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Review of Inputs Provided to Jason Associates Corporation in Support of RWEV-REP-001, the *Analysis of Postclosure Groundwater Impacts* Report

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Abstract

Report RWEV-REP-001, *Analysis of Postclosure Groundwater Impacts for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High Level Radioactive Waste at Yucca Mountain, Nye County, Nevada* was issued by the DOE in 2009 and is currently being updated. Sandia National Laboratories (SNL) provided support for the original document, performing calculations and extracting data from the Yucca Mountain Performance Assessment Model that were used as inputs to the contaminant transport and dose calculations by Jason Associates Corporation, the primary developers of the DOE report. The inputs from SNL were documented in LSA-AR-037, *Inputs to Jason Associates Corporation in Support of the Postclosure Repository Supplemental Environmental Impact Statement*. To support the updating of the original *Groundwater Impacts* document, SNL has reviewed the inputs provided in LSA-AR-037 to verify that they are current and appropriate for use. The results of that assessment are documented here.

ACKNOWLEDGMENTS

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NOMENCLATURE

DIRS	Document Input Reference System
DOE	U.S. Department of Energy
DVRFS	Death Valley Regional Flow System
EIS	Environmental Impact Statement
FEIS	Final Environmental Impact Statement
FEP	feature, event, or process
K_d	sorption coefficient
LA	License Application [for Yucca Mountain]
NRC	U.S. Nuclear Regulatory Commission
NVDWR	State of Nevada, Division of Water Resources
RAI	Request for Additional Information
RMEI	reasonably maximally exposed individual
SEIS	Supplemental Environmental Impact Statement
SNL	Sandia National Laboratories
SZ	saturated zone
TSPA	Total System Performance Assessment
UZ	unsaturated zone
USGS	U.S. Geological Survey
YMP	Yucca Mountain Project

1. INTRODUCTION

In September, 2008, the Nuclear Regulatory Commission (NRC) concluded that the U.S. Department of Energy's (DOE) license application for construction of a repository at Yucca Mountain, Nevada was docketable. It also concluded that the final environmental impact statement (FEIS) prepared by the DOE, the *Final Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada* (DOE/EIS-0250F, February 2002) and its supplements were practical to adopt. However, the NRC requested additional supplementation to the potential impacts of the proposed action on groundwater and on surface discharges of groundwater. The DOE developed the groundwater supplemental environmental impact statement, but in July 2009, informed the NRC that it would not be completing the supplement, and instead chose to publish the information in a report, the *Analysis of Postclosure Groundwater Impacts for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada* (RWEV-REP-001, DOE 2009a). In November 2013, the NRC requested that the DOE complete the supplement (NRC, 2013). In February, 2014, the DOE replied to the NRC's request, agreeing to provide an update to the 2009 *Groundwater Impacts* report RWEV-REP-001, but deferring to the NRC the task of completing the supplemental EIS (DOE, 2014).

Jason Associates Corporation was the primary developer of the 2009 analysis report for the DOE, and has been given the task of developing the new version, reviewing, and updating when necessary, the calculations in the original report. Sandia National Laboratories (SNL) had a support role in developing the 2009 report, performing some transport calculations and providing inputs to Jason taken from the *Yucca Mountain Total System Performance Assessment Model/Analysis for the License Application* (TSPA-LA) (MDL-WIS-PA-000005, Rev 00, (SNL 2008a). These inputs were documented in the Yucca Mountain Program (YMP) analysis report *Inputs to Jason Associates Corporation in Support of the Postclosure Repository Supplemental Environmental Impact Statement* (LSA-AR-037 Rev 00, SNL 2009). As part of the effort to update the 2009 *Groundwater Impacts* report, SNL has reviewed LSA-AR-037 to determine if the material provided to Jason for use in the 2009 report requires any modification based on new information. This report documents the results of that review.

2. INPUTS TO LSA-AR-037

The report LSA-AR-037 (SNL 2009) described 6 different analyses performed in support of RWEV-REP-001, the 2009 *Groundwater Impacts* report. The methodologies for those analyses are described in Section 3 of LSA-AR-037, and a summary of the results for each analysis was provided in Section 4. The analyses and inputs are listed in Table 1. SNL has assessed each of these analyses to determine if any new data have become available since the issuance of LSA-AR-037 in 2009 which could significantly alter the inputs and require that the analyses be redone. The results of that evaluation are provided in Section 3 of this report.

