REQUEST FOR ADDITIONAL INFORMATION (RAI)
Volume 3—Postclosure Chapter 2.2.1.3.5 (Climate and Infiltration)
1st Set (RAIs 1 through 8)
(DEPARTMENT OF ENERGY'S SAFETY ANALYSIS REPORT SECTIONS 2.3.1)

RAI #1 Anthropogenic Effects on Climate

Describe how net infiltration predicted for Yucca Mountain for the first 10,000 yrs represented in TSPA includes the effect of climate change caused by elevated CO_2 levels related to past and present human activities. This information is needed to evaluate compliance with 10 CFR 63.114(a)(1),(2),(5), and 63.305(a)(b),(c).

Basis: The regulations at 10 CFR 63.305 require that the characteristics of the reference biosphere be consistent with 'present knowledge' and DOE must vary factors related to climate consistent with the constraints specified at 10 CFR 63.342(c)(2) for how climate change is to be represented after 10,000 years. For the initial 10,000 years, the influence of elevated greenhouse gases (primarily CO_2) on climate from past and present human activity is not discussed in SAR Section 2.3.1 on Climate and Infiltration. SNL (2008; Section 6.2, FEPs 1.4.01.00.0A and 1.4.01.02.0A) discusses the distinction between including climate change caused by past and present human activity, and climate change related to potential future changes in human activity. In its screening justification for both FEPs, the applicant maintains that the description of present-day climate is based on "climate records that implicitly include effects of modern society over the duration of historical record."

NRC staff could not find any other discussion in the SAR or primary AMRs pertaining to how the predicted climate states represented in TSPA reflect trends in global warming related to increased greenhouse gases caused by past and present human activity. The effects of elevated CO_2 and global warming on the climate of Yucca Mountain might not be detected readily in short meteorological records, like those recorded at local and regional meteorological stations.

Of interest are three aspects related to the historical record used to support the climate model in SAR Section 2.3.1.3. One, a discussion or analysis could not be found of the change in climate at YM caused by global warming, and how that change is reflected in the meteorological inputs to the net infiltration model. Two, a discussion could not be found for the duration of the anthropogenic climate changes before the perturbations would be dampened by orbital considerations and any complex feedback mechanisms. Three, how the monsoonal and glacial transition climate analog sites, which were selected based on the paleo-record (e.g., Owens Lake ostracode and diatom record), are appropriate for representing the effect of increased greenhouse gases caused by past and present human activity.

Reference:

SNL. 2008. Features, Events, and Processes for the Total System Performance Assessment: Analyses. ANL-WIS-MD-000027 REV00. Sandia National Laboratories.

RAI #2 Net Infiltration Results

Tabulate data summarized in the four uncertainty maps of net infiltration (SNL, 2008) for each of the four climate states. The information should include net infiltration and spatial coordinates. This information is needed to evaluate compliance with 10 CFR 63.114(a)(2).

Reference:

SNL. 2008. Simulation of Net Infiltration for the Present-Day and Potential Future Climates. MDL-NBS-HS-000023 Rev01 AD01. Sandia National Laboratories.

RAI #3 Fault Properties in the Infiltration Model

Clarify whether the presence of faults affects net infiltration within the proposed repository footprint, particularly with respect to focusing from overland and subsurface lateral flow, and if so, how such effects are propagated to the unsaturated zone flow fields (including discretely modeled faults).

This information is needed to evaluate compliance with 10 CFR 63.114(a)(1,2).

Basis: SAR Section 2.3.1 and the supporting infiltration model documentation limit discussion of faults to general description of geomorphology and surficial features associated with faults, but the site-scale unsaturated zone ambient flow model explicitly represents major faults (SAR Section 2.3.2.3.5.4) that intersect 43 proposed emplacement drifts (SAR Table 2.3.4-54). Day et al. (1998) mapped numerous additional faults within the proposed repository footprint that are not explicitly represented in the unsaturated zone ambient flow model. It is not clear if the MASSIF infiltration model accounts for faults and associated differences in rock, soil, and vegetation properties in fault zones (either explicitly or implicitly), and what the technical basis is for the way faults are included in the infiltration model (if they are included) or why they are neglected (if not).

