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Addendum 1

Composite Analysis for the Area 5 Radioactive Waste Management Site at the Nevada Test Site, Nye County, Nevada

November 2001

Prepared by

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CONTENTS

ACRONYMS and ABBREVIATIONS

ALARA	As Low As Reasonably Achievable
ASTD	Accelerated Site Technology Deployment
BN	Bechtel Nevada
CA	Composite Analysis
CADD	Corrective Action Decision Document
CAI	Corrective Action Investigation
CAS	Corrective Action Site
CAU	Corrective Action Unit
Ci	Curie
Ci/g	Curies per gram
Ci/m^3	Curies per cubic meter
DAS	Disposal Authorization Statement
DoD	U.S. Department of Defense
DOE/HQ	U.S. Department of Energy/Headquarters
EPA	U.S. Environmental Protection Agency
ER	Environmental Restoration
FFACO	Federal Facilities Agreement and Consent Order
ft	foot
FY	fiscal year
GCD	Greater Confinement Disposal
GMX	Gadgets, Mechanics, and Explosives
km	kilometer
LFRG	Low-Level Waste Disposal Facility Federal Review Group
LLW	Low-Level Waste
µCi	microCurie
m	meter
mi	mile
ml	milliliter
mrem	millirem (milliroentgen equivalent man; unit of dose)
çCi	nanoCurie
NNSA/NV	National Nuclear Security Administration Nevada Operations Office
NTS	Nevada Test Site
PA	Performance Assessment
pCi	picoCurie
RIDP	Radionuclide Inventory and Distribution Project
RWMS	Radioactive Waste Management Site
SME	Subject Matter Expert
TEDE	Total Effective Dose Equivalent
TRU	Transuranic
UGTA	Underground Test Area
WM	Waste Management

EXECUTIVE SUMMARY

A disposal authorization statement (DAS) was issued by the U.S. Department of Energy/ Headquarters (DOE/HQ) on December 5, 2000, authorizing the DOE's National Nuclear Security Administration Nevada Operations Office to continue the operation of the Area 5 Radioactive Waste Management Site (RWMS) at the Nevada Test Site for the disposal of low-level waste and mixed low-level waste. Prior to the issuance of the DAS, the Low-Level Waste Disposal Facility Federal Review Group (LFRG) had conducted reviews of the performance assessment (PA) and the composite analysis (CA) for the Area 5 RWMS, in accordance with the requirements of the DOE Radioactive Waste Management Order DOE O 435.1.

A brief history of the reviews is as follows. (The reviews were conducted by independent review teams chartered by the LFRG; the review findings and recommendations were issued in review team reports to the LFRG.) The LFRG accepted the initial PA, with conditions, on August 30, 1996. Revision 2.1 to the PA was issued in January 1998, implementing the conditions of acceptance of the 1996 PA. The LFRG reviewed Revision 2.1 as part of the Area 5 RWMS CA review during 2000, and found it acceptable. The CA and the Supplemental Information provided in response to issues identified during the initial review of the CA were accepted by the LFRG. The Supplemental Information (including the responses to four key issues) is included in the Review Team Report to the LFRG, which recommends that it be incorporated into the CA and issued to all known holders of the CA.

The Area 5 RWMS DAS requires that the Supplemental Information generated during the DOE/HQ review of the CA be incorporated into the CA within one year of the date of issuance of the DAS. This report, the first addendum to the Area 5 CA, is prepared to fulfill that requirement.

The Supplemental Information includes the following:

- Issues Identified in the Review Team Report
- Crosswalk Presentation
- Maintaining Doses As Low As Reasonably Achievable

A summary of this information is included in this report, with the complete text presented in the appendices.

1.0 INTRODUCTION

A disposal authorization statement (DAS) was issued by the U.S. Department of Energy/ Headquarters (DOE/HQ) on December 5, 2000 (DOE, 2000a), authorizing the DOE's National Nuclear Security Administration Nevada Operations (NNSA/NV) to continue the operation of the Area 5 Radioactive Waste Management Site (RWMS) at the Nevada Test Site (NTS) for the disposal of low-level waste (LLW) and mixed low-level waste. Prior to the issuance of the DAS, the Low-Level Waste Disposal Facility Federal Review Group (LFRG) had conducted reviews of the performance assessment (PA) and the composite analysis (CA) for the Area 5 RWMS, in accordance with the requirements of the DOE Radioactive Waste Management Order DOE O 435.1.

A brief history of the reviews is as follows. (The reviews were conducted by independent review teams chartered by the LFRG; the review findings and recommendations were issued in review team reports to the LFRG.) The LFRG accepted the PA, with conditions, on August 30, 1996. Revision 2.1 to the PA was issued in January 1998, implementing the conditions of acceptance of the 1996 PA. The LFRG reviewed this revision as part of the Area 5 CA review during 2000 and found it acceptable. The CA and the Supplemental Information provided in response to issues identified during the initial review of the CA were accepted by the LFRG. The Supplemental Information (including the responses to four key issues) is included in the Review Team Report to the LFRG, which recommends that it is incorporated into the CA and issued to all known holders of the CA (DOE, 2000b).

The DAS identifies the following three documents under which the disposal program at the Area 5 RWMS will be conducted:

- *Performance Assessment for the Area 5 Radioactive Waste Management Site at the Nevada Test Site, Nye County Nevada*. Revision 2.1. January 1998 (Shott, *et al*., 1998).
- *Composite Analysis for the Area 5 Radioactive Management Site at the Nevada Test Site, Nye County, Nevada* (Bechtel Nevada [BN], 2000a).
- Memorandum from E. Frank Di Sanza to Virgil Sauls. "DOE/NV Revised Responses and Supplemental Information – Draft Nevada Test Site Area 5 RWMS Low-Level Waste Radiological CA," dated August 24, 2000.

The following CA condition is stated in the DAS:

> *The CA for the RWMS shall either be revised or an addendum issued within one year of the date of issuance of this DAS to incorporate the Supplemental Information. The revised CA or addendum shall be submitted to the LFRG. Nevada Operations Office shall address all secondary issues and issues identified in Appendix B of the Review Team report through the maintenance program.*

This report is the first addendum to the Area 5 CA and incorporates this Supplemental Information. The Supplemental Information includes the following:

- Issues Identified in the Review Team Report
- Crosswalk Presentation
- Maintaining Doses As Low As Reasonably Achievable (ALARA)

This information is summarized in Section 2.0. Appendices A through C contain the full text of the information as it appears in the Review Team Report.

2.0 SUPPLEMENTARY INFORMATION

2.1 Issues Identified in the Review Team Report

The Review Team Report contains four key issues and responses to these issues by the NNSA/NV. These issues, which are included in Appendix A together with NNSA/NV's responses, are the following:

> **Issue 1:** The conclusions of the Composite Analysis do not provide reasonable assurance that the dose objectives will be met. Reasonable assurance that the objectives will be met in the short term can be provided, and there are plans for activities to ensure that the dose objective will be met in the long term. The Composite Analysis conclusions should have addressed this.

> **Issue 2:** The Composite Analysis acknowledges the potential large doses from the Underground Testing Area, but presents no information on the source and does not attempt to quantify the dose. However, based on discussions during the site visit, it is

evident that data (e.g., CAMBRIC pumping test) are available that would provide support to the analysis and conclusions. These data should have been included.

Issue 3: There are significant differences in methodology and assumptions between the approved Performance Assessment and the Composite Analysis, yet no justification for the differences are presented. The rationale for the differences should have been presented.

Issue 4: There are many instances where assumptions are stated with no presentation of the basis for the assumptions. Justification (i.e., rationale) for all assumptions should have been provided.

The response to Issue 1 addresses how the CA provides the assurance that the dose objectives will be met in the short term as well as the long term (1,000-year period of compliance), considering all the sources evaluated in the CA. The sources considered and evaluated in the CA include the Area 5 RWMS, Contaminated Soil Sites, Industrial Sites, and the Underground Test Areas (UGTA). The CA estimated the total effective dose equivalent (TEDE) at each source (except the UGTA source) and the TEDE received by a hypothetical resident anywhere within the Frenchman Flat over the 1,000-year compliance period from the interacting sources without the UGTA source. The UGTA source will be evaluated and incorporated into the CA in 2005, following the completion of the UGTA Frenchman Flat Corrective Action Unit (CAU) activities.

The response to Issue 2 includes additional information on the UGTA remediation program, the CAMBRIC pumping experiment, and the results of the groundwater monitoring at the Area 5 RWMS. In summary, the response states that the characterization of the UGTA source term in groundwater beneath Frenchman Flat is continuing. A total of ten underground tests were conducted in Frenchman Flat, a small number of tests compared to other CAUs on the NTS. Present expectations are that there will be a limited potential for transport of radionuclides away from the underground tests, due largely to the flat groundwater flow gradient and low velocities. However, until further work is completed by the UGTA on the Frenchman Flat CAU, the possibility of future interactions between the underground contamination and other sources of contamination in the basin cannot be excluded. In the interim, access to underground contamination will be precluded through maintenance of institutional control.

In the response to Issue 3, bench marking comparisons of results from the PA and CA models are provided with the conclusion that, given the uncertainty in the analyses, both PA and CA models give generally consistent results. The response includes the following comparisons:

- Comparison of PA and CA Nonvolatile and Volatile Radionuclide Release and Transport Models
- Comparison of Important PA and CA Parameter Values
- Bench marking of the Area 5 CA Nonvolatile and Volatile Radionuclide Release Model Against the Area 5 PA Models; and
- Comparison of the PA and CA Radiological Assessment Models.