Inputs for the calculations that support these analyses came from two sources. First, data from the TSPA-LA (including its supporting process and component models) (SNL 2008a) was used. Since the YMP license application was submitted in 2008, there have been no changes to TSPA-LA or to the models that it is based on. In response to NRC requests for additional information (RAIs) during its review of the License Application, sensitivity analyses were run on several topics, each demonstrating that the existing models, as presented in the License Application and supporting documents, were adequate. There are no commitments associated with RAIs to update the calculations supporting the LA. Hence, the TSPA-LA feeds to the *Groundwater Impacts* report are largely unchanged. More details on each of these feeds are given in the sections below.

Table 1. Inputs used in the Analysis Report LSA-AR-037.

Section in LSA-AR-037	Analysis	Input
3.1	Modification of the Death Valley Groundwater Flow Model	Death Valley Regional Groundwater Flow System Model
3.2	Estimation of the Radionuclide Plume at the Accessible Environment.	Site-scale Saturated Zone Transport Model
3.3	Particle Tracking Analysis for Current Conditions	Death Valley Regional Groundwater Flow System Model
3.4	Estimation of Specific Discharge and Flow Paths for Future Climatic Conditions	Results from Section 4.3 and Saturated Zone Flow and Transport Abstraction Model
3.5	Calculation of Radionuclide Mass Release Rates from the TSPA-LA	TSPA Model
3.6	Evaluation of Breakthrough Curves for Nonradiological Contaminants	Saturated Zone Flow and Transport Abstraction Model
3.7	Note on the Analysis for Comparison to Groundwater Protection Standard	TSPA model; Biosphere model

The second major input to the calculations documented in LSA-AR-037 report is the Death Valley Regional Groundwater Flow System (DVRFS) Model developed by the U.S. Geological Survey (USGS) (Belcher 2004). As discussed below, an updated version of this model has not been released by the USGS since the 2009 *Groundwater Impacts* report was issued, and there have been no substantive changes to DVRFS model inputs.

3. RESULTS OF REVIEW

The results of the evaluation of inputs for LSA-AR-037 are provided in the following sections. For simplicity, each section corresponds to the same numbered section in LSA-AR-037.

3.1. Modification of the Death Valley Groundwater Flow Model

The primary input for this analysis is the Death Valley Regional Groundwater Flow System (DVRFS) Model developed by the USGS. To support groundwater transport calculations performed by Jason Associates Corporation, 5 simulations were run using the DVRFS. The simulations were run on a slightly modified version of the DVRFS model published by Belcher (2004). The 2004 DVRFS model simulated a steady-state pre-pumping condition prior to 1913 and then simulated transient flow conditions using pumping and well data from 1913 to 1998. As described in Appendix A of LSA-AR-037, the model provided by the USGS for use in the LSA-AR-037 analysis, informally referred to as the 2005 version of the DVRFS, included well data from 1998-2003 and simulated transient flow conditions until 2003. The updated DVRFS model input files also included added data and corrected an error in the input files for the 2004 DVRFS model (SNL 2009, Appendix A).

It should be noted that the 2004 DVRFS model is also used to generate boundary conditions for the Yucca Mountain Saturated Zone Site-Scale Flow Model (SNL 2007a), which was used in the TSPA-LA to track contaminants from the repository location to the boundary of the accessible environment. The TSPA data at the boundary of the accessible environment are inputs for transport calculations done in LSA-AR-037, which track the contaminants from the compliance boundary to the exposed individual in the Amargosa Valley or at Furnace Creek.

The 2004 publication of the DVRFS was a Scientific Investigations Report (Belcher 2004). The USGS republished the DVRFS model in 2010 as a Professional Paper (Belcher and Sweetkind, 2010), and the updated model was reviewed to determine if the groundwater transport calculations in LSA-AR-037 should be rerun. However, as noted in the Acknowledgements of the 2010 version (Belcher and Sweetkind, 2010, p. iii), this was a re-issuance of the 2004 model in a new format, with only editorial corrections and clarifications. The calibration of the numerical model is the same as it existed in the 2004 model; in fact, it did not even include the updated pumping and well data that were implemented in the informal 2005 DVRFS model. Because there is no difference in the numerical models described in the 2004 and 2010 reports, the 2010 publication has no impact on the results of calculations in LSA-AR-037, and does not constitute a reason for rerunning either the TSPA-LA calculations for contaminant transport to the compliance boundary, or the calculations in LSA-AR-037, tracking the contaminants from the compliance boundary to the exposed individual.