Day, W.C., C.J. Potter, D.S. Sweetkind, and C.A. San Juan. “Bedrock Geologic Map of the Central Block Area, Yucca Mountain, Nye County, Nevada.” U.S. Geological Survey Miscellaneous Investigations Series I-2601. Scale 1:6,000. 1998.

RAI #4 Time Dependence of Properties in the Infiltration Model

Justify the assumption(s) that soil and bedrock properties are invariant in the infiltration model over 10,000 years, given that this period includes three discrete climate states. This information is needed to evaluate compliance with 10 CFR 63.114(a)(1,2).

Basis: SAR Section 2.3.1.3.2.1.3 states that soil depth and properties are assumed to be constant for the next 10,000 years based on scientific judgment, but there does not appear to be any discussion of what the basis is for the scientific judgment in the SAR and supporting documents. In particular, it is not clear why soil properties (e.g., permeability, water holding capacity) would remain unaffected as climate changes over 10,000 years. Changed soil profiles may affect infiltration and overland flow patterns.

There also does not appear to be any discussion in the SAR and supporting documents regarding how bedrock properties might change over the next 10,000 years, such as might occur because of fracture infill or dissolution of carbonates under wetter climatic conditions.

RAI #5 Infiltration under Future Climatic Conditions

Explain why the infiltration model results appear to be less sensitive to mean annual precipitation than indicated in the supporting information used for post-model-development validation (e.g., SAR Figure 2.3.1-48). This information is needed to evaluate compliance with 10 CFR 63.114(a)(7).

Basis: Power-law relationships between mean annual precipitation (MAP) and mean annual infiltration (MAI) from various researchers are reported in SAR Figure 2.3.1-48. The Wilson and Guan (2004) linearization of the Maxey-Eakin relationship and the Faybishenko (2007) relationship between climate and infiltration (based on the meteorological stations used in the SAR to represent climate states) imply a rate of increase in MAI with respect to MAP. Using these relationships to scale the present-day MAI values from SAR Table 2.3.1-2 implies that the monsoon and glacial transition values of MAI would be approximately 3 times larger than the values in SAR Tables 2.3.1-3 and 2.3.1-4. It is not clear why the MASSIF infiltration model does not exhibit a similar sensitivity to climate as these relationships.

References:

Faybishenko, B. “Climatic Forecasting of Net Infiltration at Yucca Mountain Using Analogue Meteorological Data.” *Vadose Zone Journal*, 6, 77–92. Madison, Wisconsin: Soil Science Society of America. TIC: 259076. 2007.

Wilson, J.L. and Guan, H. “Mountain-Block Hydrology and Mountain-Front Recharge.” In *Groundwater Recharge in a Desert Environment: The Southwestern United States*, Hogan, J.F.;

Phillips, F.M.; and Scanlon, B.R., eds., Water Science and Application 9. Pages 113–137. Washington, D.C.: American Geophysical Union. TIC: 256760. 2004.

RAI #6 Consequences of Infiltration Variability

Describe the consequences to repository performance if the net infiltration patterns were consistent with the variant property set estimated for Pagany Wash. This information is needed to evaluate compliance with 10 CFR 63.114(a)(2).

Basis: The infiltration model appears to emphasize distributed net infiltration (only the present-day 50th percentile map out of the 12 realizations in SAR Figures 2.3.1-26 through 2.3.1-29 and 2.3.1-31 through 2.3.1-38 has channel infiltration at least comparable to distributed infiltration). However, SAR Section 2.3.1.3.4.1 describes a confidence-building exercise using observations from Pagany Wash in which a simulation with alternative properties derived from field observations yielded more channel infiltration and less distributed infiltration than a simulation with nominal properties, with an almost identical areal average infiltration and a closer match to field observations. SAR Section 2.3.1.3.3.1.2 and SNL (2007, Section 7.1.3.2) describe simulations of the entire model domain using the variant property set. Simulations with the variant property set tend to indicate similar total infiltration but with distinctly increased channel infiltration compared to the corresponding simulations with the base-case properties.

