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Title: Evaluation of Low-Level Waste Disposal Receipt Data for Los Alamos National Laboratory Technical Area 54, Area G Disposal Facility – Fiscal Year 2011

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Evaluation of Low-Level Waste Disposal Receipt Data for Los Alamos National Laboratory Technical Area 54, Area G Disposal Facility – Fiscal Year 2011

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Acronyms and Abbreviations

CWC	Consolidated Waste Capability
D&D	Decontamination and decommissioning
DOE	Department of Energy
ER	Environmental restoration
FY	Fiscal year
LANL or Laboratory	Los Alamos National Laboratory
LLW	Low-level (radioactive) waste
MDA	Material Disposal Area
NNSS	Nevada National Security Site
TA	Technical Area
WETF	Weapons Engineering Tritium Facility

1.0 Introduction

The Los Alamos National Laboratory (LANL or the Laboratory) generates radioactive waste as a result of various activities. Operational or institutional waste is generated from a wide variety of research and development activities including nuclear weapons development, energy production, and medical research. Environmental restoration (ER), and decontamination and decommissioning (D&D) waste is generated as contaminated sites and facilities at LANL undergo cleanup or remediation. The majority of this waste is low-level radioactive waste (LLW) and is disposed of at the Technical Area 54 (TA-54), Area G disposal facility.

U.S. Department of Energy (DOE) Order 435.1 (DOE, 2001) requires that radioactive waste be managed in a manner that protects public health and safety, and the environment. To comply with this order, DOE field sites must prepare and maintain site-specific radiological performance assessments for LLW disposal facilities that accept waste after September 26, 1988. Furthermore, sites are required to conduct composite analyses that account for the cumulative impacts of all waste that has been (or will be) disposed of at the facilities and other sources of radioactive material that may interact with the facilities.

Revision 4 of the Area G performance assessment and composite analysis was issued in 2008 (LANL, 2008). These analyses estimate rates of radionuclide release from the waste disposed of at the facility, simulate the movement of radionuclides through the environment, and project potential radiation doses to humans for several on-site and off-site exposure scenarios. The assessments are based on existing site and disposal facility data and on assumptions about future rates and methods of waste disposal.

The accuracy of the performance assessment and composite analysis depends upon the validity of the data used and assumptions made in conducting the analyses. If changes in these data and assumptions are significant, they may invalidate or call into question certain aspects of the analyses. For example, if the volumes and activities of waste disposed of during the remainder of the disposal facility's lifetime differ significantly from those projected, the doses projected by the analyses may no longer apply.

DOE field sites are required to implement a performance assessment and composite analysis maintenance program. The purpose of this program is to ensure the continued applicability of the analyses through incremental improvement of the level of understanding of the disposal site and facility. Site personnel are required to conduct field and experimental work to reduce the uncertainty in the data and models used in the assessments. Furthermore, they are required to conduct periodic reviews of waste receipts, comparing them to projected waste disposal rates.

The radiological inventory for Area G was updated in conjunction with Revision 4 of the performance assessment and composite analysis (Shuman, 2008). That effort used disposal records and other sources of information to estimate the quantities of radioactive waste that have been disposed of at Area G from 1959, the year the facility started receiving waste on a routine basis, through 2007. It also estimated the quantities of LLW that will require disposal from 2008 through 2044, the year in which it is assumed that disposal operations at Area G will cease.

This report documents the fourth review of Area G disposal receipts since the inventory was updated and examines information for waste placed in the ground during fiscal years (FY) 2008 through 2011. The primary objective of the disposal receipt review is to ensure that the future waste inventory projections developed for the performance assessment and composite analysis are consistent with the actual types and quantities of waste being disposed of at Area G. Toward this end, the disposal data that are the subject of this review are used to update the future waste inventory projections for the disposal facility. These projections are compared to the future inventory projections that were developed for Revision 4 of the performance assessment and composite analysis.

The approach used to characterize the FY 2008 through 2011 waste is generally the same as that used to characterize the inventory for the Revision 4 analyses (Shuman, 2008). This methodology is described in Section 2. The results of the disposal receipt review are presented in Section 3 and discussed in terms of their significance to the Area G analyses.

2.0 Waste Characterization Methodology

The Area G disposal facility consists of Material Disposal Area G (MDA G) and the Zone 4 expansion area. Two disposal unit configurations—pits and shafts—are used for the disposal of waste at the facility. Most waste is placed in large, rectangular pits; shafts are used for the disposal of higher activity waste and specific waste streams.

The waste disposed of at Area G includes institutional or routine waste, nonroutine waste, and waste from ER and D&D activities at LANL. Institutional waste consists of a wide range of materials including compactable trash (e.g., paper, cardboard, and plastic), rubber, glass, disposable protective clothing, solidified powders and ash, animal tissue, and suspect radioactive waste. Nonroutine waste has included classified waste, uranium chips from shops at LANL, and pieces of heavy equipment such as dump trucks (Rogers, 1977). The ER and D&D waste generally consists of equipment and scrap metal, building debris, and soil.

The types and quantities of LLW disposed of at Area G are recorded on shipment manifests and entered into the LANL LLW disposal database on a per-package basis. The containers used for the disposal of these items are also tracked. The information contained in the database includes a description of the waste, the volume of the waste items, and the radionuclide activities in the waste. These data were used to characterize the waste that has been disposed of since the 2008 inventory characterization (Shuman, 2008) was completed.

The FY 2008 through 2011 disposal receipts cover the period from October 1, 2007 through September 30, 2011. The waste characteristics developed on the basis of this information were used to update the existing inventories at Area G. This update was conducted on a pit- and shaft-specific basis, consistent with the 2008 inventory characterization (Shuman, 2008).

In addition to updating existing inventories, the disposal receipt review process reexamines the inventories that are projected by the performance assessment and composite analysis to require future disposal at Area G. The 2008 inventory characterization (Shuman, 2008) included projections of the quantities of LLW that will require disposal at Area G from 2008 through 2044, the year in which it is assumed that disposal operations will cease. Those estimates assumed that the disposal of institutional waste at Area G would continue at rates equivalent to those observed from 2000 through 2007. The use of 8 years of disposal data to estimate future rates of disposal was expected to capture year-to-year variations in waste generation at LANL without placing undue emphasis on programs and activities that may no longer be relevant. The quantities of ER and D&D waste expected to require disposal from 2008 through 2044 were estimated using future volume projections developed in 2007 and radionuclide concentrations characteristic of ER and D&D waste disposed of from 2000 through 2007.

To date, all disposal operations at Area G have been confined to the pits and shafts within MDA G. However, this portion of Area G is scheduled to undergo final closure by 2015; disposal operations within MDA G are scheduled to cease at the end of 2013 to meet this schedule. In terms of the pits, only pit 38 remains open at this time and this disposal unit will be filled in 2012. Investigations are underway to determine the feasibility of extending pit 38, which would provide sufficient pit capacity to accommodate waste through the end of 2013. Additional shafts may also be needed to accommodate waste through 2013.

Disposal data developed for the 2008 inventory characterization and the FY 2011 disposal receipt review were used to estimate the quantities of waste that will be disposed of in MDA G prior to its closure at the end of 2013. Disposal in pit 38 was assumed to continue until that unit is filled in 2012; no other waste was assumed to be disposed of in the pits at MDA G. Should the decision to extend pit 38 be made, the modeling conducted in support of the performance assessment and composite analysis will be updated to reflect the modified disposal unit and the waste disposed of therein. The radionuclide inventories in the waste that is used to fill pit 38 were calculated as the product of the average radionuclide concentrations in the waste placed in pit 38 through FY 2011 and the waste capacity of the disposal unit.

Low-activity waste generated by cleanup efforts at LANL has been disposed of in the headspace of pits 15, 37, and 38. Prior to the use of headspace, the disposal of waste was permitted as long as the surface of the material was at least 3 m (9.8 ft) below natural grade of the disposal site. With the advent of headspace disposal, waste could be placed to within 0.3 m (1 ft) of the soil-tuff interface, but no less than 2.5 m (8.2 ft) below the surface of the final cover placed over the facility. The radionuclide inventories developed for pit 38 distinguished between the headspace and institutional waste; the inventories in these layers were also tracked separately for pits 15 and 37.

The shafts within MDA G were assumed to receive all waste normally destined for these units through the end of 2013. With the exception of high-activity tritium waste, the operational waste that is normally placed in shafts was assumed to be disposed of at the average rate observed from 2004 through FY 2011. Radionuclide concentrations in this waste were set equal to the average concentrations observed in the shaft waste disposed of over this same period.

The 2008 inventory characterization (Shuman, 2008) estimated the inventories in the high-activity tritium waste placed in the disposal shafts. More recent information suggests that significantly greater quantities of tritium may require disposal. Based on information received from Weapons Engineering Tritium Facility (WETF) personnel, the assumption was made that three containers of high-activity tritium waste, containing as much as 300,000 Ci of tritium, would be disposed of in FY 2012. These containers are currently being readied for disposal. Although the inventories of these containers have not been finalized, they will not exceed the assumed activity. A total of six containers of high-activity waste were assumed to be disposed of in FY 2013. Four of these containers are currently in storage; based on the amount of decay expected to occur by October 1, 2012, the contents of these containers yield a tritium activity of 167,000 Ci. Two containers of waste, with an additional 120,000 Ci of tritium, are projected to require disposal as a result of normal operations.

As discussed in the FY 2010 disposal receipt review (LANL, 2011), the impending closure of MDA G has caused a shift in disposal philosophy. Whereas prior to FY 2009 essentially all of the LLW generated at LANL was disposed of at Area G, an increasing portion of the LLW generated at the Laboratory is expected to be shipped to commercial facilities or the Nevada National Security Site (NNSS) for off-site disposal. It is not clear at this time how much of the LLW generated at LANL will be disposed of on site.

The Consolidated Waste Capability (CWC) project was initiated to ensure that the solid waste management functions needed to handle the Laboratory's waste are put in place as the waste management operations at MDA G are phased out. A preliminary siting study was conducted to identify suitable locations for the consolidated waste management facility at LANL. In terms of waste disposal, it is uncertain if Zone 4 will be used for disposal; this portion of Area G was assumed to receive waste under the performance assessment and composite analysis. For the current review, it was assumed that 200 m^3 (260 yd^3) of waste will be disposed of annually in Zone 4 from 2014 through 2044; this volume represents 10 percent of the midpoint of the range of institutional waste volumes that are projected to require disposal on a routine basis (LANL, 2009).

