Nevada
Environmental
Management
Operations Activity

DOE/NV--1514

National Nuclear Security Administration

Underground Test Area Fiscal Year 2013 Annual Quality Assurance Report Nevada National Security Site, Nevada

Revision No.: 0

January 2014

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/s/ Joseph P. Johnston	01/03/2014
Joseph P. Johnston, N-I CO	Date

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UNDERGROUND TEST AREA
FISCAL YEAR 2013
ANNUAL QUALITY ASSURANCE REPORT
NEVADA NATIONAL SECURITY SITE, NEVADA

U.S. Department of Energy, National Nuclear Security Administration
Nevada Field Office
Las Vegas, Nevada

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UNDERGROUND TEST AREA
FISCAL YEAR 2013
ANNUAL QUALITY ASSURANCE REPORT
NEVADA NATIONAL SECURITY SITE, NEVADA

Approved by: /s/ Bill R. Wilborn Date: 1/6/2014

Bill R. Wilborn
Underground Test Area Activity Lead

Approved by: /s/ Robert F. Boehlecke Date: 1/6/2014

Robert F. Boehlecke
Environmental Management Operations Manager

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List of Tables *(Continued)*

List of Acronyms and Abbreviations

1-D	One-dimensional
2-D	Two-dimensional
3-D	Three-dimensional
A3RWMS	Area 3 Radioactive Waste Management Site
ACTS	Assessment and Condition Tracking System
AEC	Atomic Energy Commission
Al	Aluminum
ALS	ALS Laboratory Group
Am	Americium
ANSI	American National Standards Institute
AR	Activity ratio
ARS	American Radiation Services, Inc.
BMP	Best management practice
BN	Bechtel Nevada
C	Carbon
$CaCO_3$	Calcium carbonate
CAIP	Corrective action investigation plan
CAT	Correspondence Action Tracking
CAU	Corrective action unit
CETAMA	Commission for Establishment of Analytical Methods
CFR	*Code of Federal Regulations*
Cl	Chlorine
CO_2	Carbon dioxide
Cs	Cesium
DEM	Digital elevation model
DOC	Dissolved organic carbon

List of Acronyms and Abbreviations *(Continued)*

DOE	U.S. Department of Energy
DP	Document Production
DRI	Desert Research Institute
DVRFS	Death Valley Regional Flow System
EDD	Electronic data deliverable
E/I	Event/issue
EPA	U.S. Environmental Protection Agency
Eu	Europium
FAWP	Field activity work package
FEHM	Finite Element Heat and Mass Transfer code
FFACO	*Federal Facility Agreement and Consent Order*
F&S	Fenix & Scisson, Inc.
FSN	Fenix & Scisson of Nevada
ft	Foot
FY	Fiscal year
GISP	Greenland Ice Sheet Project
^{2}H	Deuterium
^{3}H	Tritium
H_2O	Water
HASP	Health and safety plan
HDD	Hydrologic data document
He	Helium
HFM	Hydrostratigraphic framework model
HGU	Hydrogeologic unit
H&N	Holmes and Narver, Inc.
HST	Hydrologic source term

List of Acronyms and Abbreviations *(Continued)*

HSU	Hydrostratigraphic unit
I	Iodine
ICP-MS	Inductively coupled plasma-mass spectrometry
InSAR	Interferometric Synthetic Aperture Radar
IT	Information Technology
Kr	Krypton
LANL	Los Alamos National Laboratory
LCA	Lower carbonate aquifer
LCCU	Lower carbonate confining unit
LLNL	Lawrence Livermore National Laboratory
m	Meter
MAPEP	Mixed Analyte Performance Evaluation Program
MC-ICPMS	Multi-collector inductively coupled plasma mass spectrometry
mg/L	Milligrams per liter
M&TE	Measuring and test equipment
N/A	Not applicable
Nb	Niobium
NDEP	Nevada Division of Environmental Protection
NELAC	National Environmental Laboratory Accreditation Conference
N-I	Navarro-Intera, LLC
NNSA/NFO	U.S. Department of Energy, National Nuclear Security Administration Nevada Field Office
NNSS	Nevada National Security Site
NOAA	National Oceanic and Atmospheric Administration
Np	Neptunium
NSSAB	Nevada Site Specific Advisory Board
NSTec	National Security Technologies, LLC

List of Acronyms and Abbreviations *(Continued)*

NTID	Nuclear Test Information Database
NTS	Nevada Test Site
NWIS	National Water Information System
O	Oxygen
OAA	Operational awareness activity
OFI	Opportunity for improvement
pCi/L	Picocuries per liter
PEP	Performance evaluation program
PER	Preemptive review
PET	Potential evapotranspiration
PNNL	Pacific Northwest National Laboratory
POC	Point of contact
POD	Plan of the day
Pu	Plutonium
QA	Quality assurance
QAP	Quality Assurance Plan
QAPP	Quality Assurance Project Plan
Ra	Radium
Rb	Rubidium
ROTC	Record of Technical Change
RMC	Reactive mineral category
RMU	Reactive mineral unit
RPD	Relative percent difference
RREMP	Routine Radiological Environmental Monitoring Program
RSN	Raytheon Services Nevada
RST	Radiologic source term

List of Acronyms and Abbreviations *(Continued)*

S	Sulfur
SAN	Storage area network
SBMS	Standards-Based Management System
SLAP	Standard Light Antarctic Precipitation
SME	Subject matter expert
SMOW	Standard Mean Ocean Water
Sn	Tin
SOP	Standard operating procedure
SOW	Statement of work
Sr	Strontium
SSHASP	Site-specific health and safety plan
Tc	Technetium
TCU	Tuff confining unit
TDD	Transport data document
TDIC	Total dissolved inorganic carbon
TDOC	Total dissolved organic carbon
TDR	Technical Data Repository
Th	Thorium
TIC	Total inorganic carbon
TOC	Total organic carbon
U	Uranium
UGTA	Underground Test Area
UIDMS	UGTA Information and Data Management System
USGS	U.S. Geological Survey
UZ	Unsaturated zone
WIPP	Waste Isolation Project Plant

List of Acronyms and Abbreviations *(Continued)*

XRD	X-ray diffraction
XRF	X-ray fluorescence
YMP	Yucca Mountain Project
$\delta^{13}C$	Delta carbon-13
$\delta^{2}H$	Delta deuterium
$\delta^{18}O$	Delta oxygen-18
µmhos/cm	Micromhos per centimeter

1.0 Introduction

This report is required by the Underground Test Area (UGTA) Quality Assurance Plan (QAP) and identifies the UGTA quality assurance (QA) activities for fiscal year (FY) 2013. All UGTA organizations—U.S. Department of Energy (DOE), National Nuclear Security Administration Nevada Field Office (NNSA/NFO); Desert Research Institute (DRI); Lawrence Livermore National Laboratory (LLNL); Los Alamos National Laboratory (LANL); Navarro-Intera, LLC (N-I); National Security Technologies, LLC (NSTec); and the U.S. Geological Survey (USGS)—conducted QA activities in FY 2013. The activities included conducting assessments, identifying findings and completing corrective actions, evaluating laboratory performance, and publishing documents. In addition, integrated UGTA required reading and corrective action tracking was instituted.

UGTA participants conducted 19 assessments (management, shadow, operational awareness) on topics including Yucca Flat model documentation, sample analyses, and safe operations. These activities are summarized in Section 2.0. Corrective actions tracked in FY 2013 are presented in Appendix A.

Laboratory performance was evaluated based on three approaches: (1) established performance evaluation programs (PEPs), (2) interlaboratory comparisons, or (3) data review. The results of the laboratory performance evaluations are summarized in Section 3.0, and interlaboratory comparison results are presented in Appendix B.

The UGTA Activity published eight public documents and a variety of other publications in FY 2013. The titles, dates, and main authors are identified in Section 4.0.

The Contract Managers, Corrective Action Unit (CAU) Leads, Preemptive Review (PER) Committee members, and Topical Committee members are listed by name and organization in Section 5.0. UGTA procedures either issued or revised in FY 2013 are listed in Section 6.0. Other activities that affected UGTA quality are discussed in Section 7.0.

2.0 Assessment and Corrective Action Tracking

In FY 2013, NNSA/NFO directed UGTA participants to provide UGTA-related issues (including those identified outside of assessments), assessment plans, assessment reports, corrective actions, and related closure documentation to N-I for tracking and summarization on the N-I UGTA SharePoint site. This requirement did not preclude or negate using internal tracking systems even if duplicative tracking resulted.

2.1 Assessment and Condition Tracking System (ACTS)

The N-I ACTS established a uniform method for tracking, reporting, verifying, and closing corrective actions. The NNSA/NFO UGTA Quality Assurance Task Manager (see Section 7.3) verifies corrective action closures. Non-deficiencies—such as Observations, Opportunities for Improvement (OFIs), and Best Management Practices (BMPs)—can also be tracked but are optional. Participant input was proceduralized in the N-I Standards-Based Management System (SBMS) subject area "UGTA Programmatic Interfaces," procedure PA-UPI-3, "Issue Tracking." The system allows for attaching electronic assessment plans, reports, corrective actions, and verification documentation. The UGTA QA status is a standing agenda item for the monthly Contract Manager meeting.

All outstanding UGTA assessment and gap analysis corrective actions were entered into the ACTS as findings at the beginning of FY 2013. Assessments are indicated by a whole number (e.g., 562), and those conducted in FY 2013 are listed in this section under the appropriate participant. Appendix A contains the UGTA items tracked during FY 2013. Items (findings, OFIs, observations, BMPs) may be

- associated with an assessment, indicated by the assessment number followed by a sequential number (562.1, 562.2);
- found outside of an assessment, indicated by a zero before a sequential number (0.995); or
- an event/issue (E/I) indicated by EI-fiscal year-sequential number (EI-FY13-226).

Event/issues are conditions reported through an internal N-I system. If determined to be procedural violations, they are entered into ACTS, and the E/I is closed. If not, they are tracked in the E/I database, and if UGTA related, reported with the UGTA ACTS listings.

More than 100 corrective actions were entered into ACTS in FY 2013, and 69 were closed. The open corrective actions are presented in Table A-1 of Appendix A, and the closed corrective actions are presented in Table A-2. The dates reported in the "Date Opened" columns in Tables A-1 and A-2 do not represent the date the activity was conducted, but when the information was received by the UGTA ACTS administrator. Some activities, identified in response to this report's data call, were received and entered after the fiscal year end.

2.2 Nevada Field Office

NNSA/NFO conducted two oversight, one joint, and two shadow assessments. Four operational awareness activities (OAAs) were also documented. Shadow assessments evaluate participant assessments, and OAAs are documented day-to-day management activities. Table 2-1 lists these assessments.

Table 2-1
NNSA/NFO Assessments
(Page 1 of 2)

Date	Type	Number	Scope	Result
01/13/2013	Joint	ASM-AMEM-10.2.2012-469516	N-I: Application of Modeling Document Process to Yucca Flat Flow and Transport Model	3 Observations (see N-I 551)
03/29/2013	Shadow	ASM-AMEM-10.2.2012-469517	N-I: Controlled Data/Information Systems Compliance and Use	No Findings (see N-I 578)
06/20/2013	OAA	OAA-13-AMEM-BM-70313	All: Technical Bases for UGTA Baseline Planning	1 OFI (ACTS 606)
07/10/2013	OAA	OAA-13-AMEM-BM-71013	N-I: Non-Direct Data Acceptance under UGTA QAP	1 OFI (ACTS 0.1236)
07/11/2013	Oversight	ASM-AMEM-5.13.2013-511198 (ACTS 618)	LANL: Implementation of QAP Software QA Requirements for Walkabout, PlumeCalc, and FEHM	No Findings
07/25/2013	OAA	OAA-13-AMEM-BM-72513	N-I: Decision Documentation	1 OFI (ACTS 0.1235, EI-FY13-218, and EI-FY13-220)

Table 2-1
NNSA/NFO Assessments
(Page 2 of 2)

Date	Type	Number	Scope	Result
08/07/2013	Oversight	ASM-AMEM-5.13.2013-511223 (ACTS 634)	LLNL: Implementation of QAP Requirements for Sample Control, Data Documentation, Verification, and Validation for Tritium Analyses	3 Findings
08/27/2013	OAA	OAA-13-AMEM-BM-82713 (ACTS 631)	N-I: Nature and Extent of Uncontrolled Draft Technical Documents Referenced in the FFACO Deliverable	1 OFI
09/19/2013	Shadow	ASM-AMEM-10.2.2012-469513 (ACTS 643)	NSTec: Integrated Safety Management System implementation at ER-EC-15	No Findings

FEHM = Finite Element Heat and Mass Transfer code
FFACO = *Federal Facility Agreement and Consent Order*

The NNSA/NFO OAA-13-AMEM-BM-71013 resulted in an OFI (ACTS 0.1236, see Table A-2) regarding non-direct data acceptance and/or justification documentation. The corrective action plan was as follows: (1) CAU Leads will provide a list of data generated outside of UGTA activities. (2) The data will be binned and prioritized. (3) Subject matter experts (SMEs) will be assigned to complete the acceptance/justification process. (4) Identified datasets will be entered as ACTS items to track completion.

OFI 0.1236 was closed with the anticipation of additional ACTS items when the datasets were assigned to the SMEs. However, in late October 2013, a comparable E/I was issued (EI-FY14-264, see Appendix C) regarding the Yucca Flat CAU with a similar corrective action. Subsequent discussions between UGTA participants, Science Advisors, NNSA/NFO, and the Nevada Division of Environmental Protection (NDEP) have changed the corrective action described in Appendix C. This corrective action will close EI-FY14-264, and no successive ACTS items are anticipated.

2.3 Desert Research Institute

DRI conducted 2 management assessments and closed 12 corrective actions. Table 2-2 lists these assessments.

Table 2-2
DRI Assessments

Date	Type	Number	Scope	Result
09/01/2013	Management	13-UGTA-QA-1 (ACTS 649)	Model Documentation Practices	11 Findings
05/03/2013	Management	13-UGTA-ESH-1 (ACTS 588)	UGTA Well Logging and Sampling Management Safety	7 Findings, 7 OFIs, and 3 Notable Practices

2.4 Lawrence Livermore National Laboratory

LLNL's sample control, data documentation, verification, and validation for tritium analyses were assessed by NNSA/NFO, ACTS 634 (Table 2-1). LLNL closed 13 corrective actions. However, LLNL has 11 open items pertaining to ongoing investigations (see Sections 3.2 and 3.3) and procedures (see Table A-1). The investigations will impact data and the procedure revisions, but the extent has not yet been reported. Dependent on the investigation results, additional impact analyses may be necessary.

2.5 Los Alamos National Laboratory

LANL's implementation of the QAP Software QA requirements for Walkabout, PlumeCalc, and FEHM were assessed by NNSA/NFO, ACTS 618 (Table 2-1). LANL closed one corrective action.

2.6 National Security Technologies, LLC

NSTec conducted one assessment on drilling operations that was shadowed by NNSA/NFO. Table 2-3 lists these assessments.

Table 2-3
NSTec Assessments

Date	Type	Number	Scope	Result
09/19/2013	Management	MA-13-H000-011 (ACTS 642)	Integrated Safety Management System Field Operations	1 OFI and 1 BMP

2.7 Navarro-Intera, LLC

N-I conducted five assessments. Independent and vendor assessments are conducted by N-I QA personnel. One E/I was entered into ACTS as an assessment with two findings. N-I closed 36 corrective actions. Table 2-4 lists these assessments.

Table 2-4
N-I Assessments

Date	Type	Number	Scope	Result
11/30/2012	Management	554	Review Field Documentation	1 OFI and 5 BMPs
12/18/2012	Vendor	572	Vendor's Ability To Meet Requirements	No Findings
01/08/2013	Independent	551	Application of Modeling Document Process to Yucca Flat Flow and Transport Model	3 Observations
02/28/2013	Independent	573	External Communications and Coordination of Quality and Safety Requirements	3 OFIs
03/29/2013	Management	578	Controlled Data/Information Systems Compliance	1 Finding, 5 OFIs, 4 Observations, and 3 BMPs
05/07/2013	E/I	606	Colloid Data Not Considered in Development or Review of Model Document	2 Findings

2.8 U.S. Geological Survey

USGS conducted one management assessment and closed six corrective actions. Table 2-5 lists the assessment.

Table 2-5
USGS Assessments

Date	Type	Number	Scope	Results
06/24/2013	Management	USGS-QA-2013A	Water-Level Collection	3 Findings

3.0 Performance Evaluation Programs

Laboratories that provide analytical data for the UGTA Activity include ALS Laboratory Group (ALS); American Radiation Services, Inc. (ARS); DRI; LANL; LLNL; and USGS. Analyses performed by each lab are presented in Table 3-1. Laboratories are required to be certified by NDEP Bureau of Safe Drinking Water or approved by NDEP Bureau of Federal Facilities. The commercial laboratories (ALS and ARS) are certified by NDEP Bureau of Safe Drinking Water. Other UGTA analyses are not covered under the NDEP certification program and therefore require NDEP Bureau of Federal Facilities approval. These analyses support UGTA characterization and model evaluation activities as follows:

- Naturally occurring stable and radioactive isotopes are measured to evaluate groundwater flow paths and travel times. These measurements require lower detection limits than standard methods and include analytes not certified by NDEP Bureau of Safe Drinking Water.
- Mobile radioisotopes are measured at the lowest possible concentrations to characterize contaminant extent for developing and evaluating conceptual and numerical flow and transport models. These measurements require lower detection limits than standard methods.

The UGTA QAP and the DOE Quality Systems for Analytical Services manual require laboratories to evaluate performance by participating in PEPs. In cases where established PEPs are not available, laboratory performance was assessed through interlaboratory comparisons and data evaluations. The results of these evaluations are presented in the following subsections.

3.1 Established PEPs

All data reported by ALS and ARS met the contractor's Statement of Work (SOW) compliance criteria. These laboratories participated in the following PEPs (Table 3-1):

- RadCheM and MRaD (trademarked programs) conducted by Environmental Resources Associates
- MAPEP conducted by the Radiological and Environmental Sciences Laboratory
- NELAC Fields of Testing for Clean Water Act and Safe Drinking Water Act conducted by Sigma-Aldrich, Resource Technology Corporation

Table 3-1
Analytes, Detection Limits, and PEPs
(Page 1 of 2)

<table>
<tr><th>Analyte</th><th>Detection Limit</th><th>PEP</th><th>Analyte</th><th>Detection Limit</th><th>PEP</th></tr>
<tr><td colspan="6">Commercial Laboratory</td></tr>
<tr><td>Alkalinity
(Carbonate and Bicarbonate)</td><td>20 mg/L
as $CaCO_3$</td><td rowspan="8">NELAC</td><td>Gross Alpha and Gross Beta</td><td>3 pCi/L
(Gross Alpha)</td><td>RadCheM</td></tr>
<tr><td>pH</td><td>0.01 pH unit</td><td>^{14}C</td><td>500 pCi/L</td><td rowspan="2">Evaluation</td></tr>
<tr><td>Specific Conductance</td><td>1.0 µhos/cm</td><td>^{36}Cl</td><td>4 pCi/L</td></tr>
<tr><td>Total Dissolved Solids</td><td>20 mg/L</td><td>^{90}Sr</td><td>1 pCi/L</td><td>MAPEP
MRaD
RadCheM</td></tr>
<tr><td>TOC</td><td>1 mg/L</td><td>^{238}Pu and $^{239/240}Pu$</td><td>0.1 pCi/L</td><td>MAPEP
MRaD</td></tr>
<tr><td>Total Sulfide</td><td>2.0 mg/L</td><td>Uranium</td><td>0.0001 mg/L</td><td>NELAC
MAPEP
MRaD</td></tr>
<tr><td>Total Suspended Solids</td><td>20 mg/L</td><td>Tritium
(Low Level)</td><td>3 pCi/L</td><td>Data
Evaluation</td></tr>
<tr><td>Inorganic Anions
(Bromide, Chloride,
Fluoride, Sulfate)</td><td>0.25–1 mg/L</td><td>Tritium
(Standard)</td><td>300 pCi/L</td><td>MAPEP
MRaD
RadCheM</td></tr>
<tr><td>Metals
(Aluminum, Arsenic, Barium, Cadmium, Calcium, Chromium, Iron, Lead, Lithium, Magnesium, Manganese, Potassium, Selenium, Silicon, Silver, Sodium, Strontium)</td><td>0.001–1.0 mg/L</td><td rowspan="2">NELAC
MAPEP</td><td>Gamma Emitters
(^{26}Al, ^{94}Nb, ^{137}Cs, ^{152}Eu, ^{154}Eu, ^{235}U, ^{241}Am, ^{243}Am)</td><td>10 pCi/L ^{137}Cs [a]</td><td>RadCheM [b]
MAPEP
MRaD</td></tr>
<tr><td>Mercury</td><td>0.0002 mg/L</td><td colspan="3"></td></tr>
<tr><td colspan="6">DRI</td></tr>
<tr><td>DOC [c]</td><td>--</td><td>--</td><td>^{14}C (DOC) [c]</td><td>--</td><td>--</td></tr>
<tr><td colspan="6">LANL</td></tr>
<tr><td>Tritium
(Standard)</td><td>--</td><td>Comparison</td><td>Gamma Emitters [d]
(^{26}Al, ^{94}Nb, ^{137}Cs, ^{121m}Sn, ^{126}Sn, ^{152}Eu, ^{154}Eu, ^{235}U, ^{241}Am, ^{243}Am)</td><td>0.02–15 pCi/L</td><td>Comparison</td></tr>
</table>

Table 3-1
Analytes, Detection Limits, and PEPs
(Page 2 of 2)

Analyte	Detection Limit	PEP	Analyte	Detection Limit	PEP
LLNL					
^{14}C (TIC)	~10^{-3} pCi/L	Comparison	^{129}I [c]	10^{-7} pCi/L	Evaluation
^{36}Cl [c]	10^{-6} pCi/L	Evaluation	Tritium (Low Level)	1 pCi/L	Comparison CETAMA (strontium and uranium)
δ^{2}H and δ^{18}O	--		^{86}Sr/^{87}Sr	--	
$^{3/4}$He [c]	--		^{234}U/^{238}U AR	--	
δ^{13}C	--	Comparison			
USGS					
^{86}Sr/^{87}Sr	--	Comparison	^{34}S	--	Evaluation
^{234}U/^{238}U AR	--				

[a] Detection limits for gamma emitters are based on ^{137}Cs.
[b] Only ^{137}Cs included in RadCheM.
[c] The results for these analyses are not available at this time.
[d] Radioisotopes with detection limits greater than the Safe Drinking Water Act maximum contaminant limit (CFR) are not shown.

Al = Aluminum
Am = Americium
AR = Activity ratio
C = Carbon
$CaCO_3$ = Calcium carbonate
CETAMA = Commission for Establishment of Analytical Methods
CFR = *Code of Federal Regulations*
MAPEP = Mixed Analyte Performance Evaluation Program
mg/L = Milligrams per liter
Cl = Chlorine
Cs = Cesium
DOC = Dissolved organic carbon
Eu = Europium
He = Helium
I = Iodine
Nb = Niobium
NELAC = National Environmental Laboratory Accreditation Conference
pCi/L = Picocuries per liter
Pu = Plutonium
S = Sulfur
Sn = Tin
Sr = Strontium
TIC = Total inorganic carbon
TOC = Total organic carbon
U = Uranium
δ^{13}C = Delta carbon-13
δ^{2}H = Delta deuterium
δ^{18}O = Delta oxygen-18
μhos/cm = Micromhos per centimeter

-- = Not applicable

PEP reports are business proprietary information and can be provided to NDEP upon request. These reports are Official Use Only. With two exceptions, laboratory results were within the acceptable limits. Unacceptable results were reported for selenium by U.S. Environmental Protection Agency (EPA) method 200.7, *Determination of Metals and Trace Elements in Water and Wastes by Inductively Coupled Plasma-Atomic Emission Spectrometry,* in the NELAC round WS13-1 with successful recovery in the subsequent WS13-3. Failure for bromide by EPA method 300.0, *Determination of Inorganic Anions by Ion Chromatography,* in round WS13-3 will be monitored for future performance.

LLNL successfully participated in a CETAMA performance evaluation program for elemental strontium and uranium.

3.2 Interlaboratory Comparisons

Laboratory performance was also assessed by comparing analytical results from independent laboratories with respect to established acceptance criteria (see Appendix B). Samples collected from four new UGTA wells were included in the comparison (Table 3-2). Two wells (ER-EC-12 and ER-EC-13) were sampled from two depth intervals. Some samples were collected before FY 2013; however, they were analyzed during FY 2013 and are included in the comparison.

Table 3-2
Sampled Wells

Sampling Location	Date
ER-EC-12 (Shallow)	11/27/2011
ER-EC-12 (Intermediate)	03/26/2012
ER-EC-13 (Intermediate)	07/12/2012 07/13/2012
ER-EC-13 (Deep)	03/28/2013 03/29/2013
ER-11-2	07/14/2013
ER-5-5	05/11/2013 05/16/2013

The interlaboratory comparison results are presented in Appendix B. Field duplicate samples were analyzed by ALS, and the average of the duplicates was used for the comparisons. In some cases, an analysis was performed by three labs. For these, all combinations of the analyses were compared and the range of results presented unless otherwise noted. Absolute differences are reported for $^{87}Sr/^{86}Sr$ and $^{234}U/^{238}U$ AR; and relative percent differences (RPDs) are reported for all others.

All comparison results meet the acceptance criteria (see Appendix B). With the exception of tritium, the RPDs were all within the 25 percent acceptance criteria. Tritium was near the ARS detection limit of 2.3 pCi/L. Because a low-level tritium PEP is not commercially available, one laboratory was required to perform and document an annual demonstration of capability. The demonstration of capability verified the laboratory met the performance requirement as activity levels were within established lower and upper confidence limits.

The LLNL and USGS $^{87}Sr/^{86}Sr$ and $^{234}U/^{238}U$ AR results were also well within the 0.0005 and 0.3 criteria. The remaining radioisotopes were below the detection limits and were therefore acceptable.

The commercial laboratory and LLNL detection limit differences precluded an interlaboratory comparison of ^{14}C, ^{36}Cl, and ^{129}I. To evaluate ^{14}C analysis, an ER-EC-13 (Deep) sample was submitted to the National Science Foundation-Arizona Accelerator Mass Spectrometry Laboratory at the University of Arizona. The RPD for ^{14}C (157 percent) exceeded the 25 percent acceptance criteria (Table 3-3). This was identified as an issue and entered into the ACTS to track corrective action (see Appendix A, Table A-1, EI-FY13-239).

Table 3-3
Interlaboratory Comparison for Carbon Isotopes

Laboratory	$\delta^{13}C$ (per mil)	^{14}C (percent modern carbon)
LLNL	0.05 [a] / -1.4 [b]	41
University of Arizona	-2.8 [c]	5.0

[a] Sample was preserved.
[b] Sample was filtered.
[c] Sample was not filtered or preserved.

