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Annual Summary Report

for the

Los Alamos National Laboratory Technical Area 54,

Area G Disposal Facility

Fiscal Year 2017

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Acronyms and Abbreviations

2D	Two dimensional
3D	Three dimensional
ASR	Annual Summary Report
Consent Order	Compliance Order on Consent
CY	Calendar year
D&D	Decommission and demolish
DAS	Disposal Authorization Statement
DOE	Department of Energy
DOE-EM	DOE – Environmental Management
DOE-NNSA	DOE - National Nuclear Security Administration
DRR	Disposal receipt review
DSA	Documented safety analysis
EDE	Effective dose equivalent
EM	Environmental Management
EM-LA	Environmental Management Los Alamos Field Office
EMWMP	Enduring Mission Waste Management Plan

ER	Environmental Restoration
FEHM	Finite Element Heat and Mass (porous flow simulator)
FEM	Field Element Manager
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
NNSA	National Nuclear Security Administration
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
TBD	To be determined
TDR	Time-domain reflectometry
TRU	Transuranic
UDQ	Unreviewed disposal question
UDQE	Unreviewed disposal question evaluation
WAC	Waste acceptance criteria
WCATS	Waste Compliance and Tracking Syste

1.0 Executive Summary / Introduction

The United States (U.S.) Department of Energy (DOE) Order 435.1 (DOE, 2001a) requires that radioactive waste is managed in a manner that protects worker and public health and safety, and the environment. To comply with this order, DOE field sites must prepare and maintain site-specific radiological performance assessment (PA) for LLW disposal facilities that accept waste after September 26, 1988. Furthermore, sites are required to conduct composite analysis (CA) for disposal facilities that received waste before September 26, 1988. These CAs 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.

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 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. The results of the annual review are presented in an Annual Summary Report (ASR).

The Fiscal Year (FY) 2017 ASR for the Area G disposal facility is based on new guidance described in DOE Technical Standard 5002-2017 (DOE, 2017). The new technical standard requires that the ASR follow a specific outline and address the following:

- Identify any newly discovered or planned changes in assumed conditions or proposed activities (e.g., new waste stream) or a change in disposal operations;
- Evaluate the cumulative effects of all changes, including changes evaluated in the change control processes, in relation to the Disposal Authorization Statement (DAS), PA/CA assumptions and conclusions, and the Radioactive Waste Management Basis (RWMB);
- Identify any planned analyses (e.g., Special Analyses (SAs), research and development (R&D)), or results from completed analyses, to address any questions/uncertainties raised by these changes;
- Describe the facility's annual operations as related to waste receipts, current and future inventories, monitoring results and trends, land use changes, and results of any independent or internal audits, self-assessments or other evaluations;

- Provide a status update for: any DAS conditions/limitations, key or secondary issues resulting from the Low-Level Waste Disposal Facility Federal Review Group (*LFRG*) review of the facility's PA/CA and supporting technical basis documents; and
- Certify the continued adequacy of the DAS, PA, CA and RWMB.

1.1 *Site Background*

The Laboratory generates radioactive waste as a result of various activities. Operational waste is generated at the Laboratory 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 the Laboratory undergo cleanup or remediation. The majority of this waste is low-level radioactive waste (LLW) and has traditionally been disposed of at the Technical Area 54 (TA-54) Area G disposal facility.

The Area G disposal facility consists of existing Material Disposal Area (MDA) G and potential Zone 4. Material Disposal Area G has been in continuous operation since Area G first received radioactive waste in the late 1950s, although very limited pit and shaft disposal at Area G has occurred since February 2014. 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.

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.

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 cover design 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, LANL 2018b).

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 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 FY2019 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.

1.2 *Ongoing Monitoring, R&D, and SAs*

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 ASR.

Several research and development (R&D) efforts have been initiated under the PA/CA maintenance program. These investigations are designed to improve the understanding of the current and future conditions 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 FY2017 are discussed in this report. These include (1) groundwater modeling to account for transient infiltration through and below the pits, (2) updates to the erosion model, and (3) sampling to bound cliff-face age dates as part of a cliff retreat study.

Two special analyses (SAs) were completed during FY2017: (1) to document a potential underreporting of the Am-241 inventory, and (2) to analyze the disposal of three drums, from the Fort Saint Vrain Generating Station, containing enriched uranium oxide to Pit 38. Two other SAs are in draft form. The first draft SA is awaiting final signatures; it analyzes enhanced erosion and increased infiltration at Pit 25. The second draft SA is on hold pending a decision regarding decommissioning and demolition of Dome 224 at Area G under the Laboratory's Hazardous Waste Facility Permit; the draft SA determines safe soil sampling depths to avoid encountering waste in Pit 33.

1.3 Major revisions for FY2017

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) (LANL, 2017a) proposes that the strategy for LLW management is to terminate on-site LLW disposal by using the remaining space in the Pit 38 extension and existing open shafts to dispose of a small volume of specific problem wastes that are difficult to transport off site. Plans are to halt 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 FY2018). For this ASR, on-site disposal is assumed to have stopped at the end of FY2017; the EMWMP states that on-site-disposal, following the transition of EM to the subcontractor, should be reserved for waste with no off-site path forward, and given the lack of data on what the inventory of such packages may be, a decision was made to limit inventory analysis to the disposed waste documented as of September 30, 2017. 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, 2017a).

Given the uncertainty in the future operations at the site, NNSA Los Alamos Field Office decided to revise the PA/CA calculations for the 2017 ASR to follow the assumptions of the EMWMP such that the modeling now includes no additional waste after September 30, 2017, and the proposed Zone 4 expansion area receives no waste.

Another major change implemented in the PA/CA assumptions moves the site closure date from 2046 to 2035. This change is based on the decisions to remove Zone 4 from consideration and to limit future disposal at MDA G, both of which will likely move up the site closure date.

As part of the ASR dose calculations, a major rebuild of the inventory model was performed during FY2017, following the assumptions that no new waste will be added to Area G after September 30, 2017 or to Zone 4. This rebuild was based on a new Disposal Receipt Review (DRR) undertaken to ensure that the known inventory, through September 30, 2017, extracted from the Waste Compliance and Tracking System (WCATS) system is in agreement with previous work. Where disagreement was found, inventories of individual waste packages were reviewed to ensure that the 2017 DRR uses the best available waste data. The DRR, including a discussion of the new inventory model, is included in Chu et al. (2018).

These significant changes in the PA/CA dose calculations can be revisited if and/or when waste disposal at Area G recommences and/or the closure date is modified. Thus, the current analysis includes no projections for future volumes and radionuclide inventories that were previously predicted to require disposal in the second revision of the Area G inventory (French and Shuman, 2015b), and includes only waste know to have been disposed through September 30, 2017.

Based on the current inventory of waste, Area G is expected 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.

1.4 *Report Summary*

This report summarizes the results of the FY2017 PA/CA analysis for Area G.

Section 2 presents all changes potentially affecting results of the adequacy determination for Revision 4 of the Area G Performance Assessment and Composite Analysis (LANL, 2008). This section includes all Change Control Process evaluations (UDQEs and SAs) or other change control processes (e.g., non-conformances, corrective action) used to evaluate proposed actions, changes, and new information, and discusses whether these activities are within the boundaries analyzed in the approved PA and CA.

Section 3 summarizes the impacts of the combined changes described in Section 2 on the PA, CA, DAS, and, RWMB. Results are presented in terms of calculated doses relative to dose limits for a variety of scenarios, including off-site receptors, onsite residents, and intruders. Doses have changed in this iteration of the PA/CA model due to the modified inventory and closure date, and modifications to algorithms in the PA/CA GoldSim model. The current PA/CA model does not include implementation of the enhanced groundwater pathway in Pit 38.

Sections 4 includes discussion of all waste receipts and a description of the recently revised DRR. This section also includes a table with details for the remaining open pit and seven shafts.

Section 5 presents pertinent information collected through compliance monitoring during FY2017.

Section 6 summarizes R&D activities (including field studies and SAs) and discusses how these results have impacted the PA/CA. This section also discusses possible improvements to methodologies and technologies that could enhance disposal facility performance.

Section 7 includes discussion of planned and/or contemplated changes that may impact assumptions and conclusions of the PA/CA.

Section 8 provides a status update on any DAS conditions and key or secondary issues resulting from an LFRG review of the facility's PA and CA and other technical basis documents.

Finally, Section 9 contains a certification statement signed by the Field Element Manager (FEM) attesting to the accuracy of the ASR.

2.0 Changes Potentially Affecting the PA, CA, DAS OR RWMB

This section includes all divergences from expected or previously planned conditions relevant to the PA/CA that were either implemented or considered during FY2017. Both discovered and voluntary divergences, including the results from ongoing R&D analysis are discussed. Several R&D results are pertinent to the performance of the site and the impacts of the results on the PA/CA are discussed. A FY2017 Disposal Receipt Review (DRR) was conducted based on changing assumptions regarding closure, and results from this work and implications for the PA/CA dose calculations are presented. A review of the DAS, DAS technical basis documents (PA/CA Monitoring Plan, PA/CA Closure Plan, WAC) and RWMB is included with a discussion of changes that will need to be made to these documents. Change Control Process evaluations (i.e., UDQEs) were used to evaluate four proposed actions, and were used to determine whether these activities are within the boundaries analyzed in the approved PA and CA. A discussion of the potential effect of all changes on the continued adequacy of the DAS, PA, CA and RWMB is provided at the end of this section. Table 2-1 presents a summary of all divergences relevant to Section 2.0.

Table 2-1 Potential Changes Affecting the PA, CA, DAS or RWMB

Disposal Facility or Unit	UDQE number or reason for change	Change, Discovery, Proposed Action, New Information description	Evaluation Results	Special Analysis number (if applicable)	PA,CA,DAS or RWMB Impacts
R&D on infiltration of excess water into Pit 38	Observations of water spraying and run-off/ponding at Pit 38 initiated this R&D effort	Excess water in Pit 38 drives increased flow toward groundwater	New groundwater pathway residence time distributions were tested in the PA/CA model. Dose remains below 4 mrem/yr at 1000 yrs.	N/A	Impacts the PA/CA by increasing the projected dose of 14C in groundwater; however, not implemented in Section 3.
R&D on erosion to 10,000 yrs	Part of ongoing R&D work suggested by DOE/LFRG	Requested to examine uncertainty in erosion behavior to 10,000 yrs.	Erosion to 10,000 years does not expose waste using current assumptions	N/A	No impact on PA/CA because of the current 1,000 yr compliance period

R&D on cliff retreat	Ongoing R&D work suggested by DOE/LFRG	New data on isotopic ages using surface exposure dating	New analysis suggests cliff retreat is relatively slow	N/A	No impact on PA/CA
Expansion into Zone 4	Change in disposal assumption	Planning for expansion of LLW disposal in TA-54 Zone 4 has been terminated	Lower dose predictions, especially in reaches only impacted by Zone 4 waste, where dose goes to zero	N/A	Impacts the PA/CA, RWMB, and DAS
All of MDA G	Change in disposal assumption	Site closure date moved from 2046 to 2035	Slightly higher dose predictions for intruders based on earlier exposure to tritium and strontium	N/A	Impacts the PA/CA, RWMB, and DAS
All of MDA G	Change in disposal assumption	No new waste disposed at MDA G after September 30, 2017.	Lower dose predictions. Future waste disposal will require updates to the PA/CA inventory and dose models as part of EM-LA mission	N/A	Impacts the PA/CA, RWMB, and DAS
All of MDA G	UDQE 1601	Potential under-reporting of Am-241	No under-reporting was found	SA-2016-001	No impact on PA/CA, RWMB, or DAS
Pit 38	UDQE 1701	Disposal of Ft. St. Vrain reactor waste in Pit 38.	No impact to the site was found. Inventory is adjusted to include these new waste packages.	SA-2017-001	Little impact to the PA/CA. Additional inventory is small compared to existing inventory
Pit 25	UDQE 1602	Observation of enhanced erosion of interim cover. Discovery of test covers constructed of gravel and cobble that were not removed	No immediate impact to dose was found. Recommendation made to properly cover Pit 25.	SA-2016-002 (in draft form)	No impact on PA/CA; recommendation made to install interim cover on Pit 25.

Dome 224	UDQE 1604	Plans to D&D Dome 224 initiated research related to depth of fill between asphalt pad and waste in Pit 33	Plans are on hold for D&D of Dome 224 because of tritium waste stored in the vicinity.	N/A	No impact on PA/CA, RWMB, or DAS
Pit 38	UDQE proposed but never assigned	Calculations performed for proposed tritium canister disposal in Pit 38	Plans are on hold	N/A	No impact on PA/CA, RWMB, or DAS
Error correction in PA/CA GoldSim model	Error to Henry's Law coefficients for gas-phase radionuclides, CO_2, CH_4, Kr, and Rn	Corrected Henry's Law coefficients	Reduced gas flux	N/A	Small impact on radon dose
Organic C-14	Manual addition of C-14 inventory required to account for organic C-14 portion in the model inventory	C-14 inventory added to correctly account for organic C-14 portion	Slightly higher C-14 gas production	N/A	Small impact on C-14 gas dose.

2.1 *R&D analysis*

R&D Analyses are presented in Section 6. None of the R&D work was formally included in the PA/CA model this year. However, the groundwater dose modifications caused by enhanced infiltration into Pit 38 come close to the performance objective of 4 mrem/yr, and work is ongoing to determine if model assumptions can be refined to decrease the impact of this pathway.

2.2 *Changes to assumptions of the PA/CA*

During FY2017, several changes were made to the assumptions of the PA/CA. These changes have significant impacts on the projected doses.

- **Error corrections.** An error in calculating Henry's Law coefficients used for four gas-phase radionuclides, CO_2, CH_4, Kr, and Rn, was identified and corrected. The correction and its impacts on doses and radon fluxes were documented in the disposal receipt review (DRR) report (Chu et al., 2018). Also an additional error was identified that excluded the inventory of gas-phase C-14 generated as a result of the biodegradation of organic C-14 waste. Biodegradation of organic C-14 is assumed to generate both carbon dioxide (CO_2) and methane (CH_4). The C-14 organic fraction has been added back into the inventory, and the impact on the dose projections are documented in the DRR report.

- **Revision to FY2006 and FY2014 inventory.** A review of inventory information identified that Po-209 activity was not accounted for in the PA/CA inventory model for three containers disposed of during 2006. Radionuclide activities for seven waste containers disposed in FY2014 were updated in WCATS in 2016. The inventory model was updated to include the Po-209 activity in the waste inventory, and the inventory was also revised to account for the 2016 WCATS update (details are documented in the DRR report (Chu et al., 2018)).

- **No expansion of disposal operations into Zone 4.** The Area G disposal facility formally consists of MDA G and proposed 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) (LANL, 2017a) 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. 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 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. 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. Therefore, the DRR and associated revised dose calculations assume no projected waste disposal in Zone 4.

- **DRR and dose calculations assume no additional LANL-generated waste will be disposed at MDA G after FY2017.** The EMWMP (LANL, 2017a) proposed limited disposal of specific problem wastes that are difficult to transport off site before the upcoming transition of the Laboratory's Environmental Management (EM) to a DOE subcontractor (i.e., late April, 2018). One such waste stream, consisting of three containers, was disposed during FY17 (and is included in the as-disposed inventory included in the DRR) as documented in "Special Analysis: 2017-001, Disposal of Drums Containing Enriched Uranium in Pit 38 at Technical Area 54, Area G" (Birdsell et al., 2017a). The EMWMP proposed that all other present and future LANL-generated LLW streams be shipped to off-site treatment and disposal facilities. Consequently, the DRR update and the associated dose and radon flux calculations assume no additional waste will be disposed between October 1, 2017 and closure of the facility. The implication of this assumption is that the PA inventory model and resulting dose calculations presented in this report no longer include any projected future inventory.

- **Future waste disposal will require updates to the PA/CA inventory and dose models as part of the Environmental Management Los Alamos Field Office (EM-LA) mission.** Although there is additional capacity for waste disposal in Pit 38 and in several shafts at Area G, the DRR assumes that the Laboratory will not dispose of any additional waste between September 30, 2017 and closure of the facility. During their contract, EM-LA may elect to dispose of LLW at Area G as part of their mission or as requested by NNSA. However, the decision was made for the DRR that the inventories and volumes of any assumed future waste are highly uncertain and would not be included as projected future waste at this time. As of April 30, 2018, EM-LA assumed responsibility for operations at Area G. If EM-LA chooses to dispose of waste, the PA inventory model and associated dose projections will require updating to include appropriate accounting of the waste, and such model updates will likely become the responsibility of the EM subcontractor.

- **Final disposal date moved from 2044 to 2035.** Given that expansion into Zone 4 is no longer planned, the predicted final disposal date for Area G was moved up from 2044 to 2035 in the DRR. This assumes that disposal operations cease in 2035, and final closure occurs in 2037. Moving the closure date to 2035 impacts the PA/CA giving less time for radioactive decay to reduce inventories of shorter lived isotopes. Thus, in the current ASR, dose estimates for some pathways, including drainage catchments and intruder scenarios increase by up to 23%, though doses remain well below performance objectives.

2.3 *FY17 UDQE and SA Analysis*

Section 2.3 reviews UDQEs and associated special analyses that were performed in FY2017. Two special analyses were conducted and completed; those are documented in sections 2.3.1 and 2.3.2. Two other draft special analyses were completed for future use related (1) to erosion and enhanced infiltration in Pit 25 and (2) pending D&D of Dome 224 (Sections 2.3.3 and 2.3.4).

2.3.1 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. UDQE 1601 identified a positive unreviewed disposal question (UDQ) 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.

