REQUEST FOR ADDDITIONAL INFORMATION (RAI)
Volume 3—Postclosure Chapter 2.2.1.3.13, 1st Set - Atmospheric Transport of Radionuclides and their Redistribution in Soils -
(RAIs 1 through 12)
(DEPARTMENT OF ENERGY'S SAFETY ANALYSIS REPORT Sections 2.3.10 and 2.3.11

I. Atmospheric Transport RAIs

RAI #1 Distribution of tephra and waste mass within the eruption column and partitioning into the tephra fall deposit

Provide additional justification for the parameter distributions used for the column diffusion coefficient and the magma partitioning factor in the DOE Ashplume model. This information is needed to determine compliance with 10 CFR 63.114(a)(1, 2).

Basis: DOE performance assessment results for the volcanic ash exposure scenario are sensitive to the amount of high-level waste contamination in tephra deposited directly at the receptor location and in the catchment basin of Fortymile Wash. In DOE's model, two factors influence the amount of waste that is dispersed in tephra by violent Strombolian eruption columns, the column diffusion coefficient and the magma partitioning factor (SAR Section 2.3.11.4.2.2.2).

For the first, the DOE Ashplume model for calculating the initial distribution of erupted tephra uses a coefficient for eruption column diffusion, β, that ranges from 0.01 to 0.5. However, based on model comparison (SNL, 2007, Appendix J, Section J4.5), DOE indicate that the column diffusion coefficient should range from 0.3 to 0.5. Sensitivity analyses in SNL (2007, Figure C-4) show that selection of values of β less than 0.3 decreases the waste concentration in the tephra deposit, which is expected to decrease radiological dose.

For the second factor, eruptive products resulting from violent Strombolian activity are divided between volcanic cone, lava flows, and tephra-fall deposit. The Ashplume model assumes that only waste deposited in the tephra-fall deposit contributes to dose. DOE applies the magma partitioning factor to the mass of mixed-in waste to account for the proportion that is incorporated with the tephra-fall deposit. The amount of waste in tephra, and radiological dose, are linearly proportional to the magma partitioning factor. DOE uses data from eight analog volcanic eruptions to determine a range of 0.1 to 0.5 for the magma partitioning factor (BSC, 2003; SNL, 2007). However, not all the analog eruptions showed violent Strombolian behavior and those that did have a magma partitioning factor greater than 0.3.

DOE should justify the use of a column diffusion coefficient and magma partitioning factor with values less than 0.3 and explain how values less than 0.3 are consistent with the DOE conceptual model of a violent Strombolian eruption column and downwind plume.

References:

BSC, 2003. "Characterize Eruptive Processes at Yucca Mountain, Nevada." ANL–MGR–GS–000002. Rev. 01. Las Vegas, Nevada: Bechtel SAIC Company, LLC.

SNL, 2007. "Atmospheric Dispersal and Deposition of Tephra from a Potential Volcanic Eruption at Yucca Mountain, Nevada." MDL–MGR–GS–000002. Rev. 03. ERD 01. Las Vegas, Nevada: Sandia National Laboratories.

RAI #2 Correlation of wind speed and direction

Provide a technical basis for sampling wind speed and direction as uncorrelated, randomized parameters for the altitude intervals used in the DOE Ashplume model. This information is needed to determine compliance with 10 CFR 63.114(a)(1, 2).

Basis: For each altitude interval above Yucca Mountain, the DOE Ashplume model for tephra dispersal randomly samples wind speed and direction from a data set of atmospheric measurements for that altitude (SAR Section 2.3.11.4.2.2.2). As discussed by the applicant (SNL, 2007, Appendix D), wind speed and direction appear to be correlated parameters within a specified altitude interval. These data show that wind speeds generally increase with altitude, and that biases in wind direction also occur with increases in altitude. Thus, wind speed and direction do not appear to be uncorrelated processes for different altitude intervals. DOE should justify the use of wind speed and direction as randomized, uncorrelated parameters in the performance assessment.

Reference:

SNL, 2007. "Atmospheric Dispersal and Deposition of Tephra from a Potential Volcanic Eruption at Yucca Mountain, Nevada." MDL–MGR–GS–000002. Rev. 03. ERD 01. Las Vegas, Nevada: Sandia National Laboratories.

RAI #3 Variation in waste mass per unit mass of tephra deposited on the ground

Provide a demonstration of the variation in waste mass per unit mass of deposited tephra (such as the unitless ratio of waste mass to tephra mass deposited per unit area) with distance from the assumed volcanic vent for the igneous extrusive event scenario. This information is needed to determine compliance with 10 CFR 63.114(a)(1, 2).