With the exception of high-activity tritium waste, rates of waste disposal in the shafts in Zone 4 were assumed to be the same as those observed from FY 2004 through FY 2011. Two containers of high-activity tritium waste were assumed to be disposed of annually from the start of 2014 through 2044; the activity in these containers totaled 120,000 Ci. The annual volumes of institutional waste disposed of in pits at Area G is the difference between 200 m^3 (260 yd^3) and the projected annual volumes of waste disposed of in shafts. Radionuclide concentrations in the pit waste were set equal to those observed in the waste disposed of in pits from FY 2004 through FY 2011.

The radionuclide inventories estimated for the waste disposed of from the start of FY 2012 through 2044 are approximate at best. Using radionuclide inventories in the waste that was disposed of in pit 38 through FY 2011 to estimate inventories for the waste that will fill this unit in FY 2012 is expected to provide reasonably accurate estimates of the total pit's inventory. The waste disposed of in the pit is characteristic of recent years' disposal trends and the period over which waste data are extrapolated is short. Estimates of the FY 2012 through 2044 shaft inventories are probably less certain. The radionuclide concentrations used to develop these inventories are 8-year averages taken over several disposal units, and the results are extrapolated over a period of about 30 years.

Uncertainties associated with the Zone 4 pit inventories are similar, in many regards, to those discussed for the future shafts in this area. Additional uncertainty is introduced, however, by the fact that these disposal units receive institutional waste as well as waste generated by ER and D&D efforts. Environmental restoration and D&D waste tends to have fewer radionuclides at lower concentrations than those observed in institutional waste. Given these differences, averaging radionuclide concentrations over all institutional, ER, and D&D waste that was disposed of from FY 2004 through FY 2011, as was done here, may lead to errors in the projected inventories.

The development of accurate estimates of future radionuclide inventories for the waste disposed of at Area G is complicated not only by changes in the programs that generate the waste, but also by the imminent closure of MDA G. As discussed earlier, the closure of MDA G has had, and will continue to have, significant impacts on the quantities of waste that are placed in the disposal facility. As the closure process progresses and decisions about the role of Zone 4 in future disposal operations are reached, it will be possible to develop more accurate inventory projections for the performance assessment and composite analysis.

Active institutional control over Area G will be maintained for at least 100 years following the end of disposal operations. During this period, it is assumed that persons will be prevented from intruding onto the site for extended periods of time and steps will be taken to ensure proper facility functioning. These measures will minimize any impacts to human health and the environment from the buried waste during this period.

The radionuclides included in the waste disposed of at Area G have radioactive half-lives ranging from seconds to millions of years. Many of the short-lived isotopes will decay to negligible levels by the end of the 100-year active institutional control period. The Area G inventory was simplified by eliminating these radionuclides from further consideration; the same screening process was applied in the evaluation of the disposal receipt data. All radionuclides disposed of in pits and shafts were reviewed in terms of their modes of decay; radionuclides with half-lives of 5 years or less were generally excluded from the inventory projections. The methods used in this screening process are summarized in Appendix A.

3.0 Results of the Area G Disposal Receipt Review

This section provides the results of the disposal receipt review for waste disposed of from FY 2008 through FY 2011. Section 3.1 summarizes the characteristics of this waste and compares the future inventory projections developed using the disposal receipt data to those prepared for the Revision 4 Area G performance assessment and composite analysis. The impacts of the updated inventories on the exposures and radon fluxes projected by the analyses are discussed in Section 3.2.

3.1 Waste Characteristics and Revised Inventory Projections

The total volumes and activities of LLW disposed of in FYs 2008 through 2011 are shown in Table 3-1. These quantities are provided on a unit-specific basis for all pits and shafts that received waste during this period. Radionuclide-specific inventories for the period are listed in Table 3-2, also on a unit-specific basis. The activities included in the two tables represent as-disposed activities. Only those radionuclides that were not eliminated from the inventory on the basis of half-life are included in Table 3-2. No activities are included in this table for shafts 335, 362, C13, and C14 because all of the radionuclides disposed of in these units are short-lived.

Fiscal year 2008 through 2011 disposal receipt data were used in conjunction with the methods described in Section 2 to revise the projected quantities of waste that will require disposal in the future. Tables 3-3 and 3-4 compare the inventory projections developed using these data to the future inventories presented in the inventory characterization report (Shuman, 2008). Table 3-3 provides the total volume and activity projections; Table 3-4 presents the radionuclide inventories for pits and shafts. The activities included in the two tables represent as-disposed activities; only those radionuclides not eliminated from the inventory on the basis of half-life are included in Table 3-4.

The disposal volume projected for the pits using the disposal receipt data is about 7 percent of the volume projected for the Revision 4 performance assessment and composite analysis (Table 3-3); the projected activity is about 95 percent of the earlier value. The difference in volumes is due, primarily, to the shift to off-site disposal that was assumed to occur following closure of MDA G. The total activity projected for the disposal receipt review is dominated by tritium; this radionuclide played a much smaller role in the inventory projected in 2008. The two sets of projections also differ because they address different periods of time: the estimates developed for the disposal receipt review address waste that is expected to require disposal from October 1, 2012, through 2044, whereas the projections found in the Revision 4 performance assessment and composite analysis address waste disposed of from the beginning of 2008 through 2044.

Table 3-1
Total Volumes and Activities of LLW Disposed of at Area G in FYs 2008 through 2011

Disposal Unit	FY 2008 Disposal Data		FY 2009 Disposal Data		FY 2010 Disposal Data		FY 2011 Disposal Data	
	Volume (m^3)	Activity (Ci)	Volume (m^3)	Activity (Ci)	Volume (m^3)	Activity (Ci)	Volume (m^3)	Activity (Ci)
Pits								
15	9.7E+02	1.3E-02	—	—	—	—	—	—
37	8.7E+02	3.1E-01	7.1E+02	6.1E-01	4.4E+02	5.7E-02	3.3E+03	1.5E+00
38	1.9E+03	3.8E+01	1.1E+03	1.4E+02	1.6E+03	1.4E+02	1.0E+04	6.4E+02
Shafts								
165	—	—	—	—	—	—	4.2E-01	9.6E+02
300	—	—	—	—	—	—	8.1E-01	6.8E-04
301	—	—	—	—	1.6E+00	2.7E-05	—	—
335	6.8E-01	5.1E+01	4.5E-01	5.8E+01	—	—	—	—
353	2.3E-01	3.9E+01	1.5E+00	1.3E+02	1.8E-04	3.4E-06	2.6E-02	8.3E-10
362	—	—	—	—	—	—	3.4E-01	2.7E+01
363	—	—	—	—	—	—	1.8E+00	1.9E+02
364	3.0E+00	9.8E+02	5.6E+00	1.1E+03	—	—	—	—
365	—	—	8.4E-01	1.7E+02	8.6E+00	1.5E+02	1.1E-01	1.6E+01
366	—	—	2.0E+00	4.8E+02	—	—	5.7E-01	8.7E+01
367	7.0E-01	1.4E-02	—	—	—	—	—	—
370	—	—	—	—	1.7E+01	2.5E+01	—	—
C13	—	—	—	—	4.5E-01	6.8E+01	—	—
C14	—	—	—	—	9.1E-01	9.5E+01	—	—

— = Indicates disposal unit did not receive waste during the period.

Table 3-2
Radionuclide Inventories for Disposal Pits and Shafts at Area G, FYs 2008 through 2011

Radionuclide	Activity (Ci)												
	Pits			Shafts									
	15	37	38	165	300	301	353	363	364	365	366	367	370
Ac-227	—	—	1.6E-05	—	—	—	—	—	—	—	—	—	—
Ag-108m	—	—	4.8E-04	—	—	—	—	—	—	—	—	—	—
Al-26	—	—	2.7E-07	—	—	—	—	—	—	—	—	—	—
Am-241	1.3E-05	3.8E-02	1.9E+00	—	—	—	—	—	9.6E-04	—	—	3.4E-06	
Am-243	—	—	4.3E-03	—	—	—	—	—	—	—	—	—	—
Ba-133	—	—	3.1E-02	—	—	—	—	—	6.8E-05	—	—	1.8E-04	—
Bi-207	—	—	1.8E-05	—	—	—	—	—	1.6E-06	—	—	—	—
C-14	—	—	2.6E-03	—	—	—	—	—	—	—	—	—	—
Cf-249	—	—	4.4E-06	—	—	—	—	—	—	—	—	—	—
Cf-252	—	—	8.6E-06	—	—	—	—	—	7.7E-06	—	—	—	—
Cm-244	—	—	1.0E-06	—	—	—	—	—	2.0E-03	—	—	—	—
Co-60	2.6E-06	9.0E-15	2.5E+01	—	1.2E-07	—	—	1.4E-03	3.7E-02	1.0E+01	—	—	3.8E+00
Cs-137	2.7E-06	4.8E-03	5.2E-01	—	—	—	—	—	8.9E-05	—	—	7.1E-08	—
Eu-152	—	2.3E-05	4.1E-04	—	—	—	—	—	6.4E-04	—	—	—	—
Eu-154	—	—	1.4E-05	—	—	—	—	—	—	—	—	—	—
Gd-148	—	—	—	—	—	—	—	—	—	2.5E-01	—	—	—
Gd-151	—	—	—	—	—	—	—	—	—	9.8E-01	—	—	—
H-3	3.8E-04	8.6E-01	7.5E+02	9.6E+02	—	—	8.3E-10	—	2.1E+03	2.2E+01	4.8E+02	—	9.4E-01
Ho-166m	—	—	9.9E-06	—	—	—	—	—	4.9E-05	—	—	—	—

— = Indicates radionuclide did not occur in the waste.

