Technical Evaluation Report

For the U.S. Department of Energy West Valley Draft Waste Incidental to Reprocessing Evaluation for the Concentrator Feed Makeup Tank and the Melter Feed Hold Tank

Final Report

U.S. Nuclear Regulatory Commission
Office of Federal and State Materials
and Environmental Management Programs
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EXECUTIVE SUMMARY

In June 2012, the U.S. Department of Energy (DOE) submitted the *Draft Waste Incidental to Reprocessing Evaluation for the Concentrator Feed Makeup Tank and the Melter Feed Hold Tank* to the U.S. Nuclear Regulatory Commission (NRC) for consultative review. The DOE's evaluation assesses whether the Concentrator Feed Makeup Tank (CFMT) and the Melter Feed Hold Tank (MFHT) at the West Valley Demonstration Project (WVDP) meet the waste incidental to reprocessing (WIR) criteria of Section II.B (2) (a) in DOE-Manual 435.1-1 (DOE-M 435.1-1), *Radioactive Waste Management*, which accompanies DOE Order 435.1-1. Demonstration that the criteria in DOE-M 435.1-1 are met allows DOE to dispose of the used components (UC) from both CFMT and MFHT offsite as low-level waste (LLW). This Technical Evaluation Report (TER) presents information on the DOE's evaluation process, the applicable review criteria, and the NRC's review approach, as well as the NRC's analysis and conclusions with respect to whether there is technical sufficiency to demonstrate that the DOE's proposed approach can meet the criteria of DOE-M 435.1-1 for determining that waste is not high-level waste (HLW).

The NRC staff has performed a technical review to assess whether the draft evaluation is technically sufficient to demonstrate that the UC meet the criteria in DOE M 435.1-1. The NRC has conducted this consultative review at the request of the DOE in accordance with Interagency Agreement DE-EM0001931.

Per the specific requests of the interagency agreement (IA), the NRC's review was focused on assessing whether the methodology that the DOE employed contained sound technical assumptions, analyses, projections, and conclusions. The NRC employed the relevant review procedures in Chapter 3, 6, and 7 of NUREG-1854 (NRC, 2007), to complete its review. The NRC's review focused on the following general topics, as they relate to the criteria in DOE-M 435.1-1:

- Waste characterization,
- Waste form stability,
- Waste classification,
- Removal of radionuclides to the maximum extent technically and economically practical, and
- Operational radiation protection.

Section II.B (2)(a) of DOE Manual 435.1-1 states the following:

II. B. Waste Incidental to Reprocessing.

Waste resulting from reprocessing spent nuclear fuel that is determined to be incidental to reprocessing is not high-level waste, and shall be managed under DOE's regulatory authority in accordance with the requirements for transuranic waste or low-level waste, as appropriate. When determining whether spent nuclear fuel reprocessing plant wastes shall be managed as another waste type or as high-level waste, either the citation or evaluation processes described below shall be used:

(1) Citation. Waste incidental to reprocessing by citation includes spent nuclear fuel reprocessing plant wastes that meet the description included in the Notice of Proposed Rulemaking (34 FR 8712) for proposed Appendix D, 10 CFR Part 50, Paragraphs 6 and 7. These radioactive wastes are the result of reprocessing plant operations, such as, but not

limited to: contaminated job wastes including laboratory items such as clothing, tools, and equipment.

(2) Evaluation. Determinations that any waste is incidental to reprocessing by the evaluation process shall be developed under good record-keeping practices, with an adequate quality assurance process, and shall be documented to support the determinations. Such wastes may include, but are not limited to spent nuclear fuel reprocessing plant wastes that:

(a) Will be managed as low-level waste and meet the following criteria:

- *Have been processed, or will be processed, to remove key radionuclides to the maximum extent that is technically and economically practical; and*
- *Will be managed to meet safety requirements comparable to the performance objectives set out in 10 CFR Part 61, Subpart C, Performance Objectives; and*
- *Are to be managed, pursuant to DOE's authority under the Atomic Energy Act of 1954, as amended, and in accordance with the provisions of Chapter IV of [*DOE-M 435.1-1*], provided the waste will be incorporated in a solid physical form at a concentration that does not exceed the applicable concentration limits for Class C LLW as set out in §61.55, Waste Classification; or will meet alternative requirements for waste classification and characterization as DOE may authorize.*

Based on the information provided by DOE and its associated contractor, West Valley Environmental Services, LLC, in the draft evaluation dated June 20, 2012, and letter dated September 20, 2012 (RAI response), the NRC staff has concluded that the DOE's draft evaluation is technically sufficient to demonstrate that the UC meet the NRC-reviewed portions of the criteria in DOE M-435.1-1.

DOE plans to ship the packaged UC to a suitable offsite LLW disposal facility, such as the Nevada National Security Site (NNSS, formerly the Nevada Test Site) in Nevada or the Waste Control Specialists (WCS) facility in Texas for disposal.

In addition to the NRC, the DOE has solicited review and comment from State officials and members of the public on the draft WIR evaluation and associated documentation. The DOE will make a final determination of whether the UC are or are not HLW after consideration of the NRC's comments and any State and public comments on DOE's draft evaluation.

If DOE decides to dispose of the UC at the WCS facility, the component waste packages would be disposed of as Class C LLW in the Federal Facility Waste Disposal Facility. The NRC's review does not address the long-term performance of the site ultimately selected for disposal of the UC. Therefore, the NRC's review will not address the long-term performance or long-term stability of this disposal site, but will focus only on the general topics listed above. Also noted in the IA, the NRC's review does not include independent review of the key radionuclide list because the decontamination method used and the other methods considered for additional decontamination were bulk cleaning methods that remove all radionuclides present in similar proportions; that is, the methods do not target specific radionuclides.

ABBREVIATIONS/ACRONYMS

AEC	Atomic Energy Commission
BTP	Branch Technical Position on Concentration Averaging
CFMT	Concentrator Feed Makeup Tank
CFR	Code of Federal Regulations
CNWRA	Center for Nuclear Waste Regulatory Analysis
DOE	U.S. Department of Energy
DOE-EM	U.S. Department of Energy – Environmental Management program
EIS	Environmental Impact Statement
GTCC	Greater than Class C
HLW	High-Level Waste
IA	Interagency Agreement
LLW	Low-Level Waste
MFHT	Melter Feed Hold Tank
NNSS	Nevada National Security Site Area 5 Radioactive Waste Management Site
NFS	Nuclear Fuel Services
NRC	U.S. Nuclear Regulatory Commission
NYSERDA	New York State Energy Research And Development Authority
PA	Performance Assessment
PUREX	Plutonium - Uranium Extraction
RAI	Request for Additional Information
SOW	Statement of Work
TER	Technical Evaluation Report
TRU	Transuranic Waste
UC	Used Components
WCS	Waste Control Specialist
WIR	Waste Incidental to Reprocessing
WMA	Waste Management Area
WNYNSC	Western New York Nuclear Service Center
WVDP	West Valley Demonstration Project
WVNS	West Valley Nuclear Services Company

1.0 INTRODUCTION

1.1 Background

The WVDP is located in western New York State, about 50 km (30 miles) south of Buffalo, New York. The WVDP facilities occupy a security-fenced area of about 0.676 km^2 (167 acres) within the 13.51-km^2 (3,338-acre) Western New York Nuclear Service Center (WNYNSC) located primarily in the town of Ashford in northern Cattaraugus County.

To date, the West Valley site in West Valley, New York is the first and only commercial reprocessing plant to operate in the United States. From 1966 to 1972, Nuclear Fuel Services (NFS) reprocessed 640 metric tons of spent fuel under an Atomic Energy Commission (AEC) license. Approximately four years after shutting down, NFS returned control of the facilities to the site owner, New York State Energy Research and Development Authority (NYSERDA). Operations at the facility resulted in approximately 2.3 million liters (600,000 gallons) of liquid high-level waste (HLW), which was stored below ground in carbon-steel tanks.

Figure 1-1 shows the perimeter of the WV site and the relationship of the underground tanks to the Vitrification Facility, where the Vitrification Melter was housed. Tank 8D-2 stored approximately 2.12 million liters (560,000 gallons) of neutralized PUREX wastes, which were composed of a bottom sludge layer containing insoluble hydroxides and other salts that precipitated out of solution, covered by a layer of alkaline liquid (supernatant) rich in sodium nitrate. Tank 8D-2 wastes were neutralized by adding sodium hydroxide to the nitric acid-based stream during the reprocessing of uranium fuel using the PUREX process. Neutralizing the initially acidic HLW prior to transfer caused most of the fission product elements (the major exception was cesium) to precipitate out and form sludge at the bottom of Tank 8D-2. In addition, neutralizing the wastes reduced the possibility of corrosion of the carbon steel tank. Therefore, the HLW was not homogeneous but was comprised of supernatant (liquid) and sludge (solids). Tank 8D-4 stored approximately 46,000 liters (12,000 gallons) of acidic high-level radioactive liquid waste produced in reprocessing thorium-enriched uranium fuel using the THOREX process; this waste was stored without being neutralized.

In 1980, the West Valley Demonstration Project Act (WVDP Act) was passed. The WVDP Act made DOE responsible for solidifying the liquid HLW stored in underground tanks, disposing of the waste created by solidification, and decontaminating and decommissioning the facilities used during the process. Under the WVDP Act, the DOE entered into a Cooperative Agreement with NYSERDA (DOE and NYSERDA, 1981) that established the framework for cooperative implementation of the WVDP Act. Under the agreement, the DOE was provided exclusive use and possession of a portion of the West Valley site. A supplement to the Cooperative Agreement between the two agencies set forth special provisions for the preparation of a joint Environmental Impact Statement (EIS) [DOE and NYSERDA, 1981].

In 1981, the DOE and the NRC entered into a Memorandum of Understanding that established specific agency responsibilities and arrangements for informal review and consultation by the NRC (DOE and NRC, 1981). Because NYSERDA holds the license and title to the West Valley site, the NRC put the technical specifications of the license in abeyance to allow the DOE to carry out the responsibilities of the WVDP Act.

