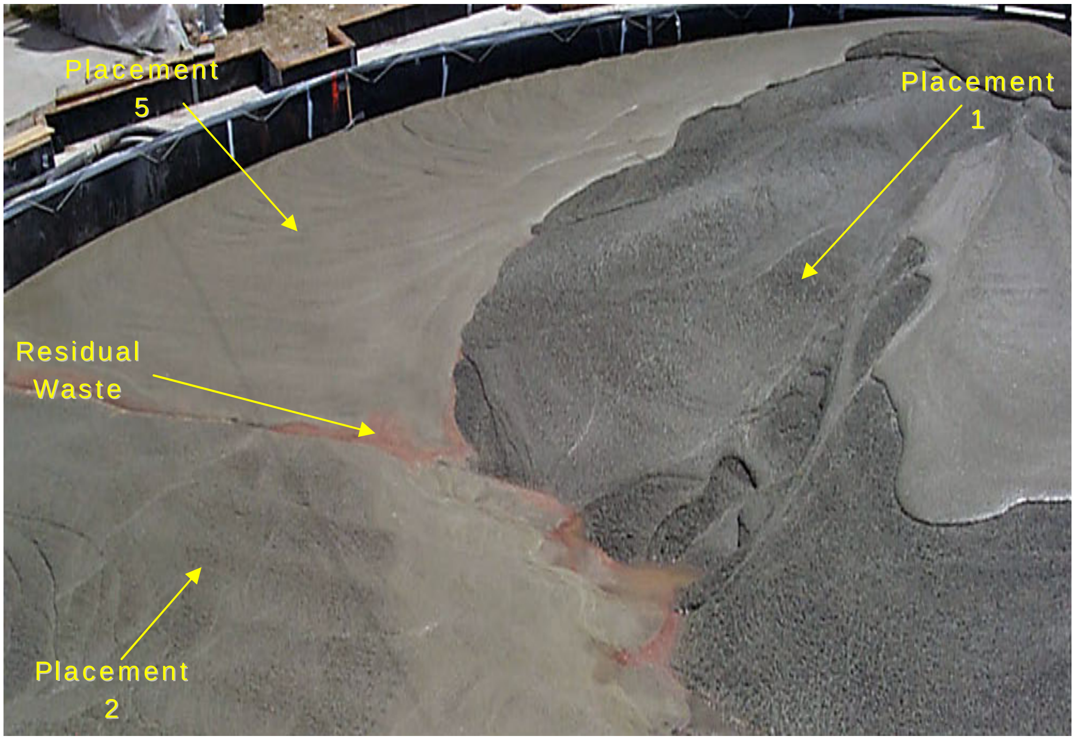

Figure RAI-17-D-3. Mounding of grout placements and vertical mixing.