The USGS is currently developing a new version of the DVRFS model, which is anticipated to be published in late 2014. The inputs and calibration of the new 2014 model will differ somewhat from the 2004 model, and will include the modifications made to the 2004 model for the calculations in LSA-AR-037, such as the use of transient flow conditions to fit well data from

1998-2003. At the time of publication of this report, the 2014 DVRFS model was not yet fully vetted, and had not been made available by the USGS.

Significant changes in the pumping rates in the Amargosa Valley might have required rerunning the DVRFS, because in the "pumping" scenarios, these pumping rates are used. The pumping rates used in the 2009 report are based on 2003 data. As shown in Table 2-1 of the *Groundwater Impacts* report (DOE 2009a), groundwater pumping in 2003 consisted largely of irrigation-related pumping in the Amargosa River section of the Central Death Valley subregion (17,600 acre-feet), while the Fortymile Canyon section (92 acre-feet) and the Funeral Mountains section (55 acre-feet) represented only minor contributions (see Moreo and Justet 2008 [DIRS 185968], database) to the total. In the Southern Death Valley subregion, the only groundwater pumping activity in 2003 was in the Shoshone-Tecopa section (27 acre-feet, including pumpage from the California Valley section; see, Moreo and Justet 2008 [DIRS 185968], database).

The 2009 *Groundwater Impacts* report DVRFS calculations used total groundwater pumping rates for the Amargosa Valley of 14,100–21,200 acre-feet per year from 1994 to 2003, averaging 16,800 acre-feet per year. These data are based on USGS estimates of groundwater withdrawal in the Valley. While more recent estimates of pumping rates by the USGS have not been published, the State of Nevada, Division of Water Resources (NVDWR) has published additional data (see, Amargosa Valley No. 230, http://water.nv.gov/data/pumpage/?basin=230, last retrieved 3/10/2014); these data are shown in Figure 1. NVDWR estimates of groundwater withdrawal rates from 2006 to 2012 range from 15,400 to 18,000 acre-feet per year, averaging 16,700 acre-feet per year. This value closely matches the value used in the 2009 *Groundwater Impacts* report.

It is important to note that the USGS pumping estimates for the Amargosa Valley have in the past been slightly higher than the groundwater withdrawal rates calculated by the NVDWR, using the same USGS source data but a different approach for estimating irrigation rates in the absence of data (see RWEV-REP-001, p. 2-16). However, since the State of Nevada data constitute the only available data for the post-2003 period, they are appropriate for use to validate the range used in the 2009 report. On the basis of this comparison, there is no need to update the DVRFS modeling done in the *Groundwater Impacts* report to capture more recent pumping data.