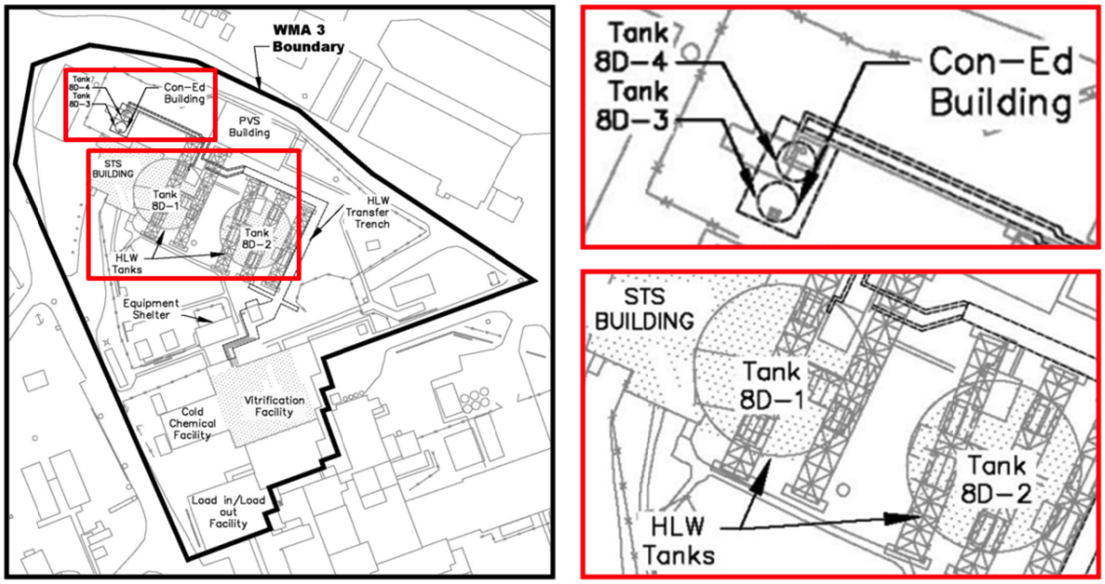

Figure 1-1: HLW Storage and Vitrification Storage Facility

In 1982, DOE selected West Valley Nuclear Services (WVNS), a Westinghouse subsidiary, as the management and operating contractor for the site. WVNS commenced operations at the WVDP on February 28, 1982. Shortly thereafter, the DOE selected vitrification as the preferred method for stabilizing HLW.

In 1988, DOE constructed the integrated radioactive waste treatment system to remove most of the radioactivity in the liquid supernatant from the underground HLW tanks, concentrate the liquid, and blend it with cement. This process separated the low activity waste stream from the high activity waste stream, which was vitrified into borosilicate glass.

Waste pretreatment and vitrification took place from 1996 to 2002 producing a total of 275 stainless-steel canisters of hardened radioactive glass. The canisters were each 305 cm (10 ft) tall and contained more than 451,000 cesium/strontium terabecquerels (12.2 million curies) in total. The salt/sludge separation process used to treat the waste prior to vitrification involved the following: separating the supernatant from the sludge in Tank 8D-2; removing the radioactive Cs-137 from liquids in both tanks by adsorbing it onto zeolite; and combining the cesium-loaded zeolite with the sludge from Tank 8D-2. Once the waste had been pretreated, the zeolite and sludge mixture was ready to be vitrified into the borosilicate glass waste form. The glass melter was shut down in September 2002.

Figure 1-2 shows the vitrification process flow. Waste was pumped from Tank 8D-2 to the 22,700-liter (6,000-gallon) Concentrator Feed Makeup Tank (CFMT), where glass formers were added to the system. Then, waste was transferred to the 18,900-liter (5,000-gallon) Melter Feed Hold Tank (MFHT) before it was fed into the Melter through the Feed Delivery System.

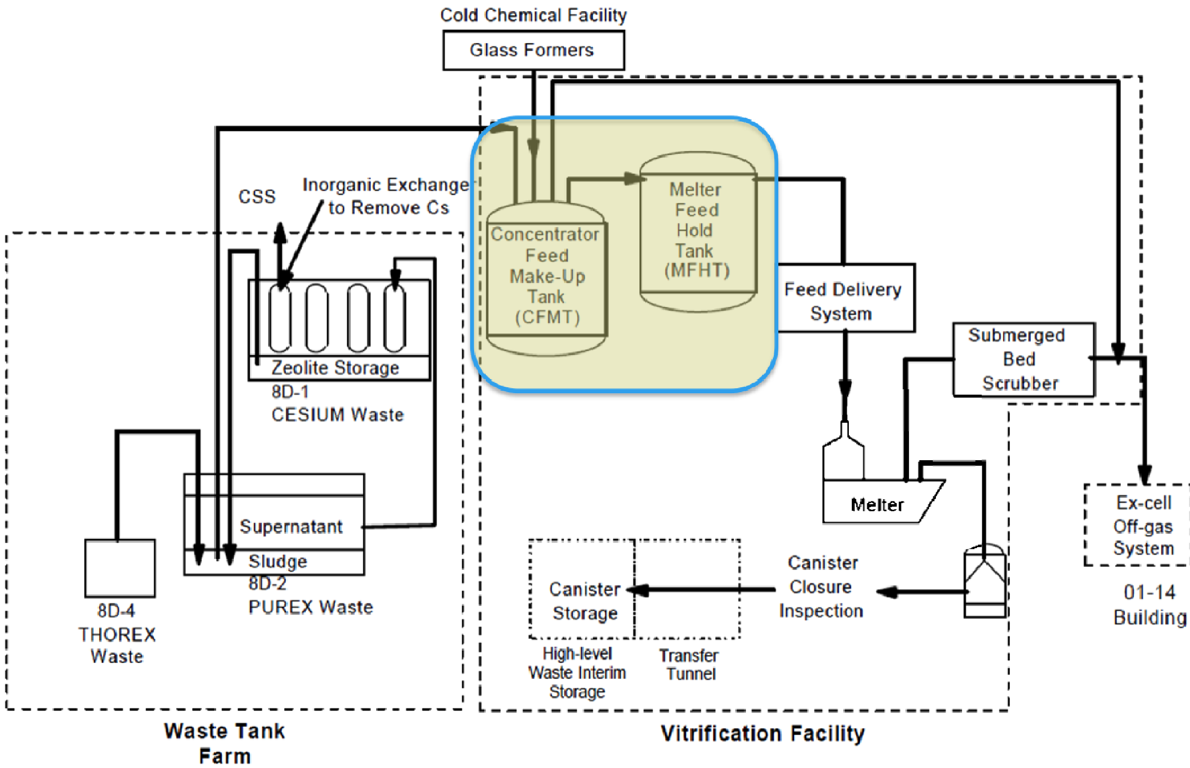

Figure 1-2: Vitrification Process Flow [Adapted from DOE (2011a)]

The cylindrical CFMT vessel, constructed of Hastelloy C-22, was 4.1 meters (13.5 feet) long and 3 meters (10 feet) in diameter and used to prepare the high-activity waste and glass formers mixture for vitrification. The CFMT served as an agitator to the vitrification process contents. The cylindrical MFHT vessel—similar but smaller than the CFMT—was 3 meters (10 feet) long and 3 meters (10 feet) in diameter and used to supply feed material from the CFMT to the vitrification melter. Both were in operation from 1996 through 2002.

Figure 1-2 illustrates the process flow with emphasis on the location of the CMFT and MFHT. After vitrification was completed in 2002, decontamination fluids were added to the CFMT and MFHT, which were then processed in the Vitrification Melter.

Since DOE completed vitrification of the treated HLW in 2002, efforts have focused on decontaminating and deactivating facilities and shipping LLW offsite, including characterization and disposal of the Vitrification Melter, the CFMT, and the MFHT. The NRC staff routinely visits the WVDP to facilitate review and consultation as required under the WVDP Act. Two such visits in 2004 focused on vitrification equipment. During these visits, NRC staff members reviewed information on the characterization, classification, and packaging for the CFMT, MFHT, and the Vitrification Melter and concluded that all applicable regulatory requirements had been met (NRC, 2004).

1.2 Waste Incidental to Reprocessing Evaluation

The DOE is evaluating whether the CFMT and the MFHT waste packages at the WVDP meet the DOE's waste incidental to reprocessing criteria of DOE-M 435.1-1, *Radioactive Waste Management*, in order to dispose of the UC offsite as LLW. DOE plans to ship the packaged CFMT and the MFHT components to either the Nevada National Security Site (NNSS, formerly the Nevada Test Site) in Nevada or the Waste Control Specialists (WCS) facility in Texas for disposal as LLW.

Consistent with the Department's policy (as per DOE-M 435.1-1), the DOE has reached out to the NRC, as well as State officials and members of the public, to solicit review and comment on a draft WIR evaluation. The DOE will make a final determination of whether the CFMT and the MFHT UC are or are not HLW after considering comments provided by the NRC (as documented in this TER), the public, and any State.

Section II.B (2)(a) of DOE-M 435.1-1 states the following:

> *II. B. Waste Incidental to Reprocessing.*
> *Waste resulting from reprocessing spent nuclear fuel that is determined to be incidental to reprocessing is not high-level waste, and shall be managed under DOE's regulatory authority in accordance with the requirements for transuranic waste or low-level waste, as appropriate. When determining whether spent nuclear fuel reprocessing plant wastes shall be managed as another waste type or as high-level waste, either the citation or evaluation processes described below shall be used:*
>
> *(1) Citation. Waste incidental to reprocessing by citation includes spent nuclear fuel reprocessing plant wastes that meet the description included in the Notice of Proposed Rulemaking (34 FR 8712) for proposed Appendix D, 10 CFR Part 50, Paragraphs 6 and 7. These radioactive wastes are the result of reprocessing plant operations, such as, but not limited to: contaminated job wastes including laboratory items such as clothing, tools, and equipment.*
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> *(2) Evaluation. Determinations that any waste is incidental to reprocessing by the evaluation process shall be developed under good record-keeping practices, with an adequate quality assurance process, and shall be documented to support the determinations. Such wastes may include, but are not limited to; spent nuclear fuel reprocessing plant wastes that:*
>
> *(a) Will be managed as low-level waste and meet the following criteria:*
>
> - *Have been processed, or will be processed, to remove key radionuclides to the maximum extent that is technically and economically practical; and*
> - *Will be managed to meet safety requirements comparable to the performance objectives set out in 10 CFR Part 61, Subpart C, Performance Objectives; and*
> - *Are to be managed, pursuant to DOE's authority under the Atomic Energy Act of 1954, as amended, and in accordance with the provisions of Chapter IV of [*DOE-M 435.1-1*], provided the waste will be incorporated in a solid physical form at a concentration that does not exceed the*

applicable concentration limits for Class C LLW as set out in §61.55, Waste Classification; or will meet alternative requirements for waste classification and characterization as DOE may authorize.

1.3 Previous NRC Reviews

In 2011, DOE consulted with the NRC during development of the *West Valley Demonstration Project Draft Waste Incidental to Reprocessing Evaluation for the Vitrification Melter* (DOE, 2011a). NRC completed this review under a similar IA with the DOE (DOE, 2010). NRC submitted its review to DOE in a TER on September 30, 2011 (NRC, 2011a).

1.4 The NRC Review Approach

NRC's review of the draft WIR evaluation was performed in accordance with the specific requests as described in the Interagency Agreement (IA), DE-EM0001931. To avoid confusion, this IA was very specific in its requests in an attempt to avoid any overlap with analogous programs either between NRC and DOE-EM, or other NRC/DOE interactions at the West Valley site.

