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Author(s): Birdsell, Kay Hanson
Stauffer, Philip H.
Atchley, Adam Lee
Miller, Elizabeth D.
Chu, Shaoping
French, Sean B.

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Annual Report for Los Alamos National Laboratory Technical Area 54, Area G Disposal Facility – Fiscal Year 2016

Authors:
Kay Birdsell, Philip Stauffer, Adam Atchley, Elizabeth Miller, Shaoping Chu, and Sean French
Los Alamos National Laboratory

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Executive Summary

As a condition to the disposal authorization statement issued to Los Alamos National Laboratory (LANL or the Laboratory) on March 17, 2010, a comprehensive performance assessment and composite analysis (PA/CA) maintenance program must be implemented for the Technical Area 54, Area G disposal facility. Annual determinations of the adequacy of the PA/CA are to be conducted under the maintenance program to ensure that the conclusions reached by those analyses continue to be valid. This report summarizes the results of the fiscal year (FY) 2016 annual review for Area G.

Revision 4 of the Area G PA/CA was issued in 2008 and formally approved in 2009. In conjunction with unreviewed disposal question evaluations and special analyses conducted under the Area G PA/CA maintenance program, these analyses are expected to provide reasonable estimates of the long-term performance of Area G and, hence, the disposal facility's ability to comply with U.S. Department of Energy (DOE) performance objectives defined under Order 435.1, Radioactive Waste Management.

The disposal of waste in pits is nearing its end as the disposal capacity in Pit 38 is exhausted. Projections of the volumes and radionuclide inventories in the waste that will require disposal in shafts are similar to those presented in the second revision of the Area G inventory. Overall, changes in the projected future inventories of waste are not expected to compromise the ability of Area G to satisfy DOE performance objectives. The Area G composite analysis addresses potential impacts from all waste disposed of at the facility as well as other sources of radioactive material that may interact with releases from Area G. The level of knowledge about the other sources included in the composite analysis has not changed sufficiently to call into question the validity of that analysis.

Ongoing environmental surveillance activities are conducted at, and in the vicinity of, Area G. Monitoring data that are applicable support some aspects of the PA/CA and are described in this annual report.

Several research and development (R&D) efforts have been initiated under the PA/CA maintenance program. These investigations are designed to improve the current understanding of the disposal facility and site, thereby reducing the uncertainty associated with the projections of the long-term performance of Area G. The status and results of R&D activities that were undertaken in fiscal year (FY) 2016 are discussed in this report. These include (1) sampling to bound cliff-face age dates as part of a cliff retreat study, (2) updates to the erosion model, and (3) groundwater modeling to account for transient infiltration through and below the pits.

Two special analyses were completed during FY 2016, (1) to update the radionuclide inventory for Material Disposal Area (MDA) B waste disposals at Area G and incorporate the update into WCATS, and (2) to upgrade the GoldSim modeling platform version for the PA/CA model and transfer the PA/CA model to Laboratory staff. In addition, two unreviewed disposal question evaluations (UDQEs) were initiated during FY 2016 to check into a potential underreporting of the Am-241 inventory and another to determine the impacts of removing a dome at the site. Significant progress was made on the two special analyses related to these UDQEs. These are described and preliminary results are summarized herein.

The Area G disposal facility consists of MDA G and potential Zone 4. To date, all disposal operations at Area G have been confined to MDA G. The Laboratory's most current Enduring Mission Waste Management Plan (EMWMP) proposes that the strategy for low-level waste (LLW) management is to terminate on-site LLW disposal by using the remaining space in Pit 38 and existing shafts to dispose of a small volume of specific problem wastes that are difficult to transport off site. Plans are to initiate disposal operations of these limited waste streams before the upcoming transition of the Laboratory's Environmental Management to a DOE subcontractor (i.e., the beginning of FY 2018). On-site disposal is expected to become less available after FY 2017. The strategy presented in the EMWMP is that all present and future LLW streams would be shipped to off-site treatment and disposal facilities, and planning for expansion of LLW disposal in TA-54 Zone 4 has been terminated. MDA G will undergo phased final closure after disposal operations end. In anticipation of the closure of MDA G, plans have been made to ship the majority of the waste generated at the Laboratory to off-site locations for disposal. It is assumed that the closure of MDA G will mark the end of both pit and shaft disposal at Area G with no expansion into Zone 4.

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Acronyms and Abbreviations

3-D	Three dimensional
Consent Order	Compliance Order on Consent
CY	Calendar year
D&D	Decommission and demolish
DAS	Disposal Authorization Statement
DOE	Department of Energy
DRR	Disposal receipt review
DSA	Documented safety analysis
EDE	Effective dose equivalent
EM	Environmental Management (LANL Associate Directorate)
EMWMP	Enduring Mission Waste Management Plan
FEHM	Finite Element Heat and Mass (model)
FY	Fiscal year
HDP	Heat dissipation probe
LANL or Laboratory	Los Alamos National Laboratory
LASL	Los Alamos Scientific Laboratory
LFRG	Low-Level Waste Disposal Facility Federal Review Group
LHS	Latin Hypercube Sampling (method)
LLW	Low-level (radioactive) waste
MATK	Model Analysis ToolKit
MDA	Material disposal area
NESHAP	Radionuclide National Emission Standards for Hazardous Air Pollutants
NMED	New Mexico Environment Department
NTS	Nevada Test Site
PA/CA	Performance Assessment and Composite Analysis
R&D	Research and development
RCRA	Resource Conservation and Recovery Act
SA	Special analysis
TA	Technical area
TDR	Time-domain reflectometry
TRU	Transuranic
UDQ	Unreviewed disposal question
UDQE	Unreviewed disposal question evaluation
WAC	Waste acceptance criteria
WCATS	Waste Compliance and Tracking System

1.0 Introduction

As a condition to Revision 1 of the disposal authorization statement (DAS) issued to Los Alamos National Laboratory (LANL or the Laboratory) on March 17, 2010 (DOE, 2010), a comprehensive performance assessment and composite analysis (PA/CA) maintenance program must be implemented for the Technical Area 54 (TA-54), Area G disposal facility. As implemented under U.S. Department of Energy (DOE) Order 435.1, Radioactive Waste Management (DOE, 2001a); DOE Manual 435.1-1, Radioactive Waste Management Manual (DOE, 2001b); and draft guidance for maintenance programs, Maintenance Guide for U.S. Department of Energy Low-Level Waste Disposal Facility Performance Assessments and Composite Analyses (DOE, 2001c), annual determinations of the adequacy of the PA/CA are to be conducted to ensure the conclusions reached by those analyses continue to be valid. Annual reports are to be submitted that

- Summarize the results of the adequacy determination;
- Describe monitoring and research and development (R&D) activities conducted at the site and discuss how the results from such activities affect the conclusions of the PA/CA;
- Describe any changes in disposal facility design, operation, and maintenance and discuss how such changes affect the PA/CA;
- Assess the need for modifications to the monitoring and R&D programs conducted in support of PA/CA maintenance; and
- Discuss the need for changes in low-level waste (LLW) disposal operations or the PA/CA maintenance program.

This report summarizes the results of the fiscal year (FY) 2016 annual review for Area G. Section 2 presents the results of the adequacy determination for Revision 4 of the Area G Performance Assessment and Composite Analysis (LANL, 2008). Section 3 summarizes the results of recent inventory revisions and discusses updates to the information used to conduct the alternate source evaluation for the composite analysis. Sections 4 and 5 present pertinent information collected through monitoring and R&D efforts, respectively, and Section 6 discusses unreviewed disposal question evaluations (UDQEs) and special analyses (SA) that were conducted to address changes in inventory characteristics and a software revision for the PA/CA model. Section 7 discusses the potential impacts of operational changes at Area G, considers informational needs, describes the progress made with respect to addressing the conditions found in the disposal authorization statement (DAS), and discusses modifications that may need to be made in response to operational changes.

2.0 Performance Assessment and Composite Analysis Adequacy

Revision 4 of the Area G Performance Assessment and Composite Analysis (LANL, 2008) was issued in 2008 and formally approved in 2009. In conjunction with the UDQEs and SAs conducted under the Area G PA/CA maintenance program, these analyses are expected to provide reasonable estimates of the long-term performance of Area G and hence, the disposal facility's ability to comply with DOE performance objectives. As discussed in Section 3 of this report, the pit and shaft inventories projected for Area G have changed relative to the inventories used to conduct the Revision 4 analyses. Nevertheless, the doses projected using the PA/CA models remain well within pertinent performance objectives for members of the public. Limits on any future disposal of high-activity tritium waste in the Zone 4 shafts have been established to maintain projected intruder exposures within acceptable limits, but as of this update to the annual report, all planning for expansion of LLW disposal in Zone 4 has been terminated (LANL, 2017).

The Area G disposal facility consists of existing Material Disposal Area (MDA) G and potential Zone 4. For consistency with previous performance assessment documentation, this document refers to the entire active and inactive disposal facility at Area G as MDA G. This nomenclature is different from what is used in Compliance Order on Consent (the Consent Order) documents, which refer to MDA G as only those disposal units within Area G subject to the corrective action requirements of the Resource Conservation and Recovery Act (RCRA). Thus, the disposal units comprising MDA G under the Consent Order are a subset of those comprising MDA G under the performance assessment.

Material Disposal Area G has been in continuous operation since Area G first received radioactive waste in the late 1950s, although almost no pit and shaft disposal at Area G has occurred since February 2014 (Section 3.1; the exception is a single container disposed of in 2015). Revision 4 of the PA/CA assumes that additional pits and shafts will be developed in Zone 4 to provide disposal capacity after the disposal units in MDA G are full. However, the Laboratory's most current Enduring Mission Waste Management Plan (EMWMP) proposes that the strategy for LLW management is to terminate on-site LLW disposal by using the remaining space in Pit 38 and existing shafts to dispose of a small volume of specific problem wastes that are difficult to transport off site. Plans are to initiate disposal operations of these limited waste streams before the upcoming transition of the Laboratory's Environmental Management (EM) to a DOE subcontractor (i.e., during FY 2018). On-site disposal is expected to become less available after FY 2017; the EMWMP states that on site-disposal after the transition of EM to the subcontractor should be reserved for waste with no off-site path forward. The strategy presented in the EMWMP is that all other present and future LLW streams would be shipped to off-site treatment and disposal facilities, and all planning for expansion of LLW disposal in TA-54 Zone 4 has been terminated (LANL, 2017). Revision 4 of the PA/CA is consistent with other plans and procedures used to manage LLW at Area G. These include documents that address disposal unit design and construction, placement of waste, and operational closure of pits and shafts (LANL, 2010a; 2015a) as well as the final closure of the disposal facility (LANL, 2009a).

The performance assessment was used to develop intruder-based radionuclide concentration limits for the disposal pits and shafts in MDA G. Radionuclide concentration limits have also been developed for the disposal of low-activity waste in the headspace of disposal Pits 15, 37, and 38. These limits are incorporated in the Laboratory waste acceptance criteria (WAC) (LANL, 2014a).

The overall conclusions of Revision 4 of the PA/CA remain valid at present. However, the long-term strategy that will be adopted for the disposal of LLW at the Laboratory is being refined at this time and could affect some of the premises upon which the analyses are based. Increasing amounts of institutional waste and waste generated by cleanup efforts at the Laboratory are being shipped off-site for disposal. This trend is expected to continue for the foreseeable future such that expansion into Zone 4 is no longer planned.

The increase in off-site shipments and the cessation of disposal will result in an overall decrease in the amount of waste disposed of at Area G relative to that projected by the PA/CA. Changes to MDA G disposal operations and modifications of the final MDA G closure strategy may also occur as the existing portion of the disposal facility nears final closure. To ensure they continue to adequately represent conditions at Area G, the PA/CA will need to be updated as new policies and plans are solidified and put into place.

The PA/CA maintenance program plan (LANL, 2011a) takes into account findings from Revision 4 of the PA/CA and the comments received from the Low-Level Waste Disposal Facility Federal Review Group's (LFRG's) review of the analyses (DOE, 2009). To address the secondary issues identified during that review and to improve the current understanding of the disposal facility and site, several R&D efforts have been, and will be, pursued. These efforts, which are identified in the plan, will reduce uncertainty in the projections of the long-term performance of Area G. A formal update of the maintenance program plan will be performed during FY 2017 to better establish plans for assessing uncertainties related to impacts of potential ground motion, disruptive processes and events, and specification of probability distributions on PA/CA predictions.

3.0 Area G Inventory Revision and Alternate Source Evaluation

Annual reviews of LLW disposal receipts are generally conducted to ensure future inventories projected for the PA/CA remain consistent with the actual waste inventories disposed of at Area G. The LLW generators at the Laboratory supply the data included in the inventory characterization; all these generators have been certified to send waste to Area G for disposal, as described in Section 7.0. Although complete revisions of the inventory supplanted these reviews in recent years (French and Shuman, 2013; 2015a), the more typical disposal receipt review (DRR) is used to calculate dose presented in this annual report. The results of the FY 2014 DRR (French and Shuman, 2015b) are summarized in Section 3.1. For FY 2015 and FY 2016, the DRR was not formally updated because so little waste was disposed. However, we present a summary in Section 3.l of the latest waste inventory data for FY 2015 and FY 2016 and describe how the latest inventory data compare with projected values used in the FY 2014 DRR. Also included are the most current dose projections based on the FY 2014 DRR.

The Area G composite analysis addresses potential impacts from all waste disposed of at the facility as well as other sources of radioactive material that may interact with releases from Area G. As part of the composite analysis maintenance program, information about alternate sources of radioactive material that may interact with Area G releases is routinely reviewed to ensure that these alternate sources were adequately addressed. The results of this evaluation are provided in Section 3.2.

3.1 Disposal Receipt Review and PA/CA Dose Predictions

The FY 2014 DRR (French and Shuman, 2015b) compiled LLW disposal data for October 1, 2013, to September 30, 2014, and used that information to update existing inventories and estimates of the types and quantities of waste that will require disposal at Area G from October 1, 2014, through 2044, the year in which the PA/CA assumes that disposal operations at Area G will cease if disposal in Zone 4 occurs. The primary objective of the DRR is to ensure future waste inventory projections developed for the PA/CA are consistent with the actual types and quantities of waste being disposed of at Area G. To this end, the disposal data that are the subject of the review are used to update the future waste inventory projections for the disposal facility. Table 3-1 provides the future waste volume and activity projections developed for the FY 2014 DRR (French and Shuman, 2015b) from October 1, 2014, through 2044. The FY 2014 DRR represents the most current inventory projections made for Area G, including Zone 4. An important assumption made in the FY 2014 DRR is that the remaining active pit (Pit 38) and active shafts within Area G would be closed at the end of calendar year (CY) 2015; this did not take place.

Table 3-1
Future Waste Inventory Estimates for Area G:
FY 2014 Disposal Receipt-Based Projections

Disposal Unit	FY 2014 Disposal Receipt-Review [a]	
	Volume (m^3)	Inventory
Pits		
Headspace Layer	2.3E+03	6.2E+00 Ci
Institutional Waste Layer	2.0E+02	2.6E+01 Ci 2.3E+04 g
Shafts	2.8E+02	3.6E+06 Ci 1.6E+06 g

[a] *Includes waste expected to require disposal in pits from October 1, 2014, to 2015 and in shafts from October 1, 2014, through 2044.*

Table 3-2 compares the waste volume and activity projections developed for the FY 2014 DRR (French and Shuman, 2015b) with disposal data pulled from the Laboratory's Waste Compliance and Tracking System (WCATS) in December 2016 for the time period corresponding to FY 2015 and FY 2016 (i.e., October 1, 2014, through September 30, 2016). However, the information in Table 3-2 is provided for time periods that do not correspond exactly to the fiscal years because of the assumption in the FY 2014 DRR about pit and shaft closure in Area G proper on December 31, 2015, and the corresponding assumption of expansion into Zone 4 shafts on January 1, 2016. These details are annotated within the table. In terms of the pit waste, a distinction is made between material placed in the headspace and institutional waste layers. The volumes of headspace and institutional waste projected by the FY 2014 DRR to require disposal in Pit 38 are significantly higher than those documented in the FY 2015 and FY 2016 disposal data. This disparity is consistent with the fact that, for Pit 38, only one waste container was disposed during FY 2015 and no waste was disposed in the pit during FY 2016. The pit was not filled and closed as projected in the FY 2014 DRR. Based on the Laboratory's EMWMP, the expectation is that following closure of Pit 38, no other pit disposals (i.e., in Zone 4) will occur at the site (LANL, 2017). Volumes and activities yet to be disposed of in Pit 38 are not expected to exceed those projected by the FY 2014 DRR shown in Table 3-1. Similarly, the FY 2014 DRR projects on average, 1.2E+05 Ci tritium per year of shaft disposal for each year from 2015 to 2044, where the actual FY 2015 and FY 2016 data show that no waste was disposed in the shafts. The EMWMP currently proposes that the existing shafts in Area G be filled and closed and that no further shaft disposal be developed in Zone 4 (LANL, 2017). In that event, future inventory projections for the shafts from 2018 through 2044 will reflect no future waste disposal. Therefore, the FY 2014 DRR projections bound the expected future inventory for both the pit and shaft wastes.

Table 3-2
FY 2015 and FY 2016 Waste Inventory Estimates for Area G: Projected FY 2015 and FY 2016 Inventory Based on the FY 2014 Disposal Receipt-Based Projections vs. Actual FY/CY 2015 and FY 2016 Inventory Characterization

Disposal Unit	Projected Inventory for FY Based on FY 2014 Disposal Receipt-Review [a]		Actual FY Waste Inventory [b, c]	
	Volume (m^3)	Inventory (Ci)	Volume (m^3)	Inventory (Ci)
FY/CY 2015 (1.25 years; Oct 1, 2014 – Dec 31, 2015)				
Pits (Pit 38)				
Headspace Layer	2.3E+03	6.2	0.0	0.0
Institutional Waste Layer	2.0E+02	2.6E+01	2.1E-01	2.5E-02[d]
Shafts (Area G)	11.6	1.5E+05	0.0	0.0
FY 2016 (0.75 years; Jan 1, 2016 – Sept 30, 2016)				
Pits				
Headspace Layer	0	0	0	0
Institutional Waste Layer	0	0	0	0
Shafts (Area G)	0	0	0	0
Shafts (Zone 4)	7.0	9.0E+04	0	0

[a] Includes waste that was expected to require disposal in pits and shafts based on FY 2014 DRR from October 1, 2014, to December 30, 2015, for the FY/CY 2015 information, and from January 1, 2016, to September 30, 2016, for the CY 2016 information. These projected inventories are still assumed in the most current PA/CA model. The 2015 time period differs to account for projected closure at the end of CY 2015 for Area G pits (Pit 38) and Area G shafts assumed in FY 2014 DRR. FY 2014 DRR assumes all waste disposal beginning January 1, 2016, takes place in Zone 4 shafts only.

[b] Includes actual waste disposal in pits and shafts from October 1, 2014, to December 31, 2015, for the FY/CY 2015 information, and from October 1, 2015, to September 30, 2016, for the FY 2016 information.

[c] Note that the FY 2015 inventory is revised (lower than) the inventory provided in the FY 2015 Annual Report (French et al., 2016a). The previous report accounted for a container that is scheduled to be disposed of at the Nevada National Security Site (former Nevada Test Site (NTS)) LLW Disposal Facility.

[d] Pit 38 waste was for a single container of depleted uranium parts; inventory is U-238.

Because the radionuclide inventories used to calculate dose based on the FY 2014 DRR are larger than the actual disposal data, predictions of dose based on the FY 2014 DRR are conservative (higher than would be calculated if a revision to the inventory were made based on FY 2015 and FY 2016 data). Thus, for this annual report, dose calculations presented are based on the FY 2014 DRR, and the dose predictions will be updated as part of ongoing FY 2017 work and as projected remaining waste disposal volumes, inventories, and closure plans become more certain.

The following discussion describes predicted doses based on the FY 2014 DRR inventory assumptions. The predicted doses are updated from those presented in the FY 2015 Annual Report (French et al., 2016a) and are consistent with SA 2016-003 (see Section 6.2), which updated the PA/CA Model to GoldSim software version 11.1.5 (Chu et al., 2017). It should be noted that without expansion into Zone 4, predicted doses for Zone 4 will decrease to zero rather than the values discussed below. The impacts of this operational change, if it occurs, will be assessed in future revisions to the PA/CA models.

A relatively small number of radionuclides make significant contributions to the doses projected for Revision 4 of the Area G PA/CA (LANL, 2008). In general, the impacts of using FY 2014 disposal receipt data to estimate future waste inventories depend upon how the quantities of these critical radionuclides are affected. These impacts were evaluated by revising the inventories used in Revision 4 of the PA/CA modeling and updating the dose and radon flux projections. The impacts that the disposal receipt-based inventories have on the dose and flux projections presented here based on the FY 2014 DRR 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 PA/CA.

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 projected Zone 4 shaft tritium inventory in the model by 960,000 Ci.

The exposures and radon fluxes projected using the updated pit and shaft inventories in the FY 2014 DRR and GoldSim Version 11.1.5 (Chu et al., 2017) are provided in Tables 3-3 through 3-5. These are the most current modeled projections, and the projections still assume that expansion and disposal in Zone 4 shafts will occur. The simulations also over predict the 2015 and 2016 actual inventory as described above. Table 3-3 gives the exposures projected for members of the public, Table 3-4 shows the radon flux estimates, and Table 3-5 provides the intruder exposure projections for the performance assessment inventory as well as the composite analysis inventory. In Table 3-3, the performance assessment dose is presented based on waste disposed of at Area G after September 26, 1988, while the composite analysis accounts for all waste disposed of at Area G, beginning in 1959. Both the performance assessment and the composite analysis project future inventory based on assumptions about predicted waste disposal through 2044. The doses projected for the All Pathways–Canyon Scenario consider the exposures received within several catchments within Cañada del Buey and Pajarito Canyon; radon fluxes are projected for several waste disposal regions within Area G. These catchments and disposal regions are shown in Figures 3-1 and 3-2, respectively.

In summary, updating the Area G inventory to reflect the FY 2014 disposal data and the expected disposal trends does not compromise the ability of the disposal facility to safely contain the waste disposed therein. Disposal records from FY 2015 and FY 2016 show that during these past 2 years, less waste was received than was predicted (Table 3-2); that is, the FY 2014 DRR projections are conservative with respect to dose projections. All doses and radon fluxes projected by the PA/CA remain within performance objectives.

Table 3-3
Exposures Projected for Members of the Public: FY 2014 Disposal Receipt Review Using GoldSim v. 11.1.5

Exposure Scenario and Location	Performance Objective (mrem/yr)	Peak Mean Dose (mrem/yr)	
		Performance Assessment	Composite Analysis
		FY 2014 Disposal Receipt Review	FY 2014 Disposal Receipt Review
Atmospheric			
LANL Boundary	10	1.7E–01	2.4E–01
Area G Fence Line	10	2.7E–03	5.1E–01
All Pathways–Canyon			
Catchment CdB1	25/30[a]	5.0E–01	8.1E–01
Catchment CdB2	25/30	1.0E+00	1.8E+00
Catchment PC0	25/30	2.5E-04	2.5E-04
Catchment PC1	25/30	2.4E–02	1.2E–01
Catchment PC2	25/30	1.9E–02	6.5E–01
Catchment PC3	25/30	1.2E–01	2.4E–01
Catchment PC4	25/30	2.2E–01	2.7E–01
Catchment PC5	25/30	3.0E–01	2.4E+00
Catchment PC6	25/30	1.6E–01	2.8E+00
Groundwater Pathway Scenarios			
All Pathways–Groundwater	25/30	7.1E–03	6.8E–03
Groundwater Resource Protection	4	1.2E–02	NA

NA = Not applicable.

[a] An all-pathways performance objective of 25 mrem/yr applies to the performance assessment; doses projected for the composite analysis must comply with the 30 mrem/yr dose constraint.

Table 3-4
Projected Radon Fluxes: FY 2014 Disposal Receipt Review Using GoldSim v. 11.1.5

Waste Disposal Region or Pit	Peak Mean Flux (pCi/m²/s) FY 2014 Disposal Receipt Review
Region 1	1.1E-06
Region 2	— [a]
Region 3	0.0E+00
Region 4	2.7E-02
Region 5	8.5E-05
Region 6	2.8E-03
Region 7	1.3E+01
Region 8	1.8E-03
Pit 15	1.4E+01
Pit 37	2.8E-01
Pit 38	1.1E+00
Entire facility	4.4E-01

[a] *— = None of the performance assessment inventory was disposed of in the waste disposal region.*

Table 3-5
Projected Intruder Exposures: FY 2014 Disposal Receipt Review Using GoldSim v. 11.1.5

Disposal Units and Exposure Scenario	Performance Objective	Peak Mean Dose (mrem/yr)
		2014 Disposal Receipt Review
MDA G Pits		
Intruder-Construction	500 mrem	3.9E+00
Intruder-Agriculture	100 mrem/yr	2.7E+01
Intruder-Post-Drilling	100 mrem/yr	1.2E+01
Zone 4 Pits		
Intruder-Construction	500 mrem	0.0E+00
Intruder-Agriculture	100 mrem/yr	0.0E+00
Intruder-Post-Drilling	100 mrem/yr	0.0E+00
MDA G Shafts		
Intruder-Construction	500 mrem	4.8E+00
Intruder-Agriculture	100 mrem/yr	8.0E+01
Intruder-Post-Drilling	100 mrem/yr	1.1E+01
Zone 4 Shafts		
Intruder-Construction	500 mrem	3.7E+00
Intruder-Agriculture	100 mrem/yr	8.6E+01
Intruder-Post-Drilling	100 mrem/yr	1.1E+01

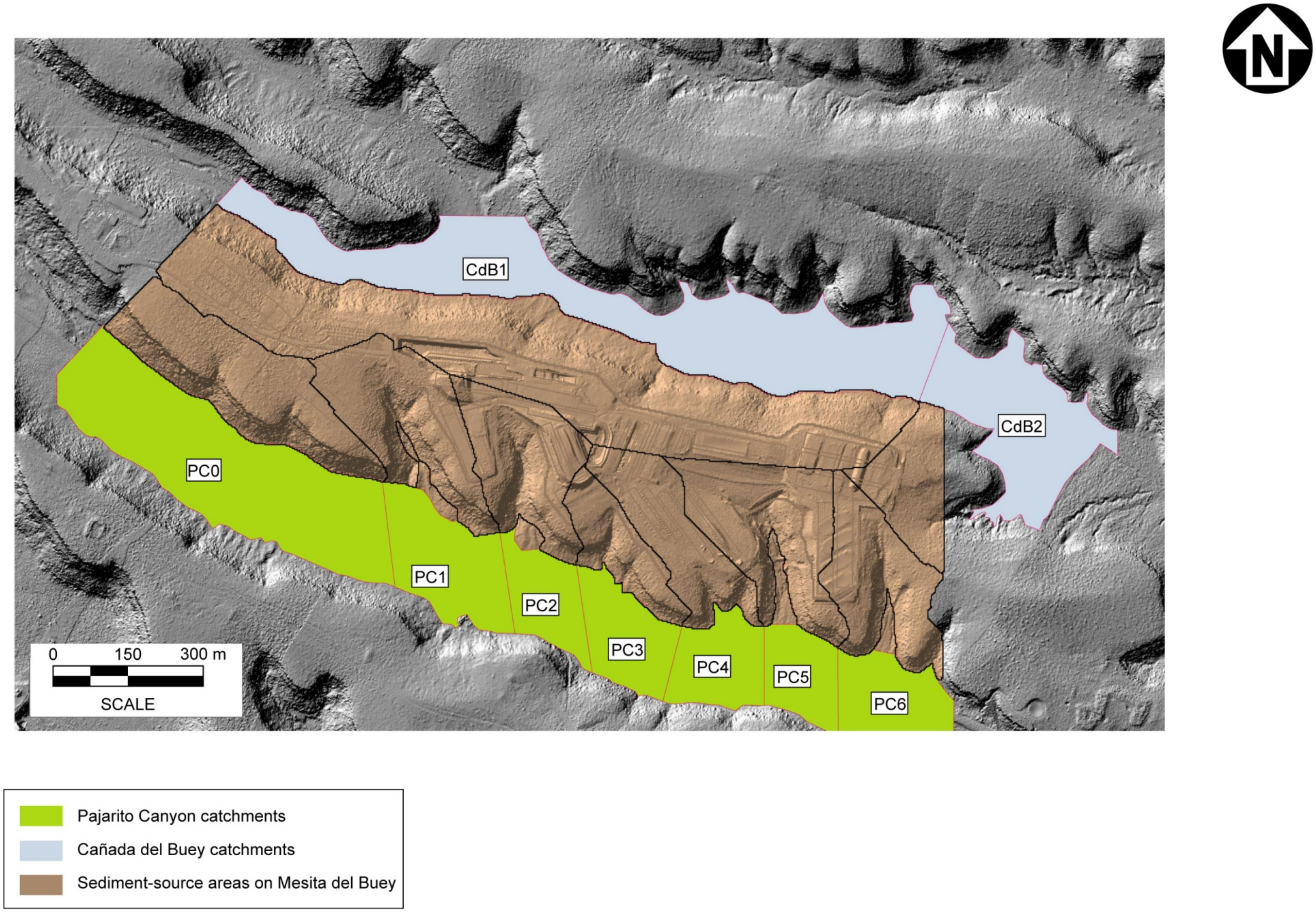

Figure 3-1
Area G Sediment Catchments in Pajarito Canyon and Cañada del Buey

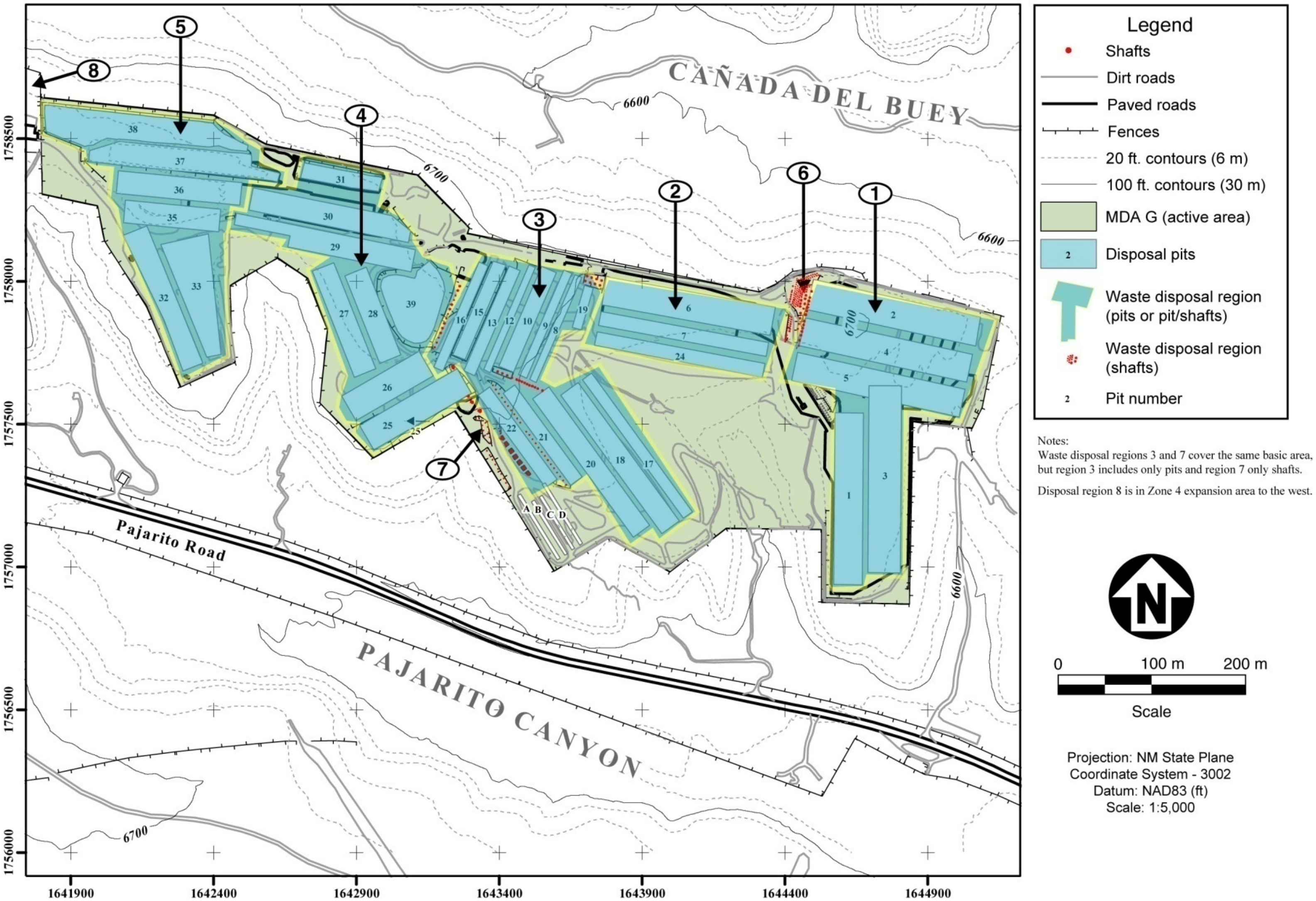

Figure 3-2
Waste Disposal Regions at Area G

Source: Apogen Technologies (formerly SEA)
LANL RRES Database, Map ID: 4531.021 (1) Rev.

3.2 Alternate Source Evaluation

The alternate source evaluation conducted in support of the Area G composite analysis (LANL, 2008) considered several sources of radioactive materials at the Laboratory: MDAs A, AB, B, C, H, J, L, and T; Cañada del Buey; and Pajarito Canyon. The MDAs, all of which are located on mesas, were included because they have been used to dispose of potentially large quantities of radioactive waste, are highly contaminated, or are located near Area G. The two canyons were included because they have received discharges of waste in the past or are otherwise contaminated and because they are adjacent to Area G. The alternate source evaluation concluded that the potential for significant interaction between Area G and other source areas is low; this conclusion was based on an assessment of the radionuclide inventories present at the various facilities, the likelihood of contaminant release, and the probability that releases from the alternate sources will come into contact with releases from Area G. Therefore, the composite analysis includes the Area G inventory; the alternative source evaluation is a qualitative evaluation of the alternative sources.

All the MDAs, except MDAs AB, C, H, and T, were excluded early in the alternate source evaluation on the basis of the relative activities disposed of at these facilities and at Area G. Specifically, the radionuclide inventories for each of the excluded MDAs were small fractions of the corresponding inventories at Area G, making it unlikely that releases from the alternate sources could significantly increase the exposures estimated for releases from Area G. MDAs AB, C, H, and T all had inventories of at least one radionuclide that were greater than the corresponding Area G inventory; however, the alternate source evaluation concluded that there was little likelihood of significant interaction between releases from these facilities and releases from Area G. Recently published information for all but one of the MDAs included in the alternate source evaluation was reviewed to determine if the conclusions of the evaluation remain valid; these reviews are summarized in Sections 3.2.1 through 3.2.6. No further consideration was given to MDA J because this facility never received radioactive waste.

Previous sampling data for Cañada del Buey and Pajarito Canyon suggest that Area G is the primary source of contamination in the canyon locations accessed by the receptors in the PA/CA. Contamination detected in canyon sediments is thought to be related to residual contamination rather than to releases from Area G pits and shafts. Transport rates for surface contamination into the canyons will decrease as the facility undergoes closure and the final cover is applied; releases to the canyons after final closure is complete will come primarily from the disposal units. Based on this information, Revision 4 of the composite analysis concluded that no significant interactions between releases from Area G and other Laboratory facilities are likely to occur within the two canyons. Environmental surveillance data collected from Cañada del Buey and Pajarito Canyon in 2014 and other sources of information have been reviewed to determine if this conclusion remains valid.

The alternate source evaluation discussed the possibility of interactions between releases from Area G and contamination that has been discharged to other canyons at the Laboratory; it was noted that Pueblo, Los Alamos, and Mortandad Canyons have received contaminant discharges as a result of activities at the Laboratory. The evaluation concluded that existing contamination beneath Mortandad Canyon, located north of Cañada del Buey and TA-54, could, under some well-pumping scenarios, interact with releases from Area G. However, the fact that water-supply pumping has had little effect on water levels to date indicates that the likelihood of such interaction is low. Contaminants that reach the aquifer tend to follow the water table gradient; this gradient is eastward or southeast beneath Mortandad Canyon and is to the southeast at Area G.

Regular groundwater monitoring of perched-intermediate groundwater (where present) and the regional aquifer is conducted at each of the alternate sources according to sampling defined in the Laboratory's Interim Facility-Wide Groundwater Monitoring Plan for a given monitoring year (e.g., LANL, 2015b). Groundwater samples are collected annually or more frequently, and concentrations of radionuclides and other chemicals are measured and reported. Groundwater quality data collected at these sites and at background (i.e., not impacted by Laboratory operations) locations, including at the City of Santa Fe's Buckman well field and within the Pueblo de San Ildefonso, indicate the widespread presence of naturally occurring uranium (LANL, 2016a). Gross-alpha and gross-beta values sampled in groundwater are also consistent with the presence of uranium. Therefore, the presence of these constituents in groundwater at concentrations within background ranges does not indicate contamination has migrated from the sites to groundwater.

In the subsections that follow and in Section 4.1.2, groundwater concentrations for radionuclides for samples collected during 2014, 2015, and 2016 are compared with groundwater background values consistent with the most recent groundwater background levels developed for the Laboratory (LANL, 2016b). Groundwater sample results were also compared to the Laboratory's screening levels for these same time periods. The screening levels used for individual radionuclides are the 4-mrem Drinking Water Derived Concentration Technical Standards provided in DOE Order 458.1. No samples related to these alternative sources or to MDA G exceed the screening levels. Table 3-6 provides information about the radionuclides included in the groundwater analyses.

Table 3-6

Analytes, Field Preparation, and Analytical Methods Used by Contract Laboratories for Samples Collected under the Interim Facility-Wide Groundwater Monitoring Plan

Analytes	Field Prep	Analytical Method
Gross alpha, gross beta	Unfiltered	EPA:900
Cesium-137, cobalt-60, gross gamma, neptunium-237, potassium-40, sodium-22	Unfiltered	EPA:901.1
Strontium-90	Unfiltered	EPA:905.0
Americium-241	Unfiltered	HASL-300:AM-241
Plutonium-238, plutonium-239/240	Unfiltered	HASL-300:ISOPU
Uranium-234, uranium-235/236, uranium-238	Unfiltered	HASL-300:ISOU
Tritium	Unfiltered	EPA:906.0
Tritium	Unfiltered	Generic:Low_Level_Tritium

3.2.1 *MDA A*

The sources of contamination at MDA A include two buried 190-m^3 (50,000-gal.) steel tanks that were used to store waste solutions from plutonium processing. The liquid contents of the tanks were recovered, treated, and disposed of between 1975 and 1983; radioactive sludge remains in the bottoms of the tanks (1.2 to 2.4 m^3 [330 to 640 gal.] in the east tank and 7 m^3 [1850 gal.] in the west tank) (Roback et al., 2011). Other sources of contamination are three pits that received solid waste and debris. The radionuclide inventories estimated for the facility are small fractions of the corresponding Area G inventories. On this basis, no significant interaction between releases from MDA A and Area G was expected.

Previously, plans were made calling for the removal of all waste from the pits and tanks at MDA A and the subsequent removal of the tanks; the Laboratory submitted an investigation/remediation work plan to the New Mexico Environment Department (NMED) in support of that action (LANL, 2009b). Subsequently, the Laboratory requested that the work plan be withdrawn; the intent was to submit a supplemental work plan to address data gaps that, once addressed, will support the evaluation of multiple remedies in a corrective measures evaluation (LANL, 2012a). Current plans call for submitting a corrective measures evaluation after completion of additional site investigations. Investigation reports will be reviewed for their relevance to the alternate source evaluation in future annual reports.

3.2.2 *MDA AB*

The alternate source evaluation considered the likelihood that the large inventories of Pu-239 and Pu-240 left behind from belowground hydronuclear experiments at MDA AB would interact with releases from Area G. Because of the depth of the contamination, the release rates of these isotopes to the surface from biotic intrusion are expected to be low relative to those at Area G. Any releases of plutonium to the regional aquifer will likely occur long after the 1,000-year compliance period, and contaminant plumes from MDA AB and Area G are not expected to intersect. For these reasons, the Revision 4 alternate source evaluation concluded that no significant interaction between releases from MDA AB and Area G is likely.

The documented safety analysis (DSA) for nuclear environmental sites at the Laboratory was used to estimate radionuclide inventories for MDA AB under the alternate source evaluation. Although this report is revised periodically, no changes to the facility's inventory have occurred since the composite analysis was conducted (LANL, 2015c). Groundwater monitoring conducted in the MDA AB monitoring group between 2014 and 2016 under the Interim Facility-wide Monitoring Plan revealed detections of gross beta and isotopes of uranium consistent with background levels (e.g., LANL, 2016c). These results do not contradict the conclusions reached in the alternate source evaluation.

3.2.3 *MDA B*

Material Disposal Area B was eliminated from the alternate source evaluation because the radionuclide inventories estimated for the facility are small compared with those at MDA G. Since that evaluation, complete removal of the waste disposed of at the facility was performed between June 2010 and September 2011. Material was excavated until the contaminant concentrations in the native tuff encountered below the waste were less than residential soil screening levels. A total of 36,200 m^3 (47,350 yd^3) of LLW was shipped from MDA B (LANL, 2013a). Most of the waste was shipped off-site, but some was disposed of in Pits 37 and 38 at Area G. The inventory in that waste is now included in the Area G inventory model (see Section 6.1). Because the MDA B cleanup effort removed the entire inventory, no releases from the area will interact with releases from Area G.

3.2.4 *MDA C*

Material Disposal Area C was the primary radioactive waste disposal facility at the Laboratory before Area G came into use. Airborne releases from MDA C will yield small contaminant concentrations relative to those from Area G, and releases from leaching are expected to discharge to the regional aquifer after the 1,000-year compliance period. These findings led to the conclusion in Revision 4 that releases from Area G and MDA C will not interact in a significant manner.

A corrective measures evaluation was issued in 2012 (LANL, 2012b), the objective of which is to recommend a corrective measures alternative that will provide long-term protection of human health and the environment. The report recommends placement of an evapotranspiration cover over the site to minimize water infiltration and exposures to the waste, soil-vapor extraction to limit the movement of volatile organic compounds toward groundwater, and institutional control and monitoring of the site for a period of 100 years following placement of the cover. Information provided in the report does not contradict the conclusions reached in the 2008 alternate source analysis. Periodic monitoring of the groundwater conducted from 2014 through 2016 (e.g., LANL, 2016d) detected low levels of gross beta, U-234 and U-238 consistent with background levels. There was also a single detection of low-level tritium (one of six samples at well R-46) at 13 pCi/L. These results are consistent with the conclusions reached in the alternate source evaluation.

3.2.5 MDAs H and L

Material Disposal Areas H and L are located on the same mesa as Area G. The alternate source evaluation assessed the likelihood that potentially high inventories of uranium at MDA H could interact with releases from Area G. It was concluded that any such interaction was unlikely because radionuclide release rates to the surface are expected to be low and because contamination leached from the waste is unlikely to reach the regional aquifer within the 1,000-year compliance period.

Intermediate and regional groundwater monitoring was conducted at several locations in the vicinity of MDA H in FY 2016, including regional wells R-37, R-40, R-51, and R-52 (Figure 4-1), all of which are located in the immediate vicinity of the disposal facility. Low levels of gross beta, U-234 and U-238 consistent with background levels were detected during groundwater monitoring sampling events conducted from 2014 through 2016 (e.g., LANL, 2016e; LANL, 2016f). Finally, low-level tritium (up to 20.9 pCi/L) was detected at R-37 during 2 of 13 sampling events. These results are consistent with the conclusions reached in the alternate source evaluation.

The alternate source evaluation removed MDA L from consideration on the basis that no radioactive contaminants are included in the disposal records for the facility. Monitoring was conducted at several regional wells close to MDA L between 2014 and 2016, including wells R-20 screen 2, R-21, R-38, R-53, R-54, and R-56 (Figure 4-1) (e.g., LANL, 2016e; LANL, 2016f). Low levels of gross alpha, gross beta, U-234, and U-235 were observed at concentrations consistent with background levels. Four total low-level detections (4 of 31 samples) of tritium at concentrations less than 8 pCi/L have been detected during this time period at wells R-20 screen 2, R-38, or R-54/R-54r near MDA L.

3.2.6 *MDA T*

The estimated inventory of Am-241 placed in the shafts at MDA T exceeds the Area G projection for this radionuclide. As a result, MDA T underwent further scrutiny in the alternate source evaluation. The evaluation concluded that radionuclide release rates from the shafts because of biotic intrusion may be similar to those projected for Area G and that contamination deposited on the surface of the facility by plants and animals may be transported by prevailing winds to critical exposure locations downwind of Area G. However, for a given release rate, airborne concentrations of radionuclides originating at MDA T will be less than 1 percent of those originating at Area G. As a result, any increases in the air pathway exposures projected for Area G, which are low to begin with, will be insignificant. The alternate source evaluation also concluded that radionuclides leached from the shaft waste are not likely to reach the regional aquifer during the 1,000-year compliance period that applies to the composite analysis.

Groundwater monitoring locations at TA-21 include regional wells R-6, R-64, and R-66. Well R-64 is adjacent to MDA T, and the other two are located downgradient of MDA T (LANL, 2016g); samples are drawn from deep and intermediate depths within the TA-21 monitoring group. Sampling conducted from 2014 through 2016 revealed low levels of gross-beta radiation, U-234 and U-238 in all three regional wells that are within background levels, with the exception of a detection of U-234 at well R-64 that was slightly above background values in 2014; this was not repeated in later sampling. Uranium-235 concentrations are generally below detection limits in regional groundwater at the Laboratory; it was detected one time out of six analyses at well R-6 during the most recent sampling round (4^{th} quarter of monitoring year 2016). FY 2017 sampling will determine if detection of U-235 is repeated. Perched-intermediate wells downstream of MDA T do indicate elevated levels of radionuclides, but those are attributed to the Solid Waste Management Unit 21-011(k), which was an effluent outfall from industrial and radioactive waste treatment plants at TA-21. The Laboratory DSA for nuclear environmental sites was used to estimate radionuclide inventories for MDA T under the alternate source evaluation; no changes to these inventories were made in the latest revision (LANL, 2015c) of this analysis. Overall, then, the conclusions reached about the likelihood of source interaction between MDA T and Area G remain unchanged.

Additional site investigations are proposed that include the installation of a vadose-zone moisture monitoring network (LANL, 2011b). A future submittal of a corrective measures evaluation for MDA T is planned, following completion of site investigations. Investigation reports will be reviewed for their relevance to the alternate source evaluation in future annual reports.

3.2.7 *Cañada del Buey and Pajarito Canyon*

As discussed earlier, it was considered unlikely that discharges from Area G to Cañada del Buey and Pajarito Canyon will interact with canyon discharges from other facilities at the Laboratory. This conclusion is based on the fact that surface contamination at Area G appears to be the primary source of the radionuclides detected in the canyons and that this source of contamination will diminish as the facility undergoes closure and a final cover is applied.

Surface and storm water and sediments are sampled in the Laboratory's major watersheds; the results of recent monitoring efforts are summarized in the Laboratory's 2015 Annual Site Environmental Report (LANL, 2016a). Surface water sampling locations near Area G include one gaging station each in Pajarito Canyon and Cañada del Buey at the east end of the disposal site and five storm water locations within or adjacent to Area G. Sediments were sampled at several locations along small drainages within the disposal site and in Pajarito Canyon and Cañada del Buey.

For storm water, U-234 and U-238 concentrations were elevated above background values throughout Pajarito Canyon from 2011 to 2015. Elevated concentrations were most likely associated with Las Conchas fire burn areas and with historical Laboratory firing sites (LANL, 2016a). Similarly Pu-238 and Pu-239/240 concentrations were elevated in upper Pajarito Canyon from 2011 through 2013 related to fire effects. Storm water samples were not analyzed for Am-241, Cs-137 or Sr-90 in 2015 because fire effects diminished in 2014 and associated activities returned to near pre-fire levels. Storm water concentrations in the most recent samples have decreased to within background levels, particularly in lower Pajarito Canyon near Area G.

In terms of sediments, Pu-239/240 and Am-241 were detected in sediment samples collected near Area G in Pajarito Canyon and in Cañada del Buey at activities above the regional background value (LANL, 2016a). This is consistent with data from previous years for radionuclide concentrations in sediments collected near Area G, which support the contention that the operational disposal facility is a source of radionuclide contamination in the adjacent canyons. Concentrations of U-234 and U-238 in sediments near Area G are within or near background values.

4.0 Monitoring Data Summary and Evaluation

Monitoring at Area G includes a variety of routine Laboratory-wide environmental surveillance activities and a smaller set of site-specific monitoring activities associated with site closure efforts. These activities are discussed below with respect to their relevance to the Area G PA/CA (LANL, 2008).

4.1 Environmental Surveillance

Environmental surveillance activities typically include the monitoring of air and meteorological conditions, direct radiation, storm water and sediments, soils, biota, and vegetation. Surveillance data collected through these efforts are summarized annually in the Laboratory's annual site environmental reports. The surveillance information discussed in this annual report was taken from the Laboratory's Annual Site Environmental Report for 2015 (LANL, 2016a), which contains the most recent published surveillance information.

The environmental surveillance data collected at or near Area G support ongoing waste disposal operations and show that measured releases from the site are below thresholds of concern. The surveillance activities focus primarily on radionuclide concentrations in environmental media, the sources of which are typically waste storage and disposal operations; most of these sources will not exist after the facility has undergone final closure. Surveillance activities that are, or may be, pertinent to both ongoing disposal activities and the PA/CA are summarized in the following sections.

4.1.1 Air Surveillance

The air-quality surveillance effort at the Laboratory monitors ambient air concentrations of contaminants generated and released at the Laboratory and characterizes the meteorological conditions at the facility. Results of the 2015 activities that are relevant to the Area G PA/CA are discussed below.

4.1.1.1 Ambient Air Sampling

The Laboratory's radiological air-sampling network measures activities of airborne radionuclides, such as plutonium, americium, uranium, and tritium. Emissions of airborne radionuclides are regulated under the Radionuclide National Emission Standards for Hazardous Air Pollutants (NESHAP), which sets a dose limit of 10 mrem/yr to any member of the public from air emissions. During 2015, the Laboratory operated 40 environmental air-monitoring stations (AIRNET stations, Figure 4-1) to sample radionuclides by collecting particulate matter, and a subset of these stations collected water vapor based on known associations of tritium (LANL, 2016a). Thirty-one of the AIRNET stations are "Environmental Compliance Stations," used to estimate off-site doses to the public as part of the Laboratory's reporting requirements under the Rad-NESHAP section of 40 Code of Federal Regulations (CFR) 61 (Table 9 of Fuehne, 2016). Environmental compliance stations are U.S. Environmental Protection Agency–approved locations meant to capture yearly effective dose equivalent (EDE) in mrem/yr. The concentrations of radioactive constituents found in the collected samples are used to estimate exposures received by a maximally exposed individual (Fuehne, 2016). During 2015, locations of six stations were adjusted to improve coverage of potential sources and receptors. Of most relevance to MDA G, White Rock station 121 was removed because stations 119, 167, 213, and 392 provide better coverage (Figure 4-1).

In addition to the compliance stations, the Laboratory operates AIRNET stations around the Laboratory at locations of both known point sources and diffusive sources of airborne radionuclides. The Area G sampling network includes eight of these samplers. However, data from these additional stations is not considered relevant for comparison to the MDA G PA/CA off-site receptor.

The majority of the radionuclides sampled by the AIRNET network at Area G enter the atmosphere following particulate resuspension. This contamination is generally the result of unplanned releases that occur during disposal operations. The atmospheric surveillance activities also target releases of vapor-phase tritium, most of which comes from the large quantities of tritium waste that have been disposed of in the shafts at Area G. The comparison of these measured releases and those projected by the PA/CA can provide some insight into the general validity of the modeling. However, because the PA/CA model does not include the same receptor locations as the AIRNET sampling, this comparison can only be done in a qualitative manner.

The PA/CA models project airborne tritium (as tritiated water) concentrations along the Laboratory boundary east of Area G, while the closest AIRNET network sampling location is in the town of White Rock, which lies within 500 ft of the Laboratory boundary. The diffusion of tritiated water vapor from the high-activity tritium waste disposed of at Area G was projected by the most recent composite analysis (February 2015) to yield a peak mean exposure of 0.25 mrem/yr along the Laboratory boundary east of Area G. This dose is projected to occur in the year 2017; the mean exposure projected for 2014 is about 0.24 mrem/yr. Results from the 2015 AIRNET sampling show the maximum average dose from tritium for a person living in White Rock (AIRNET station 213, Figure 4 -1) was approximately 0.02 mrem (Fuehne, 2016). Doses at the other White Rock stations 119, 167, and 392 were all lower than station 213 at approximately 0.01 mrem/yr. Based on these results, it appears the PA/CA model projections of tritium exposure are higher than measured values at approximately the same location. Finally, we note that although other sources of tritium other than Area G exist at the Laboratory, the exposures from tritium releases at Area G are expected to dominate the exposures estimated for White Rock because of the large quantities of tritium placed in the shafts and because the town is only 2 km (1.2 mi) away. Data from past on-site air monitoring at Area G support this interpretation, indicating the highest on-site mean atmospheric concentrations of tritium (as tritiated water) have occurred at TA-54 near shafts used for the disposal of high-activity tritium waste.