LLNL is currently investigating the $\delta^{13}C$ differences observed between DRI and LLNL reported in the FY 2012 UGTA Quality Assurance Report (see Appendix A, Table A-1, ACTS 0.984). The investigation included evaluating samples that were filtered consistent with the DRI method and samples preserved with mercuric chloride (no sample filtration) consistent with LLNL method. The $\delta^{13}C$ values for the preserved samples were lower than the filtered samples (Table 3-3). An unfiltered sample was also analyzed by the University of Arizona and was lower than both samples analyzed at LLNL. It has been determined that the sample preparation techniques impact analytical results. LLNL will publish the investigation results.

3.3 Data Evaluation

A data evaluation was conducted for commercial laboratory analysis of ^{14}C and ^{36}Cl, and USGS analysis of ^{34}S. The data evaluation included reviewing standard operating procedures (SOPs), laboratory quality control sample results, and calibration standard results. Data verification and validation documentation was also reviewed. The evaluations determined that the samples were collected and analyzed appropriately, and met data validation criteria.

LLNL is currently investigating the differences in $\delta^{2}H$ and $\delta^{18}O$ results (ACTS 0.984) that were reported in the FY12 UGTA Quality Assurance Report. LLNL identified an issue with respect to the calibration standards; and is in the process of reanalyzing samples, flagging impacted data, revising their standard operating procedure, and closing the ACTS issue. The $^{3/4}He$, ^{36}Cl, and ^{129}I results were not yet available.

4.0 Published Documents (Revision 1 and Public Released) with List of Authors

4.1 Publications by UGTA Activity

Andrews, R.W., E. Kwicklis, E. Keating, A. Tompson, and M. Zavarin. 2013. *Phase I Flow and Transport Model Document for Corrective Action Unit 97: Yucca Flat/Climax Mine, Nevada National Security Site, Nye County, Nevada,* Rev. 1, N-I/28091--080. Las Vegas, NV.

Andrews, R.W., E. Kwicklis, E. Keating, A. Tompson, and M. Zavarin 2013. *Yucca Flat/Climax Mine CAU Flow and Transport Model, Nevada National Security Site, Nye County, Nevada*, Rev. 0, N-I/28091--065. Las Vegas, NV: Navarro-Intera, LLC.

Gonzales, J.L., S.L. Drellack, and M.J. Townsend. 2013. *Completion Report for Model Evaluation Well ER-5-5, Corrective Action Unit 98: Frenchman Flat,* DOE/NV--1496. Las Vegas, NV.

Huckins-Gang, H.E., S.L Drellack, and M.J. Townsend. 2013. *Completion Report for Well ER-20-11, Corrective Action Units 101 and 102: Central and Western Pahute Mesa,* DOE/NV--1498. Las Vegas, NV.

Krenzien, S.K., and I.M. Farnham. 2012. *Underground Test Area Activity Quality Assurance Plan, Nevada National Security Site, Nevada*, DOE/NV--1450-REV.1. Las Vegas, NV.

Krenzien, S.K., and I.M. Farnham. 2013. *Underground Test Area Fiscal Year 2012 Annual Quality Assurance Report*, DOE/NV--1494, Rev. 0. Las Vegas, NV.

Mercadante, J.M., L.B. Prothro, and M.J. Townsend. 2013. *Completion Report for Model Evaluation Well ER-11-2, Corrective Action Unit 98: Frenchman Flat,* DOE/NV--1497. Las Vegas, NV.

Reed, D.N., L.B. Prothro, and M.J. Townsend. 2013. *Completion Report for Well ER-EC-14, Corrective Action Units 101 and 102: Central and Western Pahute Mesa,* DOE/NV--1499. Las Vegas, NV.

4.2 Other Publications by UGTA Authors

Cooper, C.A., R.L. Hershey, J.M. Healey, and B.F. Lyles. 2013. *Estimation of Groundwater Recharge at Pahute Mesa Using the Chloride Mass-Balance Method,* Publication No. 45251. Reno, NV: Desert Research Institute, Water Resources Center.

Fereday, W. 2013. *Dating Groundwater Using Dissolved Organic Carbon and Estimating Flow Path Travel Times in Southern Nevada Aquifers*, M.S. thesis. University of Nevada, Reno.

Garcia, C.A., K.J. Halford, and J.M. Fenelon. 2013. "Detecting Drawdowns Masked by Environmental Stresses with Water-Level Models." In *Groundwater*, Vol. 51(3): pp. 322–332.

Jasoni, R.L., J.D. Larsen, B.F. Lyles, J.M. Healey, C.A. Cooper, R.L. Hershey, and K.J. LeFebre. 2013. *Evapotranspirative Water Losses from Sagebrush and Pinyon-Pine/Juniper Ecosystems at Pahute Mesa, Nevada National Security Site, 2011–2012,* Publication No. 45248. Reno, NV: Desert Research Institute, Water Resources Center.

Lyles, B.F., G. McCurdy, C. Russell, and J.M. Healey. 2013. *Timber Mountain Precipitation Monitoring Station: 2012 Annual Report*. Letter Report to U.S. Department of Energy, National Nuclear Security Administration Nevada Field Office. Las Vegas, NV: Desert Research Institute, Water Resources Center.

Paces, J.B., P.J. Nichols, L.A. Neymark, and H. Rajaram. 2013. "Evaluation of Pleistocene Groundwater Flow through Fractured Tuffs Using a U-series Disequilibrium Approach, Pahute Mesa, Nevada, USA." In *Chemical Geology*, Vol. 358: pp. 101–118.

Ruskauff, G. J., and R.W. Andrews. 2012. *Evaluation of Software Errors and Issues, and Software Impact Assessment for Frenchman Flat, Nevada National Security Site, Nye County, Nevada*, Rev. 1, N-I/28091--063. Las Vegas, NV.

Zavarin, M., S.K. Roberts, M.R. Johnson, Q. Hu, B.A. Powell, P. Zhao, A.B. Kersting, R.E. Lindvall, and R.J. Pletcher. 2013. *Colloid-Facilitated Radionuclide Transport in Fractured Carbonate Rock from Yucca Flat, Nevada National Security Site*, LLNL-TR-619352. Livermore, CA: Lawrence Livermore National Laboratory.

Zhang, Y., E.M. LaBolle, D.M. Reeves, and C. Russell. 2012. *Development of RWHet to Simulate Contaminant Transport in Fractured Porous Media*, DOE/NV/0000939-01; Publication No. 45244. Prepared for the U.S. Department of Energy, National Nuclear Security Administration Nevada Site Office. Reno, NV: Desert Research Institute, Water Resources Center.

5.0 Key Personnel

Gayle Pawloski (LLNL) and Irene Farnham (N-I) were named as the UGTA Science Advisors when Bruce Crowe (N-I) retired. Robert Graves was made Acting USGS Contract Manager on Bonnie Thompson's retirement. Dan Levitt was appointed Acting LANL Contract Manager. Subsequent to Sept. 30, 2013, Kay Birdsell replaced Dan Levitt.

5.1 Contract Managers

Each organization assigns a Contract Manager responsible for managing the participant's tasks. There is a monthly Contract Manager meeting with NNSA/NFO. Table 5-1 lists each manager by organization.

Table 5-1
Contract Managers by Organization

Name	Organization
Chuck Russell	DRI
Dan Levitt (Acting)	LANL
Andrew Thompson	LLNL
Sam Marutzky	N-I
Ken Ortego	NSTec
Robert Graves (Acting)	USGS

5.2 CAU Leads and Science Advisors

A CAU Lead is assigned for each UGTA CAU. CAU Leads coordinate CAU-specific technical scope and priorities with other CAU Leads, focus PER Committee reviews, and communicate progress. There is a monthly CAU Lead meeting with NNSA/NFO. Table 5-2 lists the CAU Leads and their respective organizations.

The Science Advisor, Bruce Crowe, was replaced by Gayle Pawloski and Irene Farnham. They act as independent advisors for technical topics, activity strategies, and conceptual-model development; application of flow and transport models; uncertainty and sensitivity analyses; compliance with environmental standards; and data collection. They are also members of every PER Committee.

Table 5-2
CAU Leads by Organization and CAU

Name	Organization	CAU
Chuck Russell	DRI	Rainier Mesa/Shoshone Mountain
Greg Ruskauff	N-I	Frenchman Flat
Greg Ruskauff	N-I	Central and Western Pahute Mesa
Ed Kwicklis	LANL	Yucca Flat/Climax Mine

5.3 *Preemptive Review Committee Members*

The CAU-specific PER Committees provide internal technical review of ongoing work throughout the CAU life cycle. Table 5-3 lists the members by organization.

Table 5-3
PER Committee Membership
(Page 1 of 2)

Name	Organization
CAU 97, Yucca Flat/Climax Mine	
Matt Reeves	DRI
Chuck Russell	DRI
Gayle Pawloski, Science Advisor	LLNL
Andrew Tompson, Chair	LLNL
Mavrik Zavarin	LLNL
Britt Jacobson, ex-officio	NDEP
Irene Farnham, Science Advisor	N-I
Keith Halford	USGS
CAU 98, Frenchman Flat	
Jenny Chapman	DRI
Dan Levitt	LANL
Gayle Pawloski, Science Advisor	LLNL
Andrew Tompson	LLNL
Mark McLane, ex-officio	NDEP
Irene Farnham, Science Advisor	N-I
Margaret Townsend	NSTec
Joe Fenelon, Chair	USGS

Table 5-3
PER Committee Membership
(Page 2 of 2)

Name	Organization
CAU 99, Rainier Mesa/Shoshone Mountain	
Kay Birdsell	LANL
Dave Finnegan, Co-chair	LANL
Gayle Pawloski, Science Advisor	LLNL
Andrew Tompson	LLNL
Mavrik Zavarin, Co-chair	LLNL
Britt Jacobson, ex-officio	NDEP
Bob Andrews	N-I
Irene Farnham, Science Advisor	N-I
Margaret Townsend	NSTec
Joe Fenelon	USGS
CAUs 101 and 102, Central and Western Pahute Mesa	
Karl Pohlmann	DRI
Elizabeth Keating	LANL
Gayle Pawloski, Science Advisor	LLNL
Tim Rose	LLNL
Mark McLane, ex-officio	NDEP
Bob Andrews	N-I
Irene Farnham, Science Advisor	N-I
Margaret Townsend	NSTec
Wayne Belcher, Chair	USGS

5.4 Topical Committee Members

Topical Committees may be formed on an *ad hoc* basis to address items such as non-CAU-specific issues, questions, concerns, and readiness. The committees may be disbanded when their scope is complete. Table 5-4 lists the current committees and membership.

Table 5-4
Topical Committee Membership

Name	Organization
Modeling	
Matt Reeves	DRI
Ed Kwicklis	LANL
Andrew Tompson, Chair	LLNL
Bob Andrews	N-I
Bimal Mukhopadhyay	NNSA/NFO
Keith Halford	USGS
Sampling Plan	
Jenny Chapman	DRI
Dave Finnegan	LANL
Dan Levitt	LANL
Mavrik Zavarin	LLNL
Irene Farnham, Chair	N-I
Kathryn Knapp	NNSA/NFO
Sig Drellack	NSTec
Ted Redding	NSTec
Joe Fenelon	USGS
Jim Paces	USGS
Well Purging and Sampling Methods	
Chuck Russell, Chair	DRI
Dan Levitt	LANL
Mavrik Zavarin	LLNL
Jeff Sanchez	N-I
Jeff Wurtz	N-I
Kathryn Knapp	NNSA/NFO
Ken Ortego	NSTec
Terry Sonnenburg	NSTec
Robert Graves	USGS

5.5 Drilling Advisory Committees

Drilling advisory teams make real-time decisions to facilitate meeting well objectives and completing wells. Currently, only the Pahute Mesa drilling committee is active. Table 5-5 contains the membership list.

Table 5-5
Drilling Advisory Committee Membership

Name	Organization
Pahute Mesa	
Chuck Russell	DRI
Ed Kwicklis	LANL
Gayle Pawloski, Chair	LLNL
Mavrik Zavarin	LLNL
Mark McLane	NDEP
Irene Farnham, Science Advisor	N-I
Greg Ruskauff	N-I
Jeff Wurtz	N-I
Bill Wilborn	NNSA/NFO
Sig Drellack	NSTec
Ken Ortego	NSTec
Joe Fenelon	USGS

6.0 Procedures

The FY 2012 UGTA Quality Assurance Report provided an UGTA procedure matrix that closed the QAP implementation process. Table 6-1 presents UGTA procedures that were developed or revised in FY 2013. Most revisions were identified as corrective actions to assessment findings.

Table 6-1
UGTA Procedures
(Page 1 of 3)

Title	Number	Rev.	Date
DRI			
Procedures for Numerical Modeling Activities Conducted for UGTA Tasks Under the DRI Research, Engineering, and Development Services Contract for the DOE/National Nuclear Security Administration	--	--	01/07/2013
Data Information Implementation Plan	DIIP	1	07/20/2013
Standard Operating Procedure for Data/Information Management	SOP.DIM	3.1	03/11/2013
UGTA Document Review Sheet	--	--	12/20/2012
Desert Research Institute DOE/NNSA Security Program Standard Operating Procedure 150.1 - Photography and Special Permits Policy	SOP 150.1	--	03/13/2013
Standard Operating Procedure for Use of the Idronaut Geochemical Tool	SOP.Idronaut	2	03/11/2013
Standard Operating Procedure for Collecting ^{2}H, ^{18}O, ^{13}C, and ^{3}H Groundwater Samples	SOP.Isotopes	2	02/30/2013
Standard Operating Procedure for Collecting ^{2}H, ^{18}O, ^{13}C, and ^{3}H Groundwater Samples	SOP.Isotopes	2.1	09/30/2013
Standard Operating Procedure for Recording Laboratory and Field Activities	SOP.RLFA	2	03/11/2013
Standard Operating Procedure for Shipping and Control of Groundwater Samples	SOP.SCGW	3	03/11/2013
Standard Operating Procedure for Use of the Thermal Flow Meter	SOP.TFM	3	03/11/2013
Laboratory Standard Operating Procedure - Preparation of Water Samples for Dissolved Organic Carbon, Carbon-14 Analysis by Accelerator Mass Spectrometry	DO14C.SOP	1.4	09/24/2013

Table 6-1
UGTA Procedures
(Page 2 of 3)

Title	Number	Rev.	Date
LLNL			
Management of Samples and Records	SOP-UGTA-109	3	08/05/2013
Analysis of ^{99}Tc in Aqueous Samples	SOP-UGTA-111	5	09/30/2013
Analysis of ^{36}Cl in Aqueous Samples	SOP-UGTA-115	5	09/30/2013
^{87}Sr/^{86}Sr Analysis of Groundwater Samples	SOP-UGTA-117	5	09/30/2013
Uranium Isotopic Analysis of Groundwater Samples	SOP-UGTA-118	6	09/30/2013
Determination of Inorganic Anions by Ion Chromatography	SOP-UGTA-120	4	09/30/2013
Liquid Scintillation Counting Method for Analysis of Tritium in Groundwater Sample using a Tritium Column	SOP-UGTA-131	2	09/28/2013
Purification of Plutonium from Groundwater Samples for Analysis by MC-ICPMS	SOP-UGTA-135	2	09/30/2013
Collection and Analysis of Groundwater for Determination of Tritium by Helium-3 Accumulation	SOP-NGMS-121	5	08/2013
Quality Assurance and Control Requirements for Employing Numerical Simulation Codes Supporting Underground Test Area Project Hydrologic Source Term Models at Lawrence Livermore National Laboratory	--	--	01/30/2013
LANL			
Procedures for Archiving and Documenting EES-16-developed and EES-16-modified Software	EES-16-13-002	--	01/25/2013
NSTec			
Geology Job Orientation and Mentoring	OP-2151.201	1	05/02/2013
Geologic Mapping	OP-2151.202	1	05/02/2013
Rock Descriptions	OP-2151.203	1	05/02/2013
Handling and Documenting Geologic Samples	OP-2151.204	1	05/02/2013
Data Validation and Reporting	OP-2151.206	1	05/02/2013
Schmidt Hammer Measurements	OP-2151.207	1	05/02/2013
General Field Instruction for Geotechnical Activities	OP-2151.208	1	05/02/2013
Geologic Well-Site Support	OP-2151.209	1	05/02/2013

Table 6-1
UGTA Procedures
(Page 3 of 3)

Title	Number	Rev.	Date
N-I			
Annual Quality Assurance Report	PA-UPI-1	--	01/08/2013 07/13/2013
UGTA Information and Data Management System (UIDMS) Submittal	PA-UPI-2	--	01/08/2013 07/13/2013
Issue Tracking	PA-UPI-3	--	01/08/2013 07/13/2013
USGS			
U.S. Geological Survey, Nevada Water Science Center, Procedure for Manually Measuring Depth-to-Water with Steel Tapes, Electric Tapes, and Wirelines for the U.S. Department of Energy, National Nuclear Security Administration	USGS-WLCOLLECT- 01	2	09/19/2013
U.S. Geological Survey, Nevada Water Science Center, Procedure for Pressure Transducer Installation, Calibration, Data Collection, and Removal for the U.S. Department of Energy, National Nuclear Security Administration	USGS-TRANSINSTAL-01	3	09/19/2013

-- = Not applicable

^2H = Deuterium
^3H = Tritium
MC-ICPMS = Multi-collector inductively coupled plasma mass spectrometry
O = Oxygen
Tc = Technetium

7.0 Other Activities

7.1 UGTA Communication/Interface Plan

The UGTA Communication/Interface Plan was developed to provide guidelines for effective communication and interfaces between UGTA participants. The plan establishes the following:

- UGTA mission and vision
- Roles and responsibilities for key personnel
- Communication with stakeholders
- Guidance in key interface areas (such as developing task plans and new work scope; monthly reporting; reviews; and issue identification, resolution, and tracking)
- Communication Matrix

The plan is a living document that resides on the UGTA SharePoint home page and is version controlled through the Technical Data Repository (TDR). The current plan is revision 2, dated March 2013.

7.2 Preemptive Review Guidance

The UGTA participants developed PER guidance to formalize the initiation, membership, review, comment resolution, closeout and follow-up for the committees. This document is also a living document on the UGTA SharePoint home page and is controlled through the TDR. The current guidance is revision 0, dated March 2013.

7.3 NNSA/NFO Task Managers

NNSA/NFO federal task managers for QA and sampling/analysis were assigned to the UGTA Activity. Their names and responsibilities are described in the following subsections. Bimal Mukhopadhyay remains the Modeling Task Manager, and Bill Wilborn is both the Activity Lead and Field Activity Task Manager.

7.3.1 Quality Assurance

Bruce Stolte is the QA Task Manager. His responsibilities, as outlined in the UGTA Communication/Interface Plan, are as follows:

- Serves as the point of contact (POC) for the UGTA QA Program.
- Oversees, conducts, and/or shadows UGTA compliance assessments.
- Reviews notifications, corrective actions plans, and closeout for issues submitted to the ACTS and/or CAWeb (NSTec and NNSA/NFO tracking system).
- Monitors, tracks, and reports on status of QA issues.
- Sends out annual QA report data call and provide primary review of draft report.
- Acts as the NNSA/NFO POC to NDEP QA representative.

7.3.2 Sampling and Analysis

Kathryn Knapp is the Sampling and Analysis Task Manager. Her responsibilities, as outlined in the UGTA Communication/Interface Plan, are as follows:

- Oversees analytical laboratory activities.
- Oversees the Nevada National Security Site (NNSS) Integrated Sampling Plan.
- Oversees long-term monitoring activities.
- Integrates UGTA sampling and analysis with other NNSA/NFO Activities (Routine Radiologic Environmental Monitoring, Community Environmental Monitoring).
- Oversees activities associated with biosphere exposure pathway risk

7.4 Required Reading

The required reading list is housed on the UGTA SharePoint home page and identifies those personnel needing the training. The list was compiled to identify documents for training and requirement flow down. Participants acknowledge their reading by checking boxes within the Project Contacts list. The Project Contacts list is readily sorted by documents read. Current assignments include the communication plan and QAP for all participants, and the PER guidance for PER Committee members.

8.0 Conclusion

The UGTA Activity QA program concentrated on establishing processes for tracking issues, managing data, and ensuring models are documented. With the addition of an NNSA/NFO QA task manager and formal issue tracking, the UGTA Activity has become more rigorous in QA process implementation and assessments.

9.0 References Not Included in Section 4.0

CFR, see *Code of Federal Regulations.*

Code of Federal Regulations. 2013. Title 40 CFR, Part 141, "National Primary Drinking Water Regulations." Washington, DC: U.S. Government Printing Office.

U.S. Department of Energy. 2013. *Quality Systems for Analytical Services*, Revision 2.9. Oak Ridge, TN: U.S. Department of Energy Consolidated Audit Program.

U.S. Department of Energy, National Nuclear Security Administration Nevada Field Office. 2013. Written communication. Subject: *Nevada National Security Site Integrated Groundwater Sampling Plan*. Las Vegas, NV.

U.S. Department of Energy, National Nuclear Security Administration Nevada Site Office. 2012. *Underground Test Area Activity Quality Assurance Plan, Nevada National Security Site, Nevada*, DOE/NV--1450, Rev. 1. Las Vegas, NV.

U.S. Environmental Protection Agency. 1993. *Method 300.0: Determination Of Inorganic Anions By Ion Chromatography*, Rev. 2.1. Cincinnati, OH: Environmental Monitoring Systems Laboratory, Office of Research and Development.

U.S. Environmental Protection Agency. 1994. *Method 200.7: Determination of Metals and Trace Elements in Water and Wastes by Inductively Coupled Plasma-Atomic Emission Spectrometry*, Rev. 4.4. Cincinnati, OH: Environmental Monitoring Systems Laboratory, Office of Research and Development.

Appendix A

Corrective Actions Tracked FY 2013

Table A-1
Open Corrective Actions
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Tracking #	Reference #	Date Opened[a]	Due Date	Type	Participant	Deficient Condition	Corrective Actions
0.984	EI-FY13-162	01/15/2013	08/01/2013+	Observation	LLNL	Some interlaboratory stable isotope results do not agree within the acceptance criteria required by the UGTA QAP, Section 2.3.3.2.	Points of contact at LLNL and LANL were notified, and data were flagged in the database. $\delta^{2}H/\delta^{18}O$ (1) An evaluation performed by LLNL determined that the working standard may have drifted from its original stable isotope composition. (2) LLNL will recalibrate their working standard values against three international reference standards (SMOW, GISP, and SLAP). (3) LLNL will make sure these reference standards are stored in containers that minimize exchange with the atmosphere. (4) LLNL will reanalyze samples. (5) New sample results will be compared to historical values and to those of DRI. (6) The LLNL SOP will be revised to require an accuracy check of the working standard every four years using an international standard or every year using a standard contained in a sealed ampule. $\delta^{13}C$ (1) An evaluation performed by LLNL determined that the discrepancy is probably a result of (a) DRI not preserving samples and LLNL preserving samples (i.e., preliminary results suggest that unpreserved samples tend to result in lower $\delta^{13}C$ than preserved), and (b) too much time is passed before the samples are analyzed. (2) LLNL will evaluate the N-I sampling procedure and identify whether additional clarification needs to be added. (3) LLNL will design an experiment to prove and eliminate the two discrepancy sources identified above. (4) The experiment will be performed for the samples collected from the two Frenchman Flat wells. (5) The LLNL SOP will be revised to incorporate the lessons learned.

Table A-1
Open Corrective Actions
(Page 2 of 8)

Tracking #	Reference #	Date Opened[a]	Due Date	Type	Participant	Deficient Condition	Corrective Actions
0.985	EI-FY13-163	01/15/2013	02/28/2014	OFI	N-I	Underground test information is not always reported consistently between investigators or consistent with the UGTA Nuclear Test Information Database (NTID).	References to the cavity radii were removed from the presentation. Radii values were made consistent within the Yucca Flat/Climax Mine CAU Flow and Transport Model document. Science Advisors will form a committee to include the N-I Classification Officer and UGTA Derivative Classification Reviewers to determine and implement the best approach for maintaining consistency and keeping the database current.
0.988	UGTA Gap Analysis	01/15/2013	09/30/2013+	Finding	LLNL	Requirement for analysis of major cations and trace elements not documented in a procedure or process.	SOP will be revised, and a checklist will be developed for data verification and validation.
0.990	UGTA Gap Analysis	01/15/2013	09/30/2013+	Finding	LLNL	Requirement for TDIC/TDOC not documented in a procedure or process.	SOP will be revised, and a checklist will be developed for data verification and validation.
0.991	UGTA Gap Analysis	01/15/2013	09/30/2013+	Finding	LLNL	Requirement for $\delta^{13}C$ not documented in a procedure or process.	SOP will be revised, and a checklist will be developed for data verification and validation.
0.992	UGTA Gap Analysis	01/15/2013	09/30/2013+	Finding	LLNL	Requirement for ^{14}C not documented in a procedure or process.	SOP will be revised, and a checklist will be developed for data verification and validation.
0.993	UGTA Gap Analysis	01/15/2013	09/30/2013+	Finding	LLNL	Requirement for ^{129}I not documented in a procedure or process.	SOP will be revised, and a checklist will be developed for data verification and validation.
0.1000	UGTA Gap Analysis	01/15/2013	09/30/2013+	Finding	LLNL	Requirement for $\delta^{2}H$ and $\delta^{18}O$ not documented in a procedure or process.	SOP will be revised, and a checklist will be developed for data verification and validation.
0.1006	UGTA Gap Analysis	01/15/2013	09/30/2013+	Finding	LLNL	Requirement for M&TE calibrations and preventative maintenance not documented in a procedure or process.	LLNL will contribute to or maintain a SharePoint site with needed information.
0.1008	UGTA Gap Analysis	01/15/2013	09/30/2013+	Finding	DRI	The following were not compliant with the QAP: DRI SOP #1-1.1 Carbon-14 Analysis by Accelerator Mass Spectrometry; and Nevada Stable Isotope Analysis of ^{2}H, ^{13}C, and ^{18}O in Water.	Procedures have been retired, and residual procedures have been updated and submitted to DOE for review as part of the documentation package to close DRI UGTA-FY12-03.