Basis: DOE performance assessment results for the volcanic ash exposure (igneous extrusive) scenario are sensitive to the amount of high-level waste contamination in tephra deposited directly at the reasonably maximally exposed individual location and in the catchment basin of Fortymile Wash (SAR Section 2.3.11.4.2.2.3). In SNL (2007, p. 6-10), the applicant states that "waste concentration in tephra varies with location (dependent on distance and direction from vent)" but does not present data that specifically demonstrates the variation. If waste mass per unit mass of tephra varies significantly for different ground surface locations within individual realizations, a technical basis is needed for the variations.

Reference:

SNL, 2007. “Redistribution of Tephra and Waste by Geomorphic Processes Following a Potential Volcanic Eruption at Yucca Mountain, Nevada.” MDL–MGR–GS–000006. Rev. 00. Las Vegas, Nevada: Sandia National Laboratories.

RAI #4 Tephra deposit representation at the reasonably maximally exposed individual location in the Ashplume model

Provide additional information to show that using a point to model tephra deposition at the reasonably maximally exposed individual (receptor) location does not underestimate radiological dose. This information is needed to determine compliance with 10 CFR 63.114(a)(1, 2).

Basis: SAR Section 2.3.11.4.2.2.3 and a DOE report (SNL 2007a, Section 6.5.2.1.17 and Table 8-2) indicate that tephra and waste at the receptor location are calculated for a point located 18 km south of the volcanic vent. However, the tephra redistribution model uses an area to represent the location of the receptor (SAR Section 2.3.11.4.1.1.3 and Figure 2.3.11-13; SNL, 2007b, Figure 1-2 and Table 6.5.10-1). DOE performance assessment results are influenced by the amount of contaminated tephra deposited at the receptor location. Because of variation in wind speed and direction, the likelihood of tephra being deposited at a single point appears to be less than the likelihood of tephra being deposited within an area, such as that shown in SAR Figure 2.3.11-13. DOE should provide additional information to indicate that tephra fall calculated at a point in the Ashplume model appropriately represents the likelihood and characteristics of a tephra-fall deposit in the area used to represent the dose receptor in the tephra redistribution model.

References:

SNL, 2007a. “Atmospheric Dispersal and Deposition of Tephra from a Potential Volcanic Eruption at Yucca Mountain, Nevada.” MDL–MGR–GS–000002. Rev. 03. ERD 01. Las Vegas, Nevada: Sandia National Laboratories.

SNL, 2007b. “Redistribution of Tephra and Waste by Geomorphic Processes Following a Potential Volcanic Eruption at Yucca Mountain, Nevada.” MDL–MGR–GS–000006. Rev. 00. Las Vegas, Nevada: Sandia National Laboratories.

II. Redistribution RAIs

Note: A single reference list is provided at the end of this RAI group.

RAI #5 Radionuclide migration in basaltic tephra

Provide a technical basis to support the assumption that radionuclide diffusion characteristics are the same in basaltic tephra as in ambient soils. This information is needed to determine compliance with 10 CFR 63.114(a)(1, 2).

Basis: For conditions after a potential future volcanic eruption that intersects the repository and entrains waste, radionuclides on the ground surface originate as radionuclide contamination in basaltic tephra deposits. The applicant uses site-specific data from the deposition and migration of fine radionuclide particulates into current surface soils of the Fortymile Wash alluvial fan, which lack discernable basaltic tephra, to support its model for the downward migration of radionuclides following tephra deposition in the volcanic ash exposure scenario (SAR Section 2.3.11.4.2.3; SNL, 2007a).

Initial concentrations and thicknesses of contaminated tephra on interchannel divides and in fluvial channels are determined prior to calculating the downward migration of radionuclides, as summarized in SNL (2007a), Figure 6.3.3-11, Steps 5 and 6. The DOE downward migration model accounts for current soil characteristics without the presence of fresh basaltic tephra. Basaltic tephra can have different surface characteristics than typical epiclastic particles in ambient soils, which may have the potential to affect radionuclide migration processes. DOE should provide a technical basis to demonstrate that the presence of basaltic tephra will not significantly affect soil characteristics relevant to radionuclide migration.