Table 3-2 (Continued)
Radionuclide Inventories for Disposal Pits and Shafts at Area G, FYs 2008 through 2011

Radionuclide	Activity (Ci)												
	Pits			Shafts									
	15	37	38	165	300	301	353	363	364	365	366	367	370
K-40	—	3.3E-03	5.3E-03	—	—	—	—	—	—	—	—	—	—
Kr-85	—	—	3.2E-03	—	—	—	—	—	—	—	—	—	—
Nb-93m	—	—	—	—	—	—	—	—	—	5.1E-01	—	—	—
Nb-94	—	—	1.2E-04	—	—	—	—	—	—	—	—	—	—
Ni-63	—	—	1.2E-02	—	—	—	—	—	—	3.2E+01	—	—	—
Np-237	—	—	5.8E-04	—	—	—	—	—	—	—	—	—	—
Pa-231	—	—	3.2E-06	—	—	—	—	—	—	—	—	—	—
Pb-210	—	8.9E-07	8.2E-08	—	—	—	—	—	—	—	—	—	—
Pu-238	7.2E-13	5.0E-02	3.3E+00	—	—	—	—	—	7.6E-08	—	—	2.6E-03	—
Pu-239	7.3E-03	7.1E-01	2.0E+01	—	—	—	—	—	—	—	—	1.4E-03	—
Pu-240	1.2E-13	4.7E-02	4.7E-02	—	—	—	—	—	—	—	—	—	—
Pu-241	—	2.8E-04	6.5E-01	—	—	—	—	—	—	—	—	—	—
Pu-242	—	3.6E-04	3.9E-07	—	—	—	—	—	—	—	—	—	—
Ra-226	—	2.9E-04	3.5E-04	—	—	—	—	—	—	—	—	—	—
Ra-228	—	2.2E-05	1.5E-03	—	—	—	—	—	—	—	—	—	—
Sr-90	—	1.5E-03	3.8E-02	—	—	—	—	—	—	—	—	—	—
Tc-99	—	1.9E-02	1.8E-02	—	—	—	—	—	—	—	—	—	—
Th-228	—	3.7E-05	3.5E-04	—	—	—	—	—	6.6E-04	—	—	—	—
Th-229	—	—	5.4E-05	—	—	—	—	—	—	—	—	—	—

— = Indicates radionuclide did not occur in the waste.

Table 3-2 (Continued)
Radionuclide Inventories for Disposal Pits and Shafts at Area G, FYs 2008 through 2011

Radionuclide	Activity (Ci)												
	Pits			Shafts									
	15	37	38	165	300	301	353	363	364	365	366	367	370
Th-230	—	3.8E-05	—	—	—	—	—	—	—	—	—	—	—
Th-232	—	3.9E-05	1.8E-03	—	2.7E-07	2.7E-05	—	—	1.3E-02	—	3.0E-05	—	—
Ti-44	—	—	7.9E-02	—	—	—	—	—	—	3.9E-01	—	—	1.0E-02
U(DEP)	—	4.3E-03	6.3E+00	—	—	—	—	—	4.5E-02	—	—	—	—
U(NAT)	—	2.2E-01	9.6E-02	—	—	—	—	—	—	—	—	—	—
U-232	—	—	1.6E-04	—	—	—	—	—	—	—	—	—	—
U-233	—	1.8E-04	8.1E-03	—	—	—	—	—	—	—	—	—	—
U-234	2.8E-03	2.2E-01	2.8E+00	—	7.0E-05	—	—	—	—	—	—	—	—
U-235	2.8E-04	1.8E-02	1.6E-01	—	1.7E-06	—	6.5E-08	—	4.5E-05	2.9E-03	3.8E-07	5.9E-05	—
U-236	—	1.6E-06	2.4E-03	—	—	—	—	—	—	—	—	—	—
U-238	2.0E-03	2.2E-01	1.7E+00	—	6.0E-04	—	3.3E-06	—	8.2E-03	1.3E-01	1.9E-05	1.0E-02	2.6E-02
W-178	—	—	—	—	—	—	—	—	—	7.2E-01	—	—	—

— = Indicates radionuclide did not occur in the waste.

Table 3-3
Future Waste Inventory Estimates for Area G: FY 2011 Disposal Receipt-Based Projections vs. Revision 4 Performance Assessment and Composite Analysis Projections

Disposal Unit	FY 2011 Disposal Receipt Review [a]		2008 Inventory Characterization [b]	
	Volume (m^3)	Activity (Ci)	Volume (m^3)	Activity (Ci)
Pits	1.1E+04	3.7E+02	1.6E+05	3.9E+02
Shafts	3.6E+02	4.3E+06	1.0E+03	9.8E+05
Total	1.1E+04	4.3E+06	1.7E+05	9.8E+05

[a] *Includes waste expected to require disposal from October 1, 2012, through 2044.*

[b] *Includes waste expected to require disposal from beginning of 2008 through 2044.*

Table 3-4
Radionuclide and Material Type Future Inventories: FY 2011 Disposal Receipt-Based Projections vs. Revision 4 Performance Assessment and Composite Analysis Projections

Radionuclide	Activity (Ci)			
	FY 2011 Disposal Receipt Review [a]		2008 Inventory Characterization [b]	
	Pits	Shafts	Pits	Shafts
Ac-227	3.1E-06	—	6.6E-05	—
Ag-108m	2.1E-04	2.7E-08	5.8E-05	4.2E-08
Al-26	5.2E-08	—	1.2E-06	—
Am-241	1.2E+00	3.2E-03	1.5E+01	1.2E-03
Am-243	1.6E-03		3.8E-02	—
Ba-133	1.4E-01	1.3E-03	3.2E+00	—
Be-10	3.4E-04	—	—	—
Bi-207	2.2E-03	4.7E-06	7.0E-02	7.3E-06
Bk-247	1.7E-08	—	—	—
C-14	2.5E-01	—	1.2E-02	3.5E-01
Ca-41	2.1E-02	—	—	—
Cf-249	2.0E-05	—	4.7E-04	—
Cf-252	2.1E-06	2.3E-05	—	3.6E-05
Cl-36	1.3E-03	—	—	—
Cm-243	3.1E-06	—	5.1E-05	—
Cm-244	5.4E-04	5.9E-03	1.3E-02	9.3E-03
Cm-245	3.5E-06	—	2.1E-04	—
Cm-248	8.7E-08	—	2.1E-06	—
Co-60	6.9E+00	6.5E+01	7.5E+01	3.8E+01
Cs-135	2.5E-06	—	7.5E-06	—
Cs-137	2.8E-01	2.8E-01	4.8E+00	1.9E+00
D38	8.3E-01	1.5E-01	4.3E+00	7.0E+00
Eu-152	3.3E-02	1.9E-03	2.0E-01	3.0E-03
Eu-154	3.9E-03	—	3.1E-03	—
Gd-148	—	7.4E-01	—	—
H-3	3.2E+02	4.3E+06	1.9E+01	9.7E+05
Ho-163	6.2E-03	—	—	—
Ho-166m	2.7E-04	1.5E-04	6.6E-03	—

— = Indicates radionuclide did not occur in the waste.
[a] Includes waste expected to require disposal from October 1, 2009, through September 30, 2044.
[b] Includes waste expected to require disposal from beginning of 2008 through 2044.

Table 3-4 (Continued)
Radionuclide and Material Type Future Inventories: FY 2010 Disposal Receipt-Based Projections vs. Revision 4 Performance Assessment and Composite Analysis Projections

	Activity (Ci)			
	FY 2011 Disposal Receipt Review [a]		2008 Inventory Characterization [b]	
Radionuclide	Pits	Shafts	Pits	Shafts
I-129	2.7E-06	—	1.4E-04	—
K-40	4.2E-02	—	8.5E-01	2.0E-06
Kr-85	8.4E-04	2.4E-02	4.6E-04	3.7E-02
Lu-176	1.3E-07	—	—	—
Mo-93	1.5E-06	—	9.3E-05	—
Nb-91	2.2E-06	2.8E-02	5.3E-05	4.3E-02
Nb-92	5.8E-07	—	1.4E-05	—
Nb-93m	2.0E-04	8.1E+00	4.8E-03	1.0E+01
Nb-94	1.2E-03	—	6.9E-02	—
Nd-144	—	—	4.6E-08	—
Ni-59	1.3E-04	—	3.3E-05	—
Ni-63	1.5E-01	1.2E+02	9.5E-01	4.6E+01
Np-237	7.4E-04	—	2.0E-02	1.4E-07
Os-194	9.8E-09	—	6.0E-07	—
Pa-231	3.3E-06	—	1.1E-04	2.3E-07
Pb-210	3.3E-03	—	8.5E-02	1.2E-07
Pm-145	7.5E-04	—	4.6E-08	—
Pu-236	7.5E-11	—	4.6E-09	—
Pu-238	1.7E+00	1.5E-02	2.2E+01	3.5E-02
Pu-239	5.4E+00	1.1E-02	1.8E+01	3.2E-02
Pu-240	4.2E-02	—	1.3E+00	—
Pu-241	2.4E-01	—	4.9E+00	—
Pu-242	1.0E-03	—	2.6E-02	—
Pu-244	2.6E-07	—	1.6E-05	—
Ra-226	1.1E-02	5.4E-05	3.2E-01	8.4E-05
Ra-228	5.0E-03	—	1.1E-01	—
Si-32	3.0E-06	—	7.7E-05	—
Sm-151	2.9E-10	—	1.4E-08	—
Sr-90	4.2E-01	2.0E-01	9.8E+00	1.8E+00

— = Indicates radionuclide did not occur in the waste.
[a] Includes waste expected to require disposal from October 1, 2009, through September 30, 2044.
[b] Includes waste expected to require disposal from beginning of 2008 through 2044.