Table A-1
Open Corrective Actions
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Tracking #	Reference #	Date Opened[a]	Due Date	Type	Participant	Deficient Condition	Corrective Actions
0.1009	UGTA Gap Analysis	01/15/2013	09/30/2013+	Finding	LANL	The following were not compliant with the QAP: IWD-RC1-CR-0002: Sample Receipt, Beta and Gamma Counting; UGTA-LANL-SOP-4.05: Separating ^{85}Kr and Other Noble Gases from Water Samples; UGTA-LANL-SOP-4.06: Evaporation of Large-Volume Water Samples for Analysis of Radioactive Contents; UGTA-LANL-SOP-4.07: Liquid Scintillation Counting; and UGTA-LANL-SOP-5.21: Determination of Analyte Concentrations in Aqueous Solutions by ICP-MS.	SOPs will be revised, and a checklist will be developed for data verification and validation.
0.1114	N/A	06/11/2013	06/21/2013+	Finding	LANL	No chain of custody was present on sample receipt.	A copy of the chain of custody will be attached to drums showing transfer of custody from N-I to NSTec to Shipper.
0.1164	EI-FY13-225	08/06/2013	10/30/2013	Finding	N-I	N-I associate worked more than 15 hours in a 24-hour period without preapproval.	Policy was reviewed with employee. Causal analysis will be performed.
562.1	UGTA-FY12-3	12/17/2012	05/01/2013+	Finding	DRI	Laboratory analyses were conducted with interim procedures.	Procedures will be revised to meet current QAP requirements.
563.1	UGTA-FY11-1	12/17/2012	07/01/2013+	Finding	DRI	Data qualifiers have not been assigned to data generated by DRI in the past.	Retroactively review all DRI data, and assign flags for quality and completeness as specified in the UGTA QAP. Assignment of data quality flags to historical records is pending completion of the compilation of these records into the appropriate project files. Assignments of flags for quality and completeness will be assigned at that time.
564.1	UGTA-FY11-2	12/17/2012	06/01/2013+	Finding	DRI	UGTA project files are incomplete.	Identify and compile existing UGTA records. Perform a data documentation evaluation, and assign data evaluation flags. 95% of records have been compiled into official project documentation files. Assignment of data documentation evaluation flags will occur once all records have been compiled.
578.9	N/A	04/30/2013	10/31/2013	OFI	N-I	The UGTA Information/Data Management Plan and the N-I Information/Data Management Implementation Plan should be reviewed and updated to reflect changes to the procedures and to the UIDMS.	Review and revise plans as needed.

Table A-1
Open Corrective Actions
(Page 4 of 8)

Tracking #	Reference #	Date Opened[a]	Due Date	Type	Participant	Deficient Condition	Corrective Actions
631.1	OAA-13-AMEM-BM-82713/ CAweb 23902	09/11/2013	09/30/2014	OFI	N-I	Unpublished drafts of technical reports, short communications, and emails are referenced in documents.	Migrate the uBib electronic library to the TDR. Enter or verify references for the Yucca Flat/Climax Mine CAU and Frenchman Flat CAU Flow and Transport Model Rev. 1 documents. Add other historical documents. Draft and personal communication references will be "packaged" as one entry with appropriate metadata to describe the individual references for search capabilities.
634.1	ASM-AMEM-5.13.2013-511 223 finding 1-1	09/30/2013	10/30/2013	Finding	LLNL	Samples at the analytical laboratory are under chain of custody control from receipt through analysis but not through disposal.	Corrective action plan was due 10/30/2013.
634.2	ASM-AMEM-5.13.2013-511 2233 finding 1-2	09/30/2013	10/30/2013	Finding	LLNL	Sample bottles were not certified as having been pre-cleaned.	Corrective action plan was due 10/30/2013.
634.3	ASM-AMEM-5.13.2013-511 223 finding 1-3	09/30/2013	10/30/2013	Finding	LLNL	Sample arrival temperatures or storage temperatures were not documented.	Corrective action plan was due 10/30/2013.
649.1	13-UGTA-QA-1	11/04/2013	01/01/2014	Finding	DRI	Numerous modifications to the work scope, driven by the Rainier Mesa PER Committee and CAU Lead, occurred as the project progressed. Efforts to address modified scope and meet new deadlines upset the balance between project modeling and QA documentation, with modeling receiving top priority. In order to maintain revised schedules, documentation was often delayed or incomplete.	Ensure that task personnel have reviewed all relevant responsibilities for QA documentation under the UGTA QAP, DRI's QA Plan, and DRI's modeling procedures. Discuss proposed revisions to task schedules, and confirm that time and funding resources are adequate to support them.

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Tracking #	Reference #	Date Opened[a]	Due Date	Type	Participant	Deficient Condition	Corrective Actions
649.2	13-UGTA-QA-1	11/04/2013	01/01/2014	Finding	DRI	Original datasets were not centrally located on any particular computer or storage system, or effectively identified. As a result, it was often unclear which components of the datasets were used and in which models, and whether data were further processed before incorporation in the models. Only in the case of datasets attached to and described in email correspondence were the source, description, and delivery date traceable and verifiable. At least some of the datasets were copied to external hard drives for archival purposes and to protect them from loss. In addition, too much reliance is placed on DRI's email system Inbox for archiving data. Limitations in DRI's storage capacity has required project personnel to periodically delete email correspondence from their accounts, introducing the possibility that important project communications and/or datasets could be inadvertently deleted and permanently lost.	Maintain a central area for storage and documentation of project datasets as they are received from external sources. DRI network storage provides an ideal solution for this, and includes easy access and backups that protect data from loss.
649.3	13-UGTA-QA-1	11/04/2013	04/01/2014	Finding	DRI	The primary modeling codes 3DFrac, transport_preprocessor_v3, and RM_transport_postprocessor_v5 were developed at DRI and are in various stages of documentation. At present, they are missing important information that will need to be addressed as these codes are documented and reviewed. Although the authors performed extensive testing, internal review of these codes was not completed before use on the project. 3DFrac is documented in Appendix D of the Rainier Mesa/Shoshone Mountain Flow and Transport Model draft document.	Conduct an internal review of the codes 3DFrac, transport_preprocessor_v3, and RM_transport_postprocessor_v5 that have been developed at DRI; and document them as described in DRI's modeling procedures. Although not available at the time of this work, UGTA Form U-103 may be used to guide and record the review for the record package.

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Tracking #	Reference #	Date Opened[a]	Due Date	Type	Participant	Deficient Condition	Corrective Actions
649.4	13-UGTA-QA-1	11/04/2013	02/01/2014	Finding	DRI	The primary modeling code NUFT was provided by LLNL to DRI in compiled form. The delivery date and minimal information about the code was included in an email dated 14 November 2008. Little documentation of the code or its verification was provided by LLNL, and no test problems were included. Though installation of the code was verified at DRI by comparing results to independent LLNL example problems and other problems published in the literature, this process and the results were not documented.	Document the installation and testing of NUFT on DRI-GRID, and cite the review and verification process undertaken of this code for DOE's Yucca Mountain Project.
649.5	13-UGTA-QA-1	11/04/2013	02/01/2014	Finding	DRI	Though many aspects of operation and modification of DRI-developed code are described in extensive dated comments within the programs, there is generally no information describing compilation, installation, and hardware/software platform. Some of this information can be gleaned from shell scripts used to assemble input and output and execute the program.	Document installation configuration and testing of primary codes developed at DRI.
649.6	13-UGTA-QA-1	11/04/2013	02/01/2014	Finding	DRI	Verification, internal review, and archival of DRI-developed primary codes DFNMap and DRI's modification of RWHet have been completed. Verification of the other DRI-developed primary code is described only briefly in dated comments within the programs. Full description of the verification process, the files used, the results, and their location are not documented.	Fully document the verification process for DRI-developed code in preparation for internal reviews.
649.7	13-UGTA-QA-1	11/04/2013	02/01/2014	Finding	DRI	nuft2mf3 was provided to DRI by its author without independent documentation or citation, though comments within the code provide basic instructions for its use. Although the results were checked at DRI for constant zero divergence, documentation of and the files associated with this verification were not preserved.	Document the verification process for the nuft2mf3 code.
649.8	13-UGTA-QA-1	11/04/2013	01/01/2014	Finding	DRI	A central repository of code developed for the project that would help ensure version control, documentation, and backups is not in place.	Establish a central area for storage and documentation of project-developed code on DRI's network where DRI's Information Services department provides maintenance and automated backups.

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Tracking #	Reference #	Date Opened[a]	Due Date	Type	Participant	Deficient Condition	Corrective Actions
649.9	13-UGTA-QA-1	11/04/2013	07/01/2014	Finding	DRI	Input files, associated datasets and codes, and information about their development and use in the models have not been documented and archived in a DRI data documentation package.	Complete the documentation of input files, associated datasets and codes, and information about their development and use in the models; and include this information with the datasets in the data documentation package. UGTA Form U-103 can be used as guidance.
649.10	13-UGTA-QA-1	11/04/2013	07/01/2014	Finding	DRI	Processes and results of model calibration, sensitivity, and uncertainty analysis have not been documented and archived in DRI documentation packages.	Complete the documentation of processes and results of model calibration, sensitivity analysis, and uncertainty analysis; and include this information in the documentation package. UGTA Form U-104 can be used as guidance.
649.11	13-UGTA-QA-1	11/04/2013	07/01/2014	Finding	DRI	Models are not archived and placed under configuration control with documentation that ensures traceability and reproducibility by an SME. It should be noted that comprehensive descriptions of the models are included in the draft flow and transport modeling report for each CAU.	Generate a model documentation package that includes everything needed to rerun the models and generate comparable results. Storage of the model archive on DRI's network-attached storage system, provided and supported by DRI's Information Services department, will protect the archive from loss and provide ready access to authorized personnel if needed.
EI-FY13-226	N/A	07/24/2013	11/29/2013	E/I	N-I	Electronic files were not relinquished to Document Production (DP) before the technical edit to assure version control.	QA Manager has requested Formal Causal Analysis.
EI-FY13-232	N/A	08/15/2013	11/29/2013	E/I	N-I	UGTA Geochemistry Database is not current.	Data Management is loading backlog.
EI-FY13-237	N/A	08/22/2013	10/22/2013	E/I	N-I	NNSS Integrated Groundwater Sampling Plan analytical parameter requirements are inconsistent with the CAIP.	Analytical parameters listed for analysis in the NDEP-approved UGTA CAIPs and referred to under earlier versions of the UGTA QAP are not consistent with those identified in the NNSS Integrated Groundwater Sampling Plan for CAUs 97, 99, and 101. Notified N-I UGTA Project Manager of the inconsistency between documents. Document changes to planning documents in subsequent documents rather than submitting an ROTC.
EI-FY13-239	N/A	08/27/2013	11/05/2013	E/I	N-I	Groundwater sample results are vastly different between laboratories.	LLNL checked for issues with the sample or sample runs, and found none. LLNL has proposed sending available sample extractions from the LLNL sample for reanalysis by the University of Arizona.

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Tracking #	Reference #	Date Opened[a]	Due Date	Type	Participant	Deficient Condition	Corrective Actions
EI-FY13-253	N/A	09/20/2013	11/20/2013	E/I	N-I	There is no evidence that non-N-I material was checkprinted before document issuance.	A process for non-N-I produced figures and tables will be added to the checkprinting procedure.

[a]These dates do not represent the date the activity was conducted, but when the information was received by the UGTA ACTS administrator. Some activities, identified in response to this report's data call, were received and entered after the fiscal year end. (See Section 2.0 for dates conducted.)

+ = Overdue corrective actions discussed in the UGTA FY 2014 Kickoff Meeting with NNSA/NFO after fiscal year end. NNSA/NFO approved extensions until 12/31/2013. This was updated in ACTS.

CAIP = Corrective action investigation plan
FAWP = Field activity work package
GISP = Greenland Ice Sheet Precipitation
ICP-MS = Inductively coupled plasma-mass spectrometry
Kr = Krypton
M&TE = Measuring and test equipment
N/A = Not applicable
ROTC = Record of Technical Change
SLAP = Standard Light Antarctic Precipitation
SMOW = Standard Mean Ocean Water
TDIC = Total dissolved inorganic carbon
TDOC = Total dissolved organic carbon

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Tracking #	Reference #	Date Opened[a]	Date Closed	Type	Participant	Deficient Condition	Corrective Actions
0.930	N/A	10/02/2012	02/04/2013	Finding	N-I	Not clear whether all of the data used in the model document were evaluated for transferability, quality, or data source acceptance.	Evaluate whether data may have been used in N-I responsible sections of the document that need to be qualified or evaluated for transferability. See Assessment 551. A lessons learned (#782) has been developed and disseminated to all N-I UGTA modeling staff.
0.931	N/A	10/02/2012	11/21/2012	Finding	N-I	Several personnel worked more than 15 hours in a 24-hour period.	A waiver was issued for the Pahute Mesa work. Discussions will be held with UGTA and DP personnel to understand how to avoid this occurrence in the future.The official N-I policy on work hours was issued to affected personnel, and UGTA management acknowledged that a process is in place to grant waivers.
0.940	N/A	10/05/2012	11/06/2012	Finding	N-I	Electronic files associated with the Central Frenchman Flat sub-CAU models were not retrievable or missing.	The Linux cluster was retrofitted with a central head node that has large (4 terabyte) central storage (2009), and a new high-capacity tape drive capable of writing large amounts of data much faster (2011). In addition, IT also brought online a large SAN for data storage (2012).
0.987	UGTA Gap Analysis	01/15/2013	01/30/2013	Finding	LANL	Requirement for implementation was not documented in a procedure or process.	Develop a process/procedure for software configuration control.
0.989	UGTA Gap Analysis	01/15/2013	10/01/2013*	Finding	LLNL	Requirement for inorganic ions was not documented in a procedure or process.	SOP will be revised, and a checklist will be developed for data verification and validation.
0.994	UGTA Gap Analysis	01/15/2013	10/01/2013*	Finding	LLNL	Requirement for ^{36}Cl was not documented in a procedure or process.	SOP will be revised, and a checklist will be developed for data verification and validation.
0.995	UGTA Gap Analysis	01/15/2013	10/01/2013*	Finding	LLNL	Requirement for $^{87/86}Sr$ was not documented in a procedure or process.	SOP will be revised, and a checklist will be developed for data verification and validation.
0.996	UGTA Gap Analysis	01/15/2013	10/01/2013*	Finding	LLNL	Requirement for U isotopes was not documented in a procedure or process.	SOP will be revised, and a checklist will be developed for data verification and validation.
0.997	UGTA Gap Analysis	01/15/2013	10/01/2013*	Finding	LLNL	Requirement for ^{232}Th was not documented in a procedure or process.	SOP will be revised, and a checklist will be developed for data verification and validation. Analyte is not in the NNSS Integrated Groundwater Sampling Plan; data will be accepted through UGTA Form U-102; condition closed.

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Tracking #	Reference #	Date Opened[a]	Date Closed	Type	Participant	Deficient Condition	Corrective Actions
0.998	UGTA Gap Analysis	01/15/2013	10/01/2013*	Finding	LLNL	Requirement for ^{237}Np was not documented in a procedure or process.	SOP will be revised, and a checklist will be developed for data verification and validation. Analyte is not in the NNSS Integrated Groundwater Sampling Plan; data will be accepted through UGTA Form U-102; condition closed.
0.999	UGTA Gap Analysis	01/15/2013	10/01/2013*	Finding	LLNL	Requirement for Pu isotopes was not documented in a procedure or process.	SOP will be revised, and a checklist will be developed for data verification and validation.
0.1001	UGTA Gap Analysis	01/15/2013	10/01/2013*	Finding	LLNL	Requirement for ^{99}Tc was not documented in a procedure or process.	SOP will be revised, and a checklist will be developed for data verification and validation.
0.1002	UGTA Gap Analysis	01/15/2013	10/01/2013*	Finding	LLNL	Requirement for low-level tritium and noble gases was not documented in a procedure or process.	SOP will be revised, and a checklist will be developed for data verification and validation.
0.1003	UGTA Gap Analysis	01/15/2013	10/08/2013+	Finding	LLNL	Requirement for tritium was not documented in a procedure or process.	SOP will be revised, and a checklist will be developed for data verification and validation.
0.1004	UGTA Gap Analysis	01/15/2013	01/30/2013	Finding	LLNL	Requirement for an inventory of computer software and codes used was not documented in a procedure or process.	LLNL modeling protocol document will be revised.
0.1005	UGTA Gap Analysis	01/15/2013	01/30/2013	Finding	LLNL	Requirement for identifying the required and desirable attributes of a code before procurement, acquisition, or development was not documented in a procedure or process.	LLNL modeling protocol document will be revised.
0.1010	UGTA Gap Analysis	01/15/2013	09/23/2013	Finding	USGS	The following procedures did not comply with the QAP: USGS-DRIL-Sr: Rb-Sr Isotope Geochemistry; USGS-DRIL-U: U-Th Disequilibrium Studies; USGS-DSIL-S: Sulfur Isotope Analysis of Dissolved Sulfate in H_2O; YMPB-USGS-GCP-38: Determination of Chemical Composition by ICP-MS.	These analytes are not in the NNSS Integrated Groundwater Sampling Plan; data will be accepted through UGTA Form U-102.
0.1011	N/A	02/05/2013	03/28/2013	Finding	N-I	Non-direct data acceptance was not completed for Pahute Mesa historical hydraulic test data. No data quality indicators were assigned to the hydraulic property data currently on the UIDMS.	User (CAU Lead) will perform acceptance of hydraulic test data and submit data package to the TDR.
0.1012	N/A	02/05/2013	08/26/2013	Finding	USGS	Non-direct data acceptance and data quality indicators were not completed for NNSS historical rock properties published by Wood (2007).	User (USGS) will perform non-direct data acceptance as per Section 2.5 of the UGTA QAP, Form U-102, and submit data package to the TDR.

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Tracking #	Reference #	Date Opened[a]	Date Closed	Type	Participant	Deficient Condition	Corrective Actions
0.1013	N/A	02/07/2013	04/01/2013	Finding	N-I	Numerous inconsistencies found within the Hydraulic Properties Database.	Removed Hydraulic Properties Database from the UGTA SharePoint site, and verified the Rainier Mesa HDD hydraulic properties spreadsheet is in the TDR.
0.1028	N/A	02/20/2013	04/22/2013	Finding	USGS	Data not collected under the UGTA QAP needs to be qualified via non-direct data acceptance as described in Section 2.5 of the QAP.	USGS will perform non-direct data acceptance as per Section 2.5 of the UGTA QAP using Form U-102 and submit acceptance package to the TDR.
0.1049	UGTA Gap Analysis	03/06/2013	03/06/2013	Finding	N-I	The Annual UGTA QA report data call, compilation, and PEP process was not proceduralized.	Subject Area: UGTA Programmatic Interfaces was developed under the Performance Assurance Management System. Procedure: PA- UPI-1, Annual Quality Assurance Report institutionalizes the PEP process and data call.
0.1050	UGTA Gap Analysis	03/06/2013	03/06/2013	Finding	N-I	Forms and procedures do not exist to ensure QAP compliance.	Subject Area: UGTA Programmatic Interfaces was developed under the Performance Assurance Management System. Procedure: PA- UPI-2, UGTA Information and Data Management System Submittal was developed. UGTA forms for codes, data packages, and documents were developed. Submittal to the UIDMS procedure developed.
0.1051	UGTA Gap Analysis	03/06/2013	03/06/2013	Finding	N-I	No procedure exists to implement technical direction for N-I to track UGTA assessments and findings.	Subject Area: UGTA Programmatic Interfaces was developed under the Performance Assurance Management System. Procedure: PA- UPI-3, Issue Tracking was developed to implement N-I collection, tracking, and closure of UGTA participant assessments and findings.
0.1052	UGTA Gap Analysis	03/06/2013	03/06/2013	Finding	DRI	DRI modeling procedure needs to be revised to comply with the new QAP requirements.	Revise DRI modeling procedures.
0.1061	N/A	04/29/2013	10/03/2013*	Observation	N-I	Particles inappropriately exit the model boundaries or enter confining units where they essentially are trapped.	Evaluation of this issue is documented in Appendix E.7.0 of the Rainier Mesa Flow and Transport draft document. The need to perform this evaluation was noted in the use restrictions of FEHM, particularly the sptr subroutine, and Walkabout when these codes are used to evaluate saturated zone contaminant transport and that evaluations of particle trajectories be included in model documents, as appropriate.

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Tracking #	Reference #	Date Opened[a]	Date Closed	Type	Participant	Deficient Condition	Corrective Actions
0.1105	EI-FY13-205; EI-FY13-191	06/14/2013	09/30/2013	Finding	N-I	Unapproved, untested, unqualified, undocumented, or executable files were installed or saved.	The infected workstation was immediately removed from the network and scanned manually. The Trojan was detected and removed. The folders that contained the application with the executable were identified and deleted. Awareness email was sent reminding personnel of their obligations and of the cyber security policy. UGTA staff discussed the incident and reiterated the importance of complying with N-I's cyber security requirements.
0.1141	UGTA-FY13-1	09/23/2013	09/23/2013	Finding	DRI	Rubber hoses used may contaminate sample.	Recollect sample, process, and reanalyze using alternate hoses. Utilize lessons learned to prevent similar occurrence in the future.
0.1235[b]	OAA-13-AMEM-BM-72513	12/04/2013	08/08/2013	OFI	N-I	UGTA contractors need to prepare a succinct decision document for all key decisions.	Discussed at CAU Lead meeting 08/07/2013.
0.1236[b]	OAA-13-AMEM-BM-71013	12/04/2013	08/08/2013	OFI	N-I	Not all non-direct data were accepted into the UGTA Activity.	CAU Leads will provide a list of data generated outside of UGTA activities. The data will be formed to bin and prioritize the data. SMEs will be assigned to complete the acceptance process. Identified datasets will be entered as ACTS items to track completion.
551.1	N/A	01/09/2013	02/04/2013	Observation	N-I	Not all checkprints examined included either a reference to or printout of the source material.	Verify the joint UGTA and DP spreadsheets developed for the Yucca Flat/Climax Mine CAU Flow and Transport Model Final Rev. 0 document contain the correct sourcing information to the data packages or other information. Verify tables in Final Rev. 0 have appropriate source information. Maintain version control of the spreadsheets used to identify checkprint sources for the Final Rev. 0, and include as part of checkprint package. Develop a lessons learned related to QA-CPP-1 to note that spreadsheets are an appropriate and convenient means to provide controlled source information to large and complex documents.

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Tracking #	Reference #	Date Opened[a]	Date Closed	Type	Participant	Deficient Condition	Corrective Actions
551.2	N/A	01/09/2013	02/04/2013	Observation	N-I	Model parameters were not traceable through electronic files.	Verify that identified source material used for the Yucca Flat/Climax Mine CAU Flow and Transport Model Final Rev. 0 document is correctly identified. For in-process information provided by other participants, identify the source of that information (which may be an email[s]) and that the information will be evaluated for consistency with preliminary information after the information is provided in a controlled source. Add discussion of the reason for any deviations from source information (e.g., the example of porosity being in % in the TDD and a fraction in the model document). These actions will be addressed in modification to the revised data packages (LVCF087141, LVCF087151 and LVCF087161). These modifications will be completed before Modeling Manager approval. Develop a lessons learned for UGTA modeling staff on data traceability to source materials.
551.3	N/A	01/09/2013	02/04/2013	Observation	N-I	Data quality evaluations were not evident in the data packages examined.	Ensure that Appendix A of the Yucca Flat/Climax Mine CAU Flow and Transport Model Final Rev. 0 document notes that data from the HDD and TDD meet the requirements of data quality, data transferability and data acceptability. As appropriate, add discussion in Appendix A that the justification for additional data (other than those data directly developed from the HDD and TDD) used to justify parameter distributions in the model document is provided in the model document. Develop a lessons learned for UGTA modeling staff on data quality, transferability, and acceptability requirements.
554.1	N/A	12/04/2012	12/06/2012	OFI	N-I	Well ER-EC-14 Well Site Logbook did not have list of logbook contributors showing name and signatures/initials, and the owner of the logbook (N-I) was not on the inside cover page.	OFI will not be implemented at this time.
560.1	UGTA-FY12-2	03/04/2013	03/04/2013	Finding	DRI	The activities conducted at the site were not recorded in accordance with SOP.RLFA.	Additional training will be provided to all personnel involved.

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Tracking #	Reference #	Date Opened[a]	Date Closed	Type	Participant	Deficient Condition	Corrective Actions
560.2	UGTA-FY12-2	03/04/2013	03/04/2013	Finding	DRI	Water samples collected from the bulk precipitation gauge did not adhere to any SOP regarding water sampling protocols.	Additional training will be provided to all personnel involved. Governing SOPs, applicable forms, and approved equipment and supplies will be organized by Las Vegas personnel and made collectively available in one location before each activity. Checklists will be created to ensure field personnel conduct all activities as specified.
561.1	UGTA-FY12-1	12/17/2012	08/20/2013	Finding	DRI	Procedure SOP.RLFA was not followed.	SOPs will be revised to reflect interim SOPs that improve processes for ensuring data are being archived in a timely fashion, as required. A training session will be conducted with all applicable parties on the new SOPs. A procedure will be developed and implemented for controlling and disseminating the correct programs/spreadsheets for flow logging.
573.1	N/A	03/04/2013	03/18/2013	OFI	N-I	UGTA participants' compliance with the UGTA QAP and TDR requirements was not tracked, and a confirmation process was not developed.	A tracking system was established (02/01/2013) to track use of the TDR for all participants. Compliance with the QAP will be tracked via QA assessments, ACTS corrective actions, and TDR usage. All participants' issues/corrective actions are now being tracked in ACTS and statused monthly.
573.2	N/A	03/04/2013	04/08/2013	OFI	N-I	Communications between UGTA Task Leads and modelers needed improvement.	Kick-off meetings are being conducted for key tasks. A list of expected kickoffs with schedules will be developed.
573.3	N/A	03/04/2013	07/29/2013	OFI	N-I	Data deliverables (i.e., electronic data deliverables [EDDs]) were not standardized.	As LLNL develops/revises laboratory analytical procedures and those are incorporated into the NNSS Integrated Groundwater Sampling Plan, the EDDs will be described.
578.1	N/A	04/30/2013	08/05/2013	Observation	N-I	Not all data packages for Yucca Flat/Climax Mine CAU Flow and Transport Model Final Rev. 0 document were submitted to the TDR after Rev. 0.	Continue to communicate with UGTA participants to assist in timely submittal of data/software/model packages. Discuss issue in Contract Manager meeting. Update Program Interface Procedure to include 30-day requirement for TDR inclusion after final submittals to NNSA/NFO.
578.2	N/A	04/30/2013	07/17/2013	Finding	N-I	There was no procedural requirements for model archival and configuration control.	Work with DOE, N-I management, and UGTA participant Contract Managers to plan for incorporating baselined models into the TDR.