The response to Issue 4 includes a list of 22 assumptions extracted from the CA report and their justifications.

2.2 Crosswalk Presentation

As part of the review of the CA, a special presentation was made to the Review Team to address primarily the consistency of models and model parameter values used in the PAs and CAs for the Areas 3 and 5 RWMSs at the NTS, and to answer specific questions raised by the Review Team. The Area 5 RWMS PA was the first NTS PA document reviewed by the LFRG. Next, the combined PA/CA document for Area 3 RWMS was developed and reviewed. The last document to be developed was the CA for the Area 5 RWMS. There had been a continuous improvement in models and model parameter values since the PA for Area 5 was developed. Therefore, the PA/CA documents reflect these improvements or changes in models and model parameter values.

The PowerPoint® presentation slides, which are included as Appendix B, address the following categories of consistency issues and questions:

- Changes from the Area 5 PA to the Area 3 PA/CA in the treatment of nonvolatile and volatile releases; the radiological assessments; and the assessment scenarios.
- Changes from the Area 3 PA/CA to the Area 5 CA in the treatment of nonvolatile and volatile releases; the radiological assessments; and the assessment scenarios.
- Comparison of release, flux, and plant-soil concentration ratios for select radionuclides from the three documents: the Area 5 PA, the Area 3 PA/CA, and the Area 5 CA.
- Miscellaneous questions:

>Volatile emissions from the Soil Sites evaluated in the Area 5 CA,

>Inclusion of the Plutonium Valley source in the Area 5 CA,

>Monitoring and modeling results for tritium,

>I-129 inventory in the greater confinement disposal (GCD),

>Tc-99 at PIN STRIPE soil site, and

>Radiological inventory of Industrial Sites.

As noted in the DAS, the model and parameter consistency will be addressed as part of the PA/CA maintenance program (BN, 2000b).

2.3 Maintaining Doses As Low As Reasonably Achievable

NNSA/NV's commitment to the principle of maintaining doses ALARA at the NTS is discussed in Appendix C. DOE radiation protection policy (DOE Order 5400.5 for the general public, and Title 10 Code of Federal Regulations 835 for workers) and low-level waste disposal performance objectives require that radiation exposures be maintained ALARA. The *Nevada Test Site Radiation Protection Program* describes the ALARA program and a BN Company Directive (CD-0441.003) establishes the methods and assigns responsibilities for ensuring that radiation exposure is limited under ALARA. Appendix C cites the environmental restoration programs and the vadose zone monitoring at the disposal facilities as examples of the ALARA principle in action at the NTS.

Appendix C also mentions the ALARA analysis performed in the Area 5 PA where, through a cost-benefit analysis, collective doses and associated monetary impacts are evaluated. In summary, it can be stated that the only significant radiation exposure (both individual and population) in the Frenchman Flat basin can occur as a result of loss of institutional control, and that no cost-effective alternatives in the Area 5 operation would result in a significantly lower individual or population dose.

3.0 CONCLUSION

The DAS for the CA requires that within one year of the issuance of the DAS, the Supplemental Information shall be incorporated to the CA for the Area 5 RWMS. This addendum report fulfills that condition.

4.0 REFERENCES

DOE, 2000a. Memorandum from EM-22 (Jane Talarico) to Kathleen A. Carlson, Manager, Nevada Operations Office. "Disposal Authorization Statement for the Department of Energy Nevada Operations Office Nevada Test Site Area 5 Radioactive Waste Management Site Low-Level and Mixed Low-Level Radioactive Waste Disposal Facility." December 5, 2000.

DOE, 2000b. "Report on the Nevada Test Site Area 5 Radioactive Waste Management Site Low-Level Waste Radiological Composite Analysis Review." U.S. Department of Energy, Nevada Test Site, Area 5 Radioactive Waste Management Site Low-Level Radiological Composite Analysis Review Team.

Bechtel Nevada, 2000a. *Composite Analysis for the Area 5 Radioactive Waste Management Site at the Nevada Test Site, Nye County, Nevada*. DOE/NV-594. Bechtel Nevada, Las Vegas, Nevada.

———, 2000b. *Maintenance Plan for the Performance Assessments and Composite Analyses for the Area 3 and Area 5 Radioactive Waste Management Sites at the Nevada Test Site.* DOE/NV/11718-491. Bechtel Nevada, Las Vegas, Nevada.

———, 2000c. Company Directive CD-0441.003, "ALARA Program." Rev. 0. March 24, 2000.

Shott, G. J., L. E. Barker, S. E. Rawlinson, M. J. Sully, and B. A. Moore, 1998. *Performance Assessment/Composite Analysis for the Area 5 Radioactive Waste Management Site at the Nevada Test, Nye County, Nevada*. Rev. 2.1. DOE/NV/11718-176. Bechtel Nevada, Las Vegas, Nevada.

APPENDIX A

Revised Response to Issues

Issue 1: The conclusions of the Composite Analysis do not provide reasonable assurance that the dose objectives will be met. Reasonable assurance that the objectives will be met in the short term can be provided and there are plans for activities to ensure that the dose objective will be met in the long term. The Composite Analysis conclusions should have addressed this.

The Composite Analysis (CA) results are interpreted through comparison of the best estimate of the total effective dose equivalent (TEDE) at compliance points within Frenchman Flat against a dose limit of 100 mrem in one year and a dose constraint of 30 mrem in one year. The Nevada Test Site (NTS) has introduced local radioactive contamination through a combination of activities including:

- Atmospheric nuclear tests,
- Underground nuclear tests,
- Safety and/or transportation/storage experiments,
- Nuclear rocket development studies, and
- Disposal of low-level radioactive waste at the Areas 3 and 5 Radioactive Waste Management Sites (RWMSs).

The CA assesses doses for the Frenchman Flat basin. The sources that were evaluated included 14 atmospheric nuclear tests, 10 underground nuclear tests, about two dozen nonnuclear detonations of weapons components, minor contamination at Industrial Sites, and continuing disposal of low-level radioactive waste at the Area 5 RWMS (1960 to present). The CA focuses on sources capable of causing a significant radiological dose from all interacting sources in Frenchman Flat. These analyses for the CA are summarized below by topic and listed in Table A-1.

Confusion concerning the conclusions of the Area 5 RWMS CA resulted from the use of a dual logic in the document and some inconsistent statements in the expression of that logic. To summarize, dose calculations based on existing knowledge of potentially interacting sources (*except* the Underground Test Areas [UGTA] source) provide reasonable assurance that the combined TEDE for the Area 5 RWMS, the Soil Sites, and the Industrial Sites easily meet the 100-mrem dose limit and the 30-mrem dose constraint. While progress has been made in further quantifying the UGTA source, the information presented to an external peer review panel was considered to be insufficient to adequately quantify the total system uncertainty, including

Table A-1 Summary of Composite Analysis Results

Site Name	Type	Description	Conceptual Model	Release Pathway	CA Dose (mean TEDE of the maximum dose)
GMX (Gadgets, Mechanics, and Explosives)	Soil CAU	Nonvolatile radionuclides	Air resuspension; infiltration and burial not included	Airborne pathway to the accessible environment; on-site resident	6 mrem/yr (at 250 years)
Frenchman Flat Playa	Soil CAU	Nonvolatile radionuclides	Air resuspension; infiltration and burial not included	Airborne pathway to the accessible environment; on-site resident	4 mrem/yr (at 250 years)
Off-Site Locations		Near the GMX	Airborne concentrations and long-term soil deposition	Airborne	0.2 mrem/yr (at 1,000 years)
Area 5 RWMS	Waste Management (WM) Disposal Site	Volatile radionuclides	Advection, diffusion, biotic transport	Upward pathway; on-site resident	.02 mrem/yr (at 250 years)
Area 5 RWMS	WM Disposal Site	Nonvolatile radionuclides	Advection, diffusion, biotic transport	Upward pathway; on-site resident	1 mrem/yr (at 1,000 years)
Area 5 RWMS	WM Disposal Site	Nonvolatile and volatile radionuclides	Advection, diffusion	Downward pathway	None; no pathway under current conditions
UGTA Tests	Frenchman Flat CAU	Nonvolatile and volatile radionuclides	Advection, diffusion, dispersion	Groundwater pathway	Migration will occur, but groundwater access prohibited by institutional control
Industrial Sites	Integrated Frenchman Flat CAU				Insignificant radionuclide inventory
Integrated Dose	All Sources	All radionuclides	Air suspension	Airborne pathway	< 7 mrem/yr

significant uncertainty in the classified hydrologic source term and modeling results predicting the future extent of contaminant transport. Therefore, the National Nuclear Security Administration Nevada Operations Office (NNSA/NV) cannot show conclusively that interacting contamination sources that include the UGTA groundwater contamination will not exceed the dose limit and dose constraint. To provide reasonable assurance that the combined TEDE from all the potential interacting sources meet the 100-mrem dose limit and 30-mrem dose constraint, NNSA/NV will maintain control of the NTS and restrict access to the subsurface prior to the UGTA contaminant boundaries being delineated. The CA will be revised and the need for land-use constraints reassessed when additional information is obtained for the UGTA Frenchman Flat Corrective Action Unit (CAU) (expected in 2004).