Table 1-1: Applicable NRC Review Guidance and DOE-M 435.1-1 Criteria

General Review Topic	NUREG-1854 Chapter	435.1 Criterion
Waste characterization	Chapter 3: Radionuclide Removal and Concentration Limits	1
Waste form stability	Chapter 7: Site Stability, Waste Stability, and Facility Stability	2 and 3
Waste classification	Chapter 3: Radionuclide Removal and Concentration Limits	3
Removal of radionuclides to the maximum extent technically and economically practical	Chapter 3: Radionuclide Removal and Concentration Limits	3
Operational radiation protection	Chapter 6: Protection of Individuals During Operations	2

Pursuant to DOE's specific request, the NRC has reviewed the draft evaluation for the CFMT and MFHT components at the WVDP site to provide a technical opinion on whether the draft evaluation is technically sufficient to demonstrate that the WVDP CFMT and MFHT UC meet the criteria in DOE-M 435.1-1, which accompanies DOE-O 435.1-1.

The NRC's review of the draft WIR evaluation focused on assessing whether the methodology the DOE employed was based on sound technical assumptions, analyses, and projections, and resulted in acceptable conclusions. The NRC employed the relevant review procedures in Chapter 3, 6, and 7 of NUREG-1854 (NRC, 2007), to complete its review of the general topics identified in Table 1-1. The NRC reviewed the general topics identified in Table 1-1 as they relate to the criteria in DOE-M 435.1-1 (followed by applicable chapter of NUREG-1854).

The DOE plans to dispose of the CFMT and MFHT UC off-site, at a LLW disposal site such as the NNSS or WCS, neither of which are licensed or otherwise regulated by the NRC (but are instead licensed and regulated by DOE — in the case of NNSS — or by an NRC Agreement State, the State of Texas in the case of WCS). As per the IA, the NRC's review does not address the long-term performance of the disposal site or the sufficiency of the waste acceptance criteria for the potential disposal facilities being considered for disposal of the CFMT and MFHT UC. Therefore, the NRC's review will not address the long-term performance or long-term stability of this disposal site, but will focus only on the general topics listed above. The IA also notes that the NRC's review does not include independent review of the key radionuclide list because the decontamination method used and the methods considered for additional decontamination were bulk-cleaning methods that remove all radionuclides present in similar proportions; that is, the methods do not target specific radionuclides.

2.0 THE WASTE HAS BEEN PROCESSED TO REMOVE KEY RADIONUCLIDES TO THE MAXIMUM EXTENT THAT IS TECHNICALLY AND ECONOMICALLY PRACTICAL

This section of the NRC staff's technical review covers Section II.B(2)(a)(1) of DOE-M 435.1-1– that the waste has been processed, or will be processed, to remove key radionuclides to the maximum extent that is technically and economically practical.

2.1 The DOE's Characterization of Waste Inventory

The DOE estimates the amount of residual material in the CFMT and the MFHT after decontamination to be approximately 3.59 TBq (97 Ci) and 3.81 TBq (103 Ci) respectively. The inventory of the residual material, as estimated in 2004, is described in the waste characterization (WMG, 2011) and the standardized waste profile (CHBWV, 2011a).

The DOE's characterization is based on measured gamma dose rates using a Ludlum Model 1337 Geiger Mueller shielded detector probe (WMG, 2011) and analytical results from samples. The measured gamma dose rates were attributed solely to Cs-137 to estimate Cs-137 activity. OAO-GCCP-A geometry models were developed for each tank to determine a dose-to-curie conversion factor (DCF) for Cs-137, while the amounts of other radionuclides were estimated using scaling factors based on analytical results from the laboratory samples. RADman™ software was applied to calculate the activities of other radionuclides using the scaling factors and Cs-137 activity.

Nine dose rate measurements (although ten were recorded) of the CFMT (WVNSCO, 2004c) were averaged to estimate Cs-137 activity. Five analytical samples were utilized in characterizing the CFMT: two samples of batch 72 taken at different times, one sample from batch 74, one sample from batch 75, and one sample of residual liquid collected from the vessel in July 2003 after completion of vitrification (WMG, 2011). Each of the batch samples was analyzed nine times and the average was taken to calculate a representative value for each of the four batch samples. The July 2003 liquid sample was analyzed three times. The DOE originally calculated the geometric mean of seven values (4 batch sample values and the three analyses of the liquid sample) in determining the scaling factors, which the DOE later revised as discussed in the following section, treating the 3 liquid analyses as a single sample.

Nine dose rate measurements (although twelve were recorded) of the MFHT (WVNSCO, 2004c) were averaged to estimate Cs-137 activity. Six analytical samples were utilized in characterizing the MFHT: the same four batch sample values used for characterizing the CFMT plus two glass shard samples taken from the two evacuated canisters used to remove molten glass from the vitrification melter (WMG, 2011). The DOE analyzed the two glass shards three times each and averaged the values, the results of which are documented in WMG (2004a). The DOE calculated the geometric mean of six values (4 batch sample values and two glass samples) in determining the scaling factors.

Table 2-1: Total Activity Estimates as of October 2004 (DOE, 2012b)

Nuclide	CFMT [2] Activity (Ci) [1]	MFHT Activity (Ci) [1]	Melter Activity (Ci) [1]
C-14	NA	$3.98x10^{-4}$	$2.12x10^{-2}$
K-40	NA	$1.54x10^{-3}$	$8.19x10^{-2}$
Mn-54	NA	$1.67x10^{-3}$	$8.57x10^{-2}$
Co-60	$4.1x10^{-3}$	$1.58x10^{-3}$	$8.33x10^{-2}$
Ni-63	NA	$1.89x10^{-2}$	1.01
Sr-90	3.9	5.34	$2.47x10^{+2}$
Zr-95	NA	$3.72x10^{-2}$	1.65
Tc-99	$1.8x10^{-3}$	$8.34x10^{-4}$	$1.11x10^{-2}$
Cs-137	$9.5x10^{+1}$	$9.71x10^{+1}$	$4.31x10^{+3}$
Eu-154	$5.6x10^{-2}$	$3.18x10^{-2}$	1.21
Np-237	$5.6x10^{-5}$	$7.26x10^{-5}$	$6.20x10^{-3}$
Pu-238	$6.9x10^{-3}$	$9.19x10^{-3}$	$6.84x10^{-1}$
Pu-239	$1.5x10^{-3}$	$2.28x10^{-3}$	$1.59x10^{-1}$
Pu-240	$1.5x10^{-3}$	$1.74x10^{-3}$	$1.21x10^{-1}$
Pu-241	$1.4x10^{-2}$	$5.88x10^{-2}$	3.12
Pu-242	NA	NA	NA
Am-241	$3.7x10^{-2}$	$4.33x10^{-2}$	3.00
Am-242m	NA	NA	NA
Am-243	$3.3x10^{-4}$	$3.93x10^{-4}$	$3.50x10^{-2}$
Cm-242	$3.9x10^{-4}$	$3.42x10^{-4}$	$7.33x10^{-2}$
Cm-243	$3.2x10^{-3}$	$2.84x10^{-4}$	$1.68x10^{-2}$
Cm-244	$3.2x10^{-3}$	$7.36x10^{-3}$	$4.35x10^{-1}$
Cm-245	NA	NA	NA
Cm-246	NA	NA	NA
Th-228	NA	$7.79x10^{-4}$	$4.09x10^{-2}$
Th-230	NA	$6.84x10^{-6}$	$3.65x10^{-4}$
Th-232	$1.9x10^{-6}$	$7.53x10^{-6}$	$4.01x10^{-4}$
U-232	$1.0x10^{-4}$	$9.40x10^{-4}$	$5.01x10^{-4}$
U-233	$3.2x10^{-5}$	$3.86x10^{-4}$	NA
U-234	$3.2x10^{-5}$	$1.84x10^{-4}$	$9.81x10^{-3}$
U-235	NA	$7.07x10^{-6}$	$3.76x10^{-4}$
U-236	NA	$2.12x10^{-5}$	NA
U-238	$4.8x10^{-6}$	$4.23x10^{-5}$	$2.25x10^{-3}$
TOTAL	99	103	4569

[1] Conversion to Bq from curies, multiply by 0.37 TBq/Ci.
[2] From WMG 2011 as of October 1, 2004 as revised (Kurasch, 2012).

Using the gamma dose rates and the scaling factors, the DOE estimated that the total activity remaining in the MFHT as of February 9, 2004 was 3.81 TBq (103 Ci), 95 percent of which was Cs-137. The total activity in the CFMT was 3.68 TBq (99 Ci), 96 percent of which was Cs-137. The activities of the other radionuclides were inferred from Cs-137 using scaling factors. The DOE's estimate of the inventories of the vessels (also listed in Table 2-2 and 2-4 of the draft WIR evaluation) along with the inventory of the Melter (DOE, 2011a) for comparison purposes are replicated in Table 2-1.

2.2 NRC Evaluation of Waste Inventory

In this part of the review, the NRC staff evaluated the physical and chemical form of the waste, previous inventory estimates, data quality objectives, homogeneity, sampling plan for characterization, volume and mass estimates, and uncertainties.

The NRC staff has reviewed information about waste generation and treatment activities and finds that the predicted physical and chemical forms of radionuclides, as described by DOE, are consistent with the properties of contributing waste streams and treatment processes.

The NRC staff reviewed historical inventories and compared those to the radionuclides considered for waste classification purposes. NRC staff notes that some of the radionuclides listed in the inventory are denoted with an "NA." DOE clarified that certain transuranics that were listed in the sludge/supernatant inventory (Pu-242, Am-242m, Cm-245, Cm-246), were present in such small quantities in the sludge/supernatant, so they were also listed in the final residual inventory. However, since they are present in small quantities, inclusion of these transuranics does not significantly impact the sum of fractions for waste classification as discussed in Section 4.2.

The NRC staff compared the inventory of the Vitrification Melter to that of each of the vessels to identify any differences between the lists of radionuclides reported. The NRC staff noted in its review that certain radionuclides (C-14, K-40, Mn-54, Ni-63, Zr-95, Th-228, Th-230, U-235, and U-236) are listed with concentrations in the Melter and the MFHT, but not in the CFMT. Since the same material (with few exceptions) passed through both vessels and was eventually formed into HLW glass (in the Melter), NRC staff would have expected the list of radionuclides to be the same. During its review, the NRC asked for additional information regarding the differences in the radionuclides that are listed in the MFHT and the CFMT. DOE clarified that the MFHT contains several radionuclides not included in the inventory for the CFMT because the glass shard samples that were used in characterizing the MFHT were analyzed for these radionuclides while the liquid samples used for the CFMT were not analyzed for these radionuclides. Records describing the basis for the selected samples (and why certain radionuclides were analyzed while others were not) were not available, but the CFMT liquid sample and the glass shards were likely chosen to characterize each vessel since they were the last materials contained in the CFMT and the MFHT respectively.