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Tracking #	Reference #	Date Opened[a]	Date Closed	Type	Participant	Deficient Condition	Corrective Actions
588.1	13-UGTA-ESH-1	06/11/2013	08/26/2013	Finding	DRI	Worker training was expired.	Personnel will complete training. Training will relay training deficiencies to the relevant upper-level manager for action. Managers will be briefed as to oversight responsibilities.
588.2	13-UGTA-ESH-1	06/11/2013	08/26/2013	Finding	DRI	The fire extinguisher and first-aid kit was inaccessible in a locked vehicle.	Fire extinguisher and first-aid kit were moved into the cab of the truck.
588.3	13-UGTA-ESH-1	06/11/2013	08/26/2013	Finding	DRI	No spill containment was present for the generator fuel tank.	Provide containment for generator-fuel tank, either by purchasing and installing a double-walled tank on the trailer, or purchasing a tarp (to lay under the trailer when in use) and storing it on the trailer.
588.4	13-UGTA-ESH-1	06/11/2013	08/26/2013	Finding	DRI	Fire extinguisher size was insufficient for generator/fuel tank.	Determine appropriate size for fire extinguisher associated with the generator and fuel tank. Replace relevant extinguisher, if necessary. Update SSHASP and Hazard Assessment.
588.5	13-UGTA-ESH-1	06/11/2013	08/26/2013	Finding	DRI	Portable generator was not always grounded.	Determine needed grounding requirements for the generator operation, fit out the generator trailer with any needed materials for grounding, and update SSHASP to reflect needed grounding configuration.
588.6	13-UGTA-ESH-1	06/11/2013	08/26/2013	Finding	DRI	Latex gloves were not demonstrably ANSI approved.	Obtain ANSI-approved nitrile gloves, in worker-specific sizes.
588.7	13-UGTA-ESH-1	06/11/2013	08/26/2013	Finding	DRI	Work days were in excess of the 14-hour limit specified in the SSHASP.	Research work-day length requirements, and update the HASP and SSHASP accordingly. Discuss with other appropriate UGTA contractors the work-day constraint and appropriate contingency actions (e.g., field determination of sampling horizons when office personnel are unavailable). Share results of discussion with DRI field personnel.
606.1	N/A	06/12/2013	07/30/2013	Finding	LLNL	The authors of the Yucca Flat/Climax Mine CAU Flow and Transport Model document and the Yucca Flat/Climax Mine CAU Lead were unaware of the data presented in the Zavarin et al. colloid report.	Evaluate the impact of 6-year-old data on the current model document.
606.2	N/A	06/12/2013	09/30/2013	Finding	N-I	UGTA personnel were not aware of the existence of potentially relevant work in progress by other participants.	Each CAU will have a activity network flow diagram (wiring diagram) identifying input documents and task by participant.

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Tracking #	Reference #	Date Opened[a]	Date Closed	Type	Participant	Deficient Condition	Corrective Actions
642.1	MA-13-H000-011	10/16/2013	10/16/2013*	OFI	NSTec	UGTA Project PEP and HASP needed updating.	OFI will not be implemented at this time.
EI-FY13-159	N/A	11/07/2012	12/10/2012	E/I	N-I	During well development and testing activities at Well ER-EC-13, as NSTec lifted the power unit out of the junk box, the brake on the sand line released and the power tongs dropped an estimated 1.5 ft.	N-I and NSTec secured the area. NSTec personnel returned the unit to an upright position. Submitted because N-I is the Primary REOP holder.
EI-FY13-165	N/A	12/18/2012	01/11/2013	E/I	N-I	The FY 2011 UGTA Annual QA Report included performance comparison results of commercial and research laboratories that participated in established performance evaluation programs or inter-laboratory performance comparisons that should have been marked Official Use Only.	The FY 2012 UGTA Annual QA Report does not contain laboratory names. Subject Area: UGTA Programmatic Interfaces, Procedure: PA-UPI-1, Annual Quality Assurance Report revised to prohibit linking laboratories with performance.
EI-FY13-168	N/A	01/29/2013	03/11/2013	E/I	N-I	Minor damage occurred to the right front quarter panel of a NSTec truck during a wind storm.	The damage was minor and was reported to the supervisor. The N-I Tailgate Safety Briefing has been revised to raise awareness of the potential wind hazard.
EI-FY13-176	N/A	01/30/2013	09/19/2013	E/I	N-I	Potential alternate pathway of contaminants from the CLEARWATER and WINESKIN tests in the Rainier Mesa (CAU 99) exist.	Discussions were held between the principal modelers, CAU Lead, and Integration Manager. A pathway was determined to put the issue to the PER Committee. DOE has assigned scope for FY 2014 to address the PER Committee recommendations.
EI-FY13-180	N/A	04/23/2013	06/10/2013	E/I	N-I	UGTA Borehole Index changes may not have appropriate documentation.	Develop desktop guidance on N-I database maintenance adapts/incorporates changes to NWIS. Revise N-I SBMS procedure UM-QPP-1 to identify this guidance as an attachment. This should include identifying discrepancies between UGTA controlled databases and NWIS and providing recommended changes to NWIS.
EI-FY13-182	N/A	04/11/2013	06/10/2013	E/I	N-I	Work was consistently forecast optimistically, and the delays were not communicated to NNSA/NFO adequately.	Process implemented to verify consistency between the weekly and monthly reports. Also, forecast dates are being reviewed by the project managers and issues discussed with the Contract Managers.
EI-FY13-183	N/A	04/17/2013	04/30/2013	E/I	N-I	A schedule for documents to be reviewed by NNSA/NFO will be developed for UGTA.	This item will be tracked as a Correspondence Action Tracking (CAT) item #636.

Table A-2
Closed Corrective Actions
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Tracking #	Reference #	Date Opened[a]	Date Closed	Type	Participant	Deficient Condition	Corrective Actions
EI-FY13-184	N/A	04/24/2013	06/11/2013	E/I	N-I	FAWPs were completed just before work began, with minimal time for review.	N-I FAWPs will be submitted for review 5 working days in advance of planned work, for continuation of typical N-I UGTA work. N-I FAWPs will be submitted for review 8 to 10 working days in advance of typical non-continuing (i.e., start-up) activities and any planned activities that are not routine activities as described in existing UGTA guidance documents or procedures.
EI-FY13-187	N/A	05/08/2013	07/01/2013	E/I	N-I	A cable head and bailer were damaged at Well ER-11-2.	The extent of damages to the components was documented, and the N-I Well Development/Testing Lead was notified. An electronic depth encoder will be installed on the winch programmed to emit an audible alarm as the bailer is raised within 100 ft on the ground surface. Inspection and Operation guidance for the operation of the winch during bailing will be updated to include the operation and pre-operation checks of the depth encoder alarm.
EI-FY13-190	N/A	05/07/2013	06/12/2013	E/I	N-I	LLNL provided the Colloid-Facilitated Radionuclide Transport in Fractured Carbonate Rock from Yucca Flat, Nevada National Security Site report (Zavarin et al.) to N-I more than two months after the Yucca Flat/Climax Mine CAU Flow and Transport Model Final Rev. 0 document.	Impact of 6-year-old data on current model document was evaluated. Wiring diagrams were developed for each CAU showing dependencies and work products. See Assessment 606.
EI-FY13-218	OAA-13-AMEM-BM-72513	07/18/2013	09/18/2013	E/I	N-I	There was disagreement on whether or not ER-5-5 Well Development/Testing and water quality were sufficient to finish work.	FAWPs are reviewed by a larger audience to include CAU Lead, modeling team, and field supervisors. Email is sent to all UGTA personnel inviting them to the plan of the day (POD) meeting. SharePoint alerts are set for daily reports and POD upon request.
EI-FY13-220	OAA-13-AMEM-BM-72513	07/18/2013	09/18/2013	E/I	N-I	Well ER-11-2 Well Purging and Sampling work recommendations deviated from the prescribed sample collection work defined in the FAWP.	Same as above.

Table A-2
Closed Corrective Actions
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Tracking #	Reference #	Date Opened[a]	Date Closed	Type	Participant	Deficient Condition	Corrective Actions
EI-FY13-238	N/A	08/27/2013	10/07/2013*	E/I	N-I	Pull-away brake lanyard did not pass Nevada Highway Patrol inspection.	The trailer was taken out of service (red tag #1006). The damaged cable was repaired. Replacement breakaway lanyard is to be procured and installed before further use of the trailer. Additional trailers have been inspected and found one other cable that was frayed/broken and has also been tagged-out (#791). Vehicle inspection and trailer inspection checklists combined.
EI-FY13-248	N/A	09/10/2013	10/17/2013*	E/I	N-I	Duplicate document numbers were assigned to N-I documents.	A new document number was assigned to the Phase I Flow and Transport Model Document for Corrective Action Unit 97: Yucca Flat/Climax Mine, Nevada National Security Site, Nye County, Nevada Final Rev. 1, N-I/28091--080. An N-I Document Number input box was incorporated in the master DP Task Bar for each document on SharePoint. This is to inform the DP staff if a new number was assigned to an internal document. Only the DP Supervisor or lead technical editor can assign new document numbers. The lead technical editor was trained on the process.
N/A	USGS-QA-2013A	N/A	09/13/2013	Finding	USGS	Although a very thorough Pre-Task Hazard Review was conducted, the requirement was not annotated in procedure USGS-WLCOLLECT-01.	The procedure will be updated to include completion of a Pre-Task Hazard Review.
N/A	USGS-QA-2013A	N/A	09/13/2013	Finding	USGS	A space for the “last date instrument calibrated” needed to be added to the field form USGSWL-COLLECT-Frm-01 (Reference: Paragraphs 4.1.7, 4.2.8, 4.3.6, and 4.4.7).	The form will be updated to include instrument/device calibration dates.

Table A-2
Closed Corrective Actions
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Tracking #	Reference #	Date Opened[a]	Date Closed	Type	Participant	Deficient Condition	Corrective Actions
N/A	USGS-QA-2013A	N/A	09/13/2013	Finding	USGS	Although a very thorough Pre-Task Hazard Review was conducted, the requirement was not annotated in the procedure USGS-TRANSINSTAL-01.	The procedure will be updated to include completion of a Pre-Task Hazard Review.

[a]These dates do not represent the date the activity was conducted, but when the information was received by the UGTA ACTS administrator. Some activities, identified in response to this report's data call, were received and entered after the fiscal year end. (See Section 2.0 for dates conducted.)
[b]These OFIs were discussed and the corrective action plans implemented in July, and these facts are recorded in the OAA reports. Also see Section 2.2 and Appendix C for more information on 0.1236.

* = Corrective actions completed before 09/30/2013, NNSA/NFO verification and closure date shown.
+ = Overdue corrective actions discussed in the UGTA FY 2014 Kickoff Meeting with NNSA/NFO after fiscal year end. NNSA/NFO approved extensions until 12/31/2013. This was updated in ACTS.

ANSI = American National Standards Institute
ft = Foot
H_2O = Water
HASP = Health and safety plan
HDD = Hydrologic data document
IT = Information Technology
Np = Neptunium
NWIS = National Water Information System
Rb = Rubidium
SAN = Storage area network
SSHASP = Site-specific health and safety plan
TDD = Transport data document
Th = Thorium

A.1.0 References

Navarro-Intera, LLC. 2013. *Phase I Flow and Transport Model Document for Corrective Action Unit 97: Yucca Flat/Climax Mine, Nevada National Security Site, Nye County, Nevada*, Rev. 1, N-I/28091--080. Las Vegas, NV.

Navarro-Intera, LLC. 2013. Written communication. Subject: *Rainier Mesa/Shoshone Mountain CAU Flow and Transport Model, Nevada National Security Site, Nye County, Nevada*. Las Vegas, NV.

Navarro-Intera, LLC. 2013. *Yucca Flat/Climax Mine CAU Flow and Transport Model, Nevada National Security Site, Nye County, Nevada*, Rev. 0, N-I/28091--065. Las Vegas, NV.

Navarro Nevada Environmental Services, LLC. 2010. *Phase II Transport Model of Corrective Action Unit 98: Frenchman Flat, Nevada Test Site, Nye County, Nevada*, Rev. 1, N-I/28091--004, S-N/99205--122. Las Vegas, NV.

Stoller-Navarro Joint Venture. 2006. *Phase I Hydrologic Data for the Groundwater Flow and Contaminant Transport Model of Corrective Action Unit 97: Yucca Flat/Climax Mine, Nevada Test Site, Nye County, Nevada,* Rev. 0, S-N/99205--077. Las Vegas, NV.

Stoller Navarro Joint Venture. 2007. *Phase I Contaminant Transport Parameters for the Groundwater Flow and Contaminant Transport Model of Corrective Action Unit 97: Yucca Flat/Climax Mine, Nevada Test Site, Nye County, Nevada*, Rev. 0, S-N/99205--096. Las Vegas, NV.

Stoller-Navarro Joint Venture. 2008. *Phase I Hydrologic Data for the Groundwater Flow and Contaminant Transport Model of Corrective Action Unit 99: Rainier Mesa/Shoshone Mountain, Nevada Test Site, Nye County, Nevada*, Rev. 1, S-N/99205--103. Las Vegas, NV.

U.S. Department of Energy, National Nuclear Security Administration Nevada Site Office. 2012. *Underground Test Area Activity Quality Assurance Plan, Nevada National Security Site, Nevada*, DOE/NV--1450, Rev. 1. Las Vegas, NV.

U.S. Department of Energy, National Nuclear Security Administration Nevada Site Office. 2012. *Underground Test Area Fiscal Year 2011 Annual Quality Assurance Report*, DOE/NV--1471, Rev. 0. Las Vegas, NV.

U.S. Department of Energy, National Nuclear Security Administration Nevada Site Office. 2013. *Underground Test Area Fiscal Year 2012 Annual Quality Assurance Report, Nevada National Security Site, Nevada*, DOE/NV--1494, Rev. 0. Las Vegas, NV.

U.S. Department of Energy, National Nuclear Security Administration Nevada Field Office. 2013. Written communication. Subject: *Nevada National Security Site Integrated Groundwater Sampling Plan*. Las Vegas, NV.

Wood, D.B. 2007. *Digitally Available Interval-Specific Rock-Sample Data Compiled from Historical Records, Nevada Test Site and Vicinity, Nye County, Nevada*, Data Series 297. Reston, VA: U.S. Geological Survey.

Zavarin, M., S.K. Roberts, M.R. Johnson, Q. Hu, B.A. Powell, P. Zhao, A.B. Kersting, R.E. Lindvall, and R.J. Pletcher. 2013. *Colloid-Facilitated Radionuclide Transport in Fractured Carbonate Rock from Yucca Flat, Nevada National Security Site*, LLNL-TR-619352. Livermore, CA: Lawrence Livermore National Laboratory.

Appendix B

Interlaboratory Comparison

Table B-1
Interlaboratory Comparison
(Page 1 of 2)

Analyte	Unit	Sample	LLNL	USGS	ALS	ARS	RPD	Criteria
Chloride	mg/L	ER-EC-12 (Shallow)	15.1	--	15.5	--	2.9	±25% (if greater than the detection limit)
		ER-EC-12 (Intermediate)	65.5	--	68.0	--	3.7	
		ER-EC-13 (Intermediate)	57.3	--	62.0	--	7.9	
		ER-EC-13 (Deep)	55.2	--	48.5	--	13	
		ER-5-5	14.4	--	16.0	--	11	
		ER-11-2	50.0	--	50.0	--	0.09	
$^{87}Sr/^{86}Sr$	Ratio	ER-EC-12 (Shallow)	0.710436	0.710420	--	--	0.000016	±0.0005
		ER-EC-12 (Intermediate)	0.708662	0.708690	--	--	0.000029	
		ER-EC-13 (Intermediate)	0.710141	0.710130	--	--	0.000011	
		ER-EC-13 (Deep)	0.709964	0.709705	--	--	0.000259	
		ER-5-5	0.709770	0.709752	--	--	0.000018	
		ER-11-2	0.708960	0.709020	--	--	0.000060	
Strontium	µg/L	ER-EC-12 (Shallow)	10.6	8.3	<10	--	24.3	±25% (if greater than the detection limit)
		ER-EC-12 (Intermediate)	31.6	33.0	31.0	--	1.9–6.3	
		ER-EC-13 (Intermediate)	11.8	12.1	<10	--	2.5	
		ER-EC-13 (Deep)	28.2	29.3	28.8	--	1.9–3.9	
		ER-5-5	25.0	24.5	21.3	--	1.8–16.0	
		ER-11-2	6.7	7.8	<10	--	15	

Table B-1
Interlaboratory Comparison
(Page 2 of 2)

Analyte	Unit	Sample	LLNL	USGS	ALS	ARS	RPD	Criteria
Tritium	pCi/L	ER-EC-12 (Shallow)	<1.0	--	<320	<2.3	--	±25% (if greater than the detection limit)
		ER-EC-12 (Intermediate)	7.9	--	<320	4.2	--	
		ER-EC-13 (Intermediate)	<285	--	<370	<2.5	--	
		ER-EC-13 (Deep)	< 0.9	--	<330	<1.5	--	
		ER-5-5	1.1	--	<370	<2.5	--	
		ER-11-2	<626	--	<360	<2.1	--	
^{238}U	µg/L	ER-EC-12 (Shallow)	2.3	2.4	2.2	--	3.1–8.7	±25% (if greater than the detection limit)
		ER-EC-12 (Intermediate)	<0.012	0.01	0.16	--	--	
		ER-EC-13 (Intermediate)	6.3	6.8	6.4	--	0.9–8.2	
		ER-EC-13 (Deep)	7.3	7.7	7.1	--	3.0–8.0	
		ER-5-5	8.5	8.6	7.9	--	1.3–8.7	
		ER-11-2	12.6	12.9	12.0	--	2.4–6.8	
$^{234}U/^{238}U$	Activity ratio	ER-EC-12 (Shallow)	6.4	6.4	--	--	0.03	±0.3
		ER-EC-12 (Intermediate)	3.9	4.0	--	--	0.10	
		ER-EC-13 (Intermediate)	4.1	4.1	--	--	0.00	
		ER-EC-13 (Deep)	4.3	4.3	--	--	0.01	
		ER-5-5	1.9	1.9	--	--	0.01	
		ER-11-2	1.5	1.5	--	--	0.01	

-- = Not applicable

Appendix C

Justification of Datasets and Data Sources Used in the Development of Models and Parameters for the Yucca Flat/Climax Mine Flow and Transport Models

C.1.0 Introduction/Background

The UGTA Quality Assurance Project Plan (QAPP), Rev. 0 (NNSA/NSO, 2011), and QAP, Rev. 1 (NNSA/NSO, 2012), require the justification of non-direct datasets and data sources used in support of UGTA models. The previous controlled version of the UGTA QAPP, Rev. 4 (NNSA/NSO, 2003), had no such explicit requirement. It is noted that non-direct data must be evaluated for acceptability before use. The principal data documents supporting the Yucca Flat/Climax Mine CAU flow and transport modeling were completed, reviewed, and approved by NDEP in 2006 and 2007 (SNJV, 2006b and 2007, respectively), and modeling was initiated at that time.

The *Phase I Flow and Transport Model Document for Correction Action Unit 97: Yucca Flat/Climax Mine, Nevada National Security Site, Nye County, Nevada*, Rev. 1, was completed in September 2013 and accepted by NDEP in October 2013 (N-I, 2013a). This document notes that the data used in the analyses have been generally acquired in accordance with the requirements of the QAPP; most of these data have been summarized in either the HDD (SNJV, 2006b) or the TDD (SNJV, 2007), and additional non-direct data have been evaluated for acceptability in participant data packages and summarized in the flow and transport model document. In addition, it is stated that data acquired by recognized national organizations such as the National Oceanic and Atmospheric Administration (NOAA) and USGS have been determined to be acceptable.

While the flow and transport modeling of the Yucca Flat/Climax Mine CAU was initiated several years before the non-direct data justification requirement in the QAPP or QAP (NNSA/NSO, 2011 and 2012, respectively)—and while the rationale for data selected and used in the flow and transport models was summarized in the model document, which was reviewed and accepted—there was a recognized opportunity for improvement to provide additional justification for the non-direct data used in the flow and transport model document and related supporting models including the hydrostratigraphic framework model (HFM), the hydrologic source term (HST) model, and the Climax Mine sub-CAU model.

As a result of the above opportunity for improvement, the Yucca Flat/Climax Mine modeling team, under the leadership and direction of the Science Advisors and CAU Lead, undertook a task to first identify the potential non-direct datasets and data sources that were used in the development of the models and then to provide categories of justification of these non-direct datasets and data sources. The results of this evaluation are summarized in the following sections.

C.2.0 Approach To Evaluate Yucca Flat/Climax Mine CAU Non-Direct Datasets and Data Sources

Each of the modeling groups (including DRI, LANL, LLNL, N-I, and NSTec) that support the overall Yucca Flat/Climax Mine flow and transport model reviewed the datasets and the sources of the data used in the models. The review consisted of identifying the following attributes for each model (see Tables C-1 through C-8):

- Type of non-direct data
- Source of non-direct data
- Program under which the non-direct data were generated
- Description of how the non-direct data were used
- Evaluation of whether the non-direct data were used as direct input to the model or used in a corroborative fashion

After this initial tabulation of non-direct datasets and data sources, the following acceptance criteria to justify the appropriateness of the non-direct data use were developed:

1. **UGTA data documents** (i.e., HDD [SNJV, 2006b] and TDD [SNJV, 2007]) present flow and transport model data including data quality assessments, data analyses to derive expected values or probability distributions, and parameter uncertainty estimates. The documents were reviewed by the PER Committees, DOE, and NDEP.

2. **Peer-reviewed literature** including handbooks of physical or chemical constants are considered acceptable and do not require additional source acceptance justification. These documents have received sufficient technical reviews.

3. **UGTA-sponsored technical reports** completed before the current QAP (NNSA/NSO, 2012) have adequately justified their data sources and datasets, and the technical reviews have been sufficient to justify the results and conclusions. These reports include the Yucca Flat/Climax Mine HFM document (BN, 2006), HST documents (e.g., Carle et al., 2008a; Tompson, 2008; SNJV, 2009), and subject-specific documents (e.g., historical results presented in colloid reports). The documents were generally reviewed by the PER Committees (or predecessor), DOE, and NDEP.

4. **Historical NNSS (or Nevada Test Site) data** produced by LANL, LLNL, USGS, and contractors have applied sufficient QA and/or technical review to justify the use of the data. Data contained in the USGS Rock-Property Database (USGS, 2013a; and previous versions) and the Database of NNSS Groundwater Levels and Hydrograph Descriptions (Elliott and Fenelon, 2013; and previous versions) have been formally accepted by UGTA.

5. **Other DOE programs** such as Yucca Mountain Project and the Low-Level Radioactive Waste Management programs in Areas 3 and 5 of the NNSS in Nevada and the Waste Isolation Project Plant (WIPP) in New Mexico were developed under QA programs equivalent to UGTA's, and thereby satisfy current UGTA requirements.

6. **Other federal or international entities** such as NOAA, USGS, the International Atomic Energy Agency (IAEA), and the European Space Agency have sufficient internal review and QA procedures that no further justification is necessary.

7. **Flow and Transport Model Document (N-I, 2013a)** - Given that Yucca Flat/Climax Mine modeling was initiated several years before the current QAP (NNSA/NSO, 2012), it is appropriate to justify the use of the non-direct data in this document if it has not previously been justified and accepted in another project document.

8. **UGTA databases** developed and updated in compliance with QA procedures existing at the time of compilation are sufficient to justify the data, even if the data were originally generated from a non-UGTA entity, such as the weapons program and the Routine Radiological Environmental Monitoring Program (RREMP).

9. **Non-direct data from other non-UGTA reports** that are cited to provide the overall scientific context for the UGTA generated work but are not used directly in the models do not require any further justification.

These criteria were reviewed by NNSA/NFO management and determined to be applicable for Yucca Flat/Climax Mine CAU models recognizing that the development of these model preceded the current QAP requirements and that the two principal data documents (SNJV, 2006b and 2007) had been reviewed by the NNSA/NFO PER Committee, and reviewed and accepted by NDEP.

C.3.0 Justifying Yucca Flat/Climax Mine CAU Non-Direct Datasets and Data Sources

Based on the identified non-direct datasets and data sources, and the criteria that are applicable to justify these datasets and data sources, an evaluation was performed of the non-direct datasets and data sources used either directly or indirectly in support of the Yucca Flat/Climax Mine CAU models. The criteria used to justify the non-direct data appropriateness are assigned to each data type (Tables C-1 through C-8). The results of this evaluation confirm the appropriateness of the datasets and data sources used in the Yucca Flat/Climax Mine models as summarized in *Phase I Flow and Transport Model Document for Correction Action Unit 97: Yucca Flat/Climax Mine, Nevada National Security Site, Nye County, Nevada* (N-I, 2013a).

Table C-1
Yucca Flat/Climax Mine Hydrostratigraphic Framework and Reactive Mineral Models Non-Direct Data
(Page 1 of 3)

Type	Data Source[a]	Program	Use Description	Direct/Corroborative	Acceptance Criteria
Hydrostratigraphic Framework Model					
Borehole lithologic logs (interpretations based on drill cuttings, core samples and geophysical logs)	USGS, LANL, LLNL, and contractors (F&S, FSN, RSN, and BN)	Weapons Testing Program (minor input from Areas 16 and 17 Radioactive Waste Program, and A3RWMS)	HGU and HSU determination, and ultimately input to the drill-hole database	Direct as HSU tops; rarely as direct input for location/intercept of faults	4, 5 (A3RWMS), 6
Borehole geophysical logs (e.g., bulk density, natural gamma, resistivity, caliper)	(Birdwell, Wellex, Schlumberger, Dresser Atlas, Western Atlas) and by the Joint Testing Operations (LANL and LLNL – for the large-diameter emplacement holes)	Weapons Testing Program (minor input from Areas 16 and 17 Radioactive Waste Program)	HGU and HSU determination and depth refinement	Corroborative	4, 5 (A3RWMS)
USGS geologic quadrangle maps, larger-scale compilation surface maps	USGS	Weapons Testing Program	Geologic units converted to HSU assignments for ground surface; surface location of faults	Direct as HSU surface boundaries and surface traces/locations of model faults	4, 6
Tunnel geologic maps (Climax and U1a)	USGS, F&S, RSN, BN	Weapons Testing Program	HGU and HSU determination and position of subsurface contacts; fault and fracture data	Direct as HSU contacts and location of model faults (along tunnels)	4, 6
XRD data	Typically by LANL, but the larger historical dataset includes XRD data by USGS and LLNL	Weapons Testing Program	Corroborative input for HGU and HSU assignments	Corroborative	4
XRF data	Typically LANL	Weapons Testing Program	Corroborative input for stratigraphy, which in turn affected HSU assignments	Corroborative	4
Petrographic data	Typically LANL and USGS	Weapons Testing Program	Corroborative input for stratigraphy, lithology, and alteration, which in turn affected HGU and HSU assignments	Corroborative	4, 6

Table C-1
Yucca Flat/Climax Mine Hydrostratigraphic Framework and Reactive Mineral Models Non-Direct Data
(Page 2 of 3)

Type	Data Source[a]	Program	Use Description	Direct/Corroborative	Acceptance Criteria
Hydrostratigraphic Framework Model (continued)					
Geophysical data (2-D reflection and refraction, gravity, and magnetic)	Typically by USGS, but the larger historical dataset includes data collected by LANL and LLNL	Weapons Testing Program	Corroborative input for structure; initial top of the Mesozoic granite confining unit and pre-Tertiary (HSU) surface	Mostly corroborative; initial (direct) top of the Mesozoic granite confining unit and pre-Tertiary surface, which was then adjusted as needed	4, 6
Physical property data (porosity, bulk density, moisture content, grain density, sieve/size data)	Typically by USGS, H&N, RSN, and BN	Weapons Testing Program, A3RWMS	Corroborative input to HGU determination	Corroborative	4, 5 (A3RWMS), 6
Hydraulic properties (conductivity, effective porosity)	Typically USGS	Weapons Testing Program	Corroborative input to HGU determination	Corroborative	4, 6
Age dates	USGS	Weapons Testing Program	Determination and supportive information for stratigraphic control, which in turn affected HSU assignments	Corroborative	4, 6
Topography	Initially by USGS	Weapons Testing Program	DEM as ground surface	Direct	4, 6
Reactive Mineral Model					
Borehole lithologic logs (interpretations based on drill cuttings, core samples and geophysical logs)	USGS, LANL, LLNL, and contractors (F&S, FSN, RSN, and BN)	Weapons Testing Program (minor input from Areas 16 and 17 Radioactive Waste Program, and A3RWMS)	HGU, HSU, RMC, and RMU determination; and ultimately input to the drill-hole database	Direct as HSU and RMU tops	4, 5 (A3RWMS), 6
USGS geologic quadrangle maps, larger-scale compilation surface maps	USGS	Weapons Testing Program	Geologic units converted to RMU assignments for ground surface; surface location of faults	Direct as RMU surface boundaries and surface traces/locations of model faults	4, 6
XRD data	Typically by LANL, but the larger historical dataset includes XRD data by USGS and LLNL	Weapons Testing Program	Corroborative input for RMC and RMU assignments	Corroborative	4, 6

Table C-1
Yucca Flat/Climax Mine Hydrostratigraphic Framework and Reactive Mineral Models Non-Direct Data
(Page 3 of 3)

Type	Data Source[a]	Program	Use Description	Direct/Corroborative	Acceptance Criteria
Reactive Mineral Model (continued)					
Petrographic data	Typically LANL and USGS	Weapons Testing Program	Corroborative input for alteration, which in turn affected RMC and RMU assignments	Corroborative	4, 6

[a]Specific references for the hydrostratigraphic framework and reactive mineral models are listed in BN (2006) and SNJV (2007), respectively.