The following sections briefly summarize current information for radioactive sources in Frenchman Flat with respect to the CA dose objectives (sources summarized in *Table A-1*).

Area 5 RWMS

The post-1988 inventory from the Area 5 RWMS is described in the Area 5 Performance Assessment (PA). The pre-1988 inventory is estimated in the CA and includes, in addition to low-level waste in trenches, the transuranic (TRU) and low-level radioactive waste in the Greater Confinement Disposal (GCD) boreholes, the low-level radioactive waste in the GCD Test borehole, the TRU in shallow trenches, and the classified waste. The Area 5 PA evaluated the post-September 1988 inventory projected to closure in 2028 for the shallow pits and trenches, the post-1988 GCD inventory, and an estimated thorium inventory for the lower cell of P06U. The pre-1988 inventory is estimated in the CA for shallow pits and trenches and the GCD boreholes. There is no groundwater pathway for release of radionuclides under current conditions. Calculated releases are associated with an upward pathway driven by coupled processes of upward advection and diffusion and biotic uptake. The mean TEDE from the nonvolatile radionuclides (pre- and post-1988 radioactive sources) for a resident at the Area 5 RWMS is a function of time (0.3 mrem/yr at 250 years and 1 mrem/yr at 1,000 years). The mean TEDE from volatile radionuclides for a local resident reaches a maximum of 0.02 mrem/yr at 250 years. The mean TEDE from the total Area 5 inventory declines rapidly during institutional control as ^{3}H, ^{90}Sr and ^{137}Cs decay. After 250 years, the mean TEDE is dominated by the nonvolatile radionuclide inventory. The mean TEDE rises from 0.3 mrem/yr at 250 years to 1 mrem/yr at 1,000 years.

Contaminated Soil Sites

Eight contaminated soil CAUs were selected for initial analysis in the CA. Only four of the sites contain sufficient inventory to be potentially significant for the CA (see Table 4.3, page 4-5 in the CA). Two of these contain sufficient inventory to be included in the final analysis of the CA dose (Frenchman Flat Playa and the GMX). Both have relatively small inventories of 19 Ci for the Frenchman Flat Playa and 2 Ci for the GMX. Two soil sites from Table 4.3 are excluded as significant sources for the CA (the Plutonium Valley Soil Site and the PIN STRIPE Soil Site). The Plutonium Valley Soil Site is excluded on the basis of multiple lines of evidence. First, the site is separated from the Area 5 RWMS by intervening mountain ranges that intercept and reduce airborne emissions from the Plutonium Valley Soil Site. Second, the monitored airborne plutonium in Frenchman Flat is negligible. The highest mean result for 1998 is 1.3×10^{-17} µCi/ml or about 0.07 mrem/yr to the Member of Public. These data show that the Plutonium Valley Soil Site is not a significant contributor to the CA dose. The PIN STRIPE soil source has to have an extremely small inventory based on the Radionuclide Inventory and Distribution Project (RIDP). The most significant component is estimated to be 0.2 Ci of ^{90}Sr and 0.2 Ci of ^{137}Cs. Both nuclides will decay to negligible levels in 250 years (institutional control period). The activity associated with the remaining long-lived fission products will be in the µCi to the çCi range. These levels are so low that the PIN STRIPE soil source cannot be a significant contributor to the CA dose. The TEDE for the soil sites was estimated for a resident living within the contaminated area and are 4 mrem/yr for the Frenchman Flat Playa and 6 mrem/yr for the GMX (both estimates at 250 years).

Industrial Sites

Many small sites consisting of hazardous and minor radioactive waste contamination are present at the NTS and are being assessed under the Industrial Sites programs. Studies of industrial sites in Frenchman Flat are pending and the sites have been inventoried, but not characterized. Listed sites have been consolidated into a single corrective action unit (CAU 140) for efficiency in interactions with the state of Nevada. Based on current knowledge, the industrial sites are not expected to be a significant source of radioactive contamination and therefore will not contribute to the dose objectives for the CA; they are excluded from the CA sources. CAU 140 will be characterized through future studies under the Industrial Sites programs. If radionuclide inventories larger than anticipated are discovered through these characterization activities, the inventories will be included in revised CA dose calculations under the Maintenance Plan for the Area 5 RWMS.

UGTA

The Frenchman Flat CAU of the UGTA program consists of ten underground tests conducted in two clusters, one northeast of the Area 5 RWMS and the second in central Frenchman Flat. The nearest test (DERRINGER) is about 1.8 kilometers (km) (1.1 miles [mi]) north of the RWMS. All of the tests were conducted in the unsaturated zone above the alluvial aquifer, except the CAMBRIC test, located in central Frenchman Flat. The Frenchman Flat CAU is a potentially important source of radionuclide contamination and is a topic covered by a recent report (IT, 1996). This report presented the results of modeling of groundwater flow in Frenchman Flat using a regional groundwater model to provide boundary conditions (recharge flux) coupled to a CAU-specific model of flow and transport. Particle tracking from the ten test locations show travel distances of <1 km (0.6 mi) over 1,000 years. Transport simulations were performed for a steady-state flow field using a radionuclide source term calculated with a test-scale flow model combined with a geochemical reaction model. The modeled source term used unclassified data from the CAMBRIC test and this source term was applied to all tests. Future work will be performed using detailed source information from classified data. The combined flow and transport modeling show a limited potential for interaction of UGTA groundwater contamination sources with the Area 5 RWMS. This results from a combination of a flat gradient with low groundwater velocities and local northeast flow directions away from the Area 5 facility. However, an external peer review panel recently reviewed the UGTA report for the Frenchman Flat CAU (IT, 1999). They concluded that there are insufficient data (geologic, geophysical, hydrologic, source term) to have a reasonable level of confidence in the results of the transport model. Based on this review, new characterization data are being gathered and will be incorporated into revised modeling of flow and transport. Therefore, for the purposes of the CA, there remains significant uncertainty in the UGTA source term and the resulting potential for radionuclide transport. The possibility of future interactions between the underground contamination and other sources of contamination in Frenchman Flat cannot be excluded. The Frenchman Flat UGTA results will be integrated in the next iteration of the CA under the Area 5 RWMS Maintenance Plan.

Expectations based on existing knowledge are that the UGTA source in Frenchman Flat will probably not interact with the Area 5 RWMS source; therefore, the Area 5 CA will probably meet the CA dose limits with inclusion of the UGTA source. However, because of current uncertainty regarding this source term, reasonable assurance through numerical calculations that the dose will be less than the CA dose objectives cannot be provided. Therefore, reasonable assurance in the near term of meeting the dose limits will be provided through institutional control that prohibits access to the groundwater dose in

Frenchman Flat. Invoking institutional control is based on a combination of the NTS national security mission that precludes public access, the presence of historical contamination that precludes public access, the expected indefinite continuation of institutional control under the Defense Program, and the current plans for Defense Programs to assume control of Environmental Restoration (ER) and WM sites in the next 20 years.

Total Doses From Interacting Sources Without the UGTA Source

The TEDE received by a hypothetical resident of Frenchman Flat will vary with location and time. Dose is evaluated at 1,000 years when the maximum dose is expected. The TEDE is estimated by summing the results for the individual contaminated sites and the results for the off-site locations. The highest TEDE for the GMX Soil Site is expected to be less than 7 mrem in a year. Reasonable assurance is provided that the assessed interacting sources easily comply with the 100-mrem dose limit and the 30-mrem dose constraint. However, the UGTA source term has not been included in the calculations and cannot be assessed given the current state of knowledge.

Issue 2: The Composite Analysis acknowledges the potential large doses from the Underground Testing Area, but presents no information on the source and does not attempt to quantify the dose. However, based on discussions during the site visit, it is evident that data (e.g., CAMBRIC pumping test) are available that would provide support to the analysis and conclusions. These data should have been included.

The request of the review group is to provide more complete information pertinent to the Area 5 CA from the UGTA program. The UGTA is part of the Nevada ER program at the NTS and is guided by the Federal Facilities Agreement and Consent Order (FFACO) between the NNSA/NV, the state of Nevada, and the U.S. Department of Defense (DoD). One of multiple CAUs under study by the UGTA task is the Frenchman Flat testing area. The Area 5 RWMS is located in the approximate central part of the Frenchman Flat CAU. However, in contrast to the Area 3 RWMS setting, the Frenchman Flat CAU includes only ten underground tests, and there is geographical separation between test locations and the Area 5 RWMS.

The Frenchman Flat CAU is the first of the UGTA CAUs under investigation using CAU scale models to simulate flow and transport processes. A preliminary draft of these ongoing studies has been reviewed by an external peer review panel. The peer review raised concerns about the sufficiency of data for modeling transport and argued that additional characterization work is needed. Progress has been made in further quantifying the UGTA source, and the best professional judgment of the UGTA program managers is that migration of radionuclides from the underground tests in Frenchman Flat will not impact the Area 5 RWMS. This conclusion is based on a 16-year pumping experiment (CAMBRIC radionuclide migration study) and the very low hydraulic gradient in the basin. The judgment of limited radionuclide migration from testing areas remains to be supported by the final results of modeling flow and transport process in Frenchman Flat. Moreover, there will be parts of Frenchman Flat immediately surrounding two areas of clustered tests that will likely require institutional control in perpetuity.