Special analysis 2016-001 (Chu et al., 2017a) was completed during FY2017. For the SA, LANL personnel reviewed information for similar waste streams, both LLW and TRU waste, disposed at Area G to determine if underreporting of Am-241 has occurred. Four approaches were used to address potential under-reporting of Am-241 in the Area G Inventory. These approaches combined together provided a thorough review of the potential waste streams of concern generated at TA-55 or TA-50 during the time period between the late-1970s and the mid-1980s. The analysis also checked further into the pre-1971 non-retrievable waste inventory (before the time frame of concern for this analysis – the late-1970s to mid-1980s for this analysis) and by cross checking waste streams for TRU waste generated at TA-55 or TA-50 and shipped to WIPP against waste streams for LLW and TRU also generated at TA-55 or TA-50 and disposed at Area G. The review found that some Am-241 inventory of TRU waste that is retrievably-placed in Pit 9 and Trenches A-D may have the underreporting problem. However, that TRU waste will be removed from Area G and shipped for off-site disposal. Therefore the identified containers are not relevant for this special analysis because they are not permanently-disposed LLW that will remain in Area G. These container listings may, however, be relevant when considering the Am-241 inventory of the retrievable TRU waste when that waste is transferred elsewhere for disposal.

SA 2016-001 documents the potential Am-241 under-reporting issue and reviews relevant data from the WCATS database and for pre-1971 waste. The SA found no evidence for under-reporting of Am-241 for wastes permanently disposed in the pits and shafts at Area G. Therefore, no adjustments to the Am-241 inventory included in the PA/CA inventory database or model are necessary

2.3.2 Disposal of Drums Containing Enriched Uranium in Pit 38

During FY2017, permission was sought to dispose of three drums of waste generated at the Fort Saint Vrain Generating Station in Pit 38 at Area G. The waste consists of three carbon fuel blocks with enriched uranium oxide fuel pellets are stored in penetrations in the carbon blocks. The U-235 contents of two of the drums exceed the fissile material limits found in the LANL WAC. Carbon (graphite), a moderator, is present in all three of the drums in quantities greater than those permitted by the WAC (LANL, 2014). Both these requirements are related to criticality limits rather than to the performance assessment (PA). However, the void space within the waste drums exceeds 10%, which is a WAC requirement related to long-term site performance. UDQE 1701 determined that these WAC exceptions constitute a positive UDQ, and a SA was required to approve waste disposal.

Special analysis 2017-001 (Birdsell et al., 2017a) was completed during FY2017. The SA evaluates the potential impacts of disposing of this waste in Pit 38 at Area G based on the assumptions that form the basis of the Area G PA/CA. The SA found that the disposal of the three drums does not violate any of the assumptions upon which the Area G PA/CA are based. Radionuclide concentrations in the waste fall within radionuclide concentration limits for the disposal pits. Radionuclide inventories that include the waste of the three drums fall within radionuclide inventory values included in the most recent inventory model for the performance assessment. The criticality characteristics of the waste that cause it to violate the LANL WAC do not play a role in the performance modeling.

Container void space in the three drums exceeds the WAC recommendation of <10% void space. Excess void space can lead to long-term subsidence of a disposal site, which in turn can enhance radionuclide transport through processes such as increased infiltration, bioturbation, and cover failure. Real time radiography scans indicated that the containers have a maximum void volume of 21.1%. Based on the dense nature of the waste, the relatively low maximum linear compaction per drum (approximately 6 inches), and the self-healing nature of the proposed cover, potential future subsidence from the three drums was thought to be acceptable in terms of overall site performance. Subsidence that occurs during the institutional control period can be remedied. In addition, though technically exceeding the void-space requirement in the WAC, the void volume of these three drums does not lead to a measureable exceedance of the void space, particularly when the total volume of the Pit 38 extension is considered. Therefore, future subsidence occurring specifically due to these drums is likely to have no measurable impact on site performance. SA 2017-001 concluded that the three drums are acceptable with respect to the PA/CA assumptions for disposal in Pit 38 at Area G. The SA recommended that the drums be placed vertically in the pits and that there be adequate backfill around the drums to minimize potential future subsidence.

A Criticality Safety Evaluation for the waste was also conducted and found that disposal of the drums was acceptable. The three drums were disposed in the Pit 38 extension during 2017. Their contribution to the inventory is included in the FY2015-FY2017 disposal receipt review (Chu et al., 2018) and the corresponding PA/CA dose and radon flux evaluations presented in this ASR.

2.3.3 Pit 25 Cover Erosion and Presence of Unconventional Covers

Enhanced cover erosion and buried vertically-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 (Figure 2-1). The enhanced erosion and presence of these unconventional covers was found to be a positive UDQ with UDQE 1602. 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. Special Analysis 2016-002 was conducted to determine the impact of the observed erosion and the presence of these unconventional covers on the pit. This SA is currently in draft form.

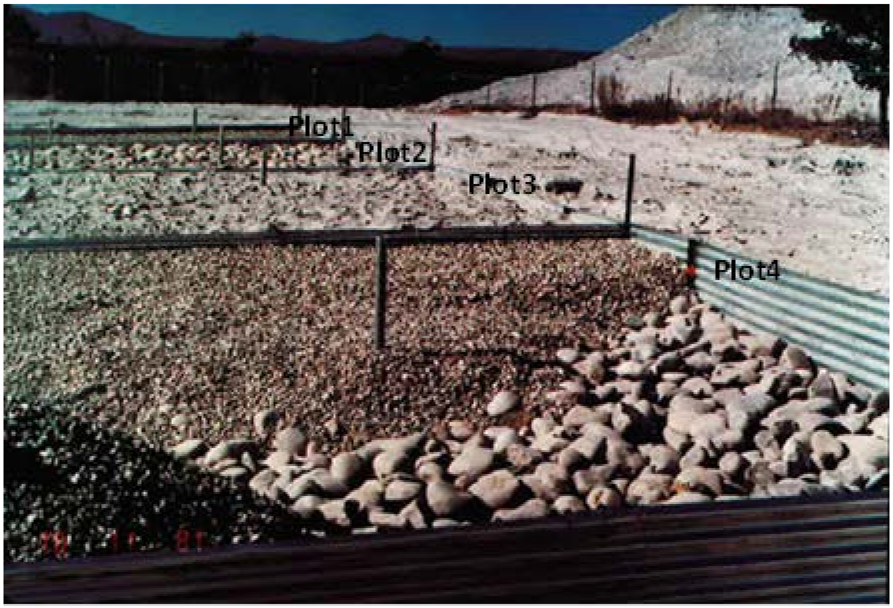

Figure 2-1 Four biointrusion-barrier test cover plots constructed along the north central border of Pit 25 in 1981. Portions of the barrier materials are shown here during construction, before the final 15 cm of topsoil was added on each plot.

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). Subsequent modeling included in SA 2016-002 indicates that enhanced infiltration likely still occurs within the unconventional covers. The largest portion of the inventory (>98%) is made up of the short-lived radionuclides ^{3}H, ^{90}Co, and ^{90}Sr, which have half lives of 12.7, 5.3, and 28.8 years, respectively. Given that these radionuclides generally decay before reaching groundwater in the groundwater pathway analysis, and that the unconventional covers are present over a relatively small area of the pit, the SA concluded that the impact on the groundwater dose would be minimal, but that additional thickness of operational cover (i.e., crushed tuff) would help alleviate the unfavorable enhanced infiltration present at the site. In addition, the cover shows some signs of erosion. However, field inspection and photo documentation from 2015 through 2018, show that deposition and additional plant growth has occurred rather than addition erosion. Although the analysis indicates these conditions may not be of immediate concern in terms of site performance, the conditions are less protective than those assumed in the PA/CA models. The three test plots that are constructed largely of cobbles do not act to buffer precipitation events; effectively this area is behaving as though it lacks an interim cover in terms of limiting infiltration into the pit. Therefore, actions to repair and enhance the interim cover on Pit 25 are recommended to remedy these conditions in the draft SA.

2.3.4 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 (Pad 5) 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 had determined that the dome and its liner be decommissioned and demolished (D&D). The Laboratory's Hazardous Waste Facility Permit was temporarily modified to remove operations at the dome. 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 that does not impact the underlying LLW inventory. However, the uncertain condition and impact of 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 were assessed and presented in a draft Special Analysis, SA 2016-004. The draft SA concludes that soil moisture samples should be collected around the footprint of the dome to a depth of 2 m if/when the dome is removed. This depth ensures that no waste will be encountered while sampling.

Since work documented in the draft SA was conducted, the Hazardous Waste Facility Permit was modified to again include Dome 224. A draft version of the SA was written to document the work that was completed in order to assist operations personnel when D&D of the dome occurs in the future. This SA is related to another effort undertaken during FY2016 to analyze disposal of tritium containers, which did not comply with WAC requirements, in Pit 38. Disposal of the tritium waste is no longer being considered. The tritium containers are stored in close proximity to Dome 224, and D&D of the dome has been cancelled until the containers are removed. Thus, both these analyses are removed from consideration in the current ASR and PA/CA dose calculations.

3.0 Cumulative Effects of Changes

A relatively small number of radionuclides made significant contributions to the doses projected for the Revision 4 Area G PA/CA (LANL, 2008). The impacts of updating inventory projections using the FY2015-FY2017 disposal receipt data and assumptions described in Section 2.2 were evaluated by running the PA/CA modeling (Chu et al., 2018) to update the exposure dose and radon flux projections. These projections also account for the corrections to the Henry's Law coefficients and the C-14 organic inventory, and to revisions made to the 2006 and 2014 inventories described earlier.

The exposures and radon fluxes projected using the updated pit and shaft inventories and other assumptions used in the 2017 DRR assessment are compared in Tables 3-1 to 3-3 to the performance objectives and to the same quantities estimated for the corrected FY2016 Area G Annual Report results (Chu et al., 2018). The corrected FY2016 annual report values are compared with the FY2017 ASR results. All GoldSim models in this document use GoldSim version 11.1.5 (Chu et al., 2017b). Table 3-1 compares the exposures projected for members of the public for the PA and CA. Figure 3-1 is a map showing the sediment catchment areas described in Table 3-1. Table 3-2 shows the radon flux estimates for the PA waste, and Table 3-3 provides the intruder exposure projections. The results provided in Tables 3-1 to 3-3 show that the respective performance objectives are met for all exposure pathways and for radon flux for both the PA and the CA wastes.

Table 3-1 presents the FY2017 ASR offsite peak mean doses for members of the public compared to the corrected FY2016 ASR offsite peak doses for the PA and CA inventories, with percentage differences. The doses that are projected for members of the public under the PA tend to be lower than those projected in the corrected FY2016 ASR results (Chu et al., 2018). A decrease of 100 percent is noted for the All Pathways-Canyon Catchment PC0, which is located next to Zone 4 and upslope from MDA G (Figure 3-1); the projected dose decreases to zero because the Zone 4 projected inventory is now zero. Other catchments and the groundwater pathway have smaller projected doses, as well, most likely due to the absence of waste in Zone 4 and the decreased projected inventory in Pit 38 and the MDA G shafts. Figure 3-2 shows a map of the MDA G area with pit and shaft locations marked, including the location of Pit 38. Pit 38 extension, referenced in other sections of this document, lies between Pit 38 and Pit 31. This map includes the 8 clusters of waste that the PA/CA is broken into. Doses decrease for the atmospheric scenarios at the LANL boundary and at the Area G fence line by 12% and 37%, respectively, although the absolute changes in the doses are small.

The doses that are projected for members of the public under the CA also generally decrease with the new assumptions and inventory information. A 100% decrease (the projected dose deceases to zero) occurs for the All Pathways-Canyon Catchment PC0 due to the absence of Zone 4 waste.

However, at Catchments PC1, PC2 and PC3, the projected doses increase by about 20%. These catchments are located closer to disposed CA waste. With a 9-year shorter operational period (the closure date changed from 2044 in the previous dose assessment to 2035 in the 2017 ASR), radionuclides have less time to decay before sediment transport processes take place, which leads to higher calculated doses in these canyon catchments. The major contributor to these increases is Sr-90, with a half-life of 28.8 years.

Table 3-2 presents the updated peak mean radon flux projections for both the corrected FY2016 ASR and the FY2017 ASR, with percentage differences. Radon fluxes projected for the PA waste tend to be lower than those reported for the corrected FY2016 Area G annual report results (Chu et al., 2018). Doses decrease the most for Zone 4 (100%, to zero) and for Pit 38 (65%) because of the absence of projected waste in Zone 4 and the lack of headspace waste in Pit 38, respectively. Decreases in the other regions are due to correcting the error in the Henry's Law coefficient, documented in Chu et al., 2018.

Table 3-3 presents the updated intruder peak mean dose projections, specific to each intruder pathway, for both the corrected FY2016 ASR and the FY2017 ASR, with percentage differences. The intruder exposure projections for the Zone 4 shafts all decrease to zero. However, there is an 18% increase for the post-drilling scenario near the MDA G shafts. This change is due to the Shaft 370 inventory revision (DRR report Table 3-2, Chu et al., 2018), and also due to earlier potential intruder drilling exposure from the shortened facility operational period, which leads to earlier exposure to tritium at the shafts. The intruder construction and agriculture exposure projections for the pits decrease approximately 7% again due to the reduction in projected waste in MDA G shafts and Pit 38.

The changes in the projected exposure doses and radon fluxes using the new DRR inventory information and disposal/closure assumptions presented in this report are mainly caused by changes made to the radionuclide inventories in the pits and shafts of MDA G and Zone 4 using the actual types and quantities of waste disposed during FY2015-FY2017, and the assumption of no future waste disposal projected after September 30, 2017. The inventory updates from the FY2017 DRR reduce the total inventory and future inventory projection for the PA/CA significantly, which has the effect of decreasing doses. However, the current plan to shorten the facility operational period from 2044 to 2035 contributes toward increasing doses in some locations due to reduced radionuclide decay for material transported into canyon catchments and to earlier intruder accessibility.

In summary, updating the Area G inventory to reflect the FY2015-FY2017 disposal data and the expected disposal trends is not expected to compromise the ability of the disposal facility to safely contain the waste disposed therein. All doses and radon fluxes projected by the PA/CA remain within performance objectives.

Updates to the DAS, WAC, and RWMB will be performed as necessary in the coming year to ensure that all changes to the PA/CA calculations are reflected. Similarly, any changes to the DAS, WAC, and RWMB must be cycled back to the PA/CA ASR to ensure consistency and capture any changes that may require recalculation of risk/dose at MDA G. Responsibilities for the MDA G PA/CA are still being negotiated between DOE-NNSA and DOE-EM as part of a recent contract change at LANL, and the schedule for PA/CA updates in the coming year will be more clear once the negotiations are finalized.

Table 3-1 Exposures for Members of the Public: FY2017 ASR vs. Corrected FY2016 ASR

Exposure Scenario and Location	Performance Objective (mrem/yr)	Peak Mean Dose (mrem/yr)					
		Performance Assessment			Composite Analysis		
		FY2017 ASR Results	FY2016* ASR Results	Change in Dose Projection (%)	FY2017 ASR Results	FY2016* ASR Results	Change in Dose Projection (%)
Atmospheric							
LANL Boundary	10	1.5E–01	1.7E–01	-12	2.3E–01	2.4E–01	-4
Area G Fence Line	10	1.7E-03	2.7E–03	-37	5.1E–01	5.1E–01	0
All Pathways–Canyon							
Catchment CdB1	25/30[a]	4.8E–01	5.0E–01	-4	7.8E–01	8.1E–01	-4
Catchment CdB2	25/30	9.6E-01	1.0E+00	-4	1.7E+00	1.8E+00	-3
Catchment PC0	25/30	0	2.5E-04	-100	0	2.5E-04	-100
Catchment PC1	25/30	2.2E–02	2.4E–02	-7	1.45E–01	1.2E–01	+21
Catchment PC2	25/30	1.7E–02	1.9E–02	-11	8.0E–01	6.5E–01	+23
Catchment PC3	25/30	1.2E–01	1.2E–01	0	2.9E–01	2.4E–01	+21
Catchment PC4	25/30	2.2E–01	2.2E–01	0	2.7E–01	2.7E–01	0
Catchment PC5	25/30	3.0E–01	3.0E–01	0	2.4E+00	2.4E+00	0
Catchment PC6	25/30	1.6E–01	1.6E–01	0	2.8E+00	2.8E+00	0
Groundwater Pathway Scenarios							
All Pathways–Groundwater	25/30	6.6E-03	7.1E–03	-7	6.3E-03	6.8E–03	-7
Groundwater Resource Protection	4	1.1E-02	1.2E–02	-8	NA	NA	NA

NA = Not applicable (per DOE Order 435.1, only exposure projected using performance assessment inventory is required to compare to the groundwater protection requirement of 4 mrem/yr)

[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.

** Corrected as per Disposal Receipt Review*

Table 3-2 Projected Radon Fluxes: FY2017 ASR vs. Corrected FY2016 ASR

Waste Disposal Region or Pit	Peak Mean Flux (pCi/m²/s)		
	FY2017 ASR Results	FY2016* ASR Results	Peak Mean Flux % difference
Region 1	1.1E-06	1.1E-06	0
Region 2	---[a]	---[b]	---[b]
Region 3	0.0E+00	0.0E+00	0
Region 4	2.6E-02	2.6E-02	0
Region 5	8.1E-05	8.2E-05	-1
Region 6	2.8E-03	2.8E-03	0
Region 7	1.3E+01	1.3E+01	0
Region 8 (i.e. .Zone 4)	0	1.8E-03	-100
Pit 15	1.4E+01	1.4E+01	0
Pit 37	2.7E-01	2.7E-01	0
Pit 38	3.8E-01	1.1E+00	-65
Entire Facility	3.8E-01	4.2E-01	-10

— = None of the performance assessment inventory was disposed of in the waste disposal region.
** Corrected as per Disposal Receipt Review*
Note: The performance objective for radon flux is 20 pCi/m²/s.