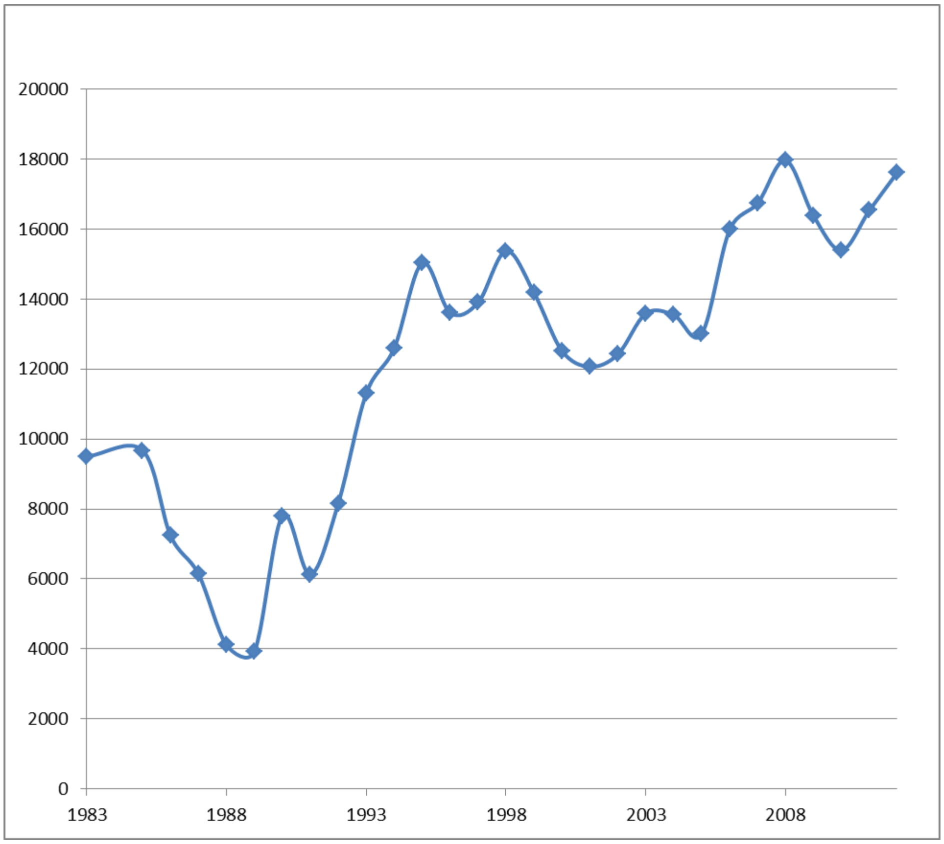

Figure 1. Groundwater pumping estimates (in acre-feet) for the Amargosa Desert generated by the State of Nevada, Division of Water Resources between 1983 and 2012.

3.2. Estimation of the Radionuclide Plume at the Accessible Environment

Contaminant transport from the point at which the contaminants entered the accessible environment to the exposed individual, located where groundwater reaches the surface in springs or by pumping, was modeled with the DVRFS model using particle tracking. To do this, it was necessary to define starting points for individual particle tracks at the compliance boundary. These starting points were derived by using the YMP base-case Site-Scale Saturated Zone Transport model (SNL 2008b), and releasing 10,000 particles from random points under the repository footprint and tracking them to the point of intersection with the boundary, thereby defining the radionuclide plume at the point it entered the accessible environment. Of the 10,000 particles released, 8,024 reached the compliance boundary, and the location and position of each of these was extracted and used as a starting point for the DVRFS calculations.

As noted previously, since the YMP license application was submitted in 2008, there have been no changes to TSPA-LA or to the models and data that it is based on. The base-case SZ transport model has not changed. Also, the boundary conditions for the site-scale model, which are based on DVRFS model calculations, continue to be the most appropriate information, since the Belcher (2004) version used to establish boundary conditions for the LA SZ transport calculations is still the most recent available version of the DVRFS. Therefore, the particle starting positions determined using the methods described in Section 3.2 and 4.2 of LSA-SAR-037 continue to be valid for use.

3.3. Particle Tracking Analysis for Current Conditions

In this calculation, the DVRFS model (Belcher 2004) was used to track particles from the starting locations on the compliance boundary to the locations of the exposed individuals, for the three scenarios investigated in the *Groundwater Impacts* report (DOE, 2009a) that were run using pre-pumping or present-day pumping conditions. The inputs to these calculations are the DVRFS model, estimates of current pumping rates, and the particle starting points determined in the previous section (Section 3.2) of LSA_SAR-037. As noted in Sections 3.1 and 3.2 of this report, these inputs have either not changed, or in the case of the current pumping rates, have not changed significantly enough to require rerunning the DVRFS model. Therefore, the particle tracking calculations described in Sections 3.3 and 4.3 of LSA-SAR-037 remain valid and do not require updating.

3.4. Estimation of Specific Discharge and Flow Paths for Future Climatic Conditions

Based on present-day climatic conditions, estimates of specific discharge for future wetter climates, namely monsoonal and glacial-transition climate states, were obtained using groundwater flow linear scale factors as in the TSPA-LA (see SNL 2008a, Table 6-4[a]). The glacial-transition scaling factor for both the TSPA-LA and the DVRFS model was 3.9, while a SZ groundwater flux ratio of 1.9 was used for TSPA-LA simulations of the monsoonal climate state. These scaling factors were used in the TSPA-LA to increase groundwater specific discharge from the present-day conditions to account for the effects of increased recharge and water table rise expected in the Yucca Mountain and surrounding areas under future wetter climates. Let us note that those estimated ratios are very similar to the values of 3.75 and 1.91 from the weighting of the UZ infiltration models for the glacial-transition and monsoonal climate states, respectively (see SNL 2008a, Table 6-4[a]). Similar flow paths as present-day climatic conditions were used to simulate future wetter climatic conditions, based on the simulations of D'Agnese et al. (1999) showing no significant change of the groundwater flow paths from below Yucca Mountain to the boundary of the accessible environment under wetter conditions with a previous version of the DVRFS model.