Based on current information, the NNSA/NV cannot now show conclusively that interacting contamination sources that include the UGTA groundwater contamination will not exceed the dose limit and dose constraint. To provide reasonable assurance that the combined TEDE from all the potential interacting sources meet the 100-mrem dose limit and 30-mrem dose constraint, NNSA/NV willmaintain control of the NTS and restrict access to the subsurface prior to the

UGTA contaminant boundaries being delineated. The CA will be revised and the need for and extent of land-use constraints reassessed when additional information is obtained for the UGTA Frenchman Flat CAU (expected in 2005).

Recognizing the ongoing status of the UGTA studies of Frenchman Flat, expanded information is provided on the background and organization of the UGTA, the results of studies of the CAMBRIC site, and the results of monitoring of groundwater beneath the Area 5 RWMS.

Underground Test Area Program

The assessment of ER sites on the NTS takes place under the FFACO between the NNSA/NV, the state of Nevada, and the DoD. The FFACO defines a Resource Conservation and Recovery (RCRA)-like process for remediation and closure of these sites and requires state of Nevada review and approval. The strategy to plan, implement, and complete environmental corrective actions at facilities where nuclear tests and associated support activities were conducted at the NTS is described in Appendix VI of the FFACO. The strategy is based on four steps: (1) identifying corrective action sites (CASs), (2) grouping the CASs into CAUs, (3) prioritizing the CAUs for funding and work, and (4) implementing the corrective action investigations (CAIs) and/or corrective actions, as applicable. Based on the source of contamination, CASs have been organized into four categories in the FFACO: (1) Industrial Sites, (2) UGTA Sites, (3) Soil Sites, and (4) Off Sites. The first three categories of sources are pertinent to the CAs and are briefly summarized below.

The FFACO identifies 908 historical nuclear detonations, which occurred in shafts or tunnels at the NTS. They are categorized into 878 CASs, which are grouped into 6 geographically distinct CAUs. Each UGTA CAU has different contaminant sources and geologic and hydrogeologic characteristics related to its location. The Yucca Flat UGTA CAU consists of 717 CASs; the Frenchman Flat (10 CASs), Western Pahute Mesa (18 CASs), Central Pahute Mesa (64 CASs), Rainier Mesa/Shoshone Mountain (66 CASs), and Climax Mine (3 CASs). The Yucca Flat CAU and the Frenchman Flat CAU are the UGTAs of concern for the Area 3 RWMS and the Area 5 RWMS CAs, respectively.

Of the ten CASs in Frenchman Flat, seven tests took place north of the Area 5 RWMS; and three south of the Area 5 RWMS. The closest test to the RWMS was the DERRINGER test, located about 1,800 meters (m) (5,906 feet [ft]) north of the RWMS. All tests, except CAMBRIC, occurred above the water table.

The objective of the UGTA CAIs is to define contaminant boundaries around each CAU where groundwater may be unsafe for domestic and municipal use. The contaminant boundary is drawn to bound the possible existence of groundwater capable of causing a median dose of 4 mrem/yr within a 1,000-year period. After the contaminant boundaries are established, NNSA/NV will maintain institutional control of the subsurface in perpetuity (as referenced in a public document entitled Accelerating Cleanup: Paths to Closure, Strategic Plan–Preserving Our Traditions . . . Forging Our Future) (DOE, 1998a).

Regional groundwater flow and tritium transport modeling has been performed to provide an initial basis for assessing flow paths from the CAUs (DOE, 1997a). A second phase of the CAI process will refine the CAU boundaries through CAU-specific models with site-specific data. Closure activities under UGTA will be accomplished through 2017 (DOE, 1997b).

The implementation of the Frenchman Flat CAI is in progress, following a CAI Plan (DOE, 1999a). The CAI was planned using the Data Quality Objective process and a value of information analysis to support the process. The CAI to date has generated a draft conceptual flow and transport model for Frenchman Flat.

An external review of the draft Frenchman Flat CAU model was performed by a panel of subject matter experts (SMEs) (IT, 1999). The SMEs concluded that the model results from the draft Frenchman Flat CAU flow and transport model, though possible, are not supported by sufficient data to establish the degree of confidence that would normally be expected. The reviewers specifically noted that large uncertainties remain in the source inventory, the radionuclide release rates from the rock matrix, the site hydrostratigraphy, the flow direction and rate, and the transport parameters (IT, 1999). The UGTA Program is in the process of acquiring additional site characterization data to address the uncertainties identified during the peer review. In fiscal year (FY) 2000, two deep boreholes were drilled north of the Area 5 RWMS; two wells are planned to be drilled south of the RWMS in FY 2001 to evaluate whether or not there is a vertical gradient between the alluvial aquifer and the carbonates and, if so, what the leakage rate might be.

Because of the uncertainty surrounding the Frenchman Flat UGTA, the initial Area 5 CA did not identify the contaminant boundaries of the areas that would be restricted to public within a 1,000-year compliance period. The next iteration of the CA will be performed when (1) the Frenchman Flat CAU model is approved and accepted under the FFACO, and/or (2) significant changes in

DOE policy regarding resource management, stewardship, or land-use withdrawal occur which deviate from those assumed and summarized in the CA and its supporting documents.

The current plan for the Frenchman Flat CAU is to obtain additional site characterization data and to develop a new CAU model. The model will be used to establish a restricted area based on a 4 mrem in a year dose from use of groundwater. The results of the investigation will be documented in a corrective action decision document (CADD) expected in 2005. The Area 5 CA will be revised and updated when the CADD is published.

CAMBRIC Pumping Experiment

The CAMBRIC test was a 0.75 kiloton event that took place on May 14, 1965. The test was conducted in Frenchman Flat approximately 5 km (3 mi) south-southwest of the Area 5 RWMS. The working point was in alluvium at 294 m (965 ft) below the ground surface, and 73 m (240 ft) below the water table. The CAMBRIC migration experiment started in 1974 by installing a well into the test cavity to determine the radionuclide content of the cavity water and the sediments (Bryant, 1992). In 1975, a second well was drilled 91 m (299 ft) from the test cavity to induce flow by pumping and observing the concentrations of radionuclides in pumped water to estimate their rate of mobility. From 1975 to 1991, 16 million cubic meters (4 billion gallons) of water were pumped. Results of the 16-year experiment indicate that tritium, radioactive gases, and anionic species readily migrate, whereas cationic species and special nuclear material are either contained in the nuclear melt glass of the cavity or highly sorbed on geologic materials.

Analyses of water samples showed that the advective velocity of tritium, ^{36}Cl, ^{85}Kr, ^{99}Tc, ^{106}Ru, and ^{129}I was nearly the same as groundwater, from the test site to the pumping well (this is expected because these radionuclides are known to be retarded by sorption). The first tritium observed in the pumping well, located 91 m (299 ft) from the test cavity, was not observed until after 900 days (2 ½ years) of pumping (Bourcier *et al*., 1999). This demonstrates that the native aquifer material has an extremely low hydraulic conductivity (even under a forced gradient) and supports the suggested theory of a very slow contaminant migration away from the shot cavity. ^{137}Cs, ^{90}Sr, and ^{239}Pu were never detected in the pumped water because of their high sorption characteristics (Bryant, 1992).

Based on the results of the CAMBRIC pumping experiment and the very low gradient in Frenchman Flat, it is the best professional opinion of UGTA program managers that migration of radionuclides from the underground tests in Frenchman Flat will not impact the Area 5 RWMS. That judgment remains to be supported by the final results of modeling flow and transport process in Frenchman Flat.

Results of Groundwater Monitoring at the Area 5 RWMS

Despite the general uncertainty in estimating the areal distribution and migration of radionuclides in Frenchman Flat groundwater, four active water supply wells and three RCRA monitoring wells around the Area 5 RWMS show no contamination related to waste disposal or underground nuclear testing. The RCRA Groundwater Monitoring Report (submitted to the state of Nevada on an annual basis) summarizes the results of RCRA detection monitoring conducted at the Area 5 RWMS. The uppermost aquifer beneath the RWMS is monitored for hazardous constituents and tritium to satisfy RCRA requirements for the mixed waste disposed in Pit 3. Groundwater monitoring results to date show no indication that hazardous or radioactive waste constituents have reached groundwater (DOE, 1999b). Tritium is the only man-made radionuclide routinely detected at the Area 5 RWMS in media other than groundwater (DOE, 1999b).

The water levels at the three RCRA wells (Ue5PW-1, Ue5PW-2, and Ue5PW-3) have been monitored quarterly since 1993. The depth to groundwater for Ue5PW-1, Ue5PW-2, and Ue5PW-3 is about 235 m (772 ft), 257 m (842 ft), and 272 m (891 ft), respectively. The groundwater table is almost flat. However, analysis of the water levels at these wells indicate a persistent, but small northeast gradient in flow direction. The advective transport velocity is estimated to be less than one foot per year. This means that radionuclides that are not adsorbed to the solid matrix will travel less than 305 m (1,000 ft) in 1,000 years. Other than tritium, most radionuclides of concern at the ten test cavities in Area 5 would be highly adsorbed to the solid matrix. These radionuclides will be retarded so much that they will not spread far from the test cavities within 1,000-year CA compliance period.

To assure the continuing high quality of the groundwater resources, the *Nevada Test Site Resource Management Plan* (DOE, 1998b) specifies a goal to maintain the quality of waters that are presently clean. This goal is explicitly tied to compliance with federal and state water quality standards and proper disposal of low-level radioactive waste. In addition, NTS procedures require that a Site Use and Development Board evaluate all activities proposed for the NTS. The Board, among other things, evaluates the activity for its potential to contaminate surface and subsurface water. Taken together, the NTS resource management policies combined and the existing clean status of most of the water underlying Frenchman Flat (exclusive of UGTA CASs) assure the future quality of the groundwater resource.