DOE stated that while different sample analytical data sets were used in characterizing the two vessels based on the judgment of the site contractor when the vessels were characterized in 2004, it would also be reasonable to conclude that the radionuclide distributions in these vessels are the same of those in the Vitrification Melter. Since the scaling factors used for the Melter are slightly higher, utilizing the Melter scaling factors as opposed to the scaling factors developed for the vessels would be more conservative. In order to determine whether use of the scaling factors developed for the Vitrification Melter would produce significantly different results, DOE calculated the residual radioactivity in each vessel using the Vitrification Melter scaling factors (WMG, 2004a) combined with the Cs-137 estimates for the CFMT and MFHT in the WMG characterization report (WMG, 2011). The results were as follows: (1) the CFMT estimate would be 3.77 TBq (102 Ci) compared to 3.68 TBq (99.4 Ci) and (2) the MFHT estimate would be 3.81 TBq (103 Ci) in both cases. Because the difference in this comparison is not significant, the NRC staff finds the list of radionuclides presented in the inventory in Table 2-1 acceptable.

The NRC staff evaluated the sampling analysis and data quality objectives to verify that relevant data quality objectives were met. The DOE states that data were validated in accordance with the requirements of the Characterization Management Plan for the Facility Characterization Project (Michalczak, 2004), which includes data quality objectives. Furthermore, the 2004 characterization was reviewed by the site contractor, WVNSC, and DOE incorporated recommendations resulting from this review. The NRC staff concluded that the approaches taken for data verification as outlined in the Characterization Management Plan for the Facility Characterization Project were appropriate, because it follows generally accepted practices.

Regarding homogeneity of the waste inventory, the NRC staff notes that the processes used in both tanks kept the material relatively homogeneous. The CFMT received pretreated batches of liquid HLW. Although there was some variation from batch to batch, each new batch was mixed with the heel of the previous batch and the combined contents were sampled and treated until it met certain specifications consistent with those required in the vitrification process. The MFHT held the HLW slurry for delivery to the Melter and included an agitation system that was used to maintain homogeneity of the slurry. DOE attributes slight variations in the dose rates, which are due to the primary gamma emitter Cs-137, at different locations on the outside of each of the vessels due to small variations in the amounts of Cs-137 in the vessel interior. This is supported by photographic evidence provided in Chapter 4 of the draft WIR evaluation (DOE, 2012b). However, the general consistency of the of the dose rates measured on the sides of the vessels (1.17 R/h to 2.25 R/h for the MFHT) as shown in the survey record (WVNSCO 2004a) support the DOE's overall assumption of generally uniform distribution of residual waste.

During the review, NRC asked DOE to provide a technical basis for the number and location of dose rate measurements and to describe how the number and location of required samples are based on assumptions about the heterogeneity of the residual waste within the tanks after cleaning. DOE explained that the "survey plans provided for nine measurements along the side of each vessel at intervals of approximately one foot, along with four measurements on the top of each vessel (if possible)" (DOE, 2012c). The sampling plan was based on the assumption that the residual contamination left after flushing was uniformly distributed on the vessel interior surfaces based on the results of visual inspections. DOE acknowledged that this assumption is somewhat contradictory to the simplifying assumption used to determine cleaning effectiveness (that prior to flushing, the material covered only the upper one-third of the vessels). DOE further clarified by stating that it is reasonable to expect that some amount of residual material was present in the lower two-thirds of the vessels prior to flushing. DOE explained that only one measurement was taken on top of the CFMT and 3 on top of the MFHT due to limited accessibility. Only nine side measurements of each vessel were used in the dose concentrations due to the assumptions of the QAD geometry model (DOE, 2012c). Given this information, along with technical drawings of the vessels showing the inaccessibility of areas on the top of the vessels, the NRC staff finds the number and location of dose rate measurements used for determining the Cs-137 activity acceptable because it follows the plans detailed in the Radiation and Contamination Survey Report (WVNSCO, 2004c).

The NRC staff evaluated the statistical metric of radionuclide concentrations used to calculate inventories in the waste determination (e.g., mean, geometric mean) to ensure that the technical basis for the selection is adequate and the metric is properly calculated. As described in the previous section, the CFMT scaling factors were originally based on the geometric average of the four batch samples and the three analyses for the single liquid sample. The MFHT scaling factors are based on the geometric average of the same four batch samples along with two glass shard samples taken from the two evacuated canisters used to remove molten glass from the Vitrification Melter (WMG, 2011). During the review NRC asked DOE to explain why the liquid sample for CFMT was treated as three separate samples in the calculation of the geometric mean and to describe any impacts on overall conclusions if this liquid sample had been treated as one sample instead of three. In its response, DOE revised the estimate for the CFMT (as shown in Table 2-1), treating the liquid sample as one instead of three separate results. DOE also revised the density of the liquid sample to be 1.15 g/cm^3 (DOE, 2012c) and the revised estimate of 3.68 TBq (99.4 Ci) is reflected above in Table 2-1 (the original estimate was 3.57 TBq (96.5 Ci). The NRC staff notes that the revised estimate does not impact conclusions about the removal of radionuclides to the maximum extent technically and economically practical or the vessel waste classification. The DOE states that applying the geometric average is appropriate because it “takes into account the differing radionuclide distributions in the samples.” NRC staff notes that the geometric mean is usually reserved for comparing items with markedly different numeric ranges. Since all these samples are meant to represent the same population of data, it is not clear to the NRC staff why DOE chose to apply the geometric mean as opposed to a different statistic. The arithmetic mean or the 95^{th} percentile would have yielded slightly higher concentrations and also slightly higher scaling factors for most radionuclides. However, NRC staff evaluated the impact of applying a different statistical metric (i.e., the arithmetic mean or the 95^{th} percentile value) and determined that use of a different statistic would not change the conclusions discussed in later Chapters of this review. During the review, the NRC staff requested additional justification regarding DOE’s use of the geometric mean. DOE clarified that because multiple results were available and they were consistent, geometric averaging was used to calculate the scaling factors citing that geometric averaging of scaling factors is a common practice throughout the commercial nuclear power industry in cases where more than one representative sample is available (DOE, 2012c). Given that use of alternative statistical metric (i.e., the arithmetic mean or the 95^{th} percentile value) would not impact the overall conclusions, the NRC staff finds DOE’s averaging approach acceptable.

In NRC’s previous review concerning the Melter (NRC, 2011), the DOE pointed to the similarity in the scaling factors for Sr-90, Np-237, Pu-238, and Am-241 of the glass samples to the batch samples. These data show that although the concentrations vary from batch to batch, the scaling factors in relation Cs-137 are similar. These data are reproduced in Table 2-2 and are relevant to this review since these are also the same batch samples that are utilized in the CFMT and MFHT characterization. The similarities in the scaling factors in Table 2-2 support the representativeness of the sample data for the residual material in the vessels.

Table 2-2: Radionuclide Scaling Factors (Ratios to Cs-137) (DOE, 2011b)

Radionuclide	Glass Sample Data	Batch 74 Data	Batch 75 Data
Sr-90	$5.73x10^{-2}$	$4.00x10^{-2}$	$7.47x10^{-2}$
Np-237	$1.41x10^{-6}$	$3.25x10^{-7}$	$6.13x10^{-7}$
Pu-238	$1.57x10^{-4}$	$5.48x10^{-5}$	$1.09x10^{-4}$
Am-241	$6.84x10^{-4}$	$2.19x10^{-4}$	$3.28x10^{-4}$

The NRC staff evaluated the impact of uncertainties due to heterogeneity, sample variability, and analytical methods. The DOE estimates that the uncertainty (from all sources) associated with the radionuclide inventories of the CFMT and MFHT in Table 2-1 is bounded by +/-20 percent concentration range. The high and low values are identified in the NNSS waste profile radiological technical basis document (CHBWV, 2011a) but are not propagated into the discussion of removal the maximum extent practical or the waste classification. The NRC staff notes that if a 20 percent upper bound is assumed, the conclusions regarding waste classification and removal to the maximum extent practical would remain the same as discussed in the following sections of this evaluation.

2.3 DOE Selection of Key Radionuclides

Section II.B of DOE-Guide 435.1-1, states the following regarding key radionuclide selection:

> *"... it is generally understood that [the term] key radionuclides applies to those radionuclides that are controlled by concentration limits in §61.55. Specifically these are: long-lived radionuclides, C-14, Ni-59, Nb-94, Tc-99, I-129, Pu-241, Cm-242, and alpha emitting transuranic nuclides with half-lives greater than five years and; short-lived radionuclides, H-3, Co-60, Ni-63, Sr-90, and Cs-137. In addition, key radionuclides are those that are important to satisfying the performance objectives of 10 CFR Part 61, Subpart C [for near-surface radioactive waste disposal facilities]."*

In following this guidance, DOE identifies key radionuclides for the draft WIR evaluation based on the radionuclides listed in §61.55 and the PA for the disposal facilities (WCS, 2011).

The key radionuclides, (also listed in Table 4-3 of the draft WIR evaluation) are replicated in Table 2.3.

Table 2-3: Key Radionuclides

Radionuclide	§61.55 Long-lived Radionuclides	§61.55 Short-lived Radionuclides	Radionuclides Important to PA
H-3		X	
C-14	X		X
Co-60		X	
Ni-59	X		
Ni-63		X	
Sr-90		X	
Nb-94	X		
Tc-99	X		X

I-129	X		X
Cs-137		X	
Th-229			X
U-233			X
U-234			X
U-238			X
Np-237	X		
Pu-238	X		
Pu-239	X		
Pu-240	X		
Pu-241	X		
Pu-242	X		
Am-241	X		
Am-243	X		
Cm-242	X		
Cm-243	X		
Cm-244	X		

2.4 NRC Evaluation of Key Radionuclides

The IA for this review specifically states that NRC's scope of review does not include an independent review of the key radionuclide list because the cleaning technologies evaluated and applied were bulk-cleaning methods. Because the technologies that the DOE applied and the alternative technologies considered for removal of radionuclides did not target specific key radionuclides and instead removed bulk volume from the vessels, the DOE's cleaning approach would be expected to remove all radionuclides in equal proportions, as opposed to only the key radionuclides. Therefore, the NRC staff does not have to make a determination on whether or not the key radionuclide list is appropriate in order to review other portions of the waste evaluation; the staff does not rely on this list for coming to a conclusion about removal to the maximum extent practical or waste classification.

2.5 Removal to the Maximum Extent Technical and Economically Practical

2.5.1 The DOE Selection of Waste Removal Technologies

The DOE considered a range of additional potential removal technologies documented in the *Decommissioning Handbook* (DOE, 1994). Approaches most relevant to the vessels included: (1) ultra-high pressure water, (2) grit blasting, (3) flushing with water, and (4) hydroblasting. Grit blasting was eliminated due to potential interference with the vitrification process, and the other three methods are generally similar except for the water pressure used. DOE further evaluated high-pressure spray, which is a combination of the other three methods, along with two other options described below.