Table 3-4 (Continued)
Radionuclide and Material Type Future Inventories: FY 2010 Disposal Receipt-Based Projections vs. Revision 4 Performance Assessment and Composite Analysis Projections

	Activity (Ci)			
	FY 2011 Disposal Receipt Review [a]		2008 Inventory Characterization [b]	
Radionuclide	Pits	Shafts	Pits	Shafts
Tb-157	8.9E-02	1.2E+02	2.1E-07	—
Tc-97	3.9E-09	—	9.2E-08	—
Tc-99	3.6E-02	—	2.8E-01	—
Th-228	1.5E-04	2.0E-03	3.0E-03	3.2E-03
Th-229	3.2E-05	—	1.4E-03	—
Th-230	1.1E-04	—	4.2E-04	—
Th-232	2.2E-02	3.9E-02	8.1E-03	6.0E-02
Ti-44	1.6E-02	1.2E+00	1.2E-02	9.0E-02
U(DEP)	1.8E+00	1.4E-01	2.4E+01	2.0E-04
U(NAT)	7.2E-02	—	2.9E-04	8.3E-01
U-232	5.8E-05	—	1.7E-04	—
U-233	1.4E-02	—	2.4E-01	—
U-234	9.1E-01	1.5E+00	1.6E+00	2.3E+00
U-235	5.4E-02	8.9E-02	1.0E-01	1.3E-01
U-236	1.1E-03	—	1.1E-02	1.8E-05
U-238	8.0E-01	5.8E-01	2.6E+00	1.1E+00

— = Indicates radionuclide did not occur in the waste.
[a] Includes waste expected to require disposal from October 1, 2009, through September 30, 2044.
[b] Includes waste expected to require disposal from beginning of 2008 through 2044.

The radionuclide inventories projected for the disposal pits using the disposal receipt data are generally small fractions of the inventories estimated for the Revision 4 performance assessment and composite analysis (Table 3-4). About 80 percent of the radionuclides included in both sets of inventory projections have updated estimates that are less than half of those projected for Revision 4; about 50 percent of the radionuclides have updated projections that are less than 5 percent of the previous estimates. The updated inventories for 11 radionuclides are greater than those estimated for the performance assessment and composite analysis.

The future shaft inventories projected using the disposal receipt data are also generally less than those estimated for the performance assessment and composite analysis (Table 3-4). However, the magnitudes of the differences between old and new projections tend to be smaller than those observed for the pits. For example, only 20 percent of the radionuclides have updated estimates that are less than half of those projected for the performance assessment and composite analysis. The better agreement between the old and new shaft inventory projections is linked to the assumption that the disposal of institutional waste in shafts at Area G will be unaffected by the use of off-site facilities for LLW disposal.

Although the receipt-based disposal inventories for most radionuclides are similar to, or less than, those estimated in 2008, the inventories of some radionuclides increase substantially within a given type of disposal unit. Examples of this include depleted uranium and Ti-44 placed in the disposal shafts. These increases are the result of cleanup activities rather than a change in the nature of the routine waste generated at the Laboratory. For example, cleanup activities at TA-3 have generated unusually large quantities of depleted uranium. This increase, however, is relatively unimportant when the total inventory of depleted uranium at Area G is taken into account. The majority of the depleted uranium has been disposed of in pits. Thus, despite significant increases in the shaft inventories of this material, the overall inventory of depleted uranium has actually decreased.

The waste responsible for the large increase in the Ti-44 inventory was generated by the D&D of target assemblies at TA-53 (Los Alamos Neutron Science Center); two shipments of target liners were disposed of in 2010. Although this type of waste is generated infrequently, it was included in the data that were used to calculate average radionuclide concentrations for the waste that will require disposal from 2014 through 2044. This approach will likely overestimate the actual future inventories of Ti-44. In fact, the shaft inventory estimate listed in Table 3-4 is about two-thirds of the inventory estimated for Ti-44 by the FY 2010 disposal receipt review, suggesting disposal rates have already stated to decline. In any event, the actual inventories of Ti-44 will continue to be monitored in future disposal receipt reviews.

The pit and shaft tritium inventories listed for the FY 2011 disposal receipt review are also substantially greater than those projected by the 2008 inventory characterization. A portion of the pit inventory reflects the disposal of larger-than-normal quantities of tritium that were generated in conjunction with the cleanup of a laboratory at TA-35 in FY 2008. This increase is small, however, compared to the tritium inventory projected for future shafts. In contrast to the cleanup wastes discussed above, the waste disposed of in the shafts is generated routinely at WETF. Like all projected radionuclide inventories, these projections are uncertain. Actual disposal rates of the radionuclide will be monitored closely and the ability of the disposal facility to safely isolate the waste will be evaluated in conjunction with future disposal receipt reviews.

3.2 Impacts of Revised Inventory Projections

A relatively small number of radionuclides made significant contributions to the doses projected for the Revision 4 Area G performance assessment and composite analysis (LANL, 2008). In general, the impacts of using FY 2008 through FY 2011 disposal receipt data to estimate future waste inventories will depend upon how the quantities of these critical radionuclides are affected. These impacts were evaluated by revising the inventories used in the Revision 4 performance assessment and composite analysis modeling and updating the dose and radon flux projections. The impacts that the disposal receipt-based inventories have on the dose and flux projections were evaluated using the assumption that the waste will be distributed within Zone 4 over an area that is the same as that adopted for the performance assessment and composite analysis.

Preliminary modeling revealed that the disposal of the entire tritium inventory projected for the Zone 4 shafts may yield doses for the agricultural intruder scenario that are in excess of the 100 mrem/yr chronic dose limit. To prevent this from happening, it was assumed that the routine high-activity tritium waste generated during the last 8 years of the disposal facility's lifetime will be disposed of elsewhere. This restriction decreases the shaft tritium inventory listed in Table 3-4 by 960,000 Ci. The model projections presented and discussed below take this reduction into account.

The exposures and radon fluxes projected using the updated pit and shaft inventories are compared in Tables 3-5 through 3-7 to the quantities estimated using version 3.500 of the site model and version 2.500 of the intruder models; all of these models take into account the impacts of headspace waste disposal (LANL, 2012). Table 3-5 compares the exposures projected for members of the public, Table 3-6 shows the radon flux estimates, and Table 3-7 provides the intruder exposure projections.

The updated future inventory projections influence the doses projected for members of the public in a variety of ways (Table 3-5). Whereas the doses for many exposure scenarios are unaffected by the updated inventories, the exposures projected for other scenarios increase significantly. The higher exposures are the result of the large increase in the quantity of tritium that is projected to be disposed of at Area G. This waste has its greatest impact on the receptors located closest to the Zone 4 expansion area; exposures for receptors located farther away show little impact from the radionuclide. All projected exposures for members of the public are less than the pertinent DOE performance objectives.

Table 3-5
Exposures for Members of the Public: FY 2011 Disposal Receipt Review Projections vs. Projections from Model Version 3.500 with Headspace Impacts

Exposure Scenario and Exposure Location	Peak Mean Dose (mrem/yr)			
	Performance Assessment		Composite Analysis	
	2011 Disposal Receipt Review	Model Version 3.500 with Headspace Impacts	2011 Disposal Receipt Review	Model Version 3.500 with Headspace Impacts
Atmospheric				
LANL Boundary	4.4E-01	1.9E-01	2.1E-01	2.2E-01
Area G Fence Line	4.4E-03	2.5E-03	5.4E-01	5.1E-01
All Pathways–Canyon				
Catchment CdB1	5.7E-01	1.5E-01	6.1E-01	4.6E-01
Catchment CdB2	2.2E-01	2.2E-01	1.0E+00	1.0E+00
Catchment PC0	7.6E-04	3.9E-04	9.0E-04	4.2E-04
Catchment PC1	4.2E-01	4.1E-02	4.7E-01	4.6E-02
Catchment PC2	1.6E-01	1.6E-01	3.1E-01	3.1E-01
Catchment PC3	1.4E-01	1.4E-01	2.5E-01	2.5E-01
Catchment PC4	2.2E-01	2.3E-01	3.3E-01	3.3E-01
Catchment PC5	3.2E-01	3.2E-01	2.1E+00	2.1E+00
Catchment PC6	1.7E-01	1.7E-01	2.4E+00	2.4E+00
Groundwater Pathway Scenarios				
All Pathways–Groundwater	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Groundwater Resource Protection	0.0E+00	0.0E+00	NA	NA

NA = Not applicable

Table 3-6
Radon Fluxes: FY 2011 Disposal Receipt Review Projections vs. Projections from Model Version 3.500 with Headspace Impacts

Waste Disposal Region	Peak Mean Flux (pCi/m^2/s)	
	2011 Disposal Receipt Review	Model Version 3.500 with Headspace Impacts
1	1.3E-06	1.3E-06
2	—	—
3	1.5E+01	1.5E+01
4	3.6E-02	3.6E-02
5	2.9E-01	2.9E-01
6	3.6E-03	3.6E-03
7	1.3E+01	1.3E+01
8	2.1E-02	2.5E-02
Entire Facility	4.0E-01	4.0E-01

— = None of the performance assessment inventory was disposed of in the waste disposal region.

Table 3-7
Intruder Exposures: FY 2011 Disposal Receipt Review Projections vs. Projections from Model Version 2.500 with Headspace Impacts

Disposal Units and Exposure Scenario	Peak Mean Dose (mrem/yr)	
	2011 Disposal Receipt Review	Version 2.500 with Headspace Impacts
1988–2013 Pits		
Intruder–Construction	3.8E+00	3.8E+00
Intruder–Agriculture	3.0E+01	3.0E+01
Intruder–Post-Drilling	6.0E+00	6.0E+00
2014–2044 Pits		
Intruder–Construction	3.5E-03	4.1E-03
Intruder–Agriculture	2.7E-02	6.3E-02
Intruder–Post-Drilling	5.2E-02	1.4E-01
1988–2013 Shafts		
Intruder–Construction	5.4E+00	5.5E+00
Intruder–Agriculture	9.1E+01	9.5E+01
Intruder–Post-Drilling	1.2E+01	1.2E+01
2014–2044 Shafts		
Intruder–Construction	3.8E+00	1.1E+00
Intruder–Agriculture	8.8E+01	2.5E+01
Intruder–Post-Drilling	1.1E+01	4.2E+00

The radon fluxes projected for the performance assessment decrease for the Zone 4 expansion area (waste disposal region 8) when the disposal receipt data are used to project future inventories (Table 3-6). Disposal region 8 is the portion of Area G that is most affected by changes in inventories because it will receive the bulk of the remaining waste to be disposed of at Area G. Overall, the facility-wide radon flux remains constant at 0.40 $pCi/m^2/s$, which is much less than the 20 $pCi/m^2/s$ performance objective.