Table 3-3 Projected Intruder Exposures: FY2017 ASR vs. Corrected FY2016 ASR

Disposal Units and Exposure Scenario	Performance Objective	Peak Mean Dose (mrem/yr)		Change in Dose Projection (%)
		FY2017 ASR Results	FY2016* ASR Results	
MDA G Pits				
Intruder-Construction	500 mrem	3.6E+00	3.9E+00	-8
Intruder-Agriculture	100 mrem/yr	2.5E+01	2.7E+01	-7
Intruder-Post-Drilling	100 mrem/yr	1.2E+01	1.2E+01	0
Zone 4 Pits				
Intruder-Construction	500 mrem	0.0E+00	0.0E+00	0
Intruder-Agriculture	100 mrem/yr	0.0E+00	0.0E+00	0
Intruder-Post-Drilling	100 mrem/yr	0.0E+00	0.0E+00	0
MDA G Shafts				
Intruder-Construction	500 mrem	4.7E+00	4.8E+00	-2
Intruder-Agriculture	100 mrem/yr	8.7E+01	8.3 E+01	+5
Intruder-Post-Drilling	100 mrem/yr	1.3E+01	1.1E+01	+18
Zone 4 Shafts				
Intruder-Construction	500 mrem	0.0E+00	3.7E+00	-100
Intruder-Agriculture	100 mrem/yr	0.0E+00	8.6E+01	-100
Intruder-Post_Drilling	100 mrem/yr	0.0E+00	1.1E+01	-100

* *Corrected as per Disposal Receipt Review*

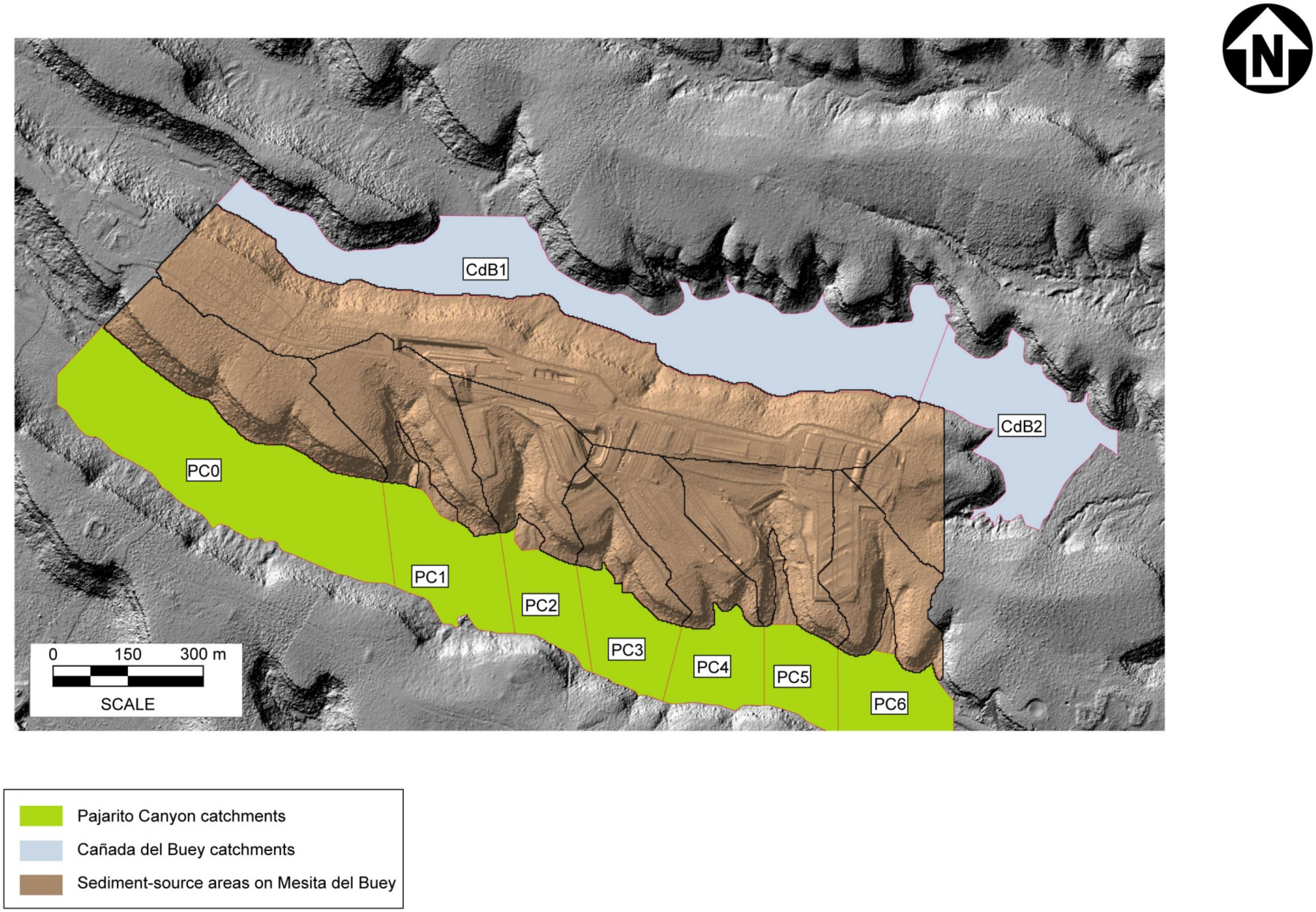

Figure 3-1 Area G Sediment Catchments in Pajarito Canyon and Cañada del Buey

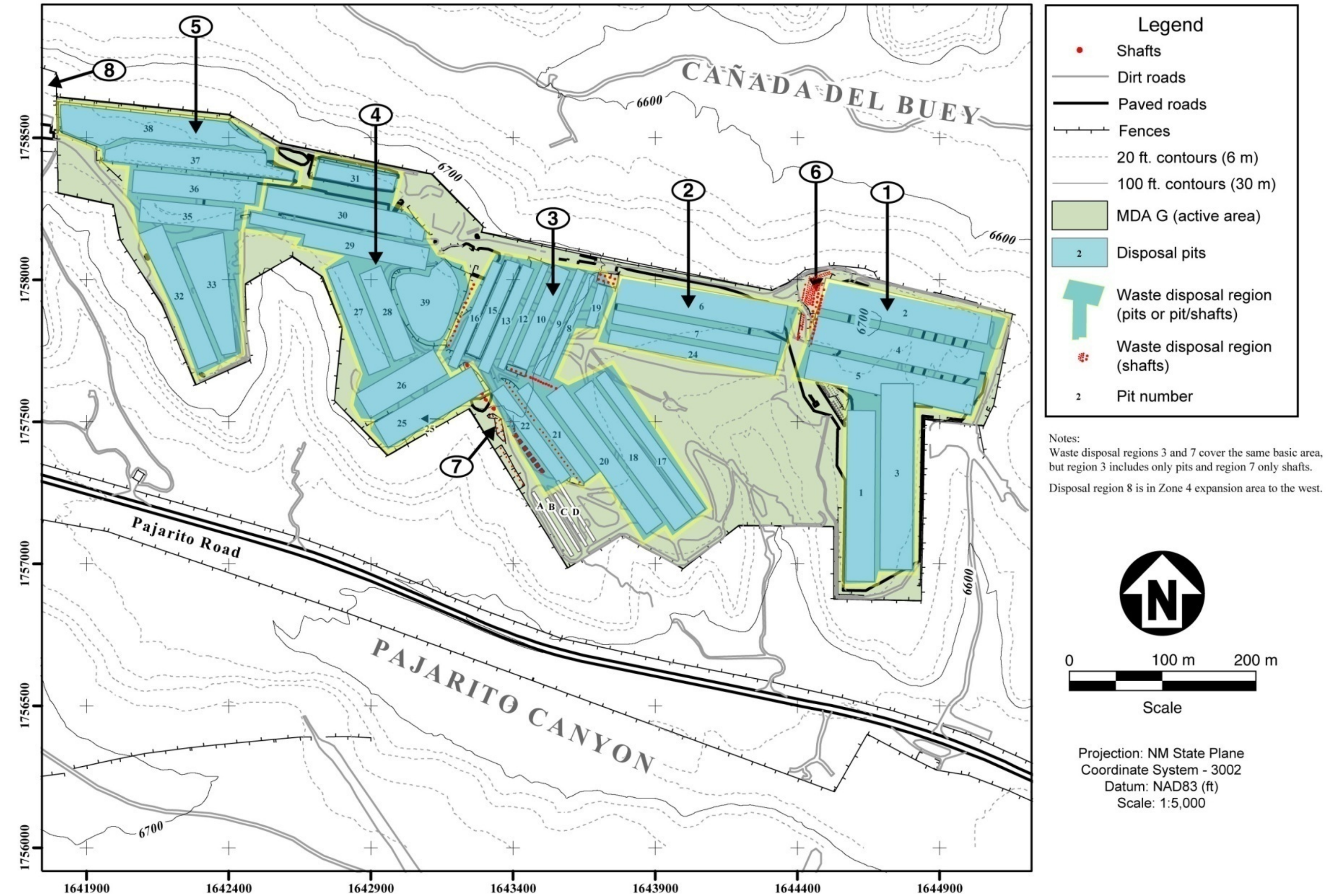

Figure 3-2 Waste Disposal Regions at Area G

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

4.0 Waste Receipts

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 FY2017 DRR are summarized below. Also included in this report are the most current dose projections based on the FY2017 DRR (Section 3).

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 3.0.

Table 4-1 summarizes information about the remaining open pit and seven open shafts at MDA G. The rest of the pits and shafts at MDA G are closed and more detail on the volumes and inventories can be found in French and Shuman (2015a). The open pit and shafts could hypothetically receive more waste in the future, however for this iteration of the PA/CA, the assumption is that these will be closed without further waste disposal. However, if the remaining volume of the Pit 38 extension and the seven shafts are used for additional waste, the PA/CA calculations are set-up to easily input additional inventory.

Because the MDAG PA/CA relies on complex three-dimensional (3D) transport, including erosion, coupled to waste regions that average inventory over clusters of pits and shafts, the DOE Technical Standard recommendation to present sums of fractions is impractical, and the analysis in Section 3 describes total dose relative to PA/CA performance objectives. R&D work on focused groundwater flow below Pit 38 has identified a potential for C-14 transport approaching performance objective limits, however revisions that reduce the impacts of conservative assumptions are ongoing, and this pathway has not been added to the current cumulative dose analysis presented in Section 3.

Table 4-1 Remaining open pits and shafts at MDA G

Pit/Shaft Number	Operational Period	Length/Width/Height (Pit) or Diameter/Depth (Shaft) (m)	Liner	Volume (m^3)	Waste Volume (m^3)
Pit 38 Extension	2013-present	93/18/13	Unlined	12000	10,000 (approximate)
Shaft 159	1989-present	0.61/14	Corrugated metal pipe, asphalt covered	4	0.32
Shaft 165	2004-present	0.91/18	Corrugated metal pipe, asphalt covered	12	3.1
Shaft 169	2004-present	0.91/18	Corrugated metal pipe	12	1.7
Shaft 170	2004-present	0.91/18	Corrugated metal pipe	12	2.3
Shaft 300	2004-present	2.4/6.7	Corrugated metal pipe	31	0.81
Shaft 301	2004-present	2.4/6.7	Corrugated metal pipe	31	2.5
Shaft 370	1999-present	4.9/18.	Unlined	340	19

4.1 *Disposal Receipt Review*

The disposal of waste during FY2015-FY2017 was limited to five containers placed in the Pit 38 extension; the total volume and inventory disposed in the pit are shown in Table 4-2. The radionuclide-specific inventories associated with the five waste containers disposed during FY2015-FY2017 as well as the radionuclide-specific totals are listed in Table 4-3. The activities and masses in the two tables represent as-disposed inventories. Only those radionuclides that were not eliminated from the inventory on the basis of half-life are included in Table 4-3. The following information is excerpted from the DRR report (Chu et al., 2018).

Table 4-2 Total Volume and Inventory of LLW Disposed of at Area G in FY2015-FY2017

Disposal Unit	Volume (m^3)	Inventory (Ci)
Pit 38 Extension	1.72E+01	1.28E-01

Table 4-3 Radionuclide-Specific Inventories of LLW Disposed in the Pit 38 Extension at Area G in FY2015-FY2017 by Container and as Totals for Pit 38

	C_ID 820688 [a] Inventory (Ci)	C_ID 824020 [b] Inventory (Ci)	C_ID 727646 [c] Inventory (Ci)	C_ID 727647 [c] Inventory (Ci)	C_ID 727648 [c] Inventory (Ci)	Pit 38 Additional Waste Inventory (Ci)
Radionuclide						
Am-241	0	3.75E-04	0	0	0	3.75E-04
Cs-137	0	2.24E-07	0	0	0	2.24E-07
Pu-238	0	9.36E-05	0	0	0	9.36E-05
Pu-239	0	3.19E-03	0	0	0	3.19E-03
Pu-240	0	7.46E-04	0	0	0	7.46E-04
Pu-241	0	1.12E-02	0	0	0	1.12E-02
Pu-242	0	4.29E-08	0	0	0	4.29E-08
Sr-90	0	2.38E-07	0	0	0	2.38E-07
Th-232	0	0	8.80E-04	1.32E-03	1.10E-03	3.30E-03
U-234	0	6.84E-09	1.58E-02	2.34E-02	4.25E-02	8.17E-02
U-235	0	1.18E-10	5.13E-04	7.59E-04	1.38E-03	2.65E-03
U-238	2.50E-02	0	4.91E-06	7.22E-06	1.33E-05	2.50E-02

[a] *Drum containing solid U-238 oxide*.

[b] *Drum vent system*.

[c] *Drums Containing Enriched Uranium from Ft. St. Vrain (Birdsell et al., 2017a).*

Table 4-4 compares the as-disposed FY2015-FY2017 inventory to the inventory projected for the same time period in the FY2014 DRR (French and Shuman, 2015b). Table 4-4 provides the total volume and activity projections; separate totals are provided for the pit waste placed in the headspace and institutional waste layers. Pit 38 received less than 0.4% (0.13 Ci compared with the projected 32.2 Ci) of the waste inventory projected in the FY2014 DRR for the FY2015-FY2017 time period. No new waste was placed in the headspace of Pit 38. The shafts received no new waste compared to the projected 3.6E+05 Ci.

Table 4-5 compares the projected future waste for FY2018 through closure based on the assumptions in this DRR to those in the FY2014 DRR (French and Shuman, 2015). Table 4-5 provides the total volume and activity projections. Neither DRR projects any new waste being disposed of in Pit 38 nor in the MDA G shafts for this time period. The current DRR assumes no new shaft waste to be disposed in Zone 4 while the FY2014 DRR estimated 3.3E+06 Ci would be disposed in the Zone 4 shafts starting in FY2018.

By disposing of much less waste than projected starting in FY2015 and not expanding into Zone 4, the updated inventory projections from Table 4-4 and Table 4-5 predict over 3.66E+06 Ci fewer will be disposed at the site than was projected in the FY2014 DRR.

Table 4-4 FY2015-FY2017 Waste Inventory Estimates for Area G: As-Disposed DRR Inventory and FY2014 DRR Projections

Disposal Unit and Waste Layer	As-Disposed FY2015-FY2017 Inventory based on the FY2017- DRR [a]		Projected FY2015-FY2017 Inventory based on FY2014 DRR [b]	
	Volume (m^3)	Inventory	Volume (m^3)	Inventory
Pits (Pit 38 only)				
Headspace Layer	0	0	2.3E+03	6.2E+00 Ci
Institutional Waste Layer	1.72E+01	1.28E-01 Ci	2.0E+02	2.6E+01 Ci 2.3E+04 g
Shafts (MDA G and Zone 4)	0	0	2.8E+01	3.6E+05 Ci 1.6E+05 g

[a] *Includes actual waste disposed in pits and shafts from October 1, 2014 through Sept 30, 2017*

[b] *Includes waste projected to require disposal in pits from October 1, 2014 through 2015 and in shafts from October 1, 2014 through Sept 30, 2017 based on FY2014 DRR*

Table 4-5 Future Waste Inventory Estimates for Area G for FY2018-Closure: FY2017 DRR Inventory and FY2014 DRR Projections

Disposal Unit and Waste Layer	Projected Future Inventory - FY2017 DRR (for FY2018 – 2035) [a]		Projected Future Inventory - FY2014 DRR (for FY2018- 2044) [b]	
	Volume (m^3)	Inventory	Volume (m^3)	Inventory
Pits (Pit 38 only)				
Headspace Layer	0	0	0	0
Institutional Waste Layer	0	0	0	0
Shafts (Zone 4)	0	0	2.56E+02	3.3E+06 Ci 1.46E+06 g

[a] *Includes current assumption about cessation of waste disposal in pits and shafts by the Laboratory from October 1, 2017 through 2035*
[b] *Includes waste expected to require disposal in Zone 4 shafts from October 1, 2017 through 2044 based on the FY2014 DRR. No additional waste was expected to require disposal in pits or MDA G shafts during this time period.*

4.2 *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, 2016a). 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, 2017b). 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 2015, 2016, and 2017 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 4-6 provides information about the radionuclides included in the groundwater analyses.

Table 4-6 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

4.2.1 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.

