REQUEST FOR ADDITIONAL INFORMATION (RAI)
Volume 3—Postclosure Chapter 2.2.1.3.7—Radionuclide Transport in the Unsaturated Zone--Set 1 (RAIs 1 through 14)
(DEPARTMENT OF ENGERGY'S SAFETY ANALYSIS REPORT SECTION 2.3.8)

RAI Associated With Flux Distribution in Faults, Fractures, and Matrix

RAI #1: Describe how UZ transport model results support the integration of transport processes in terms of the UZ barrier components and the relative importance of the transport processes.

Basis: Additional information is needed from model results to compare the activity releases from the matrix continuum, the fracture continuum, and faults at the water table and at intermediate locations within the UZ (e.g., base of the TSw, base of the CHn (vitric facies), base of the CHn (zeolitic facies)). The information is needed to verify compliance with 10 CFR 63.114(a) and (b)

RAIs Associated With Radionuclide Sorption

RAI #2: Describe how sorption is simulated in fault zones in the UZ transport model.

Basis: Aqueous radionuclides that travel through fractures in the unsaturated zone are assumed not to sorb to fracture surfaces except in fault zones (e.g., Drill Hole Wash Fault, Pagany Wash Fault) (SAR, Section 2.3.8.5.2.3). The fault zone is treated as a fracture continuum with low porosity where sorption on fracture surfaces can occur (SAR, Section 2.4.2.3.2.1.9 Unsaturated Zone Transport). DOE provides radioelement-specific sorption parameter distributions based on rock type, but the referenced supporting information (SNL, 2007, Appendix A, Section A6) does not provide sufficient information on how these, or other parameters, are used to simulate transport in the fault zones. This information is needed to verify compliance with 10 CFR 63.114(a) and 63.114(b).

RAI #3: Provide the details on how DOE weighted empirical sorption data to develop the cumulative distribution functions.

Basis: In developing the basis for the K_d statistical distributions (SAR, Section 2.3.8.3.1; SNL, 2007, Appendix A and Addendum 1), DOE notes in many places that

> "As discussed in Section A6, not all the empirical data was equally weighted in selecting the probability distribution as the influence of expected variations in water chemistry, radionuclides, and variations in rock surface properties within each major rock type were incorporated in making the selection." (see, for example, SNL, 2007, Appendix A, Section A8.1.3).

The referenced section (SNL, 2007, Appendix A, Section A6) provides only general information, and does not provide sufficient detail to allow an evaluation of the weighting methodology. For example, it is not clear if the weighting process might result in the removal of some data points from the development of the probability distributions, or if the influence of a subset of the data was increased. This information is needed to evaluate whether acceptance criteria related to system description and data uncertainty in (NRC, 2003, Section 2.2.1.3.7.3) are met, and thus verify compliance with 10 CFR 63.114(a) and 63.114(b).

RAIs Associated with Matrix Diffusion

RAI #4: Describe the technical basis for establishing the low end of the sampled uncertainty distribution for the active fracture model gamma parameter at a value of 0.2 for in the unsaturated zone transport abstraction.

Basis: For transport calculations, DOE addressed uncertainty in the gamma parameter by specifying a range of values from 0.2 to 0.6 (from a maximum possible variation between 0 and 1). DOE provided a technical basis for a nominal gamma value of 0.4 for most unsaturated zone model units between the repository horizon and the water table, based on (i) numerical simulations compared with C-14 data (SNL, 2008, PTMATP-AD02, Section 6.5.6), (ii) the calibration of gamma parameters for the site-scale flow model in TSPA (SAR, Tables 2.3.2-8 through 2.3.8-11), and (iii) the distribution of calcite coatings in unsaturated zone fractures (BSC, 2004, CMNA, Section 7.4.2). in sensitivity analyses presented by DOE (e.g., SAR Figure 2.3.8-40), radionuclide transport was significantly more sensitive to lower gamma values (e.g., values between 0.2 and 0.4) than higher values (e.g., 0.4 to 0.6). Given the demonstrated sensitivity, additional information is needed to justify the uncertainty distribution. The technical basis for the uncertainty distribution for the gamma parameter is needed to evaluate whether acceptance criteria related to system description and data uncertainty in (NRC, 2003, Section 2.2.1.3.7.3) are met, and thus verify compliance with 10 CFR 63.114(a) and 63.114(b).