The DOE fully evaluated the following options for technical and economical practicality: (1) flushing vessel internals with water using high-pressure spray; (2) mechanical removal through ball milling; and (3) chemical decontamination. The selection criteria for technology selection included technology maturity, usefulness, cost per unit activity removed, limitations, and net social costs. The DOE determined that processing decontamination fluids with a mixture of glass formers, and use of evacuated canisters were both technically and economically practical, but that ball grinding was not practical. Specifically, ball grinding produced a fine glass powder which could lead to embedded contamination within the metal. Although improvements to the process could have been made, the improvements would have been so extensive that the resulting technology would no longer be considered proven; this would make its use technically impractical. Chemical decontamination was shown to be effective in testing, but it was deemed impractical because the chemicals would have been incompatible with the requirements for an acceptable glass mixture in the vitrification process. Since the resulting flush solutions would be fed to the Melter and transferred to the evacuated canisters, this made the chemical decontamination approach unacceptable due to technical impracticality (WVNSCO, 2001).

The DOE made a simplifying assumption that residual material coated the upper one-third of each vessel based in part on physical and operational attributes associated with the two vessels. The liquid levels were generally limited to the nominal lower two-thirds of both the CFMT and MFHT. During operation, the upper portion of the vessels were periodically impacted by the liquid waste material due to splashing resulting from additional waste being added to the mixture, and the swirling induced by the mixer blades. When the vessels were refilled with new batches, the material in the lower two-thirds of the vessel would be continuously agitated, but the material in the upper portion of the vessel would have the opportunity to dry and harden. Evidence of residual material in the upper portion of the vessels was provided in photographic images showing a buildup of dried slurry around the head stiffeners. While the simplifying assumption was that residual material covered only the upper one-third of the vessels prior to flushing, the DOE also stated that it is reasonable to expect that some contamination was present on the lower two-thirds of the vessels before flushing and that some lesser amount would remain after flushing. The consistency of the dose rates measured on the sides of the vessels confirms that both the upper and lower portions of the vessel were uniformly clean after flushing (WVNSCO 2004c). High-pressure spray, consisting of using water spray to clean the inner surfaces of the vessels, was determined to be the preferred technology. Because the bottom two thirds of the vessels were expected to be relatively clean, the flushing focused on the upper third of each vessel. Water at a pressure of approximately 68.95 bar (1,000 psi) was delivered at 95 to 130 Lpm (25 to 35 gpm) through a rotary spray nozzle that had been inserted through one or more openings in the vessel heads. The CFMT and MFHT were each flushed three times, with each flush taking about 60 minutes. The external surfaces of the vessels were decontaminated with high-pressure demineralized water from a spray wand.

2.5.2 The NRC Evaluation of Waste Removal Technologies

The NRC staff has reviewed DOE's selection for radionuclide removal technologies and has concluded that DOE evaluated a reasonable range of technologies. The selection process was based on relevant sources of information and the selection criteria were reasonable. Of the selection criteria (technology maturity, usefulness, cost per unit activity removed, limitations, and net social costs), technology maturity and limitations were applied in narrowing the selection. During the review, the NRC staff asked the DOE to provide additional information regarding the impracticality of chemical decontamination for the MFHT given that the CFMT underwent an indirect chemical cleaning after it had been disconnected from the system. Sodium hydroxide was added to the CFMT in December 2003 as a means of sending the chemical to Tank 8D-4 to raise the pH of its liquid, thereby serving as an indirect chemical flush. The DOE stated while a chemical flush of the MFHT after shutdown of the vitrification system would have been technically practical; it would not have been economically practical. The costs DOE cited include development of procedures and work packages, performing the actual flushing, and managing the resulting wastes. Meanwhile, the data from visual inspections showed that the vessel had already been effectively decontaminated through the high-pressure sprays. Therefore, the costs of such an approach would have outweighed the benefits.

2.5.3 The DOE's Estimation of Waste Removal Efficiency

This section describes the DOE estimates of removal efficiency through flushing the internals with high-pressure spray. The removal efficiency for the flushing is reported based on Cs-137 activity. The DOE claims that other key radionuclides are removed in equal proportions due to the homogeneity of the glass waste, and therefore the removal efficiencies for other radionuclides would closely follow that of Cs-137. Flushing results are also supported by visual inspections using photographs taken with a camera placed inside the vessel.

The amount of Cs-137 in the vessel prior to flushing assumed an average 0.63 cm (0.25 inch) thickness in the upper one-third of the vessels and the Cs-137 concentration in the material was originally assumed to be the same as that in the last batch of slurry sent to the CFMT before the vitrification system flushing began (batch 75), which had the second highest Cs-137 concentration (429 MBq/cm^3 [$1.16x10^4$ $\mu Ci/cm^3$]) among the feed material (Kurasch, 2011). DOE revised this assumption as described in the following section of this TER during NRC's review.

Table 4-5 of the draft WIR evaluation provides a summary of the indirect and direct flushes performed on the CFMT and MFHT. DOE refers to the spray nozzles deployed and operated for two cycles as direct flushes. Indirect flushing occurred when fluids from Tank 8D-4 were transferred to the CFMT, or when fluids from the MFHT were sent back to the CFMT. In total, the CFMT received three separate two-cycle direct flushes and four indirect flushes over the course of 2002. In this same year, the MFHT received three separate two-cycle direct flushes, and three indirect flushes before the final airlifts from the Melter were completed on August 14, 2002. In September 2002, the heel of material in the MFHT was transferred to the CFMT and the vessel was filled with water which was stirred and sent to the CFMT. Then, about one year later in December 2003, about 210 liters (55 gallons) of 50 percent caustic sodium hydroxide solution and 110 liters (30 gallons) of non-radioactive water was added to the CFMT, stirred for about 30 minutes and remained in the CFMT for about one month. In late January 2004, the CFMT contents were stirred and sent to Tank 8D-4. Afterward, about 760 liters (200 gallons) of water were transferred to the CFMT, stirred, and sent to Tank 8D-4.

Inspection after flushing using video technology showed essentially no visible deposits in comparison to pictures prior to flushing which showed substantial amounts of dried slurry in both vessels (WVNSCO, 2002c and 2002d). Additionally, dose rate measurements taken on July 15, 2002 after the high-pressure spray flushing had been completed of 0.08 Gy/h and 0.22 Gy/h (8 R/h and 22 R/h) showed a reduction from the measurements taken pre-flush on May 1, 2002 of 2 Gy/h and 2.5 Gy/h (200 R/h and 250 R/h).

Table 2-4: Vessel Flushing Effectiveness in Terms of Estimated Cs-137 Removal

Condition	CFMT Remaining Inventory (Ci) (1)	CFMT Decontamination Factor	MFHT Remaining Inventory (Ci) (1)	MFHT Decontamination Factor
Before Flushing (2)	630	NA	540	NA
After All Flushes	95.3	6.6 (3)	97.1	5.6 (4)

(1) Multiply by 3.7×10^{10} to obtain Bq.
(2) The activity in each vessel before flushing began was estimated in the following manner: (a) the residual material (dried slurry) coating observed on the vessel interior surfaces before flushing was assumed to average 0.64-cm (0.250-inch) thickness over the upper one-third of the vessels, based on pre-flush visual inspection results; and (b) the Cs-137 concentration in this material was assumed to be a representative, decay corrected concentration of 5.0×10^3 μCi/cm^3.
(3) This decontamination factor is based on the best estimate Cs-137 activity. If a 20 percent greater upper bound estimate were to be used, the decontamination factor would be 5.5 rather than 6.6.
(4) This decontamination factor is based on the best estimate Cs-137 activity. If a 20 percent greater upper bound estimate were to be used, the decontamination factor would be 4.6 rather than 5.6.

2.5.4 NRC Evaluation of Waste Removal Efficiency

As part of the review, NRC asked DOE to provide additional support for the activity estimates (curies) before flushing, including: the surface area and volume assumptions, further justification for assuming the upper third of the vessels is coated, and a technical basis for assuming the concentration of batch 75. In its response, DOE noted that the batch 75 Cs-137 concentration was 429 MBq/cm^3 (1.16×10^4 μCi/cm^3) as given in the characterization report (WMG, 2011), but it was actually measured and reported as 429 MBq/g (1.16×10^4 μCi/g). Using a specific gravity of 1.33 to convert the units appropriately, the revised estimates were increased, yielding approximately 74 TBq (2,000 Ci) for the CFMT and approximately 59 TBq (1,600 Ci) for the MFHT.

Furthermore, in assuming that the Cs-137 concentration in the material was the same as that in the batch with the second highest concentration among the feed material, DOE was biasing the result towards overestimating the amount of Cs-137 in the vessels prior to flushing. Since the material remaining in the vessels is characterized by using batches 72, 74 and 75, it would be appropriate to also use this combination of samples to characterize what was in the vessel prior to flushing. Overestimating the activity before flushing could inflate the reduction factor and is therefore not a conservative approach. DOE acknowledged this in the response to RAIs (DOE, 2012c), stating that the geometric mean of *all the batches* as opposed to only batch 75 is a better approximate of the material since it likely accumulated over time. Therefore, DOE revised their approach to use the geometric mean of Cs-137 concentrations for all batches (240 MBq [6.5×10^3 μCi/cm^3]). The revised values are reflected in Table 2-4.

DOE also provided additional support for the removal efficiency by providing detailed photographic images, and pointing to the pre- and post-flushing dose rate measurements. NRC staff notes that in assuming that the upper one-third of the vessel is covered in residual material as opposed to some larger portion, DOE is potentially biasing the removal efficiency in a conservative fashion. (If DOE were to assume a larger area, the pre-flushing contamination value would have been higher.) DOE explained in the RAI responses that the one-third coverage assumption was based on the operational characteristics of the vessels, but also acknowledged that there was likely residual contamination in the bottom two-thirds of the vessel prior to flushing as well (DOE, 2012c). While the revised concentration assumption results in a lower decontamination factor, the visual inspections, dose rate reductions, along with the conservative one-third coverage assumption are sufficient to support the conclusion regarding removal efficiency. During the review, NRC staff requested additional information on the impacts of uncertainty on the removal to the maximum extent practical. In response, DOE clarified that if the upper bound for the scaling factors were applied, the CFMT reduction factor would change from 93 percent to about 92 percent. The MFHT reduction factor would change from 91 percent to about 89 percent. The dose rate reduction would also be minimally impacted. Based on the insignificance of these differences, the NRC staff concludes that the DOE has appropriately considered the impacts of uncertainty in the inventory for the purposes of determining the cleaning technology effectiveness.

In the NRC's prior review concerning the Melter (NRC, 2011), the NRC staff asked the DOE whether it considered modifications to the flushing method to improve efficiency prior to using the evacuated canisters. The DOE states that another batch of decontamination solution was not used because of concerns over acid hindering the integrity of the system (Kocialski, 2003). The DOE also stated that a decision was made in 2002 that the flushing had been satisfactorily completed before the evacuated canisters were employed (DOE, 2011a). As described in the evaluation of waste removal technologies the NRC staff questioned DOE about the practicality of a chemical wash for the MFHT after the vitrification system had been shut down and DOE sufficiently described how an additional chemical wash would not have been economically practical (DOE, 2012c).