As discussed in Section 3.1 of this report, the USGS is currently developing a new version of the DVRFS model, which is anticipated to be released in late 2014, and will include some of the modifications made to the 2004 DVRFS model for the calculations in LSA-AR-037, such as the use of transient flow conditions to fit well data collected between 1998 and 2003. Since the scaling of groundwater flow for future wetter climatic conditions with the DVRFS model is primarily a function of the estimated changes in the boundary conditions of the model and secondarily a function of the detailed distribution of the flow within the model domain (see SNL 2008a, Section 6.5[a]), changes such as the use of transient flow conditions are not expected to affect significantly the validity of those scaling factors. At the time of publication of this report,

possible changes in the boundary conditions within the 2014 DVRFS model have not been made available by the USGS.
For the reasons described above, and in the absence of any additional analyses of groundwater flow in the Yucca Mountain and surrounding areas under future climatic conditions, the approach described in Section 3.4 of LSA-AR-037 and the results described in Section 4.3 of LSA-AR-037 appear still valid and no updates are required in the present report.

3.5. Calculation of Radionuclide Mass Release Rates from the TSPA-LA

In this task, estimates of the annual and cumulative radionuclide release rates for the 300 realizations in the TSPA-LA were extracted from TSPA-LA model output files and provided to Jason Associates Corporation. These realizations capture the epistemic uncertainty in parameter values that feed the TSPA. Release rates were calculated at both the saturate/unsaturated zone boundary and at the compliance boundary. Although it was necessary to rerun the TSPA model files to output the required information for LSA-AR-037, the version of the TSPA model files (v5.005) used in these calculations is the same as that submitted with the Yucca Mountain license application. Version 5.005 is still the current version of the TSPA-LA; although TSPA simulations with modified input files were run as sensitivity analyses in response to specific RAIs during the NRC review process, no commitments to update the TSPA-LA calculations were required. For this reason, the TSPA-LA model outputs provided to Jason Associates Corporation in 2009 are still valid.

3.6. Evaluation of Breakthrough Curves for Nonradiological Contaminants

Nonradiological contaminants that could be released from the repository over the postclosure period include chemically toxic metals such as molybdenum, nickel, and vanadium, which originate from the degradation of Alloy 22 and Stainless Steel Type 316 used as repository and waste package construction materials (DOE 2009a, p. B-19). During the development of the Yucca Mountain FEIS and the Repository SEIS, those metals were identified by DOE as the major potentially hazardous nonradiological contaminants over a 10,000-year postclosure period, considering only the degradation of materials outside of the waste packages. The Analysis of Postclosure Groundwater Impacts (DOE 2009a, p. B-19) addressed the entire 1-million-year postclosure period, including the degradation of materials inside the waste packages, and additional screening studies and analyses conducted by DOE confirmed that molybdenum, nickel, and vanadium are still the only nonradiological contaminants of concern.

To evaluate the potential exposure of individuals in Ash Meadows or at Furnace Creek to nonradiological contaminants, Jason Associated Corporation performed transport analyses from the compliance boundary, where the contaminants entered the accessible environment, to the points of exposure. As inputs for these calculations, SNL evaluated transport of the non-radiological contaminants from the repository footprint to the accessible environment and provided breakthrough curves for the contaminants at that location.

The breakthrough curves were determined using two different methodologies:

- Rather than rerunning the *Saturated Zone Flow and Transport Model Abstraction* (SNL 2008c), radioelement analogs for each of the non-radiological contaminants were identified, and breakthrough curves for those analogs were used. The choice of radioelement to use as an analog was based on the estimated sorption coefficients (K_ds) for the non-radiological contaminants, which were supplied by Jacobs Associates. Inputs for the calculations documented in LSA-AR-037 are radionuclide transport calculations using the *Saturated Zone Flow and Transport Model Abstraction* (SNL 2008c) for the TSPA-LA (SNL 2008a); and K_d values for the non-radiological contaminants supplied by Jason Associates.