RAI #5: Describe the impact of vapor phase transport of carbon-14 on the comparison of the active-fracture model fitting simulation to the spatial distribution of carbon-14 in the unsaturated zone.

Basis: The applicant modeled groundwater ages, using different values of gamma in an active-fracture transport simulation in which carbon-14 is transported only in the liquid phase and compared the model results with groundwater ages estimated from carbon-14 measurements in unsaturated zone porewater and gas samples,. Air permeability tests and barometric monitoring at Yucca Mountain suggest significant vapor flow and diurnal barometric pressure fluctuations throughout the unsaturated zone. The information is needed to verify compliance with 10 CFR 63.114(c) and (g).

RAI #6: Discuss the potential for bias in the prediction of active fractures and matrix diffusion resulting from the exclusion of Cl-36 evidence.

Basis: Fracture coating record of secondary minerals used to support the active-fracture model could be analogous to a time-exposure of all flow paths over the last 10 million years, whereas a "snapshot" of present-day flow paths might correspond to a much smaller subset of active fractures. Although evidence for the existence of a few fast present-day flow paths, as suggested by bomb-pulse chlorine-36 measurements, is sparse, such data may provide an illustration of an active-fracture "snapshot". The NRC staff notes that Liu, et al. (1998) discounts chlorine-36 data as evidence for sparsely distributed active flow paths in support of the active-fracture model. The authors suggest that bomb-pulse Cl-36 occurrences are too widespread to help constrain the active-fracture model as a continuum model. The information is needed to verify compliance with 10 CFR 63.114(c) and (g).

RAI #7: Address the potential limitations of the relationship between the fraction of active fractures and the effective saturation of connected fractures on modeling flow in unsaturated fractured rock and resulting effects on uncertainty and its propagation.

Basis: Liu, et al. (1998) describe how f_a, S_e, and gamma range only between 0 and 1. With these constraints, in f_a-S_e space, only f_a- S_e pairs including and above the $f_a = S_e$ line are possible. This limitation has not been explained. In the situation, where all the fracture system is saturated ($S_e = 1$), the active fracture model would have all the fractures flowing. The relationship seems to preclude the possibility of preferential pathways. However, fracture geometries can result in preferential pathways even in fully-saturated fracture systems. DOE should address the ramifications of this limitation on matrix diffusion. The information is needed to verify compliance with 10 CFR 63.114(c) and (g).

RAI Associated with Field Testing Data

RAI #8: Describe how the data and observations from the Alcove 1 test support the flow and transport models used in the TSPA.

Basis: Figures 2.3.8-34 and -35, referred to in Section 2.3.8.3.3.3 of the SAR, show applied bromide tracer concentrations that fluctuated irregularly from 150 to 600 ppm over a period of approximately 100 days and observed seepage tracer concentrations that increased from 0 to 150 ppm in a relatively smoother curve approximately one month after the initiation of the tracer application. It is not apparent how much retardation of the tracer occurred relative to the infiltration rate, why the applied tracer concentration varied so irregularly as part of the experiment, how the fluctuating initial concentration was addressed in the interpretation of results and subsequent modeling, or what percentage of tracer mass was recovered relative to that applied. This information is needed to verify compliance with 10 CFR Part 63.114(g).

RAIs associated with Colloidal Transport

RAI #9: Explain how the transport of irreversible colloids from the EBS to the UZ is represented, particularly with regard to nonseeping drift conditions that appear to favor the release of radionuclides to the matrix continuum. If the colloids are released from the EBS directly to the UZ matrix continuum by the EBS-UZ interface model, describe how the initiation of transport in the matrix affects the transport of irreversible colloids compared to initiation of transport in fractures.

Basis: DOE did not provide details in SAR (2008) or in supporting AMRs to describe how the mass flux of irreversible colloids is handled by the advective and diffusive flux-splitting approaches implemented at the interface between the EBS and the UZ. In particular, it is not apparent how DOE models the subsequent transport of irreversible colloids in the UZ if they are released to the matrix from nonseeping drifts in the EBS. The information is needed to verify compliance with 10 CFR 63.114(a) and (b).