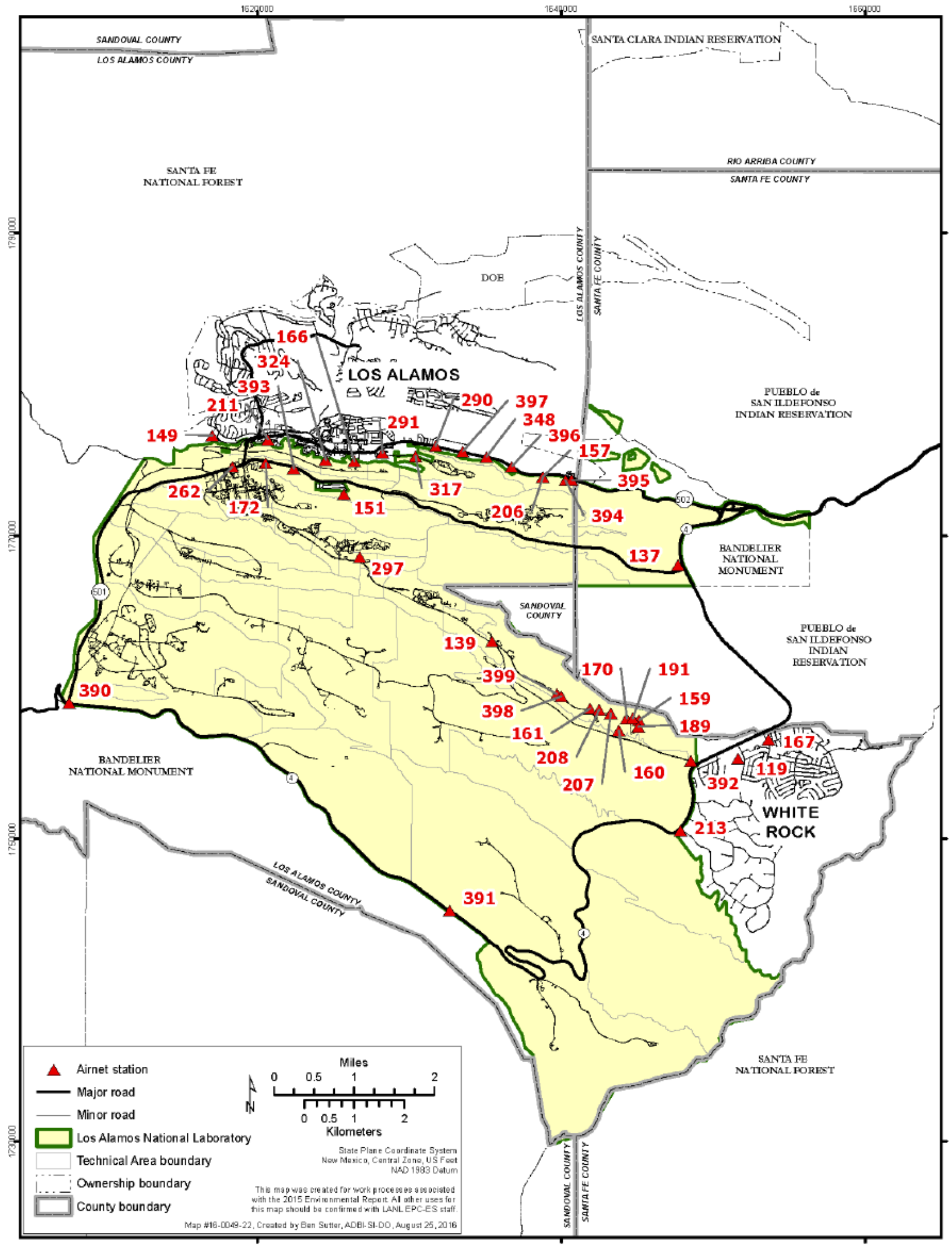

Figure 4-1
Environmental air-monitoring stations at and near the Laboratory

4.1.1.2 *Meteorological Monitoring*

A network of six towers is used to collect meteorological information within the Laboratory boundaries; one of the towers is located at TA-54 along the eastern edge of Mesita del Buey. The information collected at the towers includes wind speed and frequency, temperature, pressure, relative humidity and dew point, precipitation, and solar and terrestrial radiation. Precipitation is also measured at three non-tower locations.

Information collected from the meteorological towers supports many Laboratory activities, including the Area G PA/CA. The atmospheric transport modeling conducted with CALPUFF modeling software (Jacobson, 2005) used wind speed and frequency data from 1992 to 2001 to estimate average meteorological conditions in the vicinity of the disposal site, and long-term averages of precipitation data were used in the infiltration modeling that was conducted using the Hydrus-2D (Šimùnek and van Genuchten, 1999) computer code (Levitt, 2008 and 2011; LANL, 2013b; Stauffer et al., 2016). Given that these evaluations used average conditions, the addition of a year's worth of meteorological data will generally have a limited impact on the results of the PA/CA. Beginning in 2012 and continuing through 2016, analyses of the impacts of increased moisture introduced to pits while they were uncovered are being conducted using daily precipitation records. In this case, the impacts of the transient precipitation on water flow through the pits are being evaluated, including extreme events. For example, 13.2 in. of precipitation fell on Area G in the summer of 2013, at which time Pit 38 was not fully covered. An update of this work is included in Section 5.1 and will be documented as part of ongoing R&D activities for the groundwater pathway. This work is being implemented to address the secondary issues identified by the LFRG (DOE, 2009). Results of this R&D will determine if increased moisture collected while pits were open needs to be included in future updates of the PA/CA model.

4.1.2 *Groundwater Monitoring*

The NMED required that the Laboratory establish a groundwater monitoring network at TA-54 that provides an understanding of the nature and extent of groundwater contamination, supports RCRA monitoring requirements, and protects against off-site migration of contaminants and subsequent contamination of water supply wells. In compliance with this requirement, the Laboratory evaluated regional characterization wells drilled under the *Hydrogeologic Workplan, Los Alamos National Laboratory* (LANL, 1998) to determine if they were suitable for use in a final monitoring network. Subsequent assessments were undertaken to determine where to locate additional monitoring wells (LANL, 2007), and 13 additional regional wells were installed for monitoring at TA-54 between 2008 and 2011.

The Laboratory's groundwater monitoring plan is revised annually and submitted to NMED for approval. Monitoring is organized in terms of six monitoring groups, one of which is the TA-54 monitoring group under the Interim Facility-wide Groundwater Monitoring Plan. General surveillance activities are defined for surface water and groundwater in seven watersheds or watershed groupings; two of these, the Mortandad and Pajarito Canyon watersheds, include areas adjacent to Area G. The configuration of the TA-54 monitoring well network in FY 2016 is shown in Figure 4-2 (LANL, 2015b). In the vicinity of Area G, the network includes screens at R-23i and R-55i that sample perched-intermediate groundwater and deep regional wells R-21, R-23, R-32, R-39, R-41, R-49, R-55, R-56, and R-57. The deep wells have one or two screens for sampling the regional aquifer. Two wells that sample shallow alluvial groundwater are located slightly upgradient of and adjacent to Area G in Pajarito Canyon; alluvial wells close to Area G in Cañada del Buey are generally dry. Sampling results for the groundwater monitoring effort are published in periodic monitoring reports and the Laboratory's annual environmental report (e.g., LANL, 2016a).

Water from the regional aquifer discharges to the Rio Grande via several springs located in White Rock Canyon, several of which are located downgradient of Area G. As such, the possibility exists that contaminant releases from the disposal facility could affect these waters. Routine monitoring of these springs is conducted as part of the general groundwater surveillance efforts.

From 2014 to 2016, U-234, and U-238 were detected at all regional wells that monitor Area G at concentrations that are consistent with background levels. Other analytes that were detected at concentrations within background levels are gross-beta radiation at many of the regional wells, gross-alpha radiation at two of the regional aquifer wells, and K-40 at one of the regional wells (e.g., LANL, 2016e; 2016f). During this period, tritium is consistently detected at concentrations less than 23 pCi/L at intermediate screens 2 and 3 in well R-23i, and once (1 of 11 sampling events) at 2.49 pCi/L (very near the detection limit) at R-39. The measured tritium concentrations at R-23i fall within the range of tritium levels in rainfall (2 pCi/L to 50 pCi/L) and may indicate infiltration along Pajarito Canyon into fractured basalt near this borehole (LANL, 2009c). Sr-90 was detected in wells R-23i and R-23 in 2015 at levels above background but later sampling during 2015 and two rounds in 2016 did not repeat the exceedance of background. All other radionuclides were present at concentrations less than half of the Laboratory's screening levels

Watershed surveillance is conducted in conjunction with the groundwater monitoring effort and includes sampling of alluvial and surface waters. Results of the sampling are published in periodic monitoring reports and are also presented in the Laboratory's environmental reports. Monitoring well 18-MW-18 monitors shallow alluvial water upstream of Area G. Data from this well for samples collected from 2014 to 2016 have detections of gross alpha, gross beta, U-234, and U-238 that are all within background. No samples were available from other nearby shallow wells in Pajarito Canyon, PCAO-8, and in Canada del Buey, CDBO-6, because those wells were dry (LANL, 2016h).

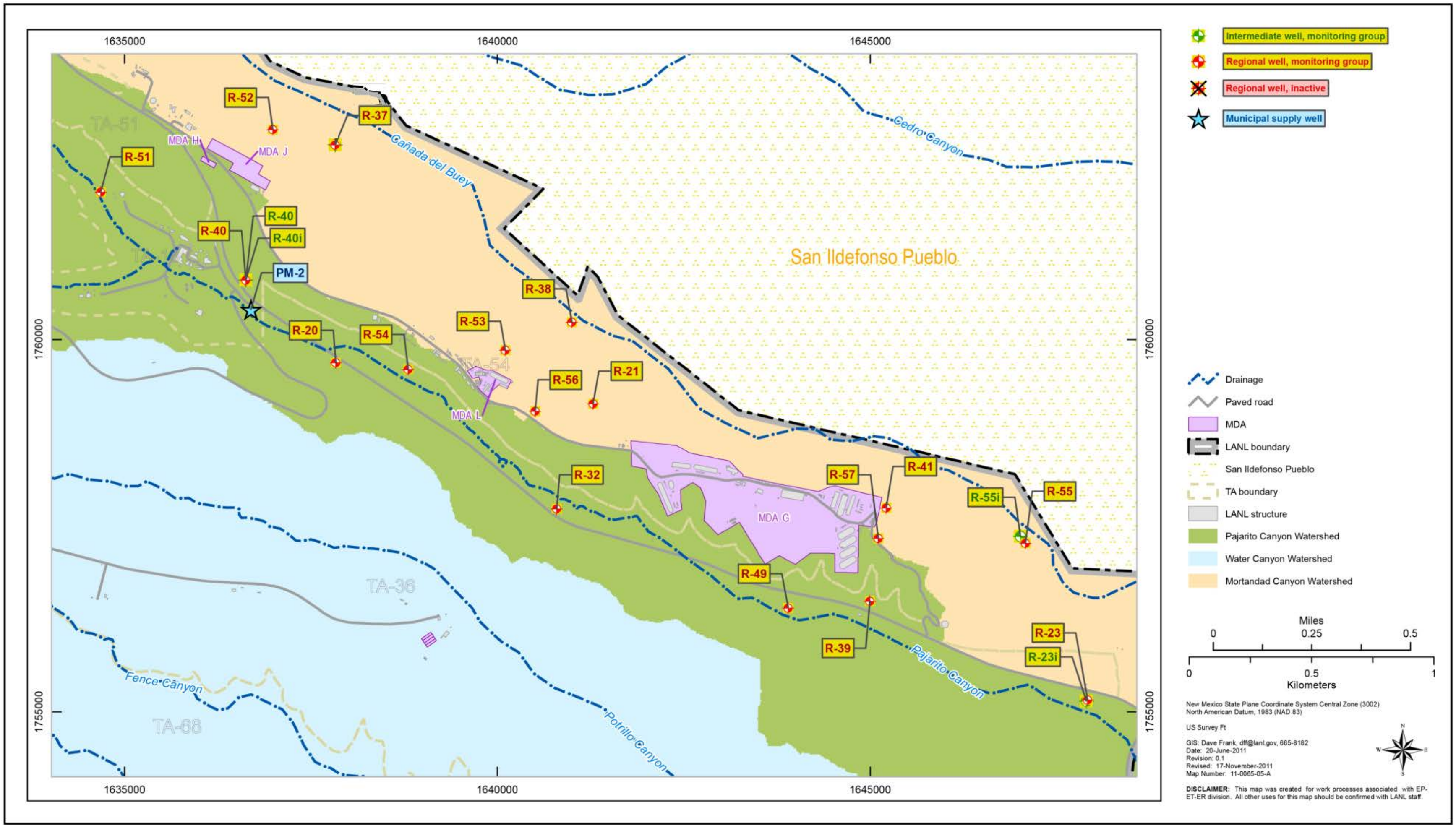

Figure 4-2
TA-54 Monitoring Network

4.2 Moisture Monitoring

Periodic monitoring is conducted at Area G to determine volumetric moisture contents adjacent to, and within, disposal units at the facility. These monitoring efforts include the collection of (1) water potentials in the floor of Pit 38 using heat dissipation probes (HDPs), (2) water contents in the interim cover of Pit 31 using time-domain reflectometry probes (TDRs), and (3) water contents collected from neutron access tubes. Moisture data were collected from the HDPs and TDRs in 2016. These field data are used for groundwater model calibration.

A report summarizing all available moisture monitoring data for Area G was completed during 2015 (Levitt et al., 2015) and updated to include new data collected during 2016 (Levitt et al., 2017). The newer report (Levitt et al., 2017) includes and analyzes the HDP data from the Pit 38 extension and the TDR data from Pit 31 downloaded in 2016. Both versions of the report include neutron probe data measured in Pits 37 and 38 in 2013. In addition to summarizing all available moisture monitoring data in the report, all the monitoring data, including the historical data sets that originated from a variety of sources, were compiled into a database. As part of this activity, a thorough investigation into the source and pedigree of neutron probe calibration equations used in previous reports was performed; these calibration equations are used to convert neutron counts into moisture content data. Investigations included analysis of original data files with measured water contents from core samples and initial neutron logs. As a result of this research, (1) both errors in calibration equations and lack of pedigree for calibration equations for the older data sets were found, (2) calibration equations were recalculated based on the original data files mentioned above, and (3) the historical moisture content data sets were reevaluated. This analysis allows for more consistent comparisons of historical neutron probe data sets to those collected in the future.

The following paragraphs summarize the results of more recent moisture monitoring activities conducted in Pits 38 and 31 at Area G.

Three boreholes were drilled into the floor of the newly excavated Pit 38 extension in 2012. Each hole was instrumented with 8 HDPs at depths ranging from 0.34 to 3.1 m (1.1 to 10.1 ft) below the pit floor. Through mid-2013, moisture contents fluctuated as the probes equilibrated with ambient conditions and in response to rainfall and snowfall events and subsequent drying.

Especially heavy rains fell at Area G in September 2013. The TA-54 meteorology station recorded 336 mm (13.2 in.) of rain between June 28, 2013, and September 19, 2013. Of this total, 180 mm (7.1 in.) fell from September 1 to September 19, including 170 mm (6.7 in.) from September 10 to September 15. At the time, the Pit 38 extension had been excavated but the disposal of waste had not begun. Sensors closest to the floor of the pit measured infiltration from the major storm within days of its occurrence while it took more than a year for the deeper sensors to detect the wetting front. Wetting also occurred at the locations of the shallow sensors immediately following the start of disposal in July 2014; the increased moisture may have been caused by the application of dust suppression water to the active waste surface. As of February 2015, a matric potential of −1 bar was observed for all of the HDPs, which corresponds to a volumetric water content of about 10 percent, or approximately 30 percent saturation. Between February 2015 and December 2016, matric potential has slowly dropped, and matric potentials in December 2016 ranged between about −1 bar and −4 bars. This corresponds to volumetric moisture contents of 5 to 10 percent, or saturations of 15 to 30 percent. The partially filled pit is still quite deep and therefore shaded, and no vegetation is present. Therefore, drying is slower than in the vegetated Pit 31 cover. It is likely that the dropping matric potentials in the bottom of the Pit 38 extension, beneath waste that was emplaced in July 2014, are more related to redistribution of water than to evaporation.

The TDRs are used to measure water contents at six depths in the interim cover of Pit 31; data are collected at depths ranging from 0.76 to 2.3 m (2.5 to 7.5 ft) below grade using two probes at each depth. Data from late 2008 to December 2016 are summarized in Levitt et al. (2017). After a period of drying from mid-2010 to mid-2013, sharp increases in volumetric water contents occurred at all depths in response to the September 2013 rains discussed earlier. At the depths of the probes, the cover has steadily dried out following those storms through late 2016. The drying is thought to result from moisture removal through evapotranspiration although some moisture redistribution to depth may also be occurring. As of December 2016, volumetric water contents in the Pit 31 cover range from about 9 to 15 percent or about 27 to 45 percent saturation. As vegetation has become better established on the Pit 31 cover, the cover has continued to dry and mitigate net infiltration into the waste zone.

5.0 Summary of Research and Development Efforts

Research and development activities are planned and implemented to address the secondary issues identified by the LFRG (DOE, 2009) and, more generally, to reduce the uncertainty associated with the PA/CA. Fiscal year 2016 activities included ongoing work on groundwater modeling, surface erosion modeling, and characterization of cliff retreat.

5.1 Groundwater Modeling

The effort to understand the impacts of transient flow on infiltration rates through the disposal units at Area G and contaminant travel times to the regional aquifer continued in FY 2016. Tasks included infiltration modeling using the Hydrus-2D (Šimùnek and van Genuchten, 1999) computer code for Pits 37, 38, 31, and 25 with some validation of the models by comparing to site moisture monitoring data (Section 4.2), compilation of precipitation data needed to characterize past water inputs into the disposal units, reexamination of the hydrological properties of waste, refinement of the time line for waste disposal and cover emplacement in Pit 38, compilation of the time line for waste disposal in Pit 31, and recalculation of conservative breakthrough curves for Pits 37 and 38 using the latest version of the Finite Element Heat and Mass (FEHM) model. These changes, combined with modifications to waste package properties, lead to increased moisture migration beneath the pits.

The latest simulation results for Pits 37 and 38 are an update to those presented in SA 2012-007, which considered the impact of water introduced to the pits with disposal of large volumes of bulk waste excavated from MDA B (LANL, 2013b). The main differences are that the simulations used a longer precipitation record that includes a very large storm in September 2013, Pit 38 remained open for several years longer, and the hydrologic properties of the fill in Pit 38 were modified to account for potentially rapid flow around waste packages, which are largely metal containers and plastic bags. The results are presented in a conference paper for Waste Management (WM) 2017 (Stauffer et al., 2016). The following paragraphs are the summary from the WM paper for the CA groundwater dose for this analysis. Carbon-14 was found to drive the groundwater dose in these simulations.

> Dose results from the Composite Analysis model are shown in Figure 5-1. The flat red line at zero dose represents results obtained using the previous groundwater pathway analysis that does not include the effects of increased water within the pits. Clearly, the inclusion of additional water in the pits leads to a significant change in the predicted dose for both the All Pathways and Groundwater Protection scenarios. Although the predicted relative dose increase is infinite, the absolute dose from C-14 remains well below regulatory limits (4 mrem/yr). After a sharp increase in the years following breakthrough (150-400 yrs), the rate of change of the dose predictions drops and begins to level out by 1000 yrs. The

Groundwater Protection scenario shows higher doses at a given time because this scenario assumes that the receptor obtains all their water from the compliance well, while the All Pathways scenario includes only a fraction of water usage from the compliance well.

Further analysis will be done as part of the continuing work on the MDA G PA/CA and will include prediction to longer times. We note that the estimated water pulse based on particles released in 2053 will over predict dose because the rate at which water (and C-14) move through the system are fixed at the 2053 rate for all time. A more realistic approach will be to include particle releases in the FEHM simulations that are tied to the release rate of the graphite rods. (Stauffer et al., 2016)

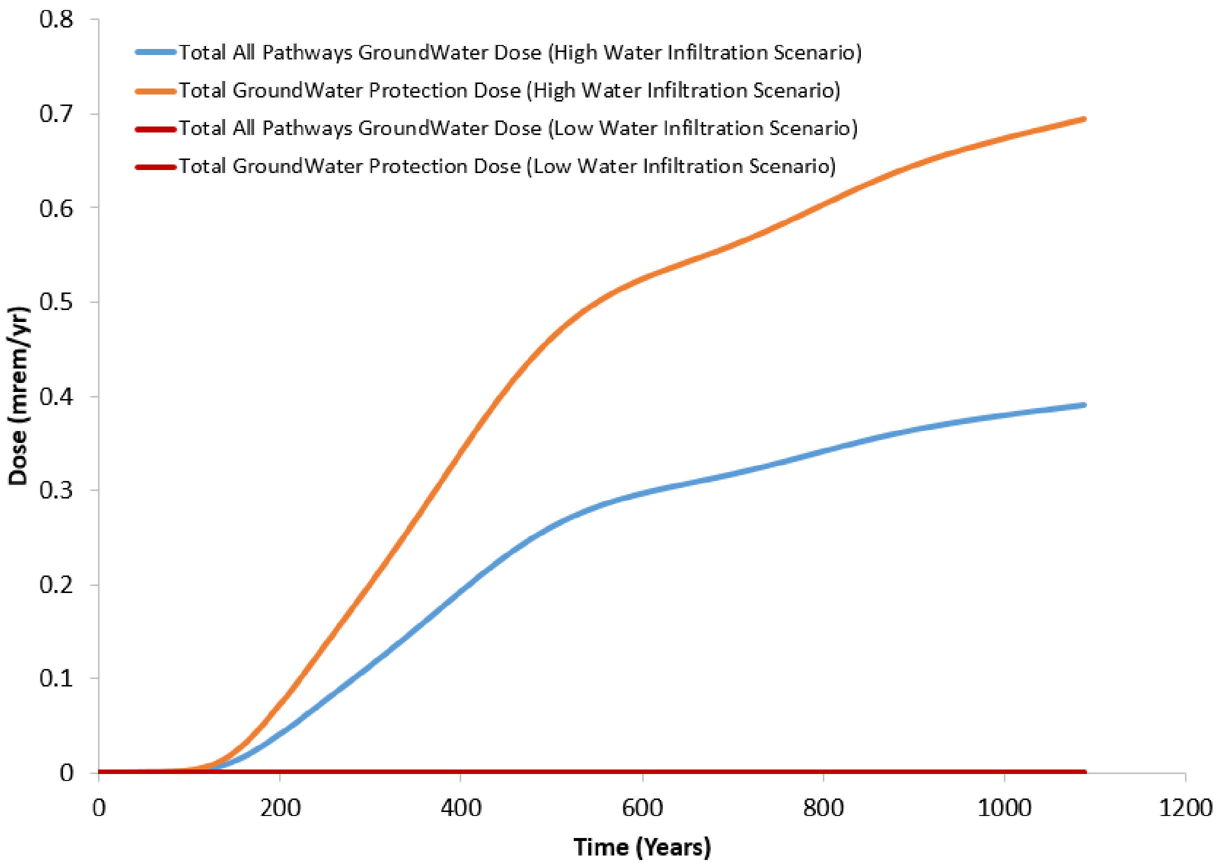

Figure 5-1
Groundwater dose projections over 1000 years for the CA with updated transient flow simulations for Pits 37 and 38

Hydrus-2D simulations for transient infiltration into Pit 31 have been completed. The simulations account for the time line of waste disposal and use detailed precipitation records. Simulated results compare well with measured moisture content data for several depths within the cover (see Section

4.2 of this report) over a time period from July 2008 through February 2015. Plans for FY 2017 include completion of Hydrus-2D models for Pits 15 and 39; simulation of conservative breakthrough using FEHM for Pits 31 and 25; and continued validation using moisture monitoring data. A final report on the impacts of transient flow in Pits 31, 37, and 38 will be completed during FY 2017.

5.2 Erosion Modeling

The Area G PA/CA projects the long-term performance of the disposal facility, incorporating the final cover placed over the closed disposal units. The SIBERIA landscape evolution model is used to evaluate the impacts of surface erosion on the cover, taking into account the complex terrain characteristic of the disposal site (Wilson et al., 2005; Crowell, 2010).

Fiscal year 2016 was a transition year: the erosion modeling task transitioned from a long-term contractor to Laboratory staff. The SIBERIA workflow was streamlined to more easily test parameter sensitivity and to identify specific methods to reduce model uncertainty. Furthermore, a visualization tool in conjunction with the sensitivity analysis was created to verify model performance specific to Area G.

The current workflow to implement SIBERIA is a complicated multistep process that requires several stand-alone numerical codes to estimate required parameters for SIBERIA. Three distinct workflow branches are necessary before a single SIBERIA model run can be used to estimate long-term erosion rates (Figure 5-2): (1) characteristic precipitation and SIBERIA parameter estimation, which requires a surrogate SIBERIA calibration; (2) integration of cap design into site topography; and (3) armor parameterization and bedrock elevation and parameterization.

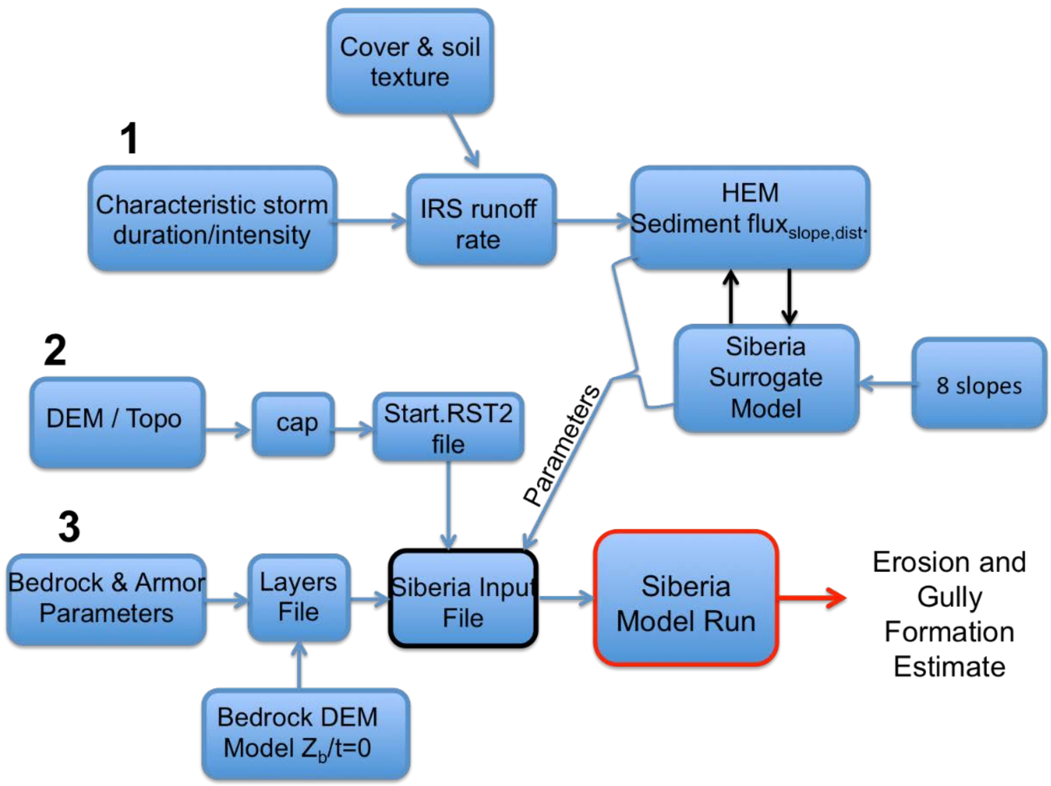

Figure 5-2
SIBERIA erosion model workflow

To (1) simplify the workflow and (2) identify large contributions to model uncertainty, the Laboratory-developed Model Analysis ToolKit (MATK) was wrapped around each branch of the SIBERIA workflow. MATK allows for massively parallel ensemble sensitivity studies of desired variables, which govern erosion and gully formation. The current approach allows for a global, full-factorial, sensitivity analysis and is capable of identifying how specific parameter combinations can cause nonlinear results. The effects of uncertain parameters on model results can be measured by sampling variable parameter space. Thus, what parameters and combinations of parameters contribute most to uncertain model results can be easily identified, guiding future research directions to reduce uncertainty. These improvements to the workflow improve software quality and will significantly improve model sensitivity analyses.

During FY 2017, updated SIBERIA simulations will be run under this updated workflow to determine the impacts of the revision the top-of-tuff surface, which was refined during FY 2015, and to study the impacts of extreme rainfall events.

5.3 Cliff Retreat

Work to characterize the mechanisms and rates of cliff retreat along the edges of Area G continued in FY 2016. Comparisons of photodocumentation from June 2012 and April 2014 revealed one location on the south side of Area G that experienced minimal cliff failure; all other locations remained unchanged. Information gathered from the April 2014 photo-documentation campaign was incorporated into an updated draft report titled *Cliff Retreat Characterization for Los Alamos National Laboratory Technical Area 54*. This Phase I report will be issued in early FY 2017.

Samples for cosmogenic dating analyses were collected in October 2015, and sample processing began mid–FY 2016. Cosmogenic dating can provide an estimate of the amount of time a particular surface has been exposed to bombardment by cosmic rays; this dating technique will provide insight into the long-term stability of the Area G cliffs and the length of time the cliffs have been in their current geometry. A total of 14 samples have been collected from the south side of Area G (Figure 5-3), with a minimum of 11 additional samples planned from the south and north sides of Area G as well as central and eastern TA-54 during a later campaign. Dr. Brent Goehring of Tulane University is conducting the cosmogenic dating experiments; to date, four sample results have been provided to the Laboratory. Table 5-1 details these results.

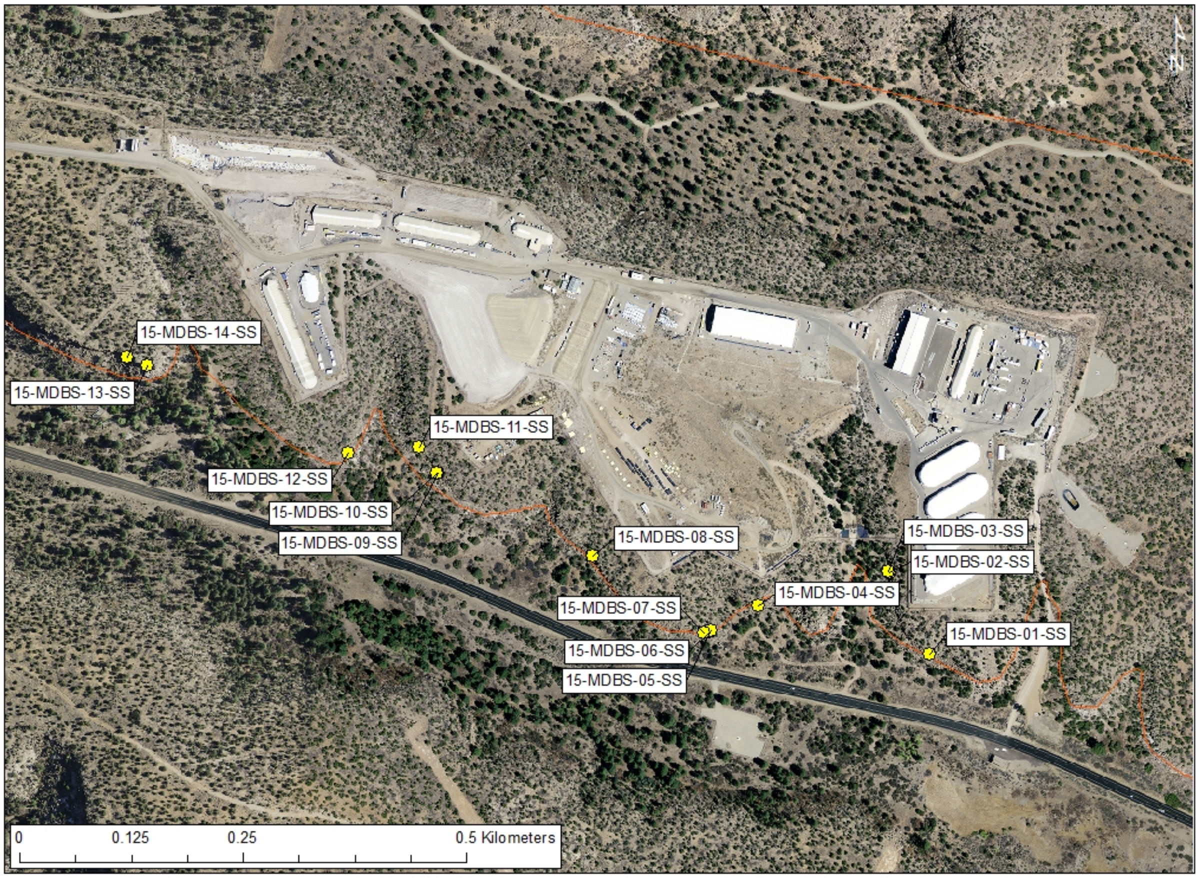

Figure 5-3
TA-54 cosmogenic sampling locations.
Yellow circles represent sample location;
red line is the TA-54 boundary

Table 5-1

FY 2016 Cosmogenic Dating Results

Sample ID	**Result**
15-MDBS-01-SS	3,503 ± 53 years
15-MDBS-02-SS	14,816 ± 455 years
15-MDBS-03-SS	14,598 ± 865 years
15-MDBS-04-SS	9,819 ± 441 years

Although initial cosmogenic dating results indicate that cliff failure and subsequent retreat may be occurring at a time scale of concern to the closure and long-term stability of MDA G, additional sampling results, when paired with average joint spacing measurements from the mesa top, will be instrumental in determining an average cliff failure distance and recurrence interval. Furthermore, age clustering of cosmogenic samples may provide insight into the correlation between seismic events and cliff failure events. Sample analysis will continue in FY 2017, and those results will be presented in a Phase II report on cliff retreat. Additional sample collection is currently planned for the spring of 2017. Statistical analyses of the sampling results will be used to determine the potential correlation between cliff stability and mesa geometry. Upon completion of those analyses, the Laboratory will determine how the cliff retreat information will feed back into the PA/CA with respect to erosion modeling and cover design.

6.0 Summary of Unreviewed Disposal Question Evaluations and Special Analyses

Two UDQEs were conducted during FY 2015 to evaluate (1) an update to the radionuclide inventory for MDA B waste disposals at Area G and (2) an upgrade to the GoldSim modeling platform. Significant progress was made on the two SAs related to these UDQEs. These analyses and the results of these efforts are summarized below.

6.1 Update to the Radionuclide Inventory for MDA B Waste Disposals

Radioactive waste excavated from the trenches at MDA B (see Section 3.2.3) has been disposed of in pits at Area G since 2012. Most recently, in 2014, the remaining 139 containers of this material were placed in Pit 38. To more accurately estimate radionuclide inventories in MDA B waste disposed at Area G, waste characterization data were reevaluated and used to establish radionuclide concentration distributions for all isotopes included in the waste. These concentration distributions were used to estimate radionuclide activities in the affected waste, including uncertainty. Unreviewed disposal question evaluation 1501 concluded that updating the radionuclide inventories in WCATS to be consistent with concentration distributions for 139 MDA B waste containers recently disposed at Area G was an unreviewed disposal question (UDQ). Special Analysis 2015-001 was completed during FY 2016 (French et al., 2016b). The SA recommended an update to the inventories listed in the WCATS database to be consistent with the concentration distributions described in the SA. The WCATS database was updated in accordance with this recommendation in November, 2016. A copy of SA 2015-001is included in Appendix A. A similar UDQE (1301) and SA 2013-001 were conducted in 2012 for 1,144 containers of MDA B waste that had undergone disposal.

The mean values of the radionuclide concentration distributions were used to calculate updated inventories for the 139 containers of waste and those values were incorporated into WCATS. The revised inventories for Am-241, Pu-238, and Pu-239 are modestly higher than those originally assigned to the waste packages. The revised inventories for the remainder of the radionuclides in the MDA B waste are 50 percent or less of those listed in the database because a less conservative approach was used to estimate the isotopes' inventories. The revisions to the MDA B waste inventories did not change the doses and radon fluxes projected for the Area G PA/CA because the reevaluated radionuclide concentration distributions presented in the SA were already incorporated into the PA/CA Inventory Model for these particular waste packages, which at the time of the model update were considered future waste predictions. That is, the inventory model included in the PA/CA already incorporates the reevaluated inventory for the 139 MDA B waste containers. The updating of WCATS, to be consistent with the reevaluated inventory and the inventory model already included in the most recent PA/CA update, was the final step needed to close this UDQE.

6.2 Upgrade of Area G PA/CA Model to Updated GoldSim Modeling Software and Transition to Laboratory Analysts

The accuracy of the PA/CA depends upon the validity of the models, data, and assumptions used to conduct the analyses. If changes in these models, data, and assumptions are significant, they may invalidate or call into question certain aspects of the analyses. The long-term performance of the Area G disposal facility is evaluated using models developed with the GoldSim modeling platform. Version 11 of GoldSim was issued in July 2013. Formerly, UDQE 1503 recommended that an SA be conducted to update the PA/CA modeling software from Goldsim version 10.11 to version 11.1.2. Since UDQE 1503 was issued, additional GoldSim software updates have occurred; for example, version 11.1.5 was issued in March 2016. In addition, in late 2015, Laboratory staff assumed the role as the primary PA/CA analysts from a long-term contractor that had been the PA/CA analyst for over two decades. Unreviewed disposal question evaluation 1603 was issued in FY 2016. It supersedes UDQE 1503 because it recommends that the initial PA/CA model update from GoldSim version 10.11 to version 11.1.2 be documented, and it also recommends additional documentation of upgrading the PA/CA Model to GoldSim version 11.1.5 and transitioning to the Laboratory analysts and computing environment. Special Analysis 2016-003 was conducted to document these steps (Chu et al., 2017). Copies of UDQE 1603 and SA 2016-003 are included in Appendix B.

The results of SA 2016-003 are that the sequential upgrades of the PA/CA Model to GoldSim versions 11.1.2 and to 11.1.5 were successful. In addition, the transfer of the model to the Laboratory analysts and computing environment were also successful.

Laboratory analysts upgraded the PA/CA Inventory, Site, Radon Flux, Intruder, and Intruder Diffusion Models to use the GoldSim version 11.1.5 modeling platform. Comparisons of modeled results to previous version indicated some differences in both the inventory models and all of the pathway models. These differences are primarily due to an upgrade implemented in version 11.1.5 of the Latin Hypercube Sampling (LHS) scheme for nonstationary stochastic parameters, as well as to other minor improvements made to GoldSim. Laboratory analysts were able to gain significant experience through this implementation exercise both in terms of running the GoldSim simulations and through analyzing the differences observed between the results with previous versions. Careful analysis was performed to ensure that the differences were associated with the GoldSim upgrade, especially the updated LHS scheme, and that the differences did not result from an error in upgrading the model. The inventory values presented in the FY 2014 DRR (French and Shuman, 2015b) are used for these simulations; these values represent the most up-to-date inventory included in the GoldSim work as of December 2016 when this special analysis was completed. Because simulation results differed from the previous GoldSim version and GoldSim version 11.1.5 was to be used for future work, the exposures and radon fluxes projected using the GoldSim version 11.1.5 are considered the most current and are those noted in Section 3 of this Annual Report update. The modeling results continue to indicate that the disposal facility satisfied all DOE Order 435.1 performance objectives.

6.3 Potential Underreporting of Am-241 Inventory for Nitrate Salt Waste

The estimated Area G inventory is a key input for projecting potential radiation doses for onsite and offsite exposure scenarios. Unreviewed disposal question evaluation 1601 identified a positive unreviewed disposal question related to the potential for systematic under-reporting of Am-241 disposed of at Area G originating from nitrate salt waste streams that went through a remediation process of liquid evaporation at TA-55 during the period from the late-1970s to the mid-1980s. The underreporting issue was discovered when reviewing nitrate salt TRU waste characterization. Laboratory personnel reviewed information for similar waste streams, both LLW and TRU waste, that have been disposed at Area G to determine if underreporting of Am-241 has occurred. Special analysis 2016-001 is being prepared to document the findings of this review. It will review relevant data from the WCATS database to determine the potential impact with respect to the Am-241 inventory for waste disposed of at Area G. A copy of UDQE 1601 is included in Appendix C. Special Analyses 2016-001 will be completed in FY 2017. Although the SA is not finalized, the review indicates that underreporting of Am-241 in the buried LLW at Area G is not an issue, and no correction is needed.

6.4 Pit 25 Cover Erosion and Presence of Unconventional Covers

Enhanced cover erosion and buried vertical-oriented pieces of corrugated sheet metal were observed on Pit 25 in March, 2015, following removal of equipment stored on the pit cover. It was determined that the sheet metal forms the perimeter for four unconventional cover test plots designed to test various biointrusion barriers (Nyhan et al., 1986; Nyhan 1989) and installed in 1981. The enhanced erosion and presence of these unconventional covers was found to be a positive UDQ with UDQE 1602, which is presented in Appendix C. Each of the four plots has a size of 6 m × 12 m and a thickness of 1 m. The four designs are (top to bottom): 15 cm of gravel and 85 cm of cobble; 100 cm of cobble; 100 cm of crushed tuff (conventional cover design); and 30 cm of gravel and 70 cm of cobble. The construction of three of the test plots differs from the conventional crushed-tuff operational covers used for most pits at Area G. They were all originally covered with 15 cm of topsoil. Observations made in 2016 indicate little topsoil and few plants present.

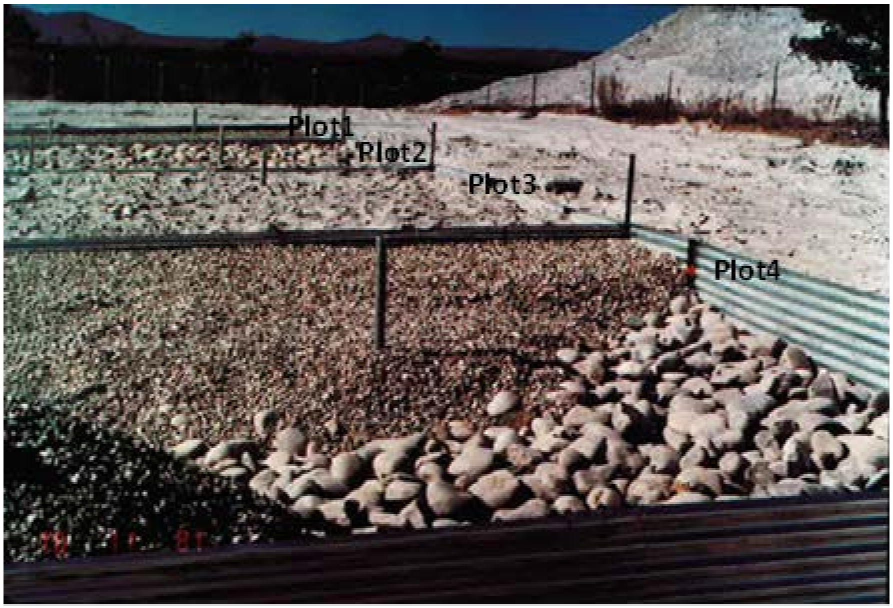

Figure 6-1
Four biointrusion-barrier test cover plots constructed along the north central border of Pit 25 in 1981. Portions of the barrier materials are shown here during construction, before the final 15 cm of topsoil was added on each plot.

Pit 25 has an operational cover. Approximately 8 percent of the operational cover consists of the four test covers described above. Enhanced infiltration beneath the three unconventional cover designs and into the underlying waste layer was observed soon after the covers were installed (Nyhan et al., 1986; Nyhan 1989). In addition, the cover shows significant signs of erosion. Although the Pit 25 cover is currently an interim cover, these conditions differ from those assumed in the Area G PA/CA because of the apparent enhanced infiltration. Special Analysis 2016-002 is being performed to determine the impact of the alternative covers on migration from the pit. Hydrus-2D simulations were run to determine the impact of enhanced infiltration and indicate that the water flux through this portion of the pit could be up to 2.2 times higher than with a crushed tuff cover. However, the impact of this on radionuclide migration has not been determined. Special Analysis 2016-001 will be completed in FY 2017. Although the SA is not finalized, a likely outcome is that a recommendation will be made to grade and add additional cover material over Pit 25 to slow erosion and decrease infiltration through the waste.

6.5 Decommissioning and Demolition of Dome 224

Dome 224 is currently used for hazardous waste storage on top of Pit 33 at Area G. The dome is underlain by an asphalt pad and a RCRA-approved double liner. The double liner routinely collects water in a sump that, in turn, is pumped out of the facility. The Laboratory and the New Mexico Environmental Department have agreed that the dome and its liner should be decommissioned and demolished (D&D). The surface completion following removal of these has not been determined, although the Laboratory would like to continue hazardous waste storage at the location. The current and potential future hazardous waste storage is a temporary, operational use of the facility and does not impact the underlying LLW inventory. However, the uncertain condition and impact of the D&D of Dome 224 and its liner on LLW waste migration from Pit 33 was found to be a positive UDQ with UDQE 1604 because there could potentially be excess water beneath the dome area. The impact on the PA of the removal of the dome and its liner and the subsequent operational closure of the area should be assessed. Special Analysis 2016-004 will review the plans for D&D of the Dome 224 and its liner, recommend best practices to ensure that water is not introduced into Pit 33 during D&D, recommend potential soil sampling of moisture if evidence of excess moisture is observed, and review plans for surface completion with respect to impacts on the PA. The SA will be conducted in early CY 2017, before the D&D operation is scheduled to begin.

7.0 Operational Changes and Status of Information Needs

The Laboratory has implemented several processes, systems, and procedures that define the operational constraints and conditions for waste disposal at Area G. The following were in place during FY 2016:

- **Waste characterization and documentation**

  - *LANL Waste Acceptance Criteria* (LANL, 2014a) defines WAC for hazardous, mixed, and radioactive waste, including the LLW disposed of at Area G.
  - *LANL Waste Management* (LANL, 2015d) sets requirements for the Laboratory's management of various hazardous, mixed, and radioactive wastes.
  - *Waste Characterization* (LANL, 2015e) summarizes the waste characterization requirements found in various regulations.
  - Radioactive *Waste Characterization* (LANL, 2016i) establishes specific requirements for characterization of radioactive waste in a manner that is compliant with DOE Order 435.1 and its companion manual M 435.1-1.
  - *Radioactive Waste Management* (LANL, 2016j) summarizes information found in various regulations, including DOE M 435.1-1, regarding the use of acceptable knowledge in making radioactive waste determinations.
  - *Waste Compliance and Tracking System (WCATS) User's Manual* (LANL, 2015f) presents a general reference of the usage of WCATS and describes the different types of tasks provided by the system.

- **Waste certification and verification**

  - *LANL Waste Management* (LANL, 2015d) describes LANL's Waste Certification Program, which requires a documented approach to ensure that waste management (treatment, storage, and disposal) of waste streams complies with applicable requirements (including DOE Order 435.1 and the accompanying manual M 435.1-1) before shipment.
  - *Radioactive Waste Management* (LANL, 2016j) summarizes the requirements for certifying, staging, and storing radioactive waste in compliance with DOE Order 435.1 and the accompanying manual M 435.1-1.
  - *Waste Certification Program Waste Verification* (LANL, 2015g) is a quality procedure that specifies the responsibilities and describes the process for waste verification by the Laboratory's Waste Management Division.
  - *Waste Assessments* (LANL, 2015h) is a quality procedure that specifies the responsibilities and describes the process for waste management assessment by the Waste Certification Program.

- **Waste packaging and transportation**
  - *LANL Waste Acceptance Criteria* (LANL, 2014a) defines WAC for hazardous, mixed, and radioactive waste, including the LLW disposed of at Area G.
  - *LANL Waste Management* (LANL, 2015d) establishes the controls necessary to prevent improper shipment of radioactive waste.
  - *LANL Packaging and Transportation Program Procedure* (LANL, 2016k) describes the requirements for packaging hazardous and nonhazardous waste for off-site shipments and on-site transfers.

- **LLW management operations**
  - *TA-54 Area G Low Level Waste Disposal and Pit/Shaft Deactivation* (LANL, 2015r) provides instructions for disposal of radioactive waste in active pits and shafts at Technical Area (TA)-54, Area G, and the subsequent deactivation of the pit/shaft.
  - *TA-54 Area G Waste Staging, Loading, and Off-Site Shipment* (LANL, 2015b) establishes the requirements for the receipt, storage, and disposal of LLW at Area G and for shipment of LLW/mixed LLW to off-site facilities for treatment and/or final disposition.
  - *TA-54 Area G Inactive Pit and Shaft Quarterly Inspections* (LANL, 2014b) provides instructions and requirements for performing inspections at TA-54 Area G for inactive pits and shafts.

- **Disposal unit design, construction, and operational closure**
  - *Pit and Shaft Design, Construction, and Operational Closure* (LANL, 2010a) provides guidelines for locating, designing, constructing, and performing operational closure of solid waste disposal pits and shafts at Area G.
  - *WDP Unreviewed Disposal Question Evaluation (UDQE) and Special Analysis (SA) Process* (LANL, 2010b) provides requirements for reviewing and approving proposed changes in LLW disposal activities and facilities to ensure that the implementation of a change will not challenge the assumptions, results, or conclusions of the Area G disposal authorization basis.

- **WAC exemption**
  - *LANL Waste* Acceptance *Criteria* (LANL, 2014a) defines WAC for hazardous, mixed, and radioactive waste, including the LLW disposed of at Area G.
  - *WDP Unreviewed Disposal Question Evaluation (UDQE) and Special Analysis (SA) Process* (LANL, 2010b) provides requirements for reviewing and approving proposed changes in LLW disposal activities and facilities to ensure that the implementation of a change will not challenge the assumptions, results, or conclusions of the Area G disposal authorization basis.

– *LANL Unreviewed Safety Question (USQ) Procedure* (LANL, 2014c) provides the requirements for reviewing and approving changes at Hazard Category 1, 2, and 3 nuclear facilities at the Laboratory.

- **Environmental monitoring**

  – *EWMO Environmental* Monitoring *Plan* (LANL, 2011c) describes the monitoring requirements for Area G.

An accurate assessment of the risks posed by the disposal of waste at Area G requires that the PA/CA be conducted in a manner that is consistent with the processes, systems, and procedures listed above. Deviations from these requirements (e.g., changes to disposal facility design, operations, and maintenance) may undermine PA/CAs that are intended to address different facility configurations or operational conditions. Consequently, an assessment of changes that have occurred at Area G and their potential effect on the underlying analyses is necessary. The results of this evaluation are provided in Section 7.1. Monitoring data evaluations and R&D activities are designed, in part, to address critical informational needs identified for the disposal facility and site. The status of these needs with respect to the Area G PA/CA is addressed in Section 7.2. The 2010 DAS issued to the Laboratory includes a number of conditions that must be satisfied under the PA/CA maintenance program; Section 7.3 discusses the status of the Laboratory's compliance with these conditions. Finally, changes to facility operations and their impact on monitoring and R&D needs are briefly considered in Section 7.4.

7.1 Impacts of Operational Changes

As discussed earlier, the Area G disposal facility consists of existing MDA G and potential Zone 4. To date, all disposal operations at Area G have been confined to MDA G. However, the Laboratory's EMWMP proposes that the strategy for LLW management is to terminate on-site LLW disposal by using the remaining space in Pit 38 and existing shafts to dispose of specific problem wastes that are difficult to transport off site. On-site disposal is expected to become less available after FY 2017; the EMWMP states that on site-disposal after the transition of EM to the new subcontractor should be reserved for waste with no off-site path forward. The strategy presented in the EMWMP is that all other present and future LLW streams would be shipped to off-site treatment and disposal facilities. All planning for expansion of LLW disposal in TA-54 Zone 4 has been terminated (LANL, 2017). Phased closure of MDA G will start after disposal operations have ended. However, the request for proposals for the new EM contract, which defines proposed work scope for the new EM contractor through 2028, does not call out closure for MDA G. Therefore, closure may not occur until after 2028.

The impending closure of MDA G has caused a shift in disposal philosophy. Whereas before FY 2009 essentially all of the LLW generated at the Laboratory was disposed of at Area G, an increasing portion of the LLW generated at the Laboratory has been shipped to commercial facilities or the Nevada National Security Site for off-site disposal. The Laboratory's current strategy for LLW is to minimize the generation and ship all newly generated waste off-site while working to open disposal pathways for any problematic wastes (LANL, 2017).

The impending closure of MDA G and the shipment of waste to off-site disposal facilities influence the operational assumptions upon which the PA/CA are based. For example, the Revision 4 analyses are based on the assumption that waste will be placed in disposal pits in this portion of Area G through 2010 and shafts through 2015; waste requiring disposal after these times was assumed to be disposed of in Zone 4. In fact, pits and shafts located in MDA G may be used for limited disposal of waste during 2017, and the current recommendation is that no additional pits or shafts be constructed in Zone 4. Assumptions made in the PA/CA regarding expansion for disposal shafts into Zone 4 and operations through year 2044 do not align with this new recommendation. Also, there is currently no estimate for when closure will begin.

The closure of MDA G is expected to coincide with an effort to optimize the final cover placed over the disposal pits and shafts. Although the cover adopted for the PA/CA is effective, it is anticipated that a more cost-effective design capable of achieving the same level of protection can be developed. Assuming an alternate design is proposed, a formal evaluation of the closure configuration will be undertaken through updates of the PA/CA. Development of the final cover design will also be coordinated with the Consent Order corrective measures implementation process.

An SA will be conducted during FY 2017 to determine the impacts on the PA/CA for a potential operational change. The removal of Dome 224 and subsequent modification to the interim cover configuration is an activity that will be performed at Area G during FY 2017 (Section 6.5). The SA will recommend actions to avoid detrimental impacts to the site during and after removal of the dome.

Postclosure land use plans for MDA G will be developed in conjunction with the MDA G corrective measures evaluation process with NMED. These plans will be influenced by the closure configuration selected for the facility as well as the future disposal plans adopted for Zone 4. Once final plans for future land use are defined, a formal evaluation will be performed to ensure consistency with the assumptions in the Area G PA/CA. The Laboratory's UDQ process provides the mechanism for initiating this evaluation.

During FY 2016, responsibility for running and maintaining the Area G PA/CA models transitioned to Laboratory staff. Concurrent with the special analysis to document the upgrade to GoldSim Version 11.1.5 (as documented in SA 2016-003 [Chu et al., 2017], Section 6.2), the Laboratory verified the reproducibility of the PA/CA model results based on a transition to new analysts and a new computing platform. In addition, during FY 2016, responsibility for running and maintaining the erosion model transitioned to LANL staff (Section 5.2). Both these transitions have been successfully implemented.

No operational closures were performed on any pits or shafts in Area G during FY 2016.