- Breakthrough curves for the non-radiological contaminants were generated by running a set of SZ flow and transport abstraction model simulations. The simulations were done using higher groundwater flow rates corresponding to glacial transition climatic conditions and using the K_d values for the non-radiological contaminants recommended by Jason Associates Corporation. Inputs for these simulations are the *Saturated Zone Flow and Transport Model Abstraction* (SNL 2008c) and the K_ds supplied by Jason Associates.

The *Saturated Zone Flow and Transport Model Abstraction* (SNL 2008c) has not been updated, nor has the TSPA-LA (SNL 2008a), since the license application was submitted. Jason Associates provided the recommended values of sorption coefficients for nickel, molybdenum, and vanadium in volcanic rocks and alluvium, which are 15, 0, and 8 mL/g, respectively (see RWEV-REP-001, Table B-1, p. B-6; DOE 2009a). The K_d values for nickel and vanadium were chosen from BSC (2001, p. 180.) and Mikkonen and Tummavuori (1994, p. 364.) Since very limited information was found in the literature for the K_d value of molybdenum (see RWEV-REP-001, p. B-8; DOE 2009a), a conservative zero K_d value was chosen for molybdenum, meaning that there would be no retardation during transport. Jason Associates has evaluated these K_d values against new literature data, published since 2009, and determined that the ranges of values used in the 2009 *Groundwater Impacts* report are bounding and adequate.

Because the inputs to the calculations described in Sections 3.6 and 4.6 of LSA-AR-037 (SNL 2009) are still valid and current, the calculated breakthrough curves at the compliance boundary are valid, and do not have to be updated.

3.7. Note on the Analysis for Comparison to Groundwater Protection Standard

In calculating groundwater activities for comparison to the mandated groundwater protection standard, Jason Associates Corporation utilized methodologies that were taken from the TSPA-LA model and from the *Biosphere Model Report* (SNL 2007b). There are three values that were calculated:

- The combined dose from beta and photon-emitting radionuclides;
- The combined ^{226}Ra and ^{228}Ra activity;
- The gross alpha activity.

To calculate the dose to the effected individual in the 2009 *Groundwater Impacts* report, Jason Associates used methodologies described in the *Biosphere Model Report* (SNL 2007b), with modifications to account for site- and use-specific differences in the exposure pathways relative to the TSPA-LA reasonably maximally exposed individual (RMEI). For instance, aquifer K_ds at some of the locations of exposure in RWEV-REP-001 differ from those used at the TSPA-LA RMEI location. Also, at Furnace Creek, it is assumed that water will be collected from a spring rather than being pumped into a house; therefore, indoor radon exposure will not occur. The models used in the TSPA-LA and described in the Biosphere Model for calculating the dose have not changed; however, sensitivity analyses in responses to two relevant NRC Requests for Additional Information (RAIs) addressed assumptions in the Biosphere submodels and are mentioned here.

In the response to the first RAI (RAI # 3.2.2.1.3.9-001, DOE 2009b), an error in the methodology used to estimate the dose due to decay products in the uranium and thorium decay chains was evaluated. In the TSPA-LA calculations, some pairs of daughter products in the decay chains are assumed to be in secular equilibrium in the groundwater. However, this relationship implicitly assumes that the parent isotope and the daughter product have the same sorption coefficients on aquifer sediments. For some radionuclides the sorption coefficient for the parent is significantly higher than for the decay product, leading to an underestimation of the amount and activity of the decay product in solution. The modified methodology described in RAI#3.2.2.1.3.9-001 corrects for sorption disequilibrium by propagating the effect through to the radionuclide-specific biological dose conversion factors. In the RAI response, this effect was evaluated for the Yucca Mountain RMEI, and was determined to have a minor effect on the dose to the RMEI. However, the analyses by Jason Associates assume different aquifer compositions and different K_ds, so the quantitative conclusion of the RAI is not directly applicable. Therefore, the methodology in RAI#3.2.2.1.3.9-001 (and also documented in Olszewska-Wasiolek and Arnold, 2011) will be used in the updated version of the *Groundwater Impacts* report to calculate the dose to the affected individual.