Table 3-7 compares the intruder dose projections that were developed using the updated inventories to those estimated by the headspace impacts analysis (LANL, 2012). The intruder doses projected using the two inventories are similar for the 1988–2013 pits and shafts; exposures for the 2014–2044 pits decrease slightly when the inventories are updated, while the exposures for the 2014–2044 shafts increase substantially. The increase in the doses projected for the 2014–2044 shafts is due primarily to the increased quantity of tritium placed in the disposal units. As mentioned earlier, it was necessary to restrict the amount of tritium placed in this portion of Area G to maintain intruder doses within acceptable limits. Specifically, it was assumed that the tritium generated during the last 8 years of disposal operations (960,000 Ci) was sent elsewhere for disposal.

It was assumed that the final elevation of the waste placed in the 2014–2044 shafts will be 1.5 m (4.9 ft) lower than that assumed for the performance assessment. As discussed in the FY 2010 disposal receipt review, limiting the near-surface placement of Ti-44 waste was necessary to comply with the inadvertent intruder performance objectives. The large increase in the projected tritium inventory increases the need for placing the waste at greater depths. With this revision, all exposures projected for the intruder scenarios remain within the 100 and 500 mrem/yr performance measures that apply to chronic and acute exposures.

In summary, updating the radionuclide inventories to reflect FY 2008 through FY 2011 disposal data and the expected disposal trends is not expected to compromise the ability of the Area G disposal facility to comply with the performance assessment and composite analysis performance objectives. It may be necessary, however, to modify operational procedures if the future inventories of one or more radionuclides increases substantially. For this reason, large increases in the inventories projected for critical radionuclides will continue to be evaluated in subsequent disposal receipt reviews.

4.0 References

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LANL, 2009, *Consolidated Waste Capability Pre-Conceptual Proposal*, LA-CP-09-001148, Revision 0, September 2009.

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Appendix A
Bases for Radionuclide Inclusion in the Area G Inventory

Active institutional control will be exercised over Area G for a period of 100 years following the end of disposal operations. During this period, persons will be prevented from intruding onto the site for extended periods and measures will be taken to maintain proper facility function. As a result of these actions, there will be little or no potential for exposures to result from radionuclides with extremely short half-lives.

Most radionuclides with half-lives of 5 years or less were excluded from the Area G inventory. The primary exception to this is radionuclides that are daughters of parents with half-lives greater than 5 years. Table A-1 lists all radionuclides that were encountered in the performance assessment and composite analysis and their half-lives, briefly describes their decay characteristics, and specifies whether, or in what manner, the constituents were included in the final inventory. Additional information about the process used to identify radionuclides for inclusion in the performance assessment and composite analysis may be found in Shuman (2008).

Table A-1
Radionuclide Decay Characteristics and Bases for Inclusion in the Area G Inventory

Radionuclide	Half-Life (yr)[a]	Decay Chain Characteristics and Assumptions
Ac-227	2.2E+01	Decays to form short-lived Fr-223 and Th-227; daughter of long-lived Pa-231. Included in final inventory.
Ac-228	7.0E-04	Decays to form long-lived Th-228; daughter of long-lived Ra-228. Included in final inventory as a short-lived daughter of Ra-228.
Ag-105	1.1E-01	Decays to form stable Pd-105; daughter of short-lived Ag-105m and Cd-105. Excluded from final inventory.
Ag-108m	4.2E+02	Decays to form short-lived Ag-108 and stable Pd-108; included in final inventory.
Ag-110m	6.8E-01	Decays to form short-lived Ag-110 and stable Cd-110; excluded from final inventory.
Ag-111	2.0E-02	Decays to form stable Cd-111; daughter of short-lived Pd-111. Excluded from final inventory.
Al-26	7.1E+05	Decays to form stable Mg-26; daughter of short-lived Si-26. Included in final inventory.
Am-240	5.8E-03	Decays to form long-lived Np-236 and Pu-240; inventory of long-lived daughters expected to be negligible. Excluded from final inventory.
Am-241	4.3E+02	Decays to form long-lived Np-237; daughter of long-lived Pu-241. Included in final inventory.
Am-242	1.8E-03	Decays to form short-lived Cm-242 and long-lived Pu-242; daughter of long-lived Am-242m. Inventory of long-lived daughter expected to be negligible; included in final inventory as a short-lived daughter of Am-242m.
Am-243	7.4E+03	Decays to form short-lived Np-239; daughter of long-lived Cm-243 and short-lived Pu-243. Included in final inventory.
As-72	3.0E-03	Decays to form stable Ge-72; daughter of short-lived Se-72. Excluded from final inventory.
As-73	2.2E-01	Decays to form stable Ge-73; daughter of short-lived Se-73. Excluded from final inventory.
As-74	4.9E-02	Decays to form stable Ga-74 and Se-74; excluded from final inventory.
Au-194	4.3E-03	Decays to form stable Pt-194; daughter of long-lived Hg-194. Included in final inventory as a short-lived daughter of Hg-194.
Au-195	5.1E-01	Decays to form stable Pt-195; daughter of short-lived Hg-195m. Excluded from final inventory.
Ba-133	1.1E+01	Decays to form stable Cs-133; daughter of short-lived Ba-133m. Included in final inventory.
Ba-137m	4.9E-06	Decays to form stable Ba-137; daughter of long-lived Cs-137. Included in final inventory as a short-lived daughter of Cs-137.
Ba-139	1.6E-04	Decays to form stable La-139; daughter of short-lived Ce-139. Excluded from final inventory.
Ba-140	3.5E-02	Decays to form short-lived La-140; daughter of short-lived Cs-140. Excluded from final inventory.

[a] *Primary source of radionuclide half-lives was KAPL (2002). Alternate sources include England and Rider (1994) and NNDC (2004).*

Table A-1 (Continued)
Radionuclide Decay Characteristics and Bases for Inclusion in the Area G Inventory

Radionuclide	Half-Life (yr)[a]	Decay Chain Characteristics and Assumptions
Be-7	1.5E-01	Decays to form stable Li-7; excluded from final inventory.
Be-10	1.5E+06	Decays to form stable B-10; included in final inventory.
Bi-207	3.2E+01	Decays to form stable Pb-207; daughter of short-lived At-211. Included in final inventory.
Bi-210	1.4E-02	Decays to form short-lived Po-210; daughter of long-lived Pb-210. Included in final inventory as a short-lived daughter of Pb-210.
Bi-211	4.1E-06	Decays to form short-lived Po-211 and Tl-207; daughter of short-lived Pb-211. Included in final inventory as a short-lived daughter of Ac-227.
Bi-212	1.2E-04	Decays to form short-lived Po-212 and Tl-208; daughter of short-lived Pb-212. Included in final inventory as a short-lived daughter of Th-228.
Bi-214	3.8E-05	Decays to form short-lived Po-214; daughter of short-lived Pb-214. Included in final inventory as a short-lived daughter of Ra-226.
Bk-247	1.4E+03	Decays to form long-lived Am-243; included in final inventory.
Bk-249	9.0E-01	Decays to form long-lived Cf-249; inventory of long-lived daughter expected to be negligible. Excluded from final inventory.
Br-76	1.8E-03	Decays to form stable Se-76; daughter of short-lived Kr-76. Excluded from final inventory.
Br-77	6.5E-03	Decays to form stable Se-77; daughter of short-lived Kr-77. Excluded from final inventory.
Br-82	4.0E-03	Decays to form stable Kr-82; daughter of short-lived Br-82m. Excluded from final inventory.
C-14	5.7E+03	Decays to form stable N-14; included in final inventory.
Ca-41	1.0E+05	Decays to form stable K-41; daughter of short-lived Sc-41. Included in final inventory.
Ca-45	4.5E-01	Decays to form stable Sc-45; daughter of short-lived K-45. Excluded from final inventory.
Cd-109	1.3E+00	Decays to form short-lived Ag-109m and stable Ag-109; daughter of short-lived In-109. Excluded from final inventory.
Cd-113m	1.4E+01	Decays to form long-lived Cd-113 and stable In-113; daughter of short-lived Ag-113. Included in final inventory.
Cd-115	6.1E-03	Decays to form short-lived In-115m and long-lived In-115; daughter of short-lived Ag-115. Inventory of long-lived daughter expected to be negligible; excluded from final inventory.
Ce-137	1.0E-03	Decays to form long-lived La-137; daughter of short-lived Ce-137m. Inventory of long-lived daughter expected to be negligible; excluded from final inventory.
Ce-139	3.8E-01	Decays to form stable La-139; daughter of short-lived Ce-139m. Excluded from final inventory.
Ce-141	8.9E-02	Decays to form stable Pr-141; daughter of short-lived La-141. Excluded from final inventory.

[a] Primary source of radionuclide half-lives was KAPL (2002). Alternate sources include England and Rider (1994) and NNDC (2004).

Table A-1 (Continued)
Radionuclide Decay Characteristics and Bases for Inclusion in the Area G Inventory

Radionuclide	Half-Life (yr)[a]	Decay Chain Characteristics and Assumptions
Ce-144	7.8E-01	Decays to form short-lived Pr-144; daughter of short-lived La-144. Excluded from final inventory.
Cf-249	3.5E+02	Decays to form long-lived Cm-245; daughter of short-lived Bk-249. Included in final inventory.
Cf-251	9.0E+02	Decays to form long-lived Cm-247; daughter of short-lived Bk-241 and Fm-255. Included in final inventory.
Cf-252	2.6E+00	Decays to form long-lived Cm-248; daughter of short-lived Fm-256. Included in final inventory.
Cl-36	3.0E+05	Decays to form stable Ar-36 and S-36; included in final inventory.
Cm-242	4.5E-01	Decays to form long-lived Pu-238; daughter of short-lived Am-242. Inventory of long-lived daughter expected to be negligible; excluded from final inventory.
Cm-243	2.9E+01	Decays to form long-lived Pu-239; included in final inventory.
Cm-244	1.8E+01	Decays to form long-lived Pu-240; daughter of short-lived Am-244 and Cf-248. Included in final inventory.
Cm-245	8.5E+03	Decays to form long-lived Pu-241; daughter of short-lived Am-245 and long-lived Cf-249. Included in final inventory.
Cm-248	3.4E+05	Decays to form long-lived Pu-244; included in final inventory.
Co-56	2.1E-01	Decays to form stable Fe-56; daughter of short-lived Ni-56. Excluded from final inventory.
Co-57	7.4E-01	Decays to form stable Fe-57; daughter of short-lived Ni-57. Excluded from final inventory.
Co-58	1.9E-01	Decays to form stable Fe-58; excluded from final inventory.
Co-60	5.3E+00	Decays to form stable Ni-60; daughter of long-lived Fe-60. Included in final inventory.
Cr-51	7.6E-02	Decays to form stable V-51; daughter of short-lived Mn-51. Excluded from final inventory.
Cs-134	2.1E+00	Decays to form stable Ba-134 and Xe-134; excluded from final inventory.
Cs-135	2.3E+06	Decays to form stable Ba-135; daughter of short-lived Xe-135. Included in final inventory.
Cs-136	3.6E-02	Decays to form stable Ba-136; excluded from final inventory.
Cs-137	3.0E+01	Decays to form short-lived Ba-137m; daughter of short-lived Xe-133. Included in final inventory.
Cu-67	7.1E-03	Decays to form stable Zn-67; daughter of short-lived Ni-67. Excluded from final inventory.
Dy-154	3.0E+06	Decays to form long-lived Gd-150; daughter of short-lived Ho-154m. Included in final inventory.
Dy-159	4.0E-01	Decays to form stable Tb-159; daughter of short-lived Ho-159. Excluded from final inventory.