4.2.2 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, 2015b). Groundwater monitoring conducted in the MDA AB monitoring group between 2015 and 2017 under the Interim Facility-wide Monitoring Plan revealed detections of gross alpha, gross beta and isotopes of uranium consistent with background levels (e.g., LANL, 2017c). These results do not contradict the conclusions reached in the alternate source evaluation.

4.2.3 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.

4.2.4 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 2015 through 2017 (e.g., LANL, 2017d) detected low levels of gross beta, U-234 and U-238 consistent with background levels. There was also a single detection of U-235/236 (one of three samples at well R-60) that was slightly greater than the 95 percentile reported background concentration. These results are consistent with the conclusions reached in the alternate source evaluation.

4.2.5 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 FY2016, including regional wells R-37, R-40, R-51, and R-52 (Figure 5-2), all of which are located in the immediate vicinity of the MDA H disposal facility. Low levels of gross alpha, gross beta, U-234 and U-238 consistent with background levels were detected during groundwater monitoring sampling events conducted from 2015 through 2017 (e.g., LANL, 2017e). There was also a single detection at each of two screens in well R-52 of U-235/236 (one of three samples at each screen) and two detection at R-40 (two of five samples at screen 2) that were slightly greater than the 95 percentile reported background concentration. Finally, low-level tritium (2.2 and 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 2015 and 2017, including wells R-20 screen 2, R-21, R-38, R-53, R-54, and R-56 (Figure 5-2) (e.g., LANL, 2017e). Low levels of gross alpha, gross beta, U-234, and U-238 were observed at concentrations consistent with background levels. Three total low-level detections (3 of 28 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. In addition, (1) single detections of U-235/236 (one of three or four samples, respectively) in wells R-21 and R-38, (2) a single detection of Am-241 (one of two samples) at R-20, and (3) a single detection of K-40 (one of four samples) at R-54 were measured with concentrations slightly greater than their respective 95th percentile reported background concentration.

4.2.6 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, 2018a); samples are drawn from deep and intermediate depths within the TA-21 monitoring group. Sampling conducted from 2015 through 2017 revealed low levels of gross alpha, gross-beta, U-234, and U-238 in all three regional wells that are within background levels. Uranium-235/236 concentrations were detected in two out of six samples at well R-6 with concentrations slightly above the 95th percentile background value. 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, 2015b) 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.

4.2.7 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.

5.0 Monitoring

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).

Broadly, the environmental surveillance results are captured in Table 5-1 (Compliance Monitoring), while the site specific monitoring results form the basis for Table 5-2 (Performance Monitoring). One exception to this is the environmental surveillance data for meteorological monitoring (Section 5.1.1.2) which are used as part of the performance monitoring process to drive simulations of transport (e.g., via groundwater and erosion)

Table 5-1 Compliance Monitoring

Disposal Facility Unit	Monitoring Type	Monitoring Results & Trends	Performance Objective Measure or other Regulatory Limit (LANL, 2017b)	Action Level	Action Taken	PA/CA Impacts
MDA G	Radionuclide Air Emissions/Ambient Air Sampling	Almost no detections. Tritium at 0.02 mrem/yr. Consistent from year to year.	EPA 10-millirem (mrem) annual dose limit (EPA 1989; DOE 100-mrem annual dose limit (DOE 2011)	Not defined	Continued monitoring	None
MDA G and other Alternative Source MDAs	Groundwater monitoring, includes alluvial, intermediate, and regional groundwater samples	Low levels of gross alpha and gross beta radiation, and U-234 and U-238 consistent with background values; occasional low-level detections of U-235/236 above background UTLs, detections of tritium at ≤ 66 pCi/L. Consistent from year to year.	Radionuclide specific values defined by: (1) DOE 4-mrem/yr derived concentration technical standards [DOE Order 458.1 Chg 3]; (2) U.S. Environmental Protection Agency maximum contaminant levels [40 Code of Federal Regulations 141–143]; (3) New Mexico groundwater Standards [20.6.2 New Mexico Administrative Code]	Not defined	Continued monitoring	None
MDA G	Watershed Quality; Storm water runoff sampling	Detections of gross alpha, gross beta radiation, U-234, U-235/236 and U-238 consistent with background values. Radionuclide	DOE Order 458.1 Chg 3; New Mexico Water Quality Control Commissions (Part 20.6.4 of NM Administrative Code)	Not defined	Continued monitoring	None

		concentrations in storm water were elevated following the Las Conchas Fire in 2011 until 2015, but have returned to background levels.				
MDA G	Watershed Quality; sediment sampling	No exceedances of screening levels in 2016; previous data show Pu-239/240 and Am-241 in sediment indicate operational facility impacts neighboring canyons.	New Mexico Environment Department's risk-based soil screening levels; LANL risk-based screening action levels; EPA regional screening levels.	Not defined	Continued monitoring	None. Operational facility currently impacts sediment in canyons. Expected to end upon site closure
Perimeter of MDA G	Biota and Soil Sampling to evaluate ecosystem health	H-3, Am-241, Pu-238, and Pu-238/239 detected above regional statistical reference levels in soils; consistent with data from previous years and not statistically increasing over time (LANL, 2017b). H-3 in tree samples above regional screening level but below dose screening levels; H-3 levels in trees are highly variable and not statistically increasing.	DOE biota dose screening levels; 1 rad/d for terrestrial plants/aquatic animals and 0.1 rad/day for terrestrial animals	Not defined	Continued monitoring	None

Table 5-2 Performance Monitoring

Disposal Facility Unit	Monitoring Purpose	Monitoring Results & Trends	PA Expected Behavior	Action Taken	PA/CA Impacts
TA-54 Weather Station	Meteorological Monitoring; meets objectives of DOE Orders 458.1 and 151.1C.	Long-term data set	None	Continuous monitoring	Used for transient infiltration modeling and erosion modeling
MDA G Pit 38Extension Heat Dissipation Probes	Unsaturated-zone moisture migration beneath pits	Data evaluated for 2012 to 2016 (Levitt et al., 2015); Signal from significant rainfall event in Sept 2013 seen moving to below 2m before waste disposal in the Pit 38 extension; slow drying trend in 2015-2016 when waste disposal started	Long-term dry conditions and low infiltration rates beneath disposal units	Continuous data logger with periodic download	Used for transient infiltration modeling
Time-domain reflectometry probes in Pit 31 operational cover	Cover performance monitoring for moisture migration	Data evaluated for 2008 to 2016 (Levitt et al., 2015); overall drying trend since vegetation established. However, sharp increase in moisture content occurred at all depths following September 2013 large rainfall event.	Long-term dry conditions and low infiltration rates through vegetated interim pit cover	Continuous data logger with periodic download	Used for transient infiltration modeling and determine long-term infiltration rates through covers
Neutron moisture monitoring	Unsaturated-zone moisture migration across Area G	Most recent measurements made in 2009 and 2013 (Levitt et al., 2015)	Long-term dry conditions and low infiltration rates across site	Periodic monitoring requires field team deployment.	Used to estimate long-term infiltration rates; identification of areas with potential focused runoff
Pore Gas Monitoring	Tritium and volatile organic chemicals	Inactive program since 2011; large tritium vapor plumes present	Tritium plume is not included in the current PA/CA	Periodic monitoring requires field team deployment.	Data can be used for conceptual and numerical modeling of gas migration
Inactive Pit and Shaft Quarterly Inspections	LLW management operations		Not applicable	Cover maintenance	Used to identify potential inconsistencies with PA/CA assumptions

5.1 *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 2016 (LANL, 2017b), 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.

5.1.1 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.

5.1.1.1 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 2016, the Laboratory operated 38 environmental air-monitoring stations (AIRNET stations, Figure 5-1) to sample radionuclides by collecting particulate matter, and a subset of these stations collected water vapor based on known associations of tritium (LANL, 2017b). 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, 2017). These include 25 stations around the perimeter of the laboratory. 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, 2017). 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). For 2016, all stations in the approved plan operated all year long and further changes were not needed.

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 a 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. Results from the 2016 AIRNET sampling show the maximum average dose from tritium for a person living in White Rock (AIRNET station 392, Figure 4 -1) was approximately 0.02 mrem (Fuehne, 2017). Doses at the other White Rock stations 119, 167, and 213 were all lower than station 3 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.

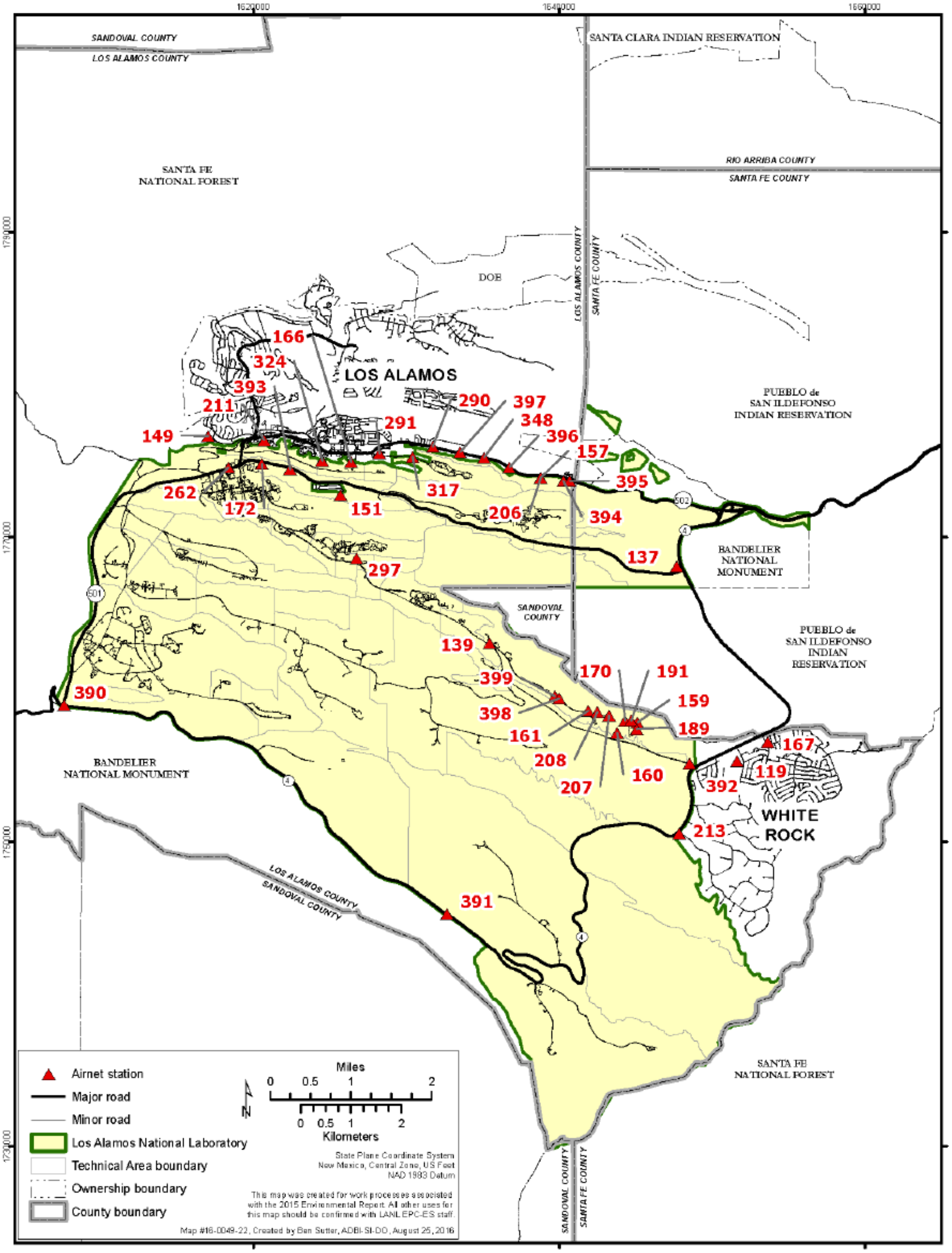

Figure 5-1 Environmental air-monitoring stations within and near the Laboratory

5.1.1.2 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 et al., 1999) computer code (Levitt, 2008 and 2011; LANL, 2013b; Stauffer et al., 2016; Dai et al., 2018). 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 were evaluated, including extreme events (Dai et al., 2018; Pawar et al., 2018). 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 (Pawar et al., 2018).

5.1.2 Surface water, Storm Water, and Sediment Monitoring

Surface water, storm water, and sediments are sampled in the Laboratory’s major watersheds; the results of recent monitoring efforts are summarized in the Laboratory’s 2016 Annual Site Environmental Report (LANL, 2017b). No surface water or storm water locations were sampled near Area G in either Pajarito Canyon or Cañada del Buey during 2016. Sediments were sampled at several locations along small drainages within the disposal site and in Pajarito Canyon and Cañada del Buey.

The 2016 MDA G annual report (Birdsell et al., 2017b) notes that some radionuclide concentrations were elevated above background in storm water in Pajarito Canyon following the Las Conchas fire in 2011. However, 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, none of the sediment samples collected near MDA G in 2016 had radionuclide concentrations that exceed screening levels (LANL, 2017b); comparisons to background values were not made in the most recent report. We note that previous 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 values (LANL, 2016c). This is consistent with data from previous years for radionuclide concentrations in sediments collected near Area G, and supports 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 ear Area G are within or near background values (LANL, 2016c).

5.1.3 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 for FY2017 is shown in Figure 5-2 (LANL, 2017a). In the vicinity of Area G, the network includes screens at R-23i and R-55i (only tritium at 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. The intermediate wells are sampled quarterly or semiannually. 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, 2017b; LANL, 2017e).

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 2015 to 2017, gross beta, 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-alpha radiation at many of the regional wells, and K-40 at one of the regional wells (e.g., LANL, 2017e). During this period, tritium is consistently detected at concentrations less than 66 pCi/L at intermediate screens1, 2, and 3 in well R-23i, twice (2 of 12 sampling events) at 2.49 and 131 pCi/L at regional well R-39, and once (1 or 12 sampling events) at 2.8 pCi/L at regional well R-41 . The measured tritium concentrations at R-23i generally 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). A limited number of U-235/236 concentrations exceeded groundwater background concentrations at R-21 (1 of 3 samples), and R-55 (2 of 5 samples). No radionuclide concentrations exceeded any regulatory standards.

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 samples shallow alluvial water upstream of Area G. Data from this well for samples collected from 2015 to 2017 have detections of gross alpha, gross beta, U-234, U-235/236, and U-238 that are all within background values. 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, 2017f).

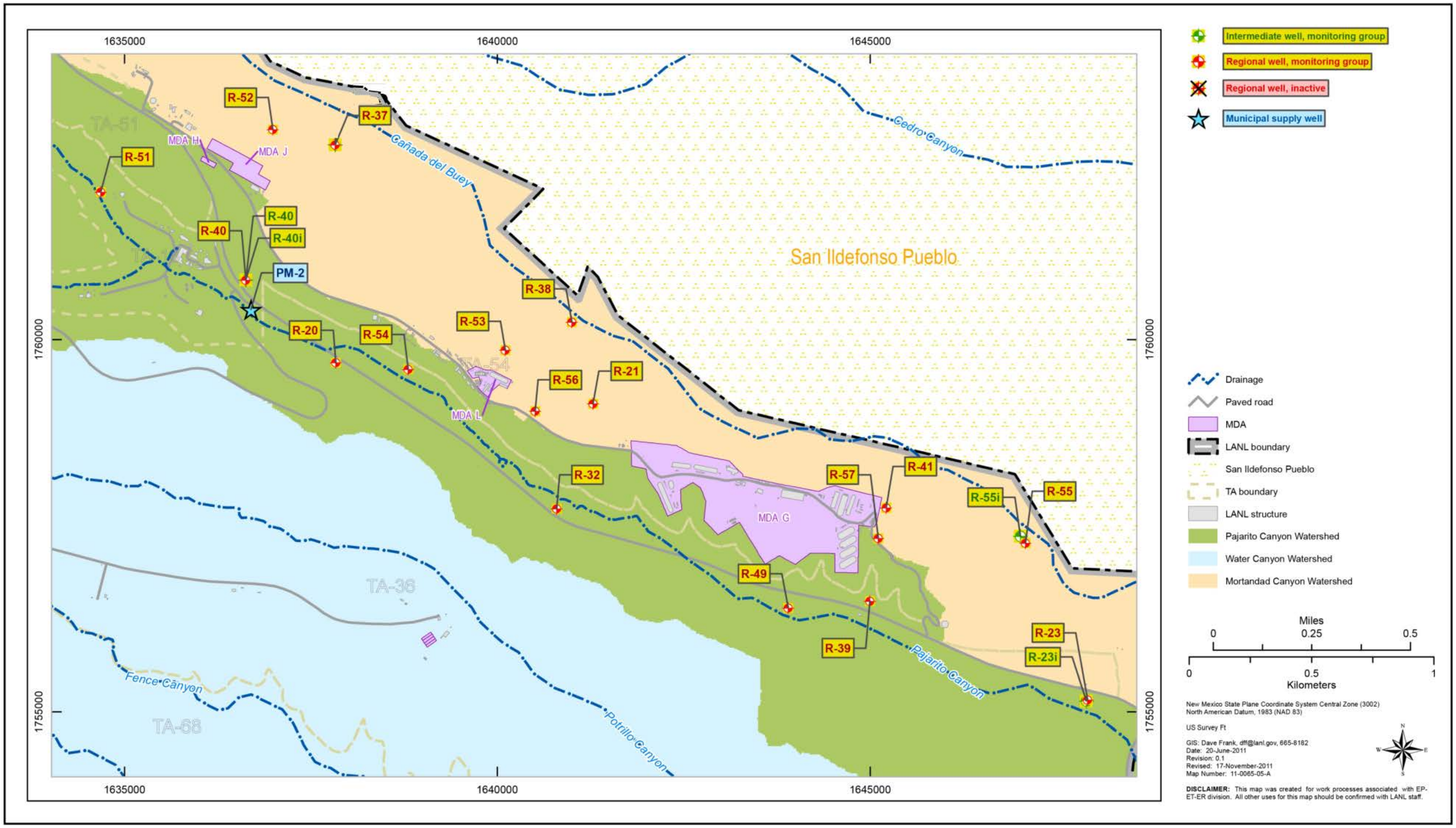

Figure 5-2 TA-54 Groundwater Monitoring Network

5.2 *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. No moisture monitoring was conducted during FY2017; however the data loggers on these monitoring tools should retain 2017 data for collection during FY2018. These field data have been and will continue to be 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 be 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.