7.2 Status of Informational Needs

Sensitivity analyses conducted in support of Revision 4 of the PA/CA identified several parameters and processes that significantly influence the projected impacts of waste disposal at Area G; additional sources of uncertainty associated with the modeling were also identified. The results of these evaluations have been used in conjunction with comments from the 2007 LFRG review of the PA/CA to identify additional information needed to improve the quality of the PA/CA. Efforts to collect this information are ongoing under the Area G PA/CA maintenance program. A formal update of the maintenance program plan will be performed during FY 2017 to establish plans for assessing uncertainties related to impacts of potential ground motion, disruptive processes and events, and specification of probability distributions on PA/CA predictions because little progress has been made on these secondary issues.

7.3 Status of Disposal Authorization Statement Compliance

Continued disposal of LLW at Area G is approved subject to the conditions in the DAS (DOE, 2010). Those conditions include the following:

- Resolution of all secondary issues identified by the LFRG in its review of the Revision 3 PA/CA (DOE, 2009)
- Issuance of the Area G PA/CA Maintenance Program Plan and Area G Environmental Monitoring Plan by March 17, 2011
- Development and implementation of operational procedures to ensure the disposal facility is operated in a manner that protects the workers, the public, and the environment
- Development and implementation of an UDQ process
- Report on progress made with respect to condition resolution to the National Nuclear Security Administration and LFRG via annual reports or other written communications

The secondary issues identified by the LFRG in its review of the PA/CA are listed in their entirety in Appendix D, along with the LFRG Review Team's recommendations regarding actions to be taken to resolve these issues. All the DAS conditions are summarized in Table 7-1, and the progress made in terms of complying with these conditions is noted. No secondary issues were fully resolved and closed during FY 2016 although progress was made on several of the issues.

Some activities will be replanned and reschedule in the FY 2017 update to the maintenance program plan, as noted in Table 7-1.

7.4 Recommended Changes

The results of the Area G PA/CA indicate that the disposal facility is capable of satisfying all DOE Order 435.1 performance objectives. Several changes have taken place in conjunction with efforts to maximize the disposal capacity of the existing disposal units at the site and, as discussed in Section 7.1, many more changes are in store. In general, the changes anticipated for Area G are expected to result in the disposal of less waste at the facility. On this basis, the operational changes are not expected to undermine the disposal facility's ability to comply with the performance objectives because a smaller waste inventory should result in lower projected doses. However, by avoiding expansion into Zone 4, which was projected to be used through the year 2044, site closure could occur earlier. Preliminary analysis indicates that higher intruder doses from exposure to shorter half-life radionuclides may be calculated, particularly for the Area G shafts, if the end of a 100-year postclosure institutional control period is assumed to advance to an earlier date because of earlier site closure. The ability of the disposal facility to perform within acceptable limits must continue to be assessed using the Laboratory's UDQE process before any operational modifications are implemented. An SA will be conducted during FY 2017 to document the impact on the PA/CA dose calculations resulting from assumptions of earlier intrusion into the waste caused by earlier site closure. Similarly, the potential impacts of changes to the closure strategy for MDA G will be evaluated and appropriate updates made to the Area G Closure Plan issued in 2009 (LANL, 2009b).

A number of R&D efforts have been identified that will help reduce the uncertainty associated with the PA/CA. These efforts will be pursued under the Area G PA/CA maintenance program, and the results will be used to update the analyses as they become available. Modifications to the scope of the R&D efforts pursued under the maintenance program may be necessary to adequately respond to changes in operations and closure strategies.

Table 7-1
LANL DAS Conditions and Resolution Status

DAS Condition	Summary of Issue or Condition	Status of Resolution
Secondary Issue 3.1.1.1 – Erosion Modeling	Wind, water, and cliff retreat modeling does not capture extreme events to the extent necessary to demonstrate adequate long-term performance.	In progress; impacts of 500-year and 1000-year storms on cover performance evaluated. Cliff retreat data collected and being analyzed; more sampling will be conducted in FY 2017 (see Section 5.3).
Secondary Issue 3.1.1.5 – Cover Degradation	Modeling is required to evaluate the impacts of cover degradation from subsidence.	No progress made during FY 2016; activity will be replanned in FY 2017 maintenance plan update.
Secondary 3.1.3.1 – All-Pathways Dose Modeling	The impacts of airborne contaminants transported from Area G are not accounted for in the All-Pathways Canyon Scenario modeling.	In progress
Secondary Issue 3.1.3.5 – Point of Compliance	Point of compliance for groundwater protection should be located at the point of maximum concentration outside of a 100-m buffer zone.	Issue resolved; see FY 2009 Annual Report (LANL, 2010c)
Secondary Issue 3.1.3.6 – Intruder Scenarios	The human intruder scenarios are overly conservative.	Issue resolved; see FY 2009 Annual Report (LANL, 2010c)
Secondary Issue 3.1.4.4 – Operational Documents	Facility operations documents must be finalized.	Issue resolved; see FY 2009 Annual Report (LANL, 2010c)
Secondary Issue 3.1.5.3 – Impacts of Focused Runoff	Modeling needs to account for the impacts of elevated water contents caused by focused runoff from surface structures.	In progress; focused runoff into open pits was simulated; transient impacts of extreme rain during September 2013 on the groundwater model were evaluated for Pits 37 and 38. Hydrus-2D simulations for Pits 31 and 25 were completed; see Section 5.1.
Secondary Issue 3.1.5.3 – Hydrogeologic Model Uncertainty	Conduct FEHM simulations to evaluate the impact of the potential conceptual model uncertainties on groundwater transport and dose estimates.	Resolved; see FY 2013 Annual Report (French and Shuman, 2014)
Secondary Issue 3.1.5.5 – Potential Ground Motion	Use site-specific data to assess potential impacts of seismic accelerations on facility design and long-term performance, including slope stability and the impacts of cliff retreat.	In progress: Reviewing Probabilistic Seismic Hazards Analysis generated for the Laboratory (URS, 2007) with respect to applicability to TA-54.
Secondary Issue 3.1.5.5 – Disruptive Processes and Events	Implement a structured screening approach to determine what potentially disruptive processes or events should be included in the performance assessment and composite analysis.	In progress: FY 2016 progress made on cliff retreat study and understanding impact of the

Table 7-1 (Continued)
LANL DAS Conditions and Resolution Status

DAS Condition	Summary of Issue or Condition	Status of Resolution
		2013 1000-year rain event on groundwater transport.
Secondary Issue 3.1.6.3 – Infiltration Rate Distribution	The manner in which the infiltration rate distribution was developed is incorrect.	Issue resolved; see FY 2009 Annual Report (LANL, 2010c)
Secondary Issue 3.1.6.3 – Modeling Enhancements	Recommended modeling enhancements include reexamination of the erosion scenarios concept, partitioning of radon between gas and liquid phases, use of continuous beta distributions in the biotic intrusion modeling, consideration of contaminant redistribution from wind, and reexamination of the infiltration rate distribution.	Comments regarding radon gas, beta distributions, and infiltration-rate distribution have been resolved; see FY 2009 Annual Report (LANL, 2010c). Resolution of erosion scenario and contaminant redistribution comments is in progress.
Secondary Issue 3.1.6.3 – Input Parameter Probability Distributions	Specification of probability distributions needs to be improved in many cases. Review all parameter distributions used in the modeling.	No progress made during FY 2016; activity will be replanned in FY 2017 maintenance plan update.
Secondary Issue 3.1.6.6 – HYDRUS Modeling	The HYDRUS modeling did not correctly account for initial moisture conditions.	Issue resolved; see FY 2009 Annual Report (LANL, 2010c)
Secondary Issue 3.1.8.2 – Sensitivity and Uncertainty Analysis	Develop and implement sensitivity analysis methods suitable for complex time-dependent nonlinear systems.	No progress made during FY 2016; activity will be replanned in FY 2017 maintenance plan update.
Secondary Issue 3.1.8.3 – Spurious Sensitivity Analysis Results	Elaborate on statements that characterize some of the results of the sensitivity analysis as spurious.	No progress made during FY 2016; activity will be replanned in FY 2017 maintenance plan update.
Secondary Issue 3.1.9.1 – Presentation and Integration of Dose Projections	More fully integrate and interpret the probabilistic and deterministic projections provided in the performance assessment and composite analysis.	No progress made during FY 2016; activity will be replanned in FY 2017 maintenance plan update.
Secondary Issue 3.1.10.1 – Software and Database Quality Assurance	Develop and implement a software and database quality assurance program that includes configuration control for all software and databases used to conduct the performance assessment and composite analysis.	In progress; update of PA/CA model with latest GoldSim 11.1.5 version completed (see Section 6.2); database for moisture monitoring data compiled during FY 2015 and new data incorporated during FY 2016 (see Section 4.2).
Secondary Issue 3.2.2.2 – Composite Analysis Inventory	Use alternate source inventories that are consistent with the LANL DSA for nuclear environmental sites.	Issue resolved; see FY 2009 Annual Report (LANL, 2010c)
Condition – Operational Procedures	Operational procedures will be developed within 90 days of issuance of this statement and implemented to ensure the disposal facility is	DAS condition resolved (LANL, 2010d)

Table 7-1 (Continued)
LANL DAS Conditions and Resolution Status

DAS Condition	Summary of Issue or Condition	Status of Resolution
	operated in a manner that protects the workers, the public, and the environment.	
Condition – Area G Performance Assessment and Composite Analysis Maintenance Plan	A revised maintenance program plan must be issued by March 17, 2011.	DAS condition resolved; see LANL Maintenance Program Plan (LANL, 2011a); updated maintenance program plan will be issued in FY 2017.
Condition – Area G Environmental Monitoring Plan	A revised maintenance program plan must be issued by March 17, 2011.	DAS condition resolved, see Environmental Monitoring Plan (LANL, 2011c)
Condition – Unreviewed Disposal Question Process	Develop and implement an UDQ process that evaluates the potential impacts of changes in disposal facility operations, on-site policy or strategy, changes in facility controls, and discoveries on the continued proper functioning of the disposal facility.	Issue resolved; see Los Alamos National Laboratory Procedure EP-AP-2204 (LANL, 2010b)
DAS Condition – Annual Progress on Condition Resolution	Report on progress made with respect to condition resolution to the National Nuclear Security Administration and LFRG via annual reports and other written communications.	Issue resolved; see Annual Reports

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Appendix A

Special Analysis 2015-001: Second Update of MDA B Waste Inventories in the Los Alamos National Laboratory Waste Compliance and Tracking System Database

LA-UR-16-25626

Special Analysis 2015-001:
Second Update of MDA B Waste Inventories in the Los Alamos National Laboratory Waste Compliance and Tracking System Database

UDQE Reference Number:
UDQE-1501

Author:
Sean B. French, Los Alamos National Laboratory
Kay H. Birdsell, Los Alamos National Laboratory
Rob Shuman

Prepared for:
Los Alamos National Laboratory

Date:
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Acronyms and Abbreviations

DOE	Department of Energy
LANL	Los Alamos National Laboratory
LLW	Low-level radioactive waste
MDA	Material Disposal Area
TA	Technical Area
WCATS	Waste Compliance and Tracking System

1.0 Introduction

Los Alamos National Laboratory (LANL) generates radioactive waste as a result of various activities. Operational waste is generated from a wide variety of research and development activities, including nuclear weapons development, energy production, and medical research; environmental restoration, and decontamination and decommissioning 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 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 (PA/CA) 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- 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 Area G disposal facility consists of Material Disposal Area (MDA) G and the Zone 4 expansion area. To date, disposal operations have been confined to MDA G. Current plans call for cessation of pit and shaft disposal operations within MDA G by October 2017. The Laboratory’s current Enduring Mission Waste Management Plan (LANL, 2016) proposes that any further planning for Zone 4 expansion be deferred for the foreseeable future, although expansion into Zone 4 expansion for shaft disposal remains a viable option.

In anticipation of the closure of MDA G, large quantities of bulk waste generated by the excavation of trenches at MDA B were sent to the facility for disposal. To estimate the radionuclide inventories associated with this waste, 92 composite samples were collected from waste containers and sent to an analytical laboratory. The data collected from the characterization effort were used in 2011 to prepare radionuclide inventories for the containers of waste that were not sampled. A description of this original characterization effort is included in Appendix A of this report. The radionuclide inventories estimated using the methods described in Appendix A are generally considered to be conservative and do not account for uncertainties inherent in the estimated activities.

In an effort to more accurately estimate radionuclide inventories for the MDA B waste disposed of in Pits 37 and 38 at MDA G, including uncertainty, concentration distributions were developed for use in the MDA G PA/CA models.

The characterization data collected from the 92 samples were reevaluated and used to establish radionuclide concentration distributions for all isotopes included in the data set. This reevaluation of the MDA B waste inventory characteristics is presented in Appendix C. These concentration distributions are used in the PA/CA models to estimate radionuclide activities in containers of MDA B waste that have undergone disposal at Area G. A follow-up activity is required to update the radionuclide inventories listed for the MDA B waste disposed of in 2014 in the Waste Compliance and Tracking System (WCATS) database. This need was identified by Unreviewed Disposal Question Evaluation (UDQE) 1501 (see Appendix B), and this evaluation, special analysis (SA) 2015-001, is related to this inventory update. Special Analysis 2015-001 addresses the inventories of 139 containers of MDA B waste that were disposed of in Pit 38 from May through August, 2014. Some background information is useful to understand the action that this SA recommends.

Background:

(1) A similar special analysis, SA 2013-001, was conducted in 2012 for 1,144 containers of MDA B waste that underwent disposal in Pits 37 and 38 at MDA G during 2011 and 2012 (French and Shuman, 2013). That SA presented the same information in Appendixes A and C that are included in this report, to document the original estimates for the MDA B waste and the reevaluated inventory distributions. An outcome of that previous SA is that the inventory database was updated to reflect the mean inventory values associated with the distributions for the 1,144 containers of waste disposed of during 2011 and 2012.

(2) The PA/CA inventory models, and dose and radon flux projections were last updated in conjunction with the transition of transuranic waste data to WCATS (SA 2014-004; French and Shuman, 2015). That update reflects the distributions of MDA B waste inventories rather than the single, conservative values described in both Appendix A of SA 2013-001 (French and Shuman, 2013) and in Appendix A of this current SA. Because the PA/CA model includes projections of future waste disposal, and the MDA B waste that was buried in May through August 2014 was already awaiting disposal at Area G, the inventory model presented in SA 2014-004 used the distributions consistent with Appendix C to describe that future waste. Therefore, the most current inventory models, and the dose and radon flux projections for the PA/CA already use the reevaluated inventory values, including the 1,144 containers disposed of during 2011 and 2012 and the additional 139 containers disposed of during 2014.

(3) Currently, the inventories listed in WCATS for the 139 containers of MDA B waste disposed of during 2014 are based on the original inventory analysis, as presented in Appendix A here. The information in WCATS for the MDA B waste disposed of during 2014 is based on assumptions that are inconsistent with the assumptions used for the inventory information in WCATS for similar MDA B disposed of during 2011 and 2012, as described in the background information listed in (1) above. In addition, the inventory information currently in WCATS for the MDA B waste disposed of during 2014 is inconsistent with the distributions used to the PA/CA inventory models and dose projections, as described in (2) above. The inventory model already in the MDA G PA/CA dose projections (French and Shuman, 2015) includes the distributions for the 17 radionuclides in 139 containers of MDA B waste disposed of during 2014 at MDA G, as presented in Appendix C of this document.

Action proposed by SA 2015-001:

This SA documents the mean values for the 17 radionuclides in 139 containers of MDA B waste disposed of during 2014 at MDA G based on the distributions presented in Appendix C and implemented in the PA/CA model.

The SA initiates the following action: ***The inventory in the WCATS database associated with the 139 containers of MDA B waste disposed during 2014 at MDA G will be updated to the mean values developed based on the distributions presented in this SA.*** This update to WCATS will result in inventories that are consistent with (1) the inventories included in WCATS for the previous 1,144 containers of MDA B waste already disposed of during 2011 and 2012 (French and Shuman, 2013), and (2) the mean values of the concentration distributions already used in the MDA G inventory model as implemented in the PA/CA models. It is important to note that the revisions to the MDA B waste inventory distributions do not change the doses and radon fluxes projected for the Area G PA/CA because the information is already included in the most recent update to that model (French and Shuman, 2015).

The methods used to develop the radionuclide concentration distributions and to update the disposal database are discussed in Section 2. The results of the evaluation are provided in Section 3, and conclusions are in Section 4.

2.0 Methods

The data collected from the 92 composite samples of MDA B waste were reevaluated and used to develop distributions of radionuclide concentrations in the waste. The methods used to develop these distributions and the results of the evaluation are provided in Appendix C. The radionuclide concentration distributions developed for the MDA B waste are summarized in Table 2-1. For most radionuclides, a single concentration distribution was developed for each isotope found in the MDA B waste; these distributions were assumed to apply to the MDA B waste regardless of where it was placed in disposal pits at Area G. These single concentration distributions address waste disposed of in 2011 and 2012 in the institutional and headspace layers of pits 37 and 38 and waste disposed of in the institutional waste layer of pit 38 in 2014.

Multiple radionuclide concentration distributions were developed for Am-241, Pu-238, and Pu-239 in the MDA B waste based on disposal location. The distributions listed in Table 2-1 for Am-241, Pu-238, and Pu-239 are specific to 137 containers of waste that were awaiting disposal at the time the waste characterization effort was conducted. (Radionuclide concentration distributions for the Am-241, Pu-238, and Pu-239 waste disposed of in 2011 and 2012 are not included here; those distributions are discussed in the Special Analysis 2013-0001 that covers those wastes (French and Shuman, 2013).) Correlations exist among the concentrations of some of the radionuclides. The correlation coefficients used to describe these relationships are included in the table. Concentration distributions are provided in the table for all radionuclides encountered in the 92 composite samples.

The WCATS database stores point estimates of the radionuclide activities found in each container or shipment of waste disposed of at Area G. The 139 containers of MDA B waste disposed of during 2014 include material excavated from the trenches at MDA B whose radionuclide concentrations were initially estimated using the procedures outlined in Appendix A. Those initial inventory estimates are currently recorded in the WCATs database.

Revised inventories were calculated for a total of 139 containers of MDA B waste. One hundred thirty-three of the containers disposed of during 2014 were among the 137 waste containers that were used to estimate the radionuclide concentration distributions given in Table 2-1. Note that there is a difference between the number of containers disposed and those that were originally sampled. However, radionuclide concentrations in the remaining six containers disposed during 2014 are assumed to be described by the same distributions. The means of the radionuclide concentration distributions described above (Table 2-1) were multiplied by the weight of the MDA B waste in each container to estimate bin-specific radionuclide inventories, as described below.

Table 2-1
Radionuclide Concentration Distributions in the MDA B Waste

Radionuclide	Concentration Distribution (pCi/g) [a]	Correlation Coefficient [b]
Am-241	LN(172.5, 18.8)	NA
Bi-214	LN(1.1, 0.03)	NA
Co-60	LN(0.009, 0.002)	NA
Cs-137	LN(0.5, 1.0)	NA
Eu-152	LN(0.1, 0.04)	NA
H-3	LN(0.7, 0.2)	NA
K-40	LN(26.3, 0.4)	NA
Pb-214	LN(1.3, 0.03)	Ra-226 – 0.83
Pu-238	LN(32.6, 11.1)	Am-241 – 0.19
Pu-239	LN(13,643, 5,658)	Am-241 – 0.57
Ra-226	LN(1.1, 0.03)	NA
Ra-228	LN(1.6, 0.03)	NA
Sr-90	LN(0.3, 0.1)	NA
Th-234	LN(6.9, 1.9)	U-234 – 0.96
U-234	LN(6.4, 1.9)	NA
U-235	LN(0.6, 0.1)	U-234 – 0.90
U-238	LN(5.8, 2.0)	U-234 – 0.99

[a] *Values listed are for the mean and standard deviation of the log normal concentration distribution for each radionuclide.*

[b] *The radionuclide to which the distribution is correlated is listed first, followed by the correlation coefficient. NA indicates no statistically significant process-based correlation was observed or the correlation was considered inconsequential for the performance modeling.*

3.0 Results

The updated inventory estimates (activity in Ci) for the 139 containers of MDA B waste are tabulated in Table 3-1. Included in the table are the waste container numbers and the as-disposed radionuclide inventories. These container-specific inventories are based on the mean values of the distributions given in Table 2-1 and the weight of each container.

The radionuclide inventories listed in Table 3-1 for Am-241, Pu-238, and Pu-239 are modestly higher than those originally assigned to the waste packages. For example, the medians of the ratios of revised to original inventories are 1.5, 1.3, and 2.7 for Am-241, Pu-238, Pu-239, respectively. The revised inventories for the remainder of the radionuclides in the MDA B waste are 50% or less of those listed in the database because a less conservative approach was used to update the isotopes' inventories. For example, the original analysis assumed the tritium concentration in the MDA B waste was equal to twice the mean value measured in the 92 composite samples. Similarly, the maximum U-234, U-235, and U-238 concentrations measured in the composite samples were used to calculate inventories of those isotopes. The analysis described in Appendix C did not make these conservative assumptions.

The revisions to the MDA B waste inventories will not change the doses and radon fluxes projected for the Area G PA/CA. The doses and fluxes projected in the most recent update to the PA/CA, last updated in conjunction with the transition of transuranic waste data to WCATS (SA 2014-004; French and Shuman 2015), already take into account the radionuclide concentration distributions described in this special analysis for the MDA B waste.

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Table 3-1
Updated Radionuclide Inventories for the MDA B Waste

Container ID	Inventory (Ci)																
	Am-241	Bi-214	Co-60	Cs-137	Eu-152	H-3	K-40	Pb-214	Pu-238	Pu-239	Ra-226	Ra-228	Sr-90	Th-234	U-234	U-235	U-238
L11217440	2.92E-03	1.86E-05	1.52E-07	8.46E-06	1.69E-06	1.19E-05	4.45E-04	2.20E-05	5.52E-04	2.31E-01	1.86E-05	2.71E-05	5.08E-06	1.17E-04	1.08E-04	1.02E-05	9.82E-05
L11219782	3.45E-03	2.20E-05	1.80E-07	9.99E-06	2.00E-06	1.40E-05	5.26E-04	2.60E-05	6.51E-04	2.73E-01	2.20E-05	3.20E-05	5.99E-06	1.38E-04	1.28E-04	1.20E-05	1.16E-04
L11219788	3.33E-03	2.13E-05	1.74E-07	9.66E-06	1.93E-06	1.35E-05	5.08E-04	2.51E-05	6.30E-04	2.64E-01	2.13E-05	3.09E-05	5.80E-06	1.33E-04	1.24E-04	1.16E-05	1.12E-04
L11219789	3.53E-03	2.25E-05	1.84E-07	1.02E-05	2.04E-06	1.43E-05	5.37E-04	2.66E-05	6.66E-04	2.79E-01	2.25E-05	3.27E-05	6.13E-06	1.41E-04	1.31E-04	1.23E-05	1.19E-04
L11221251	3.14E-03	2.01E-05	1.64E-07	9.12E-06	1.82E-06	1.28E-05	4.79E-04	2.37E-05	5.94E-04	2.49E-01	2.01E-05	2.92E-05	5.47E-06	1.26E-04	1.17E-04	1.09E-05	1.06E-04
L11221732	3.29E-03	2.10E-05	1.72E-07	9.53E-06	1.91E-06	1.33E-05	5.01E-04	2.48E-05	6.21E-04	2.60E-01	2.10E-05	3.05E-05	5.72E-06	1.31E-04	1.22E-04	1.14E-05	1.11E-04
L11221862	2.26E-03	1.44E-05	1.18E-07	6.56E-06	1.31E-06	9.18E-06	3.45E-04	1.71E-05	4.28E-04	1.79E-01	1.44E-05	2.10E-05	3.94E-06	9.05E-05	8.40E-05	7.87E-06	7.61E-05
L11221870	3.24E-03	2.06E-05	1.69E-07	9.38E-06	1.88E-06	1.31E-05	4.94E-04	2.44E-05	6.12E-04	2.56E-01	2.06E-05	3.00E-05	5.63E-06	1.29E-04	1.20E-04	1.13E-05	1.09E-04
L11221878	2.52E-03	1.61E-05	1.32E-07	7.31E-06	1.46E-06	1.02E-05	3.85E-04	1.90E-05	4.77E-04	2.00E-01	1.61E-05	2.34E-05	4.39E-06	1.01E-04	9.36E-05	8.78E-06	8.49E-05
L11221882	2.12E-03	1.35E-05	1.11E-07	6.15E-06	1.23E-06	8.61E-06	3.24E-04	1.60E-05	4.01E-04	1.68E-01	1.35E-05	1.97E-05	3.69E-06	8.49E-05	7.87E-05	7.38E-06	7.13E-05
L11221911	2.26E-03	1.44E-05	1.18E-07	6.54E-06	1.31E-06	9.16E-06	3.44E-04	1.70E-05	4.27E-04	1.79E-01	1.44E-05	2.09E-05	3.93E-06	9.03E-05	8.38E-05	7.85E-06	7.59E-05
L11221913	2.49E-03	1.59E-05	1.30E-07	7.22E-06	1.44E-06	1.01E-05	3.80E-04	1.88E-05	4.71E-04	1.97E-01	1.59E-05	2.31E-05	4.33E-06	9.96E-05	9.24E-05	8.66E-06	8.37E-05
L11221914	2.60E-03	1.66E-05	1.35E-07	7.52E-06	1.50E-06	1.05E-05	3.96E-04	1.96E-05	4.91E-04	2.05E-01	1.66E-05	2.41E-05	4.51E-06	1.04E-04	9.63E-05	9.03E-06	8.73E-05
L11222143	2.67E-03	1.70E-05	1.39E-07	7.73E-06	1.55E-06	1.08E-05	4.06E-04	2.01E-05	5.04E-04	2.11E-01	1.70E-05	2.47E-05	4.64E-06	1.07E-04	9.89E-05	9.27E-06	8.96E-05
L11222144	2.51E-03	1.60E-05	1.31E-07	7.28E-06	1.46E-06	1.02E-05	3.83E-04	1.89E-05	4.75E-04	1.99E-01	1.60E-05	2.33E-05	4.37E-06	1.01E-04	9.32E-05	8.74E-06	8.45E-05
L11222145	2.68E-03	1.71E-05	1.40E-07	7.75E-06	1.55E-06	1.09E-05	4.08E-04	2.02E-05	5.06E-04	2.12E-01	1.71E-05	2.48E-05	4.65E-06	1.07E-04	9.93E-05	9.31E-06	9.00E-05
L11222146	2.45E-03	1.56E-05	1.28E-07	7.09E-06	1.42E-06	9.93E-06	3.73E-04	1.84E-05	4.62E-04	1.93E-01	1.56E-05	2.27E-05	4.25E-06	9.79E-05	9.08E-05	8.51E-06	8.23E-05
L11222150	1.84E-03	1.17E-05	9.58E-08	5.32E-06	1.06E-06	7.45E-06	2.80E-04	1.38E-05	3.47E-04	1.45E-01	1.17E-05	1.70E-05	3.19E-06	7.34E-05	6.81E-05	6.39E-06	6.17E-05
L11222151	2.97E-03	1.90E-05	1.55E-07	8.62E-06	1.72E-06	1.21E-05	4.53E-04	2.24E-05	5.62E-04	2.35E-01	1.90E-05	2.76E-05	5.17E-06	1.19E-04	1.10E-04	1.03E-05	1.00E-04
L11222155	2.85E-03	1.82E-05	1.49E-07	8.27E-06	1.65E-06	1.16E-05	4.35E-04	2.15E-05	5.39E-04	2.26E-01	1.82E-05	2.65E-05	4.96E-06	1.14E-04	1.06E-04	9.92E-06	9.59E-05
L11222159	2.77E-03	1.76E-05	1.44E-07	8.02E-06	1.60E-06	1.12E-05	4.22E-04	2.08E-05	5.23E-04	2.19E-01	1.76E-05	2.57E-05	4.81E-06	1.11E-04	1.03E-04	9.62E-06	9.30E-05
L11222162	3.09E-03	1.97E-05	1.61E-07	8.95E-06	1.79E-06	1.25E-05	4.71E-04	2.33E-05	5.84E-04	2.44E-01	1.97E-05	2.86E-05	5.37E-06	1.24E-04	1.15E-04	1.07E-05	1.04E-04
L11222167	2.81E-03	1.79E-05	1.47E-07	8.15E-06	1.63E-06	1.14E-05	4.29E-04	2.12E-05	5.31E-04	2.22E-01	1.79E-05	2.61E-05	4.89E-06	1.12E-04	1.04E-04	9.78E-06	9.46E-05
L11222172	2.67E-03	1.70E-05	1.39E-07	7.73E-06	1.55E-06	1.08E-05	4.07E-04	2.01E-05	5.04E-04	2.11E-01	1.70E-05	2.47E-05	4.64E-06	1.07E-04	9.90E-05	9.28E-06	8.97E-05
L11222173	1.70E-03	1.09E-05	8.89E-08	4.94E-06	9.88E-07	6.91E-06	2.60E-04	1.28E-05	3.22E-04	1.35E-01	1.09E-05	1.58E-05	2.96E-06	6.81E-05	6.32E-05	5.93E-06	5.73E-05
L11222174	2.73E-03	1.74E-05	1.43E-07	7.92E-06	1.58E-06	1.11E-05	4.17E-04	2.06E-05	5.17E-04	2.16E-01	1.74E-05	2.54E-05	4.75E-06	1.09E-04	1.01E-04	9.51E-06	9.19E-05
L11222176	2.33E-03	1.48E-05	1.21E-07	6.74E-06	1.35E-06	9.44E-06	3.55E-04	1.75E-05	4.40E-04	1.84E-01	1.48E-05	2.16E-05	4.05E-06	9.31E-05	8.63E-05	8.09E-06	7.82E-05
L11222188	2.23E-03	1.42E-05	1.17E-07	6.47E-06	1.29E-06	9.06E-06	3.40E-04	1.68E-05	4.22E-04	1.77E-01	1.42E-05	2.07E-05	3.88E-06	8.93E-05	8.29E-05	7.77E-06	7.51E-05
L11222189	2.28E-03	1.46E-05	1.19E-07	6.62E-06	1.32E-06	9.27E-06	3.48E-04	1.72E-05	4.31E-04	1.81E-01	1.46E-05	2.12E-05	3.97E-06	9.13E-05	8.47E-05	7.94E-06	7.68E-05
L11222191	2.27E-03	1.44E-05	1.18E-07	6.57E-06	1.31E-06	9.20E-06	3.45E-04	1.71E-05	4.28E-04	1.79E-01	1.44E-05	2.10E-05	3.94E-06	9.06E-05	8.41E-05	7.88E-06	7.62E-05
L11222193	3.04E-03	1.94E-05	1.59E-07	8.82E-06	1.76E-06	1.24E-05	4.64E-04	2.29E-05	5.75E-04	2.41E-01	1.94E-05	2.82E-05	5.29E-06	1.22E-04	1.13E-04	1.06E-05	1.02E-04
L11222194	2.56E-03	1.63E-05	1.33E-07	7.41E-06	1.48E-06	1.04E-05	3.90E-04	1.93E-05	4.83E-04	2.02E-01	1.63E-05	2.37E-05	4.45E-06	1.02E-04	9.49E-05	8.89E-06	8.60E-05
L11222195	2.78E-03	1.77E-05	1.45E-07	8.06E-06	1.61E-06	1.13E-05	4.24E-04	2.10E-05	5.26E-04	2.20E-01	1.77E-05	2.58E-05	4.84E-06	1.11E-04	1.03E-04	9.67E-06	9.35E-05
L11222197	2.48E-03	1.58E-05	1.29E-07	7.19E-06	1.44E-06	1.01E-05	3.78E-04	1.87E-05	4.69E-04	1.96E-01	1.58E-05	2.30E-05	4.31E-06	9.92E-05	9.20E-05	8.63E-06	8.34E-05
L11222198	2.56E-03	1.63E-05	1.34E-07	7.43E-06	1.49E-06	1.04E-05	3.91E-04	1.93E-05	4.84E-04	2.03E-01	1.63E-05	2.38E-05	4.46E-06	1.02E-04	9.50E-05	8.91E-06	8.61E-05
L11222208	2.48E-03	1.58E-05	1.29E-07	7.19E-06	1.44E-06	1.01E-05	3.78E-04	1.87E-05	4.69E-04	1.96E-01	1.58E-05	2.30E-05	4.31E-06	9.92E-05	9.20E-05	8.63E-06	8.34E-05
L11222214	2.79E-03	1.78E-05	1.45E-07	8.07E-06	1.61E-06	1.13E-05	4.25E-04	2.10E-05	5.26E-04	2.20E-01	1.78E-05	2.58E-05	4.84E-06	1.11E-04	1.03E-04	9.69E-06	9.37E-05
L11222215	2.91E-03	1.86E-05	1.52E-07	8.45E-06	1.69E-06	1.18E-05	4.44E-04	2.20E-05	5.51E-04	2.30E-01	1.86E-05	2.70E-05	5.07E-06	1.17E-04	1.08E-04	1.01E-05	9.80E-05
L11222216	3.11E-03	1.98E-05	1.62E-07	9.00E-06	1.80E-06	1.26E-05	4.74E-04	2.34E-05	5.87E-04	2.46E-01	1.98E-05	2.88E-05	5.40E-06	1.24E-04	1.15E-04	1.08E-05	1.04E-04
L11222220	2.23E-03	1.42E-05	1.16E-07	6.46E-06	1.29E-06	9.05E-06	3.40E-04	1.68E-05	4.21E-04	1.76E-01	1.42E-05	2.07E-05	3.88E-06	8.92E-05	8.27E-05	7.76E-06	7.50E-05
L11222223	2.88E-03	1.84E-05	1.50E-07	8.36E-06	1.67E-06	1.17E-05	4.39E-04	2.17E-05	5.45E-04	2.28E-01	1.84E-05	2.67E-05	5.01E-06	1.15E-04	1.07E-04	1.00E-05	9.69E-05
L11222224	2.58E-03	1.64E-05	1.35E-07	7.48E-06	1.50E-06	1.05E-05	3.93E-04	1.94E-05	4.87E-04	2.04E-01	1.64E-05	2.39E-05	4.49E-06	1.03E-04	9.57E-05	8.97E-06	8.67E-05
L11222228	2.69E-03	1.72E-05	1.40E-07	7.80E-06	1.56E-06	1.09E-05	4.10E-04	2.03E-05	5.09E-04	2.13E-01	1.72E-05	2.50E-05	4.68E-06	1.08E-04	9.99E-05	9.36E-06	9.05E-05
L11222229	2.65E-03	1.69E-05	1.38E-07	7.68E-06	1.54E-06	1.08E-05	4.04E-04	2.00E-05	5.01E-04	2.10E-01	1.69E-05	2.46E-05	4.61E-06	1.06E-04	9.84E-05	9.22E-06	8.91E-05
L11222234	2.95E-03	1.88E-05	1.54E-07	8.54E-06	1.71E-06	1.20E-05	4.49E-04	2.22E-05	5.57E-04	2.33E-01	1.88E-05	2.73E-05	5.12E-06	1.18E-04	1.09E-04	1.02E-05	9.90E-05
L11222235	2.79E-03	1.78E-05	1.46E-07	8.10E-06	1.62E-06	1.13E-05	4.26E-04	2.11E-05	5.28E-04	2.21E-01	1.78E-05	2.59E-05	4.86E-06	1.12E-04	1.04E-04	9.72E-06	9.40E-05

Table 3-1
Updated Radionuclide Inventories for the MDA B Waste (*Continued*)

Container ID	Inventory (Ci)																
	Am-241	Bi-214	Co-60	Cs-137	Eu-152	H-3	K-40	Pb-214	Pu-238	Pu-239	Ra-226	Ra-228	Sr-90	Th-234	U-234	U-235	U-238
L11222236	2.77E-03	1.77E-05	1.45E-07	8.04E-06	1.61E-06	1.13E-05	4.23E-04	2.09E-05	5.24E-04	2.19E-01	1.77E-05	2.57E-05	4.82E-06	1.11E-04	1.03E-04	9.65E-06	9.32E-05
L11222252	2.30E-03	1.46E-05	1.20E-07	6.65E-06	1.33E-06	9.31E-06	3.50E-04	1.73E-05	4.34E-04	1.82E-01	1.46E-05	2.13E-05	3.99E-06	9.18E-05	8.52E-05	7.98E-06	7.72E-05
L11222258	2.81E-03	1.79E-05	1.46E-07	8.14E-06	1.63E-06	1.14E-05	4.28E-04	2.12E-05	5.30E-04	2.22E-01	1.79E-05	2.60E-05	4.88E-06	1.12E-04	1.04E-04	9.76E-06	9.44E-05
L11222259	2.60E-03	1.66E-05	1.36E-07	7.54E-06	1.51E-06	1.06E-05	3.97E-04	1.96E-05	4.92E-04	2.06E-01	1.66E-05	2.41E-05	4.53E-06	1.04E-04	9.65E-05	9.05E-06	8.75E-05
L11222260	2.68E-03	1.71E-05	1.40E-07	7.76E-06	1.55E-06	1.09E-05	4.08E-04	2.02E-05	5.06E-04	2.12E-01	1.71E-05	2.48E-05	4.66E-06	1.07E-04	9.94E-05	9.32E-06	9.01E-05
L11222261	1.72E-03	1.10E-05	9.00E-08	5.00E-06	1.00E-06	7.00E-06	2.63E-04	1.30E-05	3.26E-04	1.36E-01	1.10E-05	1.60E-05	3.00E-06	6.90E-05	6.40E-05	6.00E-06	5.80E-05
L11222263	2.83E-03	1.81E-05	1.48E-07	8.21E-06	1.64E-06	1.15E-05	4.32E-04	2.13E-05	5.35E-04	2.24E-01	1.81E-05	2.63E-05	4.93E-06	1.13E-04	1.05E-04	9.85E-06	9.52E-05
L11222264	2.63E-03	1.68E-05	1.37E-07	7.63E-06	1.53E-06	1.07E-05	4.01E-04	1.98E-05	4.98E-04	2.08E-01	1.68E-05	2.44E-05	4.58E-06	1.05E-04	9.77E-05	9.16E-06	8.85E-05
L11222268	2.27E-03	1.44E-05	1.18E-07	6.57E-06	1.31E-06	9.19E-06	3.45E-04	1.71E-05	4.28E-04	1.79E-01	1.44E-05	2.10E-05	3.94E-06	9.06E-05	8.41E-05	7.88E-06	7.62E-05
L11222270	2.36E-03	1.51E-05	1.23E-07	6.85E-06	1.37E-06	9.59E-06	3.60E-04	1.78E-05	4.46E-04	1.87E-01	1.51E-05	2.19E-05	4.11E-06	9.45E-05	8.77E-05	8.22E-06	7.94E-05
L11222272	2.50E-03	1.60E-05	1.31E-07	7.26E-06	1.45E-06	1.02E-05	3.82E-04	1.89E-05	4.73E-04	1.98E-01	1.60E-05	2.32E-05	4.36E-06	1.00E-04	9.29E-05	8.71E-06	8.42E-05
L11222274	2.72E-03	1.74E-05	1.42E-07	7.90E-06	1.58E-06	1.11E-05	4.15E-04	2.05E-05	5.15E-04	2.15E-01	1.74E-05	2.53E-05	4.74E-06	1.09E-04	1.01E-04	9.47E-06	9.16E-05
L11222276	3.41E-03	2.17E-05	1.78E-07	9.88E-06	1.98E-06	1.38E-05	5.20E-04	2.57E-05	6.44E-04	2.70E-01	2.17E-05	3.16E-05	5.93E-06	1.36E-04	1.26E-04	1.19E-05	1.15E-04
L11222278	2.76E-03	1.76E-05	1.44E-07	8.01E-06	1.60E-06	1.12E-05	4.22E-04	2.08E-05	5.22E-04	2.19E-01	1.76E-05	2.56E-05	4.81E-06	1.11E-04	1.03E-04	9.62E-06	9.30E-05
L11222280	2.37E-03	1.51E-05	1.24E-07	6.87E-06	1.37E-06	9.61E-06	3.61E-04	1.79E-05	4.48E-04	1.87E-01	1.51E-05	2.20E-05	4.12E-06	9.47E-05	8.79E-05	8.24E-06	7.96E-05
L11222287	3.32E-03	2.12E-05	1.73E-07	9.62E-06	1.92E-06	1.35E-05	5.06E-04	2.50E-05	6.27E-04	2.62E-01	2.12E-05	3.08E-05	5.77E-06	1.33E-04	1.23E-04	1.15E-05	1.12E-04
L11222539	3.28E-03	2.09E-05	1.71E-07	9.51E-06	1.90E-06	1.33E-05	5.00E-04	2.47E-05	6.20E-04	2.59E-01	2.09E-05	3.04E-05	5.70E-06	1.31E-04	1.22E-04	1.14E-05	1.10E-04
L11222543	3.03E-03	1.93E-05	1.58E-07	8.77E-06	1.75E-06	1.23E-05	4.61E-04	2.28E-05	5.72E-04	2.39E-01	1.93E-05	2.81E-05	5.26E-06	1.21E-04	1.12E-04	1.05E-05	1.02E-04
L11222559	2.74E-03	1.75E-05	1.43E-07	7.95E-06	1.59E-06	1.11E-05	4.18E-04	2.07E-05	5.18E-04	2.17E-01	1.75E-05	2.54E-05	4.77E-06	1.10E-04	1.02E-04	9.54E-06	9.22E-05
L11222957	2.63E-03	1.68E-05	1.37E-07	7.63E-06	1.53E-06	1.07E-05	4.02E-04	1.98E-05	4.98E-04	2.08E-01	1.68E-05	2.44E-05	4.58E-06	1.05E-04	9.77E-05	9.16E-06	8.86E-05
L11223211	2.97E-03	1.89E-05	1.55E-07	8.60E-06	1.72E-06	1.20E-05	4.53E-04	2.24E-05	5.61E-04	2.35E-01	1.89E-05	2.75E-05	5.16E-06	1.19E-04	1.10E-04	1.03E-05	9.98E-05
L11223443	2.78E-03	1.77E-05	1.45E-07	8.05E-06	1.61E-06	1.13E-05	4.23E-04	2.09E-05	5.25E-04	2.20E-01	1.77E-05	2.58E-05	4.83E-06	1.11E-04	1.03E-04	9.66E-06	9.34E-05
L11223444	3.50E-03	2.23E-05	1.83E-07	1.02E-05	2.03E-06	1.42E-05	5.34E-04	2.64E-05	6.62E-04	2.77E-01	2.23E-05	3.25E-05	6.10E-06	1.40E-04	1.30E-04	1.22E-05	1.18E-04
L11223445	1.97E-03	1.26E-05	1.03E-07	5.72E-06	1.14E-06	8.01E-06	3.01E-04	1.49E-05	3.73E-04	1.56E-01	1.26E-05	1.83E-05	3.43E-06	7.90E-05	7.33E-05	6.87E-06	6.64E-05
L11223447	2.92E-03	1.86E-05	1.52E-07	8.47E-06	1.69E-06	1.19E-05	4.45E-04	2.20E-05	5.52E-04	2.31E-01	1.86E-05	2.71E-05	5.08E-06	1.17E-04	1.08E-04	1.02E-05	9.82E-05
L11223448	2.56E-03	1.63E-05	1.34E-07	7.42E-06	1.48E-06	1.04E-05	3.90E-04	1.93E-05	4.84E-04	2.03E-01	1.63E-05	2.38E-05	4.45E-06	1.02E-04	9.50E-05	8.91E-06	8.61E-05
L11223450	2.75E-03	1.75E-05	1.43E-07	7.96E-06	1.59E-06	1.11E-05	4.19E-04	2.07E-05	5.19E-04	2.17E-01	1.75E-05	2.55E-05	4.78E-06	1.10E-04	1.02E-04	9.56E-06	9.24E-05
L11223451	9.27E-04	5.91E-06	4.84E-08	2.69E-06	5.38E-07	3.76E-06	1.41E-04	6.99E-06	1.75E-04	7.34E-02	5.91E-06	8.60E-06	1.61E-06	3.71E-05	3.44E-05	3.23E-06	3.12E-05
L11223454	3.14E-03	2.00E-05	1.64E-07	9.09E-06	1.82E-06	1.27E-05	4.78E-04	2.36E-05	5.93E-04	2.48E-01	2.00E-05	2.91E-05	5.45E-06	1.25E-04	1.16E-04	1.09E-05	1.05E-04
L11223455	2.92E-03	1.86E-05	1.52E-07	8.46E-06	1.69E-06	1.18E-05	4.45E-04	2.20E-05	5.52E-04	2.31E-01	1.86E-05	2.71E-05	5.08E-06	1.17E-04	1.08E-04	1.02E-05	9.82E-05
L11223461	2.65E-03	1.69E-05	1.38E-07	7.69E-06	1.54E-06	1.08E-05	4.05E-04	2.00E-05	5.02E-04	2.10E-01	1.69E-05	2.46E-05	4.62E-06	1.06E-04	9.85E-05	9.23E-06	8.92E-05
L11223462	2.80E-03	1.78E-05	1.46E-07	8.10E-06	1.62E-06	1.13E-05	4.26E-04	2.11E-05	5.28E-04	2.21E-01	1.78E-05	2.59E-05	4.86E-06	1.12E-04	1.04E-04	9.72E-06	9.40E-05
L11223480	2.97E-03	1.90E-05	1.55E-07	8.62E-06	1.72E-06	1.21E-05	4.53E-04	2.24E-05	5.62E-04	2.35E-01	1.90E-05	2.76E-05	5.17E-06	1.19E-04	1.10E-04	1.03E-05	1.00E-04
L11223483	2.66E-03	1.70E-05	1.39E-07	7.72E-06	1.54E-06	1.08E-05	4.06E-04	2.01E-05	5.03E-04	2.11E-01	1.70E-05	2.47E-05	4.63E-06	1.06E-04	9.88E-05	9.26E-06	8.95E-05
L11223484	2.84E-03	1.81E-05	1.48E-07	8.23E-06	1.65E-06	1.15E-05	4.33E-04	2.14E-05	5.36E-04	2.24E-01	1.81E-05	2.63E-05	4.94E-06	1.14E-04	1.05E-04	9.87E-06	9.54E-05
L11223485	2.54E-03	1.62E-05	1.33E-07	7.36E-06	1.47E-06	1.03E-05	3.87E-04	1.91E-05	4.80E-04	2.01E-01	1.62E-05	2.36E-05	4.42E-06	1.02E-04	9.43E-05	8.84E-06	8.54E-05
L11223486	2.65E-03	1.69E-05	1.38E-07	7.67E-06	1.53E-06	1.07E-05	4.03E-04	1.99E-05	5.00E-04	2.09E-01	1.69E-05	2.45E-05	4.60E-06	1.06E-04	9.82E-05	9.20E-06	8.90E-05
L11223488	2.66E-03	1.69E-05	1.39E-07	7.70E-06	1.54E-06	1.08E-05	4.05E-04	2.00E-05	5.02E-04	2.10E-01	1.69E-05	2.46E-05	4.62E-06	1.06E-04	9.85E-05	9.24E-06	8.93E-05
L11223490	2.43E-03	1.55E-05	1.27E-07	7.06E-06	1.41E-06	9.88E-06	3.71E-04	1.83E-05	4.60E-04	1.93E-01	1.55E-05	2.26E-05	4.23E-06	9.74E-05	9.03E-05	8.47E-06	8.19E-05
L11223491	2.61E-03	1.67E-05	1.36E-07	7.57E-06	1.51E-06	1.06E-05	3.98E-04	1.97E-05	4.94E-04	2.07E-01	1.67E-05	2.42E-05	4.54E-06	1.05E-04	9.69E-05	9.09E-06	8.79E-05
L11223492	2.58E-03	1.64E-05	1.34E-07	7.47E-06	1.49E-06	1.05E-05	3.93E-04	1.94E-05	4.87E-04	2.04E-01	1.64E-05	2.39E-05	4.48E-06	1.03E-04	9.56E-05	8.96E-06	8.66E-05
L11223952	3.03E-03	1.93E-05	1.58E-07	8.78E-06	1.76E-06	1.23E-05	4.62E-04	2.28E-05	5.72E-04	2.40E-01	1.93E-05	2.81E-05	5.27E-06	1.21E-04	1.12E-04	1.05E-05	1.02E-04
L11225200	2.98E-03	1.90E-05	1.56E-07	8.65E-06	1.73E-06	1.21E-05	4.55E-04	2.25E-05	5.64E-04	2.36E-01	1.90E-05	2.77E-05	5.19E-06	1.19E-04	1.11E-04	1.04E-05	1.00E-04
L11225203	3.09E-03	1.97E-05	1.61E-07	8.94E-06	1.79E-06	1.25E-05	4.70E-04	2.33E-05	5.83E-04	2.44E-01	1.97E-05	2.86E-05	5.37E-06	1.23E-04	1.14E-04	1.07E-05	1.04E-04
L11225205	3.01E-03	1.92E-05	1.57E-07	8.71E-06	1.74E-06	1.22E-05	4.58E-04	2.27E-05	5.68E-04	2.38E-01	1.92E-05	2.79E-05	5.23E-06	1.20E-04	1.12E-04	1.05E-05	1.01E-04
L11225206	2.89E-03	1.84E-05	1.51E-07	8.38E-06	1.68E-06	1.17E-05	4.41E-04	2.18E-05	5.46E-04	2.29E-01	1.84E-05	2.68E-05	5.03E-06	1.16E-04	1.07E-04	1.01E-05	9.72E-05
L11225207	2.27E-03	1.44E-05	1.18E-07	6.57E-06	1.31E-06	9.19E-06	3.45E-04	1.71E-05	4.28E-04	1.79E-01	1.44E-05	2.10E-05	3.94E-06	9.06E-05	8.41E-05	7.88E-06	7.62E-05

Table 3-1
Updated Radionuclide Inventories for the MDA B Waste (*Continued*)