[a] Primary source of radionuclide half-lives was KAPL (2002). Alternate sources include England and Rider (1994) and NNDC (2004).

Table A-1 (Continued)
Radionuclide Decay Characteristics and Bases for Inclusion in the Area G Inventory

Radionuclide	Half-Life (yr)[a]	Decay Chain Characteristics and Assumptions
Eu-149	2.6E-01	Decays to form stable Sm-149; daughter of short-lived Gd-149. Excluded from final inventory.
Eu-150	3.6E+01	Decays to form stable Sm-150; included in final inventory.
Eu-152	1.4E+01	Decays to form long-lived Gd-152 and stable Sm-152; daughter of short-lived Eu-152m. Included in final inventory.
Eu-154	8.6E+00	Decays to form stable Gd-154 and stable Sm-154; daughter of short-lived Eu-154m. Included in final inventory.
Eu-155	4.8E+00	Decays to form stable Gd-155; daughter of short-lived Sm-155. Excluded from final inventory.
Eu-156	4.2E-02	Decays to form stable Gd-156; daughter of short-lived Sm-146. Excluded from final inventory.
Eu-158	8.7E-05	Decays to form stable Gd-158; daughter of short-lived Sm-158. Excluded from final inventory.
Fe-52	9.5E-04	Decays to form short-lived Mn-52 and Mn-52m; daughter of short-lived Co-52. Excluded from final inventory.
Fe-55	2.7E+00	Decays to form stable Mn-55; daughter of short-lived Co-55. Excluded from final inventory.
Fe-59	1.2E-01	Decays to form stable Co-59; daughter of short-lived Mn-59. Excluded from final inventory.
Ga-68	1.3E-04	Decays to form stable Zn-68; daughter of short-lived Ge-68. Excluded from final inventory.
Gd-146	1.3E-01	Decays to form short-lived Eu-146 and, ultimately, long-lived Sm-146; daughter of short-lived Tb-146. Inventory of long-lived daughter expected to be negligible; excluded from final inventory.
Gd-148	7.5E+01	Decays to form stable Sm-144; daughter of short-lived Tb-148. Included in final inventory.
Gd-150	1.8E+06	Decays to form long-lived Sm-146; daughter of short-lived Tb-150. Included in final inventory.
Gd-151	3.4E-01	Decays to form stable Eu-151 and long-lived Sm-147; daughter of short-lived Tb-151. Inventory of long-lived daughter expected to be negligible; excluded from final inventory.
Gd-152	1.1E+14	Decays to form long-lived Sm-148; daughter of short-lived Tb-152. Included in final inventory.
Gd-153	6.6E-01	Decays to form stable Eu-153; daughter of short-lived Tb-153. Excluded from final inventory.
Ge-68	7.4E-01	Decays to form short-lived Ga-68; daughter of short-lived As-68. Excluded from final inventory.
H-3	1.2E+01	Decays to form stable He-3; included in final inventory.

[a] Primary source of radionuclide half-lives was KAPL (2002). Alternate sources include England and Rider (1994) and NNDC (2004).

Table A-1 (Continued)
Radionuclide Decay Characteristics and Bases for Inclusion in the Area G Inventory

Radionuclide	Half-Life (yr)[a]	Decay Chain Characteristics and Assumptions
Hf-172	1.9E+00	Decays to form short-lived Lu-172; daughter of short-lived Ta-172. Excluded from final inventory.
Hf-175	1.9E-01	Decays to form stable Lu-175; daughter of short-lived Ta-175. Excluded from final inventory.
Hf-178m	3.1E+01	Decays to form stable Hf-178; excluded from final inventory.
Hf-181	1.2E-01	Decays to form stable Ta-181; daughter of short-lived Lu-181. Excluded from final inventory.
Hg-203	1.3E-01	Decays to form stable Tl-203; daughter of short-lived Au-203. Excluded from final inventory.
Ho-163	4.6E+03	Decays to form stable Dy-163; daughter of short-lived Er-173. Included in final inventory.
Ho-166	3.1E-03	Decays to form stable Er-166; daughter of short-lived Dy-166. Excluded from final inventory.
Ho-166m	1.2E+03	Decays to form stable Er-166; included in final inventory.
I-125	1.6E-01	Decays to form stable Te-125; daughter of short-lived Xe-125. Excluded from final inventory.
I-129	1.6E+07	Decays to form stable Xe-129; daughter of short-lived Te-129. Included in final inventory.
I-131	2.2E-02	Decays to form stable Xe-131 and short-lived Xe-131m; daughter of short-lived Te-125. Excluded from final inventory.
In-114m	1.4E-01	Decays to form stable Cd-114 and short-lived In-114; excluded from final inventory.
In-115m	5.1E-04	Decays to form long-lived In-115 and stable Sn-115; inventory of long-lived daughter expected to be negligible. Excluded from final inventory.
Ir-192	2.0E-01	Decays to form stable Os-194 and Pt-194; daughter of short-lived Ir-192m. Excluded from final inventory.
Ir-194	2.2E-03	Decays to form stable Pt-194; daughter of short-lived Ir-194m and long-lived Os-194. Included in final inventory as a short-lived daughter of Os-194.
K-40	1.3E+09	Decays to form stable Ar-40 and stable Ca-40; included in final inventory.
Kr-81	2.3E+05	Decays to form stable Br-81; daughter of short-lived Rb-81. Included in final inventory.
Kr-85	1.1E+01	Decays to form stable Rb-85; daughter of Kr-85m. Included in final inventory.
La-137	6.0E+04	Decays to form stable Ba-137; daughter of short-lived Ce-137. Included in final inventory.
La-140	1.7E+00	Decays to form stable Ce-140; daughter of short-lived Ba-140. Excluded from final inventory.
Lu-172	1.8E-02	Decays to form stable Yb-172; daughter of short-lived Hf-172. Excluded from final inventory.
Lu-172m	7.0E-06	Decays to form short-lived Lu-172; excluded from final inventory.
Lu-173	1.4E+00	Decays to form stable Yb-173; daughter of short-lived Hf-173. Excluded from final inventory.

[a] *Primary source of radionuclide half-lives was KAPL (2002). Alternate sources include England and Rider (1994) and NNDC (2004).*

Table A-1 (Continued)
Radionuclide Decay Characteristics and Bases for Inclusion in the Area G Inventory

Radionuclide	Half-Life (yr)[a]	Decay Chain Characteristics and Assumptions
Lu-174	3.3E+00	Decays to form stable Yb-174; daughter of short-lived Lu-174m. Excluded from final inventory.
Lu-176	3.8E+10	Decays to form stable Hf-176; included in final inventory.
Lu-177	1.8E-02	Decays to form stable Hf-177; daughter of short-lived Yb-177. Excluded from final inventory.
Mn-52	1.5E-02	Decays to form stable Cr-52; daughter of short-lived Fe-52. Excluded from inventory.
Mn-52m	4.0E-05	Decays to form stable Cr-52 and short-lived Mn-52; daughter of short-lived Fe-52. Excluded from final inventory.
Mn-54	8.6E-01	Decays to form stable Cr-54 and stable Fe-54; excluded from final inventory.
Mn-56	2.9E-04	Decays to form stable Fe-56; daughter of short-lived Cr-56. Excluded from final inventory.
Mo-93	3.5E+03	Decays to form stable Nb-93; daughter of short-lived Tc-93. Included in final inventory.
Mo-99	7.5E-03	Decays to form long-lived Tc-99 and short-lived Tc-99m; daughter of short-lived Nb-99. Inventory of long-lived daughter expected to be negligible; excluded from final inventory.
Na-22	2.6E+00	Decays to form stable Ne-22; daughter of short-lived Mg-22. Excluded from final inventory.
Na-24	1.7E-03	Decays to form stable Mg-24; daughter of short-lived Ne-24. Excluded from final inventory.
Nb-91	7.0E+02	Decays to form stable Zr-91; daughter of short-lived Mo-91 and Nb-91m. Included in final inventory.
Nb-91m	1.7E-01	Decays to form long-lived Nb-91 and stable Zr-91; daughter of short-lived Mo-91. Inventory of long-lived daughter expected to be negligible; excluded from final inventory.
Nb-92	3.5E+07	Decays to form stable Zr-92; included in final inventory.
Nb-92m	2.8E-02	Decays to form stable Zr-92; excluded from final inventory.
Nb-93m	1.6E+01	Decays to form stable Nb-93; included in final inventory.
Nb-94	2.0E+04	Decays to stable Mo-94; included in final inventory.
Nb-95	9.6E-02	Decays to form stable Mo-95; daughter of short-lived Zr-95. Excluded from final inventory.
Nd-144	2.4E+15	Decays to stable Ce-140; daughter of short-lived Pm-144, Pr-144, and Pr-144m. Included in final inventory.
Nd-147	3.0E-02	Decays to form short-lived Pm-147 and, ultimately, long-lived Sm-147; daughter of short-lived Pr-147. Inventory of long-lived daughter expected to be negligible; excluded from final inventory.
Ni-56	1.6E-02	Decays to form short-lived Co-56; excluded from final inventory.
Ni-57	4.1E-03	Decays to form short-lived Co-57; daughter of short-lived Cu-57. Excluded from final inventory.