6.0 Research and Development

Research and development activities are planned and implemented to address the secondary issues identified by the LFRG (DOE, 2009) (see Appendix A) and, more generally, to reduce the uncertainty associated with the PA/CA. Fiscal year 2017 activities include ongoing work on groundwater modeling, surface erosion modeling, and characterization of cliff retreat.

6.1 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 FY2017. Tasks included 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 of this modeling predict that C-14 is the only radionuclide that influences the groundwater dose.

The modeling for FY2017 is summarized in Pawar et al., (2018). Several modifications were made to address previous questions about increasing dose at 1000 yrs that were presented in a paper for the 2017 Waste Management Conference (Stauffer et al., 2016) and in the 2016 ASR (Birdsell et al., 2017b).

The first modification relates to the breakthrough curves (BTCs) generated by the FEHM modeling that are used in the Area G PA/CA models to simulate the movement of radionuclides released from the pits to a well located 100 m (330 ft) downgradient of the disposal facility. R&D presented in the 2016 ASR assumptions included a single BTC for the entire 1000 year period while the new simulations break down this time interval into two discrete BTCs. The first BTC follows particles released in 2003, the year that the C-14 bearing waste packages were emplaced in Pit 38 (Figure 6-1).

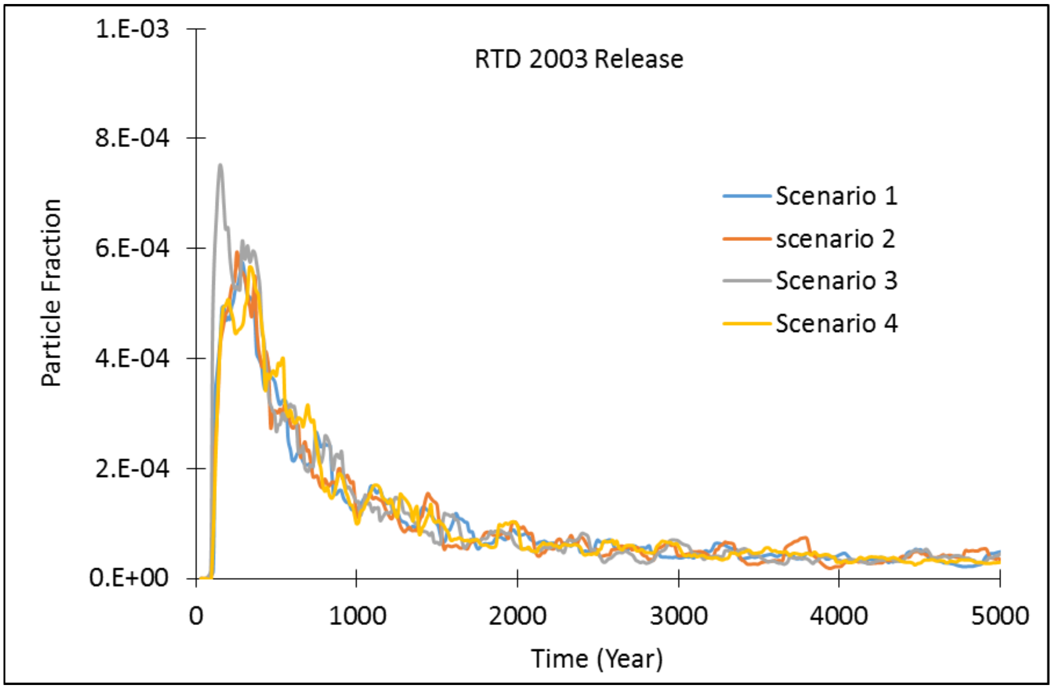

Figure 6-1 Particle breakthrough for four scenarios of water infiltration with release in 2003.

The second BTC follows particles beginning in the pit in 2135, 100 years after the projected site closure (Figure 6-2). Ideally, particles would follow the trajectory of the BTC at the moment of release; however the current logic in the PA/CA precludes the use of continuously varying BTCs. Thus all particles released from 2003 to 2135 follow a pulse of water introduced from both dust suppression and a 1000-year rain event in 2013. Both figures show results for four scenarios that varied the properties of the waste packages (porosity, initial saturation, etc.) in HYDRUS-2D simulations used to generate the boundary conditions for the FEHM model (Dai et al., 2018).

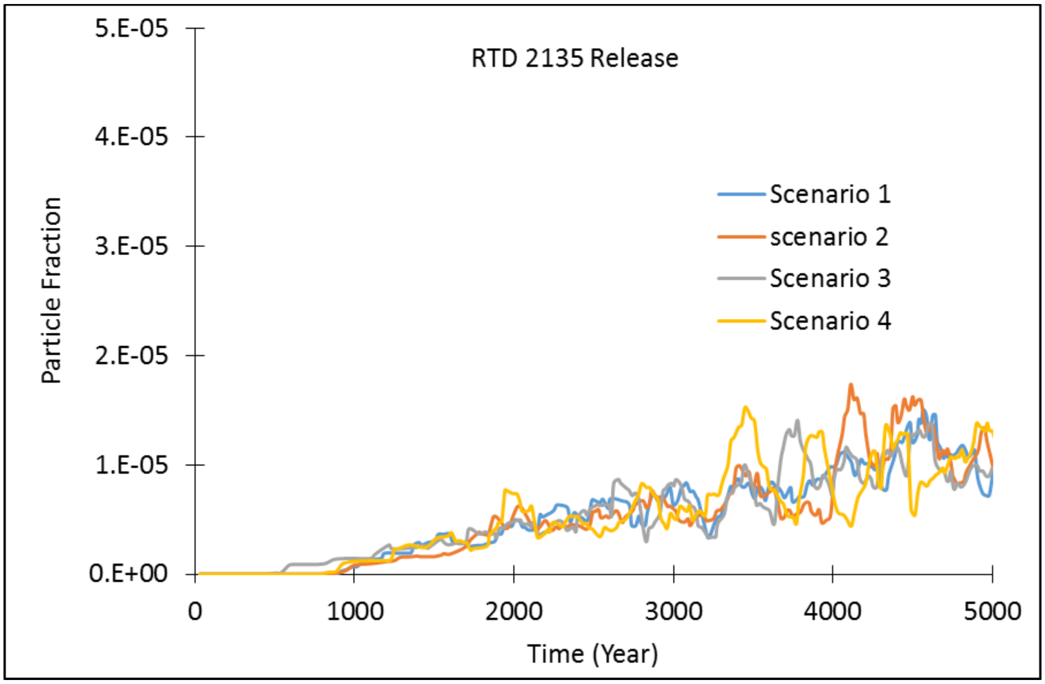

Figure 6-2 Particle breakthrough for four scenarios of water infiltration with release in 2035

A second modification was made to the simulations to use a more realistic graphite degradation parameter, thus reducing the mass of C-14 released per year from the graphite rods that represent a large fraction of the C-14 waste in the pit as described in SA 2012-007 (LANL, 2013b).

Results from the modified dose calculations are shown in Figure 6-3. The maximum dose calculated in this example remains below the performance objective of 4 mrem/yr. However, the total dose has increased significantly from near zero. Research is ongoing to determine if other conservative assumptions can be modified to reduce the final dose. Work so far has shown that an assumption of nearly 10% of the C-14 being immediately available for transport leads to a significant fraction of the dose shown in Figure 6-3. Once a final path forward is obtained, the new algorithm for this enhanced infiltration scenario will be included in the ASR results.

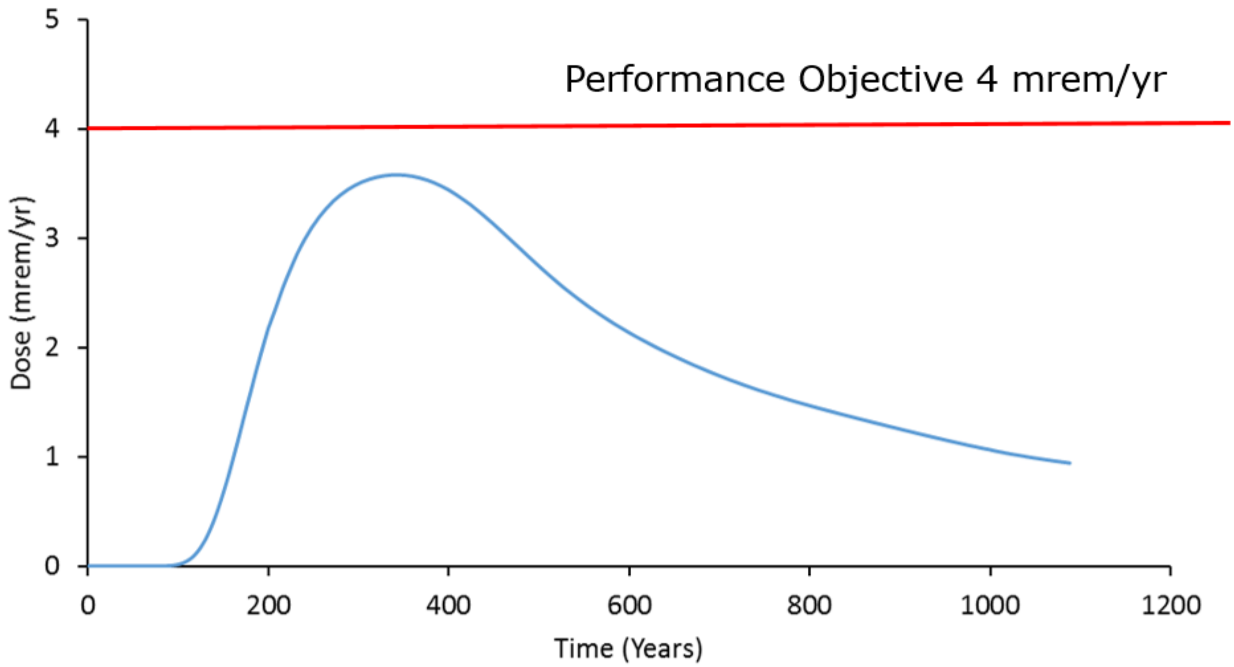

Figure 6-3 Groundwater dose projections over 1000 years for the CA with updated transient flow simulations for Pit 38

6.2 *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).

All previous erosion studies for MDA G (Wilson et al., 2005; French and Crowell, 2010; Crowell, 2013) evaluated the cover performance over 1,000 years, which spans the required PA compliance period (DOE, 2001). However, it is acknowledged that radioactive material may interact with the surrounding environment beyond the passive institutional control period of 1,000 years. Work in 2017 and 2018 extended the erosion analysis to 10,000 years to gain insight into potential for long-term erosion and to better understand the limitations of the analysis (Atchley et al., 2018). Calculations of erosion provide estimates of mass removed; however, at this time, the analysis has not been carried through to calculate exposure or dose impacts in the PA/CA site model.

To increase the efficiency of simulating long time scales, the SIBERIA workflow was streamlined to easily test parameter sensitivity and to identify specific methods to reduce model uncertainty. The modeling framework is now managed by the Model Analysis Toolkit (MATK) wrapper function. The use of MATK also enables efficient calibration and sensitivity analysis executing parallel computation of SIBERIA ensemble members. In addition to using MATK to streamline the erosion modeling framework, three-dimensional sediment transport was improved by applying the Dinfinity algorithm to simulate channel migration and refined channel networks. Furthermore, a visualization tool in conjunction with the sensitivity analysis was created to verify model performance specific to Area G.

The extended erosion analysis builds on a sensitivity analysis (Crowell 2013) and the original erosion modeling framework for MDA G (Wilson et al., 2005). The sensitivity analysis evaluates three erosion scenarios, (low-, moderate-, and high-erosion). The low-, moderate-, and high-erosion scenarios were parameterized to represent possible canopy and ground cover characteristics that affect rainfall runoff relationships. An extensive model parameterization and validation was performed to estimate probable erosion parameters for the three erosion scenarios simulated by SIBERIA and is described in detail by Wilson et al., (2005) and Atchley et al., (2018).

As expected, the 10,000-year erosion simulations show considerably more erosion than do the 1,000-year compliance period analyses (Figure 6-4). However, all three (low-, moderate-, and high-erosion scenarios) 10,000-year SIBERIA simulations show that much of the MDA G site will have remaining cover, with only a few small areas that have eroded down to the original bedrock for the high-erosion scenario (Figure 6-5). Of the small areas that are predicted to erode down to bedrock, little if any additional erosion takes place below the bedrock grade. Furthermore, the armor ringing the mesa top is simulated to be rather robust and maintains a rim elevation for the simulation period that prevents excessively deep channelization into the mesa.

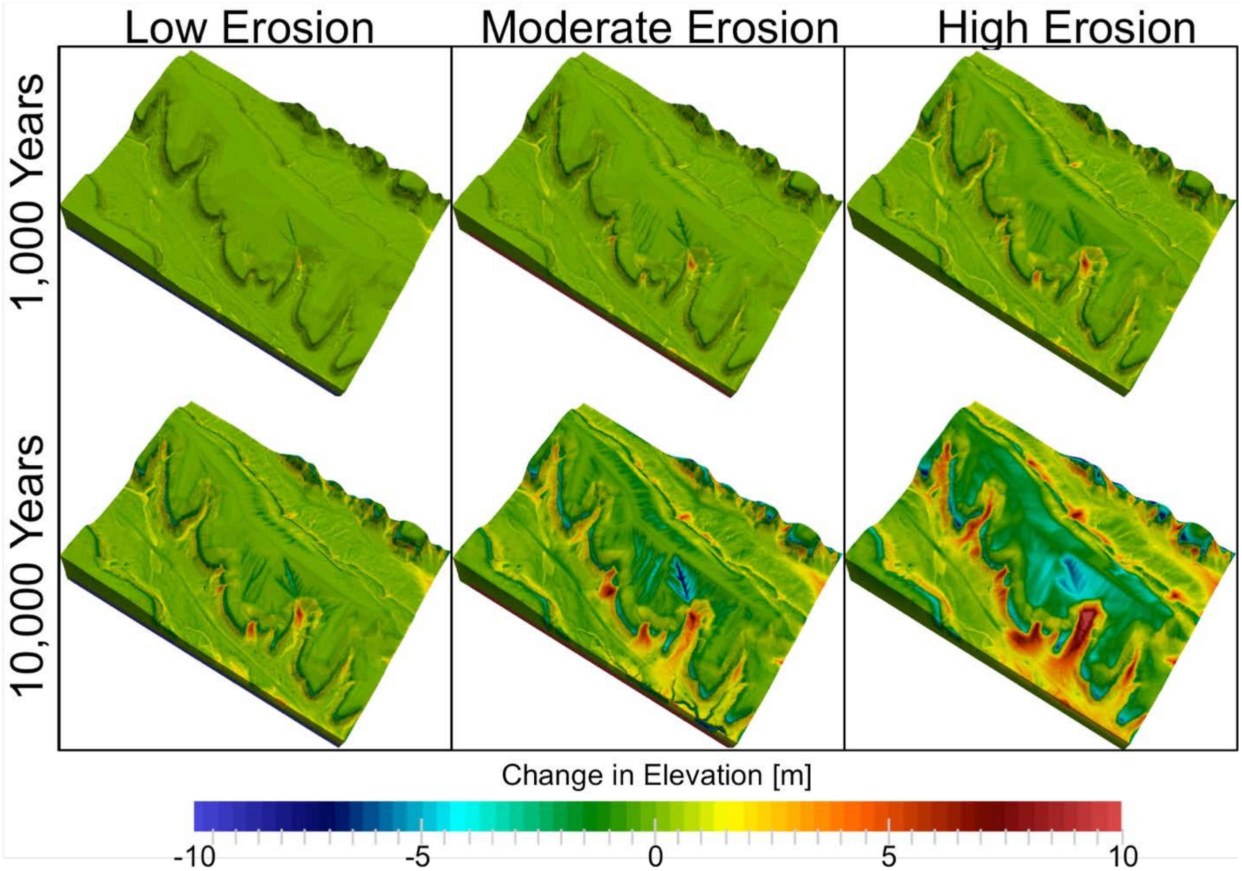

Figure 6-4 Change in elevation (m) maps for low-, moderate-, and high-erosion cases. The top row shows results for the 1,000-year compliance period. The bottom row shows results at 10,000 years, 9,000 years beyond the compliance period.