Container ID	Inventory (Ci)																
	Am-241	Bi-214	Co-60	Cs-137	Eu-152	H-3	K-40	Pb-214	Pu-238	Pu-239	Ra-226	Ra-228	Sr-90	Th-234	U-234	U-235	U-238
L11225209	2.21E-03	1.41E-05	1.15E-07	6.40E-06	1.28E-06	8.96E-06	3.37E-04	1.66E-05	4.17E-04	1.75E-01	1.41E-05	2.05E-05	3.84E-06	8.83E-05	8.19E-05	7.68E-06	7.42E-05
L11225210	2.43E-03	1.55E-05	1.27E-07	7.04E-06	1.41E-06	9.86E-06	3.70E-04	1.83E-05	4.59E-04	1.92E-01	1.55E-05	2.25E-05	4.22E-06	9.72E-05	9.01E-05	8.45E-06	8.17E-05
L11225211	2.65E-03	1.69E-05	1.38E-07	7.68E-06	1.54E-06	1.07E-05	4.04E-04	2.00E-05	5.01E-04	2.09E-01	1.69E-05	2.46E-05	4.61E-06	1.06E-04	9.83E-05	9.21E-06	8.91E-05
L11225212	1.99E-03	1.27E-05	1.04E-07	5.76E-06	1.15E-06	8.06E-06	3.03E-04	1.50E-05	3.75E-04	1.57E-01	1.27E-05	1.84E-05	3.46E-06	7.95E-05	7.37E-05	6.91E-06	6.68E-05
L11225213	2.78E-03	1.77E-05	1.45E-07	8.06E-06	1.61E-06	1.13E-05	4.24E-04	2.10E-05	5.25E-04	2.20E-01	1.77E-05	2.58E-05	4.84E-06	1.11E-04	1.03E-04	9.67E-06	9.35E-05
L11225214	2.84E-03	1.81E-05	1.48E-07	8.23E-06	1.65E-06	1.15E-05	4.33E-04	2.14E-05	5.37E-04	2.25E-01	1.81E-05	2.63E-05	4.94E-06	1.14E-04	1.05E-04	9.88E-06	9.55E-05
L11225215	2.24E-03	1.43E-05	1.17E-07	6.48E-06	1.30E-06	9.07E-06	3.41E-04	1.68E-05	4.23E-04	1.77E-01	1.43E-05	2.07E-05	3.89E-06	8.94E-05	8.29E-05	7.78E-06	7.52E-05
L11225216	2.99E-03	1.90E-05	1.56E-07	8.66E-06	1.73E-06	1.21E-05	4.55E-04	2.25E-05	5.64E-04	2.36E-01	1.90E-05	2.77E-05	5.19E-06	1.19E-04	1.11E-04	1.04E-05	1.00E-04
L11225217	2.64E-03	1.68E-05	1.38E-07	7.65E-06	1.53E-06	1.07E-05	4.02E-04	1.99E-05	4.99E-04	2.09E-01	1.68E-05	2.45E-05	4.59E-06	1.06E-04	9.79E-05	9.18E-06	8.87E-05
L11225225	2.97E-03	1.89E-05	1.55E-07	8.60E-06	1.72E-06	1.20E-05	4.52E-04	2.24E-05	5.61E-04	2.35E-01	1.89E-05	2.75E-05	5.16E-06	1.19E-04	1.10E-04	1.03E-05	9.97E-05
L11225227	2.93E-03	1.87E-05	1.53E-07	8.49E-06	1.70E-06	1.19E-05	4.46E-04	2.21E-05	5.53E-04	2.32E-01	1.87E-05	2.72E-05	5.09E-06	1.17E-04	1.09E-04	1.02E-05	9.85E-05
L11225228	2.63E-03	1.67E-05	1.37E-07	7.61E-06	1.52E-06	1.07E-05	4.00E-04	1.98E-05	4.96E-04	2.08E-01	1.67E-05	2.44E-05	4.57E-06	1.05E-04	9.74E-05	9.13E-06	8.83E-05
L11225229	2.69E-03	1.72E-05	1.40E-07	7.80E-06	1.56E-06	1.09E-05	4.10E-04	2.03E-05	5.09E-04	2.13E-01	1.72E-05	2.50E-05	4.68E-06	1.08E-04	9.98E-05	9.36E-06	9.05E-05
L11225230	2.58E-03	1.65E-05	1.35E-07	7.48E-06	1.50E-06	1.05E-05	3.93E-04	1.94E-05	4.88E-04	2.04E-01	1.65E-05	2.39E-05	4.49E-06	1.03E-04	9.57E-05	8.97E-06	8.67E-05
L11225231	2.45E-03	1.56E-05	1.28E-07	7.11E-06	1.42E-06	9.95E-06	3.74E-04	1.85E-05	4.63E-04	1.94E-01	1.56E-05	2.27E-05	4.26E-06	9.81E-05	9.10E-05	8.53E-06	8.24E-05
L11225234	2.30E-03	1.46E-05	1.20E-07	6.66E-06	1.33E-06	9.32E-06	3.50E-04	1.73E-05	4.34E-04	1.82E-01	1.46E-05	2.13E-05	3.99E-06	9.19E-05	8.52E-05	7.99E-06	7.72E-05
L11225235	3.13E-03	1.99E-05	1.63E-07	9.07E-06	1.81E-06	1.27E-05	4.77E-04	2.36E-05	5.91E-04	2.47E-01	1.99E-05	2.90E-05	5.44E-06	1.25E-04	1.16E-04	1.09E-05	1.05E-04
L11225240	2.87E-03	1.83E-05	1.50E-07	8.31E-06	1.66E-06	1.16E-05	4.37E-04	2.16E-05	5.42E-04	2.27E-01	1.83E-05	2.66E-05	4.98E-06	1.15E-04	1.06E-04	9.97E-06	9.64E-05
L11225345	3.33E-03	2.13E-05	1.74E-07	9.66E-06	1.93E-06	1.35E-05	5.08E-04	2.51E-05	6.30E-04	2.64E-01	2.13E-05	3.09E-05	5.80E-06	1.33E-04	1.24E-04	1.16E-05	1.12E-04
L11225347	2.80E-03	1.79E-05	1.46E-07	8.13E-06	1.63E-06	1.14E-05	4.27E-04	2.11E-05	5.30E-04	2.22E-01	1.79E-05	2.60E-05	4.88E-06	1.12E-04	1.04E-04	9.75E-06	9.43E-05
L11225348	2.87E-03	1.83E-05	1.50E-07	8.33E-06	1.67E-06	1.17E-05	4.38E-04	2.17E-05	5.43E-04	2.27E-01	1.83E-05	2.67E-05	5.00E-06	1.15E-04	1.07E-04	1.00E-05	9.66E-05
L11225353	2.53E-03	1.61E-05	1.32E-07	7.33E-06	1.47E-06	1.03E-05	3.85E-04	1.91E-05	4.78E-04	2.00E-01	1.61E-05	2.35E-05	4.40E-06	1.01E-04	9.38E-05	8.79E-06	8.50E-05
L11225356	3.06E-03	1.95E-05	1.60E-07	8.87E-06	1.77E-06	1.24E-05	4.67E-04	2.31E-05	5.78E-04	2.42E-01	1.95E-05	2.84E-05	5.32E-06	1.22E-04	1.14E-04	1.06E-05	1.03E-04
L11225357	2.74E-03	1.74E-05	1.43E-07	7.93E-06	1.59E-06	1.11E-05	4.17E-04	2.06E-05	5.17E-04	2.16E-01	1.74E-05	2.54E-05	4.76E-06	1.09E-04	1.02E-04	9.52E-06	9.20E-05
L11225358	2.92E-03	1.86E-05	1.52E-07	8.47E-06	1.69E-06	1.19E-05	4.46E-04	2.20E-05	5.52E-04	2.31E-01	1.86E-05	2.71E-05	5.08E-06	1.17E-04	1.08E-04	1.02E-05	9.83E-05
L11225359	2.76E-03	1.76E-05	1.44E-07	8.00E-06	1.60E-06	1.12E-05	4.21E-04	2.08E-05	5.22E-04	2.18E-01	1.76E-05	2.56E-05	4.80E-06	1.10E-04	1.02E-04	9.61E-06	9.29E-05
L11225361	2.53E-03	1.61E-05	1.32E-07	7.32E-06	1.46E-06	1.03E-05	3.85E-04	1.90E-05	4.77E-04	2.00E-01	1.61E-05	2.34E-05	4.39E-06	1.01E-04	9.37E-05	8.79E-06	8.49E-05
L11225379	2.66E-03	1.70E-05	1.39E-07	7.71E-06	1.54E-06	1.08E-05	4.06E-04	2.00E-05	5.03E-04	2.10E-01	1.70E-05	2.47E-05	4.63E-06	1.06E-04	9.87E-05	9.25E-06	8.94E-05
L11225380	2.84E-03	1.81E-05	1.48E-07	8.24E-06	1.65E-06	1.15E-05	4.34E-04	2.14E-05	5.38E-04	2.25E-01	1.81E-05	2.64E-05	4.95E-06	1.14E-04	1.06E-04	9.89E-06	9.56E-05
L11225381	2.53E-03	1.61E-05	1.32E-07	7.32E-06	1.46E-06	1.02E-05	3.85E-04	1.90E-05	4.77E-04	2.00E-01	1.61E-05	2.34E-05	4.39E-06	1.01E-04	9.37E-05	8.78E-06	8.49E-05
L11225384	2.89E-03	1.85E-05	1.51E-07	8.39E-06	1.68E-06	1.17E-05	4.41E-04	2.18E-05	5.47E-04	2.29E-01	1.85E-05	2.68E-05	5.03E-06	1.16E-04	1.07E-04	1.01E-05	9.73E-05
L11225610	2.07E-03	1.32E-05	1.08E-07	5.99E-06	1.20E-06	8.39E-06	3.15E-04	1.56E-05	3.91E-04	1.64E-01	1.32E-05	1.92E-05	3.60E-06	8.27E-05	7.67E-05	7.19E-06	6.95E-05
L12225754	1.06E-03	6.77E-06	5.54E-08	3.08E-06	6.16E-07	4.31E-06	1.62E-04	8.00E-06	2.01E-04	8.40E-02	6.77E-06	9.85E-06	1.85E-06	4.25E-05	3.94E-05	3.69E-06	3.57E-05
L12225878	2.99E-03	1.91E-05	1.56E-07	8.67E-06	1.73E-06	1.21E-05	4.56E-04	2.25E-05	5.65E-04	2.36E-01	1.91E-05	2.77E-05	5.20E-06	1.20E-04	1.11E-04	1.04E-05	1.01E-04
L12225987	1.10E-03	7.00E-06	5.72E-08	3.18E-06	6.36E-07	4.45E-06	1.67E-04	8.27E-06	2.07E-04	8.68E-02	7.00E-06	1.02E-05	1.91E-06	4.39E-05	4.07E-05	3.82E-06	3.69E-05
L12226003	3.24E-03	2.06E-05	1.69E-07	9.38E-06	1.88E-06	1.31E-05	4.93E-04	2.44E-05	6.11E-04	2.56E-01	2.06E-05	3.00E-05	5.63E-06	1.29E-04	1.20E-04	1.13E-05	1.09E-04
L12226011	2.58E-03	1.65E-05	1.35E-07	7.48E-06	1.50E-06	1.05E-05	3.93E-04	1.94E-05	4.88E-04	2.04E-01	1.65E-05	2.39E-05	4.49E-06	1.03E-04	9.57E-05	8.97E-06	8.67E-05
L12226120	3.35E-03	2.14E-05	1.75E-07	9.71E-06	1.94E-06	1.36E-05	5.11E-04	2.52E-05	6.33E-04	2.65E-01	2.14E-05	3.11E-05	5.82E-06	1.34E-04	1.24E-04	1.16E-05	1.13E-04
L12226200	3.88E-04	2.47E-06	2.02E-08	1.12E-06	2.25E-07	1.57E-06	5.91E-05	2.92E-06	7.32E-05	3.07E-02	2.47E-06	3.59E-06	6.74E-07	1.55E-05	1.44E-05	1.35E-06	1.30E-05
L12226279	3.19E-03	2.04E-05	1.67E-07	9.26E-06	1.85E-06	1.30E-05	4.87E-04	2.41E-05	6.04E-04	2.53E-01	2.04E-05	2.96E-05	5.56E-06	1.28E-04	1.19E-04	1.11E-05	1.07E-04
W734929	1.93E-04	1.23E-06	1.01E-08	5.61E-07	1.12E-07	7.85E-07	2.95E-05	1.46E-06	3.66E-05	1.53E-02	1.23E-06	1.79E-06	3.37E-07	7.74E-06	7.18E-06	6.73E-07	6.51E-06
W734930	6.83E-05	4.36E-07	3.56E-09	1.98E-07	3.96E-08	2.77E-07	1.04E-05	5.15E-07	1.29E-05	5.40E-03	4.36E-07	6.34E-07	1.19E-07	2.73E-06	2.53E-06	2.38E-07	2.30E-06
W734948	6.83E-05	4.36E-07	3.56E-09	1.98E-07	3.96E-08	2.77E-07	1.04E-05	5.15E-07	1.29E-05	5.40E-03	4.36E-07	6.34E-07	1.19E-07	2.73E-06	2.53E-06	2.38E-07	2.30E-06
W735081	4.61E-04	2.94E-06	2.41E-08	1.34E-06	2.67E-07	1.87E-06	7.03E-05	3.47E-06	8.71E-05	3.65E-02	2.94E-06	4.28E-06	8.02E-07	1.84E-05	1.71E-05	1.60E-06	1.55E-05
W736628	2.67E-04	1.70E-06	1.39E-08	7.74E-07	1.55E-07	1.08E-06	4.07E-05	2.01E-06	5.05E-05	2.11E-02	1.70E-06	2.48E-06	4.64E-07	1.07E-05	9.91E-06	9.29E-07	8.98E-06
W802093	2.13E-03	1.36E-05	1.11E-07	6.18E-06	1.24E-06	8.65E-06	3.25E-04	1.61E-05	4.03E-04	1.69E-01	1.36E-05	1.98E-05	3.71E-06	8.53E-05	7.91E-05	7.42E-06	7.17E-05

4.0 Conclusion

This SA documents updated radionuclide concentration distributions (Table 2-1 and Appendix C) and mean inventory values (Table 3-1) for 17 radionuclides in 139 containers of MDA B waste disposed of during 2014 at MDA G. These updated mean inventories are based on the distributions presented in Appendix C, which were used to calculate the most recent dose and radon fluxes projected for the Area G PA/CA. Therefore, the revisions to the MDA B waste inventories do not change the doses and radon fluxes projected for the Area G PA/CA model presented in SA 2014-004 (French and Shuman, 2015).

This SA initiates the following action: ***The inventory in the WCATS database associated with the 139 containers of MDA B waste disposed during 2014 at MDA G will be updated to the values presented in Table 3-1 of this SA.*** This update to WCATS will result in inventories that are consistent with (1) the inventories included in WCATS for the previous 1,144 containers of MDA B waste already disposed of during 2011 and 2012 (French and Shuman, 2013), and (2) the mean values of the concentration distributions used in the most current MDA G inventory model as implemented in the most current version of the PA/CA model (French and Shuman, 2015). Updating the inventory in the WCATS database associated with those MDA B wastes disposed of during 2014 at MDA G with the values presented in Table 3-1 of this Special Analysis will correct an inconsistency in WCATS for this specific MDA B waste.

5.0 References

Department of Energy (DOE), 2001, Radioactive Waste Management, U.S. Department of Energy Order DOE O 435.1 (change 1 to document issued July 9, 1999), August 28.

Los Alamos National Laboratory (LANL), 2008, *Performance Assessment and Composite Analysis for Los Alamos National Laboratory Technical Area 54, Material Disposal Area G – Revision 4,* Los Alamos National Laboratory Report LA-UR-08-06764, October.

French, S.B. and R. Shuman, 2013, *Special Analysis 2013-001: Update of MDA B Waste Inventories in the Los Alamos National Laboratory Low-Level Waste Database,* Los Alamos National Laboratory Report LA-UR-13-22618, April.

French, S.B. and R. Shuman, 2015, *Special Analysis 2014-004: Transition of Transuranic Waste Data to the Waste Compliance and Tracking System,* Los Alamos National Laboratory Report LA-UR-15-20366, January.

Los Alamos National Laboratory (LANL), 2016, *Enduring Mission Waste Management Plan at Los Alamos National Laboratory,* Los Alamos National Laboratory Controlled Publication LA-CP-16-20050, February.

Appendix A
Radiological Waste Characterization of Material Disposal Area B Waste

MDA B Radiological Waste Characterization Using MAR Gamma Spectroscopy
Revision 1

Introduction

The excavation and cleanup of the historic Manhattan Project Landfill, now referred to as MDA B, at Los Alamos is approximately 50% complete. Since the inception of this cleanup project, thorough sampling and analysis of this 6 acre landfill has been performed. Historic characterization of the MDA B landfill is summarized in the *Investigation/Remediation Work Plan for Material Disposal Area B, Solid Waste Management Unit 21-015, at Technical Area 21, Revision 1*, LA-UR-06-6918 October 2006 (IRWP). Appendix B of the IRWP, titled Historical Investigation Report (HIR), presents summaries of the historical data collected on the contaminants from the MDA B site over the past 50 years (1966-2001). Based on historical assessment of the MDA B landfill, "Am-241, Cs-137, Pu-238, Pu-239 and tritium were detected consistently across the surface of MDA B. Plutonium 239 is the most consistently detected radionuclide..."

In September 2009, the *Final Investigation Report for Direct-Push Sampling of MDA B* was submitted to the New Mexico Environmental Restoration Program. This report summarized a sampling effort of the MDA B landfill involving 124 sampling points at various depths. The results from the Direct-Push sampling have proven to be consistent with the historic sampling completed in MDA B summarized in the HIR.

Purpose

This paper describes a basis and a calculation for defining a radiological distribution based on the use of the MAR analysis of Am-241. Table 1 provides the necessary scaling factors for the individual isotopes based on the gamma spectroscopy analysis of Am-241.

Scope

This document is limited in that it will define the radiological characterization to the contaminated MDA B "soils" and "landfill" material. The fill material and soil in MDA B is the contaminated material, located below the clean cap (fill material) covering the surface of the landfill.

Characterization of the MDA B landfill as a hazardous waste is outside of the scope of this document; never the less, GEL sampling data, with the exception of anomalies identified in the field, has determined that that the waste as a whole is not RCRA hazardous waste. See Due Diligence Review for Excavation Materials From MDA B (TA21-MDAB-RPT-00001). Characterization of anomalies is addressed in the MDA B Sampling and Analysis Plan.

Assumptions

1. The isotopic distribution is based on validated analytical results from a NELAC certified laboratory of MDA B waste samples.
2. Radionuclides are evaluated as reported on analytical reports; LANL background concentrations of these nuclides are not (subtracted out) considered. In other words, all radionuclides are assumed to have a background value of zero.

3. U-234, U-235 and U-238 are reported at their highest analyzed values due to their low concentrations in the waste. Although the highest concentrations found for these uranium isotopes do not reflect the ratios found in natural uranium (nat-U), process knowledge suggests that a significant portion of the uranium activity is derived from nat-U.
4. Th-234 in the U-238 decay chain will not be reported. Daughter products of natural occurring uranium are assumed to be in secular equilibrium within the waste.
5. The average concentration of K-40 measured in the MDA B waste is below the LANL background concentration and therefore will not be reported.
6. The Tritium concentration will be assigned based on twice the average concentration measured in the GEL data (1.5 pCi/g).

MDA B Sampling and Analysis Plan

From the outset, the radiological characterization of waste removed from MDA B has been defined by the MDA B Sampling and Analysis Plan. This plan called for the collection of increment (composite) samples collected from the contaminated soil / fill material. Each of these composite samples typically represented six 20 yard bins. Each of these bins were analyzed off site by General Engineering Laboratories, a NELAC certified analytical laboratory. The following radiological analytes were evaluated within each sample.

- Am-241: Alpha Spectroscopy
- Pu-238, Pu-239/240: Alpha Spectroscopy
- Tritium: Liquid Scintillation
- Gamma Spectroscopy
- U-234, U-235/236 and U-238 by ISO_U
- Sr-90

By February of 2011 over 800 bins of contaminated soil / fill material have been removed from MDA B. These 800 bins have been characterized from 92 composite samples, analyzed for the full suite of radioactive contaminants listed above. 92 samples, representing 3348 individual isotopic data points collected within the MDA B Area of Concern (AOC) will be used to establish the average properties of the waste and form the basis for the "bounding characterization" based on the MAR gamma spectroscopy.

The development of this bounding characterization will permit the safe transportation and disposal of MDA B waste without the need for continuous sampling. Per the latest revision of the MDA B Sampling and Analysis Plan, sampling will only be required when anomalies are identified.

Characterization of Pu-239 from MAR Gamma Spectroscopy

In addition to the comprehensive radiological sampling and analysis of the MDA B contaminated soil by GEL, on site gamma spectroscopy (MAR) has been used extensively in the identification of radiological contaminants. The MAR gamma spectroscopy has an advantage over the GEL radiological data in that a MAR sample is not a composite from multiple bins, but an individual sample collected and analyzed from each waste bin; or alternatively, one sample for approximately 30,000 lbs of waste. This gamma spectroscopy uses the ISOCS modeling software from Canberra to measure gamma emitting contaminants. This analytical method, referred to as the "MAR characterization" is effective for the measurement of gamma emitting nuclides. It is recognized that the gamma spectroscopy by the MAR method does a relatively poor job of measuring Pu-239, the primary radiological contaminant in this wastestream.

Given that the MAR analysis does a reasonable job at measuring Am-241 but not Pu-239, calculation of the Pu-239 to Am-241 ratios from GEL data has been employed to indirectly and conservatively characterize the Pu-239 concentration. This process of characterizing Pu-239 in MDA B based on the Am-241: Pu-239 ratio was initiated in November of 2010 based on the complete composite population of 81 samples at that time.

This characterization protocol considered the population of 92 composite samples of contaminated soil analyzed by GEL where the concentration of Pu-239 by alpha spectroscopy was compared to the Am-241 as measured by gamma spectroscopy. In order to improve the quality of the data, the data was reviewed and scrubbed by the following techniques.

- Am-241 values below 2 pCi/g were eliminated due to their proximity to the MDA value, where data quality is suspect.
- The two highest ratios of Pu-239 to Am-241 and the two lowest ratios of Pu-239 to Am-241 were removed from the data to prevent outliers from inappropriately skewing the data set.

For the remaining 52 sample pairs of Pu-239 and Am-241, the individual Pu-239 to Am-241 ratios were calculated. For this ratio data, the standard deviation, and upper 95% confidence interval was calculated. The 95% confidence interval for the Pu-239 to Am-241 ratio was calculated at 44. In order to conservatively estimate the Pu-239 concentration from the Am-241 value from the onsite (MAR) gamma spectroscopy, one can multiply by the 95% confidence interval for the Pu-239: Am-241 ratio (44) x the Am-241 concentration. For example, where the MAR gamma spectroscopy measures Am-241 at 10 pCi/g, the Pu-239 concentration is determined by multiplying the Am-241 value of 10 pCi/g x 44 to obtain a value of 440 pCi/g Pu-239.

Importantly, based on the historic data from more than 92 composite samples representing greater than 50% of the MDA B cleanup, Am-241 and Pu-239 taken together represent greater than 96% of the radiological activity in the contaminated soil/fill material.

Characterizing the Minor Isotopes

The minor isotopes within the MDA B cumulatively account for 4% of the activity in the waste. The quantification of the major isotopes is based on the analysis by GEL of the 92 composite samples of the MDA B waste collected in 2010. The relative percents of the minor isotopes were determined based on the average concentrations measured in the 92 bin population. The average concentrations of the minor isotopes were compared to, scaled against, the average Am-241 concentration to obtain a multiplier or scaling factor that allows the concentrations of the minor isotopes to be derived from the onsite MAR analysis of Am-241. For example, Cs-137 in the GEL sample population has an average concentration of 43 pCi/g. This represents 54% (.54x) of the average Am-241 concentration of 79.5 pCi/g measured in the MDA B waste. For future samples then, to obtain the Cs-137 from the Am-241 concentration obtained via the MAR analysis, you multiply by the scaling factor of .54.

In addition to obtaining Am-241 scaling factors for certain isotopes based on the average percent radioactivity, the maximum reported values are also used to assign isotopic concentrations for the uranium isotopes and tritium. For the MDA B waste this approach is reasonable since the uranium isotopes are found at such low levels. The total uranium concentration (from all isotopes) in the waste, on average is less than 13 pCi/g. For tritium, the average concentration measured within the MDA B waste is .68 pCi/g. Conservatively, tritium activity is defined at roughly twice the average concentration, or 1.5 pCi/g.

See Table 1 below for the quantification methods of the minor and major isotopes, including the applicable Am-241 scaling factors and assigned fixed concentrations for uranium and tritium.

Table 1. Radioactive Composition and Waste Characterization Information.

Isotope	Average Conc. pCi/g	% Activity by Isotope	Isotope Category	Basis for Quantification	Am-241 Scaling Factor or Fixed Value pCi/g
Pu-239	3210.59	93.84	Major	Statistical Evaluation of MDA B GEL Sample Analysis	44x
Am-241	79.49	2.32	Major	MAR Gamma Spectroscopy	1.0
Cs-137	42.85	1.25	Minor	Relative percent of Radioactivity in MDA B GEL Sample Population	.54x (1.25/2.32)
Pu-238	16.83	.49	Minor	Relative percent of Radioactivity in MDA B GEL Sample Population	.22x (.49/2.32)
Sr-90	6.33	.19	Minor	Relative Percent of Radioactivity in MDA B GEL Sample Population	.08x (.16/2.32)
U-234	6.40	.19	Minor	Maximum value measured in GEL sample population. Reported 49% of Natural Uranium. (152 pCi/g)	@ 152 pCi/g
U-238	5.75	.17	Minor	Maximum value measured in GEL sample population. 159 pCi/g	159 pCi/g
U-235	.56	.02	Minor	Maximum value measured in GEL Sample Population. 8.24 pCi/g	8.24 pCi/g
H-3	.68	.02	Minor	Twice the average concentration.	1.5 pCi/g
Various: K-40, Th-234	N/A	~1.0	NORM & Rad. Decay	MDA B GEL Sample Analysis. See	N/A

MAR Gamma Spectroscopy Values below MDA

A significant portion, approximately 20% of MAR measurements for Am-241 are expected to be reported as less than "Minimum Detectable Activity", or < MDA. The onsite MAR gamma spectroscopy has difficulty measuring Am-241 at less than 2 pCi/g and therefore reports the Am-241 concentration as a less than value, such as < 1.5 pCi/g Am-241. In this case, in order to estimate the radioactivity contributed by the other isotopes, the less than symbol is discounted an the numerical value is used as the Am-241 concentration. If Am-241 is reported as < 2.0 pCi/g, the Am-241 concentration is reported as 2.0 pCi/g allowing the other isotopes to be assigned based on the Am-241 scaling factors described previously.

It is understood that the MAR characterization is conservative and environmentally protective, and may result in a small quantity of industrial waste being managed as low level waste. However it is believed that the labor cost, sampling cost and schedule delays from sampling and processing the associated paperwork to insure that the waste is indeed industrial waste far exceeds the environmental and budgetary cost of managing the waste as low level.

Radioactivity Characterization via MAR Gamma Spectroscopy

An Excel spreadsheet has been employed as a template that contains each of the Am-241 scaling factors and fixed concentrations for the uranium and tritium constituents. Using this template the required waste information is input including:

- Container identification number
- Waste description
- Waste Weight
- Waste Volume
- MAR Am-241 concentration or Am-241 MDA

Once these five pieces of information are input into the Excel template, each of the isotopes is automatically quantified in the three commonly used units: pCi/g, Ci/bin and Ci/M^3 of waste.

Summary

At MDA B, the Am-214 concentration is accurately characterized in the waste by skilled chemists via gamma spectroscopy using ISOCs modeling software. Although the gamma spectroscopy analysis does a relatively poor job of measuring Pu-239, the major contaminant in the contaminated soil / fill material, historical analytical data from GEL has been used with the MAR analysis to determine the relative abundance of the various isotopes in the MDA B waste. The relative concentration of Am-241 to Pu-239 is the most important value because Pu-239 represents 94% of the radioactivity in the waste. The Pu-239 to Am-241 ratio was statistically evaluated from 92 composite samples from the soil removed from MDA B over the course of the last 7 months. Using this GEL data, a Pu-239 ratio (read scaling factor) of 44 was conservatively established based on a 95% confidence interval. To obtain a Pu-239 radioactivity concentration, the Am-241 concentration from the bin specific MAR analysis is obtained by multiplying by 44. By following the MDA B sampling and analysis plan, seven minor isotopes were identified. Three of the seven minor isotopes are quantified from Am-241 scaling factors obtained based on their relative abundance measured in the GEL data set. The uranium isotopes, since there concentrations are so low, are defined based on their maximum measured values. Although tritium is a minor isotope, with an average concentration of .68 pCi/g; a conservative approach is employed where all packages are assumed to contain 1.5 pCi/g of tritium.

Author, Charles Hunt Charles Hunt Date 2/16/2011

Reviewer, Glenn Siry [signature] Date 2-16-2011

Appendix B
Unreviewed Disposal Question Evaluation 1501

ATTACHMENT 1
Page 1 of 3

UNREVIEWED DISPOSAL QUESTION EVALUATION WORKSHEET

Unreviewed Disposal Question Evaluation Worksheet			
8.1[1] UDQE Number:1501		8.1[2] Date:11-13-2014	
Section 1: Proposed Activity			
8.1[3] Update radionuclide inventories for MDA B waste disposals			
8.1[4]Section 1.1: Summary description of activity/change Radionuclide concentration distributions were developed to model MDA B waste that was to be disposed of in pits 37 and 38. The inventories listed in WCATS for this waste differ from the inventories calculated using the mean values of these concentration distributions. The database is to be updated with the mean inventories to address this discrepancy; this UDQE evaluates whether this update to the database inventories constitutes a UDQ. A similar UDQE (1301) was conducted in 2012 for 1,144 containers of waste that had undergone disposal. This UDQE (1501) addresses 139 containers of MDA B waste that have been disposed of since that time.			
8.1 [6] Section 1.2: Reference UDQE 1301; Special Analysis 2013-001: Update of MDA B Waste Inventories in the Los Alamos National Laboratory Low-Level Waste Database			
8.1[7] Section 1.3: Is the activity/change addressed by a previous UDQE or the LLW authorization basis documents?		☐ YES	☒ NO
8.1[8][A][a] UDQE No.:	Date of UDQE:		
8.1[8][A][b] Justification for not requiring a UDQE			

ATTACHMENT 1
Page 2 of 3

UNREVIEWED DISPOSAL QUESTION EVALUATION WORKSHEET

8.1[1] UDQE Number: 1501		8.1[2] Date: 11-13-2014	
8.1[10]	**Section 2: UDQE– Screening**		
2.1	Waste Characteristics ☒	Not Applicable	
a.	Does the requested variance to the Area G WAC involve a technical issue (including radionuclide content, container specifications, amount of void space in containers, waste form, etc.)?	☐ YES	☐ NO
b.	Does disposal of radioactive waste within Area G which requires a variance to the LANL WAC, P 930-1?	☐ YES	☐ NO
c.	Does the proposed activity involve the retrieval of below ground waste?	☐ YES	☐ NO
2.2	Disposal Practices ☒	Not Applicable	
a.	Does the depth of waste placement exceed the depth of placement modeled in the PA/CA?	☐ YES	☐ NO
b.	Will the distance between the top of the disposed waste and the ground surface be less than the distance specified in the PA/CA?	☐ YES	☐ NO
2.3	Procedures /Documents/Systems ☐	Not Applicable	
a.	Does the procedure or process changes define, control or administer LLW characterization and/or disposal activities?	☐ YES	☒ NO
b.	Does the activity invoke changes to DAS?	☐ YES	☒ NO
c.	Does the activity change the Chem/LL database information that impacts LLW volume, activity, and or mass information, or the methods for calculating database quantities?	☒ YES	☐ NO
2.4	Site/Facility Construction ☒	Not Applicable	
a.	Does the proposed activity involve the addition/modification of structures, affect water runoff configurations, or impact the characterization/monitoring wells and/or equipment which are currently located at Area G?	☐ YES	☐ NO
b.	Does the proposed activity bring the facility/site back into compliance with current assumptions regarding site configurations and operations as defined within PA/CA and applicable Area G disposal authorization basis documents?	☐ YES	☐ NO
c.	Does the proposed activity involve the drilling of new boreholes or monitoring wells?	☐ YES	☐ NO
d.	Will the proposed activity require changes in site grading or storm waste runoff control provisions?	☐ YES	☐ NO
2.5	New Disposal Unit Construction ☒	Not Applicable	
a.	Do any design parameters differ from the PA/CA and applicable Area G disposal authorization basis documents? These parameters include, but are <u>not</u> limited to, disposal unit dimensions, distance of units from the mesa edge, and depth of disposal units.	☐ YES	☐ NO
b.	Is there construction of new site structures or facilities?	☐ YES	☐ NO
c.	Is there contruction activities for removal of existing site structures or features?	☐ YES	☐ NO
d.	Is there construction activities for creation of new disposal units (pits and shafts)?	☐ YES	☐ NO
2.6	Interim/ Final Disposal Unit Closure ☒	Not Applicable	
a.	Will the minimum depth of cover between the top of the waste and the ground surface be less than that specified in the PA/CA and applicable DAB documents?	☐ YES	☐ NO
b.	Do any design parameters of the cover differ from the PA/CA and applicable Area G disposal authorization basis documents? These parameters include, but are <u>not</u> limited to, slope, material properties, performance characteristics, and depth.	☐ YES	☐ NO
c.	Does the proposed activity affect the closure of active disposal pits and shafts or installation of operational or final covers?	☐ YES	☐ NO

ATTACHMENT 1 Page 3 of 3		
8.1[1] UDQE Number:1501	8.1[2] Date:11-13-2014	
If the answers to all applicable questions in Section 2 are "No", the activity/change does constitute a UDQ; proceed to Section 3: UDQ Evaluation Summary and Approval.		
Section 3: UDQ Evaluation Summary and Approval		
UDQ Number:1501	Date:11-13-2104	
8.1[11] ☐ This activity/change does not (all responses are "No") constitute a UDQ		
☒ This activity/change does (at least one response is "YES") constitute a UDQ and a Special Analysis is required prior to implementing the activity/change		
A special analysis is to be prepared to document the revised radionuclide inventories. An analysis of the impacts of the changes in inventories on the doses and radon fluxes projected for the performance assessment and composite analysis is not required. That is because UDQE 1403 and special analysis 2014-004 (conducted to evaluate the impacts of transitioning transuranic waste data from the CHEM\LL database to WCATS) used radionuclide inventory distributions from which the revised inventories discussed above were derived.		
8.1[12] UDQ Evaluator		
Name (Print)Rob Shuman	Signature: Rob Shuman	Date: 11-13-14
8.1[13] UDQE Reviewer		
Name (Print) Sean French	Signature: Sean French	Date: 11-13-2014
ADC: ☑ Unclassified ☐ OUO ☐ UCNI ☐ Classified		
Derivative Classifier		
Name (Print) R. MORLEY	Signature: [signature]	Date: 11/13/14
Section 4 FINAL APPROVAL		
8.1[19]/9.[7] LLW Operations Manager:		
Name (Print)	Signature:	Date:

Appendix C
Radionuclide Concentration Distributions for Material Disposal Area B Waste

C.1 Introduction

This attachment discusses the methods used to develop radionuclide concentration distributions for Material Disposal Area (MDA) B waste that has been, or will be, disposed of at the Technical Area 54, Area G disposal facility. The distributions were developed on the basis of sample data collected from containers or bins of waste following retrieval of the material from the disposal units at MDA B. They describe the variance about the mean activity concentrations in the waste rather than the variance of the sample data. Using distributions of the mean activity concentrations is consistent with the spatio-temporal scale of the modeling conducted in support of the Area G performance assessment and composite analysis. Those analyses evaluate the impacts of radionuclide releases from the totality of the waste disposed of at the facility. In terms of the MDA B waste, then, the inventory of interest is the activity of each radionuclide summed across all containers of waste, which corresponds to the average concentration across all such containers.

The concentration distributions were defined for all radionuclides using lognormal distributions. The lognormal distribution was used since it is strictly positive, can fit a variety of shapes, and may be easily parameterized using maximum likelihood methods. Although a truncated normal distribution may fit the data when the distribution of the mean activity concentration is not highly skewed, a lognormal distribution provides a better fit when the distribution is skewed.

C.2 Development of Waste Distributions

Radionuclide activity concentration data are available from several sources. Concentrations were measured for a full suite of radionuclides in 92 composite samples that were typically collected from six 15.3-m^3 (20-yd^3) containers or bins of waste and combined to form the composite sample; Am-241 concentrations were measured in 1,144 bins of waste that have been disposed of at Area G and an additional 137 bins awaiting disposal. The objective of this characterization was to estimate mean concentrations of all radionuclides found in these 1,281 containers of MDA B waste.

Mean concentration distributions for Am-241 were developed directly using the Am-241 measurements that were collected from the 1,281 containers of waste. Concentrations of plutonium isotopes in the waste were found to correlate to the Am-241 contents; these correlations were used to estimate Pu-238 and Pu-239/240 concentrations in the waste awaiting disposal and the waste that has already been disposed of at Area G. Concentration distributions were established for the remaining radionuclides directly from the analytical data collected from the 92 composite samples. These composite samples were assumed to be representative of the material in the 1,281 waste containers. Although these samples were collected from a different set of waste containers, MDA B is the source of all the waste.

C.2.1 Assumptions

Several assumptions were made before the radionuclide distributions of interest were modeled.

- The data are statistically exchangeable. This assumption means that later samples behave like earlier samples, so all possible orderings in which data are collected are equally likely and the future is based on the past. Implicit in this assumption is that the waste in the bins is a random mixture of the original contaminated waste retrieved at MDA B.

  Under this assumption, differences in radionuclide contents between subsets of bins are not expected a priori. It can, perhaps, be argued that this is the case for the MDA B waste, although examination of the Am-241 data suggests some subsets of bins have different characteristics than others. These bins were divided into different categories based on the type of waste they contain or the origin of the waste (e.g., regular, roadside, and debris); the roadside bins were found to contain much lower concentrations of Am-241 than other bins. On the other hand, large numbers of bins have been, and will be, placed next to one another in the disposal pits at Area G, functionally mixing the different types of bins. Using statistical methods that average across potential differences is not unreasonable under these conditions.

  More complex statistical modeling than that presented here would be required if the data cannot be considered exchangeable. For example, it may be more appropriate to develop concentration distributions for each subpopulation of interest (e.g., roadside bins). If the exchangeability assumption does not hold, it is possible the variance in the distributions presented here is overestimated. However, the effect is likely to be small given the final use of the distributions in the performance assessment and composite analysis modeling.

- The multivariate statistical approach described below includes the estimation of correlation structures, such as those that exist between Am-241, Pu-238, and Pu-239. However, the GoldSim® models used to develop inventories for the performance assessment and composite analysis cannot handle multivariate correlation structures. In a case such as this, GoldSim accommodates the correlations between two of the three pairs of interest. The third correlation is, in effect, induced through simulation, although that correlation is likely to be underestimated by the software. The impact on the GoldSim output of underestimating correlation between activity concentrations for these radionuclides is to underestimate the variance in the projected distributions of radionuclide concentrations in environmental media and dose. This effect is, however, likely to be small.

- Differences in the sampling and analytical methods used to establish Am-241 concentrations in the 92 composite samples and the 1,281 containers of waste that have undergone, or are awaiting, disposal may lead to differences in relative bias and precision for the two sets of measurements. The 92 samples were collected from several bins and combined to form the composite samples; concentrations of Am-241 were measured using alpha spectroscopy. In contrast, the Am-241 concentrations were estimated for the 1,281 containers using external methods conducted using an on-site gamma-spectroscopy unit. The data indicate that the Am-241 concentrations in the 92 samples have a different distribution than the concentrations measured using gamma-spectroscopy measurements. These differences could be the result of differences in the analytical methods, or they could indicate that there are two populations of containers having different concentrations.

  It is not clear if testing or quality assurance was performed to ensure the results from the different sampling and analytical approaches are comparable. Nevertheless, an assumption was made that they are comparable and that all data are equally representative and exchangeable. This assumes there is no relative systematic bias among any of the measurements from the different sampling and analysis methods and the variance or precision is the same for all measurements.

- The 92 composite samples subjected to full characterization are representative of the other waste for which distributions are developed, including the 1,144 bins already disposed of at Area G and the 137 containers awaiting disposal. As discussed in conjunction with the first assumption, there are clear differences in the data between some subsets of waste. However, it is assumed they are equally representative of the waste, following the assumption of exchangeability.

  In general, the US Environmental Protection Agency has established data quality indicators that support evaluation of the quality of environmental data. These include precision, accuracy, representativeness, comparability, and completeness. The issues of representativeness and comparability are in question without recourse to further information. The assumption is made here that there are no representativeness and comparability issues so the required statistical analysis can be performed.

C.2.2 Exploratory Data Analysis

Exploratory data analysis was conducted to better understand the nature of the data collected from the 92 composite samples, the 1,144 bins of waste that have already been disposed of at Area G, and the 137 containers awaiting disposal. The 1,144 bins of waste that have already been disposed of at Area G were placed in two layers within pits 37 and 38: an upper headspace layer and the institutional waste layer. The exploratory data analysis distinguished between the Am-241 data for the waste in the two layers.

The assumption regarding data representativeness (the fourth assumption discussed above) can be roughly checked using box plots of the Am-241 concentrations in the 92 composite samples, the 565 waste containers disposed of in the headspace, the 579 containers placed in the institutional waste layer, and the 137 waste containers awaiting disposal in the institutional waste layer. These boxplots are provided in Figure C-1; separate plots are provided for the original data and the log-transformed data. For simplicity, these datasets are referred to as MDA B, PD-H (previously disposed of in the headspace), PD-IWL (previously disposed of in the institutional waste layer), and TBD-IWL (to be disposed of in the institutional waste layer) in the plots.

The Am-241 concentrations in the PD-H waste containers are similar to, but less variable than, those observed for the 92 composite samples. Mean concentrations in the PD-IWL waste and the TBD-IWL waste are greater than those seen in the PD-H waste. This pattern is to be expected because the headspace layer is reserved for lower-activity waste. The Am-241 concentrations in the PD-IWL waste and the TBD-IWL material appear to be greater than those from the other two data sources on average but fall within the same range of the concentrations measured in the 92 composite samples. The plots suggest there may be some bias in the gamma-spectroscopy measurements relative to the alpha-spectroscopy measurements collected from the 92 composite samples.

Some of the radionuclide concentrations measured in the 92 composite samples were reported as 0 pCi/g; zero values were replaced with half of each isotope's lowest nonzero measurement. Box plots of the data were developed for each radionuclide found in the 92 composite samples using original and log scales. Correlations were calculated on both the original and log scales, and the radionuclides were divided into distinct groups based on their correlation structures. The correlations are shown in Figures C-2 through C-5; the boxplots appear in Figures C-6 through C-21. A summary of the data is provided in Table C-1.

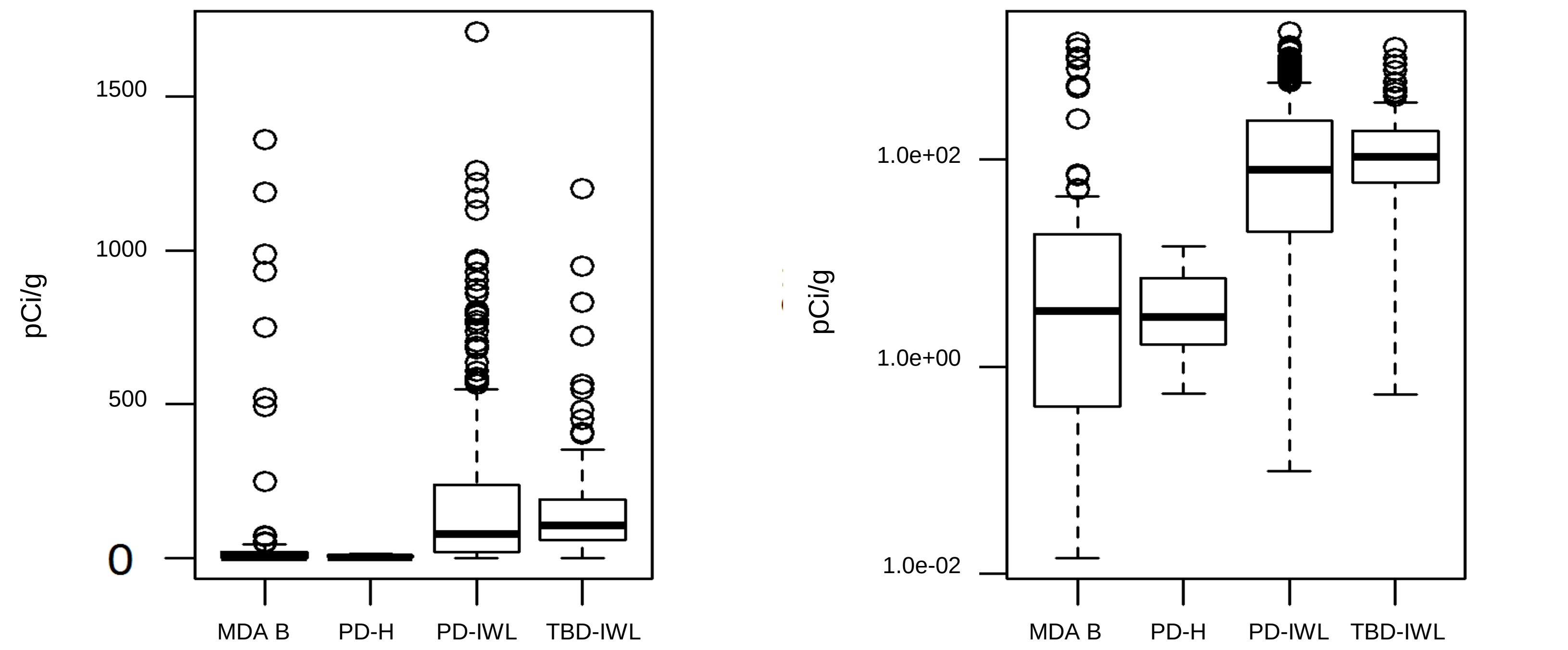


Figure C-1
Boxplots of Am-241 Measurements (from MDA B waste bins, previously disposed bins placed in the headspace and institutional waste layer, and to-be-disposed-of bins)

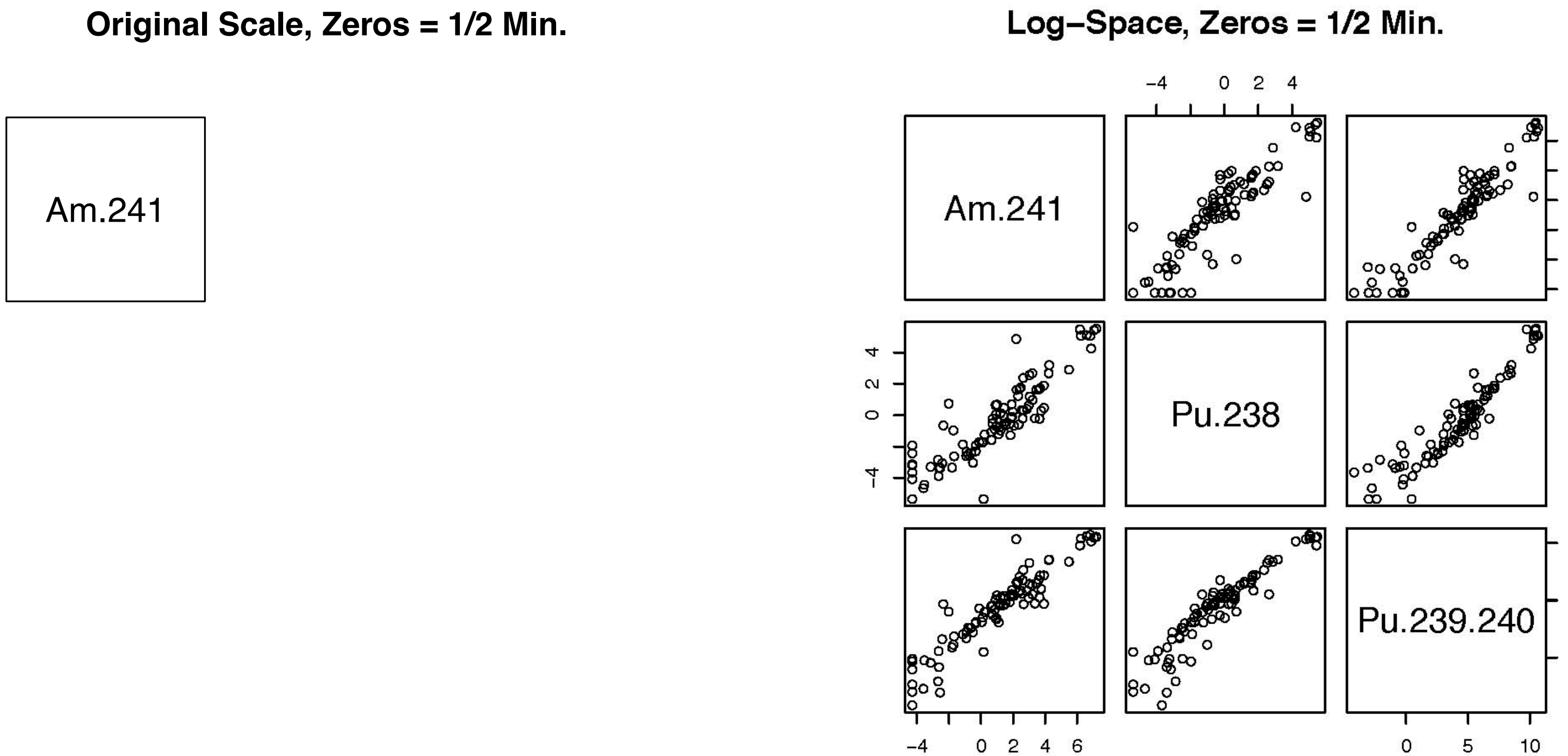


Figure C-2
Group Correlations for Am-241, Pu-238, and Pu-239/240, MDA B Data

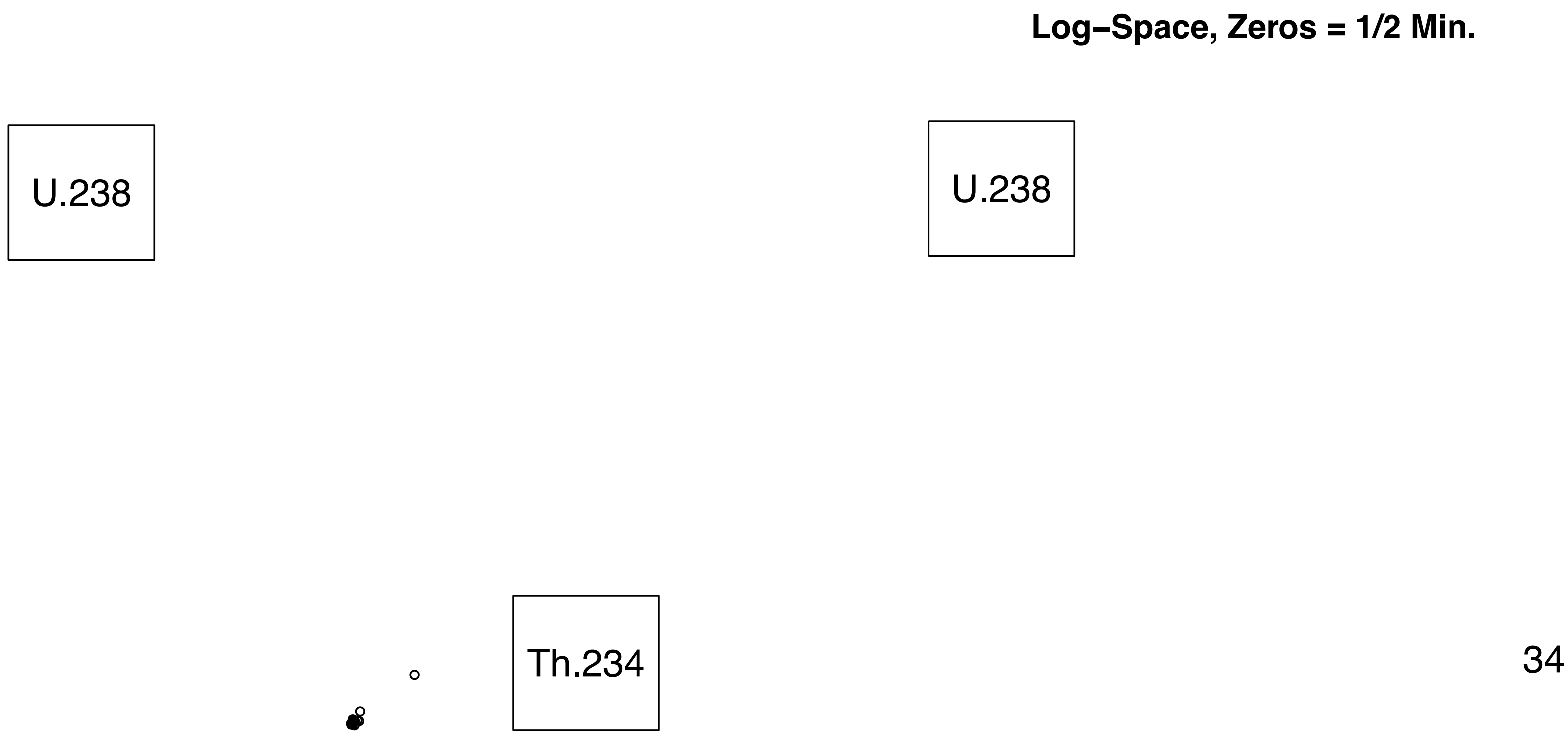


Figure C-3
Group Correlations for U-234, U-235, U-238, and Th-234, MDA B Data

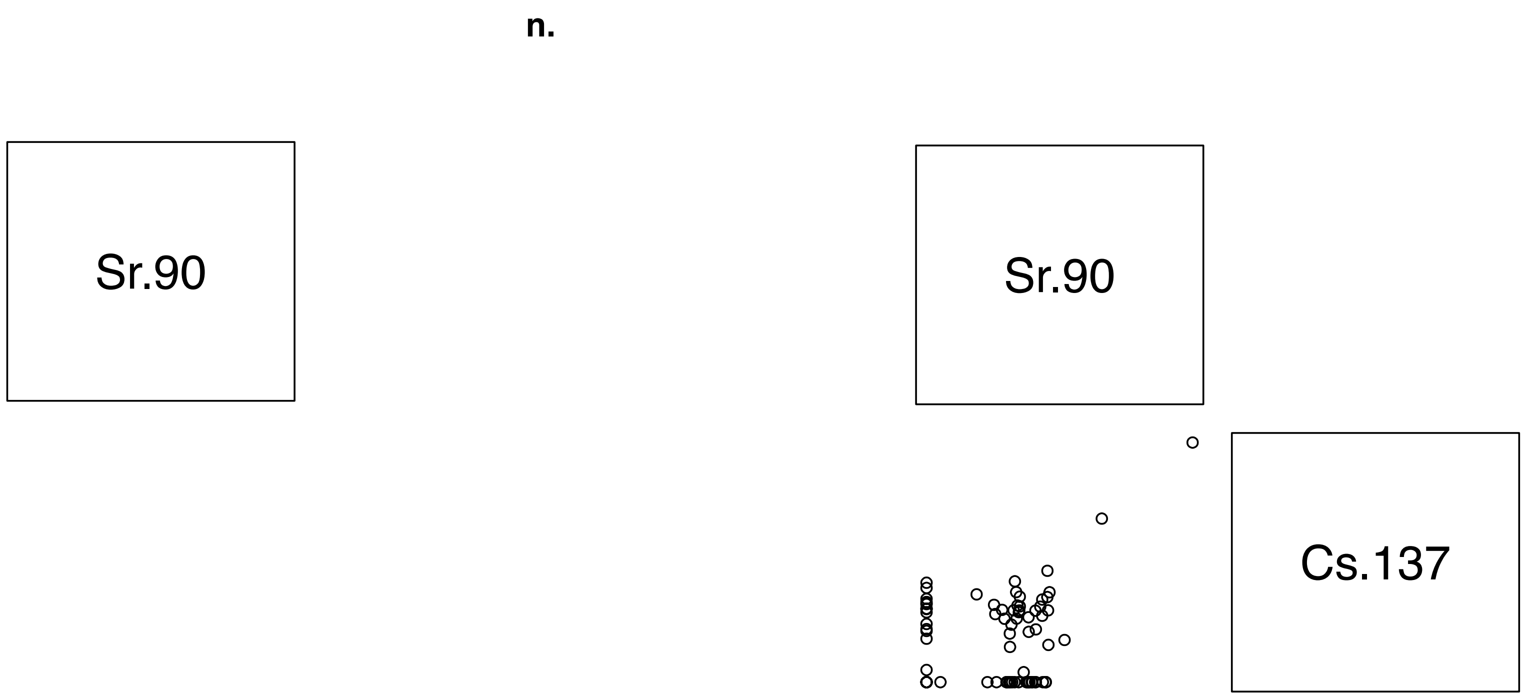


Figure C-4
Apparent Correlation for Cs-137 and Sr-90 Breakdown on Logscale, MDA B Data