RAI #6 Airborne particle concentrations over fluvial deposits in Fortymile Wash

Provide additional information on airborne waste-contaminated particle concentrations over replenished fluvial deposits to justify the parameter values for long-term airborne mass loads at the Fortymile Wash alluvial fan. Provide additional support for the statement that walking on tephra deposits does not elevate mass loads or provide information to demonstrate that the exposure times for active outdoor conditions includes time spent by the reasonably maximally exposed individual (RMEI) walking outdoors on undisturbed deposits. This information is needed to determine compliance with 10 CFR 63.114(a)(1, 2).

Basis: Inhalation of resuspended volcanic ash is the dominant dose pathway for the volcanic ash exposure scenario. Inhalation doses are influenced by short-term and long-term airborne mass loads in the DOE Total System Performance Assessment. After an eruption, the short-term airborne mass load contribution decreases with time, while the long-term mass load remains constant (SAR Section 2.3.10.3.2.2; SAR Equations 2.3.10-2 and 2.3.10-4). In the DOE model, inhalation exposure is modeled from airborne waste, resuspended from surfaces of the Fortymile Wash alluvial fan. Compared to primary tephra-fall and eolian deposits at an analog volcanic site, fluvial deposits exhibited a finer grain-size distribution (Benke et al., 2009) and may be more susceptible to airborne resuspension during some types of surface disturbing activity. The airborne mass loads immediately following the eruption are approximately three times greater than long-term airborne mass loads (BSC, 2006). For time spent outside, about 80 percent of the RMEI time is modeled as inactive (BSC, 2005, Tables 7-1 and 7-2). Given that DOE models estimate resuspension and inhalation exposure at the alluvial fan of Fortymile Wash, it is not clear how (i) resuspension over active fan deposits and replenishment with new fluvial deposits and (ii) specific information related to walking on tephra deposits (NRC, 2007) were accounted for in the DOE technical basis for airborne mass loading.

RAI #7 Relative contributions of channel and interchannel deposits to airborne waste concentration

Provide information on airborne resuspension of waste-contaminated particles from distributary channels and interchannel deposits and surfaces at the Fortymile Wash alluvial fan. Justify the assumption that inhalation exposure to radionuclides in channels and on interchannel divides is proportional to their respective fractions of the total fan surface area. This information is needed to determine compliance with 10 CFR 63.114(a)(1, 2).

Basis: Inhalation of resuspended volcanic ash is the dominant dose pathway for the volcanic ash exposure scenario. In SAR Section 2.3.11.4.5.3 and the report on redistribution of tephra and waste (SNL, 2007a, p. 5-9), the applicant discusses exposure of the reasonably maximally exposed individual to the airborne resuspension of radionuclides in soil on interchannel divides and in sediment within distributary channels at the Fortymile Wash alluvial fan. In the DOE model, dose contributions from these two surface types are assumed to be proportional to their respective fractions of the total area of the alluvial fan. This assumption is used to convert airborne mass loads to airborne waste concentrations for inhalation dose calculations. Thus, when tephra fall is not deposited directly on interchannel divides, interchannel divides represent stable surfaces that may be relatively depleted in resuspendable particulates, and the interchannel divides may provide lower contributions of resuspendable particles than fresh channel sediments. DOE has not addressed how this uncertainty in airborne particle concentration above these two surfaces has been accounted for by assuming a direct proportionality between total mass load and areal extent of surface type.

RAI #8 Spatial extent of critical slope measurements and variable tephra erosion rates

Explain how spatial grid sizes in the abstracted model adequately account for variations in the actual topography and do not smooth out steeper slopes, thereby reducing the potential for tephra mobilization. Provide additional information on how data from the selected analog sites and their incorporation into the DOE model account for uncertainty in potential future conditions for tephra erosion at Yucca Mountain. This information is needed to determine compliance with 10 CFR 63.114(a)(1, 2).

Basis: Critical slope is a sensitive parameter in the DOE Fortymile Wash Ash Redistribution model for the volcanic ash exposure scenario (SNL, 2007a, Section 6.6.3). Critical slope defines the amount of tephra mobilized and mixed into fluvial sediments. Use of an average slope for a grid area may underestimate the amount of tephra mobilized from local areas with steeper slopes within the grid spacing of the DOE abstracted model. It appears that DOE determined critical slope values from field measurements acquired long after the measured tephra fall occurred, when effects from rapid, immediately post-depositional erosion may no longer be observable. It is thus not clear if the critical slope determination (SNL, 2007a, Table 6.5.2-1) is representative of the erosion of fresh tephra fall deposits and accounts for the variability observed at historical deposits, including erosion outside active channels immediately following tephra-fall deposition. Periods of early rapid erosion have been observed at analog volcanic sites (e.g., Segerstrom, 1950, 1961; Hooper and Hill, 2004). Additional information is needed to support how DOE critical slope values and modeling of tephra mobility for average, long-term conditions account for uncertainties in the immediate post-depositional erosional characteristics of tephra deposits. Such early effects may result in short-term increases in annual dose that could influence the peak expected dose.