2-D = Two-dimensional
A3RWMS = Area 3 Radioactive Waste Management Site
BN = Bechtel Nevada
DEM = Digital elevation model
F&S = Fenix & Scisson, Inc.
FSN = Fenix & Scisson of Nevada
HGU = Hydrogeologic unit
H&N = Holmes and Narver, Inc.
HSU = Hydrostratigraphic unit
RMC = Reactive mineral category
RMU = Reactive mineral unit
RSN = Raytheon Services Nevada
XRD = X-ray diffraction
XRF = X-ray fluorescence

Table C-2
Climax Mine Sub-CAU Flow and Transport Model Non-Direct Data
(Page 1 of 6)

Type	Data Source	Program	Use Description	Direct/Corroborative	Acceptance Criteria
2007 Climax Mine Sub-CAU Flow and Transport Model					
Nuclear-test-related data for detonations in Climax Mine Stock	Boardman (1965, 1966, 1967); Borg (1970, 1971, 1973, 1975); DOE/NV (1997b, 2000); Isherwood et al. (1982); McArthur (1962, 1963); Mehta et al. (1964); Murray (1981); Quong (1969); Rabb (1968 and 1969); SNJV (2004); Sterrett (1969); Wilder (1987)	Weapons Testing Program, UGTA	Conceptualization of test-altered environment, including geometry, fracturing, hydraulic parameters, tritium distribution	Direct and corroborative	4
PRISM average annual precipitation	Daly et al. (1994)	EPA	Alternative model of spatial distribution of groundwater recharge	Direct	6
Recharge coefficients for modified Maxey-Eakin method	Epstein (2004)	DRI	Alternative model of spatial distribution of groundwater recharge	Direct	3
Recharge derived from net infiltration	Belcher et al. (2004); Hevesi et al. (2003)	UGTA, YMP	Alternative model of spatial distribution of groundwater recharge	Direct	3, 6
Recharge derived from elevation-dependent chloride mass balance method	Russell and Minor (2002); Russell (2004)	UGTA	Alternative model of spatial distribution of groundwater recharge	Direct	3
Hydrostratigraphic models for northern Yucca Flat	Documented in BN (2006); digital model provided by SNJV (Beard, 2005)	UGTA	Alternative hydrostratigraphic models in northern Yucca Flat	Direct	3
Hydrogeologic model for DVRFS	Belcher et al. (2004)	UGTA, YMP	Alternative hydrostratigraphic model	Direct	3, 6

Table C-2
Climax Mine Sub-CAU Flow and Transport Model Non-Direct Data
(Page 2 of 6)

Type	Data Source	Program	Use Description	Direct/Corroborative	Acceptance Criteria
2007 Climax Mine Sub-CAU Flow and Transport Model (continued)					
Estimates of water balance and interbasin groundwater flow rates in vicinity of the NTS	Winograd and Thordarson (1975)	AEC	Conceptualization of interbasin flow in northern Yucca Flat	Corroborative	4, 6
Estimates of groundwater flow rates from the UGTA regional flow model	DOE/NV (1997a)	UGTA	Conceptualization of interbasin flow in northern Yucca Flat	Corroborative	3
Characterization of fractures in Climax stock	Carlson et al. (1980); Yow (1984)	Spent Fuel Test - Climax	Generation of 3-D network of fracture zones (orientations)	Direct	4
Characterization of fractures in Climax stock	Maldonado (1977)	--	Generation of 3-D network of fracture zones (orientations)	Direct	4, 6
Fracture spacing in Climax stock	Wilder and Yow (1984)	Spent Fuel Test - Climax	Generation of 3-D network of fracture zones (fracture spacing)	Direct	4
Fracture lengths in Climax stock	Yow (1984)	Spent Fuel Test - Climax	Generation of 3-D network of fracture zones (fracture lengths)	Direct	4
Fracture density in Climax stock	Barton (1995); Ehlen (2000); Gillespie et al. (1993); Wilder and Yow (1984); Yow (1984)	Peer-reviewed journal articles and Spent Fuel Test - Climax	Generation of 3-D network of fracture zones (fracture density)	Direct and corroborative	2, 4
Hydraulic conductivity of Climax stock	Isherwood et al. (1982); Murray (1980); Yow (1984)	Spent Fuel Test - Climax	Calculation of hydraulic conductivity distribution	Direct and corroborative	4
Hydraulic conductivity of Climax stock	Stigsson et al. (2001); Andersson et al. (2002a,b)	Äspö Hard Rock Lab, SKB, Sweden	Calculation of hydraulic conductivity distribution	Corroborative	6, 9
Radionuclide partitioning	IAEA (1998a)	IAEA	Partitioning ratios between phases in cavity and chimney	Direct	6

Table C-2
Climax Mine Sub-CAU Flow and Transport Model Non-Direct Data
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Type	Data Source	Program	Use Description	Direct/Corroborative	Acceptance Criteria
2007 Climax Mine Sub-CAU Flow and Transport Model (continued)					
Melt glass dissolution rates	Bourcier et al. (2000); Pawloski et al. (2001); Carle et al. (2007); Mazer (1987); Zavarin et al. (2004a,b); Baxter (1983); Maldonado (1977); Knauss et al. (1990); Grambow (1987); Isherwood et al. (1982); Bethke (1996); Johnson and Lundeen (1997); Peterson et al. (1991)	UGTA and others	Model of melt glass dissolution	Direct and corroborative	3, 4, 5, 6, 9
Water levels, test geometries, temperature measurements at Climax nuclear tests	Borg (1970); Belcher et al. (2004); Murray (1981); Boardman (1966, 1967); McArthur (1962, 1963); Denton (1962); Sterrett (1969); DOE/NV (1997b, 2000)	Weapons Testing Program and UGTA	Reconstruction of temperature history in glass zones for melt glass dissolution model	Direct and corroborative	3, 4, 5
Climax granite groundwater chemistry	Isherwood et al. (1982)	Weapons Testing Program	Model of radionuclide retardation behavior	Direct	4
Climax granite mineralogy	Borg (1970); Connolly (1981); Maldonado (1977); Ryerson and Qualheim (1983)	Weapons Testing Program and Spent Fuel Test - Climax	Model of radionuclide retardation behavior	Direct and corroborative	4
Lab studies of Climax granite sorption characteristics	Feth et al. (1964); MacLean et al. (1978); Erdal et al. (1979); Treyer and Raybold (1982); Coles et al. (1980)	Spent Fuel Test - Climax	Model of radionuclide retardation behavior	Direct and corroborative	4, 6

Table C-2
Climax Mine Sub-CAU Flow and Transport Model Non-Direct Data
(Page 4 of 6)

Type	Data Source	Program	Use Description	Direct/Corroborative	Acceptance Criteria
2007 Climax Mine Sub-CAU Flow and Transport Model (continued)					
Lab studies of sorption characteristics on non-Climax granites	The following references describe the JNC sorption database that contains results from numerous studies: Shibutani et al. (1999); Suyama and Sasamoto (2004); Saito et al. (2007). Numerous other studies were also referenced (see Pohlmann et al. [2007]).	Japan Nuclear Cycle Development Institute and others	Model of radionuclide retardation behavior	Direct and corroborative	6
Lab and field studies of matrix diffusion characteristics on non-Climax granites	Skagius and Neretnieks (1986); Skagius et al. (1982); Bradbury and Green (1985, 1986); Holtta et al. (1996); Sato (1999); Yamaguchi et al. (1993); Birgersson and Neretnieks (1990); Maloszewski and Zuber (1993); Reimus et al. (2003)	Various	Radionuclide diffusion parameters	Direct and corroborative	2, 6
Estimate of porosity (undisturbed Climax granite) from borehole test	Murray (1981)	Weapons Testing Program	Porosity value assigned to unfurnished model cells	Direct	4
Porosity estimated from tracer test in fractured granite	Pohlmann et al. (2004)	Shoal offsite	Parametric distribution of equivalent porosity for fractured model cells	Direct	5

Table C-2
Climax Mine Sub-CAU Flow and Transport Model Non-Direct Data
(Page 5 of 6)

Type	Data Source	Program	Use Description	Direct/Corroborative	Acceptance Criteria
2012 Simulations of Inter-basin Groundwater Flow into Northern Yucca Flat					
Estimates of water balance and interbasin groundwater flow in vicinity of the NTS	Winograd and Thordarson (1975)	AEC	Estimate of interbasin flow rate to northern Yucca Flat	Corroborative	4, 6
Estimates of water balance and interbasin flow for regional flow systems in the Great Basin	Harrill et al. (1988)	UGTA	Estimate of interbasin flow rate to northern Yucca Flat	Corroborative	6
Groundwater flow estimates from the UGTA regional flow model	IT (1996)	UGTA	Estimate of interbasin flow rate to northern Yucca Flat	Corroborative	3
Groundwater flow estimates from the DVRFS model	Belcher et al. (2004)	UGTA, YMP	Estimate of interbasin flow rate to northern Yucca Flat	Corroborative	3, 6
Uncertainty in groundwater flow at boundaries of Yucca Flat CAU using DVRFS model and UGTA alternative HFMs and recharge models	SNJV (2006b)	UGTA	Estimate of interbasin flow rate to northern Yucca Flat	Corroborative	3
Verification of interbasin flows simulated by DVRFS model using stable isotopes and a mixing-cell model	Carroll et al. (2008)	UGTA	Estimate of interbasin flow rate to northern Yucca Flat	Corroborative	2
Analysis of groundwater flow in northern Yucca Flat	Halford (2009, 2011)	UGTA	Estimate of interbasin flow rate to northern Yucca Flat	Corroborative	3
Hydrostratigraphic models for northern Yucca Flat	Documented in BN (2006); digital model provided by SNJV (Beard, 2005)	UGTA	Alternative hydrostratigraphic models in northern Yucca Flat	Direct	3

Table C-2
Climax Mine Sub-CAU Flow and Transport Model Non-Direct Data
(Page 6 of 6)

Type	Data Source	Program	Use Description	Direct/Corroborative	Acceptance Criteria
2012 Simulations of Inter-basin Groundwater Flow into Northern Yucca Flat (continued)					
Recharge derived from net infiltration	Belcher et al. (2004); Hevesi et al. (2003)	UGTA	Alternative model of spatial distribution of groundwater recharge	Direct	3, 6
Recharge derived from elevation-dependent chloride mass balance method	Russell and Minor (2002); Russell (2004)	UGTA	Alternative model of spatial distribution of groundwater recharge	Direct	3

-- = Not applicable

3-D = Three-dimensional
DVRFS = Death Valley Regional Flow System
NTS = Nevada Test Site
YMP = Yucca Mountain Project

Table C-3
Crater Infiltration Non-Direct Data
(Page 1 of 2)

Type	Data Source	Program	Use Description	Direct/Corroborative	Acceptance Criteria
Precipitation	ARL/SORD (2013) (Note: Current citation for database)	NOAA	Precip is the primary input to Hydrus-1D and runoff models; input as daily data	Direct	5, 6
Generation of 1,000-year precipitation datasets	Srikanthan et al. (2007)	Cooperative Research Centre for Catchment Hydrology, Australia	Precip is the primary input to Hydrus-1D and runoff models; input as daily data	Direct	6, 7
PET	SNL (2008)	YMP	Sine curve was fit to the PET data; used as direct input to Hydrus-1D	Direct	5
Weighing lysimeter data	SNL (2008)	YMP	Data used to calibrate the Hydrus-1D model	Direct	5
USDA Soil Conservation Service curve numbers	USDA/NRCS (2004)	USDA	Curver numbers separate antecedent moisture conditions for the SCS-CN model	Direct	2, 5, 6
Curve number slope adjustments	Neitsch et al. (2002); Williams and Izaurralde (2005)	Texas Water Resources Institute and USDA	Adjustments to curve numbers based on slope	Direct	5, 7
Soil hydraulic properties	NSTec (2007, Table 12, U-3bh [thetaR reduced])	A3RWMS	Data used as input to the Hydrus-1D model	Direct	5
Hydrus-1D initial conditions (water potential estimated from water content data)	BN (1998); NSTec (2007)	A3RWMS	Data used as input to the Hydrus-1D model	Direct	5
Pond water, sedimentation observations at U-10i	Hokett et al. (2000)	DOE	Model calibration	Direct	3
Pond water, soil water content observations at U-3fd	Pohll et al. (1996); Tyler et al. (1992)	DOE	Model calibration	Direct	2
Soil water content observations at U-3bh, U-3ax/bl, U-2ah/a3	BN (1998); NSTec (2007)	A3RWMS	Model calibration	Direct	5

Table C-3
Crater Infiltration Non-Direct Data
(Page 2 of 2)

Type	Data Source	Program	Use Description	Direct/Corroborative	Acceptance Criteria
Pond water observations at U-5a	Wilson et al. (2000)	DOE	Model calibration	Direct	2
10-m resolution USGS DEM	USGS (2013b) (Note: Current citation for database)	USGS	Data used to define catchments and characteristics for each crater	Direct	6
10-m resolution Shuttle Radar Topography Mission-derived DEM	USGS (2013b) (Note: Current citation for database)	USGS	Data used to define catchments and characteristics for each crater	Direct	6

m= Meter
PET = Potential evapotranspiration

Table C-4
LCA Model Non-Direct Data
(Page 1 of 3)

Type	Data Source	Program	Use Description	Direct/Corroborative	Acceptance Criteria
LCA Flow Model					
Infiltration rate	N-I (2013a, Section 4.0)	See source	Recharge map	Direct	7
HSU permeability and vertical anisotropy	SNJV (2006b)	Weapons Testing Program and continual monitoring by USGS	Used as initial guess for permeability ranges for HSUs of interest during calibration of flow model	Direct	1
Water-level observations (steady state)	Elliott and Fenelon (2013)	Weapons Testing Program and continual monitoring by USGS	Develop calibration targets	Direct	1, 8; accepted using U-102 form
Boundary fluxes (lateral and vertical)	SNJV (2006b)	See source	Develop initial estimates of boundary fluxes used in calibration	Direct	1
Geochemistry and ^{14}C	N-I (2013c) (Note: Current citation for database)	See source	General evaluation of flow directions and rates (used in a corroborative fashion to compare to calibrated flow regime)	Corroborative	1
LCA Transport Model					
Thermal data	Clauser and Huenges (1995); Gillespie (2005); Reiner (2007); Robertson (1979); Sass et al. (1976); Thompson (1991)	Weapons Testing Program and other monitoring	Additional confirmation of flow regime. Data were used to corroborate flow model with separate thermal hydrologic model.	Corroborative	3, 4, 6
Dispersivity	SNJV (2007)	See source	Fixed value used	Direct	1
Bulk rock density	SNJV (2007)	See source	Determine sorption of sorbing radionuclides. Single value used for simplicity. Large uncertainty in sorption swamps uncertainty in bulk density.	Direct	1

Table C-4
LCA Model Non-Direct Data
(Page 2 of 3)

Type	Data Source	Program	Use Description	Direct/Corroborative	Acceptance Criteria
LCA Transport Model (continued)					
Matrix sorption coefficients	SNJV (2007); Dosch and Lynch (1980); Rechard and Tierney (2005); Sutton (2009)	See source	Used to define range of possible values	Data used to corroborate sampled distribution. Alternative values used for Np, Sr, Cs, and C in a sensitivity analysis.	1, 2, 3, 4
Fracture retardation coefficients	SNJV (2007)	See source	Used to define range of possible values	Data used to corroborate sampled distribution	1
Matrix porosity	SNJV (2007)	See source	Used to define the range of likely values to evaluate the possible extent of contaminant migration	Data used to corroborate sampled distribution	1
Transport aperture to hydraulic aperture ratio	SNJV (2007); Cauffman et al. (1990); Jones et al. (1992)	--	Used to define the range of likely values to evaluate the possible extent of contaminant migration	Data used to corroborate sampled distribution	1
Fracture porosity	SNJV (2007)	See source	Used to define the range of likely values to evaluate the possible extent of contaminant migration	Data used to corroborate sampled distribution. Significance of value evaluated in sensitivity analyses.	1
Free-water diffusion coefficient	Mills (1973)	Peer-reviewed journal article	Used to calculate matrix diffusion for transport	Value multiplied by tortuosity was used as direct input for matrix diffusion	2
Ratio of free-water diffusion coefficient for light and heavy radionuclides	N-I (2013a); Hershey et al. (2003)	See source	Used to define radionuclide specific diffusion coefficient	Value multiplied by tortuosity was used as direct input for matrix diffusion	3, 7

Table C-4
LCA Model Non-Direct Data
(Page 3 of 3)

Type	Data Source	Program	Use Description	Direct/Corroborative	Acceptance Criteria
LCA Transport Model (continued)					
Tortuosity	SNJV (2007)	Weapons Testing Program	Used to define a log-linear relationship with matrix porosity	Because matrix porosity is sampled, the tortuosity is a range based on sampled matrix porosity. Scale-dependent matrix diffusion evaluated in a sensitivity analysis.	1
Fracture spacing	N-I (2013b) (Note: Current citation for database); SNJV (2007)	Weapons Testing Program	Used to define the range of likely values to evaluate the possible extent of contaminant migration	Data used to corroborate sampled distribution. Significance of value evaluated in sensitivity analyses.	1, 8
Matrix sorption coefficients	Rechard and Tierney (2005)	WIPP	Used to provide alternative matrix K_ds	Direct	5
Matrix sorption coefficients	Sutton (2009)	See source	Used to provide alternative matrix K_ds	Corroborative	3, 7
Matrix sorption coefficients	Zavarin (2012a)	See source	Used to provide alternative matrix K_ds	Direct	1, 2, 3, 4, 7

-- = Not applicable

LCA = Lower carbonate aquifer

Table C-5
Colloid Transport Model Non-Direct Data

Type	Data Source	Program	Use Description	Direct/Corroborative	Acceptance Criteria
Free-water diffusion coefficients	Li and Gregory (1974); Lide (2000)	Various	Data were used to define free-water diffusion coefficients for use in 1-D transport model of LCA	Direct	2, 3
Matrix partition coefficients	Zavarin (2012a)	UGTA	Data were used to define partition coefficients (K_ds) for use in 1-D transport model of LCA	Direct	3
Radionuclide inclusion/exclusion criteria	Zavarin (2012b)	UGTA	Data were used to identify which radionuclides to include or exclude from model simulations	Direct	3
Melt-glass/groundwater radionuclide partition coefficients	IAEA (1998a)	Radionuclide specific melt-glass/groundwater partitioning coefficients	Data were used to assess what fraction of the RST to partition into groundwater	Direct	6

Note: Colloid transport model described in Appendix M of N-I (2013a).

1-D = One-dimensional
RST = Radiologic source term

Table C-6
Unsaturated-Zone Model Non-Direct Data
(Page 1 of 2)

Type	Data Source	Program	Use Description	Direct/Corroborative	Acceptance Criteria
Soil hydraulic properties	NSTec (2007)	A3RWMS	Data used as input to the Hydrus-1D model	Direct	5
Borehole water content and saturation data from the A3RWMS disposal site	BN (1998); NSTec (2007)	A3RWMS	Data used as input to the Hydrus-1D model	Corroborative	5
Soil water content and saturation data at U-3bh, U-3ax/bl, U-2ah/a3	BN (1998); NSTec (2007)	A3RWMS	Used to evaluate water contents and saturations in Wood (2007)	Corroborative	5
Measured and estimated water table elevations from multiple exploratory and emplacement holes throughout Yucca Flat	DOE/NV (1997b)	DOE	Water table elevations used to define the base of the unsaturated-zone model	Direct	5
Borehole water content, porosity and saturation profiles from Yucca Flat	Wood (2007)	DOE	Measured water contents and saturations in the unsaturated zone of Yucca Flat	Corroborative	4, 6
Borehole water content, porosity and saturation profiles from dry-drilled boreholes in Frenchman Flat	REECo (1994)	DOE	Dry-drilled borehole moisture content data from Frenchman Flat used to evaluate influences of drilling fluids on borehole moisture contents in Yucca Flat	Corroborative	5
Melt-glass partitioning coefficients for selected radionuclides	IAEA (1998a)	IAEA	Melt-glass partitioning data for selected radionuclides	Direct	6
Melt-glass partitioning coefficients for selected radionuclides	Rose et al. (2011)	DOE	Used to update IAEA (1998a) melt-glass partitioning data	Direct	5
Borehole moisture content and saturation data	BN (2005)	USGS	Moisture content and saturation data from dry-drilled holes used to evaluate moisture content and saturation data in Wood (2007)	Corroborative	5

Table C-6
Unsaturated-Zone Model Non-Direct Data
(Page 2 of 2)

Type	Data Source	Program	Use Description	Direct/Corroborative	Acceptance Criteria
Crater locations and geometry	Grasso (2000 and 2001)	USGS	GIS-based incorporation of surface-effects mapping done during the testing period	Direct	3, 6
Fracture unsaturated hydraulic properties	Kwicklis et al. (1998)	USGS	Estimates of fracture unsaturated hydraulic properties based on numerical simulations	Direct	6
Matrix permeabilities for the LCA, LCCU, and TCU	Winograd and Thordarson (1975)	AEC	Estimates of matrix permeabilities for LCA, LCCU, and TCU	Direct	4, 6
Sediment distribution throughout Yucca Flat	Sweetkind and Drake (2007)	USGS	3-D distribution of sediment texture information based on an examination of drillers logs from the weapons testing era	Direct	4, 6
Sediment hydraulic properties estimated from the sediment textural data of Sweetkind and Drake (2007)	Tokunaga et al. (2002); Schaap (1999); Scanlon and Goldsmith (1997); Khaleel and Freeman (1995); Istok et al. (1994)	Various	Sediment hydraulic properties estimated from sediment textural information	Direct	2, 5, 6
Groundwater radionuclide concentrations	N-I (2013c) (Note: Current citation for database)	DOE and predecessor agencies	Used to evaluation performance of groundwater transport models	Corroborative	8

LCCU = Lower carbonate confining unit
TCU = Tuff confining unit

Table C-7
Saturated Zone Alluvial and Volcanic Aquifer System Model Non-Direct Data

Type	Data Source	Program	Use Description	Direct/Corroborative	Acceptance Criteria
Interferometric Synthetic Aperture Radar (InSAR) data	Satellite interferometric Synthetic Aperture Radar (InSAR). Data cited in Vincent et al. (2003).	European Space Agency Eurimage Research and Demonstration Project; Center National d'Etude Spatiales Remote Sensing (ERS) satellites track 399,frame 2871 (shifted -9)	Corroborative data to evaluate the volume of water draining to the LCA	Corroborative	2, 6
Single-well testing results	Hydraulic conductivity data for tuff confining units compiled in Halford et al. (2005); West and Thordarson (1963); Moore et al. (1963); Garber and Johnston (1967); Dixon et al. (1973)	Weapons Testing Program	Corroborative data for evaluating the hydraulic conductivity and permeability of the TCU	Corroborative	4, 6
Historical water-level measurements and hydrographs	Fenelon (2005)	UGTA	USGS	Direct	3, 8
Melt-glass/groundwater radionuclide partition coefficients	IAEA (1998a)	IAEA	Direct Input	Direct	6
Groundwater radionuclide concentrations	N-I (2013c) (Note: Current citation for database)	DOE and predecessor agencies	Used to evaluation performance of groundwater transport models	Corroborative	8

Table C-8
Hydrologic Source Term Non-Direct Data
(Page 1 of 10)

Type	Data Source	Program	Use Description	Direct/ Corroborative	Acceptance Criteria
Yucca Flat Unsaturated HST Model					
Unsaturated flow and transport parameters	Blout et al. (1995)	DOE/EM Soils Project/REECo	Assign flow and transport parameters to analytical models	Direct	5
Fluid properties	Lide (1991)	Open literature	Assign flow and transport parameters to analytical models	Direct	2
Water characteristics pertinent to the distribution of inorganic carbon in the UZ	Davisson et al. (1994)	DOE/HRMP	Understand migration of ^{14}C migration in UZ	Corroborative	4
Sediment properties, recharge behavior	Fischer (1992)	USGS	Assessment of recharge rates	Corroborative	6
Assessments of ^{14}C transport properties	Thorstenson et al. (1983); Garnier (1985); Ross (1988); Striegl and Armstrong (1990); Striegl and Healy (1990); Sheppard et al. (1994); Plummer et al. (2004)	Open literature	Understand migration of ^{14}C migration in UZ	Corroborative	2
Crater recharge information	Hokett and French (1998, 2000); Hokett and Gillespie (1996); Hokett et al. (2000); Tyler et al. (1986)	DRI	Understand magnitude of crater recharge at NNSS	Corroborative	4
Crater recharge information	Tyler et al. (1992); Wilson et al. (2000)	Open literature	Understand magnitude of crater recharge at NNSS	Corroborative	2
Assessments of ^{14}C transport properties	Martin (1991)	PNNL	Understand migration of ^{14}C migration in UZ	Corroborative	9
Fluid properties	Perry and Green (1988)	Open literature	Assign flow and transport parameters to analytical models	Direct	2
Rock-Property Database, NNSS	USGS (2013a) (Note: Current citation for database); Wood (2007)	USGS	Assign flow and transport parameters to analytical models	Direct	6