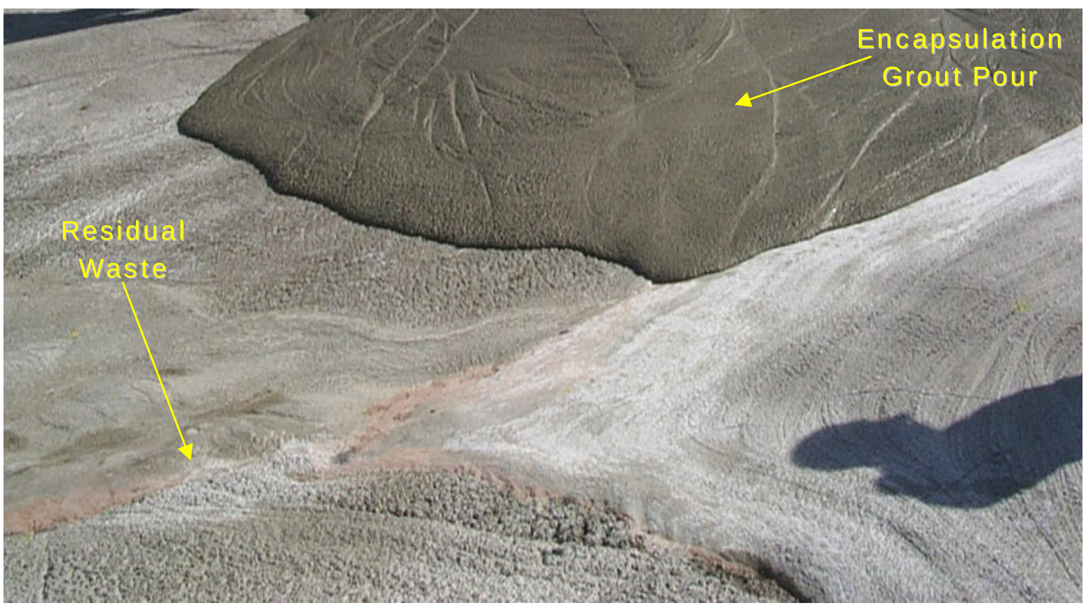

Figure RAI-17-D-4. Encapsulation grout pour covering surrogate that is on the surface.

RAI-17-D-2. 300,000-GAL TANK VAULTS METHODOLOGY

The methods discussed in the NRC draft interim guidance on concentration averaging are based on the following fundamental principles:

> *Measures are not to be undertaken to average extreme quantities of uncontaminated materials with residual waste solely for the purpose of waste classification.*

The residuals in the TFF vaults have not been averaged with extreme quantities of uncontaminated materials solely for the purpose of comparison to Class C concentration limits. Only 32.5 m^3 of grout were used in the calculations, which is approximately 3.5% of the total vault volume of 954 m^3.

> *Credit can be taken for stabilizing materials added for the purpose of immobilizing the waste (not for stabilizing the contaminated structure) even if it can not be demonstrated that the waste and stabilizing materials are reasonably well-mixed, when the radionuclide concentrations are likely to approach uniformity in the context of applicable intruder scenarios.*

A grout pour, as described above, will be used to stabilize the vault residuals. Radionuclide concentrations should approach homogeneity in the context of intruder scenarios. The technical basis for the above statement includes sampling results from cleaned vaults, engineering experience gained during mockup, and operational constraints due to inaccessibility of the sandpads.

RAI-17-D-3. 30,000-GAL TANKS METHODOLOGY

The methods discussed in the NRC draft interim guidance on concentration averaging are based on the following fundamental principles:

> *Measures are not to be undertaken to average extreme quantities of uncontaminated materials with residual waste solely for the purpose of waste classification.*

The residuals in the 30,000-gal tanks have not been averaged with extreme quantities of uncontaminated materials solely for the purpose of comparison to Class C concentration limits. The tank steel is adequate for averaging by mass and volume.

> *Credit can be taken for stabilizing materials added for the purpose of immobilizing the waste (not for stabilizing the contaminated structure) even if it can not be demonstrated that the waste and stabilizing materials are reasonably well-mixed, when the radionuclide concentrations are likely to approach uniformity in the context of applicable intruder scenarios.*

As previously described, a grout pour to stabilize the 30,000-gal tank residuals will be completed. However, this grout pour is not necessary to meet Class C concentration limits. Based on post-cleaning tank inspections, residual contamination was limited to the tank walls. Therefore, the radionuclide concentrations would be assumed to be homogeneous in the context of intruder scenarios.

RAI-17-D-4. PIPING METHODOLOGY

The methods discussed in the NRC draft interim guidance on concentration averaging are based on the following fundamental principles:

> *Measures are not to be undertaken to average extreme quantities of uncontaminated materials with residual waste solely for the purpose of waste classification.*

The residuals in the piping have not been averaged with extreme quantities of uncontaminated materials solely for the purpose of comparison to Class C concentration limits. The piping steel is adequate for averaging by mass and volume.

> *Credit can be taken for stabilizing materials added for the purpose of immobilizing the waste (not for stabilizing the contaminated structure) even if it can not be demonstrated that the waste and stabilizing materials are reasonably well-mixed, when the radionuclide concentrations are likely to approach uniformity in the context of applicable intruder scenarios.*

Grout will be pumped into the piping to stabilize the residuals. However, this grout is not necessary to meet Class C concentration limits.

RAI-17-D-5. REFERENCES

References are included in Appendix RAI-17-E.

APPENDIX RAI-17-E

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