The second RAI (RAI# 2.2.2.1.2.1-3-003; DOE 2009c) requested additional information on the effect of irrigation recycling—recycling of radionuclides back into groundwater via infiltration of pumped irrigation waters. Irrigation recycling is screened out of the TSPA-LA on the basis of FEP 1.4.07.03.0A, Recycling of Accumulated Radionuclides from Soils to Groundwater (SNL 2008d); however, the screening argument was based on a simplified biosphere-based irrigation recycling model. In the response to RAI# 2.2.2.1.2.1-3-003, a more accurate geosphere-based model for irrigation recycling was described. The geosphere-based methodology was also described in Kalinina and Arnold (2013). The geosphere-based model showed that for the Yucca Mountain TSPA, the screening argument for irrigation recycling was appropriate; the simpler biosphere-based model was slightly conservative relative to the geosphere-based model. The arguments presented in the DOE response to RAI# 2.2.2.1.2.1-3-003 are relevant for assessing the calculations in the 2009 *Groundwater Impacts* report, which implemented irrigation recycling using the biosphere-based model. On the basis of that response, it is concluded that implementing the geosphere-based irrigation recycling model would not greatly affect the calcualted dose to individuals at the exposure locations. Hence, the approach used in the

Groundwater Impacts report does not require updating to include the geosphere-based irrigation recycling model.

4. CONCLUSIONS

Report RWEV-REP-001, *Analysis of Postclosure Groundwater Impacts for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High Level Radioactive Waste at Yucca Mountain, Nye County, Nevada* was issued by the DOE in 2009 and is currently being updated. Sandia National Laboratories provided support for the original document, performing calculations and extracting data from the Yucca Mountain Performance Assessment Model that were used as inputs to the contaminant transport and dose calculations by Jason Associates Corporation, the primary developers of the DOE report. The inputs from SNL were documented in LSA-AR-037, *Inputs to Jason Associates Corporation in Support of the Postclosure Repository Supplemental Environmental Impact Statement*. To support the updating of the original *Groundwater Impacts* document, SNL has reviewed the inputs provided in LSA-AR-037 to verify that they are current and appropriate for use. This report documents the results of that review.

In support of the 2009 *Groundwater Impacts* report, SNL performed several tasks. For radionuclide contaminants migrating from Yucca Mountain, SNL provided the location of the contaminant plume, in the form of the locations at which particles tracked from the repository footprint cross the compliance boundary and enter the accessible environment. SNL also provided radionuclide mass release rates at the boundary, as a function of time. For non-radioactive contaminants, SNL provided breakthrough curves at the compliance boundary, utilizing K_ds given by Jason Associates. SNL also performed transport modeling using the USGS Death Valley Regional Groundwater Flow System model, tracking contaminants for 5 different flow scenarios from the compliance boundary to the point of exposure to individuals on the surface. A major input to these calculations in LSA-AR-037 is the USGS Death Valley Regional Groundwater Flow System model, which has not been updated since the issuance of the 2009 *Groundwater Impacts* report. Most of the other inputs are derived from the Total System Performance Assessment model and supporting models and analyses, which were submitted with the Yucca Mountain license application in 2008 and have not been changed since that time. Because the calculations documented in LSA-AR-037 are still based on the best available data there is no need to update them for the revised *Groundwater Impacts* report.

Finally, the SNL provided the methodologies used in the Yucca Mountain Biosphere model to Jason Associates, which used them to calculate doses to individuals at the points of groundwater release (through pumping or springs) to the surface. Two improvements to these methodologies were identified in responses to NRC RAIs on the Yucca Mountain license application, after publication of the 2009 *Groundwater Impacts* report. RAI#3.2.2.1.3.9-001 dealt with underestimation of the dose to the Yucca Mountain RMEI due to assumptions about equilibrium between radionuclide parents and decay products in the groundwater. The response to the RAI showed that this had only a minor effect on the dose to the Yucca Mountain RMEI, but the calculations contained aquifer-specific inputs, and this conclusion is therefore not directly applicable to the calculations done for the *Groundwater Impacts* report. For this reason, it is recommended that the updated version of that report (RWEV-REP-001-Update) include the methodology described in RAI#3.2.2.1.3.9-001. The second RAI, # 2.2.2.1.2.1-3-003, addressed the effects of assumptions in the TSPA-LA about irrigation recycling on the calculated dose to the RMEI, and concluded that they were negligible. This conclusion is neither site- or aquifer-specific, and is directly applicable to the calculations in the *Groundwater Impacts* report; therefore the approach used in the 2009 version of RWEV-REP-001 is appropriate for the updated version of that report.

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