In reviewing the *HLW Processing Systems Flushing Operations Run Plan* (WVNSCO, 2002b), as well as the noted concerns over the limited life of the Melter, the risk of its malfunction and impacts on the entire system, and the response to the RAI, the NRC staff concludes that ceasing removal activities for the MFHT and CFHT after the direct and indirect flushing activities that were carried out was reasonable (DOE, 2012c).

2.5.5 DOE Estimation of Costs and Benefits of Additional Waste Removal

Although DOE assumed that an additional flush would have removed 90 percent of the activity remaining in the vessel at conclusion of the flushing that was actually performed, DOE determined that the benefits of additional removal were limited. The low dose rates on the outside of the waste packages and compliance with the waste handling requirements at WVDP and the disposal facility would ensure protection of individuals during operation. Additionally, DOE concluded that since the impacts of disposal to the general population or to an intruder were negligible, a further reduction in radioactivity would not have been beneficial from the standpoint of potential doses. Additional removal, which would have incurred additional cleaning costs, could have also resulted in a cost savings of about $200,000 by using lighter weight steel and less shielding. However, the worker doses would have been about the same with this reduced shielding and the costs of additional waste removal would have been greater than the cost savings of $200,000. Uncertainty surrounding the potential benefits is not discussed in the DOE's analysis.

The costs included by the DOE in the draft WIR evaluation were primarily related to the cost of extending the shutdown date and continued operation of the facility. DOE conservatively did not quantify other costs such as capital costs specific to the cleaning technology, canister/container costs, the additional processing costs, shipping and disposal costs, as well as worker and public exposure costs. The Vitrification Facility operating cost per month is determined to be $1.89M per month. An additional flush, assumed to require two weeks, would have cost approximately $1M (DOE, 2012b). Uncertainty surrounding the potential costs is not discussed in DOE's analysis.

2.5.6 NRC Evaluation of Costs and Benefits of Additional Waste Removal

The NRC staff evaluated the following key assumptions regarding benefits:

- No benefit from reduced worker exposure
- No benefit from reduced public exposure, including an intruder

Even though additional removal activities are estimated to have potentially removed 90 percent of the residual activity, the additional removal does not translate into quantifiable benefits in terms of worker dose. Due to the already low doses resulting from the vessels without further removal, the NRC staff agrees that further radionuclide removal would not significantly reduce worker doses at the disposal facility.

In terms of public dose, as stated in NUREG-1854, page 3-11, "*The primary benefit of radionuclide removal is expected to be a reduction in the risk the waste will pose to the general public, including inadvertent intruders…. an analysis of the costs and benefits of additional radionuclide removal will depend in part on the performance assessment and inadvertent intruder analysis predictions*" (NRC, 2007). NRC staff reviewed only those items requested by DOE and did not independently verify the doses provided and any corresponding benefit of avoided public or intruder exposure by additional radionuclide removal. However, assuming that the dose estimates provided by DOE are accurate, even a large percentage of additional radionuclide removal would have negligible impact on the long-term dose in comparison to the social costs. Also, because the costs of additional removal would be so high, the NRC staff concludes that the impact on dose from additional flushing would be minimal in comparison to the large costs of additional radionuclide removal.

The NRC staff also evaluated the following key assumptions regarding costs:

- The vitrification operating costs and time to complete a flush
- Storage transport and disposal costs for HLW canisters

Annual operating costs for the Vitrification Facility were estimated to be between $25M and $30M per year ($500,000 per week). The DOE assumed that creation of a single new canister would have taken about two weeks from start to end, thus costing $1.0M (DOE, 2012b). The NRC staff finds these assumptions regarding cost and timing of additional operation to be reasonable considering canisters 267 through 275 (containing the flush solutions of batches 76 and 77) were processed over roughly 3 months from May 7, 2002 to August 14, 2002 (Kurasch, 2011). An additional flush could have required longer than 2 weeks, including downtime should the Melter have failed.

While the DOE does not attempt to quantify cost of HLW disposal in its summary cost benefit analysis, the NRC staff notes that the cost of storing, transporting, and disposing of a HLW canister to the repository could be substantial given that there is currently no disposal path for

HLW canisters. It is likely that the cost of disposal of additional HLW would be substantial enough to make uncertainty in DOE's estimates of the operating costs relatively insignificant.

Based on the discussion presented above, the NRC staff concludes that the costs and benefits considered are conservative and reasonable, and that the costs outweigh the benefits of additional removal activities.

3.0 THE WASTE WILL BE MANAGED TO MEET SAFETY REQUIREMENTS COMPARABLE TO THE PERFORMANCE OBJECTIVES OF 10 CFR PART 61, SUBPART C

This section of the NRC staff's technical review partially covers DOE Manual 435.1-1, Section II.B(2)(a)(2) – that waste will be managed to meet safety requirements that are comparable to the performance objectives set out in 10 CFR Part 61, *Performance Objectives*.

The performance objectives listed in 10 CFR Part 61 are as follows:

- §61.41 Protection of the general population from releases of radioactivity.
- §61.42 Protection of individuals from inadvertent intrusion.
- §61.43 Protection of individuals during operations.
- §61.44 Stability of the disposal site after closure.

According to the March 13, 2012 IA, DOE is requesting that the NRC staff focus its review on the requirements for operational radiation protection (§61.43) and the waste form stability (partial review of §61.44).

3.1 Protection of Individuals during Operations

10 CFR 61.43 states:

> *"Operations at the land disposal facility must be conducted in compliance with the standards for radiation protection set out in 10 CFR Part 20 of this chapter, except for releases of radioactivity in effluents from the land disposal facility, which shall be governed by Section 61.41 of this part. Every reasonable effort shall be made to maintain exposures as low as is reasonably achievable."*

The NRC staff's review for this section focused on DOE commitments to adhere to the appropriate regulations for protection of individuals during operations, and descriptions of how the regulations are implemented with respect to the draft WIR evaluation (DOE, 2012b). DOE has evaluated the protection of individuals during operations for disposal of the CFMT and MFHT at either NNSS or the WCS facility in Texas.

Section 61.43 references 10 CFR Part 20, *Standards for Protection Against Radiation*, which contains similar radiological protection standards to those of the DOE's for workers and the public, which can be found in 10 CFR Part 835, *Occupational Radiation Protection*, and DOE 5400.5*, Radiation Protection of the Public and the Environment*. The State of Texas regulations – found in Title 30 of the Texas Administrative Code, Chapter 336, *Radioactive Substance Rules* – also mirror §61.43. Table 3-1 shows that NRC, DOE, and the State of Texas regulations contain similar radiological protection standards. The NRC staff is not including a discussion about Nevada State Regulations because the NNSS is a Federal facility and thus isn't regulated by the state of Nevada. NNSS operations are performed in accordance with DOE regulations.

Table 3-1: Comparison of NRC, DOE, and Texas State Radiological Protection Standards

Crosswalk Topics	DOE	NRC	TX (Texas Rule)
Annual Air Emission Limit for Individual Member	DOE Order 5400.5 0.1 Sv (10 mrem)	§20.1101(d) 0.1 Sv (10 mrem)	§336.304 0.1 Sv (10 mrem)
Annual TEDE for Adult Workers	§835.202(a)(1) 0.05 Sv (5 rem)	§20.1201(a) 0.05 Sv (5 rem)	§336.305 0.05 Sv (5 rem)
Any Individual Organ or Tissue Annual Dose Limit for Adult Workers	§835.202(a)(2) 0.5 Sv (50 rem)	§20.1201(a) 0.5 Sv (50 rem)	§336.305 0.5 Sv (50 rem)
Annual Dose Limit to the Lens of the Eye for Adult Workers	§835.202(a)(3) 0.15 Sv (15 rem)	§20.1201(a) 0.15 Sv (15 rem)	§336.305 0.15 Sv (15 rem)
Annual Dose Limit to the Skin of the Whole Body and to the Skin of the Extremities for Adult Workers	§835.202(a)(4) 0.5 Sv (50 rem)	§20.1201(a) 0.5 Sv (50 rem)	§336.305 0.5 Sv (50 rem)
Limit on Soluble Uranium Intake	DOE Order 440.1A 2.4 mg/week	§20.1201(e) 10 mg/week	§336.305 10 mg/week
Dose Equivalent to Embryo/Fetus	§835.206(a) 5 mSv (0.5 rem)	§20.1208(a) 5 mSv (0.5 rem)	§336.312 5 mSv (0.5 rem)
Dose Limit for Individual Member of the Public (Total Annual Dose)	DOE Order 5400.5 1 mSv (100 mrem)	§20.1301(a) 1 mSv (100 mrem)	§336.313 1 mSv (100 mrem)
Dose Limit for Individual Members of the Public (Dose Rates in Unrestricted Areas)	§835.602 0.005 mSv/hr (0.05 mrem/hr)	§20.1301(a) 0.02 mSv/hr (2 mrem/hr)	§336.313 0.02 mSv/hr (2 mrem/hr)
Dose Limits for Members of the Public with Access to Controlled Areas	§835.208 0.001 Sv (0.1 rem)	§20.1301(b) 0.001 Sv (0.1 rem)	§336.313 0.001 Sv (0.1 rem)
As Low As Reasonably Achievable	§835.2	§20.1003	§336.2

As part of the Criterion 2 demonstration, DOE shows that the CFMT and MFHT meet the waste acceptance criteria for the NNSS (DOE, 2012a) and WCS (WCS, 2008). There is a 300 plutonium equivalent gram (PE-g) limit for waste packages disposed of at NNSS. The NRC staff agrees with DOE's assessment that the residual wastes remaining in the CFMT and MFHT meet this 300 PE-g safety requirement. DOE notes that a waste profile package for disposal of the CFMT and MFHT has already been approved by NNSS contingent upon the outcome of the WIR evaluation. WCS is limited in the total waste volume and total activity that can be accepted. For example, WCS has a license limit of 0.23 million cubic meters (8.1 million cubic feet) of waste and 190 million gigabecquerels (5.1 million Curies) of waste. DOE shows that the CFMT and MFHT will have a negligible contribution to these license limits.

3.2 Waste Form Stability

10 CFR 61.44 states:

> *"The disposal facility must be sited, designed, used, operated, and closed to achieve long term stability of the disposal site and to eliminate to the extent practicable the need for ongoing active maintenance of the disposal site following closure so that only surveillance, monitoring, or minor custodial care are required."*

As specified in the IA, the NRC staff's review focuses on waste form stability and does not include a review of the disposal site stability. Review of waste form stability involves verification of the structural stability of the waste after site closure as well as verification that void spaces in the waste will not cause differential settling of the waste or provide preferential flow paths for infiltrating water.

The following three characteristics of the waste form support the argument that the waste is in a stable form: the structural integrity of the UC; the Department of Transportation Industrial Package 2 (IP-2) shipping containers, which contain the UC; and the low-density cellular concrete that will fill the void spaces in the CFMT, MFHT, and associated packages.