It is not clear from SAR Section 2.3.1.3.4.1 why the areal average infiltration is the same with both property sets. For example, the result could be a consequence of a fortuitous selection of changed properties, or it could be a more general result that increased hillslope runoff (regardless of generating mechanism) is simply recaptured as channel infiltration. SAR Section 2.3.1.4 explains that, to a certain extent, input properties were chosen to conservatively not restrict infiltration, which may tend to result in systematically reduced runoff estimates. For example, bedrock permeability in most units does not limit simulated infiltration because of assumed fracture properties, but bedrock fracture properties are highly uncertain and reduced fracture permeability may act like the reduced soil conductivity in the variant property set by promoting runoff.

It is not clear that repository performance is not overestimated using a set of input properties that emphasizes distributed infiltration over channel (localized) infiltration even if the areal average infiltration is similar. Infiltration patterns dominated by localized infiltration may result in an overall greater percentage of percolation flux at the repository horizon becoming seepage. Relatively large and frequent wetting pulses from channels may be more likely to locally penetrate the PTn in transient pulses by maintaining locally damp conditions in the PTn, increasing seepage relative to steady percolation. Further, because the washes are much larger in the north, the two geomorphic regions (north and south of Drillhole Wash) described in SAR Section 2.3.1.3.1.3 may have different consequences for repository performance. For example, total net infiltration over the repository footprint may increase if upstream runoff in

large washes, such as Drillhole Wash, moves into the footprint and induces substantial channel infiltration.

Reference:

SNL. 2007. "Simulation of Net Infiltration for Present-Day and Potential Future Climates." MDL–NBS–HS–000023. Rev. 01. AD 01, ERD 01, ERD 02. Las Vegas, Nevada: Sandia National Laboratories.

RAI #7 Soil Depth Data

Clarify why the number of soil depth observations used to represent the range and distribution of soil depth in each soil depth class across YM is appropriate such that net infiltration is not underestimated. Of particular concern are areas with soil depth less than 0.5 m. This information is needed to evaluate compliance with 10 CFR 63.114(a)(1,2).

Basis: A small number of observations from a portion of the geomorphic environments across YM is used to support the spatially variable and uncertain parameterization of soil depth in the infiltration model.

The focus on observations in support of DOE's estimates for soil depth class 4 (0.1 to 0.5 m) is based on the sensitivity and nonlinearity of net infiltration results in general to soil depth, but also the sensitivity and nonlinearity within the range of values comprising soil depth class 4. The latter refers to the choice of a uniform distribution for sampling soil depth in the 0.1 to 0.5 m range of soil depth class 4, and the effect of that choice on infiltration results. Soil depth class 4 subsumes the majority (>70%) of the infiltration model, UZ flow model, and repository footprint domains and is represented by 35 soil depth samples.

RAI #8 Spatial Variability and the Pedotransfer Function

Explain why the use of a pedotransfer function to estimate spatially distributed soil hydraulic properties, in combination with lumping together soil groups 5, 7, and 9, does not lead to underestimates of net infiltration in the next 10,000 years. This information is needed to evaluate compliance with 10 CFR 63.114(a)(1,2).

Basis: Uncertainty in parameterization of spatially variable and highly nonlinear soil hydraulic properties can lead to uncertainty in estimating net infiltration. Depending on the application, pedotransfer functions often do not perform well in predicting soil hydraulic properties, and may lead to underestimates of net infiltration because of an underestimate of soil hydraulic property variability (e.g., Wang, et al., 2009). Instead of using site-specific data for soil hydraulic properties, DOE uses a pedotransfer function developed from soils at Hanford to estimate hydraulic properties for YM soils. The spatial variability may be further reduced by the use of a

soil class that is a combination of a combination of soil groups 5, 7, and, 9. As a model input, this soil type appears to cover >95 percent of the repository footprint (visual estimate from SAR Figure 2.3.1-18).

Reference:

Wang, T., V.A. Zlotnik, J. Simunek, and M.G. Schaap. Using pedotransfer functions in vadose zone models for estimating groundwater recharge in semiarid areas. Water Resources Research, Volume 45, W04412, doi:10.1029/2008WR006903.