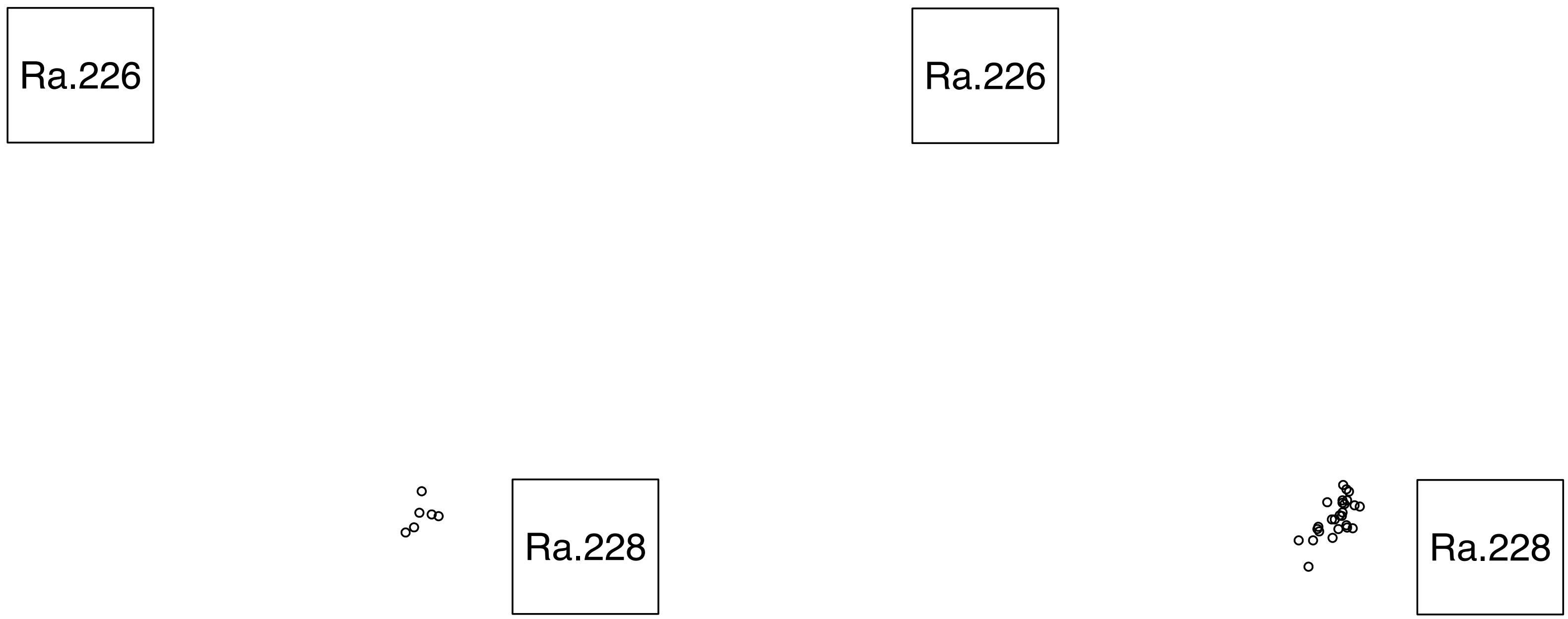


Figure C-5
Group Correlations for Bi-214, Pb-214, Ra-226, and Ra-228, MDA B Data

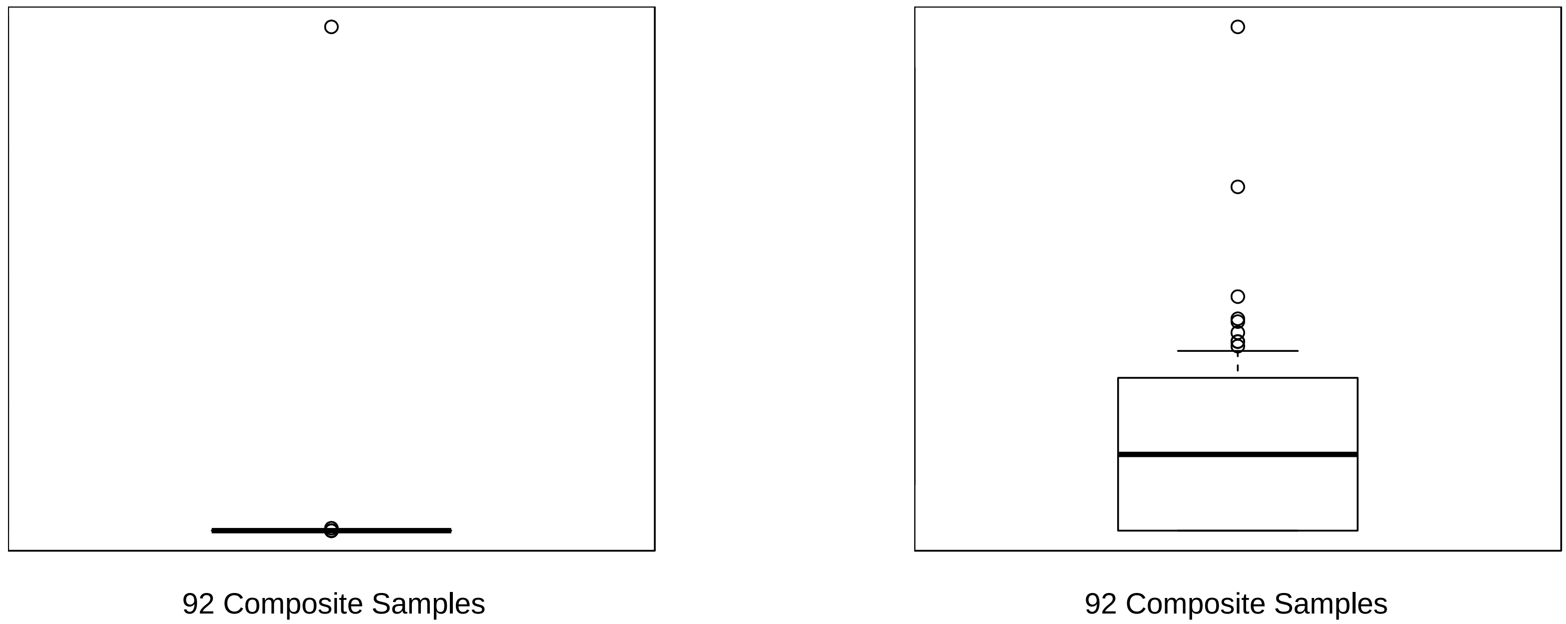
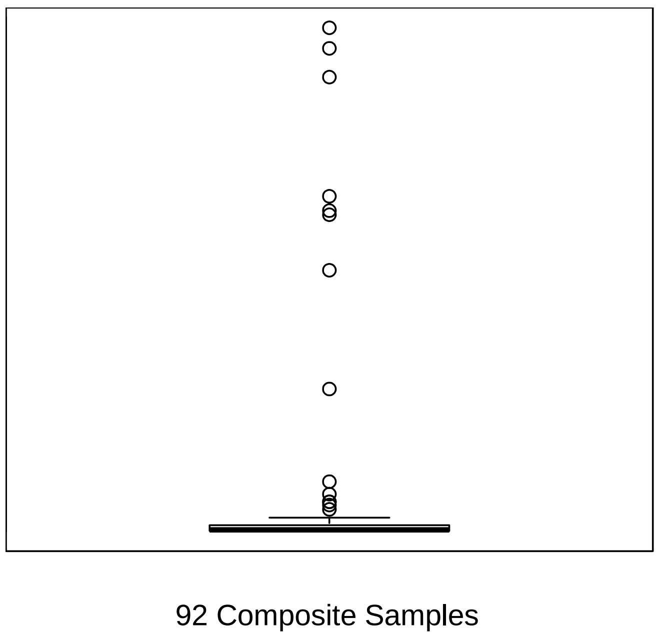


Figure C-6
Boxplots for Cs-137, MDA B Data



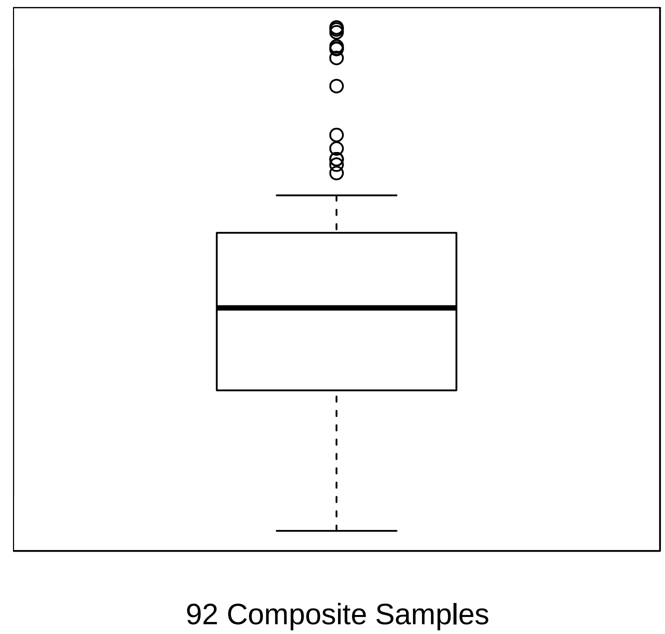


Figure C-7
Boxplots for Pu-238, MDA B Data

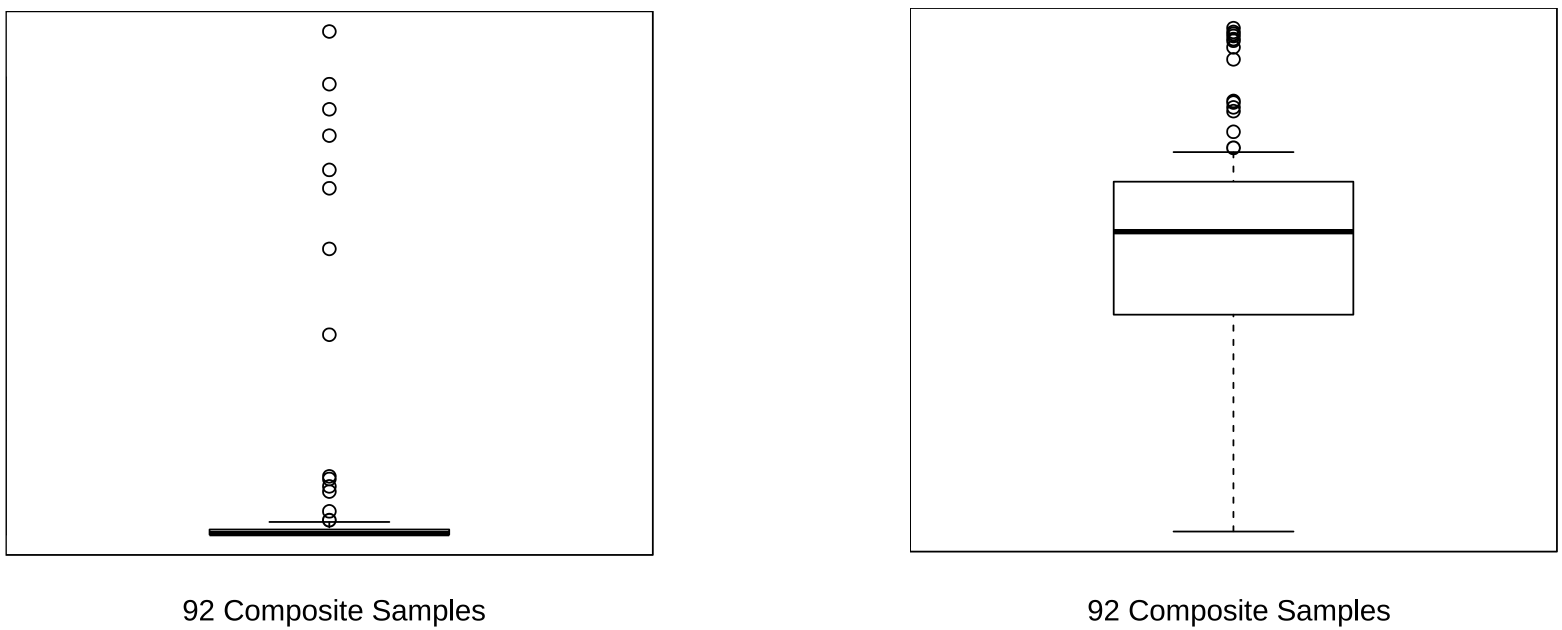


Figure C-8
Boxplots for Pu-239/240, MDA B Data

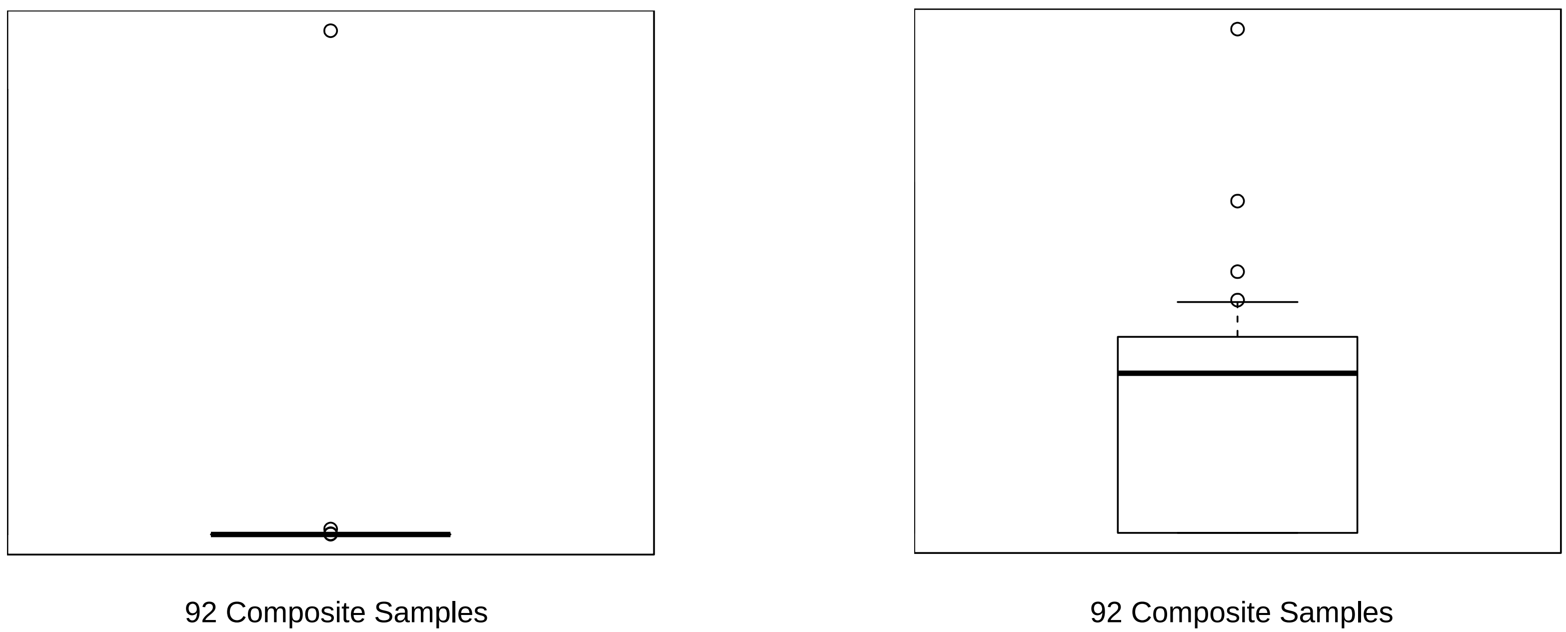


Figure C-9
Boxplots for Sr-90, MDA B Data

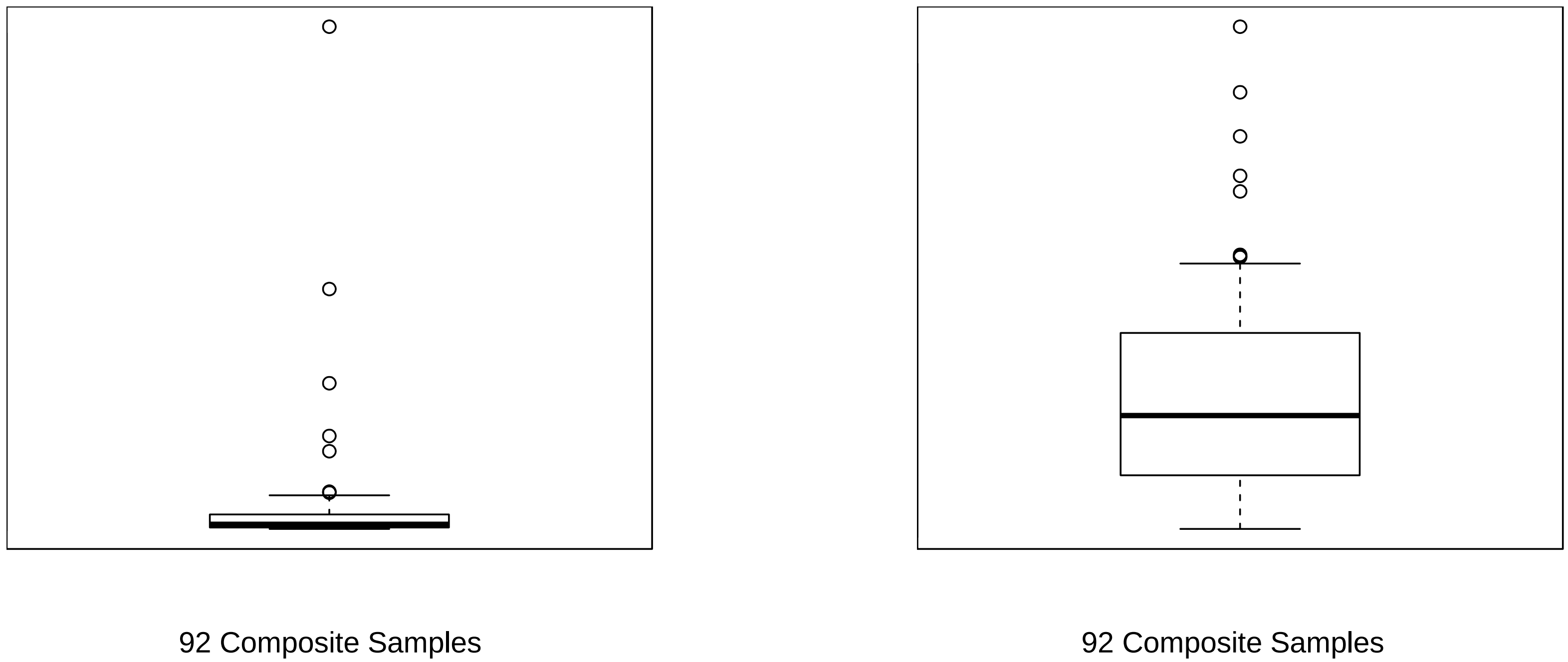


Figure C-10
Boxplots for U-234, MDA B Data

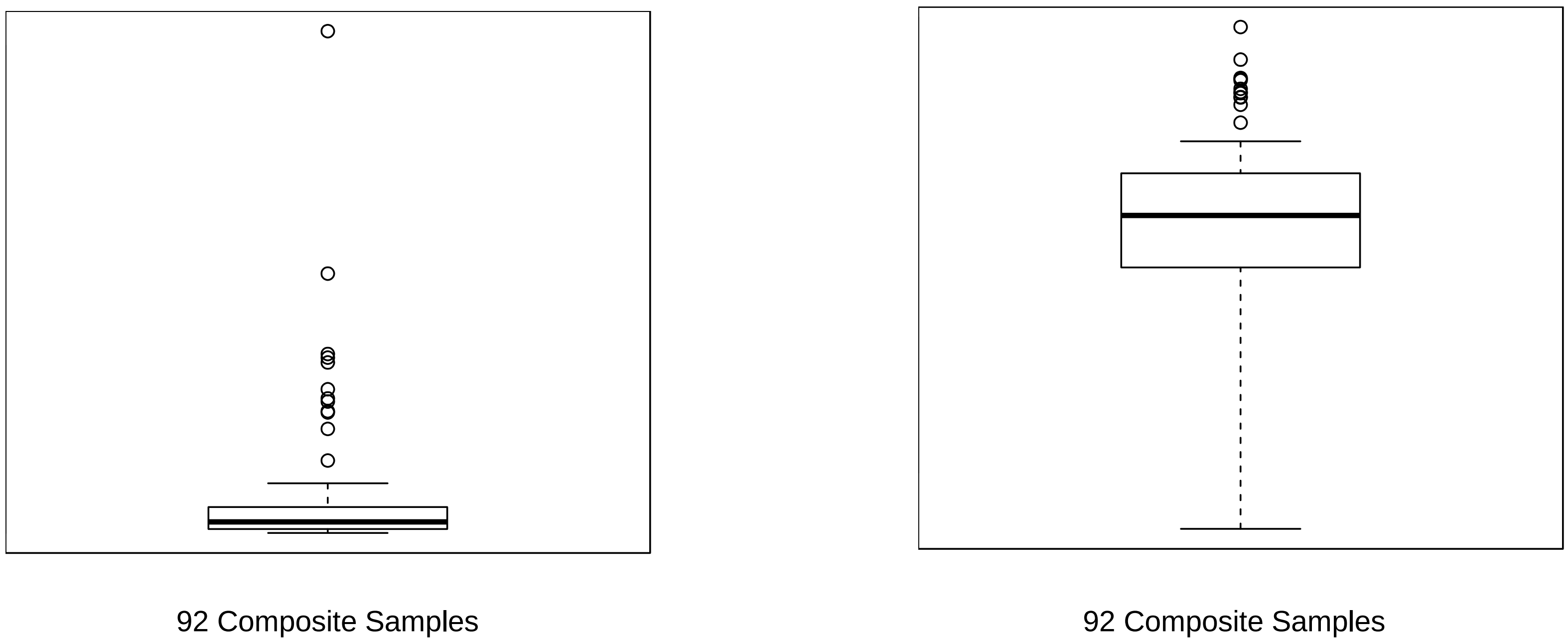


Figure C-11
Boxplots for U-235, MDA B Data

Figure C-12
Boxplots for U-238, MDA B Data

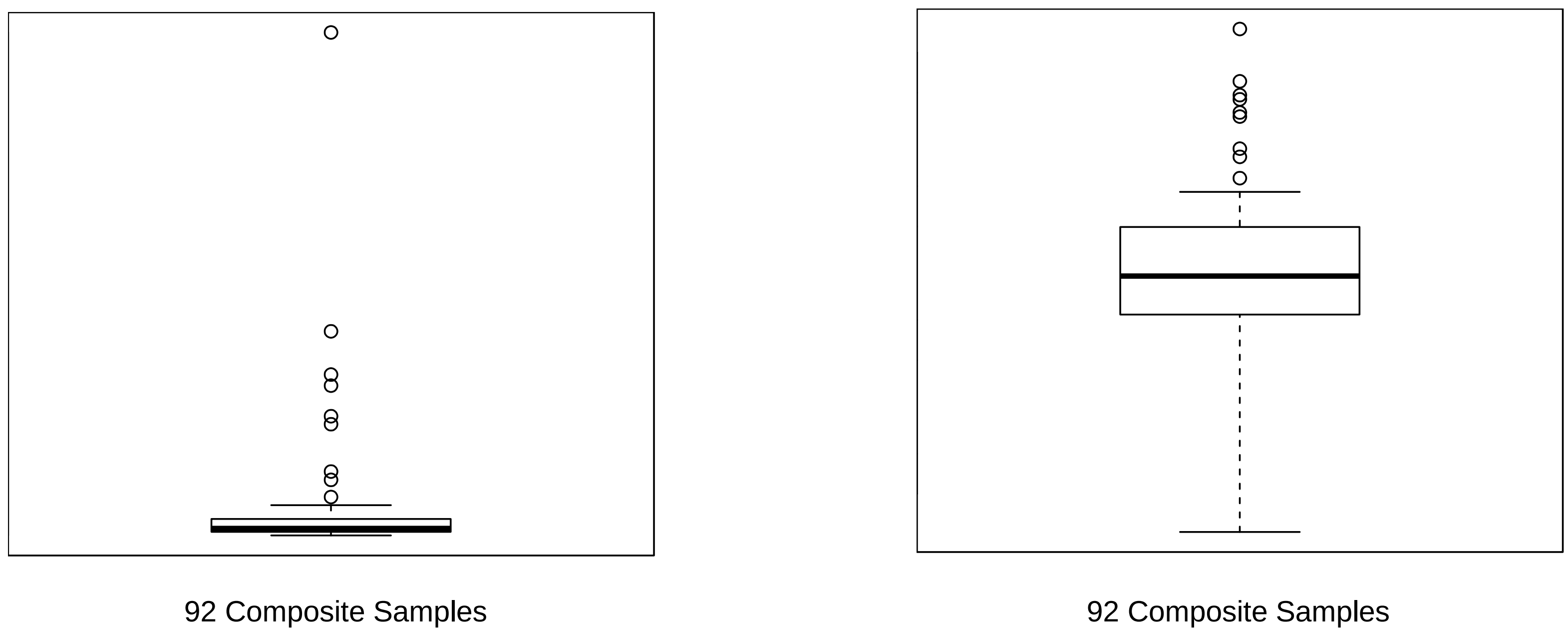


Figure C-13
Boxplots for Th-234, MDA B Data

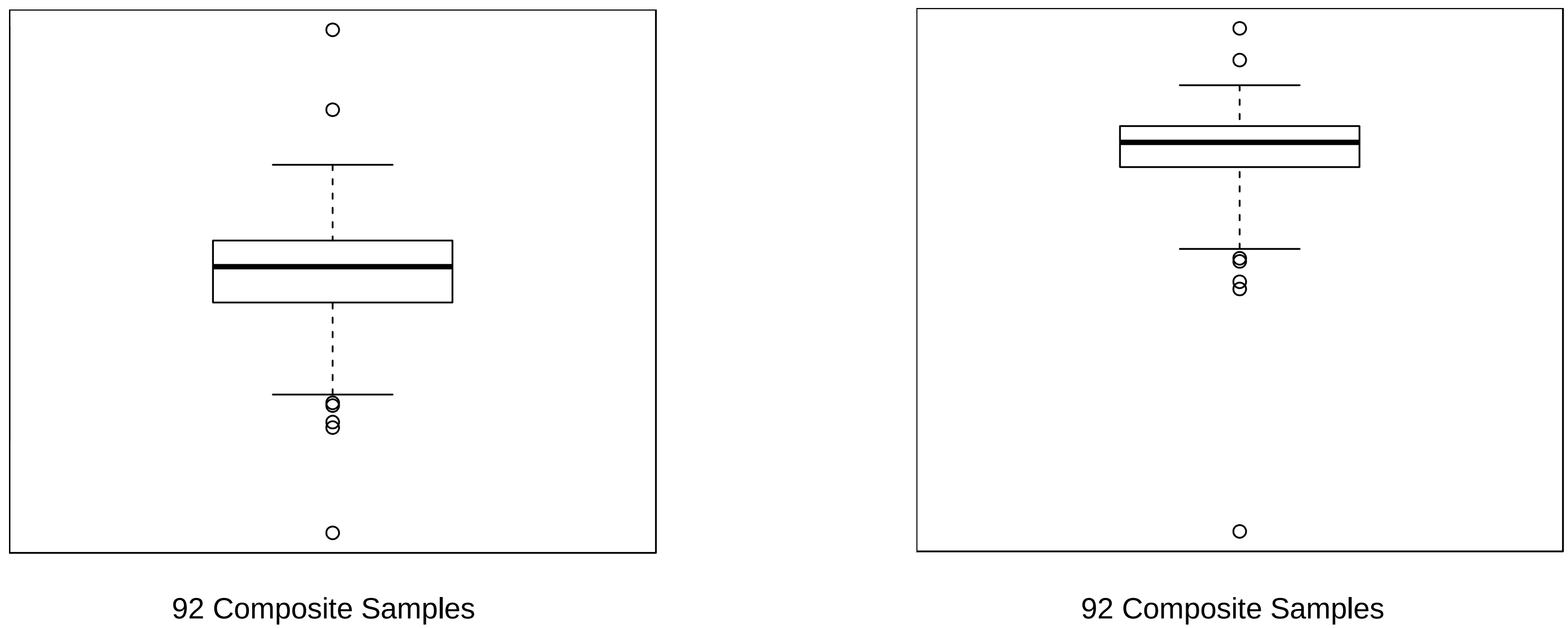
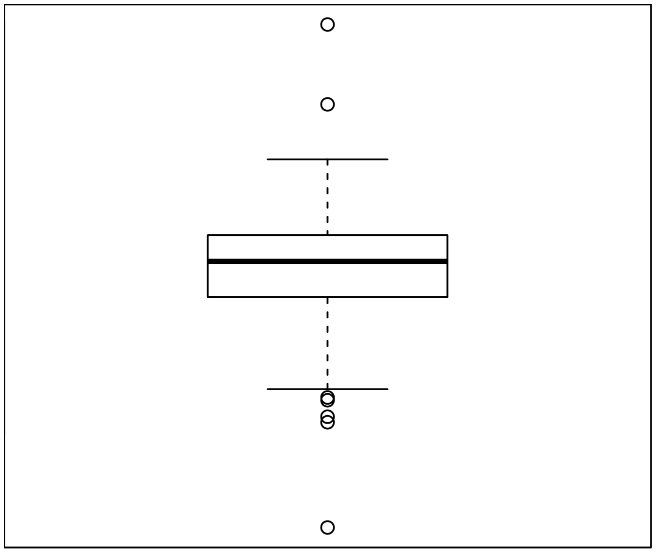
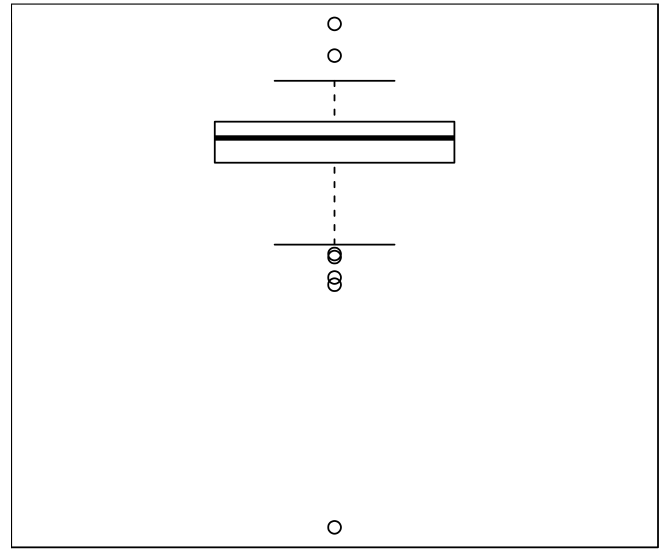


Figure C-14
Boxplots for R-226, MDA B Data



92 Composite Samples



92 Composite Samples

Figure C-15
Boxplots for Bi-214, MDA B Data

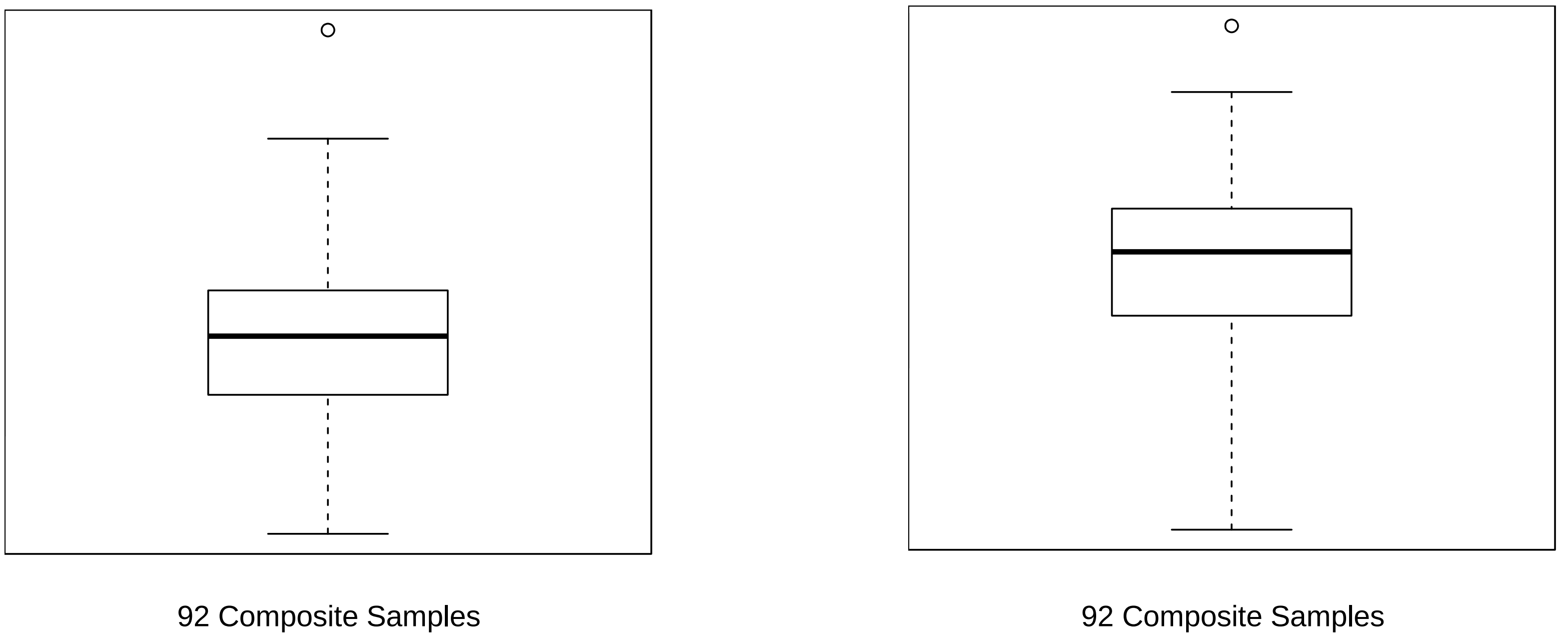


Figure C-16
Boxplots for Pb-214, MDA B Data

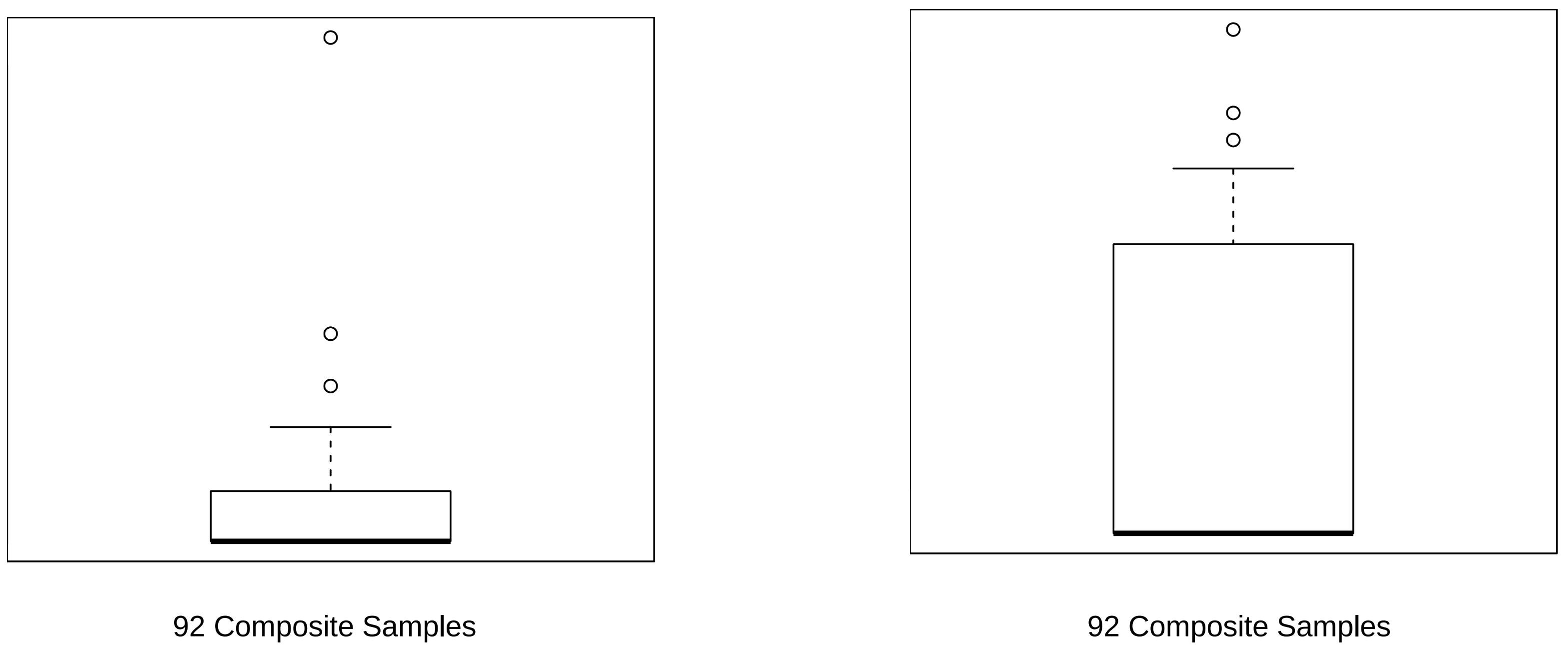


Figure C-17
Boxplots for Co-60, MDA B Data

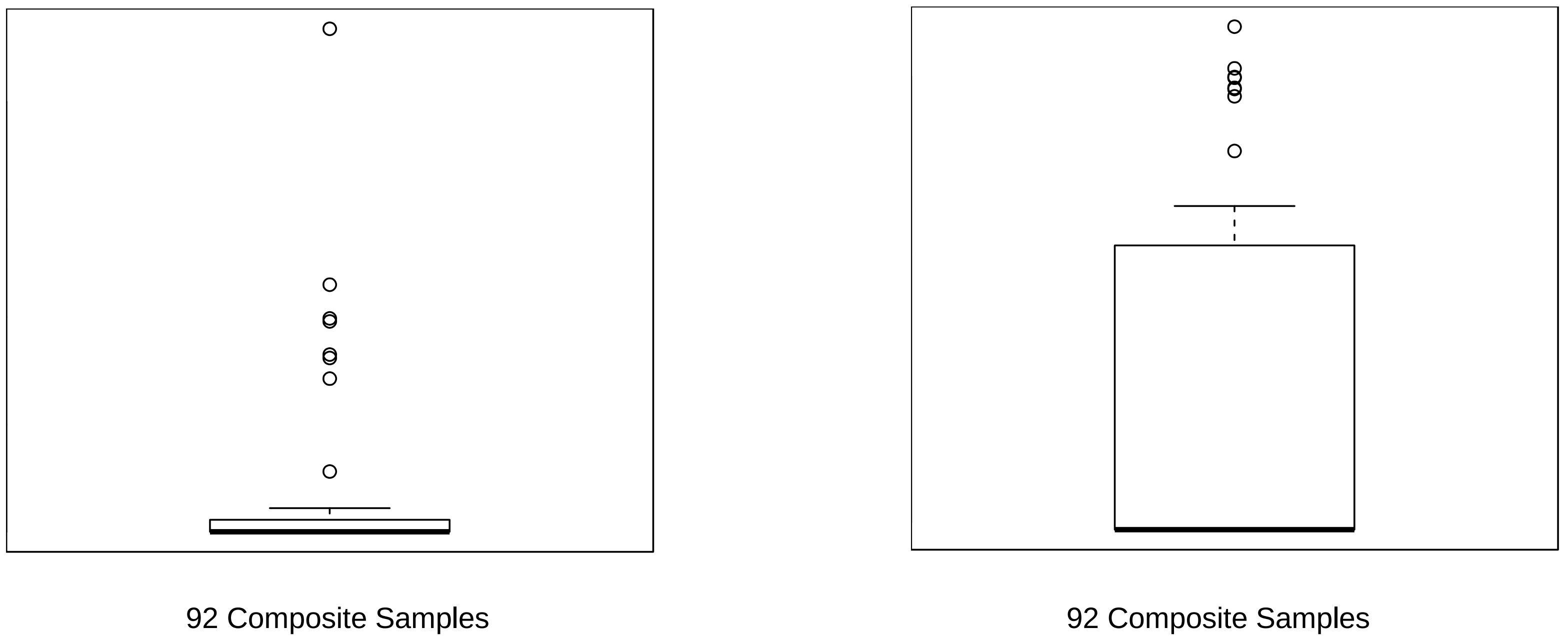


Figure C-18
Boxplots for Eu-152, MDA B Data

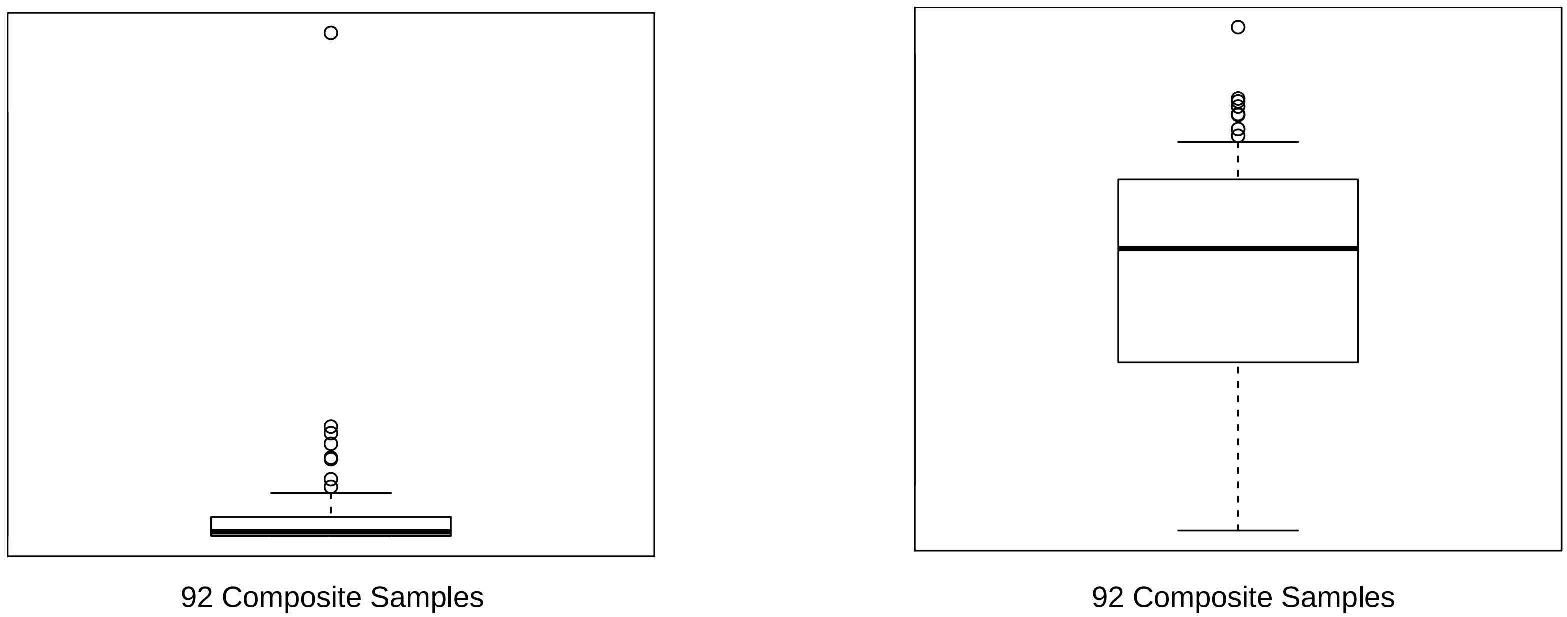


Figure C-19
Boxplots for Tritium, MDA B Data

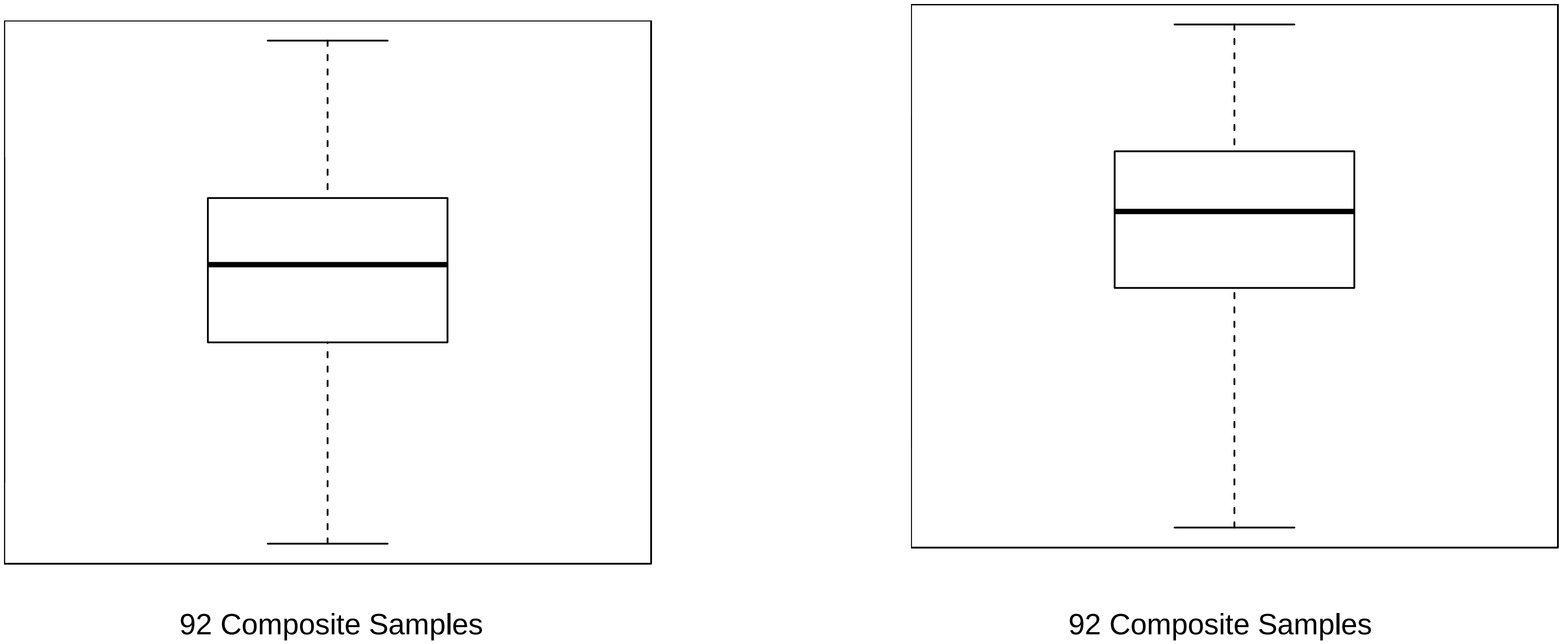


Figure C-20
Boxplots for K-40, MDA B Data

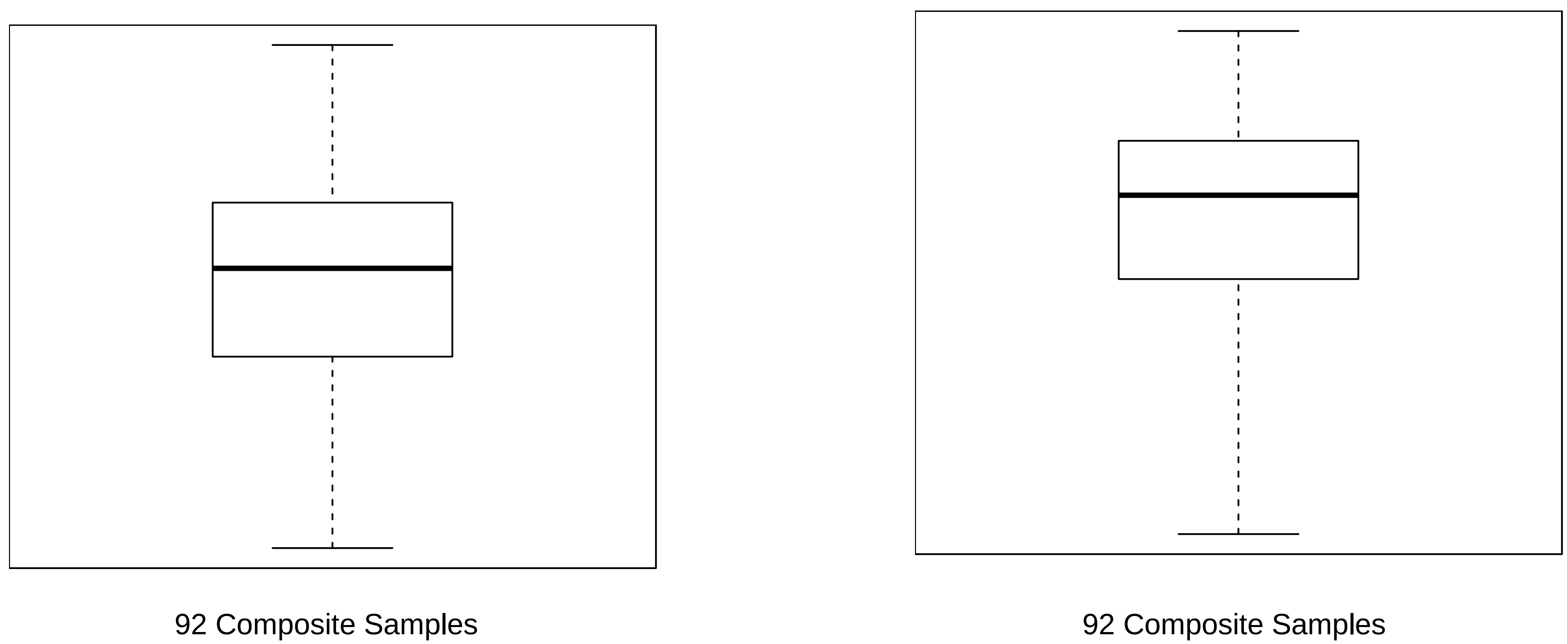


Figure C-21
Boxplots of Ra-228, MDA B Data

Table C-1
Summary Statistics for Radionuclides of Interest

Radionuclide	Sample Size	Minimum	Median	Mean	Maximum	Standard Deviation
Am-241 (MDA B)	92	0.0141	3.44	79.49	1360	250.2
Am-241 (PD-H)	565	0.545	3.00	4.60	7.19	3.64
Am-241 (PD-IWL)	579	0.098	79.0	195.5	1710	285.6
Am-241 (TBD-IWL)	137	0.541	106.0	172.3	1200	219.2
Am-241 (PD-IWL and TBDIWL)	716	0.098	90.5	191.1	1710	274.1
Bi-214	92	0.807	1.615	1.573	2.26	0.3387
Cs-137	92	0.164	1.13	1.098	1.99	0.256
Co-60	92	0.02595	2.13	6.861	150	18.24
Eu-152	92	0.0003815	0.157	0.6797	17.8	1.979
H-3	92	0.547	1.95	6.402	152	18.03
K-40	92	0.0003205	0.1815	0.5581	8.24	1.13
Pb-214	92	0.001	0.06665	6.334	566	58.99
Pu-238	92	0.000625	0.000625	0.008519	0.127	0.01588
Pu-239/240	92	0.0002155	0.002705	42.85	3920	408.7
Ra-226	92	0.164	1.13	1.098	1.99	0.256
Ra-228	92	0.528	1.455	5.755	159	18.59
Sr-90	92	0.0004425	0.0004425	0.1057	2.34	0.3272
Th-234	92	0.0154	108	3211	44000	9438
U-234	92	18.1	26.7	26.32	33.6	3.612
U-235	92	0.659	1.35	1.312	2.42	0.3055
U-238	92	0.004705	0.577	16.83	245	50.86

MDA B = The 92 composite samples from MDA B.

PD-H = Previously disposed of waste placed in the headspace.

PD-IWL = Previously disposed of waste placed in the institutional waste layer.

TBD-IWL = To be disposed of waste (awaiting disposal), to be placed in the institutional waste layer.

Statistically significant correlations were found to exist in the 92 composite samples between Am-241, Pu-238, and Pu-239/240; U-234, U-235, U-238, and Th-234; and Bi-214, Pb-214, Ra-226, and Ra-228. Significant correlations were not found to exist for Co-60, Cs-137, Eu-152, H-3, K-40, and Sr-90.

C.2.3 Fitting Distributions

The methods used to fit distributions for the radionuclide concentrations found in the MDA B waste are discussed below. Different approaches were used for the groups of correlated isotopes and the radionuclides for which no correlations were found.

The lognormal distributions developed from this effort are summarized in Table C-2. A lognormal distribution may be parameterized in several ways; the parameters listed here represent the mean and standard deviation of the lognormal distribution (m and s), which can be used directly in the GoldSim models used to conduct the Area G performance assessment and composite analysis.

The distributions listed for Am-241, Pu-238, and Pu-239/240 are specific to the material already disposed of at Area G in the headspace and institutional waste layer and the waste awaiting disposal; statistics are provided for the combination of the disposed institutional waste and the waste awaiting disposal as well. The distributions developed for the remaining radionuclides are applied to all waste regardless of its disposal status and the layer in which it is placed.

C.2.3.1 Americium-241 and Plutonium Isotopes

Americium-241, Pu-238, and Pu-239/240 are highly correlated in the 92 composite samples, both on the original and log scales (Figure C-2). Since Am-241 values are known for the 1,144 containers of waste that have undergone disposal and the 137 waste bins awaiting disposal, the Pu-238 and Pu-239/240 values were predicted for these containers using a multivariate lognormal regression model, with Am-241 as the independent variable. The regression model was established using the 92 composite sample dataset.

Table C-2
Summary of Lognormal Distributions Developed for Material Disposal Area B Waste

Radionuclide	Subset of Waste [a]	Mean (pCi/g)	Standard Deviation (pCi/g)	Correlation [b]
Am-241	PD-H	4.60	0.15	NA
Am-241	PD-IWL	195.7	11.9	NA
Am-241	TBD-IWL	172.5	18.8	NA
Am-241	PD-IWL plus TBD-IWL	190.9	10.3	NA
Bi-214	All waste	1.1	0.03	NA
Cs-137	All waste	0.5	1.0	NA
Co-60	All waste	0.009	0.002	NA
Eu-152	All waste	0.1	0.04	NA
H-3	All waste	0.7	0.2	NA
K-40	All waste	26.3	0.4	NA
Pb-214	All waste	1.3	0.03	Ra-226: 0.83
Pu-238	PD-H	2.03	0.48	Am-241: 0.11
Pu-238	PD-IWL	34.5	10.7	Am-241: 0.15
Pu-238	TBD-IWL	32.6	11.1	Am-241: 0.19
Pu-238	PD-IWL plus TBD-IWL	34.1	10.2	Am-241: 0.13
Pu-239/240	PD-H	277.1	74.4	Pu-238: 0.73
Pu-239/240	PD-IWL	16,031	5,837	Pu-238: 0.58
Pu-239/240	TBD-IWL	13,643	5,658	Pu-238: 0.57
Pu-239/240	PD-IWL plus TBD-IWL	15,473	5,356	Pu-238: 0.57
Ra-226	All waste	1.1	0.03	NA
Ra-228	All waste	1.6	0.03	NA
Sr-90	All waste	0.3	0.1	NA
Th-234	All waste	6.9	1.9	U-234: 0.96
U-234	All waste	6.4	1.9	NA
U-235	All waste	0.6	0.1	U-234: 0.90
U-238	All waste	5.8	2.0	U-234: 0.99

[a] *Subsets of waste include previously disposed (PD) and to be disposed (TBD) waste placed in the headspace (H) or institutional waste layer (IWL).*

[b] *The radionuclide to which the distribution is correlated is listed first, followed by the correlation coefficient. NA is listed for those cases for which no statistically significant process-based correlation was observed or for which the correlation was considered inconsequential for the performance modeling.*

For each segment of the waste, the regression model is fit 10,000 times; each iteration consists of the following steps.