The CFMT is constructed of Hastelloy C-22, a nickel-chromium-molybdenum-tungsten alloy. The lower part of the CFMT exterior is covered with heat transfer coils formed of stainless steel piping covered with fiberglass insulation and stainless steel sheeting. The MFHT is constructed of stainless steel and is partially covered by a cooling jacket.

NUREG-1854 directs the staff to consider waste stability, as set forth in §61.56(b). The CMFT and MFHT IP-2 packages are *"capable of supporting a uniformly distributed load (compressive strength) of 3,375 pounds per square foot strength requirement of the Nevada Test Site Waste Acceptance Criteria (DOE/NV-325)"* (WMG, 2004b; WMG, 2004c). In addition, NRC staff and contractors previously concluded that concrete can be formulated for a 500-year service life (NRC, 1989). Among other things, factors such as sulfate attack, freezing and thawing, and stress cracking were addressed in the analysis (NRC, 1989; NRC, 1990).

Criterion 3 of DOE Manual 435.1-1, Section II.B(2)(a) states:

> *"[The wastes] are to be managed, pursuant to DOE's authority under the Atomic Energy Act of 1954, as amended, and in accordance with the provisions of Chapter IV of DOE Manual 435.1-1, provided the waste will be incorporated in a solid physical form at a concentration that does not exceed the applicable concentration limits for Class C low-level waste as set out in 10 CFR 61.55, Waste Classification; or will meet alternative requirements for waste classification and characterization as DOE may authorize."*

As part of the Criterion 3 demonstration, DOE shows that the UC are in a solid physical form. DOE describes in the draft WIR that *"void spaces in both vessels and their waste containers* *have been filled with grout consisting of low-density cellular concrete to stabilize the vessels within the shipping containers during transport and to encapsulate surface contamination"* (DOE, 2012b).

The NRC staff concludes that the waste is in a stable form because all void spaces will be filled with low-density cellular concrete, which was previously determined to have a 500-year service life, and because the IP-2 packages containing the CFMT and MFHT meet the compressive strength requirements of the disposal facility. As previously noted, this review did not evaluate the durability of the waste form or packaging with respect to meeting the §61.41 or §61.42 performance objectives.

4.0 THE WASTE WILL NOT EXCEED CLASS C CONCENTRATION LIMITS AND WILL BE MANAGED IN ACCORDANCE WITH DOE REQUIREMENTS AS LLW

This section of the TER pertains to the third criterion in Section II.B(2)(a) of DOE-M 435.1-1: (i) that the CFMT and MFHT waste packages will be in a solid physical form, (ii) will not exceed Class C concentration limits, and (iii) will be managed in accordance with DOE requirements as LLW, as applicable. The DOE indicated that the focus of NRC's review under this criterion should be waste form stability and classification.

4.1 The DOE's Waste Classification Approach

Criterion 3 of DOE-M 435.1-1 Section II.B (2)(a) is reproduced below for ease of reference:

> "*[The wastes] are to be managed, pursuant to DOE's authority under the Atomic Energy Act of 1954, as amended, and in accordance with the provisions of Chapter IV of this Manual, provided the waste will be incorporated in a solid physical form at a concentration that does not exceed the applicable concentration limits for Class C low-level waste as set out in [Code of Federal Regulations] §61.55, Waste Classification, or will meet alternative requirements for waste classification and characterization as DOE may authorize.*"

Table 4-1 presents the DOE's waste classification results for the CFMT and MFHT, and the results support a conclusion that the vessels do not exceed the Class C concentration limits.

To evaluate the DOE's approach for determining the class of the vessels, the staff reviewed the waste classification requirements found in 10 CFR §61.55. Table 1 of §61.55 contains concentration limits for long-lived radionuclides including a specific class of radionuclides, alpha-emitting transuranic radionuclides with half-lives greater than 5 years. DOE listed several radionuclides that were members of this class (e.g., Np-237, Pu-238, Pu-239, Pu-240, Am-241, Am-243, Cm-243, and Cm-244) along with their corresponding contributions to the sum of fractions. Table 2 of §61.55 contains a list of concentration limits for relatively short-lived radionuclides. DOE also evaluated the contributions of short-lived radionuclides found in Table 2 to the sum of fractions. The sum of fractions approach used to determine waste classification for mixtures of radionuclides is described in §61.55(a)(7). Because the CFMT and MFHT contain a mixture of long- and short-lived radionuclides, DOE applied §61.55(a)(5) to determine waste classification. §61.55(a)(5) and (a)(7) are reproduced below for additional background information on the waste classification calculations.

> *§61.55(a)(5), "Classification determined by both long- and short-lived radionuclides. If radioactive waste contains a mixture of radionuclides, some of which are listed in Table 1, and some of which are listed in Table 2, classification shall be determined as follows: (i) If the concentration of a nuclide listed in Table 1 does not exceed 0.1 times the value listed in Table 1, the class shall be determined by the concentration of the radionuclides listed in Table 2. (ii) If the concentration of a nuclide listed in Table 1 exceeds 0.1 times the value listed in Table 1 but does not exceed the value in Table 1, the waste shall be Class C, provided the concentration of nuclides listed in Table 2 does not exceed the value shown in Column 3 of Table 2."*

§61.55(a)(7), "The sum of the fractions rule for mixtures of radionuclides. For determining classification for waste that contains a mixture of radionuclides, it is necessary to determine the sum of fractions by dividing each nuclide's concentration by the appropriate limit and adding the resulting values. The appropriate limits must all be taken from the same column of the same table. The sum of the fractions for the column must be less than 1.0 if the waste class is to be determined by that column. Example: A waste contains Sr-90 in a concentration of 50 Ci/m^3 and Cs-137 in a concentration of 22 Ci/m^3. Because the concentrations both exceed the values in Column 1, Table 2, they must be compared to Column 2 values. For Sr-90 fraction 50/150 = 0.33; for Cs-137 fraction, 22/44 = 0.5; the sum of the fractions = 0.83. Because the sum is less than 1.0, the waste is Class B."

In its statement of work, the DOE requested that the NRC evaluate the waste classification calculations against NRC's guidance found in NUREG-1854, Chapter 3, Section 3.5.1.1, "Concentration Averaging" (NRC, 2007). The NRC's guidance on concentration averaging considers three categories of averaging based on (1) physical homogeneity, (2) stabilization, and (3) site-specific (intruder) analysis considerations.

Because residual radioactivity associated with the vessels is not physically homogeneous (not evenly distributed across the entire vessel packages), NRC's guidance on concentration averaging (NRC, 1995) would also allow the DOE to consider site-specific factors in evaluating the risk to an inadvertent intruder under option (3). However, the DOE did not elect to use this option although it may have led to a smaller Class C sum of fractions, thereby providing additional confidence that the waste is not greater than Class C.

The DOE elected to use a method that is consistent with option (2) stabilization, although it did not explicitly take full advantage of this option. For example, the DOE did not attempt to average residual radioactivity over the weight of stabilizing grout it is planning to use to fill void spaces in the vessels and their respective waste containers. However, the DOE may have made reasonable arguments on how at least a fraction of the stabilizing grout may have been necessary to encapsulate or assist with immobilization of contamination within the vessels.

Radionuclide concentrations for purposes of waste classification for the CFMT are based on averaging the total activity of each radionuclide to the total weight of the vessels themselves. The weight does not include the weight of the shipping containers (i.e., shielded IP-2) or the weight of stabilizing grout used to fill voids in the vessels and voids between the vessels and their shipping containers. The total weight of the CFMT and MFHT used in the calculation was 8,530 kg (18,810 lbs) and 10.800 kg (23,710 lbs) respectively. The waste volume is calculated using the vessel weight and the density of stainless steel. The volume used was1.07 m^3 (37.6 ft^3) and 1.34 m^3 (47.4 ft^3) respectively. The resulting sums of fractions the DOE calculated based on using the average dose rates and geometric mean values of analytical data as described in the characterization report (WMG, 2011) and the related analysis (Kurasch, 2012) are shown in Table 4-1.

4.2 NRC Evaluation of the DOE's Waste Classification Approach

The NRC staff has evaluated DOE's methodology for classifying waste and finds the approach an acceptable application of Category 2 of NRC staff's guidance on concentration averaging found in NUREG-1854 (NRC, 2007) and consistent with Section 3.4 of NRC's Branch Technical Position (BTP) (NRC, 1995). It is important to note that NRC's guidance on concentration averaging in NUREG-1854 does not replace the BTP. Rather NUREG-1854 attempts to apply the concentration averaging guidance principles specifically to WIR applications, providing additional flexibility, where appropriate, consistent with the general principles of the BTP. NRC considers DOE's waste classification calculations consistent with Section 3.4 of the NRC's BTP entitled "Contaminated Materials." Section 3.4 of NRC's BTP provides for averaging over the total weight of displaced volume of the contaminated item with major void volumes subtracted from the envelope volume.

In using the weight of the vessels and the density of steel to calculate the volume, DOE avoided averaging over large void volumes. This approach follows NRC guidance, which states that large void volumes should usually not be part of the concentration averaging process as indicated in Section 3.4 of NRC's BTP. NRC also notes that DOE did not take credit for the weight of stabilizing grout used to encapsulate the residual radioactivity. Therefore, the NRC finds DOE's approach to determining the concentration appropriate.

As noted in Section 2.2 of this document, the DOE identifies high and low activity ranges that are plus or minus 20 percent, respectively of the final waste form concentrations shown in Table 4-1 and Table 4-2. Even taking this uncertainty into consideration, the inventories are still well within the fraction of Table 1 or Table 2 of §61.55. DOE also calculated the Class C concentration assuming the Melter scaling factors as a result of RAIs, and shows that the impact on the sum of fractions is insignificant (DOE, 2012c). Therefore, the NRC staff concludes that the DOE's assessment that the CFMT and MFHT is Class C, considering uncertainty in the volume of the vessels and uncertainty in the inventory estimates therein, is technically sufficient.

As noted in Section 2.2, the NRC staff reviewed historical inventories and compared those to the radionuclides considered for waste classification purposes. NRC staff notes that some of the radionuclides listed in the inventory are denoted with an "NA." DOE clarified that certain transuranics with half-lives greater than 5 yrs that were listed in the sludge/supernatant inventory (Pu-242, Am-242m, Cm-245, Cm-246), were not originally considered in the waste classification because they were present in small quantities in the sludge/supernatant. For consistency, the DOE added these radionuclides to the waste classification table. Since they are present in small quantities, inclusion of these transuranics does not significantly impact the sum of fractions.

The vessels may be transported to the Nevada National Security Site Area 5 Radioactive Waste Management Site for disposal. The vessel waste packages would be disposed of as LLW and managed in accordance with DOE requirements for LLW disposal found in Chapter IV of DOE-M 435.1-1. The waste form meets the site's acceptance criteria and the waste profile has been formally approved by the potential disposal facility. The DOE may alternatively decide to ship the waste to the commercially operated WCS federal facility waste disposal facility in Texas. The State of Texas Class C concentration limits are consistent with §61.55 and the vessels would meet the Class C LLW concentration limits established in the Texas Administrative Code.