[a] *Primary source of radionuclide half-lives was KAPL (2002). Alternate sources include England and Rider (1994) and NNDC (2004).*

Table A-1 (Continued)
Radionuclide Decay Characteristics and Bases for Inclusion in the Area G Inventory

Radionuclide	Half-Life (yr)[a]	Decay Chain Characteristics and Assumptions
Ni-59	7.6E+04	Decays to form stable Co-59; daughter of short-lived Cu-59. Included in final inventory.
Ni-63	1.0E+02	Decays to form stable Cu-63; daughter of short-lived Co-63. Included in final inventory.
Ni-65	2.9E-04	Decays to form stable Cu-65; daughter of short-lived Co-65. Excluded from final inventory.
Np-235	1.1E+00	Decays to form long-lived U-235; inventory of long-lived daughter expected to be negligible. Excluded from final inventory.
Np-237	2.1E+06	Decays to form short-lived Pa-233; daughter of long-lived Am-241. Included in final inventory.
Np-239	6.5E-03	Decays to form long-lived Pu-239; daughter of long-lived Am-243. Included in final inventory as a short-lived daughter of Am-243.
Np-242	1.0E-05	Decays to form long-lived Pu-242; inventory of long-lived daughter expected to be negligible. Excluded from final inventory.
Os-194	6.0E+00	Decays to form short-lived Ir-194; included in final inventory.
P-32	3.9E-02	Decays to stable S-32; daughter of long-lived Si-32. Included in final inventory as a short-lived daughter of Si-32.
P-33	6.9E-02	Decays to form stable S-33; daughter of short-lived Si-33. Excluded from final inventory.
Pa-231	3.3E+04	Decays to form long-lived Ac-227; daughter of short-lived Th-231. Included in final inventory.
Pa-233	7.4E-02	Decays to form long-lived U-233; daughter of long-lived Np-237. Included in final inventory as a short-lived daughter of Np-237.
Pa-234	7.6E-04	Decays to form long-lived U-234; daughter of short-lived Pa-234m. Included in final inventory as a short-lived daughter of U-238.
Pa-234m	2.2E-06	Decays to form long-lived U-234; daughter of short-lived Th-234. Included in final inventory as a short-lived daughter of U-238.
Pb-203	5.9E-03	Decays to form stable Tl-203; daughter of short-lived Bi-203. Excluded from final inventory.
Pb-210	2.2E+01	Decays to form short-lived Bi-210; daughter of short-lived Po-214. Included in final inventory.
Pb-211	6.9E-05	Decays to form short-lived Bi-211; daughter of short-lived Po-211. Included in final inventory as a short-lived daughter of Ac-227.
Pb-212	1.2E-03	Decays to form short-lived Bi-212; daughter of short-lived Po-216. Included in final inventory as a short-lived daughter of Th-228.
Pb-214	5.1E-05	Decays to form short-lived Bi-214; daughter of short-lived Po-218. Included in final inventory as a short-lived daughter of Ra-226.
Pd-107	6.5E+06	Decays to form stable Ag-107; daughter of short-lived Rh-107. Included in final inventory.

[a] *Primary source of radionuclide half-lives was KAPL (2002). Alternate sources include England and Rider (1994) and NNDC (2004).*

Table A-1 (Continued)
Radionuclide Decay Characteristics and Bases for Inclusion in the Area G Inventory

Radionuclide	Half-Life (yr)[a]	Decay Chain Characteristics and Assumptions
Pm-143	7.3E-01	Decays to form stable Nd-143; daughter of short-lived Sm-143. Excluded from final inventory.
Pm-145	1.8E+01	Decays to form stable Nd-145 and stable Pr-141; daughter of short-lived Sm-145. Included in final inventory.
Pm-146	5.5E+00	Decays to form stable Nd-146 and long-lived Sm-146. Included in final inventory.
Pm-147	2.6E+00	Decays to form long-lived Sm-147; daughter of short-lived Nd-147. Inventory of long-lived daughter expected to be negligible; excluded from final inventory.
Po-210	3.8E-01	Decays to form stable Pb-206; daughter of short-lived Bi-210. Included in final inventory as a short-lived daughter of Pb-210.
Pu-233	4.0E-05	Decays to form short-lived Np-233 and U-229, and ultimately forms long-lived U-233; inventory of long-lived daughter expected to be negligible. Excluded from final inventory.
Pu-234	1.0E-03	Decays to form short-lived Np-234 and U-230; the Np-234 decays to form long-lived U-234 while the U-230 ultimately forms long-lived Pb-210. Inventory of long-lived daughters expected to be negligible; excluded from final inventory.
Pu-236	2.9E+00	Decays to form long-lived U-232; included in final inventory.
Pu-238	8.8E+01	Decays to form long-lived U-234; daughter of short-lived Cm-242. Included in final inventory.
Pu-239	2.4E+04	Decays to form long-lived U-235; daughter of long-lived Cm-243 and short-lived Np-239. Included in final inventory.
Pu-240	6.6E+03	Decays to form long-lived U-236; daughter of long-lived Cm-244 and short-lived Np-240 and Np-240m. Included in final inventory.
Pu-241	1.4E+01	Decays to form long-lived Am-241; daughter of long-lived Cm-245. Included in final inventory.
Pu-242	3.8E+05	Decays to form long-lived U-238; daughter of long-lived Cm-246 and short-lived Am-242. Included in final inventory.
Pu-244	8.0E+07	Decays to form short-lived U-240; daughter of long-lived Cm-248. Included in final inventory.
Ra-223	3.1E-02	Decays to form short-lived Rn-219; daughter of short-lived Fr-223 and Th-227. Included in final inventory as a short-lived daughter of Ac-227.
Ra-224	1.0E-02	Decays to form short-lived Rn-220; daughter of long-lived Th-228. Included in final inventory as a short-lived daughter of Th-228.
Ra-226	1.6E+03	Decays to form short-lived Rn-222; daughter of long-lived Th-230. Included in final inventory.
Ra-228	5.8E+00	Decays to form short-lived Ac-228; daughter of long-lived Th-232. Included in final inventory.
Rb-82	2.4E-06	Decays to form stable Kr-82; daughter of short-lived Sr-82. Excluded from final inventory.

[a] Primary source of radionuclide half-lives was KAPL (2002). Alternate sources include England and Rider (1994) and NNDC (2004).

Table A-1 (Continued)
Radionuclide Decay Characteristics and Bases for Inclusion in the Area G Inventory

Radionuclide	Half-Life (yr)[a]	Decay Chain Characteristics and Assumptions
Rb-83	2.4E-01	Decays to form short-lived Kr-83m and stable Kr-83; daughter of short-lived Sr-83. Excluded from final inventory.
Rb-84	9.0E-02	Decays to form stable Kr-84 and Sr-84; excluded from final inventory.
Rb-86	5.1E-02	Decays to form stable Kr-86 and Sr-86; excluded from final inventory.
Re-183	1.9E-01	Decays to form long-lived W-183; daughter of short-lived Os-183. Inventory of long-lived daughter expected to be negligible; excluded from final inventory.
Re-184	1.0E-01	Decays to form long-lived W-184; daughter of short-lived Re-184m. Inventory of long-lived daughter expected to be negligible; excluded from final inventory.
Re-184m	1.8E-01	Decays to form short-lived Re-184 and long-lived W-184; inventory of long-lived daughter expected to be negligible. Excluded from final inventory.
Re-188	1.9E-03	Decays to form stable Os-188; daughter of short-lived W-188. Excluded from final inventory.
Rh-97	5.9E-05	Decays to form short-lived Ru-97 and, ultimately, long-lived Tc-97; daughter of short-lived Pd-97. Inventory of long-lived daughter expected to be negligible; excluded from final inventory.
Rh-99	4.4E-02	Decays to form stable Ru-99; daughter of short-lived Pd-99. Excluded from final inventory.
Rh-101	3.3E+00	Decays to form stable Ru-101; daughter of short-lived Rh-101m. Excluded from final inventory.
Rh-102	5.7E-01	Decays to form stable Pd-102 and Ru-102; daughter of short-lived Rh-102m. Excluded from final inventory.
Rh-102m	3.7E+00	Decays to form stable Ru-102 and short-lived Rh-102; excluded from final inventory.
Rh-106	9.5E-07	Decays to form stable Pd-106; daughter of short-lived Ru-106. Excluded from final inventory.
Rn-219	1.3E-07	Decays to form short-lived Po-215; daughter of short-lived Ra-223. Included in final inventory as a short-lived daughter of Ac-227.
Ru-103	1.1E-01	Decays to form stable Rh-103; daughter of short-lived Ru-103m and Tc-103. Excluded from final inventory.
Ru-106	1.0E+00	Decays to form short-lived Rh-106; daughter of Tc-106. Excluded from final inventory.
S-35	2.4E-01	Decays to form stable Cl-35; daughter of short-lived P-35. Excluded from final inventory.
Sb-124	1.6E-01	Decays to form stable Te-124; daughter of short-lived Sb-124m. Excluded from final inventory.
Sb-125	2.8E+00	Decays to form short-lived Te-125m and stable Te-125; daughter of short-lived Sn-125. Excluded from final inventory.
Sb-126	3.4E-02	Decays to form stable Te-126; daughter of long-lived Sn-126 and short-lived Sb-126m. Included in final inventory as a short-lived daughter of Sn-126.

[a] Primary source of radionuclide half-lives was KAPL (2002). Alternate sources include England and Rider (1994) and NNDC (2004).