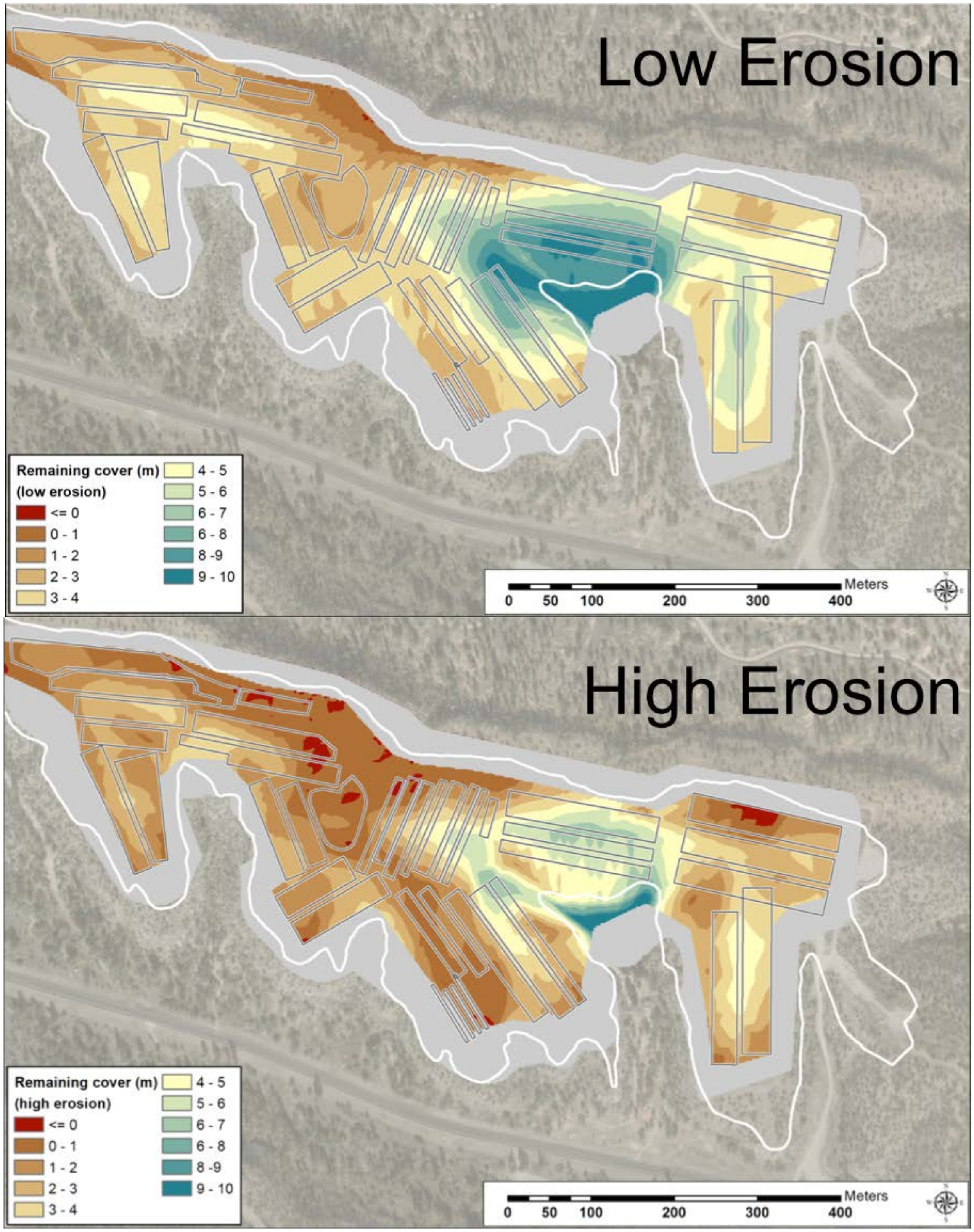

Figure 6-5 Thickness of engineered cover and fill material remaining above bedrock after 10,000 year simulation period, clipped by the riprap armor layer around the mesa top for the (top) low-erosion and (bottom) high-erosion scenarios.

The three erosion scenarios (low, moderate, and high) simulated to 10,000 years also exposed a large range of simulation uncertainty resulting in very different long-term landform evolution and sediment fluxes for each scenario. The high-erosion scenario produced rounded mesa tops and filled in canyons, whereas the moderate-erosion scenario produced extensive deep gully networks. This extended model analysis further serves to identify model performance and, specifically, points to how the MDA G erosion modeling framework can be improved. The model analysis identified three significant methods for the erosion predictions by: 1) reducing initial parameter uncertainty through ongoing surrogate site data collection, 2) exploring alternative reduced order models for SIBERIA calibration targets that account for 2D or 3D erosion physics of diffusion versus advection erosion processes, and 3) exploring alternative landscape evolution models (LEMs) that do not rely on the geomorphically effective runoff event assumption that assumes, over long time scales, erosion can be represented as a steady process, and runoff is considered as a constant, low-magnitude process that shapes the landscape. The 10,000 year analysis also brings to bear a current perspective of LEMs and the role the rainfall and runoff variability plays in landscape formation. The outlined methods for improving the erosion analyses are designed to reduce uncertainty in model and landform evolution. However, it should be noted that, in some cases, steps to reduce model uncertainty may produce estimates of erosion greater than the three cases simulated here. Never-the-less, the reduced erodibility of the bedrock and riprap armor will still likely prevent substantial excavation below bedrock grade.

6.3 *Cliff Retreat*

Work to characterize the mechanisms and rates of cliff retreat along the edges of Area G continued in FY2017. A brief overview of the work completed in FY2017 is provided herein; refer to LANL report (Miller et al., 2018), *Cliff Retreat Characterization at Technical Area 54, Los Alamos National Laboratory, Los Alamos, NM* for more details.

6.3.1 Surface Exposure Dating

Samples for surface exposure dating analyses were collected in October 2015 and processed by collaborators at Tulane University in mid- to late FY2016. Preliminary results were provided in FY2016; updated results were sent in FY2017 (following a system upgrade and subsequent re-running of samples). Surface exposure dating, also referred to as cosmogenic nuclide dating, measures isotope concentration to estimate the length of time that a rock has been exposed at or near the Earth’s surface. One of the most common components of rock and sediment is quartz (SiO_2). The silicon and oxygen atoms within quartz are continuously reacting with cosmic rays (heavy particles traveling at nearly the speed of light) that penetrate into the atmosphere, mainly originating from outside our solar system; this interaction produces measurable amounts of isotopes such as Be-10 and C-14 that accumulate in the outer layer or “skin” of a rock face. Due to the use of beryllium at LANL and subsequent potential for sample contamination, this study uses C-14 cosmogenic nuclide dating.

Surface exposure dating results ranged from 1,886 ± 42 yrs to 12,535 ± 408 yrs, indicating that block failure has occurred within the last 10,000 yrs (Figure 6-6). Surface exposure dates were used to estimate minimum erosion rates at each of the sample locations (Table 6-1). Combining mean block size and fracture spacing (collected in earlier cliff retreat studies at Area G) with exposure dates at each sample location can provide an estimate of how long it will take for a specific cliff location to retreat enough to expose a disposal pit or shaft. At each site, blocks and fractures at the edge of the cliff are digitized using ArcGIS. Measuring the distance to the closest disposal site and assuming that failure will continue to occur at the same rate as the cosmogenic dating age, it is possible to estimate how long it will take for cliff retreat to reach the pits or shafts. This calculation was done at three different locations and yielded estimates ranging from 108,000 to 328,000 yrs (Figure 6-7).

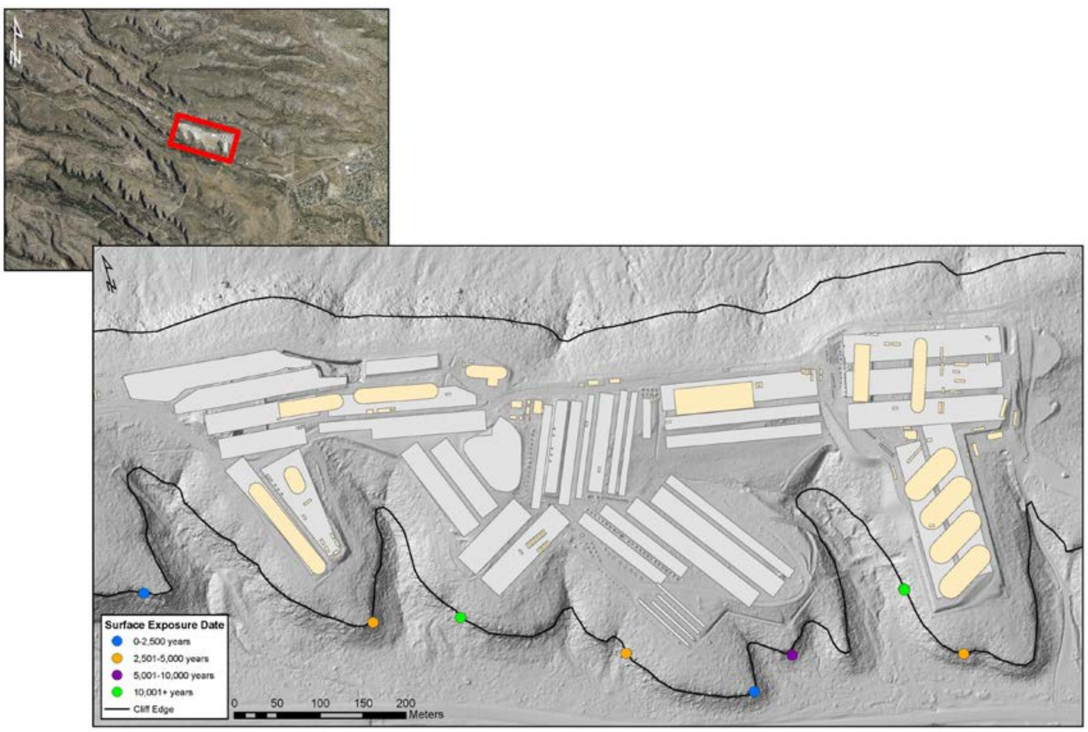

Figure 6-6 Surface exposure dating results.

Table 6-1 Surface exposure dating and calculated erosion rates.

Sample	Age (yrs)	Sample description	Erosion rate (cm/1000 years)
1	3305 ± 68	No shielding; soft and easy to cut	210.5
2	12535 ± 408	Shielded side canyon; eroded and toppled boulders	27.6
3	12542 ± 407		27.7
4	8802 ± 221	Minimal shielding; competent rock. Sample taken from a block that had toppled from the cliff	46.2
5	2391 ± 50	South-facing, minimal to no shielding; poorly welded, crumbling sample	282
8	3992 ± 81	Minimal shielding; soft and easy to cut	155.5
10	10633 ± 301	Some lichen growth and the appearance of more weathering with a higher occurrence of boulders and fresh surfaces	34.7
12	4267 ± 87	Shielded, near side drainage; difficult to cut and sample	145.5
14	1886 ± 42	Minimal shielding; soft and easy to cut	374.7

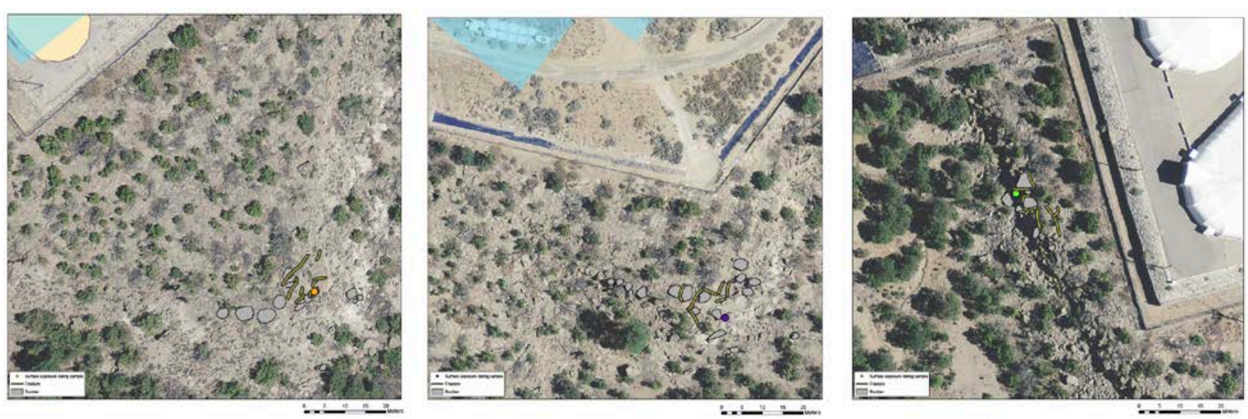

Figure 6-7 Blocks (gray) and fractures (yellow) have been digitized in ArcGIS using the aerial imagery. Assuming that failure continues to occur at the same rate as the surface exposure dating in that location, an estimate can be derived for how long it will take for retreat to lead to exposure. (Left, west) 108,000 years. (Middle, central) 328,000 years. (Right, east) 233,000 years

6.3.2 Factor of Safety Calculations

Factor of Safety (FoS) is the load-bearing capacity of a structure or component. FoS is a dimensionless value that can be calculated using the simplified equation

$$FoS = \tan(\phi)/\tan(\alpha)$$

Where

ϕ = angle of internal friction
α = slope of the cliff or block face

A FoS value less than one represents instability, even in the absence of external influences. Simply, the cliff is inherently unstable and will fail on its own, given sufficient time. A FoS value equal to or greater than one indicates a situation in which external forces are required to initiate cliff failure.

Using ArcGIS, the FoS was calculated for the TA-54 cliffs using the following ArcGIS workflow:

1. Calculate the slope of the cliffs surrounding MDA G using the 2014 aerial Lidar survey of the Laboratory and the “Slope” tool (Figure 6-8).
2. Convert the Laboratory geologic map into a raster and then assign appropriate angles of internal friction to raster classes representing units 1v-u and 2. The angle of internal friction of unit 1v-u and unit 2 are 31° (Hoek et al., 1998) and 43° (Quane and Russell, 2005), respectively
3. Use the Raster Calculator to perform the FoS calculation using Equation 1 (Figure 6-9).

Locations with higher slope result in a lower FoS value and therefore are less stable. While this result is to be expected, the FoS calculations serve to highlight the cliff locations with the lowest FoS values and therefore the least stable and highest likelihood of future failure.

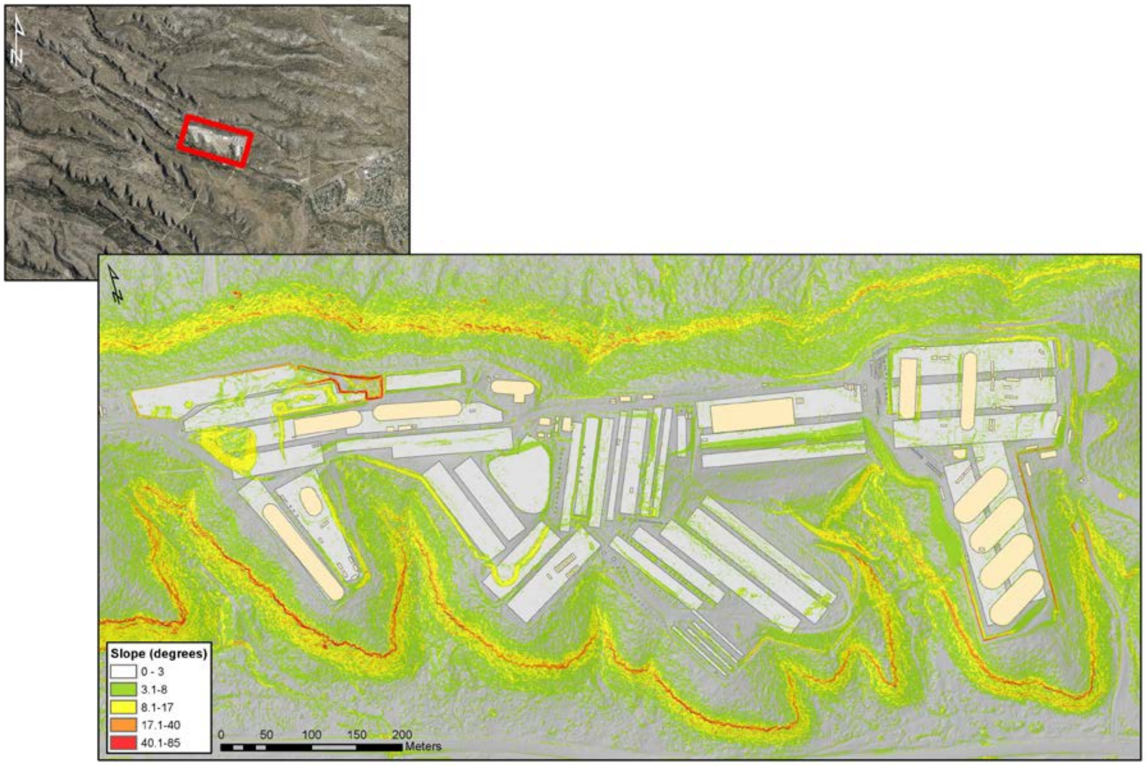

Figure 6-8 Result of ArcGIS slope calculation.