RAI #9 Scour depth in channels with fresh basaltic tephra

Justify scour depth for conditions when fresh basaltic tephra deposits may exist in Fortymile Wash, where scour depth estimates could be influenced by tephra-rich channel material and differ with those determined from current conditions. Provide information to indicate that the parameter range for scour depth does not overestimate dilution with non-basaltic, underlying sediment and underestimate the resulting waste concentration at the reasonably maximally exposed individual location. Address other available scour data for Fortymile Wash (e.g., U.S. Geological Survey Station 10251258). This information is needed to determine compliance with 10 CFR 63.114(a)(1, 2).

Basis: Tephra deposited on hillslopes after a volcanic eruption is susceptible to erosion and subsequent remobilization and redistribution). Scour depth is one of the most sensitive parameters in the DOE Fortymile Wash Ash Redistribution model for the volcanic ash exposure scenario (SNL, 2007a, Section 6.6.3). The applicant bases its determination of the parameter range for scour depth on a site-specific field measurement of Fortymile Wash for current conditions without the presence of a tephra deposit. DOE utilized scour chain data only at the Narrows (U.S. Geological Survey Station 10251250). Other field data from Fortymile Wash (e.g., U.S. Geological Survey Station 10251258) may be relevant and should be addressed by DOE.

In SNL (2007a, page 7-7), the applicant provides a rationale to justify the range of scour depth that is based on the mass of tephra remobilized and associates slightly overestimating scour depth with a larger mass of remobilized tephra. Because Figures 6.6.1-2 and 7.1.3-1 in the same report indicate that greater scour depths correspond to smaller initial waste concentrations in fluvial sediment at the receptor location, additional information is needed on how the treatment of uncertainty for scour depth affects the dilution of waste in fluvial sediment and DOE dose estimates.

RAI #10 Amount of tephra stored in channels below the scour depth

Clarify how much tephra, is stored in channels, including tephra mobilized from surrounding hillslopes into channels. If the total amount of tephra stored in channels is significant with respect to the amount of tephra routed to the receptor location, provide a basis for storing significant amounts of tephra in channels. This information is needed to determine compliance with 10 CFR 63.114(a)(1, 2).

Basis: Tephra deposited on hillslopes after a volcanic eruption is susceptible to erosion and subsequent remobilization and redistribution. Scour depth is one of the most sensitive parameters in the DOE Fortymile Wash Ash Redistribution model for the volcanic ash exposure scenario (SNL, 2007a, Section 6.6.3). In the DOE model, tephra can be stored below the scour depth in channels and not routed to the Fortymile Wash alluvial fan (SAR Section 2.3.11.4.1.1.3; SNL, 2007a, p. 6-24). The applicant states initial tephra-fall thicknesses in channels that exceed the scour depth are not very common and tephra sequestered below the scour depth is a very small fraction of the mobilized tephra (SNL, 2007a, p. C-15). However, it does not comment on the potentially greater amount of tephra mobilized from surrounding hillslopes into the channels and stored. If the DOE model stores significant amounts of tephra in channels, additional supporting information is needed to account for uncertainties in the application of the scour depth approach, and may include presentation of suitable analogs that exhibit the modeled behavior.

RAI #11 Alternative conceptual modeling for fluvial redistribution of tephra

Provide a technical basis to support the exclusion of a standard sediment dilution-mixing model from consideration as a valid alternative conceptual model in SAR section (2.3.11.4.4.3). This information is needed to determine compliance with 10 CFR 63.114(a)(3).

Basis: Although SAR Section 2.3.11.4.4.3 and SNL (2007a) discuss several different numerical methods considered in implementing the Fortymile Wash Ash Redistribution (FAR) model, the applicant does not discuss consideration of alternative conceptual models for representing potential tephra redistribution processes. A dilution-mixing model (Hawkes, 1976; Marcus, 1987) has been commonly used to represent surface redistribution processes (Pelletier et al., 2008). This model appears to represent an alternative conceptual model to the scour-dilution-mixing approach used by the applicant. DOE has not provided a technical basis to exclude this model from consideration as an alternative conceptual model in the SAR.

RAI #12 Surface wind data for eolian redistribution of tephra

Provide additional support for not including the potential effects of eolian redistribution of tephra in the performance assessment. This information is needed to determine compliance with 10 CFR 63.114(a)(1, 2).