1. Bootstrap the MDA B Am-241, Pu-238, and Pu-239/240 dataset by sampling the data records (for these three radionuclides) with replacement (the bootstrap sample size is set to 92 to match the number of composite samples).

2. Fit a bivariate regression on the log-scale using the bootstrapped data, and store the regression coefficients and the covariance matrix of the residuals. This bivariate regression model is used to predict Pu-238 and Pu-239/240 activity concentrations from the Am-241 activity concentrations. The equations for the bivariate regression are as follows:

$$E[\log(Pu-238)] = \beta_0 + \beta_1 * \log(Am-241) + \varepsilon_1 \quad (1)$$

$$E[\log(Pu-239/240)] = \beta_2 + \beta_3 * \log(Am-241) + \varepsilon_2 \quad (2)$$

$$\Sigma = \begin{bmatrix} {\varepsilon_1}^2 & Cov(residuals(Eq.1)) \\ Cov(residuals(Eq.2)) & {\varepsilon_2}^2 \end{bmatrix} \quad (3)$$

3. Bootstrap the Am-241 measurements for the waste under consideration by resampling the Am-241 measurements with replacement.

4. Compute the logarithm of the Am-241 measurements from Step 3 and fit values for Pu-238 and Pu-239/240 given the regression coefficients and covariance matrix from Step 2. This step provides bootstrapped data for the plutonium isotopes in the log-scale.

5. Exponentiate the plutonium isotope results so they are on the original scale. This step provides four sets of fitted Pu-238 and Pu-239/240 values.

6. Take the mean of the fitted plutonium values.

7. Store the means from Step 6.

At the end of the simulation, the 10,000 stored means for the plutonium isotopes represent the sampling distributions of the means. These sampling distributions were parameterized through maximum-likelihood calculations assuming a lognormal distribution for the fits. A lognormal distribution was chosen for fitting because several of the distributions are skewed, and using the lognormal distribution guarantees the mean radioactivity of the radionuclides will always be greater than zero. Histograms of the final simulated distributions of the plutonium isotopes are provided in Figures C-22 and C-23.

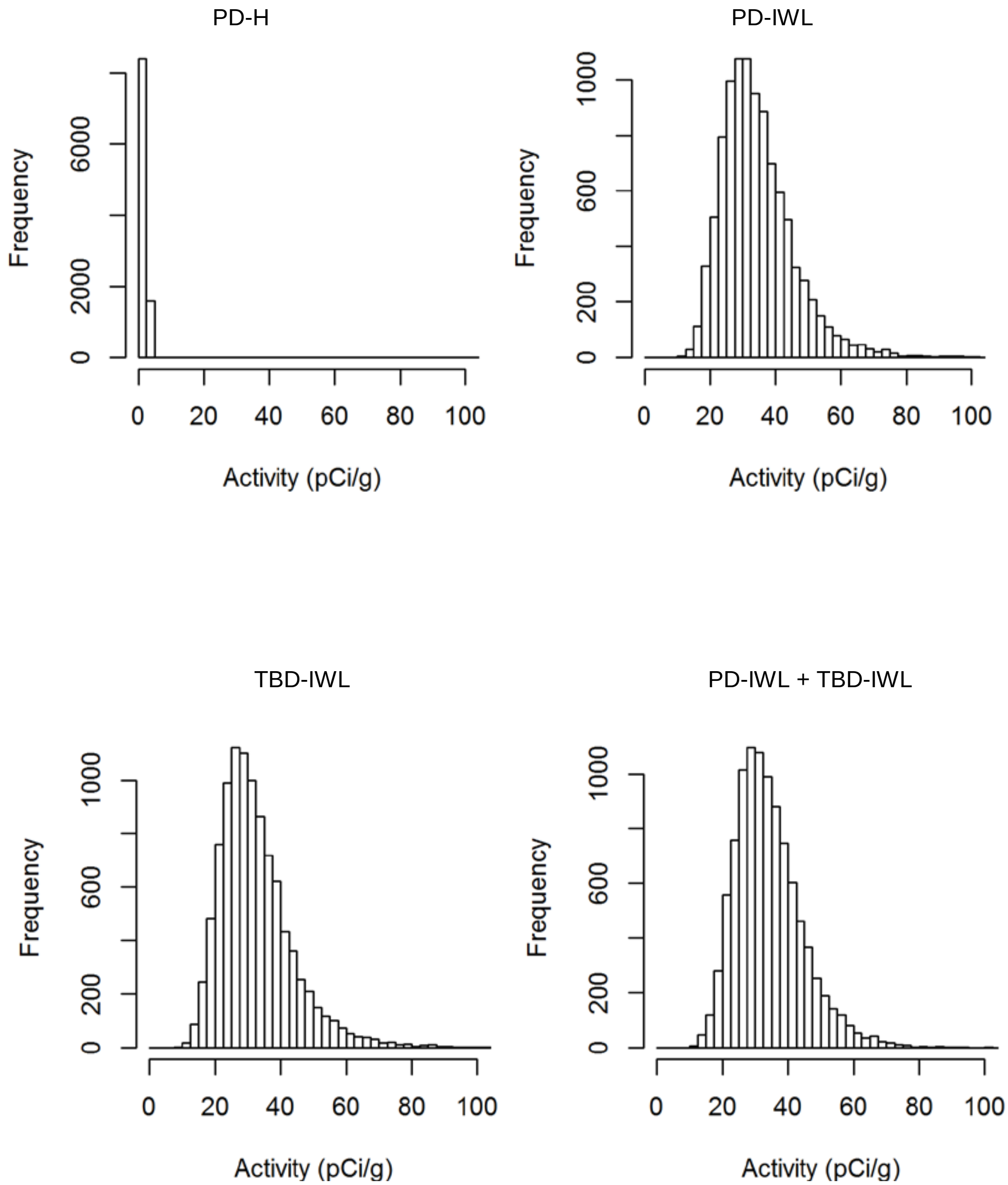


Figure C-22
Histograms of Pu-238 Simulated Means for
PD-H, PD-IWL, MDA B, and PD-IWL Plus TBD-IWL Data

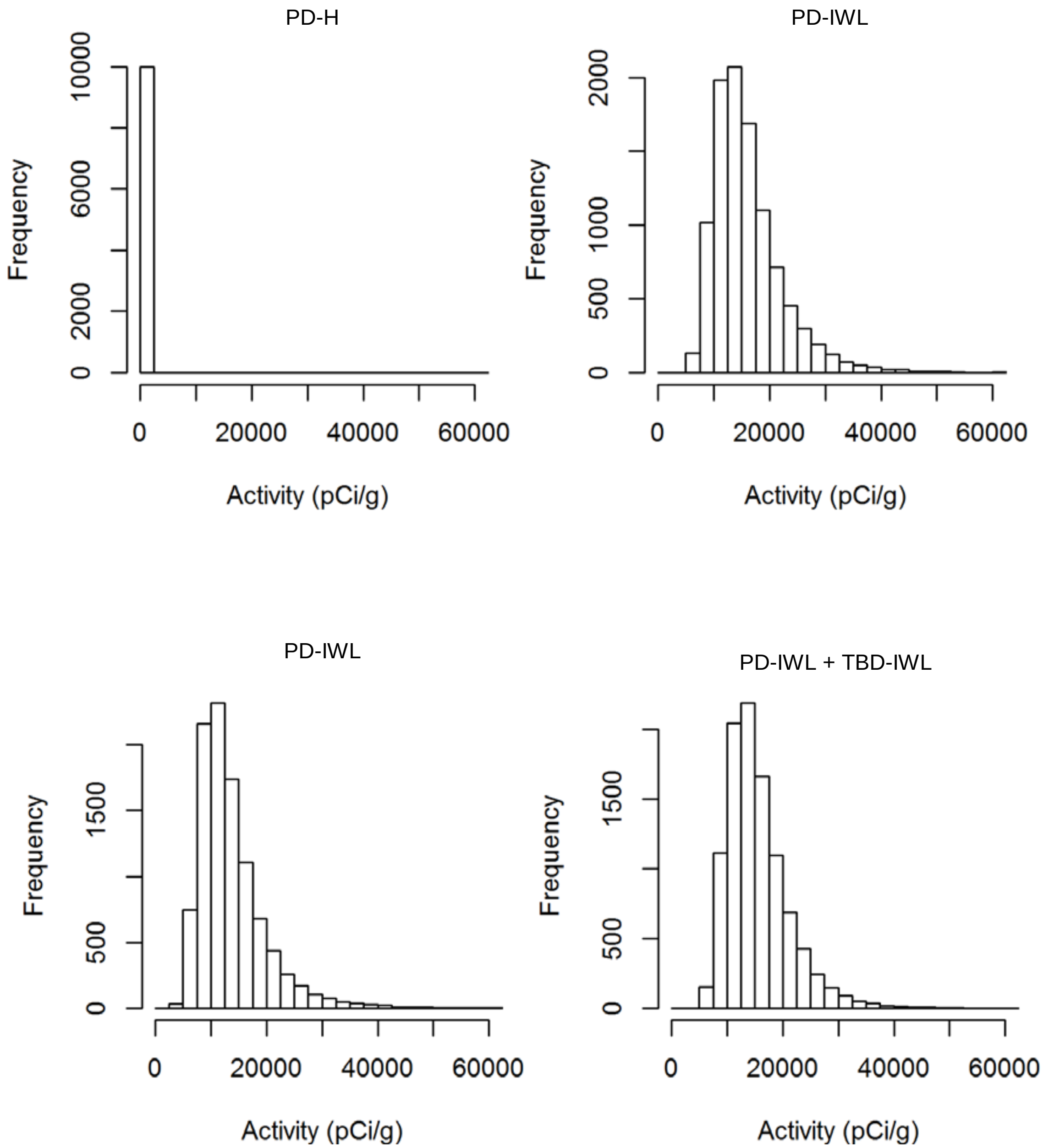


Figure C-23
Histograms of Pu-239/240 Simulated Means for PD-H, PD-IWL, TBD-IWL, and PD-IWL Plus TBD-IWL Data

The correlations between the simulated means for Am-241, Pu-238, and Pu-239/240 are not as high as the correlations found among the data themselves. The likely reason for the lower correlations is that lognormal distributions can exhibit unusual behavior in the upper tail. The box plots for the Am-241 data (Figure C-1) show an extreme right skew in the data, which can be hard to fit with any distribution. This behavior may call into question the assumption made regarding data exchangeability and suggests a statistical model that addresses separate subpopulations of bins would better fit the overall data. However, as noted in Section C.2.2, the overall goal is to estimate the mean radionuclide concentrations over large numbers of bins placed in the headspace or institutional waste layer. The exchangeability model used here is likely to provide reasonable results or fits for that endpoint but may overestimate the variance of the mean concentrations for each radionuclide.

C.2.3.2 Uranium and Thorium

The uranium isotopes (U-234, U-235, and U-238) and Th-234 are highly correlated; the high correlation between Th-234, U-234, and U-238 is probably an indication that these isotopes are in secular equilibrium. The only measurements of uranium and thorium concentrations are those collected from the 92 composite samples. Consequently, a multivariate bootstrap technique is used to develop distributions of the mean values for each radionuclide using the following steps:

1. Bootstrap the MDA B U-234, U-235, U-238, and Th-234 dataset by sampling the data records (for these four radionuclides) with replacement (the bootstrap sample size is set to 92 to match the number of composite samples).
2. Take the mean of the 92 samples for each of the four isotopes.
3. Store the means from Step 2.
4. Repeat 10,000 times.

The resulting sets of 10,000 means represent the sampling distributions of the mean for each isotope. These sampling distributions accurately reflect the correlations among the data themselves. A lognormal distribution was fit to each distribution using maximum-likelihood calculations; correlation coefficients were established for use in the performance assessment and composite analysis modeling. Histograms of the uranium and Th-234 distributions are provided in Figure C-24. A single set of distributions was developed for the uranium and thorium isotopes and applied to all waste that has been, or will be, disposed of regardless of whether the material was/is placed in the headspace or the institutional waste layer.

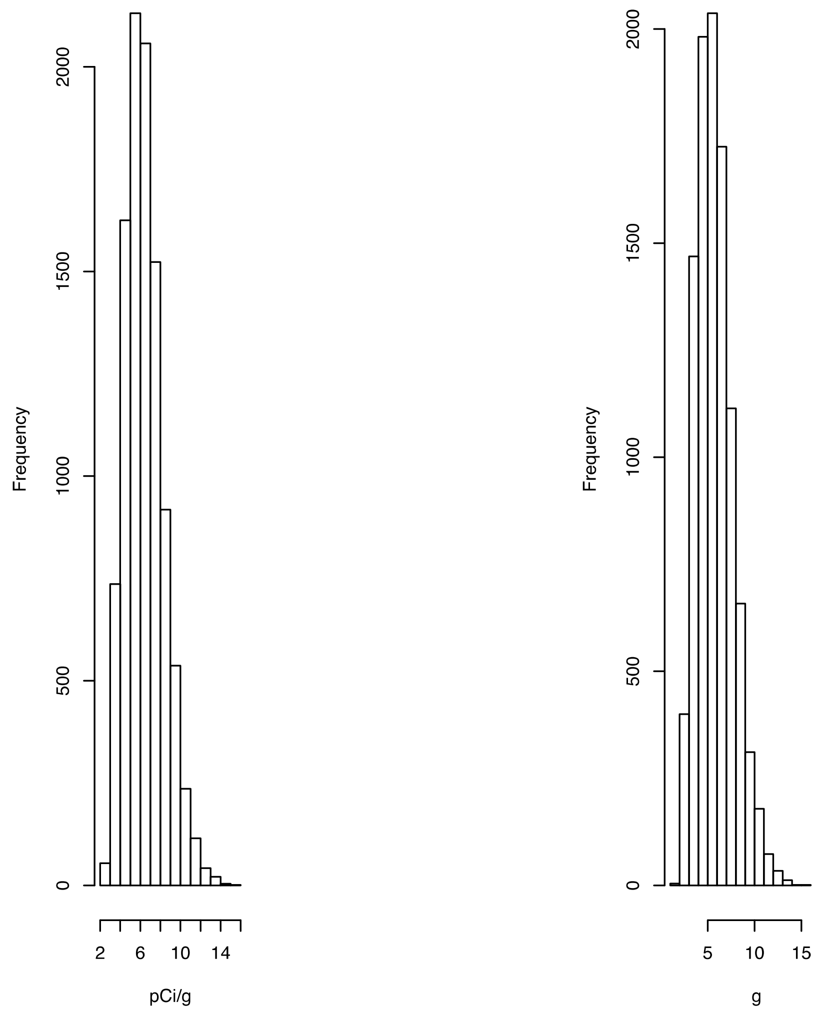


Figure C-24
Histograms of Simulated Means for U-234, U-235, U-238, and Th-234

C.2.3.3 Radium, Bismuth, and Lead

The radium isotopes (Ra-228 and Ra-226), Bi-214, and Pb-214 are highly correlated; the Ra-226 and Bi-214 data are identical, suggesting the Ra-226 data were used as a surrogate for Bi-214. Otherwise, the strong correlations between Ra-226, Bi-214, and Pb-214 are indicative of secular equilibrium and common relative abundance. Of interest, however, is the fact that the activity concentrations of Ra-226 and those of U-234 and U-235 are quite low. This finding may indicate secular equilibrium is not maintained through the uranium chain or it may indicate analytical issues at low-activity concentrations.

For this group of isotopes, the multivariate bootstrap technique described in Section C.2.3.2 was used to calculate the distributions of the mean activity concentrations, using the data collected from the 92 composite samples. Lognormal distributions were fit to each isotope using maximum-likelihood calculations, and correlations were preserved so they can be used in the performance assessment and composite analysis modeling. Histograms of the distributions are provided in Figure C-25. A single set of distributions was developed for the isotopes in this group and applied to all of the MDA B waste, regardless of the layer in which it was placed.

C.2.3.4 Remaining Isotopes

The distributions of the mean activity concentrations for the remaining radionuclides were calculated using a univariate bootstrap technique, applied to the 92 composite sample dataset. The approach is as follows:

1. Bootstrap each radionuclide's dataset by sampling the data records with replacement (the bootstrap sample size is set to 92 to match the number of composite samples).
2. Take the mean of the 92 samples for each radionuclide.
3. Store the mean from Step 2.
4. Repeat 10,000 times.

The resulting set of 10,000 means represents the sampling distribution of the mean for a particular isotope. The distribution was parameterized as lognormal using maximum-likelihood calculations. Correlations between each of the distributions calculated through this technique and the other isotopes were assumed to be zero. Histograms of the distributions are provided in Figures C-26 through C-31. A single distribution was estimated for each radionuclide and applied to all MDA B waste, regardless of the layer in which the material was placed.

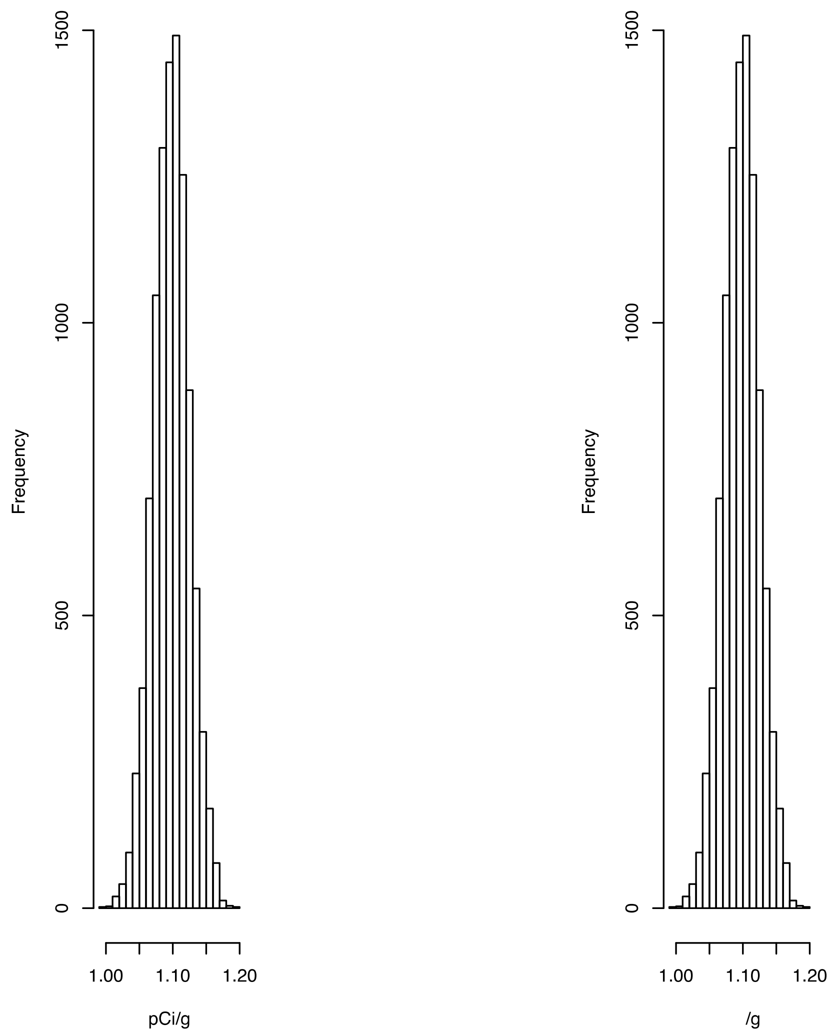


Figure C-25
Histograms of Simulated Means for Bi-214, Pb-214, Ra-226, and Ra-228

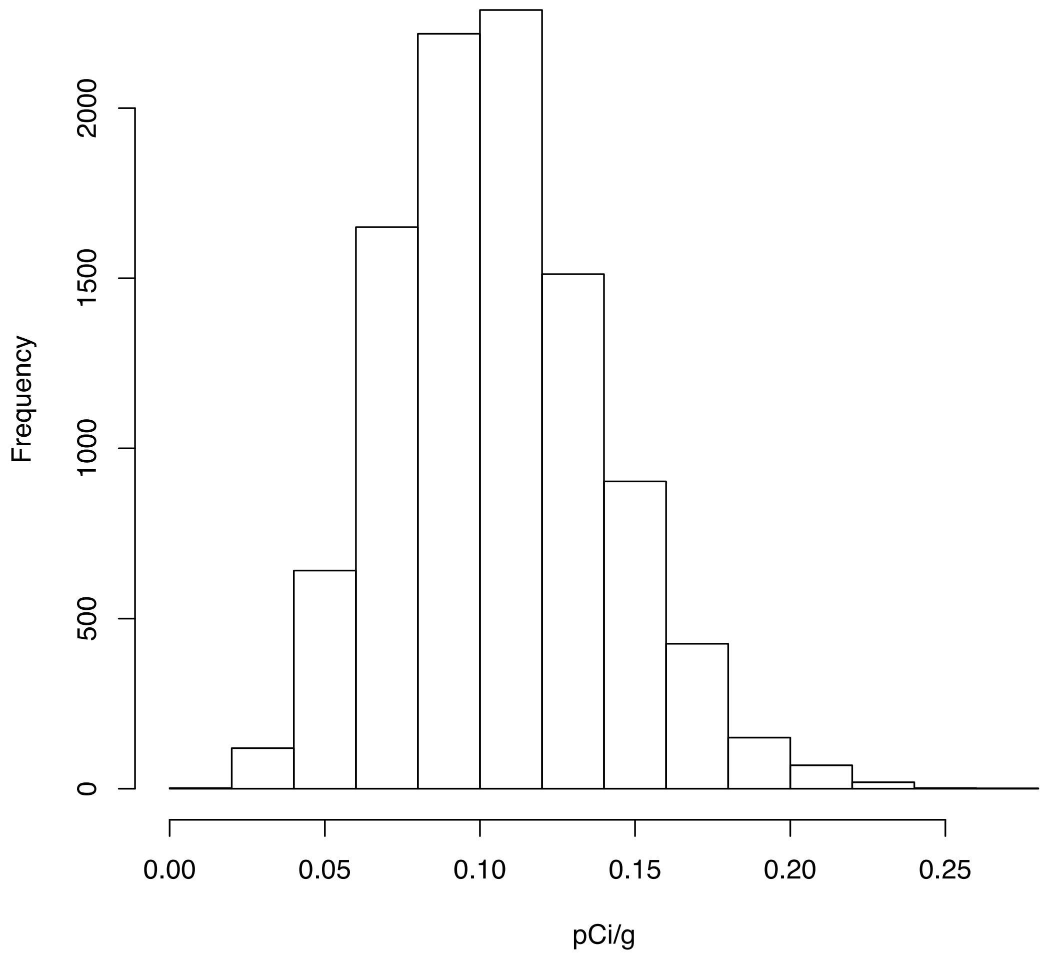


Figure C-26
Histogram of Simulated Means for Eu-152

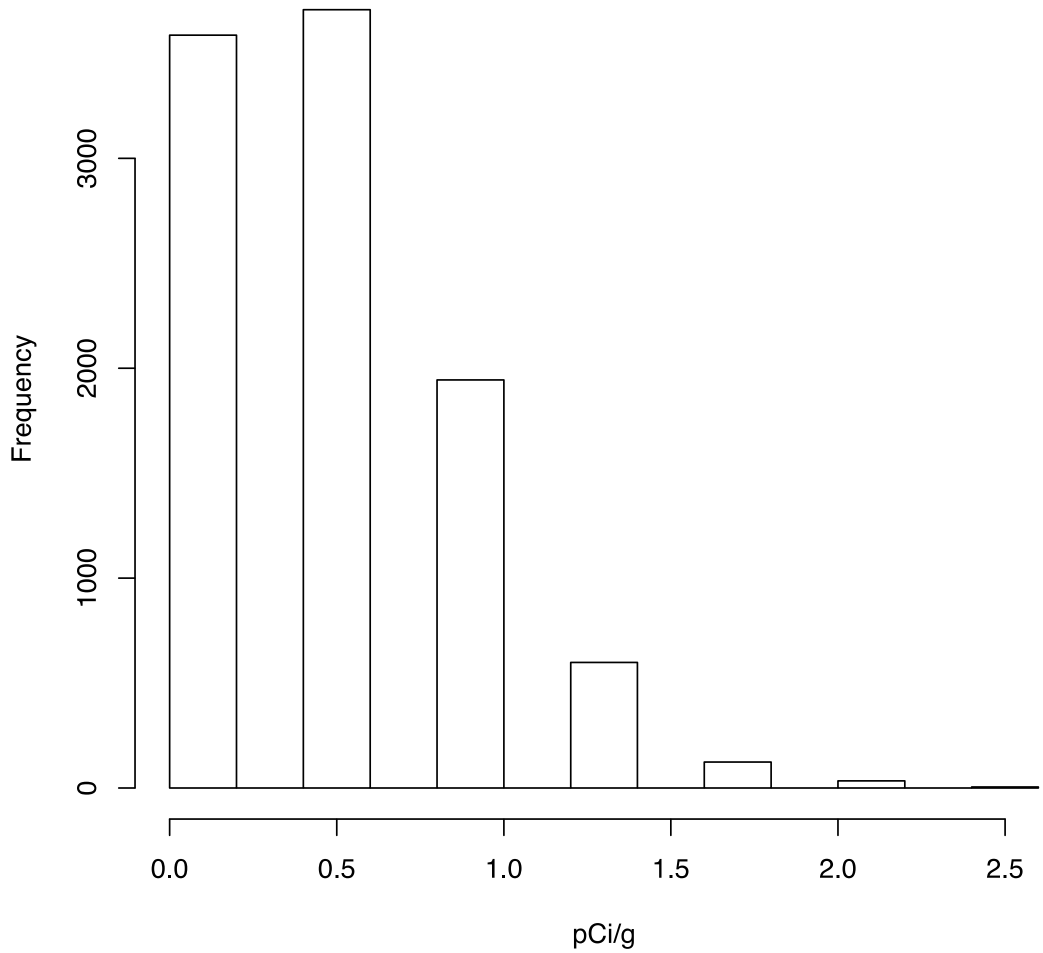


Figure C-27
Histogram of Simulated Means for Cs-137

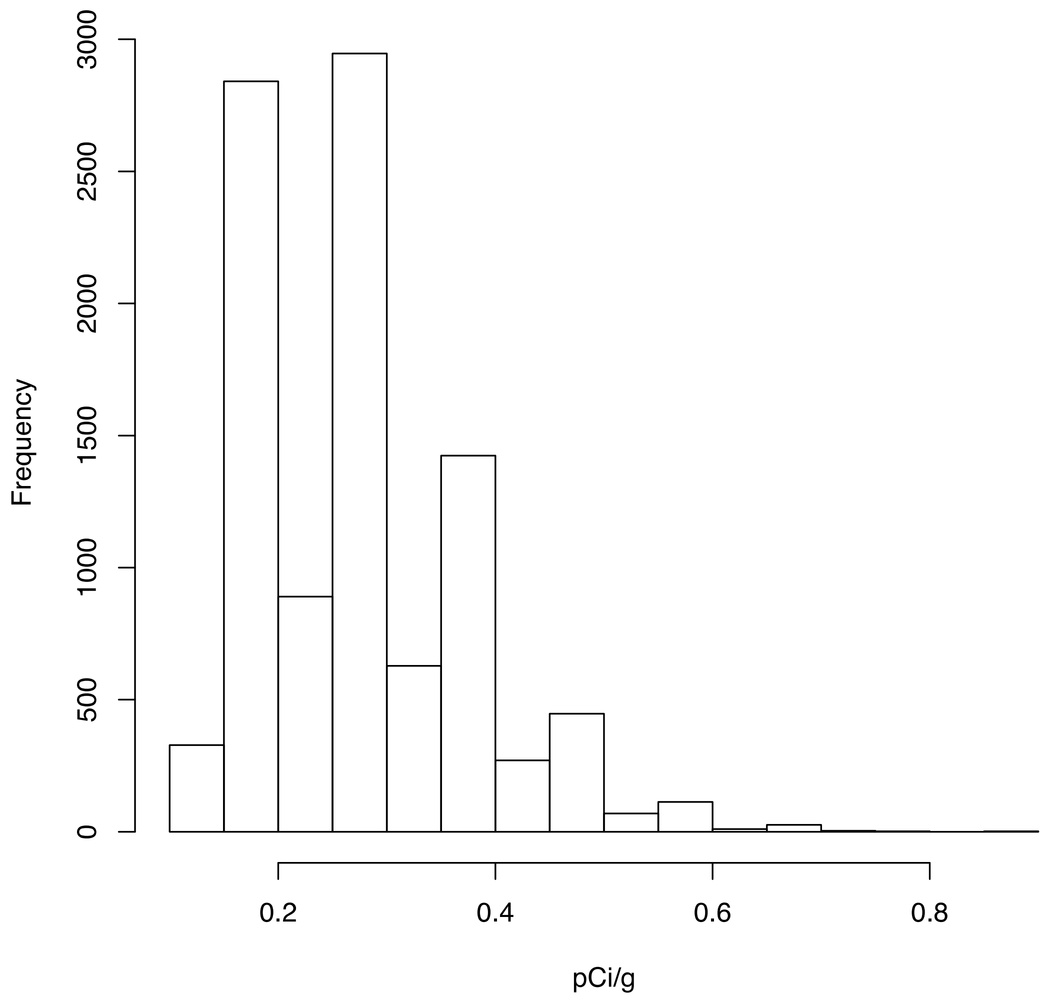


Figure C-28
Histogram of Simulated Means for Sr-90

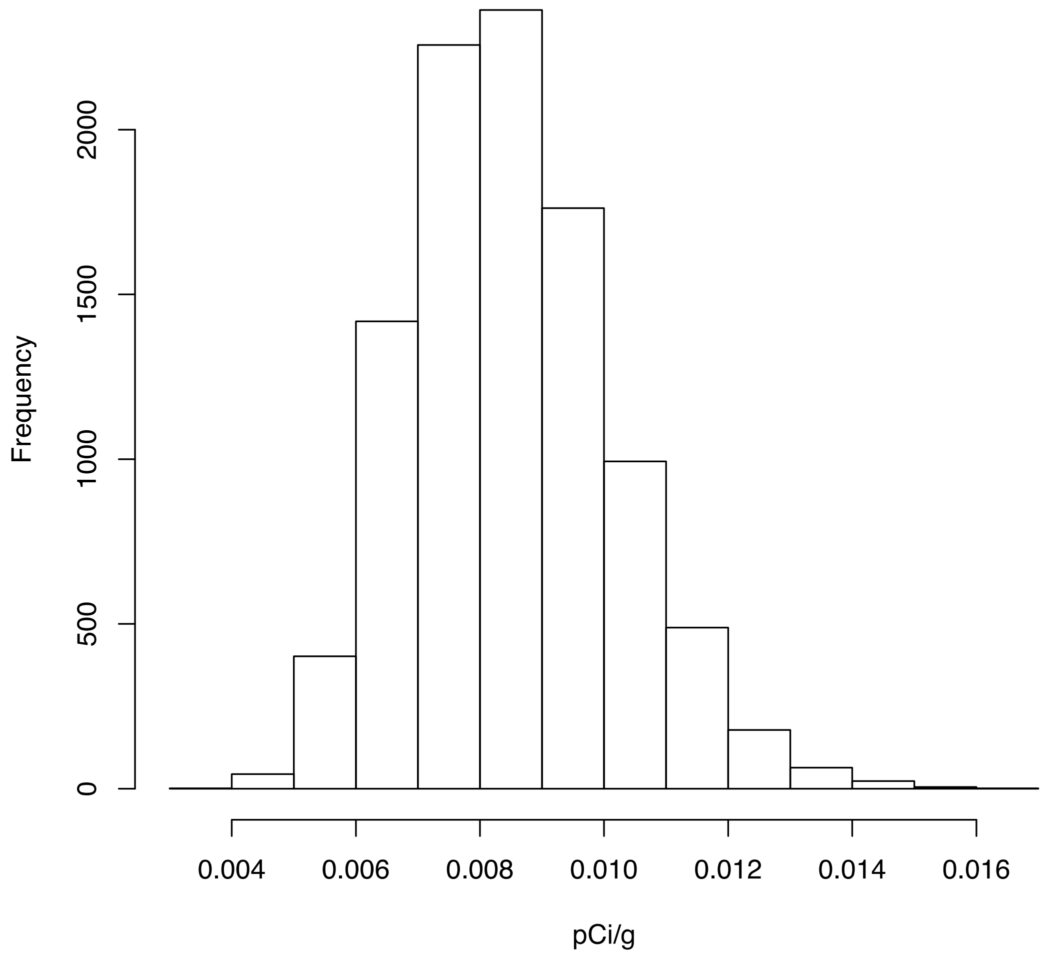


Figure C-29
Histogram of Simulated Means for Co-60

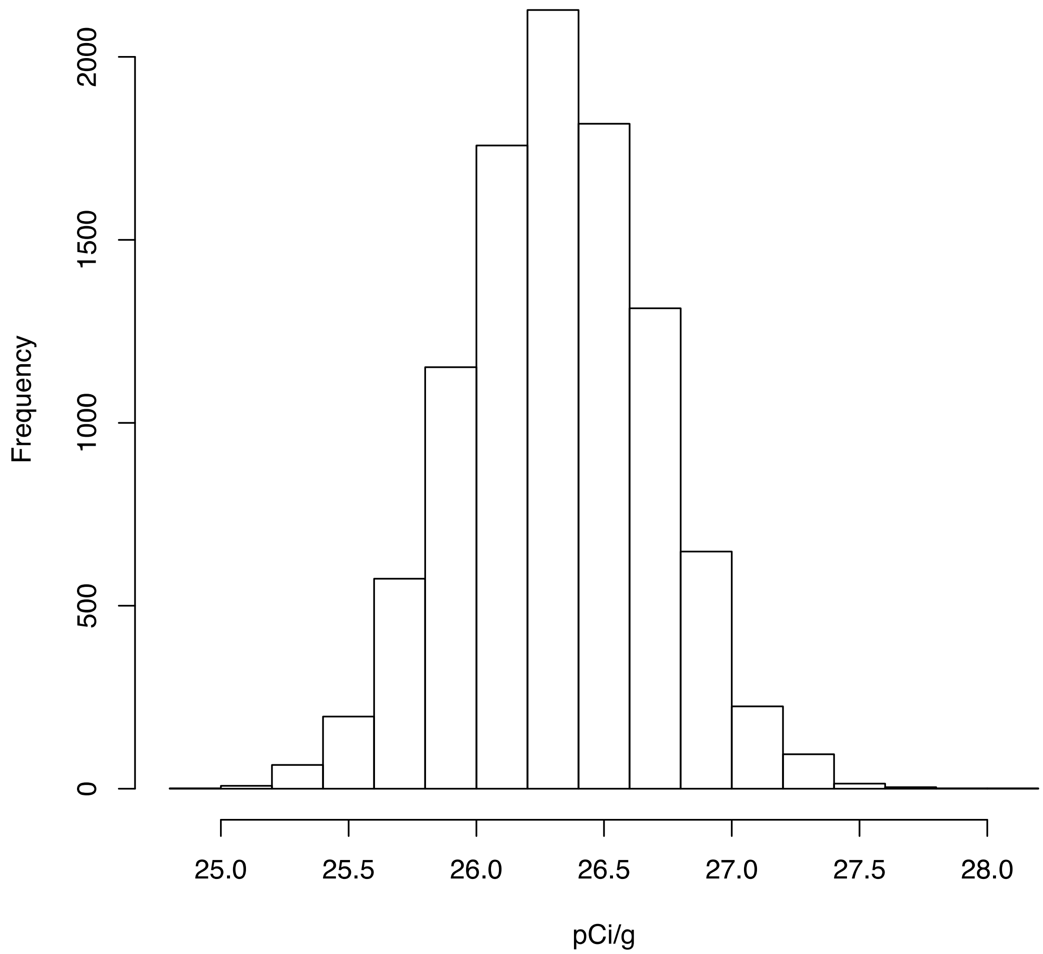


Figure C-30
Histogram of Simulated Means for K-40

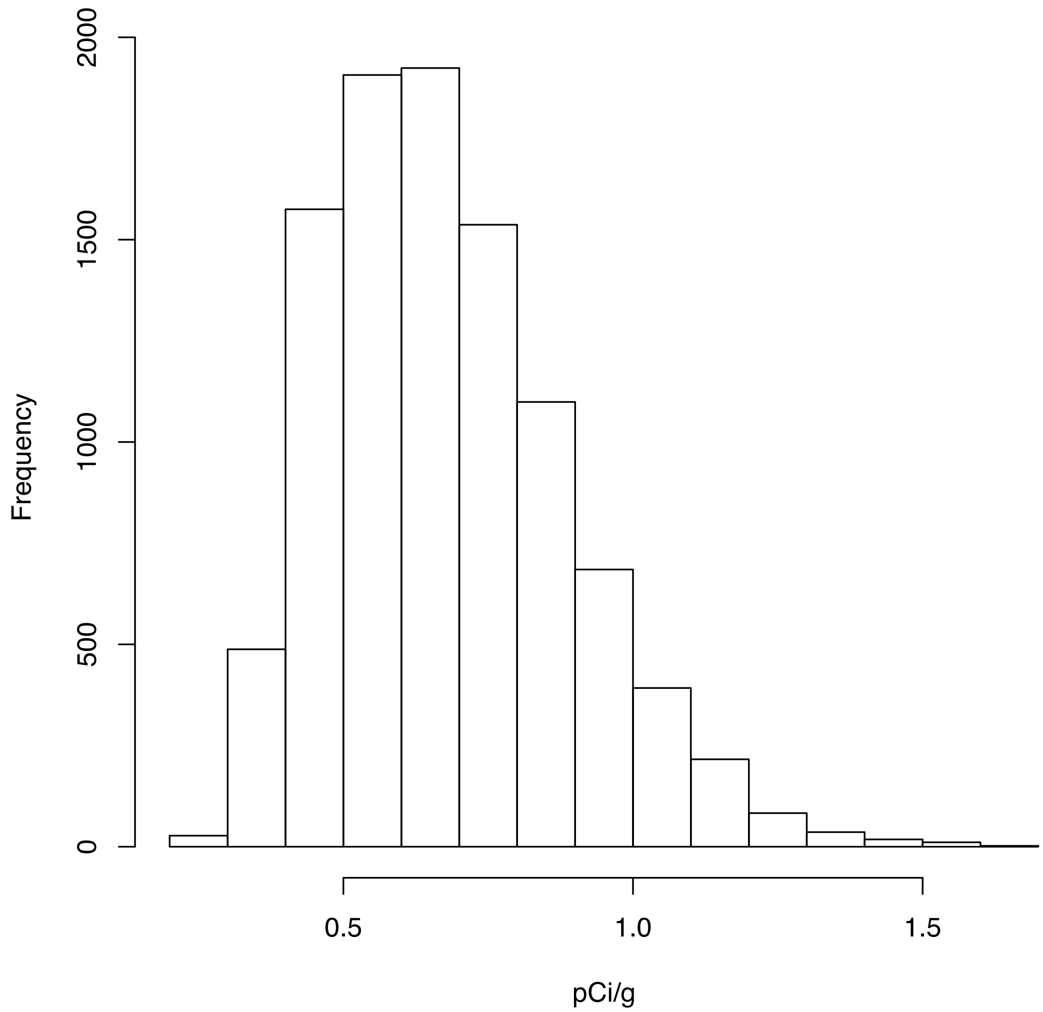


Figure C-31
Histogram of Simulated Means for Tritium

Appendix B

Special Analysis: 2016-003 Upgrade of Area G PA-CA Model to Updated Versions of GoldSim Software and to LANL Analysts

SA-2016-003
LA-UR-17-20616

Special Analysis: 2016-003
Upgrade of Area G PA-CA Model to Updated Versions of GoldSim Software and to LANL Analysts

UDQE Reference Number:
UDQE-1603
(Supersedes: UDQE-1503)

Authors:
Shaoping Chu, Kay Birdsell and Philip Stauffer - Los Alamos National Laboratory
Rob Shuman

Prepared for:
Los Alamos National Laboratory

Date:
March 2017

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Acronyms and Abbreviations

CA	Composite Analysis
D&D	Decontamination and decommissioning
DOE	Department of Energy
ER	Environmental restoration
FY	Fiscal Year
GoldSim 10.11 SP4	GoldSim Version 10.11 Service Pack 4
GoldSim 11.1.2	GoldSim Version 11.1.2
GoldSim 11.1.5	GoldSim Version 11.1.5
LANL	Los Alamos National Laboratory
LHS	Latin Hypercube Sampling
LLW	Low-level radioactive waste
MDA	Material Disposal Area
PA	Performance Assessment
PA/CA	Performance Assessment and Composite Analysis
SA	Special Analysis
TA-54	Technical Area 54
UDQE	Unreviewed Disposal Question Evaluation

1.0 Introduction

The Los Alamos National Laboratory (LANL) generates radioactive waste as a result of various activities. Operational 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 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 (PA/CA) 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 onsite and offsite exposure scenarios. The assessments are based on existing site and disposal facility data, and assumptions about future rates and methods of waste disposal.

The accuracy of the PA/CA depends upon the validity of the models, data, and assumptions used to conduct the analyses. If changes in these models, data, and assumptions are significant, they may invalidate or call into question certain aspects of the analyses. DOE field sites are required to implement a PA/CA maintenance program, which, among other things, evaluates the continued validity of the analyses. Several model updates have been conducted since the Revision 4 results were published in 2008 (LANL, 2008), including inventory updates to reflect annual disposal receipt reviews as published in the site annual reports, and in special analyses (SAs) that were performed in response to unreviewed disposal question evaluations (UDQE); the most recent examples are SA 2014-004 (LANL 2015a) and SA 2015-001 (LANL 2016).

The long-term performance of the Area G disposal facility was evaluated using models developed with the GoldSim modeling platform or environment. The Area G Site Model is used to project doses for members of the public living in the vicinity of the disposal facility and rates of radon diffusion from the undisturbed site. The Area G Intruder and Intruder Diffusion Models estimate the doses received by persons who inadvertently intrude into the waste after the facility has undergone final closure; the former model addresses radionuclides that are unaffected by vapor- or gas-phase diffusion while the latter estimates doses for radionuclides diffusing upward from the waste. The Area G Inventory Model is used to estimate radionuclide inventories for the disposal units included in the Site and intruder models.

The most recent model updates documented in special analyses (e.g., SA 2014-004 and SA 2015-001) were implemented using GoldSim version 10.11, Service Pack 4 (SP4). Since those analyses, two GoldSim software updates have been adopted sequentially for the Area G Site Model, versions 11.1.2 and 11.1.5. In addition, the contractor, who served for over 20 years as the primary Area G PA/CA analyst, conducted these latest special analyses but has retired. In late 2015, LANL staff assumed the role as the primary Area G PA/CA analysts. This special analysis, SA 2016-003, documents analyses performed to both upgrade the Area G GoldSim Site, Intruder, Intruder Diffusion, and Inventory Models and demonstrate the successful transition of the PA/CA models to the LANL analysts and the LANL computing systems. This work was recommended by UDQE 1603, which is included in Appendix A. Previously UDQE 1503 recommended that the upgrade from GoldSim version 10.11 to 11.1.2 be made (by the contractor). However, UDQE 1603 supersedes UDQE 1503 because it recommends that the initial GoldSim upgrade to version 11.1.2 be documented, but it also recommends additional documentation of upgrading to GoldSim version 11.1.5 and transitioning to LANL analysts and computing environment.

Special analysis 2016-003 details the changes made to upgrade the full set of Area G GoldSim models. The model updates are made and documented sequentially to illustrate any change to the model results that occur for each modification and to show the logic of the modeling workflow.

Step 1 – Version 11 of GoldSim was issued in July 2013. The contractor adopted version 11.1.2 of the software for the set of Area G models. Changes made in transitioning from version 10.11 to version 11.1.2 necessitated some structural changes to three of the four models used to conduct the PA/CA. Special analysis 2016-003 details the changes made to the PA/CA models so they run satisfactorily with GoldSim version 11.1.2. The step 1 model upgrade was performed by the long-term contractor. For this particular comparison, the inventory information used was for the inventory compiled through fiscal year (FY) 2013 as documented in the *Radioactive Waste Inventory for Los Alamos National Laboratory Technical Area 54, Area G, Revision 2 (*French and Shuman, 2015a).

Subsequent to the upgrade to GoldSim version 11.1.2, the 2014 Disposal Receipt Review (DRR) (French and Shuman, 2015b) was conducted and changes to the full set of Area G GoldSim models resulting from the associated inventory modifications were documented in the DRR and also included in the Fiscal Year 2014 Annual Report for the Area G

Disposal Facility (LANL 2015b). The contractor also conducted this inventory update; GoldSim version 11.1.2 was used.

Step 2 – LANL staff reran the full set of Area G GoldSim models used in the 2014 DRR (French and Shuman 2015b) and 2014 annual report (LANL 2015b) with GoldSim version 11.1.2 to verify that the results could be recreated.

Step 3 –LANL staff upgraded the full set of Area G GoldSim models used in the 2014 DRR and 2014 annual report to use GoldSim version 11.1.5 with a new licensing system (issued in March 2016) and documented the changes.

Section 2 describes the nature of the changes made to the models and the methods used to determine if the software upgrades had meaningful impacts upon the model projections. Section 3 presents the results of the investigations. Section 4 summarizes the results of the special analysis. The main conclusion is that this special analysis documents the successful (1) upgrade of the Area G PA/CA Model from GoldSim version 10.11 to versions 11.1.2 and 11.1.5, and (2) transition to LANL analysts and the LANL computing environment. Some differences in dose projections occurred because of the implementation of an improved Monte Carlo Latin Hypercube Sampling (LHS) scheme in GoldSim version 11.1.5, and this correction is expected to generate more accurate results than for previous models. Migration to GoldSim version 11.1.5 is adopted for the maintenance of the PA/CA model, and the full set of exposure and radon flux results using this model are presented in Section 4. The modeling results continue to indicate that the disposal facility satisfied all DOE Order 435.1 performance objectives.

2.0 Methods

2.1 Contractor upgrade from GoldSim version 10.11 to version 11.1.2

Several modifications were made to GoldSim in conjunction with the release of version 11 (and subsequent versions) of the software. These changes were detailed in summary documents that address versions 11 and 11.1 of GoldSim (GoldSim, 2013; 2014) and release notes accompanying the release of versions 11.1.1 and 11.1.2. The summary documents and release notes were reviewed by the previous PA/CA analyst to understand the potential implications of using version 11.1.2 of GoldSim to run the PA/CA models. The previous PA/CA analyst (contractor) conducted and documented this version upgrade.

Although the transition from version 10.11 to 11.1.2 involved several significant changes to the software, these modifications were not expected to require dramatic changes to the structure of the Area G models. Consistent with this initial impression, the Inventory Model did not require any changes to operate satisfactorily with GoldSim version 11.1.2.

Limited changes were made to the Site, Intruder, and Intruder Diffusion Models to accommodate the new version of the software. All three models use reservoir elements as a simple means of introducing waste to the disposal pits and shafts. Separate reservoirs are used to represent different subsets of the disposal units at Area G. For a given set of disposal units, radionuclide inventories start to flow into the reservoir when disposal in the pits or shafts is first initiated. Inventories mount in the reservoir until the end of the disposal period; an upper bound is imposed on the reservoir to ensure the radionuclide inventories added to the pits or shafts do not exceed the total inventories projected to have been disposed of in the disposal units.

Running the Site and Intruder Models with GoldSim version 11.1.2 caused warnings to be issued when radionuclides were added to the reservoir after the upper bound inventory was reached. The way the models are constructed, radionuclides are added using rates of addition, which can cause the upper bound of the inventory to be exceeded. With the new version of GoldSim, warning messages are issued to ensure the modeler is aware of the fact that the upper bound was reached. The warning messages were eliminated from the Area G model runs by inserting a second reservoir for each subset of disposal units into which any inventory that exceeds the upper bound flows. The additional reservoir, which lacks an upper bound, accepts the overflow from the original reservoir. The primary reservoir receives the waste that is constrained by the inventory upper bound; the activities that enter the primary reservoir are used for modeling performance. The additional reservoir is used only to avoid getting the warning messages from GoldSim, the activities in these overflow reservoirs are not used in modeling performance because they exceed the upper bound inventory, an unphysical condition.

Prior to GoldSim version 11, time histories generated by probabilistic simulations could be saved for a wide variety of elements. The new version of the software allows time histories to be saved for probabilistic assessments using Time History Results elements only. This modification required changes to the PA/CA models because they use Expression elements to save time histories of the several modeled quantities, including the dose and radon flux projections. Consequently, Time History Results elements were inserted into the Site, Intruder, and Intruder Diffusion Models to allow output of the projected doses and fluxes. The changes made to the Area G models to upgrade to GoldSim version 11.1.2 are summarized in Table 2-1.

The upgrade of GoldSim from version 10.11 to 11.1.2 was expected to have little or no impact on the inventories projected by the Inventory Model and the doses and radon fluxes projected by the Site Model and the intruder models. Nevertheless, selected model simulations were run using the models implemented with version 11.1.2 to perform spot comparisons. The spot comparisons did not compare every exposure point and were not necessarily run for the full 1000-yr post-closure simulation time period, because they were meant only to illustrate the successful implementation of the upgraded software. The results of these simulations were compared to projections from the models run with version 10.11 of GoldSim, taken from SA 2014-004 (LANL, 2014), which has identical results to those for SA 2015-001 (LANL, 2016). These simulations are consistent with inventory disposed through FY 2013.

2.2 LANL implementation of GoldSim version 11.1.2

In December 2015, LANL staff used the files from the contractor's latest version of the PA/CA models for Area G. LANL staff reran the simulations for the Site Model (LANL version 4.200) and for the Inventory, Intruder, and Intruder Diffusion Models (LANL version 3.200). For quality assurance purpose, the results of these simulations were compared to projections from the models run with GoldSim version 11.1.2, taken from the contractor's version of the Site Model (contractor version 4.100) and of the Inventory, Intruder and Intruder Diffusion Models (contractor version 3.101), which were consistent with those for the 2014 DRR (French and Shuman 2015b) and 2014 Annual Report (LANL 2015b). These simulations are consistent with inventory disposed through FY 2014.

2.3 LANL upgrade to GoldSim version 11.1.5

On February 15, 2016, GoldSim introduced a new licensing system. The latest version of the GoldSim software (version 11.1.5) implements the new licensing system. The upgrade from GoldSim version 11.1.2 to 11.1.5 includes an improvement made to the Monte Carlo LHS algorithm implemented to minimize correlation within non-scaler stochastic elements (GoldSim, 2016). The impact of this improved sampling scheme is documented, based on GoldSim release notes, in Appendix B of this Special Analysis. Other model upgrades to 11.1.3 and 11.1.4 that may impact the Area G models are included in Appendix B for completeness. Although the LHS scheme with the GoldSim software is modified, this was not expected to require changes to the structure of the Area G models. However, the modification to the LHS algorithm is expected to impact the results of the Inventory, Intruder, and Intruder Diffusion Models because those models all use LHS to sample several non-scaler stochastic elements. The Site Model and radon flux calculation will be impacted by changes in the Inventory Model and also through a distribution that controls sediment transport rates, which is a non-scaler stochastic element. The changes made for the improved LHS algorithm in effect implement a different random seed to sample the non-scaler stochastic elements which minimizes correlation between realization results, thus resulting in smoother distributions of final results, as documented in Appendix B. We note that the previous PA/CA analyst (contractor) had contacted the GoldSim developers with concerns that the previous LHS scheme did not generate smooth distributions. He anticipated that an improved sampling scheme would more accurately implement the parameter distributions defined for the PA/CA model and result in more accurate predicted doses that might differ from previous results. For quality assurance purposes, selected model simulations were run using the models implemented with version 11.1.5 to perform spot comparisons to results from version 11.1.2 of GoldSim run by LANL analysts described under Step 2 above. Again, the spot comparisons did not consider every exposure point and were not necessarily run for the full 1000-year post-closure period if peak dose occurs before then. . The simulations are done in a step-wise fashion to first document the resultant changes to the Inventory Model results and then document the changes to the Site, Intruder, and Intruder Diffusion Models. These simulations are consistent with inventory disposed through FY 2014.

Spot comparisons for the selected model simulations run with GoldSim version 11.1.5 differed enough from those run with version 11.1.2 that the full set of GoldSim simulations were run for the 1000-year post-closure period (1088 years total) to generate updated dose and radon flux projections that are considered the most recent projections as of the end of FY 2016. These simulations are consistent with inventory disposed through FY 2014 as documented in the FY 2014 DRR (French and Shuman, 2015b). We note that very little waste was disposed in FY 2015 (French et al., 2016) and no waste was disposed in FY 2016.

Table 2-1 Contractor Changes Made to the GoldSim Models Used in the Area G Performance Assessment and Composite Analysis when Upgrading from GoldSim Version 10.11 to Version 11.1.2

Model	Model Modification
Area G Inventory Model (version 3.100)	None
Area G Site Model (version 4.000 modified to be version 4.001)	Inserted an additional reservoir element in each disposal unit/region comprising Area G. These elements received the overflow from the reservoir elements used to simulate the addition of waste to the pits and shafts. The additional overflow elements were used to avoid warnings indicating that the original reservoir elements were overflowing (i.e., exceeding maximum inventory). The overflow elements are used only to avoid the GoldSim warning messages; the radionuclide activities in the overflow elements are not used in modeling performance. The radionuclide activities in the primary reservoir elements are constrained by the inventory upper boundary and are used in modeling performance. Time History Results elements were added to output total scenario doses and radon fluxes from the model. Expression elements had been used to output time histories; time histories are no longer saved for these elements when the simulations are probabilistic in nature.
Area G Intruder Model (version 3.000 modified to be version 3.001)	Inserted an additional reservoir element in each set of pits and shafts considered in the model. These elements received the overflow from the reservoir elements used to simulate the addition of waste to the pits and shafts. The additional overflow elements were used to avoid warnings indicating that the original reservoir elements were overflowing (i.e., exceeding maximum inventory). The overflow elements are used only to avoid the GoldSim warning messages; the radionuclide activities in the overflow elements are not used in modeling performance. The radionuclide activities in the primary reservoir elements are constrained by the inventory upper boundary and are used in modeling performance. Time History Results elements were added to output total scenario doses from the model. Expression elements had been used to output time histories; time histories are no longer saved for these elements when the simulations are probabilistic in nature.
Area G Intruder Diffusion Model (version 3.000 modified to be version 3.001)	Inserted an additional reservoir element in each set of pits and shafts considered in the model. These elements received the overflow from the reservoir elements used to simulate the addition of waste to the pits and shafts. The additional overflow elements were used to avoid warnings indicating that the original reservoir elements were overflowing (i.e., exceeding maximum inventory). The overflow elements are used only to avoid the GoldSim warning messages; the radionuclide activities in the overflow elements are not used in modeling performance. The radionuclide activities in the primary reservoir elements are constrained by the inventory upper boundary and are used in modeling performance. Time History Results elements were added to output total scenario doses from the model. Expression elements had been used to output time histories; time histories are no longer saved for these elements when the simulations are probabilistic in nature.