Based on the NRC's review of DOE's draft WIR evaluation and supporting references, the NRC considers the DOE's conclusions to be adequate and reasonable such that the DOE can meet Criterion 3 of DOE-M 435.1-1 related to management of WIR as LLW.

Table 4-1: Concentrator Feed Makeup Tank Waste Concentration Results

Nuclide	Activity	Class C Limit [2]		CFMT Concentration [2]		Percent	
	(Ci) [1]	(Ci/m3) [1]	(nCi/g) [1]	(Ci/m3) [1]	(nCi/g) [1]	Table 1	Table 2
C-14	NA	8.00×10^{0}					
K-40	NA						
Mn-54	NA						
Co-60	4.1x10-03			1.73×10^{-3}			
Ni-63	NA	$7.00 \times 10^{+2}$					
Sr-90	3.9x10+00	$7.00 \times 10^{+3}$		1.05×10^{0}			0.052%
Zr-95	NA						
Tc-99	1.8x10-03	3.00×10^{0}		3.90×10^{-3}		0.060%	
Cs-137	9.5x10+01	$4.60 \times 10^{+3}$		$8.91 \times 10^{+1}$			1.936%
Eu-154	5.6x10-02			4.83×10^{-2}			
Np-237	5.6x10-05		$1.00 \times 10^{+2}$		7.81×10^{-3}	0.007%	
Pu-238	6.9x10-03		**$1.00 \times 10^{+2}$**		6.08×10^{-1}	0.809%	
Pu-239	1.5x10-03		$1.00 \times 10^{+2}$		1.64×10^{-1}	0.176%	
Pu-240	1.5x10-03		$1.00 \times 10^{+2}$		1.25×10^{-1}	0.176%	
Pu-241	1.4x10-02		$3.50 \times 10^{+3}$		1.81×10^{0}	0.047%	
Pu-242	NA		$1.00 \times 10^{+2}$				
Am-241	3.7x10-02		**$1.00 \times 10^{+2}$**		2.91×10^{0}	4.338%	
Am-242m	NA		$1.00 \times 10^{+2}$				
Am-243	3.3x10-04		$1.00 \times 10^{+2}$		2.99×10^{-2}	0.039%	
Cm-242	3.9x10-04		$2.00 \times 10^{+4}$		1.15×10^{-2}	0.000%	
Cm-243	3.2x10-03		$1.00 \times 10^{+2}$		1.82×10^{-2}	0.375%	
Cm-244	3.2x10-03		$1.00 \times 10^{+2}$		4.71×10^{-1}	0.375%	
Cm-245	NA		$1.00 \times 10^{+2}$				
Sum of Fractions						**6.5%**	**2.0%**

From WMG (2011b), the calculations are based on the CFMT weight. The activity estimates used were as of October 1, 2004; the activities are now somewhat lower due to radioactive decay. The weight used in the calculation was 8,530 kg (18,810 lbs) and the volume used was 0.07 m^3 (37.62 ft^3).
Table numbers refer to §61.55, Tables 1 and 2. (Table I and Table II to Appendix E to Rule §336.362 of the Texas Administrative Code are identical to NRC's Table 1 and Table 2).
[1] Conversion to GBq from Ci, multiply by 37 GBq/Ci.
[2] Conversion to Bq from nCi, multiply by 37 Bq/nCi

Table 4-2: Melter Feed Holder Tank Waste Concentration Results

Nuclide	Activity	Class C Limit [2]		CFMT Concentration [2]		Percent	
	(Ci) [1]	(Ci/m^3) [1]	(nCi/g) [1]	(Ci/m^3) [1]	(nCi/g) [1]	Table 1	Table 2
C-14	3.98×10^{-4}	8.00×10^{0}		2.97×10^{-4}		0.004%	
K-40	1.54×10^{-3}			1.15×10^{-3}			
Mn-54	1.67×10^{-3}			1.25×10^{-3}			
Co-60	1.58×10^{-3}			1.18×10^{-3}			
Ni-63	1.89×10^{-2}	$7.00 \times 10^{+2}$		1.41×10^{-2}			0.002%
Sr-90	5.34×10^{0}	$7.00 \times 10^{+3}$		3.99×10^{0}			0.057%
Zr-95	3.72×10^{-2}			2.78×10^{-2}			
Tc-99	8.34×10^{-4}	3.00×10^{0}		6.22×10^{-4}		0.021%	
Cs-137	$9.71 \times 10^{+1}$	$4.60 \times 10^{+3}$		$7.25 \times 10^{+1}$			1.575%
Eu-154	3.18×10^{-2}						
Np-237	7.26×10^{-5}		$1.00 \times 10^{+2}$		6.72×10^{-3}	0.007%	
Pu-238	9.19×10^{-3}		$1.00 \times 10^{+2}$		8.51×10^{-1}	0.851%	
Pu-239	2.28×10^{-3}		$1.00 \times 10^{+2}$		2.11×10^{-1}	0.211%	
Pu-240	1.74×10^{-3}		$1.00 \times 10^{+2}$		1.61×10^{-1}	0.161%	
Pu-241	5.88×10^{-2}		$3.50 \times 10^{+3}$		5.44×10^{0}	0.156%	
Pu-242	NA		$1.00 \times 10^{+2}$				
Am-241	4.33×10^{-2}		$1.00 \times 10^{+2}$		4.01×10^{0}	4.009%	
Am-242m	NA		$1.00 \times 10^{+2}$				
Am-243	3.93×10^{-4}		$1.00 \times 10^{+2}$		3.64×10^{-2}	0.036%	
Cm-242	3.42×10^{-4}		$2.00 \times 10^{+4}$		3.17×10^{-2}	0.000%	
Cm-243	2.84×10^{-4}		$1.00 \times 10^{+2}$		2.63×10^{-2}	0.026%	
Cm-244	7.36×10^{-3}		$1.00 \times 10^{+2}$		6.81×10^{-1}	0.681%	
Cm-245	NA		$1.00 \times 10^{+2}$				
Sum of Fractions						**6.3%**	**1.6%**

From WMG (2011b), the calculations are based on the MFHT weight. The activity estimates used were as of October 1, 2004; the activities are now somewhat lower due to radioactive decay. The weight used in the calculation was 10.800 kg (23,710 lbs) and the volume used was 1.34 m^3 (47.42 ft^3).
Table numbers refer to §61.55, Tables 1 and 2. (Table I and Table II to Appendix E to Rule §336.362 of the Texas Administrative Code are identical to NRC's Table 1 and Table 2.).

[1] Conversion to GBq from Ci, multiply by 37 GBq/Ci.

[2] Conversion to Bq from nCi, multiply by 37 Bq/nCi.

5.0 CONCLUSIONS

5.1 NRC Review: Waste has been Processed to Remove Key Radionuclides to the Maximum Extent that is Technically and Economically Practical

Overall Conclusion: Based on the NRC's review of DOE's draft WIR evaluation and supporting references, the NRC considers the DOE's conclusions to be adequate and reasonable such that the DOE can meet the NRC-reviewed portions of Criterion 1 of DOE-M 435.1-1 related to the removal of key radionuclides. This is based on the following specific topical conclusions.

Waste Inventory:

- The NRC staff finds the list of radionuclides presented in the inventory as presented in the draft WIR evaluation acceptable.
- The NRC staff concludes that the approaches taken for data verification as outlined in the Characterization Management Plan for the Facility Characterization Project were appropriate.

Key Radionuclides:

- The IA for this review specifically states that NRC's scope of review does not include an independent review of the key radionuclide list because the cleaning technologies evaluated and applied were bulk-cleaning methods. It is not necessary for the NRC staff to make a determination on whether or not the key radionuclide list is appropriate in order to review other portions of the waste evaluation because the staff does not rely on this list for coming to a conclusion about removal to the maximum extent practical or waste classification.

Removal to the Maximum Extent Technical and Economically Practical:

- The NRC staff concludes that DOE evaluated a reasonable range of technologies that included methods to remove volumes of waste.
- The NRC staff concludes that the DOE has appropriately considered the impacts of uncertainty in the inventory as it relates to the radionuclide removal demonstration.
- The NRC staff concludes that ceasing removal activities for the MFHT and CFHT after the direct and indirect flushing activities that were carried out was reasonable.
- Due to the already low doses resulting from the vessels without further removal, the NRC staff agrees that further radionuclide removal would not significantly reduce worker doses at the disposal facility.
- Assuming that the DOE's dose estimates are accurate, even a large percentage of additional radionuclide removal would have negligible impact on the long-term dose in comparison to the social costs.

- Based on the discussion presented above, the NRC staff concludes that the costs and benefits considered are conservative and reasonable, and that the costs outweigh the benefits of additional removal activities.

5.2 NRC Review: Waste will be Managed to Meet Safety Requirements Comparable to the Performance Objectives of 10 CFR 61, Subpart C

Conclusion: Based on the NRC's review of DOE's draft WIR evaluation and supporting references, the NRC considers the DOE's conclusions to be adequate and reasonable such that the DOE can meet the NRC-reviewed portions of Criterion 2 of DOE-M 435.1-1 related to Safety Requirements associated with the Performance Objectives of 10 CFR 61, Subpart C. This is based on the following specific topical conclusions.

Protection of Individuals during Operations:

- The NRC staff agrees with DOE's assessment that the residual wastes remaining in the CFMT and MFHT meet the applicable safety requirements for protection of individuals during operations.

Waste Form Stability:

- As specified in the IA, the NRC staff's review focuses on waste form stability and does not include a review of the disposal site stability.

- The NRC staff concludes that the waste is in a stable form due to the structural integrity afforded by the CFMT and MFHT, the IP-2 packages, and the low-density cellular concrete that will fill void spaces. As previously noted, this review does not evaluate the durability of the waste form or packaging with respect to meeting the §61.41 or §61.42 performance objectives.

5.3 NRC Review: Waste will not Exceed Class C Concentration Limits and will be Managed in Accordance with DOE Requirements as LLW

Conclusion: Based on the NRC's review of DOE's draft WIR evaluation and supporting references, the NRC considers the DOE's conclusions to be adequate and reasonable such that the DOE can meet Criterion 3 of DOE-M 435.1-1 related to management of WIR as LLW.

DOE's Waste Classification Approach:

- The NRC staff has evaluated DOE's methodology for classifying waste and finds the approach an acceptable application of Category 2 of NRC staff's guidance on concentration averaging found in NUREG-1854 (NRC, 2007) and consistent with Section 3.4 of NRC's Branch Technical Position (BTP) (NRC, 1995).

- The NRC finds DOE's approach in determining the concentrations appropriate.

- The NRC staff concludes that the DOE's assessment that the CFMT and MFHT is Class C, considering uncertainty in the volume of the vessels and uncertainty in the inventory estimates therein, technically sufficient.

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7.0 REFERENCES

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