Summary

Characterization of the UGTA source term in groundwater beneath Frenchman Flat is continuing. A total of ten underground tests were conducted in Frenchman Flat, a small number of tests compared to other CAUs on the NTS. Present expectations are that there will be a limited potential for transport of radionuclides away from the underground tests, due largely to the flat flow gradient and low groundwater velocities. However, until further work is completed by the UGTA on the Frenchman Flat CAU, the possibility of future interactions between the underground contamination and other sources of contamination in the basin cannot be excluded. For the interim, access to underground contamination will be precluded through maintenance of institutional control.

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Issue 3: There are significant differences in methodology and assumptions between the approved Performance Assessment and the Composite Analysis, yet no justification for the differences are presented. The rationale for the differences should have been presented.

The PA and CA each provide justification for the assumptions, models, and parameters used. Differences have occurred over time as models have been improved and additional data collected. Many parameters in the CA are input as probability density functions. The reviewers have compared descriptive statistics of the CA probability density functions with the fixed values in the PA and concluded that there is an inconsistency if the values are different. This is not a technically valid comparison. Many of the fixed PA parameter values fall within the range of the CA distributions and are consistent. Careful comparison of the model results and parameter values indicates that there are no significant differences.

Justification can be provided for the differences in models and parameters. A bench marking comparison of results from the two sets of models confirms that the two approaches give generally consistent results considering the large uncertainty in the analysis.

Comparison of PA and CA Nonvolatile and Volatile Radionuclide Release and Transport Models

Since preparation of the Area 5 RWMS PA, additional review and comment on the PA models has occurred and additional data have been developed through site characterization and literature reviews. This additional input has caused no changes in the conceptual models of radionuclide release and transport. However, improvements in the release and transport mathematical models and data parameters have been made.

Two changes have been made to the nonvolatile radionuclide release and transport model. An additional transport pathway was added for burrowing animals. In the Area 5 RWMS PA, burrowing animals were assumed to transport contamination from waste to the overlying soil compartments. The CA model assumes burrowing animals may also transport contamination from deep soil to shallow soil. This is an assumption that may potentially increase the concentration of a radionuclide in shallow soil and, therefore, is considered conservative.

The Area 5 RWMS PA assumed that upward advection of solutes dissolved in soil pore water could occur, but screening analyses suggested that the transport rates were too slow to be of concern. Therefore, transport by liquid advection was not calculated in the Area 5 RWMS PA. Recent estimates of the upward advection rates confirm that the rates are indeed small, 2.7E-4 m/yr (Chapman, 1995, 1997). The CA model includes a pathway accounting for the slow rate of upward liquid advection. This is a conservative assumption.

Three changes have been made to the volatile radionuclide release and transport model. The Area 5 RWMS PA assumed that volatile radionuclides diffuse along a linear concentration gradient. The CA estimates the concentration gradient by solving a mass balance expression. This change is expected to be more realistic.

During review of the Area 5 RWMS PA, subsidence of the closure cap was identified as a concern by reviewers. One consequence of subsidence is assumed to be cracking of the closure cap. The CA assumes that volatile radionuclides diffuse in cracks as in free air. The total volatile radionuclide flux density from the cap is calculated as an area weighted mean of the flux density from intact cap and cracks.

The third difference involves the calculation of the effective diffusion coefficient. The CA uses a different empirical expression that is believed to give a better fit to experimental data for the dry, porous conditions expected at Area 5.

Comparison of Important PA and CA Parameter Values

The most significant parameter change between the Area 5 PA and CA is that most CA input parameters are specified as probability density functions. Probabilistic inputs include compartment dimensions of the nonvolatile radionuclide release model. This leads to three cases, depending on whether plants root in the cap only, in a portion of the waste, or throughout the waste. The transfer coefficients are calculated differently for each case.

To prepare the Area 5 CA, many parameter values had to be assigned probability density functions and data for additional radionuclides had to be developed. During this development process, much new data were identified in the literature and old data were reviewed and evaluated. In most cases, the range of values used in the CA includes the fixed value used in the PA.

The plant-soil concentration ratios are consistently identified as sensitive parameters in the nonvolatile radionuclide release model. Preparation of the Area 5 CA required that plant-soil concentration ratios be identified for many new radionuclides. Rather than append additional radionuclide data to the Area 5 PA plant-soil concentrations ratios, the compilation of the International Union of Radioecologists was selected because it is a modern, thorough data set that includes data for nearly all the radionuclides considered in the CA. Nevada Test Site- specific data from root uptake experiments were used for Pu and Am. Site-specific data were judged to be superior to the generic compilation. The distributions used in the CA are compared with the fixed values from the PA in Table A-2 for radionuclides contributing more than 95 percent of the dose in the two analyses. The fixed PA values are nearly equivalent to the median or geometric mean of the CA and, in all cases, the range of CA values included the fixed PA value. Therefore, it can be concluded that the CA distributions are consistent with the PA values.

Table A-2 Comparison of Important Plant-Soil Concentration Ratio Distributions Used in the CA with Fixed Values Used in the PA

Element	Area 5 RWMS CA		Area 5 RWMS PA	CA Geometric Mean/ PA Deterministic Value	Percentile of Deterministic PA Value
	Arithmetic Mean (Geometric Mean) of Lognormal Distribution	Standard Deviation	Deterministic Value		
C	3.2 (0.7)	1.4E1	5.5E0	0.1	88
Cl	3.2E2 (7.0E1)	1.4E3	7.0E1	1.0	81
Tc	4.8 (1.0)	2.1E1	1.5E0	0.7	56
Ra	1.3E-2 (2.9E-3)	5.8E-2	1.5E-3	1.9	36
Ac	1.6E-3 (3.5E-4)	7.1E-3	3.5E-4	1.0	50
Th	3.2E-4 (7.0E-5)	1.4E-3	8.5E-5	0.8	54
U	1.9E-2 (4.3E-3)	8.4E-2	4.0E-3	1.1	49
Pu	6.3E-3 (3.5E-4)	1.1E-1	2.0E-3	0.2	77

During preparation of the Area 5 CA, the Area 5 PA resuspension rates were reviewed. The Area 5 PA resuspension rate was derived from a literature review (Layton *et al*., 1993), using site-specific and non-site-specific data, that estimated the NTS resuspension rate to range from 3E-5 to 3E-4 yr^{-1}.

With the CA, it was assumed that there are sufficient site-specific data to estimate this parameter. Site-specific data were observed to range from 8E-5 to 1E-2 yr^{-1} (Anspaugh *et al*., 1975; Shinn *et al*., 1986). Therefore, the CA assumes that the resuspension rate is uniformly distributed from 8E-5 to 1E-2 yr^{-1}. The CA data are generally higher than the PA, but the CA distribution and the PA value are still consistent because the CA distribution includes the fixed PA value. The resuspension rate has never been identified as a sensitive parameter.

Bench Marking of the Area 5 CA Nonvolatile and Volatile Radionuclide Release Model Against the Area 5 PA Models

To assess the effects of the changes to the mathematical models and parameter values, the Area 5 CA volatile and nonvolatile radionuclide release models were benchmarked against the Area 5 PA models. The bench marking was performed by calculating a model release factor which is defined as the ratio of the concentration in the environment at some future time to the waste concentration at closure, or

$$RF(t) = \frac{C_E(t)}{C_w(t=0)}$$

where:

$RF(t)$	=	release factor at time t, m^3/g for nonvolatile release or m/yr for volatile release;
$C_E(t)$	=	environmental concentration, Ci/g for nonvolatile release or $Ci/(m^2/yr)$ for volatile release; and
$C_w(t=0)$	=	waste concentration at closure, Ci/m^3.

Release factors were calculated for the radionuclides contributing greater than 95 percent of the total dose. Release factors could not be calculated for members of serial decay chains because the long-term environmental concentration is affected by the initial concentration of more than one parent. For the nonvolatile radionuclide release model, the environmental concentrations are the surface soil concentration at 1,000 years. The CA results were taken as the mean result. The comparison shows that the two models produce consistent results for radionuclides important for performance (Table A-3).

A similar comparison was made for the volatile radionuclide release model. The model result used for comparison was the flux density at 100 years. As both models allow the complete release of the ^{14}C,

^{39}Ar, and ^{85}Kr inventory in a year, the models are assumed equivalent for these nuclides. The models appear to produce similar results for ^{3}H (Table A-4).