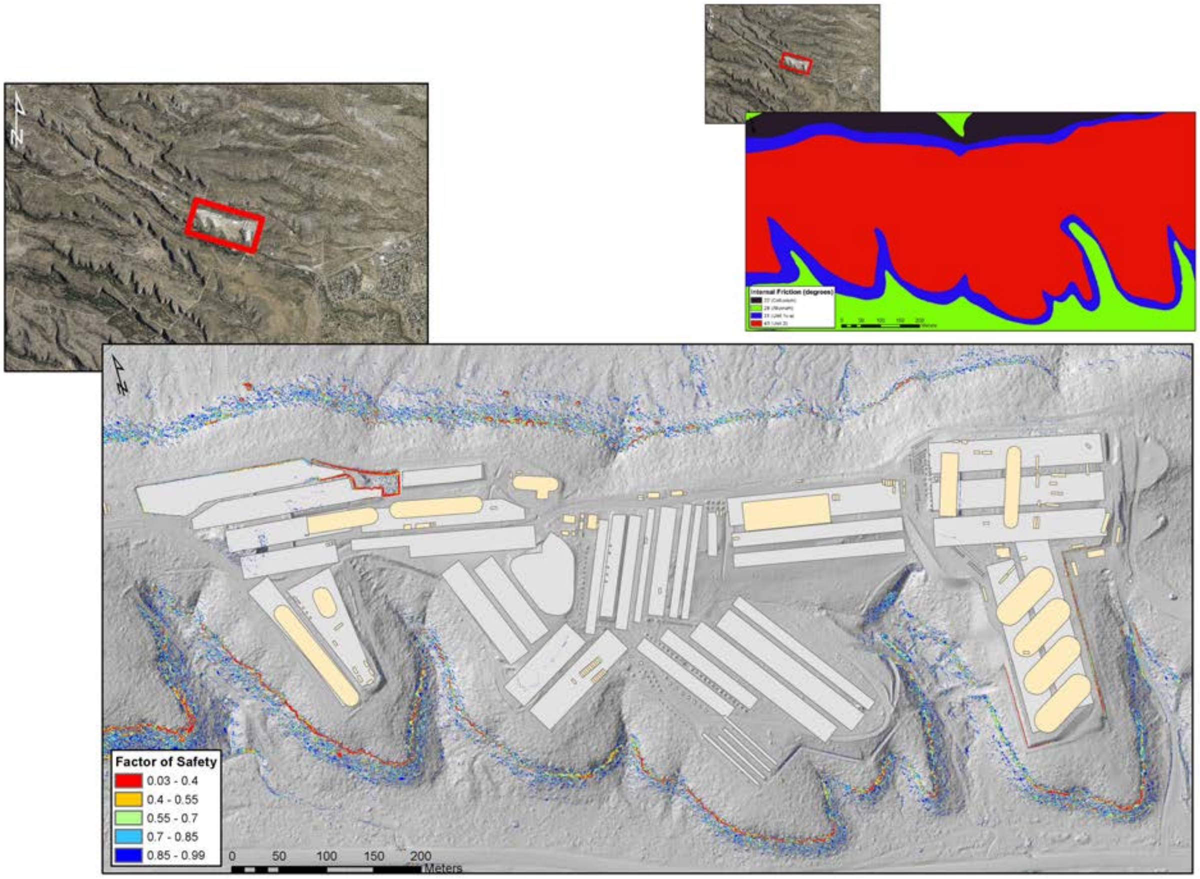

Figure 6-9 (Top) Angle of internal friction map, used during calculation of the FoS. (Bottom) Results of the FoS calculations. Red indicates very low FoS values; blue is higher FoS values (but still less than 1).

6.3.3 Change Detection using Historical Imagery

In 2014, LANL contracted with Atlantic Group to collect airborne Lidar over the entire LANL footprint. Lidar is a remote-sensing technique that uses a pulsed laser to measure distance to the surface. The result of this Lidar collection is a DEM with 0.3 m resolution. Additionally, through the use of photogrammetry software AgiSoft, legacy photos of TA-54 from the early 1960s were used to produce a historical DEM of MDA G. The resultant DEM is 0.4 m resolution.

To better assess decadal change at MDA G, the ArcGIS plug-in Geomorphic Change Detection (Wheaton et al., 2010) was used to create a DEM of Difference (DoD). The first step was to match the resolutions of both the historical and the 2014 DEM; this was done by using the ArcGIS tool *Resample* to produce a 2014 DEM with 0.4 m resolution. Then, the historical imagery was subtracted from the 2014 LANL Lidar DEM to produce a DoD (Figure 6-10). The substantial modification that has taken place on Mesita del Buey is obvious, where waste disposal and capping activities have generally increased the surface elevation. However, changes in the cliffs are less obvious. While some change is detected, particularly in the south-facing cliffs, a rigorous error analysis would need to be performed in order to take into account the inherent errors associated with the surface elevation collection methods (Wheaton et al., 2010).

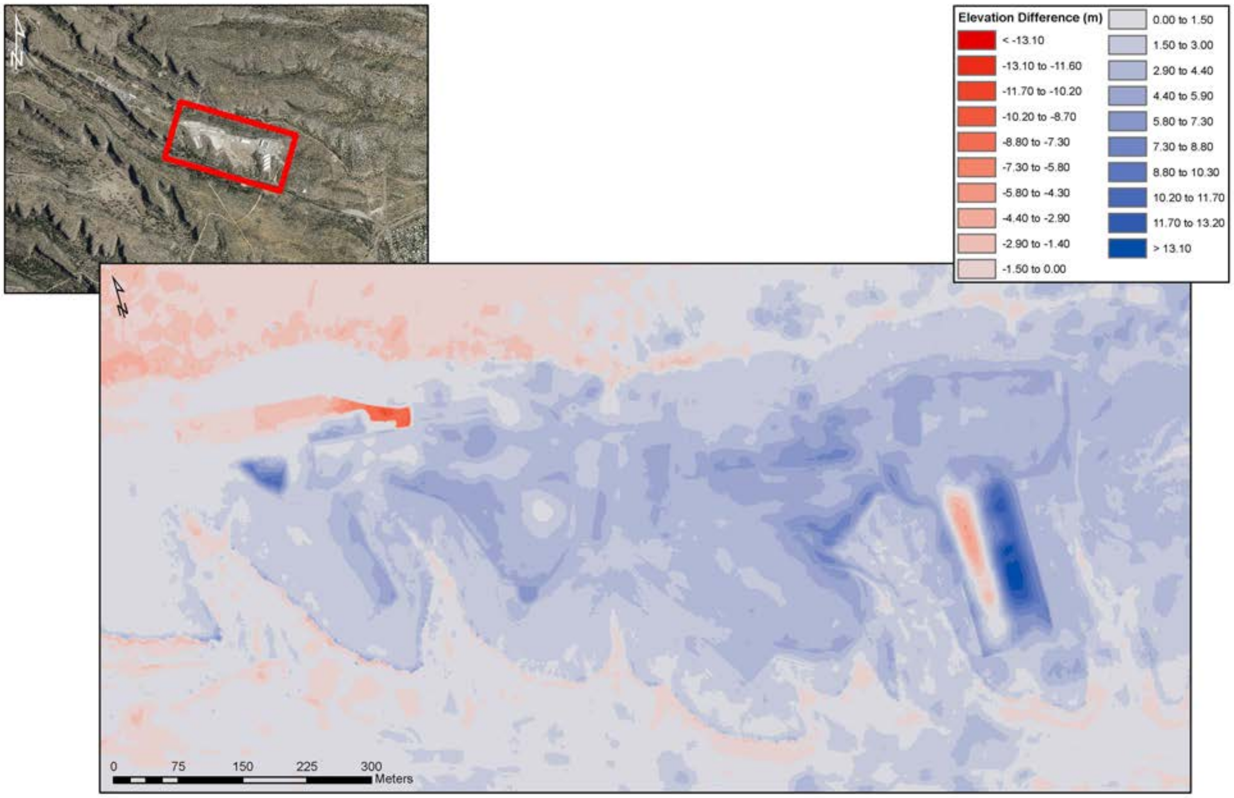

Figure 6-10 Change detection results for MDA G. The DEM produced from the historical imagery was subtracted from the new DEM produced from the 2014 LANL Lidar. Red represents erosion or surface excavation, and blue represents deposition or surface/infrastructure modification.

7.0 Planned or Contemplated Changes

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 a set of processes, systems, and procedures. 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 Laboratory has implemented a range of processes, systems, and procedures that define the operational constraints and conditions for waste disposal at Area G. These constraints and conditions inform the PA/CA and updates to the PA/CA through calculations performed in support of the Annual Summary Reports. The following were in place during FY2017:

- **Waste characterization and documentation**
  - *LANL Waste Acceptance Criteria* (LANL, 2018b) defines WAC for hazardous, mixed, and radioactive waste, including the LLW disposed of at Area G. Future work on the MDA G PA/CA should be closely tied to the WAC, with any changes in waste characterization or documentation cycling back into the DRR and dose calculations.
  - *LANL Waste Management* (LANL, 2015c) sets requirements for the Laboratory's management of various hazardous, mixed, and radioactive wastes.
  - *Waste Characterization* (LANL, 2015d) summarizes the waste characterization requirements found in various regulations.
  - Radioactive *Waste Characterization* (LANL, 2016d) 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, 2016e) 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, 2015e) 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, 2015c) 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, 2016e) 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, 2015f) 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, 2015g) 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, 2018a) defines WAC for hazardous, mixed, and radioactive waste, including the LLW disposed of at Area G.
  - *LANL Waste Management* (LANL, 2015c) establishes the controls necessary to prevent improper shipment of radioactive waste.
  - *LANL Packaging and Transportation Program Procedure* (LANL, 2016f) 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, 2015h) 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, 2015a) 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, 2018b) defines WAC for hazardous, mixed, and radioactive waste, including the LLW disposed of at Area G. Any future WAC exceptions should be coordinated with the PA/CA modeling team to ensure accurate calculation of doses at MDA 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.

Based on the constraints and conditions above, including planned and contemplated changes (Table 7-1), the PA/CA for MDA G was reanalyzed in FY2017 to generate new estimates of site performance. The results of the 2017 ASR for the Area G PA/CA indicate that the performance of the disposal facility is capable of satisfying all DOE Order 435.1 performance objectives.

Table 7-1 Planned or Contemplated Changes (TBD (to-be-determined) reflects schedule uncertainty related to the DOE-EM contract change).

Planned or Contemplated Change	Change Basis	PA/CA Impact	Schedule
Removal of Zone 4 from inventory projection	Change in disposal assumption	Greatly reduces PA/CA projected inventory	FY2018 onward - TBD
Site closure date advanced from 2044 to 2035	Change in disposal assumption	Increases dose for some short-lived radionuclides due to earlier intruder access.	FY2018 onward - TBD
No new waste will be disposed at MDA G after FY2017	Change in disposal assumption	Reduces projected inventory for MDA G.	FY2018 onward - TBD
Plan to update the RWMB	Need to include references to all SAs and ASRs	None	FY2018 onward - TBD

Plan to more fully implement software QA	Current QA is mainly on individual software, not the fully coupled system	Ensure defensible simulations	FY2018 onward - TBD
Plan to revise the PA/CA Maintenance Plan	Current plan is out of date	Improve the PA/CA by strengthening links to the RWMB, WAC, DAS, etc.	FY2018 onward - TBD
Plan to revise the PA/CA Monitoring Plan	Current plan is out of date	None	FY2018 onward - TBD
Pit 25 erosion and test covers	Draft SA 2016-002	No impact on PA/CA. Recommendation to add an interim cover on Pit 25.	FY2018 onward - TBD
Dome 224 D&D	Draft SA 2016-004	No impact on PA/CA	FY2018 onward - TBD
Neutron probe, HDP, and other moisture monitoring data	Schedule for regular data collection to be included in revision to the Monitoring Plan	None	FY2018 onward - TBD
Cliff retreat and erosion data	Plan to collect crack meter, LIDAR, and other landform evolution data to be included in revision to the Monitoring Plan	None	FY2018 onward - TBD
R&D on ground motion	Plan to analyze potential impacts from earthquakes	Unknown	FY2018 onward - TBD
Plan to revise inventory probability distributions	Current triangular distributions could be overestimating inventory	Unknown	FY2018 onward - TBD
R&D on infiltration of excess water in Pit 38; potential inclusion in PA/CA model	Observations of water spraying and run-off/ponding at Pit 38 initiated this R&D effort	Impacts the PA/CA by increasing the projected dose of 14C. Not included in current ASR doses	FY2018 onward - TBD
R&D on erosion to 10,000 yrs	Part of ongoing R&D work suggested by DOE/LFRG	No impact on PA/CA because of the current 1000 yr analysis limit	FY2018 onward - TBD
R&D on cliff retreat	Potential to tie cliff retreat to erosion modeling	No current projected impact on PA/CA	FY2018 onward - TBD

R&D on subsidence	Current PA/CA does not consider pit subsidence	Unknown	FY2018 onward - TBD
Plan to implement a disruptive event screening process	LFRG suggested a more structured screening process for disruptive events that could impact the PA/CA	Cliff retreat and 13" – 1000 yr rainfall event impacts calculated	FY2018 onward - TBD
Plan to examine sensitivity analysis for 3D system	Current analysis may need improvement.	Unknown	FY2018 onward - TBD
Plan to resolve spurious sensitivity results	Some small fraction of sensitivity results appear to be spurious	Unknown	FY2018 onward - TBD
Ongoing activities to include more detail in probabilistic results	LFRG comment includes the need to run simulations to peak dose or 10,000 yrs, break out individual dose contributions, etc.	This will make the PA/CA results easier for reviewers to interpret	FY2018 onward - TBD
Plan to add the airborne pathway to All-Pathways Canyon Scenario	LFRG comment	Unknown	FY2018 onward - TBD

In general, the contemplated or planned changes anticipated for Area G (Table 7-1) 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 in use through the year 2044, site closure could advance. In the current PA/CA calculations, the closure date has been advanced to 2035. Analysis of earlier closure indicates that higher intruder doses from exposure to shorter half-life radionuclides are calculated, particularly for the Area G shafts. 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. As plans become more firm after the transition from LANL to a new DOE-EM contractor, 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.

A discussion of the impacts of operational changes is 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.

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 FY2017; 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, 2017a). Phased closure of MDA G will start after disposal and limited waste retrieval operations have ended. Final closure will comply with both regulatory and schedule requirements under DOE Order 435.1 and under RCRA as part of the Consent Order with NMED.

The impending closure of MDA G has caused a shift in disposal practices. Whereas before FY2009 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, 2017a).

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 located in MDA G were 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 the year 2044 have been modified with this new recommendation to remove Zone 4 projected inventor and shift the closure date to 2035.

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. The Laboratory is not working to update the PA/CA cover design at this time because of uncertainty associated with closure assumptions. Cover redesign will become a high priority activity as closure plans and schedules that meet both PA/CA and NMED Consent Order objectives become more certain. Cover design work will likely be performed during the next PA/CA update.

Post-closure land use plans for MDA G will be developed in conjunction with the MDA G RCRA closure process with NMED. These plans will be influenced by the closure configuration selected for the facility. 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 and requirements of DOE Order 435.1 and RCRA. The Laboratory's UDQ process provides the mechanism for initiating this evaluation.

No operational closures were performed on any pits or shafts in Area G during FY2017.

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 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, as little progress has been made on these secondary issues. The results of the PA/CA are strongly dependent on assumptions regarding final waste inventories and site closure plans. The changes to the assumptions described in Section 2 and Table 7-1 have modified the projected doses from the PA/CA models, and these assumptions will need to be revised to be consistent with any changes made as the site moves closer to closure and associated assumptions become more certain.

8.0 *Status of DAS Conditions, Key and Secondary Issues*

The 2010 DAS issued to the NNSA Los Alamos Field Office includes a number of conditions that must be satisfied under the PA/CA maintenance program. Section 8.1 discusses the status of the Laboratory's compliance with these conditions.

8.1 *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 A, 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 8-1, and the progress made in terms of complying with these conditions is noted. No secondary issues were fully resolved and closed during FY2017 although progress was made on several of the issues. Some activities will be re-planned and reschedule in the FY2018 update to the maintenance program plan, as noted in Table 8-1, and in accordance with agreements made with EM-LA and the new DOE-EM contractor.

Table 8-1 LANL DAS Conditions and Resolution Status (Shading indicates issues that are not resolved)

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, analyzed and documented (see Section 6.3).
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 2017; Activity will be replanned and reschedule in FY2018-2019 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.	No progress made during FY2017; Activity will be replanned and reschedule in FY2018-2019 maintenance plan update.
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 FY2009 Annual Report (LANL, 2010c)
Secondary Issue 3.1.3.6 – Intruder Scenarios	The human intruder scenarios are overly conservative.	Issue resolved; see FY2009 Annual Report (LANL, 2010c)
Secondary Issue 3.1.4.4 – Operational Documents	Facility operations documents must be finalized.	Issue resolved; see FY2009 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. See Section 6.1.
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 FY2013 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.	Progress made during FY17, see Section 6.3. Activity will be continued in FY 2018-2019.
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.	Progress made during FY17, on cliff retreat and enhanced infiltration due to large 13" rainstorm (1000 year event); see Sections 6.3 and 6.1
Secondary Issue 3.1.6.3 – Infiltration Rate Distribution	The manner in which the infiltration rate distribution was developed is incorrect.	Issue resolved; see FY2009 Annual Report (LANL, 2010c)

Table 8-1 (Continued)
LANL DAS Conditions and Resolution Status

DAS Condition	Summary of Issue or Condition	Status of Resolution
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 FY2009 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 FY2017; Activity will be replanned and reschedule in FY2018-2019 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 FY2009 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 FY2017; Activity will be replanned and reschedule in FY2018-2019 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 FY2017; Activity will be replanned and reschedule in FY2018-2019 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.	In progress, we continue to implement the suggested changes.
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 (FY16 ASR); database for moisture monitoring data compiled during FY2015 and new data incorporated during FY2016 (see Section 4.2). A QA plan for modeling will be implemented in FY18-19.
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 FY2009 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 8-1 (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. Recommend review and potential update in FY2018-2019.
Condition – Area G Environmental Monitoring Plan	A revised monitoring program plan must be issued by March 17, 2011.	DAS condition resolved, see Environmental Monitoring Plan (LANL, 2011c). Recommend review and potential update in FY2018-2019.
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

9.0 NNSA-FEM Certification of the Continued Adequacy of the PA, CA, DAS and RWMB

I certify to the best of my knowledge that information in this ASR is true, accurate and complete and that any proposed or implemented changes associated with the PA or other technical basis documents provide a reasonable expectation that the performance objectives/measures identified in DOE O 435.1 will be met.