Basis: The DOE Fortymile Wash Ash Redistribution model explicitly accounts for fluvial redistribution of tephra but does not consider potential effects of eolian redistribution (SAR Section 2.3.11.4.1.1.3; SNL, 2007a, Sections 1.2 and 5.2.2). DOE considers the eolian transport of primary tephra in the Fortymile Wash drainage basin to the receptor location to be negligible, based on its characterization of the prevailing direction for strong surface winds as predominantly from the south (SNL, 2007b, Appendix D; Pelletier and Cook, 2005). However, surface-wind data in, for example, CRWMS M&O (1997, site 9) show both southerly and northerly components in response to diurnal and seasonal effects. These data show that eolian transport of tephra from north of the RMEI location cannot be excluded based on wind direction. Additional support is needed for not considering the potential effects of eolian transport.

References for RAIs 5 through 12

Benke, R.R., D.M. Hooper, J.S. Durham, D.R. Bannon, K.L. Compton, M. Necsoiu, and R.N. McGinnis, Jr. "Measurement of Airborne Particle Concentrations Near the Sunset Crater Volcano, Arizona." *Health Physics* 96(2): 97–117; 2009.

BSC. "Inhalation Exposure Input Parameters for the Biosphere Model." ANL–MGR–MD–000001. Rev. 04. ACN 01. Las Vegas, Nevada: Bechtel SAIC Company, LLC. 2006.

BSC. "Characteristics of the Receptor for the Biosphere Model." ANL–MGR–MD–000005. Rev. 04. Las Vegas, Nevada: Bechtel SAIC Company, LLC. 2005.

CRWMS M&O. Civilian Radioactive Waste Management System Management & Operating Contractor. “Regional and Local Wind Patterns Near Yucca Mountain.” B00000000-01717-5705-00081 REV 00. November 20, 1997.

Hawkes, H.E. “The Downstream Dilution of Stream Sediment Anomalies”. Journal of Geochemical Exploration. Vol. 6. pp. 345−358. 1976.

Hooper, D.M. and B.E. Hill. “Geomorphic Evolution of the Tephra Deposit from Paricutin Volcano, Mexico.” [Poster and abstract] International Association of Volcanology and Chemistry of the Earth Interior General Assembly, Pucón, Chile. San Antonio, Texas: CNWRA. 2004.

Marcus, W.A. “Copper Dispersion in Ephemeral Stream Sediments.” Earth Surface Processes and Landforms. Vol. 12. pp. 217−228. 1987.

NRC. “Review of Additional Information, Provided by DOE, Associated With Key Technical Issue Agreement 2.11 (ML070330252).” Letter (February 26) to M.H. Williams, DOE. Enclosure: “NRC, NMSS, Review of the DOE Agreement Responses Related to the Potential Geologic Repository at Yucca Mountain, Nevada: Key Technical Issue Agreements to Igneous Activity 2.112 Additional Information Needed (ML070330315).” 2007.

Pelletier, J.D., S.B. DeLong, M.L. Cline, C.D. Harrington, and G.N. Keating. “Dispersion of channel-sediment contaminants in distributary fluvial systems: Application to fluvial tephra and radionuclide redistribution following a potential volcanic eruption at Yucca Mountain.” *Geomorphology*. Vol. 94. pp. 226–246. 2008.

Pelletier, J.D. and J.P. Cook. “Deposition of Playa Windblown Dust over Geologic Time Scales.” Geology. Vol. 33. No. 11. pp. 909–912. Boulder, Colorado: Geological Society of America. 2005.

Segerstrom, K. “Erosion Studies at Parícutin, State of Michoacán, Mexico.” U.S. Geological Survey Bulletin 965–A. p. 164. 1950.

Segerstrom, K. “Deceleration of Erosion at Parícutin, Mexico.” U.S. Geological Survey Professional Paper 424–D. pp. D225–D227. 1961.

SNL. “Redistribution of Tephra and Waste by Geomorphic Processes Following a Potential Volcanic Eruption at Yucca Mountain, Nevada.” MDL–MGR–GS–000006. Rev. 00. Las Vegas, Nevada: Sandia National Laboratories. 2007a.

SNL. “Atmospheric Dispersal and Deposition of Tephra from a Potential Volcanic Eruption at Yucca Mountain, Nevada.” MDL–MGR–GS–000002. Rev. 03. ERD 01. Las Vegas, Nevada: Sandia National Laboratories. 2007b.