Table A-3 Benchmark Results for Comparison of the Area 5 PA and Area 5 CA Nonvolatile radionuclide Release Models

Nuclide	PA Inventory at Closure (Ci/m^3)	PA Surface Soil Concentra-tion at 1,000 yrs (Ci/g)	PA RF(t) (m^3/g)	Mean CA Inventory at Closure (Ci/m^3)	Mean CA Surface Soil Concentration at 1,000 yrs (Ci/g)	CA RF(t) (m^3/g)	CA RF(t)/ PA RF(t)
^{14}C	1E-5	2E-13	2E-8	3E-5	6E-14	2E-9	0.1
^{36}Cl	4E-13	1E-19	3E-7	1E-6	1E-13	8E-8	0.3
^{99}Tc	8E-5	5E-13	6E-9	9E-4	1E-11	1E-8	2.0
^{232}Th	5E-6	1E-15	2E-10	1E-5	2E-15	1E-10	0.7
^{238}U	3E-3	6E-13	2E-10	1E-3	2E-12	2E-10	0.7
^{239}Pu	3E-4	7E-14	2E-10	1E-3	2E-13	2E-10	0.9

Table A-4 Benchmark Results for Comparison of the Area 5 PA and Area 5 CA Volatile Radionuclide Release Models

Nuclide	PA Inventory at Closure (Ci/m^3)	PA Volatile Release at 250 yrs (Ci/(m^2 yr))	PA RF(t) (m/yr)	Mean CA Inventory at Closure (Ci/m^3)	Mean CA Volatile Release at 250 yrs (Ci/(m^2 yr))	CA RF(t) (m/yr)	CA RF(t)/ PA RF(t)
3H	9E-1	3E-3	3E-3	3E0	2E-2	5E-3	1.8

Comparison of the PA and CA Radiological Assessment Models

The Area 5 PA estimated the dose to a member of public through two high-probability exposure scenarios, transient occupancy and open rangeland. Reviewers requested the analysis of a resident farmer scenario for comparison purposes. A full-time resident farmer at the Area 5 RWMS is an extremely unlikely event. After the Area 5 PA was completed, a panel of SMEs examining the probability of intrusion selected a residential scenario as most appropriate. Since that time, PAs and

CAs for the NTS have used a residential exposure scenario. In terms of dose per unit radionuclide concentration in soil, the scenario doses rank as resident farmer > residential > transient occupancy > open rangeland.

After the Area 5 PA, a more complete and modern radiological assessment model was adopted for use with the residential exposure scenario. This included the use of more recent internal dose conversion factors contained in U.S. Environmental Protection Agency (EPA) Federal Guidance Report 11 (Eckerman *et al*., 1988) and more recent assessment methods (Kennedy and Strenge, 1992). The residential exposure scenario includes all the pathways included in the resident farmer scenario with three additional pathways: gas immersion, poultry ingestion, and egg ingestion.

Issue 4: There are many instances where assumptions are stated with no presentation of the basis for the assumptions. Justification (i.e., rationale) for all assumptions should have been provided.

The following is a list of the major assumptions made and their associated justification and rationale.

1. **Assumption**

   Uncertainty in waste inventory can be accounted for through random sampling using Monte Carlo simulation, a value described by a loguniform distribution. The minimum of the distribution extends one order of magnitude lower than the value reported by the generator. The maximum of the distribution extends one order of magnitude above the value reported by the generator.

   Justification

   Shott *et al*. (1997) evaluated the potential uncertainty in the fission product activity in a simulated waste package characterized by gross radiation measurements and scaling factors. The activity estimates all had ranges that spanned less than two orders of magnitude.

2. **Assumption**

   Inventory uncertainty is assumed to be 100 percent correlated within the population of containers shipped by a single generator. Inventory uncertainty between generators is assumed to be uncorrelated.

   Justification

   This is expected to be a conservative representation of uncertainty.

3. **Assumption**

   The completeness of database records and query results can be assessed by comparing the physical volume of waste in a trench with the database query results.

Justification

The ratio of the database estimated volume to the volume estimated from trench dimensions ranges from 0.67 to 1.2. This ratio is used to correct database records for missing inventory. The ratio was fit to a triangular probability distribution with a minimum of 0.9, mode of 1.2 and maximum of 1.5.

4. Assumption

Scaling factors are used to document activities of radionuclides suspected to be present in waste, but not reported by the generators.

Justification

In most cases, data necessary to estimate scaling factors are not available. Conservative estimates using waste stream knowledge are used to bound activities. Examples include scaling fission and activation products to mixtures representative of NTS underground testing debris, and assigning uranium isotopes to representative waste streams associated with depleted and enriched uranium.

5. Assumption

The inventory of disposed TRU and high-specific activity waste in the GCD boreholes is provided in existing documents.

Justification

The GCD inventory was described in a earlier report (Chu and Bernard, 1991), and has been updated in the GCD PA. The final draft of the GCD PA was submitted to NNSA/NV and was formally reviewed by DOE/Headquarters in the fall of calendar year 2000.

6. Assumption

Contaminated soil sites can be identified and screened through existing radiological site characterization projects.

Justification

Bechtel Nevada Health Protection Department maintains a list of radiological controlled areas. Aerial radiation surveys of Area 5 have been performed using helicopter-mounted sodium-iodine detectors. Site histories were consulted for some of the sites. Some soil sites could not be discriminated from background soils on aerial surveys. Desert Research Institute conducted RIDP surveys of gamma-emitting radionuclides on the NTS in the 1980s.

7. Assumption

The surface radionuclide inventory for the Frenchman Flat Industrial Sites is assumed to be insignificant for the CA.

Justification

Remediation of multiple sites on the NTS shows that radionuclide inventories are very small to nonexistent. The Industrial Sites in Frenchman Flat are not detectable on aerial radiometric surveys. The NNSA/NV program manager for the Industrial Sites does not expect to find significant radionuclide inventories at the Frenchman Flat sites (CAU 140).

8. Assumption

The RWMS conceptual model assumes pits, trenches, and GCD boreholes will be covered by a monolayer closure cap composed of native alluvium.

Justification

Closure plans have evolved from subsidence studies associated with the Area 5 PA and the Consequences of Subsidence Study (DOE, 1998). A monolayer closure cap of varying thickness and composed of native alluvium has been demonstrated to be an effective design with respect to the high evapotranspiration conditions of the NTS. A vegetated monolayer cap will be used for closure of the U-3ax/bl cell in the Area 3 RWMS. A monolayer closure cap is proposed in the Integrated Monitoring and Closure Plan (Bechtel Nevada [BN], 2000). In addition, in December FY 2001, NNSA/NV Waste Management Division constructed the Accelerated Site Technology Deployment (ASTD) Project consisting of eight performance evaluation cells. These cells will provide valuable information regarding the performance of monolayer closure caps covered with different rock mulches, impacts of different Mojave desert plants on cap performance, and the operation of various vadose zone monitoring devices.

9. Assumption

The closure cap will be maintained during institutional control (250 years) and is assumed to subside after institutional control. Subsidence will cause cracking of the cap with increased infiltration of moisture. The cap will remain above grade for 1,000 years prohibiting run-on.

Justification

Cap maintenance during institutional control is proposed in the Integrated Closure and Monitoring Plan (BN, 2000) and is described in the Consequences of Subsidence Study. Subsidence models involving cracking of the cap and focused water infiltration are described in the Area 5 PA and the Consequence of Subsidence Study.

10. Assumption

The source terms in the pits and trenches are assumed to be uniformly distributed as a single homogeneous layer of “soil-like” waste. Radionuclides are immediately available for release and no credit is taken for delayed release associated with specific waste forms or waste containers.

Justification

These are conservative assumptions used in the approved Area 5 PA and lead to overestimation of radionuclide release rates.

11. Assumption

Volatile radionuclides are transported by gaseous diffusion through the operational and closure cap and facilitated through cracking caused by subsidence (reduced tortuosity factor). Tritium and carbon are released by plant transpiration. The annual release is limited to the site inventory for ^{14}C, ^{39}Ar, and ^{85}Kr.

Justification

These are the assumptions used in the Area 5 PA. Pressure-driven advection has been shown to be small compared to diffusion. Volatile radionuclides are allowed to diffuse along a linear concentration gradient and the concentration gradient is solved using a mass balance equation. The CA uses an upgraded empirical expression of the effective diffusion equation compared to the equation used in the Area 5 PA. It is demonstrably conservative to assume no inventory depletion over a year of release. Much of the ^{3}H inventory is solidified, encapsulated, or absorbed on the waste form and will be released slowly over many years. A conservative conceptual model of crack formation was assumed that corresponds to open cracks equal to about 10 percent of the cap. Crack area was assumed to vary uniformly from 0 to 10 percent.

12. Assumption

Within the RWMS, gaseous flux is mixed in a 2-m- (6.5-ft)-high cell and radionuclides and transport of radionuclides off site is modeled by Gaussian dispersion.

Justification

These are the assumptions used in the Area 5 and Area 3 PAs. Emission rates were calculated using resuspension rates derived from NTS measurements. Plutonium resuspension rates have been measured for the GMX and Plutonium Valley soil sites. The atmospheric dispersion modeling was performed using the EPA Industrial Source Code, Long-Term dispersion model. The model and selected parameters are described in Appendix 2 of the CA. The model uses the Gaussian plume equation to derive the air concentrations at receptor locations.

13. Assumption

There is no downward liquid advection to the alluvial aquifer. Upward liquid advection is the dominant condition in the upper 35 m (115 ft) of alluvial deposits in Frenchman Flat. Upward liquid advection ceases in the upper 1.5 m (5 ft) because of extremely low water content. Biotic transport occurs as a result of plant uptake and redistribution of material from burrowing animals.

Justification

Simulation of groundwater travel times for the unsaturated alluvium in Frenchman Flat are >50,000 years. Negative water potentials driving upward advection have been measured in numerous drillholes in shallow unsaturated alluvium in Frenchman Flat. Biotic uptake (coupled plant and animal translocation of radionuclides) was assumed and modeled in the Area 5 PA, the Area 3 PA, and the GCD PA. In addition, isotopic data, chloride profiles, and seven years of data from the vegetated (measures evapotranspiration collectively) and nonvegetated (measures bare surface actual evaporation) Area 5 weighing lysimeters all indicate there is no groundwater recharge under current climatic conditions.