Table A-1 (Continued)
Radionuclide Decay Characteristics and Bases for Inclusion in the Area G Inventory

Radionuclide	Half-Life (yr)[a]	Decay Chain Characteristics and Assumptions
Sc-43	4.5E-04	Decays to form stable Ca-43; daughter of short-lived Ti-43. Excluded from final inventory.
Sc-44	4.5E-04	Decays to form stable Ca-44; daughter of long-lived Ti-44. Included in final inventory as a short-lived daughter of Ti-44.
Sc-46	2.3E-01	Decays to form stable Ti-46; daughter of short-lived Sc-46m. Excluded from final inventory.
Sc-48	4.2E-04	Decays to form stable Ti-48; excluded from final inventory
Se-73	8.1E-04	Decays to form short-lived As-73; daughter of short-lived Br-73. Excluded from final inventory.
Se-75	3.3E-01	Decays to form stable As-75; daughter of short-lived Br-75. Excluded from final inventory.
Se-79	2.9E+05	Decays to form stable Br-79; daughter of short-lived As-79. Included in final inventory.
Si-32	1.6E+02	Decays to form short-lived P-32; daughter of short-lived Al-32. Included in final inventory.
Sm-145	9.3E-01	Decays to form long-lived Pm-145; daughter of short-lived Eu-145. Inventory of long-lived daughter expected to be negligible; excluded from final inventory.
Sm-151	9.0E+01	Decays to form stable Eu-150; daughter of short-lived Pm-151. Included in final inventory.
Sn-113	3.2E-01	Decays to form short-lived In-113m and stable In-113; daughter of short-lived Sb-113. Excluded from final inventory.
Sn-119m	8.0E-01	Decays to form stable Sn-119; daughter of short-lived In-119. Excluded from final inventory.
Sn-121	3.1E-03	Decays to form stable Sb-121; daughter of short-lived In-121 and Sn-121m. Excluded from final inventory.
Sn-121m	4.4E+01	Decays to form stable Sb-121 and short-lived Sn-121; daughter of short-lived In-121. Included in final inventory.
Sn-123	3.5E-01	Decays to form stable Sb-123; daughter of short-lived In-123. Excluded from final inventory.
Sn-126	2.3E+05	Decays to form short-lived Sb-126 and Sb-126m; daughter of short-lived In-126. Included in final inventory.
Sr-82	6.9E-02	Decays to form short-lived Rb-82; daughter of short-lived Y-82. Excluded from final inventory.
Sr-85	1.8E-01	Decays to form stable Rb-85; daughter of short-lived Y-85. Excluded from final inventory.
Sr-89	1.4E-01	Decays to form short-lived Y-89m and stable Y-89; daughter of short-lived Rb-89. Excluded from final inventory.
Sr-90	2.9E+01	Decays to form short-lived Y-90; daughter of short-lived Rb-90. Included in final inventory.
Ta-179	1.8E+00	Decays to form stable Hf-179; daughter of short-lived W-179. Excluded from final inventory.
Ta-182	3.1E-01	Decays to form stable W-182; daughter of long-lived Hf-182. Excluded from final inventory because of the absence of Hf-182.

[a] Primary source of radionuclide half-lives was KAPL (2002). Alternate sources include England and Rider (1994) and NNDC (2004).

Table A-1 (Continued)
Radionuclide Decay Characteristics and Bases for Inclusion in the Area G Inventory

Radionuclide	Half-Life (yr)[a]	Decay Chain Characteristics and Assumptions
Ta-183	1.4E-02	Decays to form long-lived W-183; daughter of short-lived Hf-183. Inventory of long-lived daughter expected to be negligible; excluded from final inventory.
Tb-157	7.0E+01	Decays to form stable Gd-157; daughter of short-lived Dy-157. Included in final inventory.
Tb-158	1.8E+02	Decays to form stable Dy-158 and Gd-158; included in final inventory.
Tb-160	2.0E-01	Decays to form stable Dy-160; excluded from final inventory.
Tc-95	2.3E-03	Decays to form stable Mo-95; daughter of short-lived Ru-95 and Tc-95m. Excluded from final inventory.
Tc-95m	1.7E-01	Decays to form stable Mo-95 and short-lived Tc-95; daughter of short-lived Ru-95. Excluded from final inventory.
Tc-97	4.2E+06	Decays to form stable Mo-97; daughter of short-lived Tc-97m. Included in final inventory.
Tc-99	2.1E+05	Decays to form stable Ru-99; daughter of short-lived Mo-99 and Tc-99m. Included in final inventory.
Tc-99m	6.9E-04	Decays to form stable Ru-99 and long-lived Tc-99; daughter of short-lived Mo-99. Inventory of long-lived daughter expected to be negligible; excluded from final inventory.
Te-125m	1.6E-01	Decays to form stable Te-125; excluded from final inventory.
Te-129m	9.2E-02	Decays to form long-lived I-129 and short-livedTe-129; daughter of short-lived Sb-129. Inventory of long-lived daughter expected to be negligible; excluded from final inventory.
Th-227	5.1E-02	Decays to form short-lived Ra-223; daughter of long-lived Ac-227. Included as a short-lived daughter of Ac-227.
Th-228	1.9E+00	Decays to form short-lived Ra-224; daughter of short-lived Ac-228. Included in final inventory.
Th-229	7.3E+03	Decays to form short-lived Ra-225; daughter of long-lived U-233. Included in final inventory.
Th-230	7.5E+04	Decays to form long-lived Ra-226; daughter of long-lived U-234. Included in final inventory.
Th-231	2.9E-03	Decays to form long-lived Pa-231; daughter of long-lived U-235. Included in final inventory as a short-lived daughter of U-235.
Th-232	1.4E+10	Decays to form long-lived Ra-228; daughter of long-lived U-236. Included in final inventory.
Th-234	6.6E-02	Decays to form short-lived Pa-234m; daughter of long-lived U-238. Included in final inventory as a short-lived daughter of U-238.
Ti-44	6.0E+01	Decays to form short-lived Sc-44; daughter of short-lived V-44. Included in final inventory.
Tl-204	3.8E+00	Decays to form stable Hg-204 and long-lived Pb-204; inventory of long-lived daughter expected to be negligible. Excluded from final inventory.
Tl-208	5.8E-06	Decays to form stable Pb-208; daughter of short-lived Bi-212. Included in final inventory as a short-lived daughter of Th-228.

[a] *Primary source of radionuclide half-lives was KAPL (2002). Alternate sources include England and Rider (1994) and NNDC (2004).*

Table A-1 (Continued)
Radionuclide Decay Characteristics and Bases for Inclusion in the Area G Inventory

Radionuclide	Half-Life (yr)[a]	Decay Chain Characteristics and Assumptions
Tm-170	3.5E-01	Decays to form stable Er-170 and Yb-170; excluded from final inventory.
Tm-171	1.9E+00	Decays to form stable Yb-171; daughter of short-lived Er-171. Excluded from final inventory.
U-232	7.0E+01	Decays to form long-lived Th-228; daughter of long-lived Pu-236. Included in final inventory.
U-233	1.6E+05	Decays to form long-lived Th-229; daughter of short-lived Pa-233. Included in final inventory.
U-234	2.5E+05	Decays to form long-lived Th-230; daughter of short-lived Pa-234 and Pa-234m and long-lived Pu-238. Included in final inventory.
U-235	7.0E+08	Decays to form short-lived Th-231; daughter of long-lived Pu-239. Included in final inventory.
U-236	2.3E+07	Decays to form long-lived Th-232; daughter of long-lived Pu-240. Included in final inventory.
U-237	2.1E-03	Decays to form long-lived Np-237; inventory of long-lived daughter expected to be negligible. Excluded from final inventory.
U-238	4.5E+09	Decays to form short-lived Th-234; daughter of long-lived Pu-242. Included in final inventory.
U-239	4.5E-05	Decays to form short-lived Np-239 and, ultimately, long-lived Pu-239; inventory of long-lived daughter expected to be negligible. Excluded from final inventory.
V-48	4.4E-02	Decays to form stable Ti-48; daughter of short-lived Cr-48. Excluded from final inventory.
V-49	9.1E-01	Decays to form stable Ti-49; daughter of short-lived Cr-49. Excluded from final inventory.
V-52	1.4E-06	Decays to form stable Cr-52; daughter of short-lived Ti-52. Excluded from final inventory.
W-178	5.9E-02	Decays to form short-lived Ta-178. Excluded from final inventory.
W-181	3.3E-01	Decays to form stable Ta-181; daughter of short-lived Re-181. Excluded from final inventory.
W-185	2.0E-01	Decays to form stable Re-185; daughter of short-lived Ta-185. Excluded from final inventory.
Xe-133	1.4E-02	Decays to form stable Cs-133; daughter of short-lived I-133. Excluded from final inventory.
Y-88	2.9E-01	Decays to form stable Sr-88; daughter of short-lived Zr-88. Excluded from final inventory.
Y-90	7.3E-03	Decays to form stable Zr-90; daughter of long-lived Sr-90. Included in final inventory as a short-lived daughter of Sr-90.
Y-91	1.6E-01	Decays to form stable Zr-91; daughter of short-lived Sr-91. Excluded from final inventory.
Yb-169	8.8E-02	Decays to form stable Tm-169; daughter of short-lived Lu-169. Excluded from final inventory.
Zn-65	6.7E-01	Decays to form stable Cu-65; daughter of short-lived Ga-65. Excluded from final inventory.

[a] *Primary source of radionuclide half-lives was KAPL (2002). Alternate sources include England and Rider (1994) and NNDC (2004).*

Table A-1 (Continued)
Radionuclide Decay Characteristics and Bases for Inclusion in the Area G Inventory

Radionuclide	Half-Life (yr)[a]	Decay Chain Characteristics and Assumptions
Zn-69m	1.6E-03	Decays to form stable Ga-69 and short-lived Zn-69; excluded from final inventory.
Zn-72	7.4E-04	Decays to form short-lived Ga-72; daughter of short-lived Cu-72. Excluded from final inventory.
Zr-88	2.3E-01	Decays to form short-lived Y-88; daughter of short-lived Nb-88. Excluded from final inventory.
Zr-93	1.5E+06	Decays to form stable Nb-93; daughter of short-lived Y-93. Included in final inventory.
Zr-95	1.8E-01	Decays to form short-lived Nb-95 and Nb-95m; daughter of short-lived Y-95. Excluded from final inventory.
Th-231	2.9E-03	Decays to form long-lived Pa-231; daughter of long-lived U-235. Included in final inventory as a short-lived daughter of U-235

[a] *Primary source of radionuclide half-lives was KAPL (2002). Alternate sources include England and Rider (1994) and NNDC (2004).*

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