RAI #10: Reconcile apparent differences in the SAR regarding arrival time for plutonium associated with irreversible colloids.

Basis: Modeling results presented in the SAR indicate that plutonium is transported more readily through the UZ as a solute or reversible colloid than as an irreversible colloid. The modeled arrival time of irreversible colloids is longer than and contributes less to ^{239}Pu activity releases from the UZ than the dissolved and reversible colloids in the UZ (e.g., SAR Fig. 2.4-108). However, results presented elsewhere in the SAR indicate that irreversible colloids have short travel times in the UZ (e.g., SAR Section 2.3.8.5.4). The information is needed to verify compliance with 10 CFR 63.114(a) and (b).

RAI #11: Explain how TSPA represents the status of irreversible colloids that are permanently filtered at a matrix - matrix interface if the interface becomes saturated when water table rises due to future climate change.

Basis: DOE states that colloid transport is more important to waste isolation in the saturated zone than in unsaturated zone, but no explanation is provided in the SAR for the potential effects of remobilization of irreversible colloids trapped at a UZ interface by colloid exclusion if saturation and flow rates at the interface change. The information is needed to verify compliance with 10 CFR 63.114(a) and (b).

RAI #12: Explain why uncertainty about the fraction of irreversible colloids that travel unretarded (i.e., the fast irreversible colloid fraction) is not propagated in the UZ transport abstraction.

Basis: DOE assigned a fixed value (0.00168) in TSPA to represent the fraction of fast irreversible colloids in the transport abstraction. DOE acknowledged that the selected value is uncertain. DOE identified a cumulative distribution function for this parameter but did not provide a technical basis or sensitivity analysis to support the use of a constant value for all transport calculations. The information is needed to verify compliance with 10 CFR 63.114(b).

RAI #13: Describe how the UZ transport model represents the transport of irreversible colloids in the matrix after they are admitted there by advective transport from fractures.
Basis: DOE excludes matrix diffusion of irreversible colloids, but the colloid size exclusion process allows a fraction of small colloids to enter the matrix advectively under some conditions.

It is not apparent how the transport of irreversible colloids in the matrix is implemented by the UZ transport model, particularly with respect to colloid filtration at matrix-matrix interfaces. The information is needed to verify compliance with 10 CFR 63.114(a) and (b).

RAI #14: Provide details for how DOE selected the range of $K_{d,coll}$ values that are used to model sorption of radionuclides onto montmorillonite/smectite.

Basis: The colloid sorption coefficients ($K_{d,coll}$) for reversible sorption of Pu and Am onto smectite differ by several orders of magnitude from those used to model sorption of Pu and Am onto the matrix of identified rock types in the UZ transport model. Provide additional information about the technical basis for the selection of the $K_{d,coll}$ distribution of values, including, if relevant, the information reported in DTN 180391. The information is needed to verify compliance with 10 CFR 63.114(a) and (b).

References

BSC. *Conceptual Model and Numerical Approaches for Unsaturated Zone Transport.* MDL-NBS-HS-000005 Rev 01. Las Vegas, Nevada: Bechtel SAIC Company. 2004.

DOE. "Yucca Mountain Repository License Application: Safety Analysis Report." DOE/RW–0573 Rev 0. Las Vegas, Nevada: DOE, Office of Civilian Radioactive Waste Management. 2008.

Liu,H.H., Doughty, C., and Bodvarsson, G.S. 1998. "An Active Fracture Model for Unsaturated Flow and Transport in Fractured Rocks." Water Resources Research, 34 (10) , 2633-2646. Washington, D.C. American Geophysical Union.

NRC. "Yucca Mountain Review Plan: Final Report." NUREG-1804, Revision 2. Washington, DC: U.S. Nuclear Regulatory Commission. July 2003.

SNL. *Particle Tracking Model and Abstraction of Transport Processes.* MDL-NBS-HS-000020. Rev. 02. AD 02, ERD 02. (?) Las Vegas, Nevada: Sandia National Laboratories. 2008.

SNL. "Radionuclide Transport Models Under Ambient Conditions (U0060)." MDL-NBS-HS-000008. Rev. 02 ACN002 ADD01. Las Vegas, Nevada: Sandia National Laboratories. 2007.