Table C-8
Hydrologic Source Term Non-Direct Data
(Page 2 of 10)

Type	Data Source	Program	Use Description	Direct/ Corroborative	Acceptance Criteria
Yucca Flat Unsaturated HST Model (continued)					
Historical precipitation data	ARL/SORD (2013) (Note: Current citation for database)	NOAA/DOE	Identify and assign precipitation inputs to models as a means to calculate recharge	Direct	5, 6
Chemical sorption data	SNJV (2007); see also Zavarin and Bruton (2004a,b)	UGTA	Identify and assign sorption (K_d) coefficients to transport models	Direct	1
Saturated HST/Pressurization Effects					
Descriptions and observations of testing impacts on groundwater levels	Hale et al. (1963); Beetem et al. (1965); Garber et al. (1971); Garber and Johnston (1967, 1971)	USGS	For conceptualization and calibration: Descriptions and observations of testing impacts on groundwater levels	Corroborative	6
Descriptions and observations of testing impacts on groundwater levels	Buddemeier and Isherwood (1985)	Weapons Testing Program	For conceptualization and calibration: Description of testing impacts on groundwater levels	Corroborative	4, 6
Chronology of recompletion well observations at BILBY (U-3cn)	DOE/NV (1998)	DOE Nevada Environmental Restoration Project	For conceptualization and calibration: Description and timing of borehole and post-test observations	Direct and corroborative	5
Descriptions and observations of testing impacts on groundwater levels	Knox et al. (1965)	Open literature	For conceptualization and calibration: Descriptions and observations of testing impacts on groundwater levels	Corroborative	2
Descriptions and observations of testing impacts on groundwater levels	Burkhard and Rambo (1991)	Containment	For conceptualization and calibration: Descriptions and observations of testing impacts on groundwater levels	Corroborative	4
Descriptions and observations of testing impacts on groundwater levels	Charlie et al. (1996)	Open literature	Description of testing impacts on groundwater levels	Corroborative	2

Table C-8
Hydrologic Source Term Non-Direct Data
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Type	Data Source	Program	Use Description	Direct/ Corroborative	Acceptance Criteria
Saturated HST/Altered Zone Conceptualization					
Descriptions of factors influencing test cavity and chimney formation and their hydraulic properties	Boardman et al. (1964); Hanson et al. (1981); Boardman and Meyer (1965)	Weapons Testing Program	Conceptualization of test-altered zones	Corroborative	4
Description, conceptualization, and quantification of RST partitioning following an underground test	IAEA (1998a,b,c)	IAEA study of the radiological situation at the atolls of Mururoa and Fangataufa	RST inventory partitioning processes and quantification	Direct	6
Review of the radionuclide migration pumping experiment at Frenchman Flat	Hoffman et al. (1977)	Weapons Testing Program	Conceptualization of test-altered zones, including the exchange volume	Corroborative	4
Information pertinent to the migration of radionuclides in groundwater at the NNSS	Borg et al. (1976a,b)	Plowshare/Weapons Testing Program	Conceptualization of test-altered zones	Corroborative	4
Saturation-matric potential relationships in gravel	Tokunaga et al. (2002)	Open literature	Rock/fluid properties	Direct and corroborative	2
Postshot geologic studies of excavations below RAINIER ground zero	Wadman and Richards (1961)	Weapons Testing Program	Conceptualization of test-altered zones, including exchange volume	Direct and corroborative	4
Summary of the HANDCAR nuclear explosion	Werth (1970)	Weapons Testing Program	Conceptualization of test-altered zones, with focus in carbonate	Direct and corroborative	4
Saturated HST/Rock-Fluid Properties					
Permeability of fault-related rocks	Evans et al. (1997)	Open literature	Rock-fluid properties	Direct	2
Thermophagies properties of fluid systems	Lemmon et al. (2009)	Open literature	Rock-fluid properties	Direct	2

Table C-8
Hydrologic Source Term Non-Direct Data
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Type	Data Source	Program	Use Description	Direct/ Corroborative	Acceptance Criteria
Saturated HST-Cavity Release Model					
Kinetic data regarding glass dissolution as a function of temperature, glass composition, and solution	Mazer (1987)	Underground Nuclear Waste Repository Studies	Conceptualization and quantification of melt glass dissolution mechanisms and rates	Direct and corroborative	5
Descriptions of HST modeling efforts at Frenchman Flat (CAMBRIC) and Pahute Mesa (CHESHIRE), and test categorization activities at Yucca Flat	Tompson et al. (1999); Pawloski (1999); Pawloski et al. (2001, 2005); Carle et al. (2007)	UGTA	Sorption and related conceptualization data in previous HST reports and the Yucca Flat test categorization report	Direct	3
Carbonate HST/Source Term Conceptualization					
Descriptions of test categorization activities at Yucca Flat	Pawloski (2007)	UGTA	Identification of carbonate tests	Direct	3
Contaminant boundary calculations at the SHOAL underground nuclear test	Pohll and Pohlmann (2004)	UGTA	Identification and use of maximum contaminant limits	Direct and corroborative	3
Descriptions of HST modeling efforts at Frenchman Flat (CAMBRIC), Pahute Mesa (CHESHIRE), and Yucca Flat saturated zone; Unclassified NNSS radiologic inventory data	Tompson et al. (1999); Bowen et al. (2001); Pawloski et al. (2001); Smith and Goishi (2000); Smith et al. (2003); Carle et al. (2007); Tompson (2008)	UGTA	Identification and quantification of the RST	Direct and corroborative	3
Unclassified published data descriptive of detonation histories and releases of radiological effluents	Schoengold et al. (1996); DOE/NV (1997b, 2000)	Weapons Testing Program	For identification and specification of radiological releases from tests	Direct and corroborative	4
Unclassified descriptions of tritium source term data at NASH and CAMBRIC	Coles (1977); Hoffman (1978)	Weapons Testing Program/Radionuclide Migration	For bounding and specifying unclassified source term estimates in models	Direct and corroborative	4

Table C-8
Hydrologic Source Term Non-Direct Data
(Page 5 of 10)

Type	Data Source	Program	Use Description	Direct/ Corroborative	Acceptance Criteria
Carbonate HST/Source Term Conceptualization (continued)					
Description, conceptualization, and quantification of RST partitioning following an underground test	IAEA (1998a,b,c)	IAEA study of the radiological situation at the atolls of Mururoa and Fangataufa	RST inventory partitioning processes and quanti fiction	Direct and corroborative	6
Memorandum describing nuclear explosions conducted in limestone and dolomite	Ramspott (1977)	NTS Containment	Specification of a measured NASH test cavity radius	Direct and corroborative	4
Description of the significance of ^{14}C and ^{228}Ra from a health physics perspective	Moeller et al. (2006)	Open literature	For description and specification of maximum contaminant limits	Direct and corroborative	2
Carbonate HST/Site Characterization					
Review and analysis of groundwater levels in the areas of Rainier Mesa, Shoshone Mountain, and Yucca Flat, NNSS	Fenelon (2005); Fenelon et al. (2008)	UGTA	For specification of water levels–both static and transient–as model boundary conditions and calibration targets	Direct and corroborative	3
Evaluation of hydrologic source term processes for underground nuclear tests in Yucca Flat: saturated tests	Tompson (2008)	UGTA	For describing the locations of HST models addressed in the Yucca Flat CAU	Direct and corroborative	3
Description of the hydrostratigraphic model and available hydrologic data in Yucca Flat	BN (2006); SNJV (2006b)	UGTA	For specifying and understanding characteristics of hydrostratigraphic units and faults	Direct and corroborative	1
Description of available water quality data in and about the NNSS	N-I (2013c)	UGTA	For specifying and understanding water quality and related geochemical processes in Yucca Flat groundwater	Corroborative	8

Table C-8
Hydrologic Source Term Non-Direct Data
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Type	Data Source	Program	Use Description	Direct/ Corroborative	Acceptance Criteria
Carbonate HST/Site Characterization (continued)					
Description of available contaminant mass transport data in Yucca Flat	SNJV (2007); Carle et al. (2008b)	UGTA	Mineralogic compositions and reactive mineral distributions	Corroborative	1,3
Subsurface temperature profiles and hydrologic Implications in and about the NNSS	Gillespie (2005)	UGTA	Identification and understanding the potential impacts of geothermal gradients on groundwater flow	Corroborative	3
Description of native uranium concentrations in NNSS carbonate rocks	Paces (2007)	UGTA	Provide perspectives on natural background uranium concentrations	Corroborative	3
Descriptions of geology, rock properties, mineralogy, and well pumping in and about carbonate rock formations at the NNSS	Ramspott (1970, 1972); Ramspott et al. (1970); Borg (1975); McKague (1980); Wagoner and Ramspott (1981); Pawloski (1982); Buddemeier and Isherwood (1985)	NTS Containment/Radionuclide Migration	For specification of geology, rock properties, mineralogy, and well pumping processes in groundwater models	Direct and corroborative	4
Description of chemical and mineralogic evolutionary trends within the Timber Mountain Oasis Valley Caldera Complex, Nevada	Broxton et al. (1989)	Open literature	Provide perspectives on natural background uranium concentrations	Corroborative	2
Carbonate HST/Test Phenomenology					
Development of phenomenological models of underground nuclear tests on Pahute Mesa, NNSS	Pawloski (1999)	UGTA	For estimating cavity radii as a function of test yield, depth of burial, and overburden rock density	Corroborative	3
Description of nuclear test phenomenology in carbonate rocks	Nimz (2006)	UGTA	For describing carbonate rock transformations at high temperature	Corroborative	3

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Type	Data Source	Program	Use Description	Direct/ Corroborative	Acceptance Criteria
Carbonate HST/Test Phenomenology (continued)					
Evaluation of the hydrologic source term from underground nuclear tests on Pahute Mesa (HST model report)	Pawloski et al. (2001)	UGTA	For identification and specification of HST processes and rock properties	Direct and corroborative	3
Description of melt debris and radionuclide partitioning behavior for tests conducted in carbonate rock	Zavarin et al. (2008)	UGTA	For characterizing test melt debris and estimating CO_2 gas releases from tests conducted in carbonate rock	Corroborative	3
Descriptions of processes associated with cavity and chimney formation, alteration of rock properties, gas releases, and related source term processes	Boardman and Meyer (1965); Boardman et al. (1966); Boardman (1970); Werth (1970)	NTS Plowshare/Weapons Testing Program	For identification and characterizing cavity and chimney geometries, measured and calculated cavity radii, altered rock properties, test-altered zones, gas release, and related source term processes	Corroborative	4
Descriptions of nuclear test melt and its formation	Higgins (1972); Butkovich (1974)	UGTA	For describing the processes and rock properties of nuclear test melt debris, with a focus on carbonate rock	Direct and corroborative	4
Descriptions of nuclear test melt and its formation in carbonate rock environments	Higgins (1972)	NTS Containment	For describing the processes associated with nuclear test melt debris, with a focus on carbonate rock	Corroborative	4
Dolomite-magnesian calcite relations at elevated temperatures and CO_2 pressures; CRC Handbook	Graf and Goldsmith (1955); Weast (1984); Lide (2007)	Open literature	For describing the processes associated with nuclear test melt debris, with a focus on carbonate rock	Corroborative	2

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Type	Data Source	Program	Use Description	Direct/ Corroborative	Acceptance Criteria
Carbonate HST/Flow and Transport Model					
Evaluation of hydrologic source term processes for underground nuclear tests in Yucca Flat: Unsaturated tests	McNab (2008)	UGTA	For conceptualization of crater infiltration process	Corroborative	3
Descriptions of radionuclide transport in fractured carbonate rocks, including experimental data	Zavarin et al. (2005, 2007)	UGTA	For conceptualization of radionuclide mobility in fractured carbonate rock	Corroborative	3
Various monographs and technical reports describing the underlying basis for hydrothermal fluid flow and mass transport phenomena in porous and fractured rock and the numerical simulations of these processes using the NUFT code	Bird et al. (1962); Keenan et al. (1969); Bear (1979); van Genuchten (1980); Pollock (1986); Gerke and van Genuchten (1993); Holman (1990); Manteufel et al. (1993); Zimmerman et al. (1993); Nitao and Bear (1996); Ho (1997); Liu et al. (1998); Nitao (1998, 2000); Neuman and Wierenga (2003); SNL (2007); Troldborg et al. (2007); Sun et al. (2008)	Open literature	For the mathematical conceptualization and development of numerical models describing hydrothermal fluid flow and mass transport phenomena in porous and fractured rock	Corroborative	2,5
Subsurface temperature profiles and hydrologic Implications in and about the NNSS; hydrologic data at the NNSS	Gillespie (2005); SNJV (2006b)	UGTA	For identifying representative values and ranges of thermal conductivity, permeability, and porosity parameters	Corroborative	3
Descriptions of factors influencing test cavity and chimney formation and their hydraulic properties	Boardman et al. (1966); Werth (1970); Ramspott and Howard (1975); McKague (1980); Wagoner and McKague (1984); Burkhard (1989)	NTS Plowshare/Containment	For identifying representative values and ranges of solid and bulk density, permeability, and porosity	Corroborative	4

Table C-8
Hydrologic Source Term Non-Direct Data
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Type	Data Source	Program	Use Description	Direct/ Corroborative	Acceptance Criteria
Carbonate HST/Flow and Transport Model (continued)					
Descriptions of thermodynamic and solubility properties of tritium, Noble gases	Price (1958); Popov and Tazetdinov (1960); Clever (1979, 1980); Murphy et al. (1982); Lee (1997); Holocher et al. (2002); Ekwurzel (2004)	Open literature	For identifying representative values and ranges of the thermodynamic and water solubility properties of tritium and related components	Corroborative	2
Quantitative hydrogeology textbook	de Marsily (1986)	Open literature	For identifying representative values and ranges of the tortuosity parameter	Corroborative	2
Geochemical and isotopic evaluation of groundwater velocities in Yucca Flat	SNJV (2006a)	UGTA	For calibrating simulated flow velocities	Corroborative	3
Review and analysis of groundwater levels in the areas of Rainier Mesa, Shoshone Mountain, and Yucca Flat, NNSS; Descriptions of groundwater in Yucca Flat, Analyses of the impacts of heat on groundwater flow at Pahute Mesa	Hevesi et al. (2002); Carle et al. (2003); Fenelon (2005); Gillespie (2005); SNJV (2006b); Fenelon et al. (2008)	UGTA	For specification of boundary conditions for water levels and calibrating groundwater flow velocity, infiltration rate, geothermal gradient, and the rate of melt glass cooling	Direct and corroborative	3
Descriptions of factors influencing test cavity and chimney formation and their hydraulic properties	Boardman et al. (1966); Werth (1970); Pawloski (1982)	NTS Plowshare/Containment	For calibration of saturation (or water content) and temperatures during pre and post-test conditions in models	Corroborative	4

Table C-8
Hydrologic Source Term Non-Direct Data
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Type	Data Source	Program	Use Description	Direct/ Corroborative	Acceptance Criteria
Hydrologic Source Term[a]					
Melt-glass/groundwater radionuclide partition coefficients	IAEA (1998a)	IAEA	Used to assess what fraction of the RST to partition into groundwater	Direct	6
Radionuclide Inventory	Bowen et al. (2001)	Weapons Testing Program	Used to compute the yield-weighted fraction of the Yucca Flat radionuclide inventory to be assigned to each detonation	Direct	3
Radionuclide exchange volume	U.S. Congress/OTA (1989)	Weapons Testing Program	Conceptual model development	Direct	4, 6
Nuclear testing history information	DOE/NV (2000)	Weapons Testing Program	Used to assign yields, locations, test dates and other information related to weapons tests	Direct	4
Groundwater radionuclide concentrations	N-I (2013c)	DOE and predecessor agencies	Used to evaluation performance of groundwater transport models	Corroborative	8

[a]HST described in Appendix C of N-I (2013a).

CO_2 = Carbon dioxide
PNNL = Pacific Northwest National Laboratory
Ra = Radium

C.4.0 References

ARL/SORD, see Air Resources Laboratory/Special Operations and Research Division.

Air Resources Laboratory/Special Operations and Research Division. 2013. "Nevada Test Site (NTS) Climatological Rain Gauge Network." As accessed at http://www.sord.nv.doe.gov/home_climate_rain.htm on 31 December.

Andersson, P., B. Dershowitz, J. Hermanson, P. Meier, E.-L. Tullborg, and A. Winberg. 2002a. *Final Report of the True Block Scale Project: 1) Characterization and Model Development,* TR-02-13. Stockholm, Sweden: Swedish Nuclear Fuel and Waste Management Co. (SKB).

Andersson, J., J. Berglund, S. Follin, E. Hakami, J. Halvarson, J. Hermanson, M.Laaksoharju, I. Rhén, and C.-H. Wahlgren. 2002b. *Testing the Methodology for Site Descriptive Modelling: Application for the Lexemar Area*, TR-02-19. Stockholm, Sweden: Swedish Nuclear Fuel and Waste Management Co. (SKB).

BN, see Bechtel Nevada.

Barton, C.C. 1995. "Fractal Analysis of Scaling and Spatial Clustering of Fractures." *In Fractals in the Earth Sciences*. C.C. Barton and P.R. LaPointe, eds. New York, NY: Plenum Press.

Baxter, R.G. 1983. *Description of Defense Waste Processing Facility Reference Form and Canister*, DP-1606, Rev. 1. Savannah River, GA: Savannah River Plant.

Bear, J. 1979. *Hydraulics of Groundwater*. New York, NY: McGraw-Hill, Inc.

Beard, T. Stoller-Navarro Joint Venture. 2005. Email to K. Pohlmann (DRI) titled "YF North Area Base Model Grids," 5 April. Las Vegas, NV.

Bechtel Nevada. 1998. *Hydrogeologic Characterization of the Unsaturated Zone at the Area 3 Radioactive Waste Management Site*, DOE/NV/11718-210. Prepared for the U.S. Department of Energy, Nevada Operations Office. Las Vegas, NV.

Bechtel Nevada. 2005. *Site Characterization Data from the U3ax/bl Exploratory Boreholes at the Nevada Test Site*, DOE/NV/11718--003-REV.1. Prepared for the U.S. Department of Energy, National Nuclear Security Administration Nevada Site Office. Las Vegas, NV.

Bechtel Nevada. 2006. *A Hydrostratigraphic Model and Alternatives for the Groundwater Flow and Contaminant Transport Model of Corrective Action Unit 97: Yucca Flat-Climax Mine, Lincoln and Nye Counties, Nevada*, Report DOE/NV/11718-1119. Las Vegas, NV.

Beetem, W.A., C.G. Angelo, and B.P. Robinson. 1965. *Quality of Water Studies at Bilby Site*, Technical Letter NTS-113. Denver, CO: U.S. Geological Survey.

Belcher, W.R., J.B. Blainey, F.A. D'Agnese, C.C. Faunt, M.C. Hill, R.J. Laczniak, G.M. O'Brien, C.J. Potter, H.M. Putnam, C.A. San Juan, and D.S. Sweetkind. 2004. *Death Valley Regional Ground-Water Flow System, Nevada and California–Hydrogeologic Framework and Transient Ground-Water Flow Model,* Scientific Investigations Report 2004-5205. Reston, VA: U.S. Geological Survey.

Bethke, C.M. 1996. *Geochemical Reaction Modeling*. New York, NY: Oxford University Press.

Bird, R.B., W.E. Stewart, and E.N. Lightfoot. 1962. *Transport Phenomena.* New York, NY: John Wiley & Sons, Inc.

Birgersson, L., and I. Neretnieks. 1990. "Diffusion in the Matrix of Granitic Rock: Field Test in the Stripa Mine." In *Water Resources Research*, 26(11): pp. 2833–2842.

Blout, D.O., D.P. Hammermeister, K.A. Zukosky, and K.D. Donnelson. 1995. *Site Characterization Data from the Area 5 Science Boreholes, Nevada Test Site, Nye County, Nevada*, DOE/NV 11432-170, UC-721. Las Vegas, NV: Reynolds Electrical & Engineering Co., Inc.

Boardman, C.R. 1965. *A Measurement of the Void Volume and Fracture Permeability Resulting from the Hardhat Event*, UCID-4893. Livermore, CA: University of California, Lawrence Radiation Laboratory.

Boardman, C.R. 1966. *Some Characteristics of the HARD HAT Chimney and Surrounding Wall Rock*, URCL-50177. Livermore, CA: University of California, Lawrence Radiation Laboratory.

Boardman, C.R. 1967. *Results of an Exploration into the Top of the Piledriver Chimney,* UCRL-50385. Livermore, CA: University of California, Lawrence Radiation Laboratory.

Boardman, C.R. 1970. "Engineering Effects of Underground Nuclear Explosives." In *Proceedings of Symposium on Engineering with Nuclear Explosives*, CONF-700101. pp. 43–67. Las Vegas, NV. 14–16 January.

Boardman, C.R., and G.L. Meyer. 1965. *Macro-Deformation Resulting from a Contained Nuclear Explosion in Dolomite*, PNE-802F. Livermore, CA: University of California, Lawrence Radiation Laboratory.

Boardman, C.R., D.D. Rabb, and R.D. McArthur. 1964. "Responses of Four Rock Mediums to Contained Nuclear Explosions." In *Journal of Geophysical Research*, Vol. 69(16): pp. 3457–3469.

Boardman, C.R., G.L. Meyer, and D.D. Rabb. 1966. *Macrodeformation Resulting from the Handcar Event*, UCRL-50149. Livermore, CA: University of California, Lawrence Radiation Laboratory.

Borg, I.Y. 1970. *Survey of Piledriver Results and Preliminary Interpretation of Three Postshot Cores in and near the Cavity*, UCRL-50865. Livermore, CA: University of California, Lawrence Radiation Laboratory.

Borg, I.Y. 1971. *Some Shock Effects in Granodiorite to 270 kbar at the Piledriver Site,* UCRL-73377, Rev. 1. Livermore, CA: Lawrence Livermore Laboratory.

Borg, I.Y. 1973. *Comparison of Shock Effects in Granitic Rock Recovered from the Monique Event, Algeria, and the Piledriver Event, Nevada Test Site,* UCRL-51349. Livermore, CA: Lawrence Livermore Laboratory.

Borg, I.Y. 1975. "Radioactivity Trapped in Melt Produced by a Nuclear Explosion." In *Nuclear Technology*, Vol. 26(1): pp. 88–100.

Borg, I., R. Stone, H.B. Levy, and L.D. Ramspott. 1976a. *Information Pertinent to the Migration of Radionuclides in Ground Water at the Nevada Test Site, Part 1: Review and Analysis of Existing Information,* UCRL-52078(PT. 1). Livermore, CA: Lawrence Livermore Laboratory.

Borg, I., R. Stone, H.B. Levy, and L.D. Ramspott. 1976b. *Information Pertinent to the Migration of Radionuclides in Ground Water at the Nevada Test Site, Part 2: Annotated Bibliography,* UCRL-52078(PT. 2). Livermore, CA: Lawrence Livermore Laboratory.

Bourcier, W.L., S. Roberts, D.K. Smith, S. Hulsey, L. Newton, A. Sawvel, C. Bruton, C. Papelis, W. Um, C.E. Russell, and J. Chapman. 2000. *Determination of Reactive Surface Area of Melt Glass,* UCRL-ID-145181. Livermore, CA: Lawrence Livermore National Laboratory.

Bowen, S.M., D.L. Finnegan, J.L. Thompson, C.M. Miller, P.L. Baca, L.F. Olivas, C.G. Geoffrion, D.K. Smith, W. Goishi, B.K. Esser, J.W. Meadows, N. Namboodiri, and J.F. Wild. 2001. *Nevada Test Site Radionuclide Inventory, 1951–1992,* LA-13859-MS. Los Alamos, NM: Los Alamos National Laboratory.

Bradbury, M.H., and A. Green. 1985. "Measurements of Important Parameters Determining Aqueous Phase Diffusion Rates through Crystalline Rock Matrices." In *Journal of Hydrology*, Vol. 82: pp. 39–55.

Bradbury, M.H., and A. Green. 1986. "Investigations into the Factors Influencing Long Range Matrix Diffusion Rates and Pore Space Accessibility at Depth in Granite." In *Journal of Hydrology*, Vol. 89(1–2): pp. 123–139.

Broxton, D.E., R.G. Warren, F.M. Byers, and R.B. Scott. 1989. "Chemical and Mineralogic Trends within the Timber Mountain–Oasis Valley Caldera Complex, Nevada: Evidence for Multiple Cycles of Chemical Evolution in a Long-Lived Silicic Magma System." In *Journal of Geophysical Research-Solid Earth*, Vol. 94(B5): pp. 5961–5985.

Buddemeier, R.W., and D. Isherwood comps. 1985. *Radionuclide Migration Project 1984 Progress Report*, UCRL-53628. Livermore, CA: Lawrence Livermore National Laboratory.

Burkhard, N.R. 1989. *Physical Properties in LLNL Yucca Flat Areas: The ROCK PILE Concept*, UCRL-100837. Livermore, CA: Lawrence Livermore National Laboratory.

Burkhard, N.R., and J.T. Rambo. 1991. "One Plausible Explanation for Groundwater Mounding." In *Proceedings of the 6th Containment of Underground Nuclear Explosions, Vol. 2,* CONF-9109114. Livermore, CA: Lawrence Livermore National Laboratory.

Butkovich, T.R. 1974. *Rock Melt from an Underground Nuclear Explosion*, UCRL-51554, Livermore, CA: Lawrence Livermore Laboratory.

Carle, S.F., R.M. Maxwell, and G.A. Pawloski. 2003. *Impact of Test Heat on Groundwater Flow at Pahute Mesa, Nevada Test Site*, UCRL-ID-152599. Livermore, CA: Lawrence Livermore National Laboratory.

Carle, S.F., R.M. Maxwell, G.A. Pawloski, D.E. Shumaker, A.F.B. Tompson, and M. Zavarin. 2007. *Evaluation of the Transient Hydrologic Source Term for the Cambric Underground Nuclear Test at Frenchman Flat, Nevada Test Site*, UCRL-TR-226916. Livermore, CA: Lawrence Livermore National Laboratory.

Carle, S.F., M. Zavarin, Y. Sun, and G.A. Pawloski. 2008a. *Evaluation of Hydrologic Source Term Processes for Underground Nuclear Tests in Yucca Flat, Nevada Test Site: Carbonate Tests,* LLNL-TR-403485. Livermore, CA: Lawrence Livermore National Laboratory.