14. Assumption

No volatile radionuclides are released from the soil sites. Soil sites change only by radioactive decay over time. Radionuclides are resuspended in air and dispersed through Frenchman Flat.

Justification

The high temperatures generated during a nuclear detonation and the long period since atmospheric testing in Frenchman Flat (>37 years) have exposed contaminated sites to arid, hot conditions, effectively removing volatile radionuclides. Monitoring results show that the dose from volatile radionulcides is negligible. For example, the ^{3}H concentration is $<3 \times 10^{-6}$ pCi/L and the noble gas monitoring was discontinued after years of background results. No credit is taken for burial processes at soil sites.

15. Assumption

Monitoring results can be used to validate model results in the Area 5 CA.

Justification

The mean 1998 ^{3}H concentration at the Area 5 RWMS is 6×10^{-6} pCi/ml, consistent with calculated model results of 5×10^{-2} pCi/ml (2028 projections). The model results give releases that are significantly greater than the monitoring results consistent with the conservative nature of CA model calculations.

16. Assumption

The ^{129}I inventory in the GCD is screened out in the CA as negligible. The ^{99}Tc inventory can be screened out at PIN STRIPE.

Justification

The possible GCD inventory can be bounded by considering the $^{129}I/^{137}Cs$ activity ratio. The estimate bound is 50 µCi. The ^{129}I in shallow pits and trenches of Area 5 is 2,700 µCi. The shallow inventory is 50 times the bounding GCD inventory. Based on the highest measured ^{137}Cs at PIN STRIPE from RIDP, the ^{99}Tc activity can be bounded using the $^{99}Tc/^{137}Cs$ activity ratio of 2×10^{-4}. The maximum ^{99}Tc is 0.002 pCi/g. The maximum PIN STRIPE dose is 0.00009 mrem/yr.

17. Assumption

The CA has benefitted from updating of radiological assessment models with respect to assumptions used in the Area 5 PA.

Justification

The resident farmer scenario was added in response to review concerns and as a result of assessments by SMEs involved in the expert judgement study of the Inadvertent Human Intruder. A more complete and modern radiological assessment model was adopted for the new scenario, including updated internal dose conversion factors and addition of gas immersion, poultry ingestion, and egg ingestion pathways.

18. Assumption

No significant release mechanisms in 1,000 years from deeply buried radionuclide sources (GCD and Pit 6).

Justification

These are based on the extremely low upward advection rates used in the Area 5 CA, and their somewhat modified values used in the Area 3 PA. NOTE: The GCD PA allows some radionuclide releases in 1,000 years through combined advection, diffusion, and biotic uptake. This is partly based on correlated deep depths of root intrusion and insect burrowing. The releases documented in the individual protection requirements of the GCD PA are extremely small and their inclusion would have a small effect on the CA dose objectives. A planned future activity under the PA maintenance program is integration and increased consistency between all NTS PAs.

19. Assumption

The rate of removal of activity from a given soil compartment by animal burrowing is assumed to be proportional to the rate of burrow excavation.

Justification

Site-specific data are not available for the burrow excavation rate and colony density. Parameter values are estimated from multiple studies of ants and termites in arid sites of the western United States.

20. Assumption

The plant uptake rate constant assumes that the rate of removal of activity from a soil compartment by plant growth and senescence is proportional to biomass production. The proportionality constant is the product of the plant-soil ratio and the mass fraction of plant roots in the source compartment.

Justification

This assumption is consistent with assumptions used in the Area 5 and Area 3 PAs. The aboveground primary productivity was estimated from values reported in the literature for arid sites, including several sites on the NTS. Plant-soil concentration ratios are geometric means derived from the International Union of Radioecologists. The primary reference is the data set of Kennedy and Strenge (1992). A large value of the geometric standard deviations was used in probability distributions to ensure that referenced data encompass conditions for the conceptual model of the Area 5 RWMS.

21. Assumption

Probability density functions are used for many parameter values in the CA. This provides a more complete and defendable description of parameter uncertainty. In most cases, the range of values used in probability distributions in the CA encompasses the fixed bounding value (deterministic bound) used in the Area 5 PA.

Justification

The use of probability distribution functions allows a full range of parameter values to be sampled during Monte Carlo simulation. Latin hypercube sampling is used to facilitate simulation convergence. Simulation modeling allows uncertainty to be propagated through complex calculations. Probability distributions are chosen to reflect the state of knowledge of parameter values (uniform distributions for limited data, triangular data for moderate information, normal or lognormal distributions for more complete data). Probability distributions are carefully chosen to maintain consistency, where possible, with bounding deterministic values used in the Area 5 PA. Deviations from Area 5 PA parameter values are generally related to acquisition of new information (particularly NTS-specific data) or increased knowledge of processes associated with the conceptual model. A major emphasis was on the use of probability distributions for plant parameters because these are identified as sensitive parameters for the nonvolatile radionuclide release models.

22. Assumption

An attempt was made to maintain consistency between the post-1988 inventories in the PA, the CA inventories, and the treatment of inventory uncertainty.

Justification

See Assumption 1. The same methods were used to prepare the post-1988 inventories for the PA and the inventories for the CA. Some differences are a direct reflection of the completeness and quality of data records for the pre-1988 versus post-1988 inventories. This is a common and unavoidable problem at nearly all of the DOE low-level waste disposal facilities. The review responses for the Area 5 PA include probabilistic assessment of inventories and thus the probabilistic approach used in the CA has precedence in the approved Area 5 PA.

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APPENDIX B

Crosswalk Presentation

May 15-19, 2000

U.S. Department of Energy
National Nuclear Security Administration/Nevada Operations Office
Nevada Support Facility
Las Vegas, Nevada

Changes from Area 5 PA to Area 3 PA/CA Nonvolatile Release

- Parameter Inputs Are Statistical Distributions
  - Explicitly Considers Parameter Uncertainty
- Added Burrowing Animal Transfer from Deep Soil to Shallow Soil
  - Conservative/More Detail
  - Based on Reviewer Comments
- Added Upward Liquid Advection
  - Conservative/More Detail
  - Based on Reviewer Comments

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Page 1:Date

Changes from Area 5 PA to Area 3 PA/CA Volatile Release

- Concentration Gradient for Diffusion Calculated Differently
  - Area 5 PA - Assumes Linear Concentration Gradient.
  - Area 3 PA - Uses Gradient Obtained as Solution to Mass Balance Expression.
    - Physically More Realistic
- Model Calculates Flux in Cracks
  - More Conservative/Accounts for Subsidence

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Page 2:Date

Changes from Area 5 PA to Area 3 PA/CA Radiological Assessment

- Area 5 PA Analyzes Most Probable Scenarios
  - Transient Use, Open Rangeland
- Plus Scenario Requested by DOE Reviewers
  - Resident Farmer
- Area 3 PA Analyzes Conservative Bounding Scenarios
  - Community, Community with Agriculture
  - Based on DOE Reviewer Comments
  - Based on Expert Panel Elicitation

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Page 3:Date

Changes from Area 5 PA to Area 3 PA/CA Radiological Assessment

- Area 5 PA Uses Method Based on NRC Reg. Guide 1.109 (1977)
- Area 3 PA Uses Method Based on NRC NUREG/CR-5512 (1992)
  - More Up-to-Date Method
  - More Realistic
- Area 3 PA Input Are Statistical Distributions
  - Explicitly Considers Parameter Uncertainty

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Page 4:Date

Comparison of Resident Farmer and CA Resident Pathways

Pathway	Area 5 PA Resident Farmer	Area 3 PA/CA, Area 5 CA Community Resident
Soil Inhalation	X	X
Gas Inhalation	X	X
Gas Immersion		X
External Irradiation	X	X
Soil Ingestion	X	X
Beef and Milk Ingestion	X	X
Poultry and Egg Ingestion		X
Vegetable Ingestion	X	X

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Page 5:Date

Changes from Area 3 PA/CA to Area 5 CA Nonvolatile Release

- Plant Rooting Depth Becomes Stochastic Variable
- Compartment Dimensions Become Stochastic Variables
  - Based on Reviewer Comments
  - More Fully Considers Uncertainty

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Page 6:Date

Changes from Area 3 PA/CA to Area 5 CA Volatile Release

- Different Empirical Expression Used for Effective Diffusion Coefficient.
  - More Realistic, Considers Porosity and Water Content of the Medium

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Page 7:Date

Changes from Area 3 PA/CA to Area 5 CA Radiological Assessment

- None

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Page 8:Date

Comparison of Release Models at 1,000 Years

$$RF = \frac{pCi/g\, soil\, at\, 1000\, yrs}{Ci/m^3\, Waste\, at\, Closure}$$

Nuclide	Area 5 PA RF	Area 5 CA RF	CA/PA
Cl-36	2.5E5	1.0E5	0.4
Tc-99	6.1E3	1.4E5	2.3
Ra-226	1.5E2	1.3E2	0.8
U-238	2.0E2	2.0E2	1.0
Pu-239	1.0E3	1.0E2	0.1

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Page9:Date

Comparison of Area 5 PA and Area 5 CA Models

$$RF = \frac{Flux(Ci/m^2/yr)}{Ci/m^3\, Waste}$$

Nuclide	Area 5 PA RF	Area 5 CA RF	CA/PA
H-3	2.7E-3	5.1E-3	1.6
C-14			1.0
Ar-39			NA
Kr-85			1.0

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Page 10:Date

Comparison of Plant-Soil Concentration Ratios

Element	Area 5 PA	Area 5 CA Geo. Mean	Area 5 CA 5th – 95th %
Cl	70	70	4 – 1E3
Tc	1.5	1.1	6E-2 – 2E1
Ra	0.0015	0.003	2E-4 – 5E-2
U	0.004	0.004	2E-4 – 7E-2
Pu	0.002	0.0003	6E-6 – 2E-2

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Page11:Date

Volatile Emissions from Soil Sites

- Soil Sites Are 29 - 49 Years Old. Volatile Emissions Are Expected to Have Ceased Long Ago.
- Monitoring Results Confirm that the Dose from Volatile Radionuclides Is Negligible.
  - Beyond RWMS, H-3 Concentration Is <3E-6 pCi/l (<0.00003 DCGs or <0.003 mrem/yr).
  - Noble Gas Monitoring Discontinued After Years of Background Results.