Peter Maggiore

Signature of on behalf of the Los Alamos DOE-NNSA Field Element Manager

10.0 References

Atchley, A.L., Birdsell K.H., Middleton, R., 2018. Updated Erosion Analysis for Material Disposal Area G, Technical Area 54, Los Alamos National Laboratory Report LA-UR-18-23419, Rev 1, May.

Birdsell, K.H., Stauffer, P.H., S.B. French, 2017a, Special Analysis: 2017-001 – Disposal of Drums Containing Enriched Uranium in Pit 38 at Technical Area 54, Area G. 44p., LA-UR-17-24345, May.

Birdsell, K.H., P.H. Stauffer, A. Atchley, E. Miller, S.P. Chu, S.B. French, 2017b, Annual Report for Los Alamos National Laboratory Technical Area 54, Area G Disposal Facility - Fiscal Year 2016, 82p., LA-UR-17-22215, March.

Chu, S., P.H. Stauffer, K.H. Birdsell, S.B. French, and J.M. Veilleux, 2017a, *Special Analysis: 2016-001 Analysis of the Potential Under-Reporting of Am-241 Inventory for Nitrate Salt Waste at Area G*, Los Alamos National Laboratory Report LA-UR-17-26674, September.

Chu, S., K.H. Birdsell, P.H. Stauffer and S.B. French, 2017b, *Special Analysis: 2016-003 Upgrade of Area G PA/CA Model to Updated Versions of GoldSim Software and to LANL Analysts*, Los Alamos National Laboratory Report LA-UR-17-20616, June.

Chu, S., K.H. Birdsell, P.H. Stauffer and S.B. French, 2018, *Evaluation of Low-Level Waste Disposal Receipt Data for Los Alamos National Laboratory Technical Area 54, Area G Disposal Facility – Fiscal Years 2015-2017,* Los Alamos National Laboratory Report LA-UR-18-23560 Rev. 1, May.

Crowell, K.J., 2010, *Updated Surface Erosion Modeling for Repository Waste Cover at Los Alamos National Laboratory Technical Area 54, Area G,* Los Alamos National Laboratory Report LA-UR-10-06442, September.

Crowell, K.J., 2013, Sensitivity of Surface Erosion Modeling For Los Alamos National Laboratory Technical Area 54, Area G, Los Alamos National Laboratory Report LA-UR-13-24013.

Dai, Z., K.H. Birdsell, P.H. Stauffer and B. Newman, 2018, Simulations of Moisture Movement through Pits 37 and 38 at Los Alamos National Laboratory Technical Area 54, Area G, Los Alamos National Laboratory Report LA UR-18-23686, Rev 1, May.

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

DOE, 2001b, Radioactive Waste Management Manual, U.S. Department of Energy DOE M 435.1-1 (change 1 to document issued July, 9, 1999), June 19.

DOE, 2001c, Implementation Guide for use with DOE M 435.1-1: Maintenance Guide for U.S. Department of Energy Low-Level Waste Disposal Facility Performance Assessments and Composite Analyses, U.S. Department of Energy draft report DOE G 435.1-4.

DOE, 2009, Review Team Report for the 2006 Performance Assessment and Composite Analysis for Material Disposal Area G in Technical Area 54 Los Alamos National Laboratory, Prepared by the Department of Energy Low-Level Waste Disposal Facility Federal Review Group Review Team, February 25.

DOE, 2010, Department of Energy memorandum from James J. McConnell and Randal S. Scott to Donald L. Winchell, Jr. regarding Revision No. 1 of the Disposal Authorization for the Los Alamos National Laboratory Low-Level Waste (LLW) Disposal, Area G, March 17.

DOE, 2017, DOE Standard – Disposal Authorization Statement and Tank Closure Documentation, DOE-STD-5002-2017, May 2017.

Fuehne, D.P., 2017, 2016 LANL Radionuclide Air Emissions Report, Los Alamos National Laboratory report LA-UR-17-24454.

French, S. and Crowell, K.J., 2010, Updated Surface Erosion Modeling for Repository Waste Cover at Los Alamos National Laboratory Technical Area 54, Area G, Los Alamos National Laboratory Report LA-UR-10-06442, September.

French, S.B. and R. Shuman, 2013, *Radioactive Waste Inventory for Los Alamos National Laboratory Technical Area 54, Area G, Revision 1*, Los Alamos National Laboratory Report LA-UR-13-24762, June.

French, S.G. and R. Shuman, 2014, *Annual Report for Los Alamos National Laboratory Technical Area 54, Area G Disposal Facility – Fiscal Year 2013,* Los Alamos National Laboratory Report LA-UR-14-22975, April.

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.

Hoek, E., Marinos, P., and Benissi, M., 1998, "Applicability of the Geological Strength Index (GSI) Classification for Very Weak and Sheared Rock Masses: The case of the Athens Schist Formation," *Bulletin of Engineering Geology and the Environment*, Vol. 57, pp. 151–160.

Jacobson, K.W., 2005, *Air Dispersion Analysis for Los Alamos National Laboratory Technical Area 54, Material Disposal Area G*, Los Alamos National Laboratory Report LA-UR-05-7232, September.

Los Alamos National Laboratory (LANL), 1998, *Hydrogeologic Workplan Los Alamos National Laboratory*, Los Alamos National Laboratory Report, May 22.

LANL, 2007, *Technical Area 54 Well Evaluation and Network Recommendations, Revision 1*, Los Alamos National Laboratory Report LA-UR-07-6436, October.

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.

LANL, 2009a, *Closure Plan for Los Alamos National Laboratory Technical Area 54, Area G,* Los Alamos National Laboratory Report LA-UR-09-02012, March.

LANL, 2009b, *Phase II Investigation/Remediation Work Plan for Material Disposal Area A, Solid Waste Management Unit 21-014, at Technical Area 21, Revision 1*, Los Alamos National Laboratory Report LA-UR-09-5806, September.

LANL, 2009c, Pajarito Canyon Investigation Report, Revision 1, Los Alamos National Laboratory Report LA-UR-09-4670, August.

LANL, 2010a, *Pit and Shaft Design, Construction, and Operational Closure,* Los Alamos National Laboratory Procedure EP-AP-2202, June.

LANL, 2010b, *WDP Unreviewed Disposal Question Evaluation (UDQE) and Special Analysis (SA) Process*, Los Alamos National Laboratory Procedure EP-AP-2204, June.

LANL, 2010c, *Annual Report for Los Alamos National Laboratory Technical Area 54, Area G Disposal Facility – Fiscal Year 2009,* Los Alamos National Laboratory Report LA-UR-10-02250, April.

LANL, 2010d, Letter from M.J. Graham, Associate Director for Environmental Programs, Los Alamos National Laboratory, to G.J. Rael, Contracting Office Representative, Environmental Projects Office, Los Alamos, *Implementation Evidence Package of operational procedures and documents that ensure the Los Alamos National Laboratory Low-Level Waste disposal facility at Technical Area 54, Area G is operated in a manner consistent with requirements in the Area G Disposal Authorization Statement (reference 2),* Los Alamos Reference EP2010-5020, June 8, 2010.

LANL, 2011a, *Area G Performance Assessment and Composite Analysis Maintenance Program Plan,* Los Alamos National Laboratory Report LA-UR-11-01522, March.

LANL, 2011b, *Work Plan for Vadose Zone Moisture Monitoring at Material Disposal Area T at Technical Area 21,* Los Alamos National Laboratory Report LA-UR-11-3831, August.

LANL, 2011c, *EWMO Environmental Monitoring Plan,* Los Alamos National Laboratory Report LA-UR-11-01523, March.

LANL, 2012a, Letter from M.J. Graham, Los Alamos National Security, LLC, and P. Maggiore, Department of Energy, to John Kieling, Hazardous Waste Bureau, New Mexico Environment Department, Santa Fe, New Mexico, *Request for Withdrawal of Phase II Investigation/Remediation Work Plan for Material Disposal Area A, Solid Waste Management Unit 21-014, at Technical Area 21, Revision 1*, April 12, 2012.

LANL, 2012b, *Corrective Measures Evaluation Report for Material Disposal Area C, Solid Waste Management Unit 50-009 at Technical Area 50*, Los Alamos National Laboratory Report LA-UR-12-24944, September.

LANL, 2013a, *Investigation/Remediation Report for Material Disposal Area B, Solid Waste Management Unit 21-015, Revision 2*, Los Alamos National Laboratory document LA-UR-13-24556, June.

LANL, 2013b, *Special Analysis 2012-007: Impacts of Water Introduced into Pits 37 and 38 at Technical Area 54, Area G*, Los Alamos National Laboratory Report LA-UR 13-22839, March.

LANL, 2014a, *Waste Acceptance Criteria*, *LANL Waste Acceptance Criteria*, Los Alamos National Laboratory Procedure P930-1, January

LANL, 2014b, *TA-54 Area G Inactive Pit and Shaft Quarterly Inspections*, EP-AREAG-FO-DOP-1077, April.

LANL, 2014c, *LANL Unreviewed Safety Question (USQ) Procedure*, Los Alamos National Laboratory Procedure SBP112-3-R1.2, December.

LANL, 2015a, *TA-54 Area G Waste Staging, Loading, and Off-Site Shipment,* EP-DOP-2215, October.

LANL, 2015b, *Documented Safety Analysis for the Nuclear Environmental Sites at Los Alamos National Laboratory*, NES-ABD-0101, R. 8, May.

LANL, 2015c, *LANL Waste Management*, Los Alamos National Laboratory Procedure P409, July.

LANL, 2015d, *Waste Characterization*, Los Alamos National Laboratory Administrative Procedure ADESH-AP-TOOL-111, December.

LANL, 2015e, *Waste Compliance and Tracking System (WCATS) Version 2 User's Manual*, Los Alamos National Laboratory Work Instruction MAN-5004, July.

LANL, 2015f, *Waste Certification Program Waste Verification*, Los Alamos National Laboratory Quality Procedure WM-PROG-QP-236, October.

LANL, 2015g, *Waste Assessments*, Los Alamos National Laboratory Quality Procedure WM-PROG-QP-250, October.

LANL, 2015h, *TA-54 Area G Low Level Waste Disposal and Pit/Shaft Deactivation*, EP-DOP-2216, July.

LANL, 2016a, *Interim Facility-Wide Groundwater Monitoring Plan for the 2017 Monitoring Year*, October 2016-September 2017, Los Alamos National Laboratory Report LA-UR-16-23408, May.

LANL, 2016b, *Groundwater Background Investigation Report, Revision 5*, Los Alamos National Laboratory Report, LA-UR-16-27907, October.

LANL, 2016c, *Los Alamos National Laboratory 2015 Annual Site Environmental Report, Rev 1*, Los Alamos National Laboratory Report LA-UR-16-26788, October.

LANL, 2016d, *Radioactive Waste Characterization*, Los Alamos National Laboratory Work Instruction ADESH-TOOL-314, February.

LANL, 2016e, *Radioactive Waste Management,* Los Alamos National Laboratory Administrative Procedure ADESH-AP-TOOL300, February.

LANL, 2016f, *LANL Packaging and Transportation Program Procedure,* Los Alamos National Laboratory Procedure P151-1, February.

LANL, 2017a, *Enduring Mission Waste Management Plan at Los Alamos National Laboratory*, Los Alamos National Laboratory Controlled Publication LA-CP-17-20037, February

LANL, 2017b, *Los Alamos National Laboratory 2016 Annual Site Environmental Report, Rev 1*, Los Alamos National Laboratory Report LA-UR-17-27987, Rev. 1, September

LANL, 2017c, *Annual Periodic Monitoring Report for the Material Disposal Area AB Monitoring Group, Monitoring Year 2016*, Los Alamos National Laboratory Report LA-UR-17-27253, August.

LANL, 2017d, *Annual Periodic Monitoring Report for the Material Disposal Area C Monitoring Group*, Los Alamos National Laboratory Report LA-UR-17-23551, May.

LANL, 2017e, *Annual Periodic Monitoring Report for the Technical Area 54 Monitoring Group*, Los Alamos National Laboratory Report LA-UR-17-23550, May.

LANL, 2017f, *Annual Periodic Monitoring Report for the General Surveillance Monitoring Group*, Los Alamos National Laboratory Report LA-UR-17-30461, November.

LANL, 2018a, *Annual Periodic Monitoring Report for the Technical Area 21 Monitoring Group*, Los Alamos National Laboratory Report LA-UR-18-20869, February.

LANL, 2018b, LANL Waste Acceptance Criteria, Los Alamos National Laboratory Procedure P409-1, March

Levitt, D.G., 2008, *Modeling of an Evapotranspiration Cover for the Groundwater Pathway at Los Alamos National Laboratory Technical Area 54, Area G*, Los Alamos National Laboratory Report LA-UR-08-5468, August.

Levitt, D.G., 2011, *Modeling the Movement of Transient Moisture Through Disposal Units at Los Alamos National Laboratory Technical Area 54, Area G*, Los Alamos National Laboratory Report LA-UR-11-05424, September.

Levitt, D.G., K. H. Birdsell, T.L. Jennings, and S.B. French, 2015, *Moisture Monitoring at Area G, Technical Area 54, Los Alamos National Laboratory*, Los Alamos National Laboratory Report LA-UR-15-24881, June.

Levitt, D.G., K. H. Birdsell, T.L. Jennings, and S.B. French, 2017, *Moisture Monitoring at Area G, Technical Area 54, Los Alamos National Laboratory, 2016 Status Report*, Los Alamos National Laboratory Report LA-UR-17-20267, January.

Miller, E., K. Birdsell, P. Stauffer, E. Schultz-Fellenz, R. Kelley, B. Goehring, and S. French, 2018. *Cliff Retreat Characterization at Technical Area 54, Los Alamos National Laboratory, Los Alamos, NM*, Los Alamos National Laboratory Report LA-UR-18-23663 Rev 1, May.

Nyhan, J.W., W. Abeele, T. Hakonson, E.A. Lopez, (1986). Technology Development for the Design of Waste Repositories at Arid Sites: Field Studies of Biointrusion and Capillary Barriers, LA-10574-MS, UC-708, Los Alamos National Laboratory.

Nyhan, J.W., (1989). Development of Technology for the Long-Term Stabilization and Closure of Shallow Land Burial Sites in Semiarid Environments, LA-11283-MS, UC-721, Los Alamos National Laboratory.

Pawar, R., S. Chu, A.L. Atchley, K. Birdsell, and P.H. Stauffer, 2018, Groundwater Modeling and Predictions of C-14 Transport from Pit 38 at TA-54, Area G, Los Alamos National Laboratory, Los Alamos National Laboratory Report LA-UR-18-23491 Rev 1, May.

Quane, S.L., and Russell, J.K., 2005, "Ranking Welding Intensity in Pyroclastic Deposits," *Bulletin of Volcanology*, Vol. 67, pp. 129–143.

Roback, R., H. Boukhalfa, K. Spencer, A. Abdel-Fattah, S. Ware, P. Archer, N. Xu, M. Schappert, and E. Gonzales, 2011, *Characterization of Sludge and Water Samples Obtained from the General's Tanks during April 2010 Sampling*, Los Alamos National Laboratory, Los Alamos National Laboratory Report LA-UR-11-06876, December.

Šimùnek, J., M. Sejna, and M. Th. van Genuchten, 1999, *The Hydrus-2D Software Package for Simulating Two-Dimensional Movement of Water, Heat, and Multiple Solutes in Variably Saturated Media. Version 2.0*, IGWMC-TPS53, International Ground Water Modeling Center, Colorado School of Mines, Golden, Colorado.

Stauffer, P.H., K.H. Birdsell, Z. Dai, D. Levitt, A. Atchley, R.J. Pawar, S.P. Chu, and S.B. French, 2016, *Simulated Impacts of Water Introduced into Pits 37 and 38 at Technical Area 54, Area G, Los Alamos National Laboratory*, Los Alamos National Laboratory, Los Alamos National Laboratory Report LA-UR-16-29480; Waste Management 2017 conference proceedings.

Wheaton, J.M., Brasington, J., Darby, S.E., and Sear, D.A., 2010, "Accounting for Uncertainty in DEMs from Repeat Topographic Surveys: Improved Sediment Budgets," *Earth Surface Processes and Landforms,* Vol. 35, No. 2, pp. 136-156.

Wilson, C.J., K.J. Crowell, and L.J. Lane, 2005, *Surface Erosion Modeling for the Repository Waste Cover at Los Alamos National Laboratory Technical Area 54, Material Disposal Area G*, Los Alamos National Laboratory Report LA-UR-05-7771, September

Appendix A

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™ 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

Department of Energy (DOE), 2006, *Low-Level Waste Disposal Facility Review Group Manual, Revision 2*, Department of Energy Low-Level Waste Disposal Federal Review Group, October.

DOE, 2009, Review Team Report for the *2006 Performance Assessment and Composite Analysis for Material Disposal Area G in Technical Area 54 Los Alamos National Laboratory*, Prepared by the Department of Energy Low-Level Waste Disposal Facility Federal Review Group Review Team, February 25.

Shuman, R., 2006. *GoldSim Model Documentation and Data Selection for Los Alamos National Laboratory Technical Area 54, Material Disposal Area G Performance Assessment and Composite Analysis*, Los Alamos National Laboratory report LA-UR-06-4391, Los Alamos, New Mexico, December.