Carle, S.F., M. Zavarin, and G.A. Pawloski. 2008b. *Spatial Variability of Reactive Mineral and Radionuclide K_d Distributions in the Tuff Confining Unit: Yucca Flat, Nevada Test Site*, LLNL-TR-402227. Livermore, CA: Lawrence Livermore National Laboratory.

Carlson, R.C., W.C. Patrick, D.G. Wilder, W.G. Brough, D.N. Montan, P.E. Harben, L.B. Ballou, and H.C. Heard. 1980. *Spent Fuel Test – Climax: Technical Measurements Interim Report*, *FY 1980,* UCRL-53064. Livermore, CA: Lawrence Livermore National Laboratory.

Carroll, R.W.H., G.M. Pohll, S. Earman, and R.L. Hershey. 2008. "A Comparison of Groundwater Fluxes Computed with MODFLOW and a Mixing Model Using Deuterium: Application to the Eastern Nevada Test Site and Vicinity." In *Journal of Hydrology*, Vol. 361(3–4): pp. 371–385.

Cauffman, T.L, A.M. LaVenue, and J.P. McCord. 1990. *Ground-Water Flow Modeling of the Culebra Dolomite, Volume II: Data Base*, SAND89-7068/2, Albuquerque, NM: Sandia National Laboratories.

Charlie, W.A., G.E. Veyera, D.S. Durnford, and D.O. Doehring. 1996. "Porewater Pressure Increases in Soil and Rock from Underground Chemical and Nuclear Explosions." In *Engineering Geology*, Vol. 43(4): pp. 225–236.

Clauser, C., and E. Huenges. 1995. “Thermal Conductivity of Rocks and Minerals.” In *Rock Physics & Phase Relations: A Handbook of Physical Constants*, pp. 105–126. T.J. Ahrens ed. Washington, DC: American Geophysical Union.

Clever, H.L., ed. 1979. *Helium and Neon, IUPAC Solubility Data Series,* Vol. 1. Oxford, England: Pergamon Press.

Clever, H.L., ed. 1980. *Argon, IUPAC Solubility Data Series,* Vol. 4. Oxford, England: Pergamon Press.

Coles, D.G., Lawrence Livermore Laboratory. 1977. Letter to Distribution titled “Nash Source Term for Tritium,” 15 August. Livermore, CA.

Coles, D.G., H.C. Weed, and J.D. Tewhey. 1980. *Geochemical Studies of Sorption and Transport of Radionuclides in Rock Media*, UCRL-52929. Livermore, CA: Lawrence Livermore National Laboratory.

Connolly, J.A. 1981. *Hydrothermal Alteration in the Climax Granite Stock at the Nevada Test Site*. M.S. thesis, Arizona State University.

DOE/NV, see U.S. Department of Energy, Nevada Operations Office.

Daly, C., R.P. Neilson, and D.L. Phillips. 1994. “A Statistical-Topographic Model for Mapping Climatological Precipitation over Mountainous Terrain.” In *Journal of Applied Meteorology*, Vol. 33(2): pp. 140–158.

Davisson, M.L., J.M. Kenneally, D.K. Smith, G.B. Hudson, G.J. Nimz, and J.H. Rego. 1994. *Preliminary Report on the Isotope Hydrology Investigations at the Nevada Test Site: Hydrologic Resources Management Program, FY 1992–1993*, UCRL-ID-116122. Livermore, CA: Lawrence Livermore National Laboratory.

de Marsily, G. 1986. *Quantitative Hydrogeology: Groundwater Hydrology for Engineers.* San Diego, CA: Academic Press, Inc.

Denton, V. 1962. Memorandum to G. Higgins titled “Water Level at Hardhat,” 21 June. VFD 62-277.

Dixon, G.L., K.A. Sargent, and R.W. Spengler. 1973. *Lithologic Logs and Stratigraphic Identification of Exploratory and Emplacement Drill Holes in Area 3, Nevada Test Site*, USGS-474-151; NTS-244. Denver, CO: U.S. Geological Survey.

Dosch, R.G., and A.W. Lynch. 1980. “Radionuclide Transport in a Dolomite Aquifer.” In *Scientific Basis for Nuclear Waste Management*, Vol. 2, edited by C.J.M. Northrup Jr. pp. 617–624. New York, NY: Plenum Press.

Ehlen, J. 2000. "Fractal Analysis of Joint Patterns in Granite." In *International Journal of Rock Mechanics and Mining Sciences*, Vol 37(6): pp. 909–922.

Elliott, P.E., and J.M. Fenelon. 2013. *Database of Groundwater Levels and Hydrograph Descriptions for the Nevada Test Site Area, Nye County, Nevada*: Data Series 533, Version 4.0. Reston, VA: U.S. Geological Survey.

Ekwurzel, B. 2004. *LLNL Isotope Laboratories Data Manual*, UCRL-TR-203316. Livermore, CA: Lawrence Livermore National Laboratory.

Epstein, B. 2004. *Development and Uncertainty Analysis of Empirical Recharge Prediction Models for Nevada's Desert Basins*. M.S. thesis, University of Nevada Reno.

Erdal, B.R., R.D. Aguilar, B.P. Bayhurst, W.R. Daniels, C.J. Duffy, F.O. Lawrence, S. Maestas, P.Q. Oliver, and K. Wolfsberg. 1979. *Sorption-Desorption Studies on Granite,* LA-7456-MS. Los Alamos, NM: Los Alamos Scientific Laboratory.

Evans, J.P., C.B. Forster, and J.V. Goddard. 1997. "Permeability of Fault-Related Rocks, and Implications for Hydraulic Structure of Fault Zones." In *Journal of Structural Geology*, Vol. 19(11): pp. 1393–1404.

Fenelon, J.M. 2005. *Analysis of Ground-Water Levels and Associated Trends in Yucca Flat, Nevada Test Site, Nye County, Nevada, 1951-200*3, Scientific Investigations Report 2005-5175. Carson City, NV: U.S. Geological Survey.

Fenelon, J.M., R.J. Laczniak, and K.J. Halford. 2008. *Predevelopment Water-Level Contours for Aquifers in the Rainier Mesa and Shoshone Mountain Area of the Nevada Test Site, Nye County*, Scientific Investigations Report 2008-5044. Reston, VA: U.S. Geological Survey.

Feth, J.H., C.E. Roberson, and W.L. Polzer. 1964. *Sources of Mineral Constituents in Water from Granitic Rocks, Sierra Nevada, California and Nevada,* USGS Water-Supply Paper 1535-I. Washington, DC: U.S. Geological Survey.

Fischer, J.M. 1992. *Sediment Properties and Water Movement Through Shallow Unsaturated Alluvium at an Arid Site for Disposal of Low-Level Radioactive Waste Near Betty, Nye County, Nevada*, Water Resources Investigations Report 92-4032, Reston, VA: U.S. Geological Survey.

Garber, M.S., and R.H. Johnston. 1967. *A Summary of Lithologic Data, Aquifer Tests, and Construction of Hydraulic Test Well U3cn-5, Nevada Test Site,* Technical Letter NTS-200. Denver. CO: U.S. Geological Survey.

Garber, M.S., and R.H. Johnston. 1971. *Hydraulic-Test and Quality-of-Water Data from Hole U-3cn PS#2, Bilby Site, Nevada Test Site*, Technical Letter NTS-230. Denver, CO: U.S. Geological Survey.

Garnier, J.M. 1985. "Retardation of Dissolved Radiocarbon through a Carbonated Matrix." In *Geochimica et Cosmochimica Acta*, Vol. 49(3): pp. 683–693.

Gerke, H.H., and M.T. van Genuchten. 1993. "Evaluation of a First-Order Water Transfer Term for Variably Saturated Dual-Porosity Flow Models." In *Water Resources Research,* Vol. 29(4): pp. 1225–1238.

Gillespie, D. 2005. *Temperature Profiles and Hydrologic Implications from the Nevada Test Site Area,* DOE/NV/13609-40; Publication No. 45211. Las Vegas, NV: Desert Research Institute.

Gillespie, P.A., C.B. Howard, J.J. Walsh, and J. Watterson. 1993. "Measurement and Characterisation of Spatial Distributions of Fractures." In *Tectonophysics*, Vol. 226(1–4): pp. 113–141.

Graf, D.L., and J.R. Goldsmith. 1955. "Dolomite–Magnesian Calcite Relations at Elevated Temperatures and CO_2 Pressures." In *Geochimica et Cosmochimica Acta,* Vol. 7(3–4): pp. 109–128.

Grambow, B. 1987. *Nuclear Waste Glass Dissolution: Mechanism, Model and Application*, Report No. 87-02. JSS Project, Swedish Nuclear Fuel and Waste Management Co.

Grasso, D.N. 2000. *Geologic Surface Effects of Underground Nuclear Testing, Yucca Flat, Nevada Test Site, Nevada*, Open-File Report 00-176. Denver, CO: U.S. Geological Survey.

Grasso, D.N. 2001. *GIS Surface Effects Archive of Underground Nuclear Detonations Conducted at Yucca Flat and Pahute Mesa, Nevada Test Site, Nevada,* Open-File Report 2001-272. Denver, CO: U.S. Geological Survey.

Hale, W.E., I.J. Winograd, and M.S. Garber. 1963. *Preliminary Appraisal of Close-in Aquifer Response to the BILBY Event, Yucca Flat, Nevada*, Technical Letter NTS-63. Denver. CO: U.S. Geological Survey.

Halford, K.J., U.S. Geological Survey. 2009. Letter to A. Tompson (LLNL) regarding fluxes in northern Yucca Flat simulated by DVRFS model, 16 January. Carson City, NV.

Halford, K.J., U.S. Geological Survey. 2011. Letter to K. Pohlmann (DRI) containing review comments on report "Numerical Simulation of Inter-basin Groundwater Flow into Northern Yucca Flat, Nevada National Security Site" by K. Pohlmann and M. Ye, 15 February. Carson City, NV.

Halford, K.J., R.J. Laczniak, and D.L. Galloway. 2005. *Hydraulic Characterization of Overpressured Tuffs in Central Yucca Flat, Nevada Test Site, Nye County, Nevada*, Scientific Investigations Report 2005-5211. Carson City, NV: U.S. Geological Survey.

Hanson, M.E., R.W. Terhune, and C.R. McKee. 1981. *Explosion Phenomenology and Permeability Enhancement in Earth Media*, UCRL-85811. Livermore, CA: Lawrence Livermore National Laboratory.

Harrill, J.R., J.S. Gates, and J.M. Thomas. 1988. *Major Groundwater Flow Systems in the Great Basin Region of Nevada, Utah and Adjacent States*. Hydrological Investigation Atlas HA-694-C, scale 1:1,000,000. Denver, CO: U.S. Geological Survey.

Hershey, R.L., W. Howcroft, and P.W. Reimus. 2003. *Laboratory Experiments To Evaluate Diffusion of ^{14}C into Nevada Test Site Carbonate Aquifer Matrix*, DOE/NV/11508-55; Publication No. 45180. Las Vegas, NV: Desert Research Institute.

Hevesi, J.A., A.L. Flint, and L.E. Flint. 2002. *Preliminary Estimates of Spatially Distributed Net Infiltration and Recharge for the Death Valley Region, Nevada-California,* Water-Resources Investigations Report 02-4010. Sacramento, CA: U.S. Geological Survey.

Hevesi, J.A., A.L. Flint, and L.E. Flint. 2003. *Simulation of Net Infiltration and Potential Recharge Using a Distributed-Parameter Watershed Model of the Death Valley Region, Nevada and California,* Water-Resources Investigations Report 03-4090. Sacramento, CA: U.S. Geological Survey.

Higgins, G.H., Lawrence Livermore Laboratory. 1972. Memorandum letter to Distribution titled “Preliminary Estimates of the Effect of Carbonate on Containment,” UOPK 72-1. Livermore, CA.

Hoffman, D.C., Los Alamos Scientific Laboratory. 1978. Personal communication to T.M. Humphrey and RNM distribution titled “Analyses of Water Samples from UE-2ce.” Los Alamos, NM.

Hoffman, D.C., R. Stone, and W.W. Dudley, Jr. 1977. *Radioactivity in the Underground Environment of the Cambric Nuclear Explosion at the Nevada Test Site*, LA-6877-MS. Los Alamos, NM: Los Alamos Scientific Laboratory.

Hokett, S.L., and R.H. French. 1998. *Evaluation of Recharge Potential at Crater U5a (WISHBONE)*, DOE/NV/11508-32; Publication No. 45160. Las Vegas, NV: Desert Research Institute, Water Resources Center.

Hokett, S.L., and R.H. French. 2000. *Evaluation of Recharge Potential at Subsidence Crater U19b, Central Pahute Mesa, Nevada Test Site*, Publication No. 45161. Las Vegas, NV: Desert Research Institute.

Hokett, S.L., and D.R. Gillespie. 1996. *Preliminary Evaluation of Recharge Potential at Subsidence Crater U5A in Frenchman Flat, Nevada Test Site*, DOE/NV/11508-15; Publication No. 45147. Las Vegas, NV: Desert Research Institute.

Hokett, S.L., D.R. Gillespie, G.V. Wilson, and R.H. French. 2000. *Evaluation of Recharge Potential at Subsidence Crater U10i, Northern Yucca Flat, Nevada Test Site*, DOE/NV/11508-53; Publication No. 45174. Las Vegas, NV: Desert Research Institute.

Ho, C.K. 1997. "Models of Fracture-Matrix Interactions during Multiphase Heat and Mass Flow in Unsaturated Fractured Porous Media," SAND97-1198C. In *Proceedings of the Sixth Symposium on Multiphase Transport in Porous Media.* ASME International Mechanical Engineering Congress and Exposition, Dallas, TX. 16–21 November.

Holman, J.P. 1990. *Heat Transfer,* Seventh Edition. New York, NY: McGraw-Hill, Inc.

Holocher, J., F. Peeters, W. Aeschbach-Hertig, M. Hofer, M. Brennwald, W. Kinzelbach, and R. Kipfer. 2002. "Experimental Investigation on the Formation of Excess Air in Quasi-Saturated Porous Media." In *Geochimica et Cosmochimica Acta*, Vol. 66(23): pp. 4103–4117.

Holtta, P., M. Hakanen, A. Hautojarvi, J. Timonen, and K. Vaatainen. 1996. "The Effects of Matrix Diffusion on Radionuclide Migration in Rock Column Experiments." In *Journal of Contaminant Hydrology*, Vol. 21(1): pp. 165–173.

IAEA, see International Atomic Energy Agency.

IT, see IT Corporation.

International Atomic Energy Agency. 1998a. *The Radiological Situation at the Atolls of Mururoa and Fangataufa, Technical Report, Volume 3: Inventory of Radionuclides Underground at the Atolls,* IAEA-MFTR-3. In "Proceedings of an IAEA Conference, Vienna, 30 June – 3 July." Vienna, Austria.

International Atomic Energy Agency. 1998b. *The Radiological Situation at the Atolls of Mururoa and Fangataufa, Technical Report, Volume 4: Release to the Biosphere of Radionuclides from Underground Nuclear Weapons Tests at the Atolls,* IAEA-MFTR-4. In "Proceedings of an IAEA Conference, Vienna, 30 June – 3 July." Vienna, Austria.

International Atomic Energy Agency. 1998c. *The Radiological Situation at the Atolls of Mururoa and Fangataufa, Technical Report, Volume 6: Dose Due to Radioactive Materials Present in the Environment or Released from the Atolls,* IAEA-MFTR-6. In "Proceedings of an IAEA Conference, Vienna, 30 June – 3 July." Vienna, Austria.

Isherwood, D., J. Harrar, and E. Raber. 1982. *Characterization of Climax Granite Ground Water,* UCRL-53309. Livermore, CA: Lawrence Livermore National Laboratory.

Istok, J.D., D.O. Blout, L. Barker, K.R. Johnejack, and D.P. Hammermeister. 1994. "Spatial Variability in Alluvium Properties at a Low-Level Nuclear Waste Site." In *Soil Scientists Society of America*, Vol. 58(4): pp. 1040–1051.

IT Corporation. 1996. *Groundwater Flow Model Documentation Package* (*Underground Test Area Subproject Phase I Data Analysis Task, Volume VI),* ITLV/10972-181. Prepared for the U.S. Department of Energy, Nevada Operations Office. Las Vegas, NV.

Johnson, J.W., and S.R. Lundeen. 1997. Written communication. Subject: "GEMBOCHS Thermodynamic Datafiles for Use with the EQ3/6 Modeling Package." Livermore, CA: Lawrence Livermore National Laboratory.

Jones, T.L., V.A. Kelley, J.F. Pickens, D.T. Upton, R.L. Beauheim, and P.B. Davies. 1992. *Integration of Interpretation Results of Tracer Tests Performed in the Culebra Dolomite at the Waste Isolation Pilot Plant Site*, SAND92-1579, UC-721. Sandia, NM: Sandia National Laboratories.

Keenan, J.H., F.G. Keyes, P.G. Hill, and J.G. Moore. 1969. *Steam Tables: Thermodynamic Properties of Water Including Vapor, Liquid, and Solid Phases (English Units).* New York, NY: John Wiley & Sons.

Khaleel, R., and E.J. Freeman. 1995. *Variability and Scaling of Hydraulic Properties for 200 Area Soils, Hanford Site*, WHC-EP-0883. Prepared for the U.S. Department of Energy Assistant Secretary for Environmental Management. Richland, WA: Westinghouse Hanford Company.

Knauss, K.G., W.L. Bourcier, K.D. McKeegan, C.I. Marzbacher, S.N. Nguyen, F.J. Ryerson, D.K. Smith, H.C. Weed, and L. Newton. 1990. "Dissolution Kinetics of a Simple Analogue Nuclear Waste Glass as a Function of pH, Time, and Temperature." In *Material Resources Society Symposium Proceedings*, Vol. 176: pp. 371–381.

Knox, J.B., D.E. Rawson, and J.A. Korver. 1965. "Analysis of a Groundwater Anomaly Created by an Underground Nuclear Explosion." In *Journal of Geophysical Research*, Vol. 70(4): pp. 823–835.

Kwicklis, E.M., F. Thamir, R.W. Healy, and D. Hampson. 1998. *Numerical Simulation of Air- and Water-Flow Experiments in a Block of Variably Saturated, Fractured Tuff from Yucca Mountain, Nevada,* Water-Resources Investigations Report 97-4274. Denver, CO: U.S. Geological Survey.

Lee, K.H. 1997. *Analysis of Vadose Zone Tritium Transport from an Underground Storage Tank Release Using Numerical Modeling and Geostatistics*, UCRL-LR-128840. Livermore, CA: Lawrence Livermore National Laboratory.

Lemmon, E.W., M.O. McLinden, and D.G. Friend. 2009. "Thermophysical Properties of Fluid Systems." In *NIST Chemistry WebBook*, NIST Standard Reference Database Number 69. P.J. Linstrom and W.G. Mallard eds. Gaithersburg MD: National Institute of Standards and Technology.

Li, Y.-H., and S. Gregory. 1974. "Diffusion of Ions in Sea Water and in Deep-Sea Sediments." In *Geochimica et Cosmochimica Acta* 38(5): pp. 703–714.

Lide, D.R., ed. 1991. *Handbook of Chemistry and Physics,* 72nd Edition. Boca Raton, FL: CRC Press.

Lide, D.R., ed. 2000. *CRC Handbook of Chemistry and Physics*, 81st Edition. Boca Raton, FL: Taylor & Francis Group/CRC Press.

Lide, D.R., ed. 2007. *CRC Handbook of Chemistry and Physics*, 88th edition. Boca Raton, FL: Taylor & Francis Group/CRC Press.

Liu, H.H., C. Doughty, and G. S. Bodvarsson. 1998. "An Active Fracture Model for Unsaturated Flow and Transport in Fractured Rocks." In *Water Resources Research,* Vol. 34: pp. 2633–2646.

MacLean, S.C., D.G. Coles, and H.C. Weed. 1978. *The Measurement of Sorption Ratios for Selected Radionuclides on Various Geologic Media*, UCID-17928. Livermore, CA: Lawrence Livermore Laboratory.

Maldonado, F. 1977. *Summary of the Geology and Physical Properties of the Climax Stock, Nevada Test Site,* Open-File Report 77-356. 25 pp. Denver, CO: U.S. Geological Survey.

Maloszewski, P., and A. Zuber. 1993. "Tracer Experiments in Fractured Rocks: Matrix Diffusion and the Validity of Models." In *Water Resources Research*, Vol. 29(8): pp. 2723–2735.

Manteufel, R.D., M.P. Ahola, D.R. Turner, and A.H. Chowdhury. 1993. *A Literature Review of Coupled Thermal-Hydrologic-Mechanical-Chemical Processes Pertinent to the Proposed High-Level Nuclear Waste Repository at Yucca Mountain*, NUREG/CR-6021, CNWRA 92-011. Prepared for the U.S. Nuclear Regulatory Commission. San Antonio, TX: Center for Nuclear Waste Regulatory Analyses.

Martin, W.J. 1991. "The Interaction of Carbon-14 Carbonate Solution Species with Semiarid Sediment." In *The 37th Annual Conference on Bioassay.* Pacific Northwest Laboratory, Ottawa, ON, Canada.

Mazer, J.J. 1987. *Kinetics of Glass Dissolution as a Function of Temperature, Glass Composition, and Solution pHs.* Ph.D. thesis, Northwestern University. Evanston, IL.

McArthur, R.D. 1962. *Preliminary Geologic Data from Drill Hole U15a 28S, Hardhat Event, NTS*, GN 4-62. Livermore, CA: University of California, Lawrence Radiation Laboratory.

McArthur, R.D. 1963. *Geologic and Engineering Effects the Hardhat Event, (Preliminary,.* UCID-4580. Livermore, CA: University of California, Lawrence Radiation Laboratory.

McKague, H.L. 1980. *Summary of Measured Medium Properties of Paleozoic Rocks at the DOE Nevada Test Site,* UCRL-52884. Livermore, CA: Lawrence Livermore National Laboratory.

McNab, W.W. 2008. *Evaluation of Hydrologic Source Term Processes for Underground Nuclear Tests in Yucca Flat, Nevada Test Site: Unsaturated Tests and the Impact of Recharge*, LLNL-TR-403360. Livermore, CA: Lawrence Livermore National Laboratory.

Mehta, M.M., V.S. Gupta, and W.H. Somerton. 1964. *Changes in Physical Properties of Rocks in the Vicinity of an Underground Nuclear Explosion*, UCRL-13105. Livermore, CA: University of California, Lawrence Radiation Laboratory.

Mills, R. 1973. "Self-Diffusion in Normal and Heavy Water in the Range 1-45.Deg." In *The Journal of Physical Chemistry*, Vol. 77(5): pp. 685–688.

Moeller, D.W., M.T. Ryan, R.N. Cherry, Jr., and L.C. Sun. 2006. "Significance of ^{14}C and ^{228}Ra in Terms of the Proposed Yucca Mountain High-Level Radioactive Waste Repository." In *Health Physics,* Vol. 91(3): pp. 238–248.

Moore, J.E., A.C. Doyle, G.E. Walker, and R.A. Young. 1963. *Ground-Water Test Well 2, Nevada Test Site, Nye County, Nevada*, with a section on geophysical logs by R.D. Carroll, Open-File Report TEI-836. U.S. Geological Survey.

Murphy, C.E., C.W. Sweet, and R.D. Fallon. 1982. "Tritium Transport around Nuclear Facilities." In *Nuclear Safety,* Vol. 23(6).

Murray, W.A. 1980. *Permeability Testing of Fractures in Climax Stock Granite, Nevada Test Site*, UCRL-85231. Livermore, CA: Lawrence Livermore National Laboratory.

Murray, W.A. 1981. *Geohydrology of the Climax Stock Granite and Surrounding Rock Formations, NTS,* UCRL-53138. Livermore, CA: Lawrence Livermore National Laboratory.

N-I, see Navarro-Intera, LLC.

NNSA/NSO, see U.S. Department of Energy, National Nuclear Security Administration Nevada Site Office.

NSTec, see National Security Technologies, LLC.

National Security Technologies, LLC. 2007. *Characterization Report Area 3 Radioactive Waste Management Site, Nevada Test Site, Nevada*, DOE/NV/25946--080. Prepared for the U.S. Department of Energy, National Nuclear Security Administration Nevada Site Office. Las Vegas, NV.

Navarro-Intera, LLC. 2013a. *Phase I Flow and Transport Model Document for Corrective Action Unit 97: Yucca Flat/Climax Mine, Nevada National Security Site, Nye County, Nevada*, Rev. 1, N-I/28091--080. Las Vegas, NV.

Navarro-Intera, LLC. 2013b. Written communication. Subject: "UGTA Fracture Characterization Database," UGTA Technical Data Repository Database Identification Number UGTA-4-128. Las Vegas, NV.

Navarro-Intera, LLC. 2013c. Written communication. Subject: "UGTA Geochemistry Database," UGTA Technical Data Repository Database Identification Number UGTA-4-129. Las Vegas, NV.

Neitsch, S.L., J.G. Arnold, J.R. Kiniry, and J.R. Williams, and K.W. King. 2002. *Soil and Water Assessment Tool Theoretical Documentation, Version 2000*, TWRI Report TR-191. College Station, TX: Texas Water Resources Institute.

Neuman, S.P., and P.J. Wierenga. 2003. *A Comprehensive Strategy of Hydrogeologic Modeling and Uncertainty Analysis for Nuclear Facilities and Sites*, NUREG/CR-6805. Washington, DC: U.S. Nuclear Regulatory Commission.

Nimz, G.J., Lawrence Livermore National Laboratory. 2006. Personal communication titled "Phenomenology of Nuclear Tests in Carbonate Rocks." Livermore, CA.

Nitao, J.J. 1998. *Reference Manual for the NUFT Flow and Transport Code,* Version 2.0, UCRL-MA-130651. Livermore, CA: Lawrence Livermore National Laboratory.

Nitao, J.J. 2000. *Documentation of the Thermal Energy Balance Equation Used in the USNT Model of the NUFT Flow and Transport Code*, UCRL-ID-139836. Livermore, CA: Lawrence Livermore National Laboratory.

Nitao, J.J., and J. Bear. 1996. "Potentials and Their Role in Transport in Porous Media." In *Water Resources Research*, Vol. 32(2): pp. 225–250.

Paces, J.B., Lawrence Livermore National Laboratory. 2007. Personal communication to M. Zavarin (LLNL) titled "Uranium Concentrations in NTS Carbonate Rocks." Livermore, CA.

Pawloski, G.A. 1982. *Results from Exploratory Drill Hole UE2ce Northwest Yucca Flat, Nevada Test Site, Near the Nash Event,* UCID-19324. 3 March. Livermore, CA: Lawrence Livermore National Laboratory.

Pawloski, G.A. 1999. *Development of Phenomenological Models of Underground Nuclear Tests on Pahute Mesa, Nevada Test Site—BENHAM and TYBO*, UCRL-ID-136003. Livermore, CA: Lawrence Livermore National Laboratory.