3.0 Results

3.1 Contractor Comparison of PA/CA Models using GoldSim v11.1.2 versus GoldSim v10.11

Spot comparisons were made between the inventories projected by the Area G Inventory Model with GoldSim versions 10.11 and 11.1.2, and between the doses and radon fluxes projected by the Site Model and the intruder models with the two versions of software. The results of these comparisons are presented and discussed below. These results are consistent with those documented in SA 2014-004 (LANL, 2015a) and SA 2015-001 (LANL, 2016) using inventory data through FY 2013.

Implementing the Inventory Model with GoldSim version 11.1.2 had no impact on the radionuclide inventories projected by the model. Mean and median radionuclide inventories projected for pits 30, 31, 32, 36, and 39; the headspace waste in pits 15, 37, and 38; and the institutional waste in pits 15, 37, and 38 were identical when the Inventory Model was run with version 10.11 and 11.1.2 of the software.

The Site Model was run with the two versions of GoldSim using the composite analysis (CA) inventory. The peak median and mean doses projected for the atmospheric scenario (LANL boundary and Area G fenceline receptors), All Pathways – Canyon Scenario (receptor in catchment PC6), and All Pathways – Groundwater Scenario differed by 1 percent or less (Table 3-1). Radon flux projections were projected for the performance assessment (PA) inventory using the two versions of GoldSim. Fluxes were projected for various subsets of the disposal units at Area G as well as the entire facility. The peak median and mean fluxes for the disposal units and the entire facility were nearly identical (Table 3-2).

Intruder model runs conducted using GoldSim versions 10.11 and 11.1.2 projected peak mean and median doses that differed by 1 percent or less (Table 3-3). Comparisons considered projections for the Material Disposal Area (MDA G) pits and Zone 4 shafts under the post-drilling, agricultural, and construction scenarios. Similar results were observed for the doses projected by the Area G Intruder Diffusion Model for the MDA G pits, MDA G shafts, and Zone 4 shafts under the post-drilling and agricultural scenarios. Median and mean doses differed by less than 0.01 percent when the model was run using the two software versions.

The implementation of the PA/CA models with GoldSim version 11.1.2 had no significant impacts on the doses and radon fluxes projected by the Site, Intruder, and Intruder Diffusion Models. Differences in the projected quantities were 1 percent or less. These differences are likely due to changes in the causality sequence of the software, changes made to individual elements including those used in contaminant transport modeling, and improvements made in the numerical precision of various calculations. The modeling results continue to indicate that the disposal facility satisfies all DOE Order 435.1 performance objectives.

Table 3-1 Contractor Comparison of Site Model Dose Projections (Composite Analysis) - GoldSim version upgrade (v10.11 to v11.1.2)

	Dose Projections (mrem/yr)			
	GoldSim Version 11.1.2 Model V4.001		GoldSim Version 10.11 Model V4.000	
Exposure Scenario	**Peak Median Dose**	**Peak Mean Dose**	**Peak Median Dose**	**Peak Mean Dose**
Atmospheric Scenario – LANL Boundary	0.18	0.25	0.18	0.25
Atmospheric Scenario – Area G Fenceline	0.026	0.46	0.026	0.47
All Pathways – Canyon, Catchment PC6	0.11	2.4	0.11	2.4
All Pathways – Groundwater	0.0045	0.0069	0.0045	0.0069

Table 3-2 Contractor Comparison of Site Model Radon Flux Projections (Performance Assessment) - GoldSim version upgrade (v10.11 to v11.1.2)

	Radon Flux Projections (pCi/m^2-s)			
	GoldSim Version 11.1.2 Model V4.001		GoldSim Version 10.11 Model V4.000	
Waste Disposal Region or Pit	**Peak Median Flux**	**Peak Mean Flux**	**Peak Median Flux**	**Peak Mean Flux**
Region 1	2.0E-08	1.1E–06	2.0E-08	1.1E–06
Region 2	---[a]	---[a]	---[a]	---[a]
Region 3	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Region 4	1.2E–02	3.5E–02	1.2E–02	3.5E–02
Region 5	7.2E–05	8.4E–05	7.2E–05	8.4E–05
Region 6	3.9E-05	3.3E–03	3.9E-05	3.3E–03
Region 7	9.2E+00	1.3E+01	9.2E+00	1.3E+01
Region 8	7.7E–04	3.4E–03	7.7E–04	3.4E–03
Pit 15	1.1E+01	1.4E+01	1.1E+01	1.4E+01
Pit 37	2.3E–01	2.8E–01	2.3E–01	2.8E–01
Pit 38	1.4E+00	1.6E+00	1.4E+00	1.6E+00
Entire facility	3.9E–01	4.6E–01	3.9E–01	4.6E–01

[a] = *None of the performance assessment inventory was disposed of in the waste disposal region.*

Table 3-3 Contractor Comparison of Intruder and Intruder Diffusion Model Dose Projections - GoldSim version upgrade (v10.11 to v11.1.2)

	Dose Projections (mrem/yr)			
	GoldSim Version 11.1.2 Model V3.001		GoldSim Version 10.11 Model V3.000	
Model, Disposal Units, and Exposure Scenario	**Peak Median Dose**	**Peak Mean Dose**	**Peak Median Dose**	**Peak Mean Dose**
Intruder Model				
MDA G Pits				
Post-Drilling Intruder	4.2	11.7	4.2	11.8
Agricultural Intruder	8.5	11.5	8.5	11.5
Construction Intruder	1.5	2.9	1.5	2.9
Zone 4 Shafts				
Post-Drilling Intruder	1.2	1.5	1.2	1.5
Agricultural Intruder	0.0023	0.13	0.0023	0.12
Construction Intruder	4.2E-5	0.0011	4.3E-5	0.0011
Intruder Diffusion Model				
MDA G Pits				
Post-Drilling Intruder	0.22	0.30	0.22	0.30
Agricultural Intruder	8.5	19.3	8.5	19.3
MDA G Shafts				
Post-Drilling Intruder	4.3	4.9	4.3	4.9
Agricultural Intruder	15.4	19.9	15.4	19.9
Zone 4 Shafts				
Post-Drilling Intruder	9.3	10.0	9.3	10.0
Agricultural Intruder	71.4	85.6	71.4	85.6

3.2 LANL Implementation of PA/CA Models using GoldSim version 11.1.2

LANL staff reran the contractor's simulations for the Site Model and for the Inventory, Intruder, and Intruder Diffusion Models that were presented in the FY 2014 DRR (French and Shuman, 2015b) and FY 2014 Area G Annual Report (LANL 2015b). Both the contractor and LANL ran the simulations with GoldSim version 11.1.2. Spot comparisons were made between the contractor's and LANL's model results for the inventories projected by the Area G Inventory Model and the doses and radon fluxes projected by the Site Model and intruder models. This implementation is used to verify that the LANL analysts are able to recreate the contractor's results. The results of these comparisons are presented and discussed below.

Inventory model simulations run by LANL analysts (LANL version 3.200) show identical results to the radionuclide inventories projected by the contractor's last model version (version 3.101). Mean and median radionuclide inventories projected for pits 30, 31, 32, 36, and 39; the headspace waste in pits 15, 37, and 38; and the institutional waste in pits 15, 37, and 38 were identical when the Inventory Model was run using Goldsim version 11.1.2 by the LANL analysts and the previous contractor.

The Site Model was run using the contractor's model files (version 4.100) at LANL (version 4.200) using both PA and CA inventories through FY 2014. The peak median and mean doses projected for the atmospheric scenario (LANL boundary and Area G fenceline receptors), All Pathways – Canyon Scenario (receptor in catchment PC6), and All Pathways – Groundwater Scenario results were identical (Tables 3-4a and 3-4b). Radon flux projections were made for the PA inventory. Fluxes were projected for various subsets of the disposal units at Area G as well as the entire facility. The peak median and mean fluxes for the disposal units and the entire facility were identical (Table 3-5) for the model as run by the contractor and by LANL analysts.

Intruder model runs conducted using the contractor's model files (version 3.101) and LANL version 3.200 projected peak mean and median doses created identical results (Table 3-6). Comparisons considered projections for the MDA G pits and Zone 4 shafts under the post-drilling, agricultural, and construction scenarios. The same results were obtained for the doses projected by the Area G Intruder Diffusion Model for the MDA G pits, MDA G shafts, and Zone 4 shafts under the post-drilling and agricultural scenarios. Median and mean doses were identical for the model as run by the contractor and by LANL analysts.

The implementation of the PA/CA models using GoldSim version 11.1.2 by LANL analysts and on the LANL computing environment had no impacts on the projected inventory nor the doses and radon fluxes projected by the Site, Intruder, and Intruder Diffusion Models. The projected results were identical to the contractor's latest model results as presented in the Area G FY 2014 DRR (French and Shuman 2015b). This shows that LANL successfully transferred and ran the GoldSim models (using GoldSim version 11.1.2) and recreated the model results. The modeling results continue to indicate that the disposal facility satisfies all DOE Order 435.1 performance objectives.

Table 3-4a Comparison of Site Model Dose Projections (Performance Assessment) – LANL vs. Contractor's latest version (both using GoldSim version 11.1.2)

	Dose Projections (mrem/yr)			
	LANL Version 4.200		Contractor Version 4.100	
Exposure Scenario	Peak Median Dose	Peak Mean Dose	Peak Median Dose	Peak Mean Dose
Atmospheric Scenario – LANL Boundary	0.12	0.17	0.12	0.17
Atmospheric Scenario – Area G Fenceline	0.0025	0.0027	0.0025	0.0027
All Pathways – Canyon, Catchment PC6	0.0046	0.13	0.0046	0.13
All Pathways – Groundwater	0.0044	0.0070	0.0044	0.0070

Table 3-4b Comparison of Site Model Dose Projections (Composite Analysis) – LANL vs. vs. Contractor's latest version (both using GoldSim version 11.1.2)

	Dose Projections (mrem/yr)			
	LANL Version 4.200		Contractor Version 4.100	
Exposure Scenario	Peak Median Dose	Peak Mean Dose	Peak Median Dose	Peak Mean Dose
Atmospheric Scenario – LANL Boundary	0.17	0.24	0.17	0.24
Atmospheric Scenario – Area G Fenceline	0.025	0.45	0.025	0.45
All Pathways – Canyon, Catchment PC6	0.11	3.25	0.11	3.25
All Pathways – Groundwater	0.0045	0.0071	0.0045	0.0071

We note that there were model changes made between the contractor's Site Model version 4.100 and version 4.001, Intruder and Intruder Diffusion Model version 3.101 and 3.001, Inventory Model version 3.101 and version 3.100. In support of the FY 2014 DRR, the changes include the actual rather than projected inventories disposed in FY 2014; and Am-242m, Pb-205, and Po-209 were added to the species list. These changes caused differences in the results for GoldSim version

11.1.2 simulations presented in this section to those presented in the previous section of this report (shown in Table 3-4 to 3-6 vs. Table 3-1 to 3-3). The changes in the tables are a reflection of the actual inventory update rather than as a result of running a different GoldSim version or in changing from the contractor to the LANL analysts.

Table 3-5 Comparison of Site Model Radon Flux Projections (Performance Assessment) – LANL vs. Contractor's latest version (both using GoldSim version 11.1.2)

	Radon Flux Projections (pCi/m²/s)			
	LANL Version 4.200		Contractor Version 4.100	
Waste Disposal Region or Pit	Peak Median Flux	Peak Mean Flux	Peak Median Flux	Peak Mean Flux
Region 1	1.86E-08	1.3E-06	1.86E-08	1.3E-06
Region 2	---[a]	---[a]	---[a]	---[a]
Region 3	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Region 4	1.3E-2	3.3E-2	1.3E-2	3.3E-2
Region 5	7.17E-05	8.45E-05	7.17E-05	8.45E-05
Region 6	3.35E-05	3.3E-3	3.35E-05	3.3E-3
Region 7	8.96E+00	1.32E+1	8.96E+00	1.32E+1
Region 8	8.37E–07	3.7E–03	8.37E–07	3.7E–03
Pit 15	1.04E+1	1.41E+1	1.04E+1	1.41E+1
Pit 37	2.25E–01	2.8E–01	2.25E–01	2.8E–01
Pit 38	9.01E-01	1.17E+00	9.01E-01	1.17E+00
Entire facility	3.64E-01	4.35E-01	3.64E-01	4.35E-01

[a] = *None of the performance assessment inventory was disposed of in the waste disposal region.*

Table 3-6 Comparison of Intruder and Intruder Diffusion Model Dose Projections – LANL vs. Contractor's latest version (both using GoldSim version 11.1.2)

	Dose Projections (mrem/yr)			
	LANL Version 3.200		Contractor Version 3.101	
Model, Disposal Units, and Exposure Scenario	**Peak Median Dose**	**Peak Mean Dose**	**Peak Median Dose**	**Peak Mean Dose**
Intruder Model				
MDA G Pits				
Post-Drilling Intruder	4.39	12.18	4.39	12.18
Agricultural Intruder	8.41	11.25	8.41	11.25
Construction Intruder	1.47	2.83	1.47	2.83
Zone 4 Shafts				
Post-Drilling Intruder	0.98	1.19	0.98	1.19
Agricultural Intruder	0.00051	0.013	0.00051	0.013
Construction Intruder	1.91E-5	0.00048	1.91E-5	0.00048
Intruder Diffusion Model				
MDA G Pits				
Post-Drilling Intruder	0.19	0.27	0.19	0.27
Agricultural Intruder	6.91	17.33	6.91	17.33
MDA G Shafts				
Post-Drilling Intruder	4.06	4.8	4.06	4.8
Agricultural Intruder	14.94	18.81	14.94	18.81
Zone 4 Shafts				
Post-Drilling Intruder	9.3	10.01	9.3	10.01
Agricultural Intruder	71.39	85.62	71.39	85.62

3.3 Comparison of LANL Model in GoldSim v11.1.5 with new licensing system versus LANL Model in GoldSim v11.1.2

LANL staff upgraded the simulations presented in section 3.2 for the Inventory, Site, Intruder, and Intruder Diffusion Models from GoldSim version 11.1.2 to version 11.1.5. Spot comparisons were made between the inventories projected by the Area G Inventory Model with GoldSim versions 11.1.5 and 11.1.2, and between the doses and radon fluxes projected by the Site Model and intruder models with the two versions of software. All comparisons documented in Section 3.3 use FY 2014 inventory information (French and Shuman, 2015b). Because differences were obtained for the intruder scenarios using the spot comparisons, the intruder scenarios were more fully analyzed, including comparing doses as functions of time and calculating the combined intruder peak doses. The results of this suite of comparisons for the intruder scenarios are presented and discussed below in addition to the spot comparisons.

Inventory Model

Implementing the Inventory Model with GoldSim version 11.1.5 created differences in the simulated radionuclide inventories because sampling of the inventory distributions was modified with the improved LHS algorithm, as described in Appendix B. Radionuclide inventories calculated by the model for each individual realization change, but the impact on the mean values over the large number of Monte Carlo realizations is small. Mean and median radionuclide inventories projected for pits 30, 31, 32, 36, and 39; the headspace waste in pits 15; and the institutional waste in pits 37 show very little or no differences when the Inventory Model was run using versions 11.1.2 and 11.1.5 of the Goldsim software (Table 3-7), with mean inventories for specific radionuclides differing by less than 1.5% and median inventories differing by less than 4%. For most radionuclide species, the differences were much less than the percentages noted here; for example, most radionuclide-specific mean inventories did not change. The inventory of the Zone 4 Shafts was also compared, the median inventory values for that area differed by less than 0.1%, and the mean values were identical.

Table 3-7 Comparison of PA Inventory Model Dose Projections – GoldSim version upgrade (v11.1.2 to v11.1.5)

	Inventory Projections (Ci) – Pits 30, 31, 32, 36, 39			
	LANL Version 3.200 (GoldSim v11.1.5)		LANL Version 3.200 (GoldSim v11.1.2)	
Species	**Median Inventory**	**Mean Inventory**	**Median Inventory**	**Mean Inventory**
Am241	1.16	1.16	1.15	1.16
Am243	1.35E-06	1.35E-06	1.35E-06	1.35E-06
C14	1.58E-04	1.76E-04	1.58E-04	1.76E-04
Co60	12.37	12.49	12.30	12.49
Cs135	3.36E-04	3.74E-04	3.36E-04	3.74E-04
Cs137	23.46	25.51	23.77	25.35
I129	3.53E-06	3.92E-06	3.53E-06	3.92E-06
Np237	2.10E-03	2.34E-03	2.10E-03	2.34E-03
Pa231	5.98E-05	6.66E-05	5.98E-05	6.66E-05
Pb210	0.31	0.35	0.31	0.35
Pu239	2.57	2.57	2.57	2.57
Ra226	1.54E-02	1.71E-02	1.54E-02	1.71E-02
Sr90	17.26	19.06	17.59	18.91
Tc99	0.09	0.10	0.09	0.10
Th232	0.13	0.14	0.13	0.14
U235	0.64	0.64	0.63	0.64
U238	5.17	5.23	5.19	5.23
	Inventory Projections (Ci) – Pit 15 Headspace Waste			
	LANL Version 3.200 (GoldSim v11.1.5)		**LANL Version 3.200 (GoldSim v11.1.2)**	
Species	**Median Inventory**	**Mean Inventory**	**Median Inventory**	**Mean Inventory**
Am241	2.62E-04	2.62E-04	2.62E-04	2.62E-04
Co60	3.23E-06	3.33E-06	3.23E-06	3.33E-06
Cs137	8.50E-04	8.75E-04	8.50E-04	8.75E-04
H3	4.73E-04	4.73E-04	4.73E-04	4.73E-04
Pu238	8.73E-05	8.73E-05	8.73E-05	8.73E-05
Pu239	1.47E-02	1.47E-02	1.47E-02	1.47E-02
Ra226	0.25	0.28	0.25	0.28

Sr90	1.88E-04	2.10E-04	1.89E-04	2.10E-04
U234	0.12	0.12	0.12	0.12
U235	6.66E-03	6.78E-03	6.66E-03	6.78E-03
U238	0.10	0.10	0.10	0.10
	Inventory Projections (Ci) – Pit 37 Institutional Waste			
	LANL Version 3.200 (GoldSim v11.1.5)		**LANL Version 3.200 (GoldSim v11.1.2)**	
Species	**Median Inventory**	**Mean Inventory**	**Median Inventory**	**Mean Inventory**
Ac227	1.21E-05	1.35E-05	1.21E-05	1.35E-05
Am241	0.45	0.45	0.45	0.45
C14	0.06	0.06	0.06	0.06
Cl36	1.25E-03	1.39E-03	1.25E-03	1.39E-03
Cs137	0.93	1.03	0.94	1.04
Np237	3.83E-05	4.26E-05	3.83E-05	4.26E-05
Pu238	1.09	1.09	1.09	1.09
Ra228	0.02	0.02	0.02	0.02
Sn126	4.96E-05	5.87E-05	4.88E-05	5.95E-05
Sr90	0.99	1.05	1.03	1.06
Th228	3.56E-03	3.96E-03	3.56E-03	3.96E-03
U235	0.33	0.34	0.33	0.34

Pathway Models

For the Site, Radon Flux, Intruder, and Intruder Diffusion Models, spot comparisons were analyzed using two steps to determine sequential changes in results for each of the pathway models with and without changes to the inventory:

1) Comparison between simulation results for the Site, Radon Flux, Intruder, and Intruder Diffusion Models run using GoldSim version 11.1.5 versus version 11.1.2 with both sets of models run using the identical inventory as generated by the Inventory Model using GoldSim version 11.1.2. This step analyzes the differences in the results for these four pathway models resulting from the GoldSim version upgrade with no inventory changes.

2) Comparison between simulation results using the Site, Radon Flux, Intruder, and Intruder Diffusion Models each run with version 11.1.5 but different versions of the inventory, as generated with the Inventory Model run with both GoldSim version 11.1.5 and version

11.1.2. This step allows for the analysis of differences resulting from the inventory change only as well as the combined inventory changes and pathway model changes resulting from the GoldSim upgrade to version 11.1.5.

The results of these stepwise comparisons for each of the pathway models are described below.

Site Model

The Site Model was run with the two versions of GoldSim using both the PA and CA inventories (i.e., generated with GoldSim versions 11.1.2 and 11.1.5); results are provided in Tables 3-8a and 3-8b, respectively. The tables are set up so the simulation results for GoldSim version 11.1.2 are in the two right-hand columns, the results using the version 11.1.2 Inventory Model with the version 11.1.5 Site Model are provided in the two center columns, and the results using version 11.1.5 for both the Inventory and the Site Models are provided in the two left-hand columns. The spot comparisons show the following results:

For the PA inventory, the peak median and mean doses projected for the atmospheric scenario (LANL boundary, Area G fenceline receptors) and All Pathways – Groundwater Scenario results are very close, with peak mean doses differing by less than 1.5%. The All Pathways – Canyon Scenario for a receptor in catchment PC6 shows the most significant difference (Table 3-8a), with a 19% increase in peak mean dose for the mean PA inventory in this one catchment. However, the absolute increase in peak mean dose in catchment PC6 is 0.025 mrem/yr, and the projected dose is far below the performance objective (i.e., 0.155 mrem/yr vs. the performance objective of 25 mrem/yr).

For the CA inventory, the peak median and mean doses projected for the atmospheric scenario (LANL boundary) and All Pathways – Groundwater Scenario results are close, with no difference for the atmospheric scenario at the LANL boundary, and a decrease in the peak mean dose for the groundwater scenario of less than 4.5%. The atmospheric scenario (Area G fenceline receptors) and All Pathways – Canyon Scenario (receptor in catchment PC6) show some differences (Table 3-8b), with a 13% increase for the mean CA inventory for the atmospheric scenario (Area G fenceline receptors) and a 14% decrease for the mean CA inventory for catchment PC6 receptors.

For those Site Model pathways showing the greatest differences, both the changes in the Site Model (the two center columns in the tables) and the changes in the Inventory Model (which then propagate to the Site Model as input; the two left-hand columns in the tables) contribute to the differences in the results.

Table 3-8a Comparison of Site Model Dose Projections (Performance Assessment) – GoldSim version upgrade (v11.1.2 to v11.1.5)

	Dose Projections (mrem/yr)					
	LANL Version 4.200 (GoldSim v11.1.5, using v11.1.5 inventory model)		LANL Version 4.200 (GoldSim v11.1.5, using v11.1.2 inventory model)		LANL Version 4.200 (GoldSim v11.1.2, using v11.1.2 inventory model)	
Exposure Scenario	**Peak Median Dose**	**Peak Mean Dose**	**Peak Median Dose**	**Peak Mean Dose**	**Peak Median Dose**	**Peak Mean Dose**
Atmospheric Scenario – LANL Boundary	0.12	0.17	0.12	0.17	0.12	0.17
Atmospheric Scenario – Area G Fenceline	0.0025	0.0027	0.0025	0.0027	0.0025	0.0027
All Pathways – Canyon, Catchment PC6	0.0057	0.155	0.0053	0.15	0.0046	0.13
All Pathways – Groundwater	0.0043	0.0071	0.0044	0.007	0.0044	0.007

Table 3-8b Comparison of Site Model Dose Projections (Composite Analysis) – GoldSim version upgrade (v11.1.2 to v11.1.5)

	Dose Projections (mrem/yr)					
	LANL Version 4.200 (GoldSim v11.1.5, using v11.1.5 inventory model)		LANL Version 4.200 (GoldSim v11.1.5, using v11.1.2 inventory model)		LANL Version 4.200 (GoldSim v11.1.2, using v11.1.2 inventory model)	
Exposure Scenario	**Peak Median Dose**	**Peak Mean Dose**	**Peak Median Dose**	**Peak Mean Dose**	**Peak Median Dose**	**Peak Mean Dose**
Atmospheric Scenario – LANL Boundary	0.17	0.24	0.17	0.24	0.17	0.24
Atmospheric Scenario – Area G Fenceline	0.027	0.51	0.027	0.49	0.025	0.45
All Pathways – Canyon, Catchment PC6	0.12	2.79	0.13	2.91	0.11	3.25
All Pathways – Groundwater	0.0046	0.0068	0.0045	0.0071	0.0045	0.0071

To be sure that the Site Model was implemented correctly in GoldSim version 11.1.5 (i.e., that the different results were not an error in model set up), a pair of deterministic simulations using element mean values was carried out for the Site Model, one run using GoldSim version 11.1.2 and another using GoldSim 11.1.5., both using the same PA inventories (i.e., a single deterministic inventory estimate). This comparison, which is not influenced by the upgraded LHS scheme, shows the results are identical for these two deterministic simulations, which demonstrates the successful upgrade of the Site Model from GoldSim version 11.1.2 to 11.1.5. For the probabilistic simulations, the differences in the results in the Site Model shown in Tables 3-8a and 3-8b are due to the upgraded stochastic LHS scheme and other changes made between the two GoldSim versions, as documented in Appendix B.

Radon Flux Model

Radon fluxes were projected for the PA inventory run with the Inventory Model under the two versions of GoldSim and the Radon Flux model under the two versions of GoldSim. Fluxes were projected for various subsets of the disposal units at Area G as well as the entire facility. The calculated peak median and mean radon fluxes for most of the individual regions and pits show some differences. For those areas with the largest radon fluxes, Region 7 and Pit 15, the peak mean radon flux differs by less than 0.1 pCi/m^2/s (<0.5%) for the two models. For some areas with low radon fluxes, such as Regions 1, 4, 6, and 8, the radon fluxes decreased by fairly large percentage, 13 to 51%, but the absolute differences were less than 0.002 pCi/m^2/s. The radon flux for the entire facility shows very little difference (0.2% and 0.001 pCi/m^2/s for peak mean flux) (Table 3-9) for the two GoldSim versions.

To determine if the differences in the results for the Radon Flux Models run with the two GoldSim versions were significant, five sets of the Radon Flux Model were run using different random seeds. Each full Radon Flux Model simulation consisted of one-thousand realizations using LHS of the non-stationary variables. The analyses demonstrated that the natural statistical variations in the results of the Radon Flux Model are of the same order of magnitude as the differences between GoldSim versions 11.1.2 and 11.1.5, listed in Table 3-9. In addition, areas with higher radon fluxes showed less percentile variability; areas with lower radon fluxes showed higher percentile variability, but still very small absolute variability. This analysis indicates that the upgrade of the Radon Flux Model to GoldSim version 11.1.5 was implemented satisfactorily, and differences in the simulated radon fluxes for the two GoldSim versions are due to upgrading of the LHS scheme and to natural variability in the sampling of parameters.

Table 3-9 Comparison of Site Model Radon Flux Projections (Performance Assessment) – GoldSim version upgrade (v11.1.2 to v11.1.5)

	Radon Flux Projections (pCi/m²/s)					
	LANL Version 4.200 (GoldSim v11.1.5, using v11.1.5 inventory model)		LANL Version 4.200 (GoldSim v11.1.5, using v11.1.2 inventory model)		LANL Version 4.200 (GoldSim v11.1.2, using v11.1.2 inventory model)	
Waste Disposal Region or Pit	Peak Median Flux	Peak Mean Flux	Peak Median Flux	Peak Mean Flux	Peak Median Flux	Peak Mean Flux
Region 1	2.17E-08	1.13E-06	2.25E-08	1.16E-06	1.86E-08	1.30E-06
Region 2	---[a]	---[a]	---[a]	---[a]	---[a]	---[a]
Region 3	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Region 4	0.013	0.027	0.012	0.028	0.013	0.033
Region 5	7.16E-05	8.48E-05	7.14E-05	8.44E-05	7.17E-05	8.45E-05
Region 6	3.33E-05	0.0028	3.59E-05	0.0032	3.35E-05	0.0033
Region 7	9.4	13.2	8.96	13.22	8.96	13.22
Region 8	8.2E–07	1.8E–03	8.45E-07	2.1E-03	8.37E–07	3.7E–03
Pit 15	11.38	14.15	10.36	14.08	10.36	14.08
Pit 37	2.29E–01	2.79E–01	2.25E-01	2.82E-01	2.25E–01	2.82E–01
Pit 38	9.0E-01	1.10E+00	9.01E-01	1.09E+00	9.01E-01	1.17E+00
Entire facility	3.65E-01	4.36E-01	3.64E-01	4.35E-01	3.64E-01	4.35E-01

[a] = *None of the performance assessment inventory was disposed of in the waste disposal region.*

Intruder and Intruder Diffusion Models

Spot comparisons for Intruder Model runs using GoldSim versions 11.1.2 and 11.1.5 projected peak mean and median doses with very small (< 0.5%) to significant percentage differences (i.e., a 31% increase in peak mean dose [from 0.013 mrem/yr to 0.017 mrem/yr, or an absolute dose increase of 0.004 mrem/yr] for the Zone 4 agricultural intruder) (Table 3-10). The spot comparisons considered projections for the MDA G pits and Zone 4 shafts under the post-drilling, agricultural, and construction scenarios. Differences in results were also observed for the doses projected by spot comparisons for the Area G Intruder Diffusion Model for the MDA G pits, MDA G shafts, and Zone 4 shafts under the post-drilling and agricultural scenarios. For example, the peak mean intruder diffusion dose for an agricultural intruder in the Area G Shafts decreased by 29.5% (from 18.81 mrem/yr to 13.28 mrem/yr) while the other intruder scenarios differed by between 0 and <6%. As with the radon flux results, the largest percentage differences correspond to areas with smaller absolute doses. The intruder models use a large number of non-stationary stochastic variables to parameterize the ingestion of animal products and crops that are impacted by the upgrade to GoldSim version 11.1.5 (see Appendix B).

Because there are significant percentage differences in some of the dose projections for many of the locations between many of the individual intruder and intruder diffusion pathways using this spot comparison (although the large percentage differences correspond to areas that have lower projected doses), a combined dose assessment for the intruder scenarios was run to understand the impacts with respect to the PA intruder scenario. The combined intruder dose assessment produces peak mean dose results that are determined based on the sum of the intruder and the intruder diffusion scenarios as functions of time, which can be compared to performance metrics for the intruder scenario so the impact of this change with respect to the performance objectives is determined. Figure 3-1 compares time-dependent doses calculated for the intruder, intruder diffusion, and combined intruder doses for the MDA G pits calculated with Goldsim versions 11.1.5 and 11.1.2; the three sets of results for the three models are very similar. Figure 3-2 compares the same information for the MDA G shafts. For the MDA G shafts, the Intruder Diffusion Model results differ for the two GoldSim versions, primarily as a function of the peak dose calculated after 189 years, just as the intruder arrives. Table 3-11 provides the predicted peak mean doses for the intruder scenarios using the two GoldSim versions. These results are for the combined dose for the intruder and intruder diffusion pathways. Also included, in parentheses, is information about when the peak dose occurs and which of the pathways (I for intruder; ID for intruder diffusion) dominates the peak mean dose, and the percentage difference between the GoldSim version 11.1.5 and 11.1.2 results. This table shows that the doses predicted for the MDA G Pits and the Zone 4 shafts do not change. For the MDA G Shafts, the doses change by 8.3% or less. The updated results differ because of the improvements to the LHS scheme implemented in GoldSim version 11.1.5 and are thought to be more accurate than the previous results. We note that the times for the peak dose for the Intruder Diffusion Models for the MDA G Shafts differ (Table 3-1) for the two GoldSim versions, with the version 11.1.5 peak occurring at 1088 years and the version 11.1.2 peak occurring at 189 years. Figure 3-2 shows that this difference occurs because the doses predicted at these two times are coincidentally very similar (approximately 80 mrem/yr), and the slightly higher intruder diffusion dose at 189 years calculated with version 11.1.2 pushes the combined dose at that time to a marginally higher value than occurs at 1088 years. This is a very minor difference, as can be seen in the figure, meaning that the two GoldSim versions are giving similar results. The Zone 4 shaft intruder dose is dominated by diffusion of tritium, which is assumed to have no variability in its inventory for the Zone 4 shaft region. Therefore, it is not impacted by the updated LHS, and no difference occurs with the GoldSim upgrade.

Table 3-10 Comparison of Intruder and Intruder Diffusion Model Dose Projections – GoldSim version upgrade (v11.1.2 to v11.1.5)

	Dose Projections (mrem/yr)					
	LANL Version 3.200 (GoldSim v11.1.5, using v11.1.5 inventory model)		LANL Version 3.200 (GoldSim v11.1.5, using v11.1.2 inventory model)		LANL Version 3.200 (GoldSim v11.1.2, using v11.1.2 inventory model)	
Model, Disposal Units, and Exposure Scenario	**Peak Median Dose**	**Peak Mean Dose**	**Peak Median Dose**	**Peak Mean Dose**	**Peak Median Dose**	**Peak Mean Dose**
Intruder Model						
MDA G Pits						
Post-Drilling Intruder	3.98	11.55	3.96	10.99	4.39	12.18
Agricultural Intruder	8.38	11.12	8.35	11.08	8.41	11.25
Construction Intruder	1.48	2.82	1.47	2.83	1.47	2.83
Zone 4 Shafts						
Post-Drilling Intruder	0.98	1.18	0.99	1.17	0.98	1.19
Agricultural Intruder	0.00036	0.017	0.00038	0.014	0.00051	0.013
Construction Intruder	1.86E-5	0.00028	1.67E-5	0.00027	1.91E-5	0.00048
Intruder Diffusion Model						
MDA G Pits						
Post-Drilling Intruder	0.19	0.27	0.19	0.27	0.19	0.27
Agricultural Intruder	6.47	17.31	6.86	17.49	6.91	17.33
MDA G Shafts						
Post-Drilling Intruder	3.88	4.52	4.01	4.73	4.06	4.8
Agricultural Intruder	10.59	13.28	14.54	18.43	14.94	18.81
Zone 4 Shafts						
Post-Drilling Intruder	8.98	9.81	8.98	9.81	9.3	10.01
Agricultural Intruder	71.38	85.62	71.37	85.61	71.39	85.62

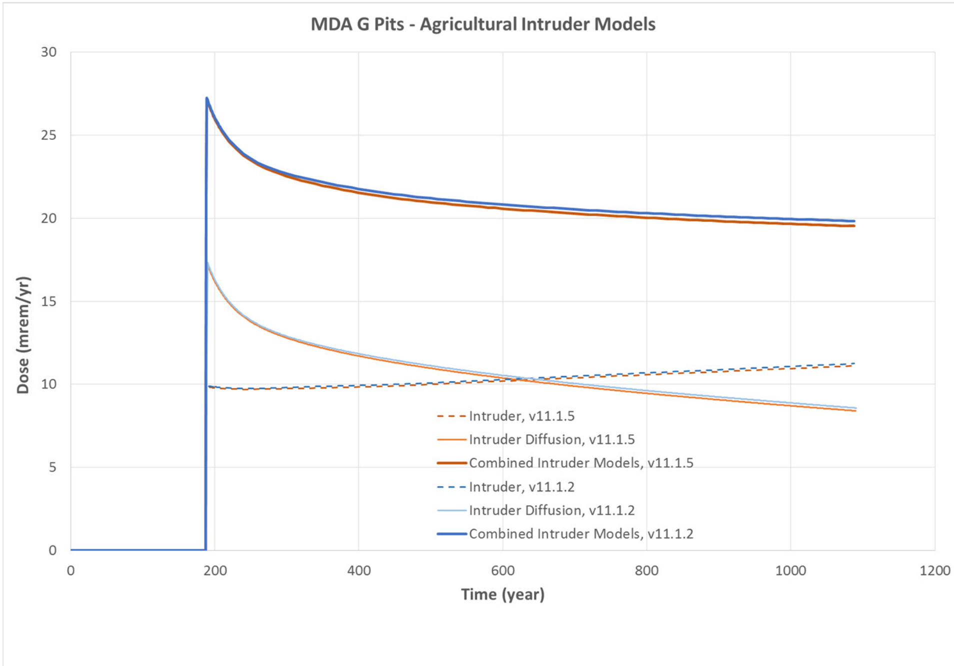

Figure 3-1. Intruder Dose Projections for MDA G Pits, including results for the Intruder and Intruder Diffusion Models and the combined intruder dose

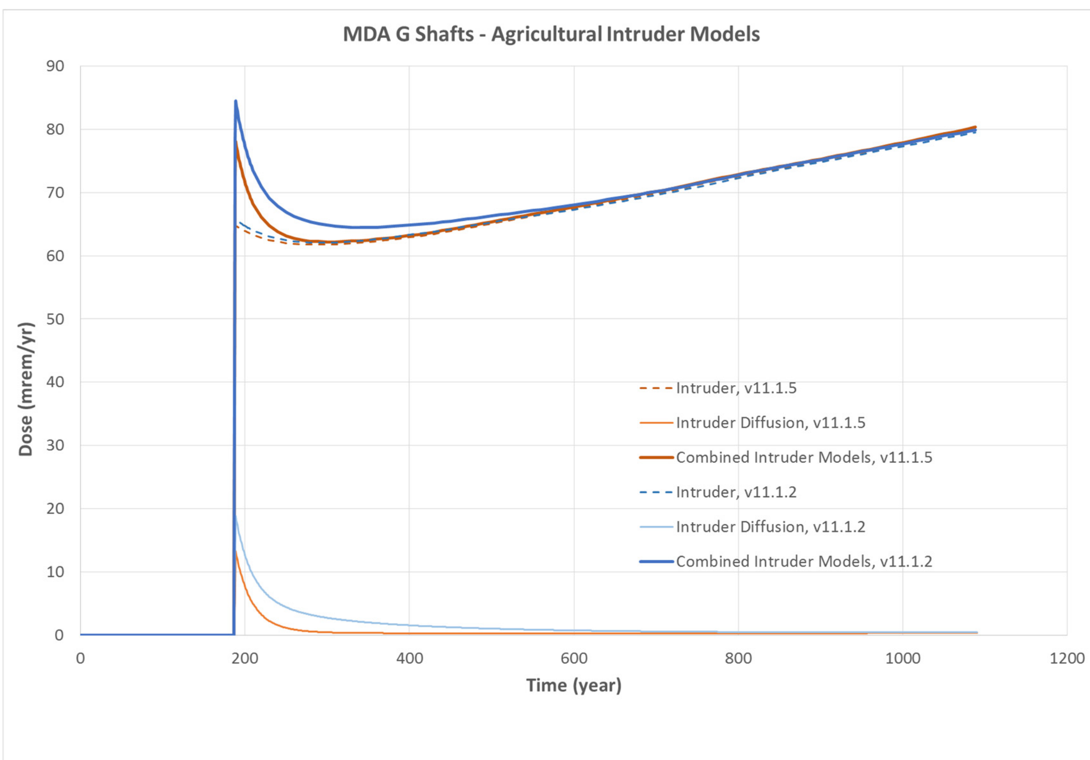

Figure 3-2. Intruder Dose Projections for MDA G Shafts, including results for the Intruder and Intruder Diffusion Models and the combined intruder dose

Table 3-11 Projected Intruder Exposures: Update from GoldSim v11.1.2 to v11.1.5

Disposal Units and Exposure Scenario	Performance Objective	Peak Mean Dose (mrem/yr)	Peak Mean Dose (mrem/yr)	% Difference
		LANL Version 3.200 (GoldSim v11.1.5, using v11.1.5 inventory model)	LANL Version 3.200 (GoldSim v11.1.2, using v11.1.2 inventory model)	
MDA G Pits				
Intruder-Construction	500 mrem	3.9 (189, I)[a]	3.9 (189, I)	0
Intruder-Agriculture	100 mrem/yr	27 (189, ID)	27 (189, ID)	0
Intruder-Post-Drilling	100 mrem/yr	12 (670, I)	12 (770, I)	0
MDA G Shafts				
Intruder-Construction	500 mrem	4.8 (1088, I)	4.7 (1088, I)	2.1
Intruder-Agriculture	100 mrem/yr	80 (1088, I)	85 (189, I)	-5.9
Intruder-Post-Drilling	100 mrem/yr	11 (189, I)	12 (189, I)	-8.3
Zone 4 Shafts				
Intruder-Construction	500 mrem	3.7 (188, ID)	3.7 (188, ID)	0
Intruder-Agriculture	100 mrem/yr	86 (188, ID)	86 (188, ID)	0
Intruder-Post-Drilling	100 mrem/yr	11 (188, ID)	11 (188, ID)	0

[a] = *Values in parentheses indicate the simulation year when the peak mean dose occurs (add 1959 to calculate the calendar year) and the dominant exposure scenario (I = Intruder; ID = Intruder Diffusion)*

The implementation of the intruder and intruder diffusion scenarios are considered to be satisfactory based on this analysis. The modeling results related to the upgrade of GoldSim from version 11.1.2 to 11.1.5 continue to indicate that the disposal facility satisfies all DOE Order 435.1 performance objectives.

4.0 Summary

The accuracy of the PA/CA dose predictions depends upon the validity of the models, data, and assumptions used to conduct the analyses. If changes in these models, data, and assumptions are significant, they may invalidate or call into question certain aspects of the analyses. The long-term performance of the Area G disposal facility is evaluated using models developed with the GoldSim modeling platform or environment. The most recent model updates documented in special analyses (e.g., SA 2014-004 and SA 2015-001) were implemented using GoldSim version 10.11, Service Pack 4 (SP4). Since those analyses, two GoldSim software updates have been adopted sequentially for the Area G Site Model, versions 11.1.2 and 11.1.5. In addition, a contractor, who served for over 20 years as the primary Area G PA/CA analyst, conducted the latest completed special analyses but has retired. In late 2015, LANL staff assumed the role as the primary Area G PA/CA analysts.

This special analysis, SA 2016-003, documents analyses performed to both upgrade the Area G GoldSim Site, Intruder, and Inventory Models and demonstrate the successful transition of the PA/CA models to the LANL analysts and the LANL computing systems. This work was recommended by UDQE 1603 (see Appendix A). Previously UDQE 1503 recommended that the contractor upgrade from GoldSim version 10.11 to 11.1.2. However, UDQE 1603 supersedes UDQE 1503. UDQE 1603 recommends that both the initial GoldSim upgrade to version 11.1.2 and the upgrade to version 11.1.5 be documented. It also recommends proof of the successful transition of the PA/CA GoldSim model to the LANL analysts and computing environment. Special analysis 2016-003 details the changes made to upgrade the GoldSim Area G models and the implementation by new LANL analysts.

The results of Special Analysis 2016-003 are that the upgrade to GoldSim version 11.1.5 and the transfer of the model to LANL analysts were both successful. More specifically the special analysis shows:

Contractor Upgrade from GoldSim Version 10.11 to 11.1.2: Limited changes to the GoldSim model were required to upgrade to Version 11.1.2 as described in Table 2-1. The implementation of the PA/CA models with GoldSim version 11.1.2 had no significant impacts on the doses and radon fluxes projected by the Site, Intruder, and Intruder Diffusion Models. Differences in the projected quantities were 1 percent or less. These differences are likely due to changes in the causality sequence of the software, changes made to individual elements including those used in contaminant transport modeling, and improvements made in the numerical precision of various calculations. The modeling results continue to indicate that the disposal facility satisfies all DOE Order 435.1 performance objectives.

LANL Implementation of GoldSim version 11.1.2: LANL analysts were able to successfully recreate the contractor's simulations for the Inventory, Site, Intruder and Intruder Diffusion Models as presented in the FY 2014 Area G Annual Report (LANL 2015b). The implementation of the PA/CA models using GoldSim version 11.1.2 by LANL analysts and on the LANL computing environment resulted in no changes to the projected inventory nor the doses and radon fluxes projected by the Site, Intruder, and Intruder Diffusion Models. This shows that LANL successfully transferred and ran the GoldSim models and recreated the model results. The modeling results continue to indicate that the disposal facility satisfied all DOE Order 435.1 performance objectives.

LANL Implementation of GoldSim version 11.1.5: LANL analysts upgraded the PA/CA Inventory, Site, Radon Flux, Intruder, and Intruder Diffusion Models to use the GoldSim version 11.1.5 modeling platform. Comparisons of modeled results to those obtained with version 11.1.2 indicated some differences in both the inventory models and all of the pathway models. These differences are primarily due to an upgrade implemented in version 11.1.5 of the LHS scheme for non-stationary stochastic parameters, as well as to other minor improvements made to GoldSim, as described in Appendix B. LANL analysts were able to gain significant experience through this implementation exercise both in terms of running the GoldSim simulations and through analyzing the differences observed between the results of version 11.1.2 and 11.1.5. Careful analysis was performed to ensure that the differences were associated with the GoldSim upgrade, especially the updated LHS scheme, and that the differences did not result from an error in our upgrading the model. The inventory values presented in the FY 2014 DRR (French and Shuman, 2015b) are used for these simulations; these values represent the most up-to-date inventory included in the GoldSim work as of December 2016 when this special analysis was completed. Because simulation results differed from the previous GoldSim version, and we intend to use GoldSim version 11.1.5 for future work, we present the exposures and radon fluxes projected using the GoldSim version 11.1.5 in Tables 3-12 through 3-14. The Zone 4 pits are included in the table for completeness although current plans are that those pits will not be developed. The modeling results continue to indicate that the disposal facility satisfied all DOE Order 435.1 performance objectives.

Table 3-12 Exposures Projected for Members of the Public: FY 2014 Disposal Receipt Review as Calculated using GoldSim version 11.1.5 Site Model

Exposure Scenario and Location	Performance Objective (mrem/yr)	Peak Mean Dose (mrem/yr)	
		Performance Assessment	Composite Analysis
Atmospheric			
LANL Boundary	10	1.7E–01	2.4E–01
Area G Fence Line	10	2.7E–03	5.1E–01
All Pathways–Canyon			
Catchment CdB1	25/30[a]	5.0E–01	8.1E–01
Catchment CdB2	25/30	1.0E+00	1.8E+00
Catchment PC0	25/30	2.5E-04	2.5E-04
Catchment PC1	25/30	2.4E–02	1.2E–01
Catchment PC2	25/30	1.9E–02	6.5E–01
Catchment PC3	25/30	1.2E–01	2.4E–01
Catchment PC4	25/30	2.2E–01	2.7E–01
Catchment PC5	25/30	3.0E–01	2.4E+00
Catchment PC6	25/30	1.6E–01	2.8E+00
Groundwater Pathway Scenarios			
All Pathways–Groundwater	25/30	7.1E–03	6.8E–03
Groundwater Resource Protection	4	1.2E–02	NA

NA = Not applicable.

[a] An all-pathways performance objective of 25 mrem/yr applies to the performance assessment; doses projected for the composite analysis must comply with the 30 mrem/yr dose constraint.

Table 3-13 Projected Radon Fluxes: FY 2014 Disposal Receipt Review as Calculated using GoldSim version 11.1.5 Site Model

Waste Disposal Region or Pit	Peak Mean Flux (pCi/m²/s) LANL 11.1.5 result
Region 1	1.1E-06
Region 2	—[a]
Region 3	0.0E+00
Region 4	2.7E-02
Region 5	8.5E-05
Region 6	2.8E-03
Region 7	1.3E+01
Region 8	1.8E-03
Pit 15	1.4E+01
Pit 37	2.8E-01
Pit 38	1.1E+00
Entire facility	4.4E-01

[a] *— = None of the performance assessment inventory was disposed of in the waste disposal region.*

Table 3-14 Projected Intruder Exposures: FY 2014 Disposal Receipt Review as Calculated using GoldSim version 11.1.5 Site Model

Disposal Units and Exposure Scenario	Performance Objective	Peak Mean Dose (mrem/yr)
		LANL 11.1.5 result
MDA G Pits		
Intruder-Construction	500 mrem	3.9E+00
Intruder-Agriculture	100 mrem/yr	2.7E+01
Intruder-Post-Drilling	100 mrem/yr	1.2E+01
Zone 4 Pits		
Intruder-Construction	500 mrem	0.0E+00
Intruder-Agriculture	100 mrem/yr	0.0E+00
Intruder-Post-Drilling	100 mrem/yr	0.0E+00
MDA G Shafts		
Intruder-Construction	500 mrem	4.8E+00
Intruder-Agriculture	100 mrem/yr	8.0E+01
Intruder-Post-Drilling	100 mrem/yr	1.1E+01
Zone 4 Shafts		
Intruder-Construction	500 mrem	3.7E+00
Intruder-Agriculture	100 mrem/yr	8.6E+01
Intruder-Post-Drilling	100 mrem/yr	1.1E+01

In summary, this special analysis documents the successful (1) upgrade of the Area G PA/CA Model from GoldSim version 10.11 to versions 11.1.2 and 11.1.5, and (2) transition to LANL analysts and the LANL computing environment. Some differences in dose projections occurred because of the implementation of an improved LHS scheme in version 11.1.5, and this correction is expected to generate more accurate results than for previous models. Migration to GoldSim version 11.1.5 will be adopted for the maintenance of the PA/CA model. The modeling results continue to indicate that the disposal facility satisfied all DOE Order 435.1 performance objectives as indicated in Table 3-12 through 3-14.

5.0 References

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French, S.B. and R. Shuman, 2015a, *Radioactive Waste Inventory for Los Alamos National Laboratory Technical Area 54, Area G, Revision 2,* Los Alamos National Laboratory Report LA-UR-15-20428, January.

French, S.B. and R. Shuman, 2015b, *Evaluation of Low-Level Waste Disposal Receipt Data for Los Alamos National Laboratory Technical Area 54, Area G Disposal Facility – Fiscal Year 2014,* Los Alamos National Laboratory Report LA-UR-15-22799, April.

French, S.B., P.H. Stauffer, and K.H. Birdsell, 2016, *Annual Report for Los Alamos National Laboratory Technical Area 54, Area G Disposal Facility – Fiscal Year 2015,* Los Alamos National Laboratory Report LA-UR-16-21238, February.

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http://www.goldsim.com/Downloads/Software/RelNotes.htm

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LANL, 2015b, Annual Report for Los Alamos National Laboratory Technical Area 54, Area G Disposal Facility, Fiscal Year 2014, Los Alamos National Laboratory Report LA-UR-15-22953, May 2015.

LANL, 2016, *Special Analysis: 2015-001 Transition of Transuranic Waste Data to the Waste Compliance and Tracking System*, Los Alamos National Laboratory Report LA-UR-16-25626, July.

Appendix A – Unreviewed Disposal Question Evaluation 1603

WDP Unreviewed Disposal Question Evaluation (UDQE) and Special Analysis (SA) Process	Document No.: EP-AP-2204 Revision: 0 Effective Date: June 7, 2010
UET	Page: 1 of 3

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UNREVIEWED DISPOSAL QUESTION EVALUATION WORKSHEET

Unreviewed Disposal Question Evaluation Worksheet			
8.1[1] UDQE Number:1603		8.1[2] Date:12-Aug-2016	
Section 1: Proposed Activity			
8.1[3] Upgrade the GoldSim models used to conduct the Revision 4 Area G performance assessment and composite analysis to version 11.1.5 of the software.			
8.1[4]Section 1.1: Summary description of activity/change The GoldSim models used to conduct the Revision 4 performance assessment and composite analysis were last implemented using version 10.5 of GoldSim. Changes incorporated into the software since version 11 may influence the structure of the models, although impacts on the dose and radon flux projections are not anticipated. Therefore, the potential impact of the software upgrade on the performance assessment and composite analysis needs to be evaluated. In addition, LANL analysts have assumed the PA-CA modeling roll from the long-term contractor who has been responsible for the development and running of the GoldSim PA-CA model. The potential impact of changing both analyst and computing systems also needs to be evaluated.			
8.1 [6] Section 1.2: Reference LANL, 2008, Performance Assessment and Composite Analysis for Los Alamos National Laboratory Technical Area 54, Area G, Revision 4, Los Alamos National Laboratory Report LA-UR-08-6764, October. UDQE 1503 French, S.B. and R. Shuman, 2015, *Special Analysis 2014-004: Transition of Transuranic Waste Data to the Waste Compliance and Tracking System,* Los Alamos National Laboratory Report LA-UR-15-20366, January.			
8.1[7] Section 1.3: Is the activity/change addressed by a previous UDQE or the LLW authorization basis documents?		☐ YES	☒ NO
8.1[8][A][a] UDQE No.:	Date of UDQE:		
8.1[8][A][b] Justification for not requiring a UDQE			

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UNREVIEWED DISPOSAL QUESTION EVALUATION WORKSHEET

8.1[1] UDQE Number: 1603	8.1[2] Date: 12-Aug-2016		
8.1[10] **Section 2: UDQE– Screening**			
2.1 Waste Characteristics	☒	Not Applicable	
a. Does the requested variance to the Area G WAC involve a technical issue (including radionuclide content, container specifications, amount of void space in containers, waste form, etc.)?		☐ YES	☐ NO
b. Does disposal of radioactive waste within Area G which requires a variance to the LANL WAC, P 930-1?		☐ YES	☐ NO
c. Does the proposed activity involve the retrieval of below ground waste?		☐ YES	☐ NO
2.2 Disposal Practices	☒	Not Applicable	
a. Does the depth of waste placement exceed the depth of placement modeled in the PA/CA?		☐ YES	☐ NO
b. Will the distance between the top of the disposed waste and the ground surface be less than the distance specified in the PA/CA?		☐ YES	☐ NO
2.3 Procedures /Documents/Systems	☒	Not Applicable	
a. Does the procedure or process changes define, control or administer LLW characterization and/or disposal activities?		☐ YES	☐ NO
b. Does the activity invoke changes to DAS?		☐ YES	☐ NO
c. Does the activity change the Chem/LL database information that impacts LLW volume, activity, and or mass information, or the methods for calculating database quantities?		☐ YES	☐ NO
2.4 Site/Facility Construction	☒	Not Applicable	
a. Does the proposed activity involve the addition/modification of structures, affect water runoff configurations, or impact the characterization/monitoring wells and/or equipment which are currently located at Area G?		☐ YES	☐ NO
b. Does the proposed activity bring the facility/site back into compliance with current assumptions regarding site configurations and operations as defined within PA/CA and applicable Area G disposal authorization basis documents?		☐ YES	☐ NO
c. Does the proposed activity involve the drilling of new boreholes or monitoring wells?		☐ YES	☐ NO
d. Will the proposed activity require changes in site grading or storm waste runoff control provisions?		☐ YES	☐ NO
2.5 New Disposal Unit Construction	☒	Not Applicable	
a. Do any design parameters differ from the PA/CA and applicable Area G disposal authorization basis documents? These parameters include, but are <u>not</u> limited to, disposal unit dimensions, distance of units from the mesa edge, and depth of disposal units.		☐ YES	☐ NO
b. Is there construction of new site structures or facilities?		☐ YES	☐ NO
c. Is there contruction activities for removal of existing site structures or features?		☐ YES	☐ NO
d. Is there construction activities for creation of new disposal units (pits and shafts)?		☐ YES	☐ NO
2.6 Interim/ Final Disposal Unit Closure	☒	Not Applicable	
a. Will the minimum depth of cover between the top of the waste and the ground surface be less than that specified in the PA/CA and applicable DAB documents?		☐ YES	☐ NO
b. Do any design parameters of the cover differ from the PA/CA and applicable Area G disposal authorization basis documents? These parameters include, but are <u>not</u> limited to, slope, material properties, performance characteristics, and depth.		☐ YES	☐ NO
c. Does the proposed activity affect the closure of active disposal pits and shafts or installation of operational or final covers?		☐ YES	☐ NO

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8.1[1] UDQE Number:1603	8.1[2] Date:12-Aug-2016
If the answers to all applicable questions in Section 2 are "No", the activity/change does constitute a UDQ; proceed to Section 3: UDQ Evaluation Summary and Approval.	
Section 3: UDQ Evaluation Summary and Approval	
UDQ Number:1603	Date:12-Aug-2016
8.1[11] ☐ This activity/change does not (all responses are "No") constitute a UDQ	
☒ This activity/change does (at least one response is "YES") constitute a UDQ and a Special Analysis is required prior to implementing the activity/change	
All questions in Section 2 have been answered "Not Applicable" indicating the activity does not constitute a UDQ. The activity is, however, determined to be a UDQ because it requires changes to the models that are used to conduct the performance assessment and composite analysis. This UDQE replaces UDQE 1503; it covers the sequential GoldSim upgrade from version 10.5 to version 11.1.2 (the subject of UDQE 1503) and to version 11.1.5. In addition, as a quality assurance step, it is recommended that the successful transition to LANL analysts and LANL computing environment be documented.	