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Page 12:Date

Inclusion of Pu Valley Source

- Model Pu Concentrations Are Higher Than Monitoring Results Without Pu Valley.
  - Model at RWMS: 1.1E-17 uCi/ml Pu-239,240
  - Measured at RWMS: 8.3E-19 uCi/ml Pu-239,240
- Therefore, Including Pu Valley Causes Significant Overestimation of Airborne Pu.
- Makes Little Physical Sense to Include Pu Valley with Intervening Mountain Ranges.

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Page 13:Date

Inclusion of Pu Valley Source

- Airborne Pu Is Negligible in Frenchman Flat, (Except at the GMX Site). Highest Dose from Monitoring Is 0.07 mrem/yr in 1998. Therefore, Even if Pu Valley Contributes 100 Percent of the Dose, Pu Valley Must Be Negligible Also.

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Page 14:Date

Comparison H-3 Monitoring and Model Results

- Mean 1998 H-3 Concentration at Area 5 RWMS: 6E-6 pCi/ml
- Model Result for 2028: 5E-2 pCi/ml
- Model Results Are 8,000 Times Monitoring Results. Model Is Very Conservative - Ignores Ability of Containers and Waste Forms to Retard H-3 Release.

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Page 15:Date

I-129 in GCD

- Only Fission Product Source in GCD Is Fuel Cladding in Borehole 6.
- Borehole 6 Cs-137 Inventory Is 240 Ci.
- Assuming I-129/Cs-137 Activity Ratio of 2E-7, Possible GCD Inventory of 50 uCi.
- Shallow Pits and Trench I-129 Inventory Is 2,700 uCi.
- Shallow Inventory Is 50 Times GCD Inventory. Shallow I-129 Inventory Is Screened Out as Negligible.

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Page 16:Date

Tc-99 at PIN STRIPE

- Highest Measured Cs-137 at PIN STRIPE Was 11 pCi/g (from RIDP)
- Assuming Tc-99/Cs-137 Activity Ratio of 2E-4, Maximum Tc-99 is 0.002 pCi/g
- Assuming CA Scenario Dose Conversion Factor of 4.79E10 (mrem g)/(Ci yr), Maximum PIN STRIPE Dose Is 0.00009 mrem/yr

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Page17:Date

Industrial Sites

- Kay Block House Is the Only Distinct Frenchman Flat Industrial Site Surveyed by RIDP (Only Site Above Background).
- RIDP Found 0.009 Ci Cs-137 (Background), 0.008 Ci Sr-90 (Background), 0.2 Ci Eu-152.
- Highest Eu-152 Concentration, 4 pCi/g
- Assuming CA SDCF (1.7E12 (mrem g)/(Ci yr)), 4 mrem/yr Today, 0.00001 mrem/yr in 250 Years

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Page 18:Date

APPENDIX C

Maintaining Doses as Low As Reasonably Achievable (ALARA)

U.S. Department of Energy (DOE) radiation protection policy (DOE Order 5400.5 for the general public and Title 10 Code of Federal Regulations 835 for workers) and low-level waste disposal performance objectives require that radiation exposures be maintained As Low As Reasonably Achievable (ALARA). Maintaining releases ALARA requires a process of optimization of radiation protection considering both economic and social factors and is described in the Area 5 Performance Assessment (PA) (Shott, *et al*., 1998), where a strategy was proposed to implement a cost-benefit analysis to evaluate optimum protection. A few future occupancy scenarios, including estimated collective doses and associated monetary impacts, is evaluated in the Area 5 PA as well (Shott, *et al*., 1998).

Disposal options that could potentially reduce future radiation exposures include:

1. Increasing burial depth of waste.
2. Increasing closure cap thickness.
3 Installation of an engineered barrier mitigating/preventing both human and other biological intrusion into the waste. Examples include such things as deploying a thick metal sheet across the cap or emplacing lime in a layered cap.
4 Major decrease or elimination of container and intercontainer void space.
5 Methods to accelerate microbial degradation and corrosion of waste containers, thereby inducing subsidence during the period of institutional control.
6 Any number of methods to decrease or prevent infiltrating water from reaching the underlying waste (e.g., thick caps; caps vegetated with shallow-rooted, highly transpiring plants; rock mulches; layered cap, etc.). The DOE's National Nuclear Security Administration Nevada Operations Office (NNSA/NV) currently has an Accelerated Site Technology Deployment (ASTD) project that was constructed in December 2000 to evaluate methods of minimizing percolating water and optimize vadose monitoring.

However, according to Shott *et al*. (1998), the potential costs for Options 1 through 4 above appear much greater than the value of the actual reduction in risk. Other indirect methods in which ALARA is deployed at the Nevada Test Site (NTS) includes the physical, chemical, and biological characteristics of the two waste disposal areas at the NTS that include:

- Site aridity (low precipitation and high potential evapotranspiration);
- Lack of recharge under current climatic conditions, as demonstrated by isotopic data, chloride profiles, and seven years of data from vegetated (evapotranspiration) and nonvegetated (bare surface evaporation) weighing lysimeters;
- Depth to groundwater; and
- Presence of zeolite minerals in the unsaturated and saturated zones that retard the movement of most radionuclides, with the exception of tritium and the actinide radionuclides.

At the present time, NNSA/NV has one of the most advanced vadose zone monitoring systems in the DOE complex. This system, indirectly, will assist in implementing the ALARA principle by providing an early-warning detection system of potential exposure, thereby allowing the implementation of mitigative actions (e.g., cap thickness) prior to any exposure ever occurring. Vadose zone monitoring devices used at the NTS include:

- Time domain reflectometry for determining soil moisture,
- Heat dissipation probes (for determining soil temperature and soil matric potential which is the primary driving force for unsaturated flow),
- Neutron probes (for determining soil moisture), and
- Soil gas sampling ports (for determining the potential migration of primarily tritium).

In addition to these vadose monitoring devices, there are future plans to install real-time tritium detection devices in the landfill caps and the potential deployment of deep-rooted plants utilized as soil-water sampling lysimeters. Presently, air monitoring stations used for detecting the off-site transport of radionuclides are located around both Area 3 and Area 5 Radioactive Waste Management Sites (RWMSs) disposal facilities. In addition, plants and animals are occasionally sampled for radionuclide uptake. In essence, the entire environmental monitoring program is applying the ALARA principle.

The Soils Program at the Tonopah Test Range applies the ALARA principle to safety and has attempted to apply ALARA in establishing corrective action levels for remediation. The corrective action levels are based upon current military-based scenarios. One of the reasons the state of Nevada Division of Environmental Protection (NDEP) has not agreed upon a cleanup standard is that NNSA/NV does not have institutional control because the Tonopah Test Range is Bureau of Land

Management land withdrawn by the U.S. Department of Defense. In contrast, because of the nature and small surface areal extent of contamination, the Industrial Site, have applied the ALARA principle to both safety and cleanup levels. An agreement has been reached between NNSA/NV and NDEP that the cleanup standards for one Industrial Site be two to three times background concentrations. It is anticipated that this cleanup standard will establish precedence. In addition, ALARA is also used to determine characterization and remediation safety practices (e.g., exposure times, distance and shielding-personal protective equipment).

The NNSA/NV programs at the NTS, including the Yucca Mountain Project, operate under design features, and reducing radiation exposures for both workers and the public to levels that are ALARA has long been a primary goal at the NTS (DOE, 2000). An NTS Sitewide ALARA committee operates under a charter that follows three principles including:

1. Application of radiological and safety design considerations to all facilities to reduce exposure to individuals and releases to the environment;
2. Implementation of radiological controls during operations, testing, maintenance, research, and other support activities to minimize exposures and releases to the environment; and
3. Monitoring of radioactive material and radiation, together with measurements of worker radiation dose, to verify and document that doses are being maintained ALARA.

The ALARA program commitment for the NTS is described in the *Nevada Test Site Radiation Protection Program* (DOE/NV 1999). Bechtel Nevada, the integrated contractor for the NTS, maintains a Company Directive (CD-0441.003) that establishes the methods and assigns responsibilities for ensuring radiation exposures is limited under ALARA (Bechtel Nevada, 2000).

In the case of Frenchman Flat, the only significant radiation exposure (both individual and population) would result from a loss of institutional control. There does not appear to be any cost-effective options that would result in significantly lower doses.

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