Pawloski, G.A. 2007. Written communication. Subject: *Categorization of Underground Nuclear Tests on Yucca Flat and Climax Mine, Nevada Test Site, for Use in Radionuclide Transport Models.* Livermore, CA: Lawrence Livermore National Laboratory.

Pawloski, G.A., A.F.B. Tompson, and S.F. Carle eds. 2001. *Evaluation of the Hydrologic Source Term from Underground Nuclear Tests on Pahute Mesa at the Nevada Test Site: The CHESHIRE Test*, UCRL-ID-147023. Livermore, CA: Lawrence Livermore National Laboratory.

Pawloski, G.A., G. WoldeGabriel, and I. Farnham. 2005. Written communication regarding *Categorization of Underground Nuclear Tests on Yucca Flat and Climax Mine, Nevada Test Site, for Use in Radionuclide Transport Models*. Livermore, CA: Lawrence Livermore National Laboratory; Los Alamos, NM: Los Alamos National Laboratory; and Las Vegas, NV: Stoller-Navarro Joint Venture.

Perry, R.H., and D.W. Green. 1988. *Perry's Chemical Engineers' Handbook,* 6th Edition. New York, NY: McGraw-Hill, Inc.

Peterson, E., K. Lie, N. Rimer, R. Nilson, and G. Higgins. 1991. "Thermodynamic Evolution of Nuclear Cavities." In *6th Symposium on Containment of Underground Nuclear Explosions*, Volume 1, CONF-9109114. pp. 257-274. 24-27 September. University of Nevada, Reno.

Plummer, M.A., L.C. Hull, and D.T. Fox. 2004. "Transport of Carbon-14 in a Large Unsaturated Soil Column, in: Special Section: Understanding Subsurface Flow and Transport Processes at the Idaho National Engineering & Environmental Laboratory (INEEL) Site." In *Unsaturated Zone Journal*, Vol. 3: pp. 109–121.

Pohll, G., and K. Pohlmann. 2004. *Letter Report: Contaminant Boundary at the Shoal Underground Nuclear Test*, DOE/NV-993. Las Vegas, NV: Desert Research Institute.

Pohll, G.M., J.J. Warwick, and S.W. Tyler. 1996. "Coupled Surface−Subsurface Hydrologic Model of a Nuclear Subsidence Crater at the Nevada Test Site." In *Journal of Hydrology*, Vol. 186(1–4): pp. 43–62.

Pohlmann, K., G. Pohll, J. Chapman, A.E. Hassan, R. Carroll, and C. Shirley. 2004. *Modeling To Support Groundwater Contaminant Boundaries for the Shoal Underground Nuclear Test*, DOE/NV/13609-13; Publication 45184. Las Vegas, NV: Desert Research Institute, Division of Hydrologic Sciences.

Pohlmann, K., M. Ye, D. Reeves, D. Decker, J. Chapman, and M. Zavarin. 2007. *Modeling of Groundwater Flow and Radionuclide Transport at the Climax Mine Sub-CAU, Nevada Test Site*, DOE/NV/26383-06; Publication No. 45226. Las Vegas, NV: Desert Research Institute.

Pollock, D.W. 1986. "Simulation of Fluid Flow and Energy Transport Processes Associated with High-Level Radioactive Waste Disposal in Unsaturated Alluvium." In *Water Resources Research*, Vol. 22(5): pp. 765–775.

Popov, M.M., and F.J. Tazetdinov. 1961. "Vapor Pressure of T_2O." In *Atomnaya Energiya,* Vol. 8(5): pp. 420–424.

Price, A.H. 1958. “Vapour Pressure of Tritiated Water.” In *Nature,* Vol. 181(4604): p. 262.

Quong, R. 1969. “Permeability Increases in Hardhat Granodiorite Samples Fractured by Exploding Foils,” UCRL-50783. Livermore, CA: University of California, Lawrence Radiation Laboratory.

REECo, see Reynolds Electrical & Engineering Co., Inc.

Rabb, D.D. 1968. *Size-Distribution Study of Piledriver Particles*, UCRL-50489. Livermore, CA: University of California, Lawrence Radiation Laboratory.

Rabb, D.D. 1969. *Particle-size Distribution Study: Piledriver Event,* UCRL-72078. Livermore, CA: University of California, Lawrence Radiation Laboratory.

Ramspott, L., Lawrence Radiation Laboratory. 1970. Memorandum letter to L.S. Germain titled “Nuclear Explosions in Limestone and Dolomite,” 14 December. UOPKB 70-121.

Ramspott, L., Lawrence Livermore Laboratory. 1972. Memorandum letter to J.H. Hill titled “Carbonate Assay on Samples from Hole No. U-10p,” 4 April. Livermore, CA.

Ramspott, L., Lawrence Livermore Laboratory. 1977. Memorandum letter to Colonel G. Bulin titled “Results of Water Table Determination for Nash and Bourbon (U),” 8 April. DET76-10. Livermore, CA.

Ramspott, L.D., and N.W. Howard. 1975. *Average Properties of Nuclear Test Areas and Media at the USERDA Nevada Test Site*, UCRL-51948. Livermore, CA: Lawrence Livermore Laboratory.

Ramspott, L.D., R.L. Braun, and W.F. Wadleigh. 1970. *Mineral Composition, CO_2 Content, and Grain Density of Drill Hole Samples from Yucca Flat, Nevada Test Site*, UCRL-50915, Livermore, CA: University of California, Lawrence Radiation Laboratory.

Rechard, R.P., and M.S. Tierney. 2005. “Assignment of Probability Distributions for Parameters in the 1996 Performance Assessment for the Waste Isolation Pilot Plant. Part 2. Application of Process.” In *Reliability Engineering and System Safety*, Vol. 88(1): pp. 33–80.

Reimus, P., G. Pohll, R. Mihevc, J. Chapman, M. Haga, B. Lyles, S. Kosinski, R. Niswonger, and P. Sanders. 2003. “Testing and Parameterizing a Conceptual Model for Solute Transport in a Fractured Granite Using Multiple Tracers in a Forced-Gradient Test.” In *Water Resources Research*, Vol. 39(12): p. 1356.

Reiner, S.R. 2007. *Ground-Water Temperature Data, Nevada Test Site and Vicinity, Nye, Clark, and Lincoln Counties, Nevada, 2000–2006,* Data Series 269. Carson City, NV: U.S. Geological Survey.

Reynolds Electrical & Engineering Co., Inc. 1994. *Site Characterization and Monitoring Data from Area 5 Pilot Wells, Nevada Test Site, Nye County, Nevada,* DOE/NV/11432-74. Las Vegas, NV.

Robertson, E.C. 1979. *Thermal Conductivities of Rocks*, Open-File Report 79-356. Reston, VA: U.S. Geological Survey.

Rose, T.P., Q. Hu, P. Zhao, C.L. Conrado, R. Dickerson, G.F. Eaton, A.B. Kersting, J.E. Moran, G. Nimz, B.A. Powell, E.C. Ramon, F.J. Ryerson, R.W. Williams, P.T. Wooddy, and M. Zavarin. 2011. *Radionuclide Partitioning in an Underground Nuclear Test Cavity*, LLNL-TR-409817. Livermore, CA: Lawrence Livermore National Laboratory.

Ross, B. 1988. "Gas-Phase Transport of Carbon-14 Release from Nuclear Waste into the Unsaturated Zone." In *Scientific Basis for Nuclear Waste Management XI*, M.J. Apted and R.E. Westerman ed. pp. 273–284. Warrendale, PA: Material Research Society.

Russell, C.E. 2004. *Letter Report: Documentation of Data and Method for EDCMB Extended Analysis*. Las Vegas, NV: Desert Research Institute, Division of Hydrologic Sciences.

Russell, C.E., and T. Minor. 2002. *Reconnaissance Estimates of Recharge Based on an Elevation-Dependent Chloride Mass-Balance Approach*, DOE/NV/11508-37; Publication No. 45164. Las Vegas, NV: Desert Research Institute, Water Resources Center.

Ryerson, F.J., and B.J. Qualheim. 1983. *Mineralogic and Petrologic Investigation of Pre-Test Core Samples from the Spent Fuel Test–Climax*, UCID-19976. Livermore, CA: Lawrence Livermore Laboratory.

SNJV, see Stoller-Navarro Joint Venture.

SNL, see Sandia National Laboratories.

Saito, Y., M. Ochs, T. Suyama, A. Kitamura, M. Shibata, and H. Sasamoto. 2007. *An Update of the Sorption Database: Correction And Addition Of Published Literature Data*, JAEA-Data/Code 2007-014. JAEA Technical Report (in Japanese with English abstract).

Sandia National Laboratories. 2007. *Multiscale Thermohydrologic Model,* ANL-EBS-MD-000049 REV 03 AD 01. Las Vegas, NV.

Sandia National Laboratories. 2008. *Simulation of Net Infiltration for Present-Day and Potential Future Climates,* MDL-NBS-HS-000023 REV 01 AD 01. Las Vegas, NV.

Sass, J.H., W.H. Diment, A.H. Lachenbruch, B.V. Marshall, R.J. Munroe, T.H. Moses, Jr., and T.C. Urban. 1976. *A New Heat-Flow Contour Map of the Conterminous United States*, Open-File Report 76-756. Reston, VA: U.S. Geological Survey.

Sato, H. 1999. "Matrix Diffusion of Simple Cations, Anions, and Neutral Species in Fractured Crystalline Rocks." In *Nuclear Technology*, Vol. 127(2): pp. 199–211.

Scanlon, B.R., and R.S. Goldsmith. 1997. "Field Study of Spatial Variability in Unsaturated Flow beneath and adjacent to Playas." In *Water Resources Research*, Vol. 33(10): pp. 2239–2252. Washington, DC: American Geophysical Union.

Schaap, M.G. 1999. *Rosetta, Version 1.0, Class Average Hydraulic Parameters*. Riverside, CA: U.S. Department of Agriculture, Agricultural Research Service, U.S. Salinity Laboratory.

Schoengold, C.R., M.E. DeMarre, and E.M. Kirkwood. 1996. *Radiological Effluents Released from U.S. Continental Tests 1961 through 1992*, DOE/NV-317 (Rev. 1), UC-702. August. Prepared for the U.S. Department of Energy, Nevada Operations Office. Las Vegas, NV: Bechtel Nevada.

Sheppard, M.I., L.L. Ewing, and J.L. Hawkins. 1994. "Soil Degassing of Carbon-14 Dioxide: Rates and Factors." In *Journal of Environmental Quality*, Vol. 23(3): pp. 461–468.

Shibutani, T., Y. Tachi, H. Sato, and M. Yui. 1999. *Sorption Database for Radionuclides on Bentonite and Rocks,* JNC Technical Report (in Japanese with English abstract) TN8410 99-050. Japan Nuclear Cycle Development Institute.

Skagius, K., and I. Neretnieks. 1986. "Porosities and Diffusivities of Some Nonsorbing Species in Crystalline Rocks." In *Water Resources Research*, Vol. 22(3): pp. 389–398. Washington, DC: American Geophysical Union.

Skagius, K., G. Svedberg, and I. Neretnieks. 1982. "A Study of Strontium and Cesium Sorption on Granite." In *Nuclear Technology*, Vol. 59: pp. 302–313.

Smith, D.K., and W. Goishi. 2000. *Unclassified Radiologic Source Term for Nevada Test Site Areas 19 and 20*, UCRL-ID-141706. Livermore, CA: Lawrence Livermore National Laboratory.

Smith, D.K., D.L. Finnegan, and S.M. Bowen. 2003. "An Inventory of Long-Lived Radionuclides Residual from Underground Nuclear Testing at the Nevada Test Site, 1951–1992." In *Journal of Environmental Radioactivity*, Vol. 67(1): pp. 35–51.

Srikanthan, S., F. Chiew, and A. Frost. 2007. *Stochastic Climate Library: User Guide*. Australia: Cooperative Research Centre for Catchment Hydrology.

Sterrett, T.S. 1969. *Drilling Investigation of the Lower Part of the Piledriver Cavity,* UCRL-50765. Livermore, CA: University of California, Lawrence Radiation Laboratory.

Stigsson, M., N. Outters, and J. Hermanson. 2001. *Äspö Hard Rock Laboratory, Prototype Repository Hydraulic DFN Model No: 2,* IPR-01-39. Stockholm, Sweden: Swedish Nuclear Fuel and Waste Management Co. (SKB).

Stoller-Navarro Joint Venture. 2004. *Unclassified Source Term and Radionuclide Data for the Groundwater Flow and Contaminant Transport Model of Corrective Action Units 101 and 102: Central and Western Pahute Mesa, Nye County, Nevada,* Rev. 0, S-N/99205--022. Las Vegas, NV.

Stoller-Navarro Joint Venture. 2006a. *Groundwater Flow Model of Corrective Action Units 101 and 102: Central and Western Pahute Mesa, Nevada Test Site, Nye County, Nevada*, Rev. 0, S-N/99205--076. Las Vegas, NV.

Stoller-Navarro Joint Venture. 2006b. *Phase I Hydrologic Data for the Groundwater Flow and Contaminant Transport Model of Corrective Action Unit 97: Yucca Flat/Climax Mine, Nevada Test Site, Nye County, Nevada,* Rev. 0, S-N/99205--077. Las Vegas, NV.

Stoller Navarro Joint Venture. 2007. *Phase I Contaminant Transport Parameters for the Groundwater Flow and Contaminant Transport Model of Corrective Action Unit 97: Yucca Flat/Climax Mine, Nevada Test Site, Nye County, Nevada*, Rev. 0, S-N/99205--096. Las Vegas, NV.

Stoller-Navarro Joint Venture. 2009. *Unclassified Source Term and Radionuclide Data for Corrective Action Unit 97: Yucca Flat/Climax Mine, Nevada Test Site, Nevada*, Rev. 2, S-N/99205--114. Las Vegas, NV.

Striegl, R.G., and D.E. Armstrong. 1990. "Carbon Dioxide Retention and Carbon Exchange on Unsaturated Quaternary Sediments." In *Geochimica et Cosmochimica Acta*, Vol. 54(8): pp. 2277–2283.

Striegl, R.G., and R.W. Healy. 1990. "Transport of $^{14}CO_2$ in Unsaturated Glacial and Eolian Deposits." In *Chemical Modeling of Aqueous Systems II,* American Chemical Society Symposium Series 416, D.C. Melchior and R.L. Bassett ed. pp. 202–210. Washington, DC.

Sun, Y., K.H. Lee, T.A. Buscheck, Y. Hao, and S.C. James. 2008. *Modeling Thermal-Hydrologic Processes for a Heated Fractured Rock System: Impact of a Capillary-Pressure Cap*. Livermore, CA: Lawrence Livermore National Laboratory.

Sutton, M. 2009. *Review of Distribution Coefficients for Radionuclides in Carbonate Minerals*, LLNL-SR-415700. Livermore, CA: Lawrence Livermore National Laboratory.

Suyama, T., and H. Sasamoto. 2004. *A Renewal of the JNC-Sorption Database (JNC-SDB) Addition of Literature Data Published from 1998 to 2003*, JNC TN8410 2003-018. JNC Technical Report (in Japanese with English abstract).

Sweetkind, D.S., and R.M. Drake, II. 2007. *Geologic Characterization of Young Alluvial Basin-Fill Deposits from Drill-Hole Data in Yucca Flat, Nye County, Nevada*, Scientific Investigations Report 2007-5062. Reston, VA: U.S. Geological Survey.

Thompson, P.H., Raytheon Services Nevada. 1991. Memorandum to K. Hahn (LANL) titled "Geothermal Investigations of LANL Areas of Yucca Flat," GEO-1223. Las Vegas, NV.

Thorstenson, D.C., E.P. Weeks, H. Haas, and D.W. Fisher. 1983. "Distribution of Gaseous $^{12}CO_2$, $^{13}CO_2$, and $^{14}CO_2$ in the Subsoil Unsaturated Zone of the Western U.S. Great Plains." In *Radiocarbon*, Vol. 25: pp. 315–346.

Tokunaga, T.K., J. Wan, and K.R. Olson. 2002. "Saturation-Matric Potential Relations in Gravel." In *Water Resources Research*, Vol. 38: p. 1214. Washington, DC: American Geophysical Union.

Tompson, A.F.B., ed. 2008. *Evaluation of Hydrologic Source Term Processes for Underground Nuclear Tests in Yucca Flat, Nevada Test Site: Saturated Tests*, LLNL-TR-403429. Livermore, CA: Lawrence Livermore National Laboratory.

Tompson, A.F.B., C.J. Bruton, and G.A. Pawloski eds. 1999. *Evaluation of the Hydrologic Source Term from the Underground Nuclear Tests in Frenchman Flat and the Nevada Test Site: The CAMBRIC Test,* UCRL-ID-132300. Livermore, CA: Lawrence Livermore National Laboratory.

Treyer, E.N., and N.A. Raybold. 1982. *The Elution of Radionuclides through Columns of Crushed Rock from the NTS,* LA-9329-MS. Los Alamos, NM: Los Alamos National Laboratory.

Troldborg, L., J.C. Refsgaard, K.H. Jensen, and P. Engesgaard. 2007. "The Importance of Alternative Conceptual Models for Simulation of Concentrations in a Multi-Aquifer System." In *Hydrogeology Journal*, Vol. 15(5): pp. 843–860.

Tyler, S.W., W.A. McKay, J.W. Hess, R.L. Jacobson, and K. Taylor. 1986. *Effects of Surface Collapse Structures on Infiltration and Moisture Redistribution*, DOE/NV/10384-04; Publication No. 45045. Las Vegas, NV: Desert Research Institute, Water Resources Center.

Tyler, S.W., W.A. McKay, and T.M. Mihevc. 1992. "Assessment of Soil Moisture Movement in Nuclear Subsidence Craters." In *Journal of Hydrology*, Vol. 139(1–4): pp. 159–181.

U.S. Congress/OTA, see U.S. Congress, Office of Technology Assessment.

USDA/NRCS, see U.S. Department of Agriculture, Natural Resources Conservation Service.

USGS, see U.S. Geological Survey.

U.S. Congress, Office of Technology Assessment. 1989. *The Containment of Underground Nuclear Explosions,* OTA-ISC-414. Washington, DC: U.S. Government Printing Office.

U.S. Department of Agriculture, Natural Resources Conservation Service. 2004. *National Engineering Handbook*, Part 630, "Hydrology." Washington, DC.

U.S. Department of Energy, National Nuclear Security Administration Nevada Site Office. 2003. *Underground Test Area Quality Assurance Project Plan, Nevada Test Site, Nevada,* DOE/NV--341, Rev. 4. Las Vegas, NV.

U.S. Department of Energy, National Nuclear Security Administration Nevada Site Office. 2011. *Underground Test Area Quality Assurance Project Plan, Nevada National Security Site, Nevada,* DOE/NV--1450, Rev. 0. Las Vegas, NV.

U.S. Department of Energy, National Nuclear Security Administration Nevada Site Office. 2012. *Underground Test Area Quality Assurance Plan, Nevada National Security Site, Nevada,* DOE/NV--1450, Rev. 1. Las Vegas, NV.

U.S. Department of Energy, Nevada Operations Office. 1997a. *Regional Groundwater Flow and Tritium Transport Modeling and Risk Assessment of the Underground Test Area, Nevada Test Site, Nevada,* DOE/NV-477, UC-700. Las Vegas, NV.

U.S. Department of Energy, Nevada Operations Office. 1997b. *Shaft and Tunnel Nuclear Detonations at the Nevada Test Site: Development of a Primary Database for the Estimation of Potential Interactions with the Regional Groundwater System,* DOE/NV--464, UC-700. Las Vegas, NV.

U.S. Department of Energy, Nevada Operations Office. 1998. *Recompletion Report for BILBY,* DOE/NV-500. Las Vegas, NV.

U.S. Department of Energy, Nevada Operations Office. 2000. *United States Nuclear Tests, July 1945 through September 1992,* DOE/NV--209-REV 15. Las Vegas, NV.

U.S. Geological Survey. 2013a. "Mercury Core Library and Data Center, *Rock-Property Database.*" As accessed at http://nevada.usgs.gov/mercury/rock.html on 31 December. Mercury, NV.

U.S. Geological Survey. 2013b. "The *National Map* Viewer and Download Platform*.*" As accessed at http://nationalmap.gov/viewer.html on 31 December.

van Genuchten, M. Th. 1980. "A Closed-Form Equation for Predicting the Hydraulic Conductivity of Unsaturated Soils." In *Soil Science Society of America Journal*, Vol. 44(5): pp. 892–898. Madison, WI.

Vincent, P., S. Larsen, D. Galloway, R.J. Laczniak, W.R. Walter, W. Foxall, and J.J. Zucca. 2003. "New Signatures of Underground Nuclear Tests Revealed by Satellite Radar Interferometry." In *Geophysical Research Letters*, Vol. 30(22): p. 2141.

Wadman, R.E., and W.D. Richards. 1961. *Post-Shot Geologic Studies of Excavations below RAINIER Ground Zero*, UCRL 6586. Livermore, CA: University of California, Lawrence Radiation Laboratory.

Wagoner, J.L., and H.L. McKague. 1984. *Variation of Physical Properties of Alluvium in an Arid Basin*, UCRL-90672. Livermore, CA: Lawrence Livermore National Laboratory.

Wagoner, J.L., and L.D. Ramspott. 1981. *Results of Exploratory Drill Hole UE7ns East-Central Yucca Flat, Nevada Test Site,* UCID-18979. 2 March. Livermore, CA: University of California, Lawrence Livermore National Laboratory.

Weast, R.C., ed. 1984. *Handbook of Chemistry and Physics,* 64th Edition. Boca Raton, FL: CRC Press.

Werth, G.C. 1970. *The Handcar Nuclear Explosion in Dolomite*, UCRL-50951. Lawrence Livermore, CA: University of California, Lawrence Radiation Laboratory.

West, L.R., and W. Thordarson. 1963. *Summary of Hydraulic Data, Water Chemistry, and Abridged Lithologic Log of Ground-Water Test Well 8, Nye County, Nevada*, Technical Letter NTS-47. U.S. Geological Survey.

Wilder, D.G. 1987. *Influence of Stress-Induced Deformations on Observed Water Flow in Fractures at the Climax Granitic Stock*, UCRL-95539-Rev.1. Livermore, CA: Lawrence Livermore National Laboratory.

Wilder, D.G., and J.L. Yow, Jr. 1984. *Structural Geology Report: Spent Fuel Test - Climax Nevada Test Site,* UCRL-53381. Livermore, CA: Lawrence Livermore National Laboratory.

Williams, J.R., and R.C. Izaurralde. 2005. *The APEX Model*. As accessed at ftp://ftp-fc.sc.egov.usda.gov/NHQ/nri/ceap/brcreport_2005.pdf. Temple, TX: U.S. Department of Agriculture, Natural Resources Conservation Service.

Wilson, G.V., D.M. Ely, S.L. Hokett, and D.R. Gillespie. 2000. "Recharge from a Subsidence Crater at the Nevada Test Site." In *Soil Science Society of America Journal*, Vol. 64(5): pp. 1570–1581.

Winograd, I.J., and W. Thordarson. 1975. *Hydrogeologic and Hydrochemical Framework, South-Central Great Basin, Nevada-California, with Special Reference to the Nevada Test Site,* Professional Paper 712-C.

Wood, D.B. 2007. *Digitally Available Interval-Specific Rock-Sample Data Compiled from Historical Records, Nevada Test Site and Vicinity, Nye County, Nevada*, Data Series 297. Reston, VA: U.S. Geological Survey.

Yamaguchi, R., Y. Sakamoto, and M. Senoo. 1993. "Consideration of Effective Diffusivity of Strontium in Granite." In *Journal of Nuclear Science and Technology*, Vol. 30(8): pp. 796–803.

Yow, J.L., Jr., 1984. *Geologic Structure Mapping Database Spent Fuel Test – Climax, Nevada Test Site,* DE85006267. Livermore, CA: Lawrence Livermore National Lab.

Zavarin, M. Lawrence Livermore National Laboratory. 2012a. Email to W. McNab (LLNL), P. Martian (N-I), A. Tompson (LLNL), and R. Andrews (N-I) regarding LCA radionuclide sorption coefficients, 16 March. Livermore, CA.

Zavarin, M. Lawrence Livermore National Laboratory. 2012b. Email to P. Martian (N-I) regarding preliminary RST screening calculation, 1 February. Livermore, CA.

Zavarin, M., and C.J. Bruton. 2004a. *A Non-Electrostatic Surface Complexation Approach to Modeling Radionuclide Migration at the Nevada Test Site: I. Iron Oxides and Calcite*, UCRL-TR-208673. Livermore, CA: Lawrence Livermore National Laboratory.

Zavarin, M., and C.J. Bruton. 2004b. *A Non-Electrostatic Surface Complexation Approach to Modeling Radionuclide Migration at the Nevada Test Site: II. Aluminosilicates*, UCRL-TR-208672. Livermore, CA: Lawrence Livermore National Laboratory.

Zavarin, M., S.K. Roberts, P. Zhao, R.W. Williams, T.P. Rose, A. Rainer, and G.A. Pawloski. 2004a. *High-Temperature Studies of Glass Dissolution Rates Close to Saturation*, UCRL-TR-204874. Livermore, CA: Lawrence Livermore National Laboratory.

Zavarin, M., S.K. Roberts, B.E. Viani, G.A. Pawloski, and T.P. Rose. 2004b. *Nuclear Melt Glass Dissolution and Secondary Mineral Precipitation at 40 to 200 ˚C*, UCRL-TR-204870. Livermore, CA: Lawrence Livermore National Laboratory.

Zavarin, M., M.R. Johnson, S.K. Roberts, R. Pletcher, T.P. Rose, A.B. Kersting, G. Eaton, Q. Hu, E. Ramon, J. Walensky, and P. Zhao. 2005. *Radionuclide Transport in Tuff and Carbonate Fractures from Yucca Flat, Nevada Test Site*, UCRL-TR-219836. Livermore, CA: Lawrence Livermore National Laboratory.

Zavarin, M., S. Roberts, P. Reimus, and M. Johnson. 2007. *Summary of Radionuclide Reactive Transport Experiments in Fractured Tuff and Carbonate Rocks from Yucca Flat, Nevada Test Site*, UCRL-TR-225271. Livermore, CA: Lawrence Livermore National Laboratory.

Zavarin, M., P. Zhao, M. Hu, B.A. Powell, R.W. Williams, and A.B. Kersting. 2008. *Debris Characteristics and Radionuclide Partitioning Behavior in Underground Nuclear Tests Detonated in Carbonate Rock, Report in Preparation*. Livermore, CA: Lawrence Livermore National Laboratory.

Zimmerman, R.W., G. Chen, T. Hadgu, and G.S. Bodvarsson. 1993. "Dual-Porosity Model with Semianalytical Treatment of Fracture/Matrix Flow." In *Water Resources Research*, Vol. 29(7): pp. 2127–2137.