8.1[12] UDQ Evaluator		
Name (Print) Kay Birdsell	Signature: Kay Birdsell	Date: 8/12/16
8.1[13] UDQE Reviewer		
Name (Print) Shaoping Chu	Signature: Shaoping Chu	Date: 8/12/16
ADC: ☒ Unclassified ☐ OUO ☐ UCNI ☐ Classified		
Derivative Classifier		
Name (Print) Kay Birdsell	Signature: Kay Birdsell	Date: 1/27/17
Section 4 FINAL APPROVAL		
8.1[19]/9.[7] LLW Operations Manager:		
Name (Print) LESLIE SONNENBERG	Signature: Leslie Sonnenberg	Date: 3/13/2017

Appendix B - Supplemental Information about GoldSim's version 11.1.5 Improved Latin Hypercube Sampling Algorithm

This Appendix documents recent upgrades made to the GoldSim model that are relevant to the Area G Performance Assessment and Composite Analyses Models described in the main body of this report. Included are GoldSim release notes and an email correspondence, as documented below.

Improved LHS Implementation for Non-scalar Stochastics

support.goldsim.com/hc/en-us/articles/217079098-Improved-LHS-Implementation-for-Non-scalar-Stochastics

Ryan Roper - March 07, 2016 11:09

Introduction

In GoldSim version 11.1.5, an improved Monte Carlo Latin Hypercube Sampling (LHS) algorithm was implemented to minimize correlation within non-scalar Stochastic elements. The change does not impact scalar Stochastic sampling or sampling of non-scalar Stochastics with LHS turned off. In other words, for a given seed, sampled results should be identical between versions 11.1.4 and 11.1.5 for scalar Stochastic elements and for non-scalar Stochastic elements with LHS turned off. With this change, note that for a given seed and with LHS turned on, only the sampled result of the first array item of a non-scalar Stochastic element will be the same when comparing versions 11.1.4 and 11.1.5.

This article first provides some basic background information about Latin Hypercube Sampling before describing limitations of the old implementation (in versions 11.1.4 and earlier) and how correlation within non-scalar Stochastic elements could occur. Then, LH sampling results from version 11.1.5 are shown to illustrate the improvement in the algorithm.

Background on Latin Hypercube Sampling

In GoldSim, Latin Hypercube Sampling is enabled by default in the Monte Carlo settings. LHS is used to ensure that the entire space of a stochastic parameter is well sampled, even in situations where relatively few Monte Carlo realizations are used. To do this, the distribution function of a stochastic parameter is divided into equal probability strata and then a value is sampled from each of the strata in random order. The number of strata is equal to the number of realizations, up to a maximum of 10,000 strata.

For illustration, take the simple case of a uniform 0 to 1 Stochastic element in a model with 5 realizations. Values are sampled in random order from the following 5 equal probability strata of the uniform distribution: 0 to 0.2, 0.2 to 0.4, 0.4 to 0.6, 0.6 to 0.8 and 0.8 to 1.0. Shown below are actual sampled results from a GoldSim model.

Realization	Seed 1	Seed 2	Seed 3
1	0.0486	0.744	0.839
2	0.904	0.272	0.467
3	0.424	0.821	0.209
4	0.656	0.517	0.188
5	0.231	0.192	0.748

Note that for each random seed (i.e. each column) there is always a value from each of the 5 strata. Highlighted in gray are values sampled from the 0.6 to 0.8 stratum. If the strata are numbered in increasing order (e.g. 0 to 0.2 is stratum 1, 0.2 to 0.4 is stratum 2 and so on to 0.8 to 1.0, which is stratum 5), then it can be seen for seed 1 that the sampling order was 1, 5, 3, 4, 2; The sampling order for seed 2 was 4, 2, 5, 3, 1 and the sampling order for seed 3 was 5, 3, 2, 1, 4.

Latin Hypercube Sampling in Versions 11.1.4 and Earlier

LH sampling results shown in the previous section are for a scalar Stochastic element. Whether the model (used to generate the results above) is run in 11.1.4 or 11.1.5, results are identical. For non-scalar Stochastics, however, sampled results are different between the two versions. Take, for example, a 3-item vector Stochastic sampled over 5 realizations. In version 11.1.4, results are like those shown below. The colors correspond to the 5 different strata.

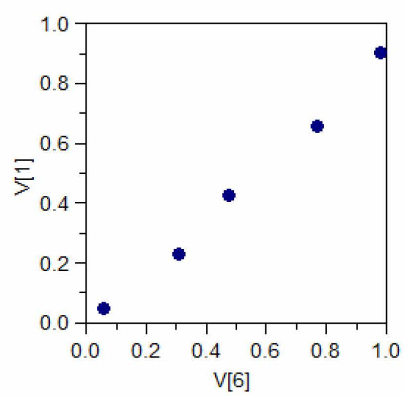
Realization	V[1]	V[2]	V[3]
1	0.0486	0.894	0.491
2	0.904	0.479	0.617
3	0.424	0.735	0.227
4	0.656	0.212	0.077
5	0.231	0.109	0.973

The order in which the strata are sampled for the first array item, V[1], is 1, 5, 3, 4, 2. Note that the order for the subsequent columns (corresponding to array items V[2] and V[3]) are the same, but simply shifted by one position relative to the previous column. So the order for V[2] is 5, 3, 4, 2, 1 and the order for V[3] is 3, 4, 2, 1, 5. The old LHS implementation only generates a single randomized sequence for sampling the strata. It reuses this same sequence for every item of the non-scalar Stochastic, just shifting the starting stratum by one for each array item. A pattern, as shown in the results above, is generated as a consequence.

Another consequence of the old LHS implementation can be seen when the size of the array is greater than the number of realizations. In the example below, the results are for a 6-item vector. As explained already, values are only sampled from 5 different strata since there are 5 realizations in the model. For any given realization, values for array items V[1] through V[5] are sampled from the 5 different strata in random order. Thereafter, starting with array item V[6], the strata are again sampled in the same random order.

Realization	V[1]	V[2]	V[3]	V[4]	V[5]	V[6]
1	0.0486	0.894	0.491	0.69	0.344	0.06
2	0.904	0.479	0.617	0.261	0.101	0.983
3	0.424	0.735	0.227	0.0461	0.813	0.477
4	0.656	0.212	0.077	0.817	0.563	0.772
5	0.231	0.109	0.973	0.48	0.744	0.306

A consequence of this is that V[1], V[6], V[11], ... are sampled from the same stratum, V[2], V[7], V[12], ... are sampled from the same stratum, and so on. As a result, there is very high correlation between items within an array. This can be seen dramatically in a scatter plot. Below is a scatter plot of the values of V[1] and V[6] from the table above. The correlation value is 0.997.



Improved LHS Results in GoldSim Version 11.1.5

As stated previously, the old LHS implementation only generates (for a given Stochastic element) a single randomized sequence for sampling the strata. It then reuses this same sequence for every item of a non-scalar Stochastic, just shifting the starting stratum by one for each array item.

2/4

In the new LHS implementation (starting in GoldSim version 11.1.5) a different seed is used for each individual array item of a non-scalar Stochastic. As a result, the order in which strata are sampled is different for each array item. This eliminates the correlation seen in the examples above. Below are the results generated in version 11.1.5 for the same 3-item vector Stochastic for which version 11.1.4 results are shown in the previous section.

Realization	V[1]	V[2]	V[3]
1	0.0486	0.294	0.691
2	0.904	0.479	0.417
3	0.424	0.135	0.227
4	0.656	0.612	0.077
5	0.231	0.909	0.973

Below are the results generated in version 11.1.5 for the same 6-item vector Stochastic for which 11.1.4 results are shown in the previous section.

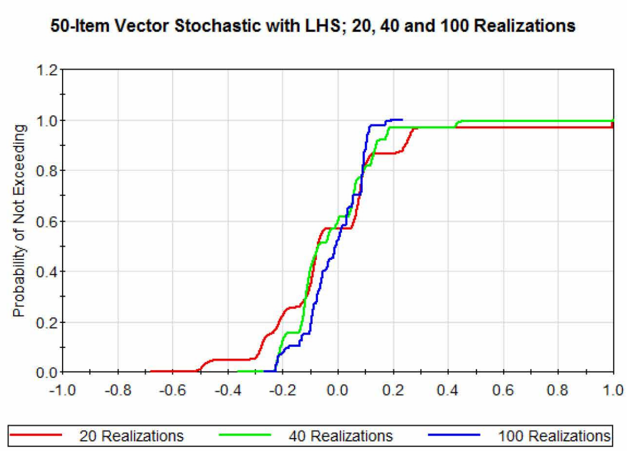
Realization	V[1]	V[2]	V[3]	V[4]	V[5]	V[6]
1	0.0486	0.294	0.691	0.49	0.144	0.86
2	0.904	0.479	0.417	0.261	0.501	0.183
3	0.424	0.135	0.227	0.646	0.213	0.277
4	0.656	0.612	0.077	0.0174	0.763	0.572
5	0.231	0.909	0.973	0.88	0.944	0.706

Comparison of Distributions of Correlations

It is clear from this simple example that the LHS implementation in version 11.1.5 at least eliminates the patterns seen previously in the version 11.1.4 results. However, the best gauge to evaluate how well the new implementation generates independent, random values for non-scalar Stochastic elements is to compare the distribution of correlations between array items.

Sampled results of a 50-item vector stochastic were generated for 20, 40 and 100 realizations. Then, correlation results were copied from a multivariate result element into Lookup Tables and analyzed. By running the model for 1225 realizations, referencing a different correlation value from the tables on each realization, it was possible to generate result distributions of the correlation values.

Distributions of correlation values generated in version 11.1.4 for 20, 40 and 100 realizations are shown below.



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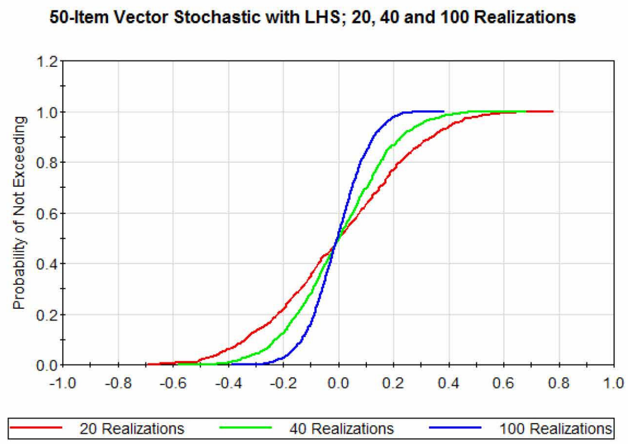
Distributions of correlation values generated in version 11.1.5 for 20, 40 and 100 realizations are shown below. In contrast to the 11.1.4 results, which are irregularly distributed, the results in 11.1.5 are much more smoothly distributed. Distributions are centered at 0 and the spread in the distributions decreases with increasing number of realizations.



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Email correspondence from Ryan Roper, Goldsim, to Shaoping Chu, LANL, Oct 17, 2016:

Hi Shaoping –

Below are the changes we made in 11.1.3, 11.1.4 and 11.1.5 that could possibly affect results between 11.1.2 and 11.1.5. Note that this list includes changes that should only impact probabilistic models. The key is to read through these and see if you have any of the elements in your model that are mentioned in these tasks. For example, for the first one below, you'd want to check if you have any information or material delays that have vector initial values.

11.1.3:
- Fixed an issue where vector initial values were incorrectly applied for information and material delays [5276]
- Fixed an issue where changed() and OnChanged functions were triggered by a resampled stochastic even if the value of the stochastic did not change [5278]
- Fixed an issue where logical elements (AND, OR and NOT) triggered changed() and OnChanged monitoring functions even if their output values did not change [5279]
- Fixed an issue in the Extrema Element where reset only worked if the value of the monitored output changed when the reset was triggered [5285]
- Fixed an issue in the History Generator where the 'target' was incorrectly applied when running distributed process if the 'target' varied with time and the 'History Type' was set to 'Random Walk' [5301]
- Fixed an issue where elements in subsystems may update their initial values twice. As a result of this fix, some models may produce different results if there are one or more subsystems with (1) triggered events that trigger when an element output changes or (2) stochastic elements in the static list. In the latter case, stochastics previously sampled twice at time zero will now only be sampled once. Thus, even if a model uses the same random seed, observed sampled values of some stochastics may be different in 11.1.3 and previous versions. [5306]
- Time Series function 'lookup' behavior was corrected to reflect any time shifting settings specified on the Time Series element [5310]
- Fixed an issue in the Event Delay element where incoming events were not correctly handled while the 'wait for' precedence condition was not satisfied. [5311]

11.1.4:
- Fixed an issue causing inaccurate statistical results when a set of sampled values consists of a continuous distribution with discrete spikes (spikes being caused by repeated sample values). The issue was observed in the Sampled Results distribution type of the Stochastic element and generated statistical results based on Final Value or Time History result values. Assuming a sorted list of sample values, a numerical error is introduced at the first continuous sample value directly following a discrete sample value (spike). The contribution of the sample value is underreported. The error is a function of the difference between the continuous and discrete sample value and can be calculated as follows: (curVal - ((prevVal + curVal) / 2)) * curWeight / 2. curVal=value of first continuous sample, prevVal=value of discrete sample just before curVal, curWeight=sample's weight. [5365]

11.1.5:
- Improved the Monte Carlo Latin Hypercube Sampling algorithm (LHS) to minimize correlation within non-scalar Stochastic elements. Note that non-scalar Stochastic elements generate different results for any but the first array item (when comparing with results generated in GoldSim 11.1.4; assuming 'Repeat Sampling Sequence' is enabled). For more information search for 'Improved LHS implementation for non-scalar Stochastics' on the GoldSim Help Desk site. [5362]

Please let me know if you have any questions.

Regards,
Ryan

Appendix C

Unreviewed Disposal Question Evaluation

Forms for Questions Requiring Additional Analyses

ATTACHMENT 1
Page 1 of 3

UNREVIEWED DISPOSAL QUESTION EVALUATION WORKSHEET

Unreviewed Disposal Question Evaluation Worksheet			
8.1[1] UDQE Number:1601	8.1[2] Date:03-Aug-2016		
Section 1: Proposed Activity			
8.1[3] Reconsidering the inventory for Am due to ingrowth in post-1988 LLW and pre-1988 CA waste.			
8.1[4]Section 1.1: Summary description of activity/change Under-reporting of Am ingrowth for Pu waste streams may have occurred because of the method for reporting accountable special nuclear material.			
8.1 [6] Section 1.2: Reference			
8.1[7] Section 1.3: Is the activity/change addressed by a previous UDQE or the LLW authorization basis documents?		☐ YES	☒ NO
8.1[8][A][a] UDQE No.:	Date of UDQE:		
8.1[8][A][b] Justification for not requiring a UDQE			

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UNREVIEWED DISPOSAL QUESTION EVALUATION WORKSHEET

8.1[1] UDQE Number: 1601		8.1[2] Date: 03-Aug-2016	
8.1[10]	**Section 2: UDQE– Screening**		
2.1	Waste Characteristics ☒	Not Applicable	
a.	Does the requested variance to the Area G WAC involve a technical issue (including radionuclide content, container specifications, amount of void space in containers, waste form, etc.)?	☐ YES	☐ NO
b.	Does disposal of radioactive waste within Area G which requires a variance to the LANL WAC, P 930-1?	☐ YES	☐ NO
c.	Does the proposed activity involve the retrieval of below ground waste?	☐ YES	☐ NO
2.2	Disposal Practices ☒	Not Applicable	
a.	Does the depth of waste placement exceed the depth of placement modeled in the PA/CA?	☐ YES	☐ NO
b.	Will the distance between the top of the disposed waste and the ground surface be less than the distance specified in the PA/CA?	☐ YES	☐ NO
2.3	Procedures /Documents/Systems ☐	Not Applicable	
a.	Does the procedure or process changes define, control or administer LLW characterization and/or disposal activities?	☐ YES	☒ NO
b.	Does the activity invoke changes to DAS?	☐ YES	☒ NO
c.	Does the activity change the Chem/LL database information that impacts LLW volume, activity, and or mass information, or the methods for calculating database quantities?	☒ YES	☐ NO
2.4	Site/Facility Construction ☒	Not Applicable	
a.	Does the proposed activity involve the addition/modification of structures, affect water runoff configurations, or impact the characterization/monitoring wells and/or equipment which are currently located at Area G?	☐ YES	☐ NO
b.	Does the proposed activity bring the facility/site back into compliance with current assumptions regarding site configurations and operations as defined within PA/CA and applicable Area G disposal authorization basis documents?	☐ YES	☐ NO
c.	Does the proposed activity involve the drilling of new boreholes or monitoring wells?	☐ YES	☐ NO
d.	Will the proposed activity require changes in site grading or storm waste runoff control provisions?	☐ YES	☐ NO
2.5	New Disposal Unit Construction ☒	Not Applicable	
a.	Do any design parameters differ from the PA/CA and applicable Area G disposal authorization basis documents? These parameters include, but are <u>not</u> limited to, disposal unit dimensions, distance of units from the mesa edge, and depth of disposal units.	☐ YES	☐ NO
b.	Is there construction of new site structures or facilities?	☐ YES	☐ NO
c.	Is there contruction activities for removal of existing site structures or features?	☐ YES	☐ NO
d.	Is there construction activities for creation of new disposal units (pits and shafts)?	☐ YES	☐ NO
2.6	Interim/ Final Disposal Unit Closure ☒	Not Applicable	
a.	Will the minimum depth of cover between the top of the waste and the ground surface be less than that specified in the PA/CA and applicable DAB documents?	☐ YES	☐ NO
b.	Do any design parameters of the cover differ from the PA/CA and applicable Area G disposal authorization basis documents? These parameters include, but are <u>not</u> limited to, slope, material properties, performance characteristics, and depth.	☐ YES	☐ NO
c.	Does the proposed activity affect the closure of active disposal pits and shafts or installation of operational or final covers?	☐ YES	☐ NO

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8.1[1] UDQE Number:1601	8.1[2] Date: 03-Aug-2016	
If the answers to all applicable questions in Section 2 are "No", the activity/change does constitute a UDQ; proceed to Section 3: UDQ Evaluation Summary and Approval.		
Section 3: UDQ Evaluation Summary and Approval		
UDQ Number:1601	Date: 03-Aug-2016	
8.1[11] ☐ This activity/change does not (all responses are "No") constitute a UDQ		
☒ This activity/change does (at least one response is "YES") constitute a UDQ and a Special Analysis is required prior to implementing the activity/change		
Under-reporting of Am inventory in the waste disposed at Area G may have occurred. The significance of this under-reporting has not been assessed. Changes to the inventory model and the subsequent dose projections calculated for both the PA and CA waste may result if this under-reporting is confirmed.		
8.1[12] UDQ Evaluator		
Name (Print)Kay Birdsell	Signature: Kay Birdsell	Date: 8/3/16
8.1[13] UDQE Reviewer		
Name (Print) Philip Stauffer	Signature: [signature]	Date: 8/3/16
ADC: ☒ Unclassified ☐ OUO ☐ UCNI ☐ Classified		
Derivative Classifier		
Name (Print)	Signature:	Date:
Section 4 FINAL APPROVAL		
8.1[19]/9.[7] LLW Operations Manager:		
Name (Print) Leslie Sonnenberg	Signature:	Date:

ATTACHMENT 1
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UNREVIEWED DISPOSAL QUESTION EVALUATION WORKSHEET

Unreviewed Disposal Question Evaluation Worksheet			
8.1[1] UDQE Number:1604	8.1[2] Date:03-Aug-2016		
Section 1: Proposed Activity			
8.1[3] Decommissioning & Demolition (D&D) of Dome 224 and associated concrete ring-wall, asphalt pad, and liner.			
8.1[4]Section 1.1: Summary description of activity/change Dome 224 is used for hazardous waste storage on top of Pit 33 at Area G. D&D of the dome and associated concrete ring-wall and underlying asphalt and liner are required to address NMED concerns related to collection of water between the liners.			
8.1 [6] Section 1.2: Reference			
8.1[7] Section 1.3: Is the activity/change addressed by a previous UDQE or the LLW authorization basis documents?		☐ YES	☒ NO
8.1[8][A][a] UDQE No.:	Date of UDQE:		
8.1[8][A][b] Justification for not requiring a UDQE			

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UNREVIEWED DISPOSAL QUESTION EVALUATION WORKSHEET

8.1[1] UDQE Number: 1604		8.1[2] Date: 03-Aug-2016	
8.1[10]	**Section 2: UDQE– Screening**		
2.1	Waste Characteristics	☒ Not Applicable	
a.	Does the requested variance to the Area G WAC involve a technical issue (including radionuclide content, container specifications, amount of void space in containers, waste form, etc.)?	☐ YES	☐ NO
b.	Does disposal of radioactive waste within Area G which requires a variance to the LANL WAC, P 930-1?	☐ YES	☐ NO
c.	Does the proposed activity involve the retrieval of below ground waste?	☐ YES	☐ NO
2.2	Disposal Practices	☒ Not Applicable	
a.	Does the depth of waste placement exceed the depth of placement modeled in the PA/CA?	☐ YES	☐ NO
b.	Will the distance between the top of the disposed waste and the ground surface be less than the distance specified in the PA/CA?	☐ YES	☐ NO
2.3	Procedures /Documents/Systems	☒ Not Applicable	
a.	Does the procedure or process changes define, control or administer LLW characterization and/or disposal activities?	☐ YES	☐ NO
b.	Does the activity invoke changes to DAS?	☐ YES	☐ NO
c.	Does the activity change the Chem/LL database information that impacts LLW volume, activity, and or mass information, or the methods for calculating database quantities?	☐ YES	☐ NO
2.4	Site/Facility Construction	☐ Not Applicable	
a.	Does the proposed activity involve the addition/modification of structures, affect water runoff configurations, or impact the characterization/monitoring wells and/or equipment which are currently located at Area G?	☒ YES	☐ NO
b.	Does the proposed activity bring the facility/site back into compliance with current assumptions regarding site configurations and operations as defined within PA/CA and applicable Area G disposal authorization basis documents?	☒ YES	☐ NO
c.	Does the proposed activity involve the drilling of new boreholes or monitoring wells?	☐ YES	☒ NO
d.	Will the proposed activity require changes in site grading or storm waste runoff control provisions?	☒ YES	☐ NO
2.5	New Disposal Unit Construction	☒ Not Applicable	
a.	Do any design parameters differ from the PA/CA and applicable Area G disposal authorization basis documents? These parameters include, but are <u>not</u> limited to, disposal unit dimensions, distance of units from the mesa edge, and depth of disposal units.	☐ YES	☐ NO
b.	Is there construction of new site structures or facilities?	☐ YES	☐ NO
c.	Is there contruction activities for removal of existing site structures or features?	☐ YES	☐ NO
d.	Is there construction activities for creation of new disposal units (pits and shafts)?	☐ YES	☐ NO
2.6	Interim/ Final Disposal Unit Closure	☐ Not Applicable	
a.	Will the minimum depth of cover between the top of the waste and the ground surface be less than that specified in the PA/CA and applicable DAB documents?	☐ YES	☒ NO
b.	Do any design parameters of the cover differ from the PA/CA and applicable Area G disposal authorization basis documents? These parameters include, but are <u>not</u> limited to, slope, material properties, performance characteristics, and depth.	☐ YES	☒ NO
c.	Does the proposed activity affect the closure of active disposal pits and shafts or installation of operational or final covers?	☒ YES	☐ NO

ATTACHMENT 1 Page 3 of 3		
8.1[1] UDQE Number:1604	8.1[2] Date: 03-Aug-2016	
If the answers to all applicable questions in Section 2 are "No", the activity/change does constitute a UDQ; proceed to Section 3: UDQ Evaluation Summary and Approval.		
Section 3: UDQ Evaluation Summary and Approval		
UDQ Number:1604	Date: 03-Aug-2016	
8.1[11] ☐ This activity/change does not (all responses are "No") constitute a UDQ		
☒ This activity/change does (at least one response is "YES") constitute a UDQ and a Special Analysis is required prior to implementing the activity/change		
Dome 224 is used for hazardous waste storage and is underlain by an asphalt pad and a RCRA-approved double liner. The dome is located atop Pit 33. The double liner routinely collects water in a sump that in turn is pumped out of the facility. To address NMED concerns, D&D is required for the dome, the concrete ring-wall, and the underlying asphalt and liner. The impact on the PA of this D&D activity, and the subsequent operational closure of the area should be assessed.		
8.1[12] UDQ Evaluator		
Name (Print)Kay Birdsell	Signature: KB	Date: 8/3/16
8.1[13] UDQE Reviewer		
Name (Print) Philip Stauffer	Signature: PStauffer	Date: 8/3/16
ADC: ☒ Unclassified ☐ OUO ☐ UCNI ☐ Classified		
Derivative Classifier		
Name (Print)	Signature:	Date:
Section 4 FINAL APPROVAL		
8.1[19]/9.[7] LLW Operations Manager:		
Name (Print) Leslie Sonnenberg	Signature:	Date:

Appendix D
Secondary Issues Identified by the Low-Level Waste Disposal Facility Federal Review Group Review Team

The Department of Energy (DOE) Low-Level Waste Disposal Facility Federal Review Group (LFRG) Review Team identified 20 secondary issues in its review of the Revision 3 Area G performance assessment and composite analysis; these issues are listed below. This listing describes each issue and provides the LFRG Review Team's recommendations regarding actions to be taken to resolve it. The numbers assigned to the issues correspond to the numbering system adopted in the LFRG Review Team report (DOE, 2009), and include both the number of the issue and the review criteria addressed by the issue; a complete listing of the review criteria may be found in the LFRG Manual (DOE, 2006).

7.2.1. Facility/Site Characteristics (3.1.1.1., 3.1.1.5., and 3.1.1.6.)

Criterion 3.1.1.1.:

Erosion Modeling: The wind, cliff retreat, and water erosion models do not fully capture the extremes necessary to demonstrate adequate performance over the 1,000 year performance period. The recommendations delineated in Sections 7.3.4 and 7.3.5 of the 2006 performance assessment and composite analysis need to be rigorously pursued, including external review of work plans to ensure maximum defensibility and programmatic efficiency (Shuman 2006). Running the erosion model with a 1,000 year precipitation event should be considered.

Criterion 3.1.1.5.:

Cover Degradation Due to Subsidence or other Localized Processes: Given the acknowledged potential for subsidence and the presence of containers with structural integrity that may outlive institutional controls, additional justification is needed for not considering degradation in performance of the cover after loss of institutional control. Considering the long times expected for degradation of some of the containers on the site, full remediation cannot be expected for subsidence occurring during the post-institutional control period. The justification for the cover to remain intact for 1,000 years is not provided and any such justification may be difficult to defend.

Modeling needs to be conducted to evaluate the influence of localized cover degradation on infiltration rate distributions used for the groundwater pathway model. Further, as information on expected cover performance is developed, the infiltration rate distributions need to be updated using this specific cover design information. It is expected that an optimal cover design will result in lower infiltration rates than those used in the current analysis. To evaluate the potential impacts of localized subsidence and cover degradation on migration and projected dose, it is necessary to modify the GoldSim^{TM} Material Disposal Area (MDA) G model and inputs to incorporate potential increases in infiltration rate over time. Based on draft updates to cover modeling, the assumed performance of the cover is expected to improve. Thus, the net effect of improved performance and localized increases in infiltration is not expected to result in a significant increase in overall infiltration.

Criterion 3.1.1.6.:

See secondary issue under criterion 3.1.1.5.

7.2.2. Performance Objectives/Measures (3.1.3.1., 3.1.3.5., and 3.1.3.6.)

Criterion 3.1.3.1.:

All-Pathways Dose Problem: The exposure scenarios for the "member of the public" scenarios are not fully coupled with the performance objectives. They are, instead, separated by the transport mechanisms (groundwater, air, and surface water). A consequence of this is that the all pathways performance objective is not fully evaluated. A concern is that the air pathway does apply to the exposure scenarios in Cañada del Buey and Pajarito Canyon.

The effect or lack thereof of this pathway needs to be demonstrated so that the all pathways performance objective can be fully evaluated. This needs to be done by (1) making the separations in scenarios clearer in the text, (2) explaining more clearly why the separation in pathways does not underestimate dose at any of the receptors locations, and (3) (preferable) modeling the air pathway to the canyon receptors to estimate the all pathways dose for those receptors (for other receptors the need to combine across transport mechanisms can probably be explained away). Given the observed doses for the separated scenarios, this is extremely unlikely to change any conclusions, but from a regulatory as well as a technical perspective, this issue needs to be addressed.

Note also that the air pathway as evaluated through the atmospheric scenario includes exposure routes that do not need to be included. Inhalation and immersion are the only routes that need to be evaluated. Ingestion and shine can be omitted. This is relevant to modeling the air pathway to the canyons receptors.

Criterion 3.1.3.5.:

Point of Compliance for Groundwater Protection during Institutional Control: There is some confusion regarding the point of compliance for groundwater protection. Section 1.5 and Table 1-1 indicate that the point of assessment for groundwater protection is the site boundary during institutional control, but the results presented in Figures 4-29 and 4-30 are for the point of maximum concentration outside a 100-m buffer zone. The point of assessment, as specified at DOE Manual 435.1-1, Section IV.P.(2)(b), is to be at the point of maximum concentration outside a 100 m buffer zone for groundwater protection at all times unless justification is provided for some other point. Additional justification is needed if the point of compliance for groundwater protection is the site boundary during institutional control.

Criterion 3.1.3.6.:

Overly Conservative Intrusion Analysis: The inadvertent human intrusion scenarios are overly cautious. Appropriate credit should be taken for site-specific factors that limit the probability that intrusion will occur. Since the basement scenario is the constraining scenario in the current model, some credit could be taken for the likelihood of a basement in the presence of a house. Very few houses in Los Alamos have basements. Other possible considerations include the likelihood of construction and well drilling (given that current water in Los Alamos comes from wells drilled in the canyons) and the exposure routes, which include mixing of waste in the surface soils and subsequent use of those soils to support a vegetable garden, and dairy cows. There are many possibilities for reducing conservatism in this analysis so that the intrusion doses are more realistic. The main issue is one of using site-specific factors to support this analysis, instead of using a default scenario that does not apply well to this arid site.

Under the performance assessment maintenance program, the assessment needs to use site-specific factors to refine the intrusion model to better represent likely home construction and lifestyle characteristics of the intruder. The intent is to make the intrusion scenario more realistic for this arid site than is currently the case.

7.2.3. Point of Assessment (3.1.4.1., 3.1.4.2., and 3.1.4.4.)

Criterion 3.1.4.1.:

See secondary issues under criterion 3.1.3.5.

Criterion 3.1.4.2.:

See secondary issue under criterion 3.1.3.5.

Criterion 3.1.4.4.:

Operations Restrictions: The 2006 performance assessment and composite analysis contains no reference to facility operations documents that are used to control parameters that could affect performance assessment findings and conclusions (Shuman 2006). Important to the findings and conclusions of the performance assessment for the active portion of Area G is an operational restriction on the depth below the surface for placement of the uppermost waste container in a pit or shaft. A draft operational document that contains this information has yet to be finalized. For Zone 4, when new pits and shafts are excavated, other important operational restrictions will be minimum distance from canyon wall to pit or shaft and maximum depth of pit or shaft. If additional excavations were to occur in the active portion, these restrictions would also apply.

The draft operations document that addresses these parameters for MDA G needs to be finalized in a timely manner, ensuring that the scope is appropriate for current activities in MDA G and considering any planned activities and operations as appropriate. A subsection needs to be added to Section 1.4 of the 2006 performance assessment and composite analysis that references operational controls and that describes and references documents used to control MDA G operations important to performance assessment findings or conclusions (Shuman 2006). If there are other documents in effect for Technical Area 54 that are used to control activities that could affect MDA G (e.g., borehole drilling, utility, or other excavation in the canyon areas around the mesa), these need to be included.

7.2.4. Conceptual Model (3.1.5.3., 3.1.5.4., and 3.1.5.5.)

Criterion 3.1.5.3.:

- *Influence of Focused Runoff on Migration*: The current conceptual model assumes undisturbed conditions at the site. Field data have indicated localized high water contents in the subsurface from focused run-off from surface structures (e.g., asphalt pads). The influence of these structures on the conceptual model for long-term flow and transport needs to be evaluated. The on-going activities to address these issues as described in the maintenance plan need to be pursued.

- *Hydrogeologic Model Uncertainty*: Recent field sampling has detected radionuclides in the vicinity of MDA G. Multiple hypotheses have been proposed to explain the presence of the radionuclides, some of which include MDA G as a potential source.

  Groundwater transport in the current model is based on a single conceptual model, which does not address uncertainties that may result in shorter travel times. Potential uncertainties include hydraulic properties, overall hydrogeologic framework model, evaporative boundary at the base of the Tshirege Member Unit 2, assumed boundary conditions on the east and west boundaries (fixed head or vertical gradients), and Guaje Pumice/Cerros del Rio basalt interface properties. With the current computational approach, the potential influence of these uncertainties on expected doses is not represented in the current GoldSim™ model. Given this limitation, these Uncertainties are not included in the sensitivity analysis. Additional 3-dimensional simulations using the Finite Element Heat and Mass (FEHM) model need to be performed to evaluate the impact of the potential conceptual model uncertainties on groundwater transport and dose estimates.

Criterion 3.1.5.4.:

See secondary issue under criterion 3.1.1.5.

Criterion 3.1.5.5.:

- See secondary issue under Criterion 3.1.1.1.

- *Potential Ground Motion*: Seismic accelerations are not provided as required to assess potential impacts on facility design or long-term performance, including slope stability and potential impacts on disposal area integrity related to potential retreat of the steep mesa walls toward the disposal facility. Site-specific ground motion data need to be provided as appropriate for design, geotechnical slope stability analyses, and site suitability assessment.

- *Geomorphic Slope Stability*: Geotechnical data are required to confirm highly uncertain geomorphic slope stability estimates and assess the impact of facility construction and disposal area operations (excavation and compaction) on site and slope stability. Geotechnical data and analyses need to be acquired to confirm geomorphic stability assumptions and ensure operation and disposal configuration consistent with performance goals.

- *Performance Assessment Disruptive Processes and Events*: There is no clear structured procedure for screening potentially disruptive processes or events for consideration in the performance assessment. Criteria based on likelihood or consequence need to be developed that would help explain the inclusion or exclusion of potentially disruptive processes or events. Radiological assessment guidance from regulatory agencies and DOE's safety basis regulations should be consulted to develop the screening criteria.

7.2.5. Mathematical Models (3.1.6.2., 3.1.6.3., and 3.1.6.6.)

Criterion 3.1.6.2.:

See secondary issues under criteria 3.1.6.3. and 3.1.6.6.

Criterion 3.1.6.3.:

- *Infiltration Distribution Data Averaging*: Distribution averaging has been performed for infiltration rate, but not correctly. There are 17 data points for infiltration rate based on the chloride profiles. These data represent annual flux rates over a long period of time. Consequently, they are already time averaged for the scale of this performance assessment. What is missing is a spatial averaging. The data range from near 0 to 3 mm/year. The current model effectively resamples 1,000 times instead of 17 times for each resampled data set that is created. Hence, the uncertainty in the distribution used is narrower than it should be.

  An appropriate way to build a distribution of the average to accommodate spatial averaging is to bootstrap the data (resample with replacement 17 times because there are 17 data points) 1,000 (many) times, take the average of each of the 1,000 sets of 17 samples to arrive at a distribution of the average. This is the distribution that should be used in the model. In addition, the Pajarito Plateau infiltration map needs to be included in the 2006 performance assessment and composite analysis to provide additional confidence in the infiltration rate distribution (Shuman 2006). In the future, the infiltration distribution needs to be transitioned from being based on background field data, as described above, to being based on rates simulated for the proposed cover design for the corrective measures evaluation, when they become available.

- *Modeling Enhancements*: There are a series of modeling issues that can be addressed in the next refinement of the MDA G model (under the performance assessment maintenance program), including the following:
  - The erosion model currently uses three erosion rate models in SIBERIA that are respectively associated with low, moderate, and high erosion. It is not clear exactly how these designations were arrived at. Some clarification is needed. These three models (results) are sampled randomly in GoldSim™ with probabilities respectively of 10 percent, 80 percent, and 10 percent, meaning that the moderate erosion scenario is used most frequently. Refinement of this approach is needed. The rationale for these probabilities is weak and needs to be supported with expert judgment. The need for more than one model needs to be more fully explained, and the range of allowable models needs to be expanded. One option is to introduce more discrete cases. Another option is to restructure the model to allow a continuous range (if possible).
  - Air recycling of soil close to the surface is described but is dismissed based on zero net soil gain or loss. However, the movement of soil through this process also results in movement of contaminants. This transport mechanism needs to be evaluated. Options include formal modeling and justified explanation for why the effect of this transport mechanism is negligible.
  - A discrete set of beta functions are used in the biotic models for plants and animals to apportion root mass and burrow volume to different subsurface soil intervals. Inclusion of a single additional parameter is needed to allow a continuous range of beta functions to be used instead.
  - It does not appear that the diffusion model included partitioning of radon into water which would decrease radon fluxes and doses. This needs to be allowed.
  - The probability distribution for average infiltration rate needs to be revised per presentation in the issues column of the review criterion matrix. The performance assessment/composite analysis maintenance program needs to review all comments about model improvements that are made in this document and in the criterion matrix to ensure that appropriate refinements to the 2006 performance assessment and composite analysis model are made (Shuman 2006).
- *Input Data Probability Distributions*: Specification of probability distributions needs to be improved in many cases (too numerous to fully document here but see the review criterion matrix responses). There are numerous instances, and in some ways it is easier to require that all the distributions be revisited. For example, concerns have been expressed that some of the dose or exposure route distributions are very wide. Concerns have been expressed that based on very little data the input distributions for some physical parameters are too

narrow. In many cases, the distributions need to be backed up by more technical/statistical rigor and need to be defended by showing the data and the statistical methods that were used. There are several, or perhaps many, cases of distributions that are formed based on disparate sources of data followed by some best professional judgment. In those cases, efforts need to be undertaken or reported to engage some subject matter expert in final formulation of the distribution. For example, the distributions for K_d are often very tight, yet they are based on very few data points. It would make more sense in these cases for the distributions to be wider considering the amount of uncertainty. This might lead to identification of these as sensitive parameters and hence a need for future data collection (which is clearly needed across the complex for some geochemical parameters). The same approach needs to be used for solubility limits.

Other examples of distributions that need to be revisited and improved or refined include the initial cover depth distributions (why are they assumed to be triangular given the amount of data that are available? either use the data empirically, or fit more appropriate distributions); radon emanation coefficient (many disparate sources of data, the highest values of which are not included in the final distribution with insufficient explanation for their exclusion); physical properties such as bulk density, porosity and K_ds (the distributions are the same for crushed tuff and waste; however, the text indicates that there should be more uncertainty for the waste); sediment allocation fractions have noted uncertainty but are modeled deterministically with no explanation; various biotic parameters (again data from many sources, but sometimes enough data that proper statistical methods could be used to estimate distributions); waste thickness (perhaps better information is available); carbon-14 gas generation rates (data from many disparate sources, but statistics and/or expert opinion could be used to combine these data).

Expert opinion can be used effectively to support a combination of data to form distributions, and in so doing greater credibility is bought by using domain experts. Also, for several parameters, probability distributions are not used when they could be used. The uncertainties can then be fully explored and supportable decisions can be made on how to allocate resources to collection of new information.

More general distribution issues relate to the types of distributions used. Triangular or truncated distributions in any form (uniform, truncated normal, truncated lognormal) are not ideal because they do not allow any chance of using values outside the range of the distribution. For example, a K_d for plutonium of 77 mL/gm is allowed, but 77.1 mL/gm is not allowed. This does not intuitively make sense. (Please note that the K_d distribution for Np appears to be misspecified in Table 16 in Appendix K.) From a decision analysis or statistical perspective, this assumption suggests that there is no chance ever in any sense that the K_d could be 77.1 mL/gm. In terms of uncertainty reduction, this can cause problems. However, a related issue is one of "distribution averaging" (see below), which would obviate the need for truncated distributions.

Consideration needs to be given to the spatio-temporal scale of the model when specifying distributions. Probability distributions need to be specified to match the spatio-temporal scale, which probably means that distributions should be of the average instead of the data in many cases. The point is that the model is run for many tens of acres over 1,000 (or more) years. A single data point for a parameter often represents a point in time and space. The spatio-temporal scales of the model and the data are different. However, the data can often be manipulated so that an estimate of a distribution on the right spatio-temporal scale can be developed. This might be referred to as distribution averaging.

There are many advantages to this approach to specifying probability distributions. One obvious advantage is that it is the right approach. The model is a systems-level model trying to understand risks (doses) to receptors at various locations—risk is inherently based on an average response. Another advantage is that the variance component of an input distribution now represents uncertainty instead of variability. This is important because uncertainty is reducible by collecting more data, whereas variability is not. Another advantage is that the end results are now probability distributions for the mean dose. These distributions are typically a lot tighter than the ones that are currently common in performance assessments. Since the output is a distribution of the mean, the 95th percentile corresponds to the classical 95th upper confidence limit on which most Environmental Protection Agency–type risk-based decisions are made. Also, since uncertainty is now the basis of the variance components, sensitivity analysis directly supports identification of sensitive parameters for which uncertainty can be reduced.

Note that a lot of care needs to be taken when performing distribution averaging. The effects are not always obvious (for example, directly averaging plant root depth data does not appropriately support separation of plant root mass into subsurface soil layedistribution averaging is still needed, but across the soil layers and not across the plant root depths). One last note on distribution averaging is that it is not easy when parameter distributions are based on disparate sources of data or expert opinion, but elicitation methods exist that can help with this when necessary.

Distribution averaging has been performed for one parameter in this model, and that is the infiltration rate (curiously, few or no other parameters in the groundwater model are specified in GoldSim™ as probability distributions). So, in the case of infiltration rates, distribution averaging has been performed, but not correctly. There are 17 data points for infiltration rate based on the chloride profiles. These data represent annual flux rates over a long period of time (1,000 years or more). Consequently, they are already time-averaged for the scale of this performance assessment. What is missing is a spatial averaging. The data range from near 0 to 3 mm/year. An appropriate way to build a distribution of the average to accommodate spatial averaging is to bootstrap the data (resample with replacement 17 times because there are 17 data points) 1,000 (many) times and then take the average of each of the 1,000 sets of 17 samples to arrive at a distribution of the average. This is the distribution that should be used in the model. The current model effectively re-samples 1,000 times instead of 17 times for each resampled data set that is created. Hence, the uncertainty in the distribution used is narrower than it should be.

The performance assessment/composite analysis maintenance program needs to review all specific comments about input probability distributions that are made in the report and in the criterion matrix to ensure that appropriate adjustments to the input distributions are made in the next versions of the 2006 performance assessment and composite analysis model (Shuman 2006).

Criterion 3.1.6.6:

Data for Infiltration Rate Distribution: Currently the infiltration rate distribution is based on both field data and HYDRUS simulations of the proposed cover. The current cover modeling using HYDRUS described in Appendix G is problematic. Simulated fluxes depend on initial conditions assumed and fluxes appear to increase with increasing cover thickness. These HYDRUS results should not be used as a basis for the development of the infiltration rate distributions used in the groundwater analysis. All references to HYDRUS results and Appendix G need to be removed from the performance assessment.

7.2.6. Exposure Pathways and Dose Analysis (3.1.7.1.)

Criterion 3.1.7.1.:

See secondary issues under criterion 3.1.3.6.

7.2.7. Sensitivity and Uncertainty (3.1.8.2. and 3.1.8.3.)

Criterion 3.1.8.2.:

Sensitivity and Uncertainty Analysis: The sensitivity analysis methods used need to be updated with currently available methods. Techniques exist now for sensitivity analysis of complex time-dependent non-linear systems. Some of these techniques were used for the Nevada Test Site (NTS) low-level waste (LLW) disposal site performance assessment/composite analysis.

A major strength of this model is that it was set up probabilistically. This allows sensitivity and uncertainty analyses to be performed globally instead of one parameter at a time and allows sensitive parameters to be identified using nonlinear methods. Sensitive parameters have been identified for most of the end-point results. It has been suggested that the results of the sensitivity analysis are used to drive decisions about further data/information collection and, hence, model refinement. However, the MDA G model is a complex, time-dependent, nonlinear model. The previously mentioned approach taken to sensitivity analysis is appropriate for linear models. That is, it identifies linear effects. Nonlinear sensitivity analysis methods are available and need to be used. The performance assessment/composite analyses performed for the NTS LLW sites used these methods. These methods might identify different sensitive parameters than can be found using the techniques employed for this model (Spearman rank correlation).

The results of the sensitivity analysis are presented in terms of correlation coefficients, where the correlations are between the input parameters (variables) and the output or response (variable). It was also noted that the correlations are all statistically significant at the 0.01 level. This statement is unnecessary and potentially can be incorrectly interpreted as providing evidence of successful identification of sensitive parameters. The correlations are based on 1,000 simulated responses or data points. Probably all (or nearly all) of the parameters would show a significant result at the 0.01 level. What is more appropriate is to present the p-values (observed significance levels) associated with each correlation, rank the p-values and use those as a separate line of evidence for identification of sensitive parameters. The smaller the p-value the greater the evidence of a sensitive parameter. The p-value approach and the correlation coefficient approach should match closely. Note that this is not needed if nonlinear sensitivity analysis methods are used, as suggested above.

The sensitivity analysis needs to be run at different time points in the model. A different set of sensitive parameters will probably be identified at 100 years than are identified at 1,000 years.

The uncertainties are inherent in the output distributions. That is, a probabilistic model explicitly addresses uncertainty numerically. Note that the model, like most probabilistic models, addresses parameter uncertainty only. It does not address other uncertainties such as decision uncertainty, model uncertainty, or scenario uncertainty. However, there is another uncertainty issue that should be addressed: the stabilization of the results of a probabilistic simulation. One thousand simulations were used for the model results, but there is no analysis of the stability of the output distributions based on this number of simulations. Since mean, 5^{th}, and 95^{th} percentiles are presented (see below, medians should be presented as well), these statistics all need to be subject to uncertainty stabilization analysis. This would be performed by running different numbers of simulations several times and evaluating the range of results for each of the statistics identified. The mean and median should stabilize before the more extreme percentiles, but this analysis needs to be performed so that the number of simulations used can be better justified, even if that means more simulations are needed. This needs to be a component of probabilistic modeling under the performance assessment maintenance program. An issue for the LFRG is that the criterion matrix does not address this issue.

There was some concern expressed at the review team meetings about the comparison of deterministic and probabilistic results. Based on subsequent discussions, the median results need to be reported for the probabilistic analysis, and the median of the input distributions needs to be used as input to the deterministic run. The median is much more likely to match reasonably than use of another statistic or use of ad hoc deterministic inputs.

Another issue that is not addressed is correlation between parameters. However, this is common to all probabilistic performance assessment models and other complex environmental models at this time. Correlation issues need to be dealt with in the future where appropriate and possible.

The performance assessment/composite analysis maintenance program needs to update sensitivity analysis methods, evaluate stabilization of the model for different numbers of simulations, compare the probabilistic and deterministic runs using medians (use medians as input to the deterministic runs, and compare to the median output for the probabilistic runs; note that the medians of the probabilistic output should be presented in the report), and evaluate the use of correlations between parameters where possible and appropriate.

Criterion 3.1.8.3.:

- *Spurious Sensitivity Analysis Results*: The statement is made (p. 4-86) that other parameters were also highly correlated to the expected dose in the sensitivity analysis for the all pathways case but were not deemed necessary for discussion because they were considered spurious results. This requires further elaboration. The parameters need to be identified and why the results are considered spurious should be explained. Why the spurious results do not indicate problems with the sensitivity analysis in general also needs to be explained.

- See secondary issue under criterion 3.1.8.2.

7.2.8. Results Integration (3.1.9.1. and 3.1.9.6.)

Criterion 3.1.9.1.:

- See secondary issues under criteria 3.1.1.5. and 3.1.8.3.

- *Presentation and Integration of Dose Results*: Additional effort is necessary for the integration and interpretation of the probabilistic and deterministic results. For example, in the presentation of doses for the all-pathways canyon scenario, the deterministic results cannot be directly compared with the probabilistic results. This precludes the ability to interpret and integrate the results from the two different modeling approaches. In general, the intent is for the different modeling approaches to complement each other and build confidence in the overall approach and conclusions. The ability to integrate and interpret the results is also made more difficult because of the lack of details regarding radionuclide-specific contributions to the doses over time and identification of significant pathways for key radionuclides.

The probabilistic simulations need to be run to peak dose or 10,000 years, whichever is smaller, and the deterministic and probabilistic results should be plotted together to enable a direct comparison. Additional figures need to be provided that illustrate the relative contributions of different radionuclides and some information is also needed regarding the pathways that dominate doses for specific radionuclides.

Criterion 3.1.9.6.:

See secondary issues under criteria 3.1.1.1. and 3.1.5.5.

7.2.9. Quality Assurance (3.1.10.1.)

Criterion 3.1.10.1.:

Software and Database QA: Quality assurance (QA) processes in place for checking, reviewing, and documenting calculations and input files are reasonable. Based on a review of the QA summary, configuration control process, and change control log for software and database changes were not evident for: FEHM, CALPUFF, CALMET, HYDRUS, SIBERIA, GoldSim™ Platform and MDA G implementation, Hill Slope Erosion Model, and Inventory, and other databases. It is generally required to have a user's manual for analysis software, and there was no user's manual for the specific MDA G GoldSim™ models. Also, the LFRG criteria require that the QA measures be discussed in the performance assessment and that is not currently the case.

QA processes need to be developed (using a graded approach) and implemented for configuration control for all software and databases used for the 2006 performance assessment and composite analysis (Shuman 2006). The QA summary needs to be included as an appendix to the performance assessment/composite analysis. A user's manual for the MDA G GoldSim™ models should be developed, but attention to this issue should await clarification of what is needed in such manuals. The LFRG is considering development of criteria that will describe the purpose, expected audience, and content of users manuals. Addressing this issue before the LFRG criteria are available could result in the need for user's manual revisions. Furthermore, the criteria ultimately established by the LFRG may be satisfied by the existing 2006 performance assessment and composite analysis Appendix K of the GoldSim™ model documentation and data selection (Shuman 2006).

7.2.10. Radioactive Sources/Release Mechanism (3.2.2.2.)

Criterion 3.2.2.2.:

Composite Analysis Inventory: Alternate source inventories are lower than and inconsistent with inventory estimates in documented safety analyses (DSAs) for nuclear environmental sites. The composite analysis inventory estimates for the material disposal areas need to be updated to be consistent with those of the DSAs, since these are viewed as official DOE-sanctioned estimates.

7.2.11. Assumptions (3.2.5.1.)

Criterion 3.2.5.1.:

See secondary issues under criteria 3.1.1.5. and 3.1.5.3.

7.2.12. Modeling (3.2.6.3., 3.2.6.5., and 3.2.6.7.)

Criterion 3.2.6.3.:

See secondary issues under criteria 3.1.1.5. and 3.1.5.3.

Criterion 3.2.6.5.:

See secondary issues under criteria 3.1.6.3. and 3.1.6.6.

Criterion 3.2.6.7.:

See secondary issue under criterion 3.1.1.5.

7.2.13. Sensitivity/Uncertainty (3.2.8.1.)

Criterion 3.2.8.1.:

See secondary issue under criterion 3.1.8.2.

7.2.14. Results Integration (3.2.10.1.)

Criterion 3.2.10.1.:

See secondary issues under criteria 3.1.1.5., 3.1.8.3., and 3.1.9.l.

7.2.15. Quality Assurance (3.2.11.1.)

Criterion 3.2.11.1.:

See secondary issue under criterion 3.1.10.1.

References

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